Department of Computer Science

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# Evaluation of TCP Performance in hybrid Mobile Ad Hoc Networks

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Master's Project

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## Abstract

*Nowadays a lot of research efforts focus on Mobile Ad-hoc NETworks (MANETs). A MANET is a collection of mobile autonomous nodes, which can move arbitrary, leading to a constantly changing network topology. However, today most of the information is still stored on wired servers. A wired network has a hierarchical topology, while in a MANET the topology is usually flat to allow for nodes to easily change there position in the network. Due to the different topological natures of these systems, interconnectivity is not trivial.*

*To further complicate the situation the Transmission Control Protocol (TCP) is designed for wired networks, in a MANET with different link and route characteristics, as multihop and frequent packet losses, the performance of current TCP proposals drop considerably.*

*The purpose of this report is to give an overview of the current MANET – Internet connectivity situation and to evaluate TCP performance in a hybrid MANET where mobile nodes connect to a wired network through a gateway.*

*The report is divided into two parts. The first theoretical part will evaluate the different routing and mobility problems that occur in a realistic scenario with multiple gateways. Main problems that will be discussed are: path selection, gateway discovery, handover between gateways and address configuration in current solutions.*

*In the last part, a simulation-based evaluation will be made on a simplified scenario where one gateway is linking the two different networks. The simulation will be conducted with ns-2.28, which is extended with support for Uppsala University version of Ad-hoc On-demand Distance Vector (AODVUU) as routing and gateway discovery protocol and TCP AP (Adaptive Pacing) as transport protocol. In the performance evaluation, AODVUU and Destination-Sequenced Distance-Vector Routing (DSDV) combined with TCP Newreno, TCP Vegas and TCP AP will be used. The simulation based evaluation concluded that the best performance was achieved with TCP Vegas in conjunction with AODVUU.*

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# 1 Introduction

A MANET (Mobile Ad-hoc NETwork) is a network that consists of autonomous mobile wireless nodes that can communicate without the need of a central point of coordination. This differs from traditional wireless networks which normally need an Access Point or Base Station and is therefore dependent on an existing wired network. A difference from an ad hoc network is that a MANET, for abbreviations see Appendix A, must support changing network topologies, as all nodes are allowed to move and attach at arbitrary points in the network.

The need for MANETs originally came from the need in a military and emergency situation to quickly build a functional network without the need of any existing infrastructure. Today, the use for MANETs has been extended to be able to provide cheap and global access to the Internet, among other things.

When a MANET is interconnected with the Internet, or another wired network, this is called a hybrid MANET as there is one or more special node(s) called gateway(s) that can understand, and translate between wired network and MANET protocols. In following chapters it is assumed that most of the traffic crosses the border between the MANET and the Internet.

In a hybrid MANET, nodes must be able to find routes towards the Internet passing through gateway nodes. Before to communicate however, the nodes must discover where the gateway is located in the MANET. Gateway discovery, constant routing changes and lack of a central point of coordination, these are all the new challenges that do not exist in a wired network.

In a typical MANET environment, as an 802.11b WLAN in ad hoc mode, the node has shared access to an unstable, lossy, half duplex link of around 2 Mb. In a typical wired network, as an Ethernet LAN, every node has exclusive access to a stable, low loss, duplex link of around 100Mb. The current transport protocols, as most TCP variants, are mostly developed and fine tuned for wired networks, so they are not always directly applicable in a MANET environment.

The common de-facto standard for reliable transport layer in the Internet is TCP, and UDP is typically used for unreliable end-to-end delivery of multimedia data. As UDP cannot provide performance guarantees.  UDP usually starves TCP when competing for resources in the same network. Therefore, extensions of UDP are used for multimedia transport such as the real-time protocol (RTP) together with RTCP which provides feedback on QoS delivery and enables rate control for better coexistence with TCP. Classical TCP performance degrades significantly in isolated ad-hoc networks mainly due to TCPs inability to distinguish between packet loss caused by congestion and by other factors intrinsic to multihop networks. In MANETs, a significant portion of packet losses are caused by link failures either due to high bit error rate, mobility of nodes or network partitions. Another source of problems is the complex cross-layer interaction between the MAC, routing and transport layer. When TCP probes for bandwidth aggressively during the slow start phase, there is a high probability for MAC layer contention induced packet loss, which will cause the routing protocol to trigger route error messages even if the route is still valid thus increasing the problem even more. When TCP starts to react, the routing protocol might already use a different route, which causes unnecessary route changes, even in static scenarios, and large oscillation of the congestion window size. Several solutions for TCP as well as new transport layer protocols have been proposed that try to avoid the problems of TCP. In order to decrease the incompatibility issues, it is desirable that transport protocols for hybrid MANETs are compatible with TCP.

Therefore, the problem statement of this thesis can be formulated as:

The purpose of this thesis is to give an overview of the current MANET – Internet connectivity situation and to evaluate how different TCP variants, perform in a hybrid MANET, measured in terms of throughput, goodput and fairness.
To present the current MANET – Internet connectivity situation a sum up of current “state of the art” proposals will be done.
A simulation-based evaluation study will be conducted, by performing different simulations in a hybrid MANET environment using ns2 [41].

The reminder of this thesis is structured as follows. In Chapter **2**, the background and some of the different problems with the interconnection between a MANET and a wired network, as transport protocols, addressing, routing, gateway discovery and handover, are discussed.

In Chapter **3** the discussion from Chapter 2 will be continued and extended with a presentation of some promising proposals, like Mobile IP [18], half tunnelling [26], AODVUU[40], TCP Vegas[4], TCP AP[6], TCP FeW [22] and more general proposals, aimed to solve several problems, like *“Gateway and address autoconfiguration for IPv6*

*adhoc networks"* by Jelger et al. [16] and *"Global connectivity for IPv6 Mobile Ad Hoc Networks"* by Wakikawa et al [37].
In Chapter **4**, the simulation setup is presented, as mobility, traffic scenarios as well as the TCP variants and routing protocols used in the different simulations.
There will also be a short description of the scripts used to produce the simulations.

Chapter **5** evaluates and shows the result of a subset of these simulations, with graphs showing congestion window, throughput and goodput.

The last Chapter **6** concludes and summarizes the theoretical overview and the simulation results, as well as presenting future work.

# 2 Background

In this Chapter the underlying problems and difficulties concerning MANET - Internet connectivity will be introduced.

## 2.1 Introduction

Nodes in a hybrid MANET need to communicate with fixed hosts in the Internet. Today one of the most used transport protocols in Internet is TCP. Few studies as [35] have been made on the performance issues that occur, when connecting a MANET to the Internet and those only have been mainly focused on UDP. UDP does not need to re-establish a new connection at each address change or resend lost packets, as UDP does not guarantee delivery and therefore does not use ACK or other mechanisms to recover from lost packets. Because of this connectionless behaviour, UDP does not suffer from the address changes that happen in a MANET as much as TCP does.

TCP uses a connection oriented approach where packets flow from a sender to a destination node, where each flow is identified by certain parameters, with the IP-address being one of them. A change of the IP-address will therefore cause a drop of that connection. Another issue with TCP is that it uses a congestion control that is not adapted to a MANET environment and as a result, TCP sometimes will not use the entire available network capacity. Therefore, this study will concentrate on TCP performance in MANET – Internet connectivity and gateway discovery.

In general, MANETs do not incorporate the term of subnets as wired IP networks do. Instead, a MANET has a completely flat topology where the only requirement for a node is that its address is unique within that MANET. This makes sense as nodes are mobile and can attach at arbitrary points to the MANET. Therefore, routing protocols must cope with this new addressing structure.

The intersection between a MANET and a wired network is a node called gateway or access router, which has at least the functionality of translating addressing structures, routing protocols, and physical network interfaces between the two networks, see Figure 1.

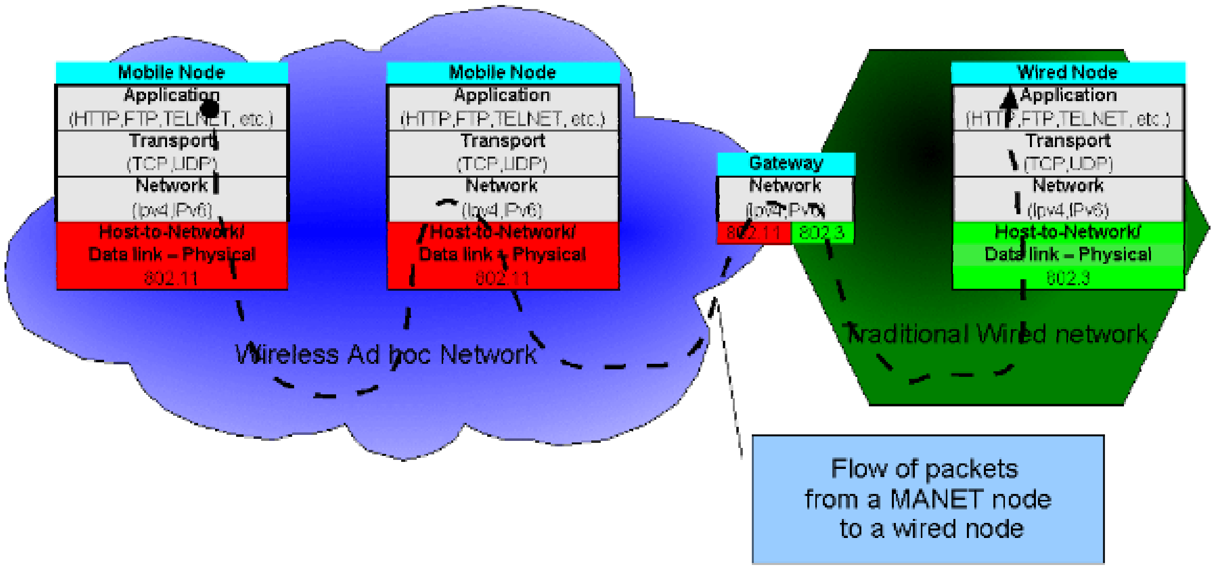


*Figure 1 Flow of packets via a MANET – Wired Gateway*

The number of gateways depends mainly on the area that the network is supposed to cover, radio propagation and node density. However, having multiple gateways introduce new issues e.g. handover and gateway discovery, as will be presented in more detail in Chapter 2.4.2 and 2.4.1.

A simple solution to interconnect a MANET with a wired network would be to let a gateway act as a proxy and do network address translation, and answer all route requests that it knows belong to an Internet address. However, this means that, when using a reactive routing protocol see Chapter 2.3.1, the MANET nodes, because of the flat addressing structure in a MANET see Chapter 2.2.1, cannot distinguish between wired and MANET nodes. The gateway must keep an entry in the routing table for each of the different connections [24]. The result of this invisibility forces the mobile node to send a route request every time a packet should be routed to a new Internet node. Depending on the scenario, this will cause a flood of route request in the MANET; also the routing tables will increase.

This simple solution, although theoretically feasible, will also cause inefficiency with mobility. Even if there is another gateway fewer hops away from the mobile node, packets will always be routed through the same gateway and a not optimal path through the low bandwidth MANET will be used. In a more realistic scenario, the node would change gateway either because it loses the link or to improve performance.

Tests have shown that the throughput of TCP roughly follows a 1/n curve where n is the number of hops [32], when the nodes are connected in a “linear” chain. This means that everything else the same, there is only about 1/3 of the throughput left, when there are 3 wireless hops between the sender and receiver. Therefore, short hop distance to the gateway is crucial for an efficient Internet connectivity. This will be treated in more detail in Chapter. 2.3.2.

This suggests that some sort of gateway discovery algorithm to find the closest gateway should be performed and the closest gateway should be chosen as efficiently as possible to minimize MANET traffic. However, allowing the mobile node to change gateway will break ongoing TCP connections, as the Internet node only knows the IP address of the gateway, which acted as proxy for the mobile node. In case Mobile IP [18] is used to maintain the TCP connection, an increased overhead will be the result, as a re-registration with the new gateway is necessary. The advantage with Mobile IP is that each node in the MANET maintains the same IP address independently of the gateway attached.

If not Mobile IP is used it leads to another problem, what IP address will the mobile node have in the Internet? In the simple scenario described here, the gateway does NAT and acts as a proxy but as we have seen, this has its drawbacks. A closely related problem is as mentioned before how the mobile node gets its unique address within the MANET.

A lot of research is focused on MANET connectivity; although some solutions exist to solve these problems today [16][37], they all have there deviances [35] and a lot still remain to be solved.

The rest of this chapter will describe in more detail the problems mentioned and discuss the impacts they have on network connectivity and performance.

## 2.2 Addressing

An ideal IP address would be unique, globally routable and location independent as mobile nodes move in and between MANETs and connect to different gateways.

The fact that it is common that mobile nodes in a MANET use IP addresses does not mean that it is straightforward to interconnect a MANET with a wired infrastructure [35].

IPv6 has some extended capabilities, e.g. address autoconfiguration and extended address space over IPv4, which some proposals use to more easily circumvent the differences between hierarchical and flat structures [35].

### 2.2.1 Hierarchical/Flat Addressing

One of the main problems is that in a wired IP network, the addressing scheme is completely hierarchical and nodes belong to subnets which are interconnected via gateways.

| | | | |
|---|---|---|---|
| 110 | *NET–ID* | *SUBNET-ID* | NODE-ID |

*Table 1 Common address field of an IPv4 header*[1]

The IP address is not only a unique identifier[2] but it also devotes the place the node have in the network hierarchy, so every node routes the packets through a known default gateway, if the IP address is not within its own subnet. If the packets come from one of the gateway's subnets it relays them out on that subnet, otherwise it sends them to its own default gateway and so on. This is also known as longest prefix matching and is similar to how a post address works when you post a letter[3].

The decision to route the packet to the gateway or not is usually solved by having a specific subnet mask on each node that is evaluated against the nodes own IP address and the IP address of each sent packet. If there is a mismatch, that packet belongs to the "outside" and is routed through the nodes default gateway. This scheme, although very efficient where nodes and gateways are static, has its limitations as it does not allow nodes, and in particular not gateways, to attach at different points in the network without reconfiguration of the IP addresses.

Within a MANET where there are high mobility and many nodes, link and route changes would occur frequently, which makes the cost of maintaining a hierarchical tree structure too high in most cases [37].

So instead, in a MANET a flat address topology is used where the IP address only is a unique identifier for that node and does not carry any network topology information. This is beneficial as it minimizes the impact of route changes, at a cost of slightly more complicated routing. However, this also implies that there is a conceptual difference between hierarchical-

[1] Net-id, which is the identifier that the routers in the internet base their routing information, combined with subnet-id determines the nodes place in the hierarchy.

[2] In that particular network

[3] In Sweden 20060215

IP and flat-IP, which could not easily be overcome as hierarchical-IP nodes will not recognize MANET nodes with an IP address not belonging to the same subnet as its gateway[4] [38].

The most appealing approach to solve the problem with nodes changing subnets would be to route the packets through the MANET and use the same gateway during the entire connection. As mentioned before, the most beneficial is to use the closest gateway to the Internet. However, there is always a trade off between the number of hops and the overhead in changing gateway as will be explained further in Chapter 2.4.2.

### 2.2.2 Address Autoconfiguration

Address autoconfiguration is the procedure that a node uses to get, and configures, its IP-address. In a traditional wired IPv4 network, this was achieved using a central DHCP server, which assigned IP-addresses to the nodes. This is also called stateful autoconfiguration. This method works well for fixed networks as partitions rarely happen and as nodes are mostly stationary so IP-address requests seldom occur. Therefore, the overhead of the DHCP requests will be small and congestion will not be a problem.

For a MANET however, the situation is completely different, network partitions and merges occur frequently as nodes move within the MANET. Address requests are therefore assumed frequent so this approach is not suitable for MANETs due to the risk for congestion and loss of packets. In a MANET, there is also no easy way of obtaining which DHCP server to use because of mobility and flat addressing structure.

The second approach is stateless auto-configuration, which was incorporated in the IPv6 standard, where a node auto-configures an IP address without help from a central entity (as a DHCP server). However, the IPv6 auto-configuration mechanism is developed for one-hop networks and therefore only allows nodes to generate a link-local address, and do not take into consideration multihop networks. Modifications to this mechanism [17][30][37] exists, which will be described in more detail in Chapter 3.2.2

As no central entity dictates IP addresses, depending on the solution of auto-configuration parameters, the problem of duplicate addresses can occur. In those cases, some duplicate address detection (DAD) must be employed.

As a general, but not mandatory, rule it is best to let the mobile node belong to the same subnet as its default gateway as this simplifies filter and routing management. This is the same as giving a mobile node a globally routable IP-address. Unfortunately, this conflicts

[4] Unless the gateway does some sort of NAT, as will be shown in later chapters this only postpones the problem.

with changing the gateway during a connection, because this involves changing IP-address of the node [35].

## 2.3 Routing and TCP in a MANET

In this chapter, we will present some of the problems with TCP and routing in a MANET.

### 2.3.1 Routing

MANETs have their own routing protocols mainly due to their flat structure of the addresses and mobility. Some of them are invented or just adapted from wired protocols [27]. All protocols must follow some principles to be beneficial for an ad-hoc network such as to be adaptive to a dynamic topology or scalable with the number of nodes. Furthermore, the main challenge for a routing protocol is to be able to represent the current topology at all time.

Routing protocols in MANETs are classified in three different groups: Proactive, reactive and hybrid. This classification is done based on how the protocol works to find a proper path for a concrete destination.

**Proactive** protocols follow the same philosophy as link-state and distance vector protocols used for wired networks; each node of the network has its own table with all neighbour nodes and the cost of each different path. The primary problem in proactive routing protocols is that every intermediate node has to update constantly a table with all the information about other nodes in the network. Moreover, each time control messages are sent in the network, this excess of information, may generate congestion in the network and loss of data packets due to buffer overflows and MAC contention. The maintenance of the paths is expensive because constantly routes can be broken because of the nodes' mobility, which generate constant updates of information in each node. Therefore, link-state protocols are not suitable in high mobile MANET, with many route table changes, because in each node topology information is replicated. Examples of proactive routing protocols are DSDV and OLSR.

**Reactive** protocols or on demand, start a route discovery each time that they have a packet to send to a destination and its route is not known. Usually, nodes that implement reactive protocols have a cache where all the routes discovered are stored for future uses; routes not used recently are expired even if they are still valid. The key feature of on-demand protocols is acquiring routing information only when it is actually required, avoiding maintaining long routing tables. Sender will have to acquire a route to the destination before the communications start which suppose an increase of the transmission time for the first packet.

The goal of an on-demand protocol is to offer optimal path for each node that requires it, without having obligation to maintain updated information. Examples of reactive routing protocols are DSR and AODV.

**Hybrid** protocols use both proactive and reactive techniques. Hybrid protocols maintain state information for neighbour links, within a limited area from the node. Route discovery is performed to determine a path for a destination, which is far away from the source node.
All these protocols have advantages and disadvantages depending on the mobility, traffic, etc. Example of a hybrid routing protocols is ZRP.

### 2.3.2 TCP

TCP was designed for wired low-loss, stable networks with a high bandwidth-delay product (BDP, in some graphs mentioned BWD), which determines the number of packets that can be in transit in the network. Therefore, it misinterprets many of the network characteristics when used in a MANET environment [36]. One of the already investigated characteristic [36], is that TCP interprets packet loss as congestion and reduce its congestion window, which is the amount of packets that TCP will allow to be in flight in the network at the one time, to compensate for this. In a MANET, this is far from always true as wireless links by nature are error-prone and the correct behaviour, in the case of bit errors in the transmission, would be to retransmit the packets immediately as fast as possible.

In a mixed environment with both UDP and TCP flows the situations become even more troublesome [32].

Even in a single hop environment but with unreliable wireless links, TCP throughput will suffer from successive retransmissions. If the link-layer also resends packets, this can lead to bad protocol interaction, which causes TCP retransmission timers to expire, and make TCP resend these packets as well. This is even more prevalent in a multihop environment as these transmissions often collide, at intermediate nodes, with data or ACK packets. As shown in [32] this lead to that TCP will have a throughput curve close to 1/n, where n is number of hops.

In a MANET where nodes are mobile, link breaks are frequent, the more links (hops) involved the higher the path break probability is [36]. Path breaks also triggers new route requests from the network layer and if this takes more time than TCP retransmission timeout (RTO) then TCP goes into slow start and throughput is even more decreased.

The use of a sliding window for flow control, as TCP use, requires that the link-layer provide long- and short-term fairness for optimal performance in a low-bandwidth network.

The reasons for this is, that with an unfair link-layer the unfair treated nodes will assume a congested network and back off, while the privileged nodes will send faster as they assume a lightly loaded network. In MANETs today the ad hoc standard for the link-layer is IEEE 802.11. Unfortunately, this protocol cannot provide short-term fairness, because of the binary exponential backup algorithm used to avoid collisions a node that has captured the channel has greater chance of capturing it again [23]. This will create burstiness in the traffic that will penalize TCP throughput. [36]. Interconnected with a wired network this short-term unfairness also will lead to long-term unfairness [39].

Window size is also problematic when a MANET connects to a wired network. Tests have shown [39] that in a pure MANET a window size of 1/3 of path length is the optimal. In a normal MANET scenario, this evaluates to one or two as optimum. However, this is unacceptable in a wired network where this window size will cause unacceptable low throughput [39].

## 2.4 Interconnection and Mobility

To reach the Internet a node must fulfil certain criteria. A node, to be able to send packets, must have a globally routable address and a known path or gateway to reach the destination. To know which path to take normally a gateway discovery has to be done, as may change due to mobility.

### 2.4.1 Gateway Discovery

When a mobile node should reach an Internet node; does it know if the node’s address is within the MANET and if it does where should it send the traffic? As seen in Chapter 2.3.1, this is not obvious and sometimes requires a MANET wide route request.

Different solutions have emerged to make the node aware of what and where to send the traffic to reach an Internet node, mainly there are the three main approaches used in MANET routing protocols, e.g. proactive, reactive and hybrid.

In a **Proactive** approach, the gateway periodically floods the MANET with HELLO messages, which also can contain network prefixes so that mobile nodes can decide what and where the traffic should be routed to reach the gateway. The advantage of this is that it scales well with the number of nodes that want to reach Internet. However, it does not scale with the total number of nodes in the MANET [34].

In a **Reactive** approach, the node is not aware of the route to the Internet (e.g. gateway) in advance and therefore does a flooding route search, which the gateway answers. This has the advantage that it does not create traffic unless a node really wants to reach the Internet. The drawback is that it is not scalable in the realistic scenario when many nodes want to access the Internet [34].

In a **Hybrid** approach, the gateway send proactive HELLO messages to a limited group (e.g. the number of hops from the gateway) and let the nodes further away reactively find the gateway. For a minimal overhead, an optimal size of the group must be found. As shown in [34] the optimal size of the group varies depending on scenario and network condition so some sort of estimation must be made by the gateway on these parameters.

Solutions exist [16][37][34] that use the above-mentioned approaches. There also exist solutions without the need for a specific gateway discovery mechanism as they use a hierarchical tree structured addressing and routing scheme based on MIPv6 [38]. This however put some constrains on the allowed mobility and number of nodes in the MANET.

### 2.4.2 Handover Strategy

In reality, a scenario with one gateway can be found, but to extend the coverage or performance usually several access routers or gateways are used, which connect the MANET with the wired network.

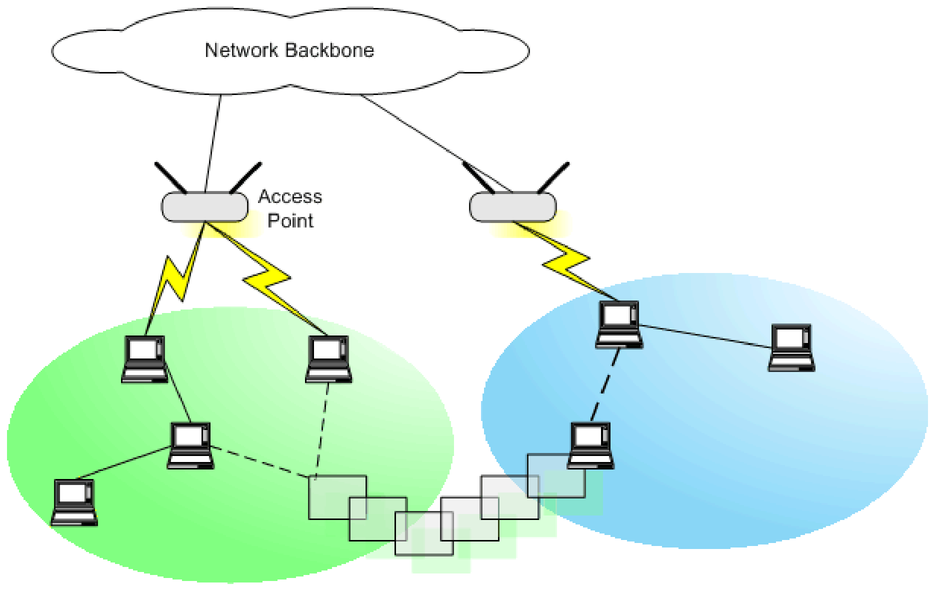


*Figure 2 Handover [43]*

In general, a handover between gateways is initiated because of mobility, packet loss or to reach a better path. After the handover is done, all packets must be sent through the new gateway. Conventional wireless networks perform handovers depending on the link quality [10]. However, in multihop topologies, usually just a few nodes have a direct connection with the gateway and most of the mobile nodes access the wired network through multiple nodes.

Sometimes handover may be useful to load balance between different gateways, avoiding packet drops because of buffer overflow or network congestion.

Handover strategies, is a topic in research, although some protocols are already beginning to emerge.

MRAN, Mobile Radio Access Networks [13], which offers access to the Internet for the ad-hocnodes, presents handover maintenance and constantly tries to optimize gateway connectivity. Two different kinds of handover can occur: Forced and optimizing handovers.

**Forced handover** is involuntary. In some situations, communication is not possible with the access router due to broken route or just that a mobile node has been disconnected. Then a new gateway discovery has to be started, just like the first time that the node appears in the network. Forced handover is possible in all gateway discovery approaches, proactive, reactive and hybrid.

**Optimizing handover** as a difference to forced handover is voluntary and is used to find a better gateway in terms of number of hops, as well as other parameters that may be influent to the delivery of packets. Not all gateway discovery approaches can implement this handover because advertisements from the gateways are required, as proactive and hybrid do.

From this information, mobile nodes can decide if another gateway is better than the current one. If Mobile-IP is used, to maintain transmissions while changing IP-address, the mobile node will start a registration with the new access router before it breaks the link with the old one.

It is important to determine precisely when an optimizing handover really is beneficial, instead of waiting for a forced handover. This because each optimizing handover introduces a delay and a break in the flow of packets transmitted. Moreover, not all the proposals allow storing packets in a buffer (e.g. reactive and hybrid) [13] and for this reason it is possible to have loss of packets that will cause retransmissions. In Chapter 3.3.1 these decisions of the node will be treated in more detail, since it is important to know when it is effective to execute an optimizing handover and how the transmission would be affected in terms of delivery of packets, goodput and packets delay.

### 2.4.3 Mobility Management and Mobile IP

Nowadays, most of the research is focused on how to improve MANET performance, not its connectivity with other networks. However, interconnectivity between MANET and wired networks is one of the most important current problems to be solved because of the necessity to communicate with the Internet, not only between mobile nodes. Using Mobile IP [18] wired nodes could conserve their own home address in the entire network. Unfortunately, Mobile IP, keeping this own address, does not solve all problems concerning addressing and routing in a MANET. Several different strategies to send packets to an external node exist e.g. default route and tunnelling.

Reactive protocols have not the possibility to determine whether a destination is a fixed node or not. Therefore, unless reserved prefixes for MANET nodes or other similar techniques are used, a request must be flooded through the MANET. In some cases, the gateway will answer, offering to take care of these destinations, otherwise if the network not replies, it is assumed that it is an external node. On the other hand, proactive routing protocols are able to know if a node belongs to an ad-hocnetwork, by checking for each address in their routing tables. Moreover, intermediate nodes between the source and the destination have to keep the destination address in their routing tables for future uses and verify that is an external node, if not a request must be flooded through the network); this phenomenon is called “Cascading effect” [24]. Its consequence is congestion in the network and the growth of intermediate route-tables. In the attempt of reduce the amount of request packets sent in the network a **default route** is created. The default route technique is especially useful for the packets that have the same prefix address destination and share most of the hops, avoiding route discoveries for nodes from the same subnet. However, this method has some drawbacks when it is used in a multiple gateway scenario, especially during a handover [26]. Some possible solutions are presented in Chapter 3.3.2.1

Another alternative is to create a tunnel between the source and the destination, simulating one hop communication when it actually is a multihop connection. Our study will be focused on the “**half-tunnel**” proposed by Uppsala University [26]. It is called half-tunnel because tunnelling only is performed in one way, from the mobile node to the fixed host, in the other direction the gateway may forward information without difficulties. When a packet for a fixed host has been detected, as explained in the above section, the packet is encapsulated with a new header, with the gateway as a destination. Then, in the gateway, the packet is decapsulated and the original packet will be sent to the real wired destination. With this strategy, intermediate nodes have not to maintain any routing table. Cascading effect and look-ups are avoided because packets will be routed to the gateway as normal packets in an ad-hoc network, using a MANET routing protocol. A more detailed comparison could be found in Chapter 3.3.2.2

## 2.5 Summary

As shown in this chapter there are several problems with the interconnection between MANET and the Internet nodes.

The main problem comes from what a MANET is, namely mobile and multihop. Many of the other problems derive from these two characteristics.

Mobility leads to the need to change the addressing structure, which in turn causes adaptation of address auto-configuration procedures and routing protocols. Closely related to this are gateway discovery and handover strategies, in terms of finding the optimal path to a wired node.

Multihop effects and complicates the problems that mobility presents and in turn introduces some new issues, as TCP performance degradation.

The proposals to solve these and the other issues mentioned will be treated in the following chapter.

# 3 State of The Art

In this chapter current state of the art proposals and implementations, to problems and issues described in Chapter 2, will be presented.

## 3.1 Introduction

In Chapter 2, we introduce some of the problems that can occur in a hybrid MANET environment where there exist both wired and wireless mobile nodes. In this chapter, it will be presented some promising proposals to solve these problems.

A brief technical overview is presented together with a short description of the consequences that they can impose in a hybrid MANET scenario. Because some proposals not only cover one topic, the structure of the different parts is slightly changed from Chapter 2 to accommodate for easier understanding. To focus on our main topic some previous sections as hierarchical/flat addressing and routing, are omitted as they will be mentioned in a context relevant for our study.

As nodes can move freely within and between different MANETs, it is important that there exist some mechanisms that allow the nodes to keep the connection during these transitions.

It is important that nodes can be reached by a permanent address so that knowledge about a mobile node’s current gateway is not needed. For global route-ability in the Internet, it is important that the mobile nodes have an address from the same subnet as its current gateway. As will be shown further in Chapter 3.2 some of these requirements are fulfilled by using Mobile IPv6 and some extension of IPv6 autoconfiguration schemes.

To reach or to be reached from the Internet, a mobile node must know or be able to discover the route to the gateway, which interconnects the MANET and the wired Internet. In a multiple gateway scenario it is important to know which gateway offers the most efficient interconnection. There must also be a mechanism that is able to handle a proper switch of gateways during an ongoing connection, to avoid unnecessary packet retransmissions.

Some solutions for gateway discovery and handover that solve these issues will be presented in Chapter 3.3.

As explained before, the TCP protocol performance in a MANET has many issues that degrade performance; there are other transport protocols e.g. [2] specific for MANETs that deal with these problems. However, when a MANET is interconnected with the wired Internet a TCP interoperable protocol is preferable, as to avoid gateways to do costly transport layer adaptation. All of these topics are fields of research so new solutions spring forward constantly; this chapter tries to summarize the current state of art.

## 3.2 Addressing

### 3.2.1 Mobile IP support IPv6

Mobile IP is a standard communication protocol, described in [18]. This protocol provides an efficient mechanism to allow mobility within the Internet. Mobile IP support for IPv6 is an adaptation of Mobile IPv4 for the new version of IP addresses, IPv6.

Nodes that implement Mobile IP can be identified by their permanent home IP address independently of which point they use to access to the Internet.

When a mobile node changed its place in the topology and is attached to another subnet, it is identified by a care-of address, but it still will receive packets addressed to its home address. The visitor node obtains this care-of-address with the same mechanism as IPv6, auto-configuration scheme; the care-of-address has the prefix of the subnet in the visiting link. Each packet addressed to the home IP address will be rerouted to the current care-of-address, and finally will arrive to the mobile node.

Figure 3 shows all the possible steps that the system has to follow to allow direct communication between the sender, correspondent, and mobile node in a network which implements Mobile IPv6. The address changes are completely transparent for higher layers (e.g. transport layer) because this information is maintained in the network layer.

Hence, applications will not be affected by mobility. The relation between home address and care-of address is called “binding”, which requires a previous binding registration. The “binding registration” is done using a request-reply approach. A mobile node when it is away from its home agent sends a “binding update” packet to the home agent with the updated care-of address. The home agent answers with an “Acknowledgement binding”; this information will be kept in cache, for future uses. A mobile node may be related to multiple care-of-addresses, one for every network linked.

Mobile IP is suitable to be used across homogenous and heterogeneous networks; can facilitate communication between two Wireless networks as well as between an Ethernet and a Wireless network. As it is shown in Figure 3 the node that wants to send a packet to a mobile node is called correspondent node and it is either wired or wireless.

Mobile nodes inform about their location and current care-of address, for each correspondent node so they can update their list of mobile node addresses, called “correspondent registration”. Mobile nodes can receive packets in two different ways from correspondent nodes: bidirectional tunnelling and route optimization.

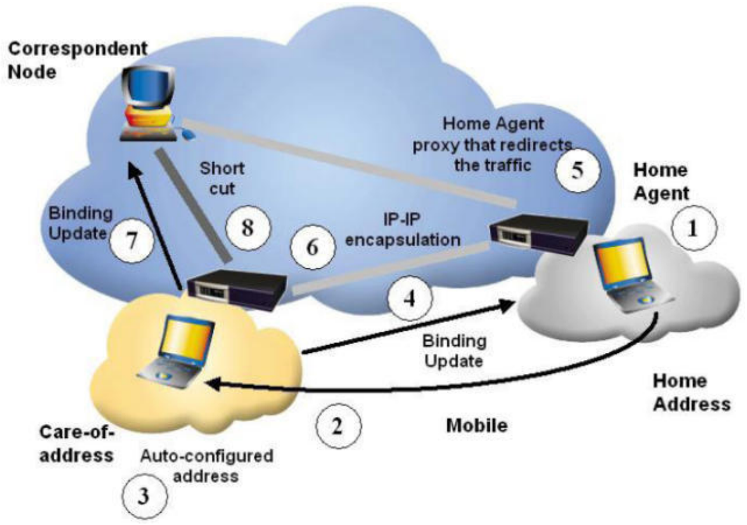


*Figure 3 Network implementing Mobile IP [42]*

In bidirectional tunnelling, packets are sent directly to the home agent, where they are tunnelled using IPv6 encapsulation and send to the mobile node. Mobile node uses a “reverse tunnel” to send packets back to the correspondent node. The drawback of this scheme is that it introduces overhead and it will in some cases use a longer path to route the packets to the mobile node. The advantage is that no modifications are needed at the correspondent node.

However, in route optimization, correspondent nodes previously have to support correspondent registration. Packets are sent directly to the mobile node using the care-of address already obtained in the registration. Using correspondent registration packets get the care-of address of the destination node; packets are forward straight to the mobile node, called short cut in Figure 3, avoiding intermediate nodes as the home agent. This method reduces congestion at the home agent and improves performance because of a shorter path between the nodes.

A variant of the IPv6 header is also added to the packet, containing the home address of the mobile node. In that case, the mobile nodes set the source address to its care-of address.

Mobile nodes with the mechanism called “dynamic home agent address discovery”, can discover the IP address of a home agent within their own home link, even when they are visiting other networks.

The use of the Mobile IPv6 makes mobility transparent for layers above network layer.
Mobile IP Fast Handover protocol [20] has been developed to reduce the time when the mobile node changes its point of attachment. A handover involves a break of packets flow, while a mobile node registers to the new care-of address. For real-time applications or voice-over-IP, these interruptions cannot be acceptable.

It is important that mobile nodes can trust their own home agent so they can establish private communications. In [3] it is described a security implementation for Mobile IP that makes it possible to do encrypting “binding updates”. Connections between mobile and correspondent nodes have to implement more complex mechanisms to assure truthfulness. To provide authentication nodes have to implement a “return route-ability procedure”, where mobile nodes and home agent send cookies to the correspondent node. Then, the correspondent node build a pair of keys that will be shared between all nodes involved in the communication. Afterwards, the mobile node builds a binding message key that will be used to sign the binding update message, exchanged between the nodes during the binding process.

In MANETs it is beneficial to use Mobile IP especially when multiple gateways are involved, to keep the connection while the mobile nodes are moving between the different gateways.

### 3.2.2 Address Autoconfiguration

As stated earlier in Chapter 2.2.2, using stateful address configuration is not suitable and sometimes even not possible in a MANET.

To let the nodes have the same prefix as its current gateway but still change its address as little as possible, [16][31]have split the IPv6 address field in two 64 bit fields. A MANET local-address field that is used for routing within the MANET and a prefix (of the current gateway) that is added to the MANET-local address to provide global connectivity. The MANET-local address consists in both cases of the EUI-48 (e.g. MAC) address and an added 16-bit pattern. In [31] the pattern is predefined (e.g. ff:fe) and in [16] it is a 16-bit random number.

The decision to use a random number in [16] will, in the case of identical EUI-48 addresses (very unlikely, as the MAC address should be unique), reduce the collision probability to 1/64536, in these cases.

Because of the low probability of address collision Jelger et al. therefore chose to do not use a complex DAD (Duplicate Address Detection) procedure, Jelger et al. explain in [17] why a simple DAD procedure could fail in a MANET, mainly this is because of the continuous network divisions and merges. However, in [31] Perkins et al. use a simple DAD procedure, where a node via a temporary address; broadcast the suggested address and if there are no replies the suggested address is chosen by the node.

The prefix that later is added to the MANET-local address is advertised by the current gateway to provide a global routable address. When the mobile node is attached to another gateway, the nodes prefix will change accordingly.

A completely different scheme (e.g. hierarchical) is used in [38] where each node acts as a DHCP server and distributes local addresses to joining neighbourhood nodes according to its place in the address tree, see Figure 4.

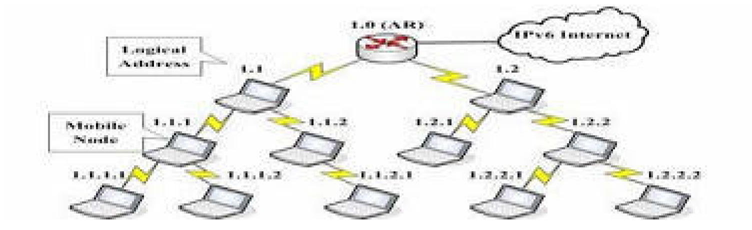


*Figure 4 Address tree routed at the gateway (adopted with permission from [38])*

This scheme simplifies and avoids many problems (e.g. addressing, routing and gateway discovery) connected with MANETs. However, it also implies relatively small MANETs with low mobility, e.g. walking speed, which is an extension of a wired infrastructure.

To conclude, in small MANETs, according to number of nodes, with low mobility (e.g. with few path breaks, merges and divisions), all schemes work well. However, [38] provide the most straightforward implementation, as it builds on well-known approaches. In a more mobile scenario where path breaks become a burden both [16][31] can provide a more robust and scalable solution.

## 3.3 Interconnection and Mobility

### 3.3.1 Handover

Multihop radio access networks MRAN provide access to the Internet for mobile nodes in ad-hocnetworks. Because of mobility, topology is constantly changing and a permanent connection with the Internet cannot be possible through a single gateway.

In a multiple gateway scenario, when there is a need to change gateway while packets still are on flight, this change is called handover. As it is shown in Figure 5, MN0 performs a handover.

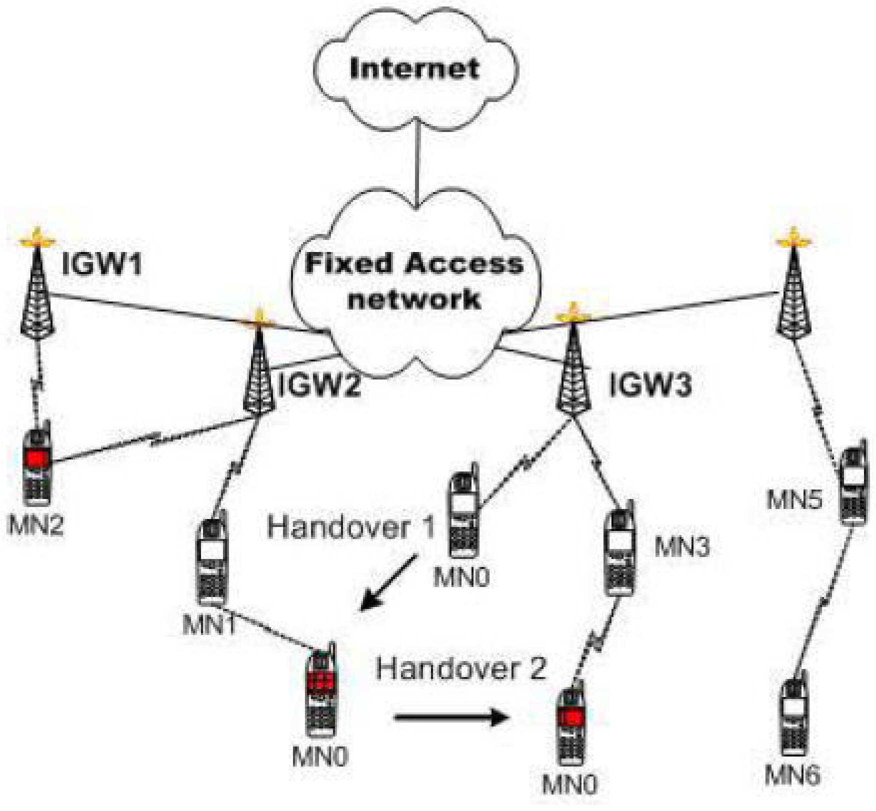


*Figure 5 Handover [10]*

A Handover can be performed for two different reasons, because of a link breakage or to optimize the connection.

Forced handovers are normally produced when the route between the mobile node and the gateway is broken, because of nodes' mobility, etc. This, however, requires active monitoring for path breaks. In the case that another path to the gateway does not exist, the mobile node starts a gateway discovery to find out the route to the closest gateway in the system. Usually in multihop environments, mobile nodes do not have a direct connection with the gateway, therefore it is difficult to start a handover based on link quality [10]. Links are normally measured in terms of number of hops. Depending of the cause, handovers are classified in forced or optimizing handovers [13]. It is hard to determine features of a route, built of different hops. The mobile node is normally the responsible to determine when a handover has to be done. The entire path, including all the intermediate links, should be considered before the mobile node takes the decision of perform a handover.

With reactive routing protocols, a gateway discovery is only initiated when the mobile node has the necessity to send some packets to the wired network. The connection with the gateway will be used until a link breakage occurs; only then, a new route discovery is going to be performed.

In proactive and hybrid environments, gateways send continuously advertisement messages with information about the current number of hops from the gateway to the mobile node. The mobile node can then compare this with the information it has about the current gateway connection. In the case that another gateway would have a shorter path, an optimizing handover starts. Before to break the link with the existing gateway, a registration begins to the new gateway, when the mobile node is attached properly, then the communication with the old gateway is ended. Using optimizing handover, the rate of forced handovers is reduced considerably although signalling increases.

Depending on the handover decision, different kind of signalling has to be used [9]. The signalling system used for forced handovers is divided into two phases: gateway discovery and registration. In the first phase, the mobile node finds a new gateway while in the second phase the node registers with the new gateway.

In the Optimizing-based handover signalling mechanism, first information from the new gateway is received by the mobile node, when the new care-of address is already assigned to the node a notification of the change is sent to the network to update its caches.

Optimizing handovers reduce number of hops to the gateway and improve the utilisation of the network. However, it has to be considered that for each optimizing handover the flow packets is broken and a delay is produced. Hence, it is crucial to define properly the optimum situation when it is better to carry out an optimizing handover instead of waiting for a forced handover. To establish the rules considered in this decision, several parameters of the network have to be considered. Packet delivery ratio, handover delay and signalling overhead are some of the parameters to consider before doing a handover. Packet delivery ratio refers to the fraction between packets sent to the Internet and packets generated in the source node.

Handover delay is the time between the point, where the mobile node detects that handover is required and the completion of the handover procedure. In forced handovers, this parameter reflects the time it takes to discover a new gateway and register with it. However, as in optimizing handover the gateway address is already known, the handover is determined by the time necessary to register with the new gateway. Obviously, increasing the advertising messages from the different gateways will give more information to reduce the delay, offering a better path.

To guarantee an efficient network it is important to find the balance between forced and optimizing handovers, otherwise handover delay will be increased and delivery ratio reduced.

Some studies as [9][10] show that for identical mobility scenario proactive routing protocols perform better than the reactive ones, in terms of packet delivery ratio and average packet delay, as a consequence of knowing the entire network topology. In a forced handover this means that the registration can start immediately and no gateway discovery has to be performed first, which reduces the handover delay. The results obtained for hybrid approaches are comprised between proactive and reactive values. Handover delay is shorter in proactive approaches. When the link is broken another alternative can be used avoiding to start a new gateway discovery. Nevertheless, both approaches have a similar rendition in environments with a high number of gateways, only scalability features are lower in proactive approaches.

### 3.3.2 Interconnectivity

This section is based on the paper from Uppsala University [26].

Nowadays, several researchers [26][35] are focused on finding the proper way to interconnect Ad hoc networks and the wired Internet, because of the interminable range of possibilities that an Internet access can offer. Because of the two different kinds of addressing, hierarchical and flat, the principal issue is to find the location where to send the packets.

Several solutions can be performed to find the location of the correspondent node depending on the routing protocol used in the MANET. Proactive protocols can determine if a node is or is not within the MANET, by checking its routing table.

On the other hand, reactive protocols have to flood a request message through the network; the absence of answers from the network usually means that the node is from the wired network, although this is not 100% reliable as packet losses can occur. Broch et al. [5] propose a more advantageous solution instead of using timeout. Here, the gateway insures that the requested node is not in the MANET. How this insurance is done, depends on the specific addressing scheme scenario, e.g. if all MANET nodes have a special prefix the gateway, by looking at the address, can determine if it is a MANET or wired destination, and replies offering itself to be a proxy for this node. During the gateway discovery it is a good moment to notify all the intermediate nodes about the location of the wired node [26]. Intermediate nodes will then keep this information in cache for future use. However, some devices might have limited memory capacity, so big route tables and caches seem to big high overhead. The straightforward procedure, after the location of the node is resolved, is to find a route to the destination and forward the packets. Intermediate nodes will keep this information in their routing table as a one-hop destination, connected directly to the gateway. The drawback of this solution is that intermediate routing tables will grow, and each route to the Internet, has to be independently maintained. However, it is not a good solution because of the "cascading effect", as the knowledge whether to send the packet on the route to the gateway or directly to the MANET destination requires each node along the route to the gateway to perform a MANET wide route request in order to be sure that the address does not belong to a MANET node.

Two of the most promising alternatives to reach an Internet connection from a mobile node in a MANET network are default route and tunnelling [26].

#### 3.3.2.1 Default Route

All the nodes attached to a gateway share most of hops to reach the gateway. In the attempt to reduce the amount of request packets sent in the network a default route is created, only for proactive routing protocols, thus avoiding constant route discoveries to the gateway. In reactive routing scenarios, before to send packets through the default route, the sender has to be assured that the destination is located in the wired network. To determine the location of the correspondent node a route request is flooded through the network from every node along the default route, leading to the "cascading effect" [26]. However, it is not necessary to flood this route request messages in a shared prefix approach [16], as the system can recognize the location of the node just by checking the prefix. In a proactive routing protocol, as DSDV, this is less of a problem since the nodes already are aware of the entire MANET topology and therefore by doing a route table lookup can decide if the location is inside the MANET or in the wired network.

In single hops, a direct connection with the gateway, the default route points to the default gateway that is used to forward packets to the Internet. Nevertheless, in multi-hop scenarios forwarding is not as easy as in the single-hop scenario as consequence of path breaks or changes. The topology is changing and the closest gateway could not be the same as a few minutes before, producing inconsistent states. Sometimes in multi-hop scenarios it could be helpful to have connections with more than one gateway, for load balancing or to perform handovers.  However, one of the weaknesses of using default routes is that in multi-hop scenarios there is only the possibility to point, the default route, at one gateway each time. Consequently, a sort of default routes are generated, one for each gateway, even so only the destination could choose which one to use; intermediate nodes will follow the route already established for the source node.

There are two different possibilities to keep the default route in the routing table: first, the default route only indicates the next hop to the default gateway. Second, the default route indicates which current gateway is the preferred one to be the default. Wakikawa et al. suggest the second approach, in which the default route points to the current default gateway [37].

#### 3.3.2.2 Half-tunnelling

Half-tunnelling is the solution of tunnelling presented by Uppsala University. It is called half-tunnelling because actually there is only tunnelling required in one way of the communication. Wired nodes have not problems to send back packets to the ad-hoc network. Data is sent via normal wired routing to the gateway, which will do the appropriate address translation if the mobile node does not have the same prefix as its gateway.

The goal of Half-tunnelling is to create an imaginary one-hop connection between the source mobile node and the gateway. The packets are sent through the tunnel, without taking care of how the nodes are attached to the Internet or the addressing implied.

When the node detects that the correspondent node is located in the Internet, packets are encapsulated with a new header with the explicit IP address of the gateway as a destination. Then, in the gateway, packets are decapsulated and the original packet is sent to the fixed node.

Several benefits can be obtained using half-tunnelling instead of default route, some of them will be described: All the existing routing protocols can use half-tunnelling, no modifications or adaptations of the core protocol have to be done. Moreover, intermediate nodes do not need to be conscientious about the tunnelling; they forward encapsulated packets as normal packets in an ad-hoc network. Only the source node and the gateway know that the packet is destined to the fixed network, consequently the cascading effect is avoided and the number of entries in the routing table decreases considerably. Intermediate nodes only have to perform one look-up in the routing table. In half-tunnelling intermediate nodes do not have to check the location of the destination node, the location of the gateway is already known.

The source node is responsible to decide when a change of gateway has to be done. Even if a forced handover has to be done, the source node has to consent it. A source node can send packets to multiple gateways to improve load balancing and robustness.

In terms of security, half-tunnelling implements the same security that normal ad-hoc communications, with authentication implemented it is possible to avoid masqueraded attacks of the gateway.

Some simulations done in different environments [26], with Uppsala University's implementation of ADOV named AODVUU, shows that half-tunnelling perform much better in ad-hoc networks than default route. Half-tunnelling presents a proper way to forward packets to the Internet nodes, using the standard routing protocols, and maintaining the intermediate node beyond it.

### 3.3.3 Gateway Discovery

#### 3.3.3.1 Gateway and Address Autoconfiguration for IPv6 Ad Hoc Networks

Jelger et al. use in this proposal the default route, next hop, in [16] to provide Internet connectivity, however to allow more than one gateway and improve stability they introduce the concept of "prefix continuity".

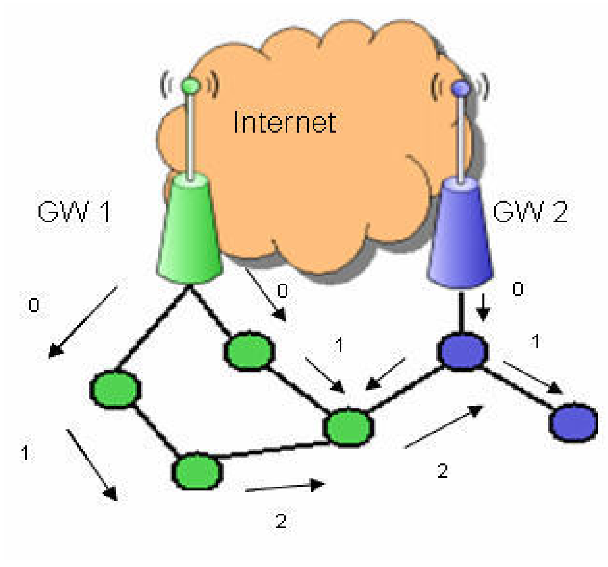


*Figure 6 Prefix Continuity [44]*

To achieve prefix continuity each gateway periodically flood GW_INFO messages to its one-hop closest neighbours, thus it is a proactive gateway discovery approach. A GW_INFO message contains information of number of hops to the gateway and the gateway's prefix. This message is propagated, if the node has the same prefix as found in the GW_INFO message. Each node updates the "number of hops to gateway" field. This scheme, with propagating GW_INFO messages, makes nodes aware of which gateways are in the surroundings and how many hops away they are, still avoiding to flood the entire network.

Nodes can choose to use a gateway if the number of hops to that gateway is fewer, called ”distance algorithm”, or try to use a gateway with the same prefix as long as possible , called "stability algorithm". As nodes chose to use a gateway, it adopts that gateways prefix; a prefix tree will be formed with a root at the gateway.

If a proactive routing protocol is used it will also use its upstream neighbour, with the same prefix, as default route. However, if a reactive routing protocol is used no default route will be used; instead a gateway can answer on route request for destinations outside the MANET.

With the distance algorithm where a node always chooses the closest gateway, it will change its prefix quite often but it will only affect few nodes, as the prefix chain is short.

If a stable prefix is preferred, the stability algorithm is used and a node tries to use the same prefix as long as possible. However, long prefix chains can be formed, as the node will favour upstream neighbour nodes with the same prefix.

If a change occurs in the beginning of the chain, a bulk change will occur as all downstream neighbours also have to change their prefixes. Therefore, there is not so big difference on the total number of prefix changes if a node use stability or distance algorithm.

However, the load-balance is improved with the distance algorithm. Nodes will be more evenly spread between the different prefix trees, gateways, and the size variation between the trees will be less.

A benefit of the stability algorithm is evidently that prefixes are kept longer, so the network becomes more stable and prefix changes only occur when absolutely necessary. As shown by simulation in [17]. Because prefix continuity, can create routes that are fragile to changing topologies, performance is at best, as shown by simulation [33], when there is few link breakages and low mobility. A general benefit form using [16] is that gateway advertisements are flooded in a controlled fashion, as the messages are only propagated by nodes with the same prefix as in the advertisement.

#### 3.3.3.2 Global Connectivity for IPv6 Mobile Ad Hoc Networks

Wakikawa et al. is proposing in [37] both a proactive and reactive discovery method. With the proactive method, unsolicited gateway advertisement messages (IGWADV) are periodically flooded through the MANET. When using the reactive method, the gateway advertisement message is only sent as unicast response to a gateway solicitation message (IGWSOL), sent by a node to the ALL_MANET_GW_MULTICAST multicast address.

These messages can be implemented in two different ways [37], either as an extension to IPv6 Neighbour Discover Protocol (NDP) or as an extension to the specific MANET routing protocol.

From these messages a node chose a prefix to create a globally routable address and a default route. A host based route towards the gateway is also created at the node.

When a route destination is not known a priori, (i.e. when reactive routing protocols are used) a route request should be performed via the MANET routing protocol. If no route is found, a node then use its default route and send the packet via either a routing header (i.e. tunnelling) directly to the gateway or to the next hop in the default, called next hop routing.

If the gateway has a MANET local route to the destination and tunnelling has been used, it will reply with an ICMP Redirect error message to the sender. Then the sender will perform a new route request, to the destination, to learn the host route.

The gateway keeps a list of nodes that use its prefix for global access. This list is used for both route examination and address management, in case of MobileIPv6. When proactive routing protocols are used, the gateway can see which nodes are in its vicinity by checking the topology map. If a reactive routing protocol is used, this check cannot be done, as most reactive routing protocols do not keep the entire topology in its cache.

However, even if any method of obtaining information is allowed, all MANET nodes are obliged to contact the gateway; at least once it establishes an internet route with the gateway. During this contact, the gateway records them as nodes with globally routable addresses. In the IGWADV message, there is also the possibility for the gateway to set a 1-bit Acknowledgment flag (A). If this A flag is set, a MANET node, when it auto-configures its address must send an Internet gateway confirmation (IGWCON) message to the gateway.

In the case of multiple gateways, in a single MANET, the associated node lists are exchanged between the gateways, to make all gateways aware of the entire topology. The gateways listen to routing information but preferably not participate in the normal MANET routing, thus not forward flooded packets, like route requests, to its neighbours on the behalf of other MANET nodes. This simplifies route examination as described in [37]. Simulation

[33] has shown that the performance varies heavily both under different mobility scenarios and with different routing protocols. Although, these simulations also show that compared to [16], the performance, of packet delivery ratio, both reactive and proactive methods scales well with the node speed and number of link breakages. A slight performance gain could be seen when using the proactive method; the drawback is a larger overhead because of periodically flooding the network with IGWADV messages.

#### 3.3.3.3 Other Approaches

In the implementation of AODV [28] done at Uppsala University, AODVUU [40], the gateway acts as a proxy and will respond to RREQ messages that belongs in the wired part with a special RREPI. This special message tells the nodes that all messages sent too that address, in the wired network, should be sent via the gateway. The packets are forwarded to the gateway by using the half-tunnelling approach described in Chapter 3.3.2.2.

In the ns2.28 implementation of DSDV [8], it is added the possibility to use next-hop routing to reach nodes that are not inside the MANET. When nodes first are configured they are manually assigned a gateway, so no real gateway discovery is performed. And as DSDV is a proactive protocol, the nodes will check their routing tables and if they don’t find any route they will send the packets to the gateway address, if that exists in the routing table otherwise the packet is dropped.

## 3.4 TCP

### 3.4.1 TCP FeW

TCP FeW [22] is a proposal by Nahm et al. where they focus on the fact that in a MANET the bandwidth-delay product (BWD) is low compared to a wired network. In a multihop scenario, a BWD of around 2 packets can be assumed, in a wired network the BWD can be in the order of 100 – 1000 packets.

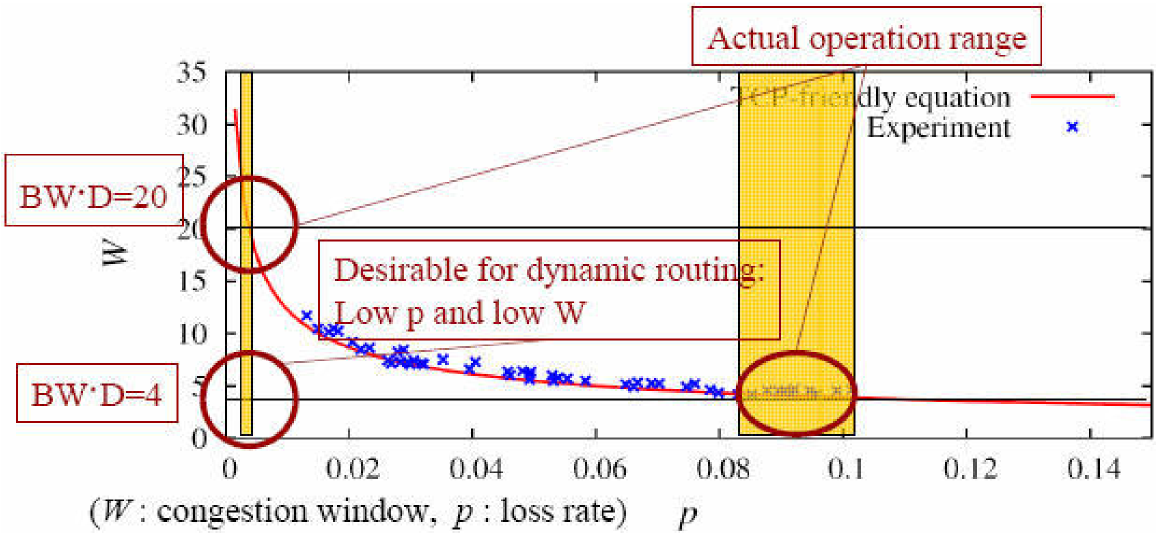


*Figure 7 Optimal window size for low BWD [21]*

TCP uses a window (W) to estimate how many packets simultaneously can be on flight in the network, in congestion avoidance phase W = W + ΔW (where ΔW=1) for every round trip time (RTT) independent of the network capacity. In a wired network an increase with 1 packet is considered a mild traffic probe as it is only around 0.1 – 1 % of the available network capacity. However, in a MANET an increase of 1 packet is around 50% of the available network capacity and will rapidly lead to contention in the MAC layer and hidden terminal problems that will cause packet collisions.

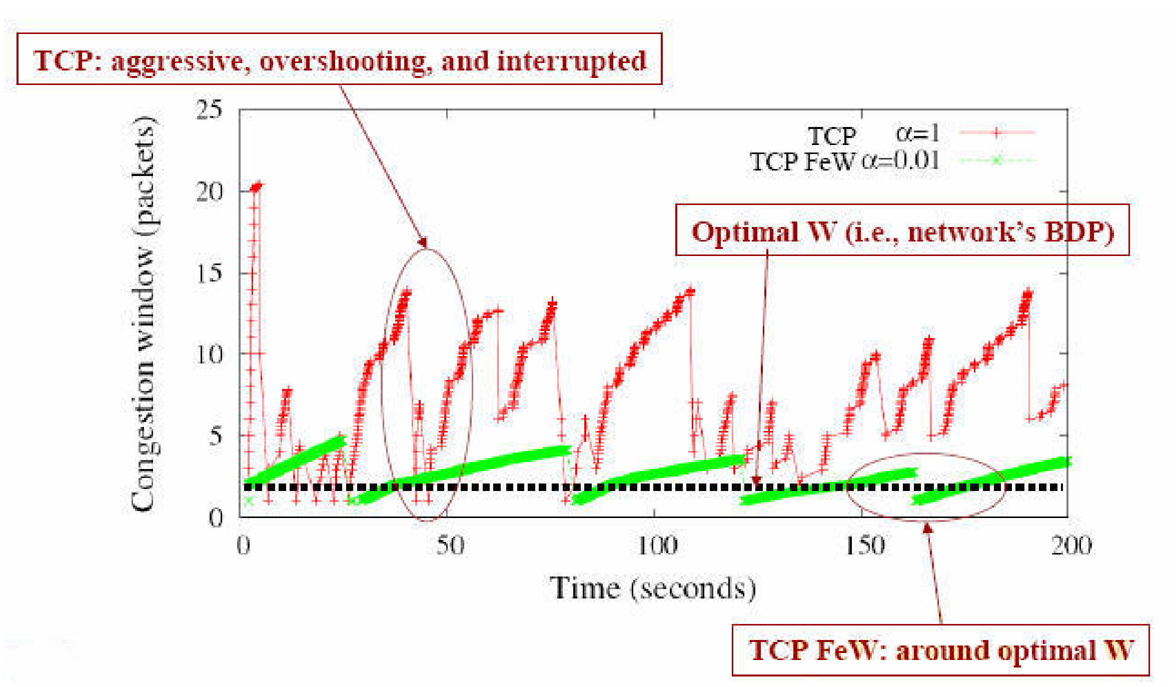


*Figure 8 TCP window size over time [21]*

Generally, MANET routing protocols do not distinguish between different types of losses that occur e.g. losses due to MAC contention, channel errors, mobility etc.

Reactive routing protocols as DSR or AODV detect route failure during an ongoing session, through loss detection.

As TCP increase its window too fast, it will overflow the network and a MAC layer contention will occur. This will lead to route-maintenance requests, as the routing protocol assumes a broken route when the MAC layer loses packets. These unnecessary route-maintenance requests will be triggered, and contribute to the contention. This loop continues until TCP timeout, or as long as the MAC contention is persistent.

Therefore Nahm et al. has suggested a fractional window increment (FeW) scheme where $\Delta W = \alpha$, $0 < \alpha \leq 1$ (in legacy TCP $\alpha = 1$). The FeW scheme also allows fractional window (W) size ($0 < W \leq 1$) interpreted as sending 1 packet every RTT/W. Modifications to TCP ACK and slow-start thresholds are also accommodated to allow a windows size lower than 1, $W < 1$. With the above modifications and for example, if W=0.20, a data transmission is scheduled every 5 RTT and W is updated accordingly. The aggressiveness of the traffic probing, in terms of window increment-size, is with this scheme determined by the size of α, a smaller α lead to a milder traffic probing. Through evaluation of a TCP friendly algorithm and simulations Nahm et al. has found that with α=0.01, TCP FeW maintain its maximum throughput through the different simulated scenarios [22].

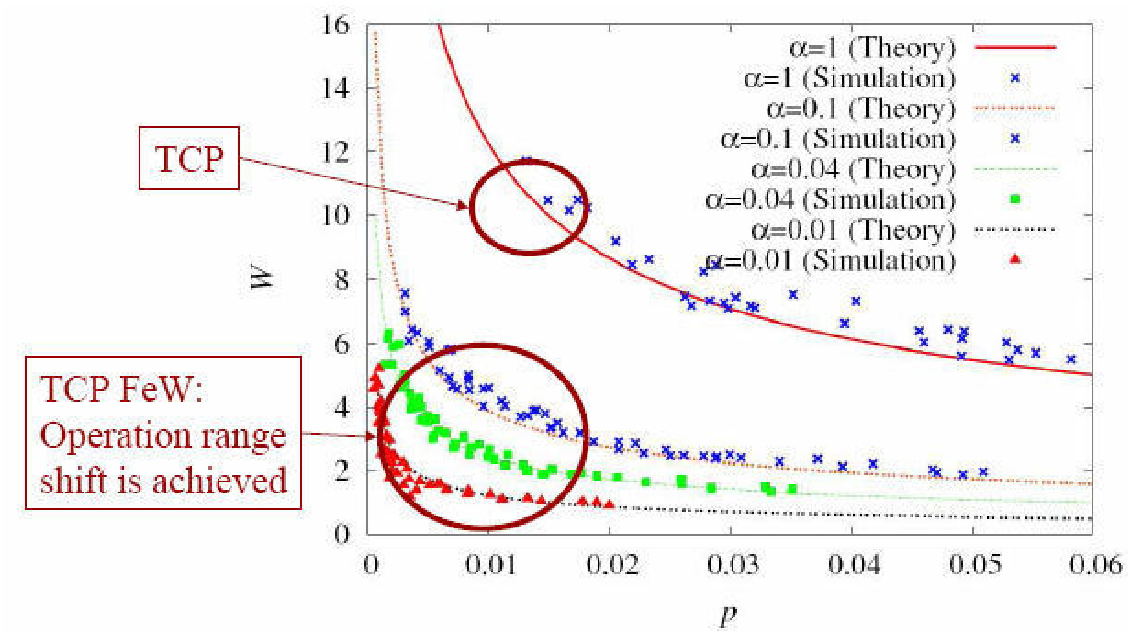


*Figure 9 Window sizes for different α values in a low BWD multi-hop network [21]*

The drawback of this scheme is that in a high BWD environment, TCP utilizes the available bandwidth less aggressively. Consequently, it will take longer time for the TCP connection to reach the maximal available throughput and therefore the performance will not be optimal. However, Nahm et al. has mainly focused their work on the bad cross-layer cooperation that occurs between MANET reactive routing protocols and TCP in a "pure" MANET.

### 3.4.2 TCP Vegas

Brakmo et al. presented TCP Vegas [4] 1995 as an interoperable variant of TCP to increase throughput, reduce packet loss and therefore retransmissions, while not jeopardizing fairness.

The main difference between TCP Reno and Vegas is the philosophy in which it determines the available BWD in the network.

TCP Reno effectively determines the available BWD by increasing the number of packets on flight, until the network is congested and start to drop packets. This method is undesirable, as it can make TCP overshoot and create buffer overflows in gateways and routers in a wired network. As seen in Chapter 3.4 it also leads to MAC layer contention in a wireless multihop network.

TCP Vegas rather than first congest the network and then adapt, proactively adapts the window, according to the difference (diff) between expected and actual throughput, to avoid packet loss.

To achieve this proactive behaviour, Brakmo et al. proposed a scheme where $W = W + \Delta W$. If $diff < \alpha$ $\Delta W = 1$, if $\alpha < diff < \beta$ $\Delta W = 0$ and if $diff > \beta$ $\Delta W = -1$. This difference is calculated by $diff = Thr_{expected} - Thr_{actual} \geq 0$, where $Thr_{expected}$ is Current W/minimum RTT and $Thr_{actual}$ is the throughput calculated as how many packets sent during the time between a packet is sent and its ACK is returned. Typically the two thresholds $\alpha$ and $\beta$ are set between 1 and 3 in a wired network e.g. $\alpha = 1$ and $\beta = 3$[5], in practise $\alpha = \beta = 2$[6].
Modifications to the slow start behaviour and retransmission schemes are also accommodated to avoid packet loss and unnecessary packet retransmissions.

Analytical models and simulations conducted with wired networks have shown that TCP Vegas measures congestion by end-to-end queuing delay [19] and if the queue sizes at intermediate nodes, routers, are large [12], TCP Vegas achieves better throughput and packet loss ratio than TCP Reno. At the time of writing this report, no studies known to the authors, of TCP Vegas performance has been conducted in a hybrid MANET enviroment.

In the case of inadequate queue sizes, TCP Vegas cannot utilize its improved congestion detection mechanism and reverts to the same behaviour as TCP Reno [12]. Furthermore, [12] shows that the higher the available bandwidth is the more efficient TCP Vegas performs.

Further studies in multihop wireless networks [7], verify that packet loss in TCP is mainly due to MAC (IEEE802.11) layer contention, and not due to inadequate queue, buffer, sizes at intermediate nodes.

A remark is that TCP Vegas, stated in [4] and further investigated in [19], can lead to persistent congestion. However, the conditions that lead to persistent congestion are highly unlikely, in a realistic scenario, as they require connections to start up serially [19][7].

The desirable aspects of TCP Vegas are:

- It is solely a modification on the sender side and therefore can interoperate with any valid TCP implementation without modifications.
    - Allows for incremental deployment
- Do not need modifications, e.g. of $\alpha$ and $\beta$ parameters, to operate well in both wired and wireless networks.
- Do not require explicit cross-layer notification or information.
- Reduce losses and retransmissions

[5] Barkmo et al. defines that $\alpha < \beta$ to avoid fluctuations, however recent studies suggest that $\alpha = \beta$ to improve fairness [11][19].
[6] As shown in [7] a setting of $\alpha = \beta = 2$ also gives the best performance in a wireless multihop network.
[7] Even if it is highly unlikely Low et al. propose a method to solve the problem with persistent congestion [19]

    - Saves battery power
- Could be combined with the FeW scheme described in Chapter 3.4.1

A further enhancement that is beneficial, in a MANET, to both TCP Vegas and TCP Newreno is ACK thinning, especially with higher bandwidths, as result of the IEEE 802.11 standard, the cost of sending small packets, as ACKs, increase with the bandwidth [7]. However, as this requires changing the receiver side, it does not allow incremental deployment.

Simulations [7] done by ElRakabawy et al. show that TCP Vegas $\alpha = \beta = 2$ outperforms TCP Newreno, especially noteworthy is that TCP Vegas achieved as much as 99% less packet retransmissions in some of the simulated static multihop wireless network scenarios.

### 3.4.3 TCP AP

TCP with Adaptive Pacing is a hybrid approach that implements adaptive pacing while retaining TCP end-to-end semantics and thus is TCP interoperable with any valid TCP implementation [6].

The two main characteristics in this proposal is a new congestion detection and control mechanism. Congestion detection is proactively performed by detecting link contention via fluctuations of RTT samples. Congestion control is achieved by pacing the transmission, based on the above measure of contention and the delay until the sender can send the next packet, without interfering with the ongoing transmission of the former packet. This delay is calculated by measuring RTT and by knowing available link capacity, information from the MAC layer, and number of hops, taken from the routing layer, between the sender and the receiver. Due to the hidden terminal effect, in a chain topology, a TCP sender at node i can only transmit a packet successfully as soon as node (i+3) has finished its transmission. The authors of [6] refer to the time elapsed between transmitting a TCP packet by node i and receiving the packet at node (i+4) as the 4-hop propagation delay (FHD).

Two parameters that control the functionality are N and $\alpha$. N is the number of recent RTT samples to take into consideration and $\alpha$ is the averaging weight parameter in the exponentially weighted moving average (EWMA) algorithm used to estimate the 4-hop propagation delay.

As shown in [6], TCP AP outperforms TCP Newreno in static wireless multihop networks. As this report focuses on hybrid MANETs the result may not be directly comparable.

The desirable aspects of TCP AP are:

- It is solely a modification on the sender side and therefore can interoperate with any valid TCP implementation without modifications.

    - Allows for incremental deployment
- Use the knowledge of how traffic is forwarded in multihop environments, to avoid congesting the network.
- Reduce losses and retransmissions
    - Saves battery power

The drawback is that it is not clear how the pacing mechanism works in a hybrid MANET where there exist wired links on the path or where there only is a single wireless hop.

#### 3.4.4 TCP with ELFN

To compensate for the disability of TCP to detect if packet loss is due to congestion or some other reasons, Holland et al. propose a scheme with Explicit Link Failure Notification (ELFN) [14]. The motivation to use ELFN is to avoid that TCP enter congestion avoidance in the case of packet loss that does not originates from congestion e.g. link or route failures. The scheme that Holland et al. propose is, when a notification comes from lower layers, TCP “freezes” and disable its congestion control mechanism until a route is restored. In Holland et al. proposal, retransmission timers are disabled and probe packets are sent at periodic intervals to see if the route is re-established. When a route is re-established, TCP starts where it “left off” when the notification occurred.

As Holland et al. shows, with mobile nodes, TCP Reno with ELFN outperforms TCP Reno without ELFN in almost all scenarios [14].

However, as mentioned before and investigated more in [7][22], TCP can in itself provoke packet loss and force route changes even if there is no mobility involved.

#### 3.4.5 A Comment on MAC Layer Unfairness

As mentioned before, in a low-bandwidth network, it is essential for TCP flow fairness that the MAC layer is fair. Unfortunately, IEEE 802.11 MAC is not fair and this result in disadvantageous behaviour, this is even worse when MANET local TCP flows compete with MANET-Internet flows [25].

However, as shown in [39] with a relatively small window size (W<8), fairness is not a problem.

## 3.5 Summary

In this chapter, some solutions are presented to solve the problems, already expressed in Chapter 2, when a MANET wants to interconnect with a wired network.

As it is explained in Chapter 2, addressing is one of the most important problems. For this reason to implement Mobile IP is a good solution because independently of the point that nodes are attached, they conserve their IP address. Modification to IPv6 stateless auto-configuration mechanism is also important, to support address configuration over multi-hop networks, without the need for a central entity.

Three different approaches, “Gateway and Address Autoconfiguration for IPv6 Ad Hoc Networks” [16], “Global Connectivity for IPv6 Mobile Ad Hoc Networks” [37] and AODVUU [40], to perform gateway discovery in a MANET network are presented.

In [16], Jelger et al. use “prefix continuity”, to limit the flooding of gateway advertisement messages. To send packets to the gateway next-hop routing is used.

Wakikawa et al. [37] is a more flexible proposal that allows both reactive and proactive discoveries methods, to achieve a global address and to create a default path to the gateway. To later send the packets to an internet node both next-hop routing and tunnelling are defined in the proposal.

AODVUU use special route request reply message to inform the nodes about gateways. To send packets to the gateway tunnelling is used.

When the route to the gateway is known, all packets that have as a destination a fixed node have to be sent to the gateway. To facilitate this connection to the fixed network two proposals are described to avoid continuous route discoveries, default route or next-hop routing and half-tunnelling.

Moreover, several solutions to ease the problems with TCP’s congestion control mechanism in MANET are proposed. As a consequence of the lack in research of how TCP performs in hybrid MANETs, and as several of these variations mainly deal with problems in pure MANETs, their performance can not be predicted in hybrid scenarios.

All solutions and conclusion drawn in this chapter are mostly theoretical. The following chapter will describe some of the simulations.

# 4 Simulation setup

In this chapter the simulations setup, of a subset of the implementations described in Chapter 3, will be described.

## 4.1 Introduction

In this chapter some of the simulations conducted to evaluate TCP performance in a hybrid MANET will be presented.

ns2 [41] is an open source simulator used for networking research, version 2.28 of this simulator will be used in all the simulations.

Ns2 is not a finished product and constantly new versions come out with new protocols or functionalities implemented. The simulator used in the simulations was extended with support for TCP AP and AODVUU. The makefile is also changed so that the simulator compiled in Suse Linux 9.3. This was done by installing the ns2.29 allinone package and later adding the ns2.28 directory and changing the makefiles so ns2.28 compiled in an ns2.29 environment.

To run a simulation a Tool Command Language (TCL) script has to be written, defining the environment for that simulation. In the script it has to be specified in detail the characteristics of the scenario: dimensions, time of simulation, nodes, links, protocols and so on.

To have a visual perception of the simulation there is an animation tool called Network AniMator (NAM) that graphically shows the output file of the simulation. In NAM, nodes are presented following the topology described in the script, time modifications can be done and packets can be seen while they are being sent through the link. Sometimes it is hard to distinguish packets from different nodes, for that reason some options can be used to see the difference, as the colour or the shape. Moreover, queues can be monitored to see when and which packets are discarded.

With the latest versions of ns2, a mobility generator is bundled, which is very useful for huge simulations, to avoid generating all the node movements in the script.

To simplify code in wireless scenarios, some features as traffic or the mobility of the nodes, can be defined in a separate file.

During the simulation, data can be recorded in output or trace files. It usually is difficult to evaluate the results of the simulation looking directly at the output file. To show graphs of the simulation results, scripts that extract data from the output files and a graph-plotting program have to be used; one option is to use Xgraph. Another option used to visualise the results throughout this report, is gnuplot[8].

[8] The bar graphs are handcrafted by inspecting trace-files and plotted with Microsoft Excel™.

### 4.1.1 Objectives

The aim of Chapter 4 is to describe the simulations and parameters used to evaluate how a selected set of different solutions, already explained in Chapter 3, perform in a simulated environment. Nowadays, in the field of telecommunications it is expensive and time consuming to perform a real experiment, using physical devices in a characteristic environment. Therefore, other alternatives have been developed and simulations are one of the best chances to have an idea of how a scenario can perform in the reality, with a low budget and quite fast. It is important to remark that the results acquired from the simulations are a guidance of how the performance will be in a real environment, as the results obtained might be far from the real implementation. There are parameters, such as the physical properties of the network, like the antennas, radio modules or obstacles and so on, which affect the results and cannot be represented easily in a simulation.

It is essential to have a well-structured script where all the parameters are presented as general variables, making easy to be understood for other users or in future uses, these parameters will be modified depending of which kind of simulation is required to be done.

The main objective of this simulation part is to evaluate the MANET routing protocol AODVUU together with different transport protocol, where the main one is TCP AP.

As a reference to compare the results obtained, simulations with DSDV as a routing protocol have been done as well, to show how the routing protocol influences the simulation.

Another important factor to consider is the traffic between the different nodes in the scenario. Four different traffic files have been developed to represent a wide range of possible traffic flows in the network see Chapter 4.2.2.

The different simulations that have been done in this section have been represented in four different mobility scenarios (Chain, Chain 5+1, Grid 7x7, Random48) which are explained in more detail in section 4.2.1. These scenarios represent different possible environments and show how determinant is the environment in the obtained results.

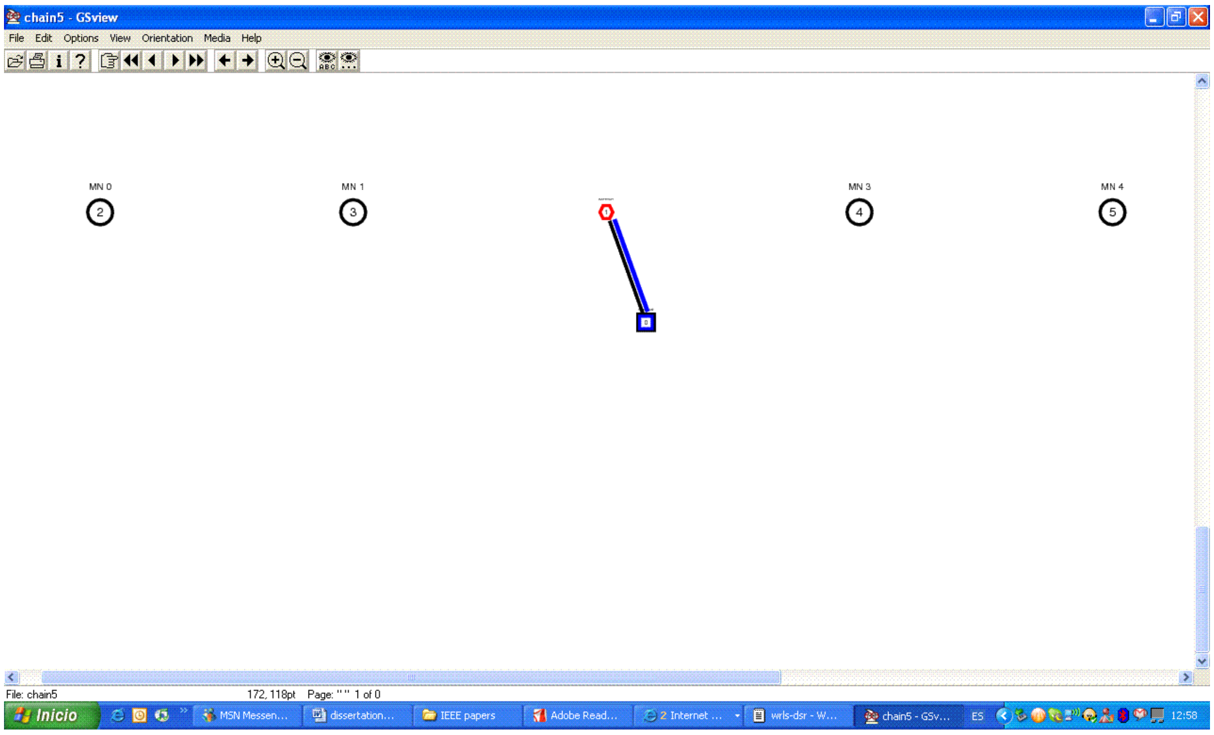
## 4.2 Simulation Environment

The simulation is conducted with four different mobility scenarios combined with four traffic scenarios. The traffic scenarios are the same to each mobility scenario except for mobility scenario chain5+1, where four specific traffic scenarios are used.

### 4.2.1 Mobility Scenarios

Four mobility scenarios are defined to represent different distinct situations. These settings try to be as realistic as possible.

#### 4.2.1.1 Chain5


chain5 - GSview
File Edit Options View Orientation Media Help
MN 0
MN 1
MN 3
MN 4
2
3
0
4
5
1
File: chain5
172, 118pt Page: "" 1 of 0
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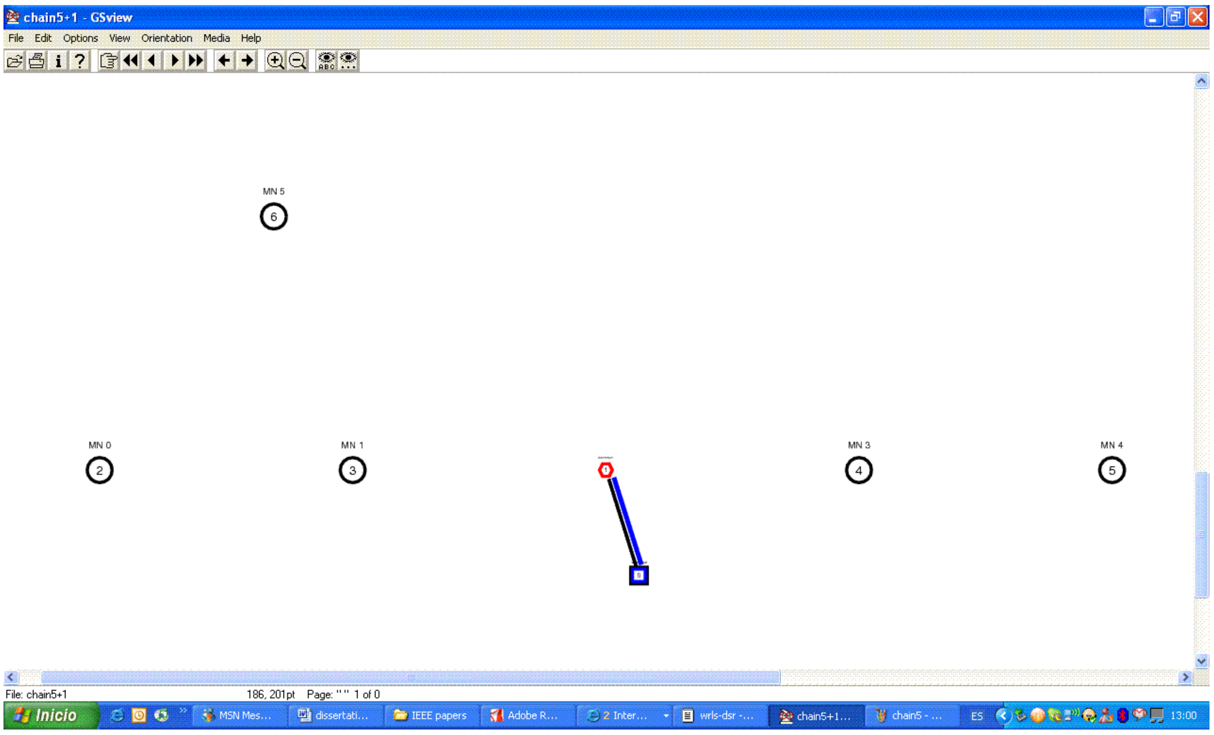
12:58

*Figure 10 Simulation using the mobility scenario Chain 5*

The first mobility scenario, as seen in the Figure 10, is the simplest of all. This setting has four mobile nodes and one gateway, which is the responsible to forward packets to the wired network. The nodes are organized following the structure of a 800 meters chain, where each node is separated by 200 meters. The gateway is placed exactly in the middle, the same distance to the gateway from both endpoints of the chain. All the nodes can reach the gateway with just one or two hops. Packets from one of the endpoints of the chain will need an intermediate node to reach the gateway, and this can produce some delays or drops.

Moreover, the mobile nodes are static, as they do not change the position during the entire simulation. This static distribution of the nodes reduces the number of signalling packets in the network because gateway discoveries or routing tables updates will be not so frequent.

### 4.2.1.2 Chain5+1


chain5+1 - GSview
File Edit Options View Orientation Media Help
MN 5
6
MN 0
2
MN 1
3
0
1
MN 3
4
MN 4
5
File: chain5+1
186, 201pt Page: "" 1 of 0
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13:00

*Figure 11 Simulation using the mobility scenario Chain 5+1*

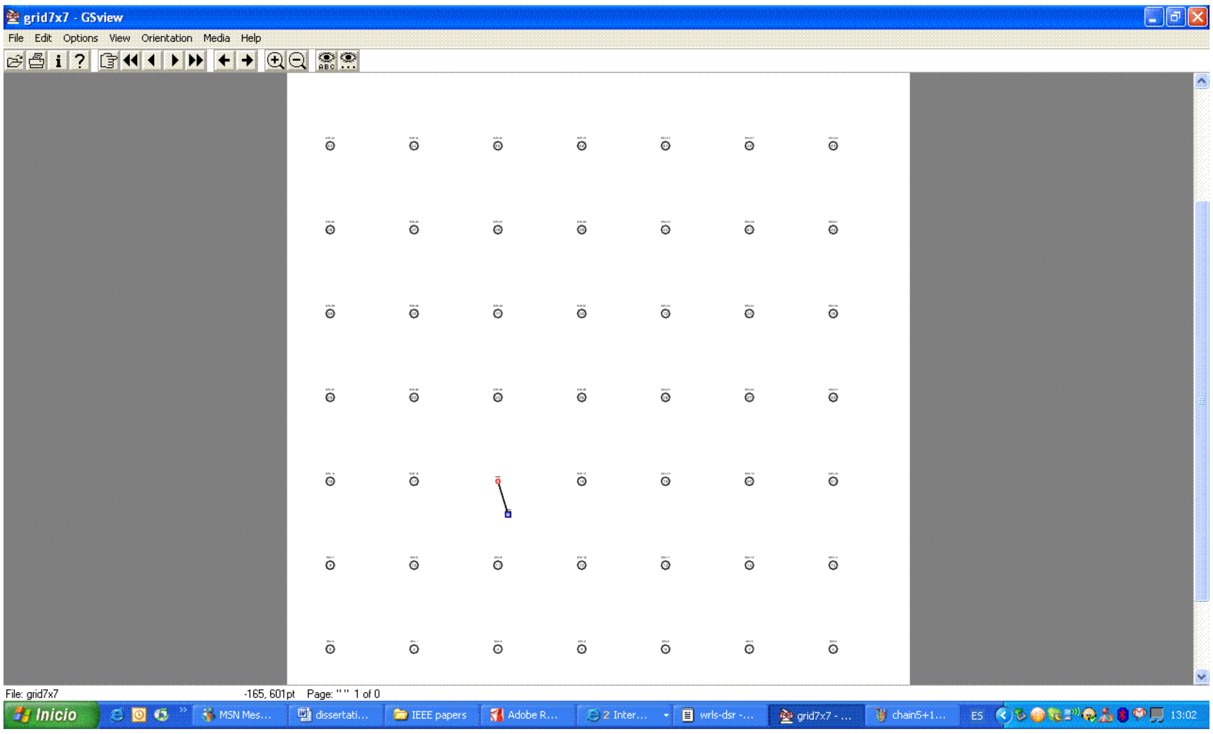
The mobility scenario chain 5+1 follows the same principles as the scenario, chain 5, explained just before, with the only difference that in this case there is one mobile node, MN 5 in Figure 11. This is to give some more dynamism to the scenario, because it is not usual that mobile nodes are static all the time. This extra mobile node is placed some meters above the chain. The initial position of the mobile node is on the most left possible, over node 0.

For the duration of the simulation the mobile node is moving straight from the left to the right side and back several times, with speeds varying between 1.5 and 60 m/s with varying pauses at the end sides. During this movement, the position of the mobile node is changing and consequently the route to reach the gateway. The number of hops from the mobile node to the gateway alters from three to one, depending of the position of the node. In that case, some control packets have to be sent through the network until a new route is created to reach the gateway. The results obtained will depend not only of the position of the mobile node but also on the routing protocol and the variant of TCP. The location of the mobile node is relevant in terms of delay and congestion.

The exact movement and speed of the mobile node is shown in the code sample below. The values before setdest are the node and at what time the movement starts, values presented after setdest are the destination (X) and (Y) in meters, followed by the speed in m/s. The reason of using value 0.1 as the destination value and not 0.0 is because the simulator in some cases do not work when the value 0.0 is used.

```
$ns_ at 10.0 "$node_(5) setdest 800.0 200.0 20.0"
$ns_ at 55.0 "$node_(5) setdest 0.1 200.0 30.0"
$ns_ at 90.0 "$node_(5) setdest 800.0 200.0 10.0"
$ns_ at 170.0 "$node_(5) setdest 0.1 200.0 20.0"
$ns_ at 220.0 "$node_(5) setdest 800.0 200.0 5.0"
$ns_ at 400.0 "$node_(5) setdest 0.1 200.0 40.0"
$ns_ at 430.0 "$node_(5) setdest 800.0 200.0 60.0"
$ns_ at 450.0 "$node_(5) setdest 0.1 200.0 1.5"
```

#### 4.2.1.3 Grid7x7



grid7x7 - GSview
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13:02

*Figure 12 Simulation using the mobility scenario Grid 7x7*

In the next mobility scenario, there are forty-eight mobile nodes and one gateway. The mobile nodes are placed in a square of seven nodes in each side with a separation of 200 metres between them. Each node’s radio coverage is 250 m. The number of mobile nodes in this simulation increases considerably compared to the other two simulations previously presented. Although, the mobile nodes are still static and do not change their position during the simulation.

The gateway is placed exactly in the position 400x400, see Figure 12, instead of in the middle, thus different numbers of hops, from one to eight, will be performed depending of the placement of the transmitter node.

### 4.2.1.4 Random48

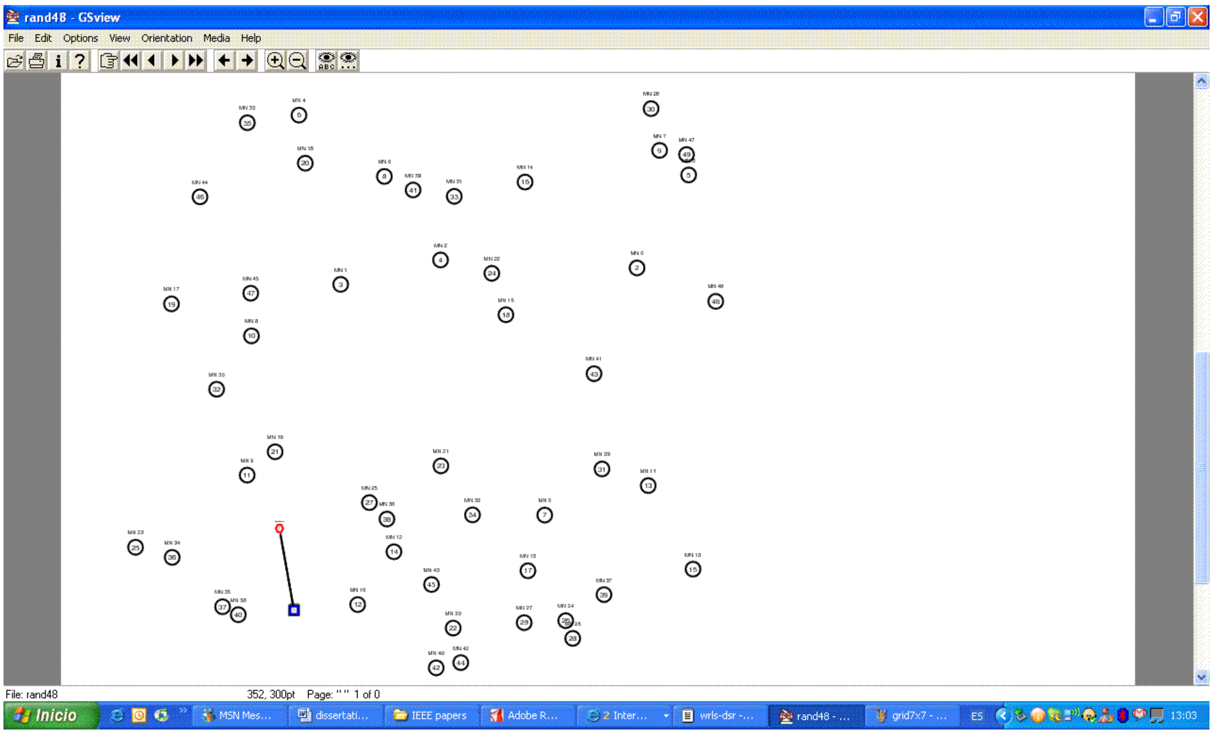

*Figure 13 Simulation using the mobility scenario Random 48*

This scenario has forty-eight mobile nodes and one static gateway placed in the same location, 400x400 as in the mobility scenario Grid 7x7 previously defined, see Figure 13. The space of the simulation is 1200x1200 meters and all nodes can move free inside a square of 800x800 meters. The size of this square is arbitrarily chosen to a smaller value than the simulation area, as the simulator cannot in all cases handle node movements in the borderlines of the simulation area correctly. The nodes move with a speed varying between 1 and 20 m/s and they take random pauses of 5 seconds making an average speed of 7.36 m/s.

The moving nodes are associated with a movement file; this file has the information of the trajectory that the nodes will follow. This information is generated randomly, that means that every node will follow a different trace. Although, because of the node's mobility, routes are constantly broken and the number of hops is modified. In this scenario it will be more evident than in the other scenarios the difference between routing protocols and how they work to find the proper route.

## 4.2.2 Traffic Scenarios

To discover the impact of the different traffic scenarios on TCP performance, the simulations have been run with different traffic-files. These traffic files determine, between which nodes, which kind of and when the traffic-flows start and stop. The traffic flows try to simulate a scenario where one or two MANET node(s) are uploading file(s) to a wired host, so the traffic is always originating from the MANET and directed towards the wired network. The flow-delay is a parameter that decides how much time should pass until the traffic flow starts and how long time before the end of the simulation the traffic should stop. This is to be able to better show the resulting traffic flow in a graph, if not used the last ACK packets would be after that the simulation ends and invisible in the graphs, see Appendix B.

We have selected different traffic scenarios to cover as many typical traffic situations as possible.

Default values for all traffic files unless stated otherwise:

- Type of traffic — FTP, simulating a large file transfer
- Transport Layer Agent — TCP (TCP variants see Chapter 4.3)
- Flow(s) — 1 or 2
  - Identification — 1 for first flow and 2 for second flow
  - Start
    - Flow 1 — 1 & 2 flows, start of simulation + flow-delay (20)
    - Flow 2 — (end of simulation– flow-delay)/4 (220)
  - Stop
    - Flow 1 — if 1 flow, (end of simulation-flow-delay) (880)
      if 2 flows, (end of simulation-flow-delay)/2 (440)
    - Flow 2 — end of simulation – flow-delay (880)

For each mobility scenario, Chain5, Grid7x7 and Random48, there are 4 different traffic files.

In all traffic files, unless otherwise stated, the source node of the flow crossing MANET/Internet border is denoted as node 0 and the destination is the Wired Host.

**1_tcp-from_node_0**

One FTP flow from the MANET to the wired network.

**1-tcp-from-node-0-1-tcp-between-node-4-node-0**

Two FTP flows, one from the MANET to the wired network and another one within the MANET, between Mobile Node 0 and Mobile Node 4.

**2-tcp-from-node-0-node-4-simultaneous**

Two FTP flows, from the MANET, Mobile Node 0 and Mobile Node 4, to the wired network both starting and stopping at the same time. They start at: 20 and stop at 880.

**2_tcp-from_node4_node0**

Two FTP flows, from the MANET, Mobile Node 0 and Mobile Node 4, to the wired network.

In mobility scenario chain5+1, where there is a moving node (Mobile Node 5) there exists the same traffic files but the flow that originates from the MANET starts at Mobile Node 5 instead of Mobile Node 0. There also exists one traffic scenario where there is only traffic within the MANET, namely **1_tcp-between_node_5-node_0.** In this scenario, there is one FTP flow between Mobile Node 5 and Mobile Node 0, trying to evaluate the impact, a moving node can have on the performance.

## 4.3 TCP Variants

As one of the most widespread transport protocols in use today, as well as in the foreseeable future, TCP is a protocol with a variety of different variants, as seen in previous chapters.

The code samples below show where it is determined which variable combination that yields the different TCP variant.

```
set opt(tcp_name)   "Newreno"           ;#Newreno, Vegas
set opt(tcp_ext)     ""                 ;#AP Only works with Newreno
```

### 4.3.1 TCP Newreno

The most widely deployed variant of TCP is Newreno. Although not perfect in all environments, it has proven both its effectiveness and adaptability in the current Internet.

Therefore, Newreno will be used as the standard baseline to compare the other approaches against.

The following code sample shows the default parameters used in the simulation, see [41] for details:

```
Agent/TCP/Newreno set newreno_changes_ 0
Agent/TCP/Newreno set newreno_changes1_ 1
Agent/TCP/Newreno set partial_window_deflation_ 1
Agent/TCP/Newreno set exit_recovery_fix_ 0
```

### 4.3.2 TCP Vegas

TCP Vegas was developed as a compatible replacement for Newreno. The main goals for developing Vegas was to solve Newrenos lack to adapt its congestion window in a high bandwidth Network, while still not over saturate a low bandwidth network.

In the simulations we selected α = β = 2, as this is the optimal setting in a multihop wireless network [7].

In our scenario the most interesting aspect with Vegas is that Vegas proactivley determine the congestion window and not reactively by provoking packet loss as Newreno does.

The following code sample shows the default parameters used in the simulation see [4][7][41] for details:

```
Agent/TCP/Vegas set v_alpha_ 2
Agent/TCP/Vegas set v_beta_ 2
Agent/TCP/Vegas set v_gamma_ 1
Agent/TCP/Vegas set v_rtt_ 0
Agent/TCP/Vegas/RBP set rbp_scale_ 0.75
Agent/TCP/Vegas/RBP set rbp_rate_algorithm_ 1
Agent/TCP/Vegas/RBP set rbp_segs_actually_paced_ 0
Agent/TCP/Vegas/RBP set rbp_inter_pace_delay_ 0
```

### 4.3.3 TCP AP

TCP AP (Adaptive Pacing) is based on Newreno but like Vegas, TCP AP proactively determines the congestion window, with different methods though.

TCP AP is more adapted for wireless multihop networks than Vegas, as TCP AP incorporates an adaptive pacing mechanism, to overcome MAC contention, which follows from the traffic bursts that normal TCP tend to generate as it will send as many packets, and as fast,  as it can within the allowed congestion window size.

In a pure MANET pacing is beneficial as it improves fairness and goodput when RTT is fluctuating [6], however in a network with stable RTT and large buffers TCP pacing is not so beneficial [1].

In the simulations we selected α = 0.7 and N = 50, as suggested by the authors as the optimal setting [6].

In our scenario the most interesting aspect is, in what sense the pacing is beneficial in a mixed scenario with both “stable” wired and “unstable” wireless networks.

The following code sample shows the default parameters used in the simulation see [6] for details:

```
Agent/TCP/Newreno/AP set n_factor_ 4
Agent/TCP/Newreno/AP set rate_interval_ 0.05
Agent/TCP/Newreno/AP set n_hop_delay_ 0
Agent/TCP/Newreno/AP set avg_n_hop_delay_ 0
```

```
Agent/TCP/Newreno/AP set coeff_var_ 0
Agent/TCP/Newreno/AP set adev_ 0
Agent/TCP/Newreno/AP set history_ 50
Agent/TCP/Newreno/AP set delaybound_ 0.5
Agent/TCP/Newreno/AP set alpha_ 0.7
Agent/TCP/Newreno/AP set ll_bandwidth_ 2e6
```

## 4.4 Routing and Gateway Discovery

AODVUU and DSDV are the routing protocols used in all the simulations. The one evaluated in detail is however AODVUU. DSDV is included for the interested as a reference, to see the difference a proactive routing protocol with gateway and next-hop routing support has on performance. The DSDV used is the version that comes with ns2.28.

### 4.4.1 AODVUU

```
#Wireless
set opt(rp)             AODVUU                    ;# DSDV, AODVUU
```

AODVUU is version 0.91 of the implementation of AODV by Uppsala University, as a reactive routing protocol with added functionality for gateway discovery and half tunnelling capabilities.

The following code sample shows the default parameters for mobile nodes used in the simulation, see AODVUU in [40] for details:

```
Agent/AODVUU set expanding_ring_search_ 1 ;#for RREQs
Agent/AODVUU set ratelimit_ 1 ;#rate limiting for RREQs and RERRs
Agent/AODVUU set llfeedback_ 1 ;# use link layer
Agent/AODVUU set internet_gw_mode_ 0 ;#1 = gateway node

Agent/AODVUU set unidir_hack_ 0
Agent/AODVUU set rreq_gratuitous_ 0
Agent/AODVUU set local_repair_ 0
Agent/AODVUU set receive_n_hellos_ 0
Agent/AODVUU set hello_jittering_ 0
Agent/AODVUU set wait_on_reboot_ 0
Agent/AODVUU set debug_ 0
Agent/AODVUU set rt_log_interval_ 0
Agent/AODVUU set log_to_file_ 0
```

```
Agent/AODVUU set optimized_hellos_ 0
```

## 4.5 Description of the Simulations

In this chapter, there will be described a table of 16 “template” simulations. To save place and to increase readability the simulations that only differ from these templates by only changing TCP variant or routing protocol is omitted, see *Table 2*. The complete list of the simulations, with DSDV and different wired bandwidth, can be found in appendix G.

| **Traffic/Mobility scenarios** | Chain5 | Chain5+1 | Grid7x7 | Rand48 |
|---|---|---|---|---|
| 1_tcp-from_node_0 | **1** | | **9** | **13** |
| 1-tcp-from-node-0-1-tcp-between-node-4-node-0 | **2** | | **10** | **14** |
| 2-tcp-from-node-0-node-4-simultaneous | **3** | | **11** | **15** |
| 2_tcp-from_node_0_node4 | **4** | | **12** | **16** |
| 1_tcp-from_node_5 | | **5** | | |
| 2-tcp-from-node-0-node-5 | | **6** | | |
| 1_tcp-between_node_5-node_0 | | **7** | | |
| 2-tcp-from-node-0-node-5-simultaneous | | **8** | | |

*Table 2 Template simulations*

**Simulation 1**

The simulation 1 reflects how a FTP flow behave in a chain 5 scenario with 5 mobile nodes, the one which it is in the middle acts as a gateway connecting with the Internet and reaching both directions of the chain with the same number of hops. In this particular simulation the traffic is send from the mobile node 0, the node most to the left in the chain, to the gateway, two hops right, which will forward the packet to the wired network.

**Simulation 2**

The simulation 2 represents how a flow of packets is transmitted in a chain. The node presented in the middle of the chain works as a gateway and the other four as a mobile nodes. In this setting there are two flows of traffic one of them goes from a mobile node 0 to the wired node, and the second flow of packets goes through one point of the chain to the other one, from node 0 to node 4. In that case, there is a critic route between node 0 and the gateway because both traffic flows use the same hops.

**Simulation 3**

The simulation 3 reflects how packets sent in a FTP flow. In that case there are two different flows both of them to the wired node but with different sources each point of the chain node 0 and node 4. Do not share hops because they use two paths completely different. The gateway is the only point in common for these two traces.  Both flows start and stop at the same time, to be able to determine the fairness between the both flows.

**Simulation 4**

In that case, simulation 4 is very similar to the previous simulation number 3 because the involved nodes are exactly the same, node 0, node 4 and a wired node. The main difference in this simulation is that the both flows do not start at the same time. This is to evaluate if there is a difference if both flows start simultaneous or if they start at an arbitrary point.

**Simulation 5**

As is explained before chain5+1 is an extension of chain 5, for this reason special traffic files are used, where the extra mobile node is involved. Simulation 5 is the first one using chain 5+1 as a scenario. In this particular case, the traffic file goes from the mobile node 5 to the wired host. During the simulation node 5 is attached to different mobile nodes in the chain and therefore the number of hops is changing constantly. Each time that the node is attached to a new intermediate node it has to do a gateway discovery to reach the wired host.

**Simulation 6**

This simulation is similar to simulation 4, the difference is that one of the flows comes from the moving node, mobile node 5.

**Simulation 7**

At the beginning of the simulation node 5 will have direct connection with the destination because it will be one hop to the source. However, during the simulation the node will move between the extreme ends of the chain. So it will be between 1 and 5 hops to the destination. In this simulation it can be observed how important the number of hops between source and receiver is for the delay.

**Simulation 8**

This simulation is similar to simulation 3. The difference is that one of the flows comes from (the) moving node, mobile node 5.

**Simulation 9**

In this simulation, we evaluate throughput in a static grid, representing fixed rely stations and stationary desktop computers uploading a large file to a wired host. The traffic is sent from mobile node 0 to the wired host, the number of hops between the gateway and the mobile node is at least 4.

**Simulation 10**

In this simulation, it is evaluated the performance of two competing FTP streams in a static grid, representing fixed rely stations and stationary desktops computers where one node is uploading a file to a wired host while communicating with another node in the grid.

**Simulation 11**

In this simulation, it is evaluated the fairness and performance between two competing FTP streams in a static grid, representing fixed rely stations and stationary desktops computers uploading large files to a wired host.

**Simulation 12**

In this simulation, it is evaluated the performance of two competing FTP streams in a static grid, representing fixed rely stations and stationary desktops computers uploading large files to a wired server, where both flows don’t start at the same time.

**Simulation 13**

In this simulation, it is evaluated the performance in a scenario where the 48 nodes move freely in an 800x800m area at speeds varying between 1 and 20 m/s with 5 seconds pause, representing nodes at walking or driving speed, where one node is uploading a large file to a wired host.

**Simulation 14**

In this simulation, it is evaluated the performance between two competing FTP streams in a scenario where the 48 nodes move freely in an 800x800m area at speeds varying between 1 an 20 m/s with 5 seconds pause, representing nodes at walking or driving speed where one node is uploading a file to a wired host while starting a download from another MANET node.

**Simulation 15**

In this simulation, it is evaluated the fairness and performance between two competing FTP streams in a scenario where the 48 nodes moves freely in a 800x800m area at speeds varying between 1 an 20 m/s with 5 seconds pause, representing nodes at walking or driving speed uploading large files to a wired host, both flows start at the same time.

**Simulation 16**

In this simulation, it is evaluated the fairness and performance between two competing FTP streams in a scenario where the 48 nodes moves freely in a 800x800m area at speeds varying between 1 an 20 m/s with 5 seconds pause, representing nodes at walking or driving speed uploading large files to a wired host, where the flows start at different times.

## 4.6 Simulation scripts

In this section some crucial variables, to understand the simulation script, will be presented. All of these variables can be changed by giving command line options to the main script, e.g. *–variable value*, if no command line option is given the default values shown in the examples below will be used .

Code sample with default values

```
... skipped code TCP version and extension
set opt(max_cwnd)           199                 ;#-1 disable
set opt(max_win)            64                  ;# < 200 for TCP AP
... skipped code scenario, traffic and wireless routing protocol
set opt(Wireless-rate)      2e6
#Wired
set opt(Wired-Bandwidth)    100Mb
set opt(Wired-Delay)        2ms
#Start and stop parameters
set opt(stop)               900.0
set opt(start-trace)        0.0
set opt(flow-delay)         20
#Clock in tracefiles
set opt(granularity)        1.0
```

Quick definition of variables:

| | |
|---|---|
| • `opt(max_cwnd)` | Maximum congestion window |

| | |
|---|---|
| | in **number of packets**, -1 disable |
| • `opt(max_win)` | Maximum Advertised window in **number of packets**, -1 disable |
| • `opt(Wireless-rate)` | Physical bandwidth wireless in **bits** |
| • `opt(Wired-Bandwidth)` | Physical bandwidth wired **Mbits** |
| • `opt(Wired-Delay)` | Delay on wired link in **milliseconds** |
| • `opt(stop)` | Simulation time in **seconds** |
| • `opt(start-trace)` | Time to start trace in **seconds** |
| • `opt(granularity)` | Time between trace probes in **seconds** |
| • `opt(flow-delay)` | see Chapter 4.2.2 |

### 4.6.1 Traces

The following parameters will be traced during all simulations:

- Congestion window in number of packets of sending node(s)
- Throughput and Goodput in Kbit/s measured at the sending node(s)
- Throughput and Goodput in Packets/s measured at the sending node(s)
- In the case of 2 streams, fairness in terms of "Jain's Fairness" index [15].

### 4.6.2 Formulas

Formulas:

- Goodput (KBits/s)= $\frac{Transmittedbytes(bytes) - \mathrm{Re}\,transmittedbytes(bytes)}{time(s)} \times \frac{8}{1000}$
- Jain's Fairness Index $= \frac{\left(\sum_{1}^{n} X_i\right)^2}{n \times \left(\sum_{1}^{n} X_i^{\,2}\right)}$
    - o n is the number of flows and $X_i$ is the throughput of the i:th flow, see [15] for details.

### 4.6.3 Running the Simulation and Post Processing

There are two post processing scripts, postprocess.pl and afterburner.pl. The former processes the trace files into a format that gnuplot can use to produce graphs. The latter is used to collect data from different simulations to combine them into one graph.

**Running the simulation**

To reproduce the simulations used in this thesis there is a small helper script called simulations.pl that feed the main script with correct command line options.
To run all simulations, the command line to use is “perl simulations.pl all”. This will run all the simulations with a wired bandwidth of 100 Mb and 2ms delay, to run the simulation with different bandwidth and delay the command line is “perl simulations.pl all `–Wired-Bandwidth 756Kb -Wired-Delay 25ms`”. , If only a subset of the simulations should be run, the exact simulations must be specified like “perl simulations.pl 1 6 100” for simulations 1, 6 and 100. To remember is that the simulation number, given on the command line, is not the template simulation number in Chapter 4.5, the simulation number is the one stated in appendix G.3.

## 4.7 Summary

In this chapter, the different parts and parameters of the simulation setup are described to easier understand and clarify Chapter 5. This chapter can also be used as a reference and overview of the complete code that can be found in appendix D.
Later in Chapter 5, some of the different “template” simulations will be used to evaluate and visualise the results obtained from all of the simulations found in appendix G.4.

All of the above described simulations are conducted with AODVUU and DSDV combined with TCP Vegas, TCP Newreno and TCP AP. All of these simulations were thereafter run one time with a wired bandwidth of 100Mb and a delay of 2ms and one time with a wired bandwidth of 756KB and a delay of 25ms.

# 5 Evaluation of Simulations

In this chapter results from some of the simulations, described in Chapter 4, will be presented and evaluated.

## 5.1 Introduction

Chapter 4 describes all the parameters for the simulation setup. It is important to have a previous knowledge about what will be simulated to understand correctly the results obtained in this chapter. Using the script attached in the appendix D.2 around a couple of hundred simulations have been run. With all this information, it is difficult to go into detail about every simulation run, so this chapter can be seen as an overview, where some simulations are highlighted to give a more clear view, on which parameters are influent in the situation.

In this chapter we consider it decisive to present in a graphically way the results acquired from the simulations.

So, to save space and to increase the readability only the simulations 1, 5, 9 and 13 are presented, as these are the simulations where the difference in traffic is most clear.
However, all the graphs from the simulations are found in appendix G.4 Each graph is representing a specific simulation with all three TCP variants, Newreno, Vegas and TCP AP (Newreno AP).

In all simulations, the congestion window is limited to 199 packets, as this is the default limit for TCP AP. Even though this limit is set in the simulator, as seen in the grid scenario, this limit is exceeded and TCP AP fails. The advertised window is set to 64 packets.

The simulation is conducted as a comparison between three TCP variants, TCP Newreno, TCP Vegas and TCP AP, and two different routing protocols, AODVUU and DSDV.

In the main simulation setup the wired bandwidth is set to 100Mb with a delay of 2ms to represent a local LAN. Additionally as a small comparison, a second simulation run is conducted with a wired bandwidth of 756Kb and 25ms, delay representing a typical Internet connection.

## 5.2 Performance parameters

The following performance parameters are evaluated in more detail: congestion window, throughput and goodput.

For each simulation that we present there are five graphs representing congestion window, throughput, goodput, aggregate of throughput and congestion window. For reference there is also included one graph representing the aggregate throughput when using DSDV.
**Congestion window** is measured at the sender as number of packets allowed on flight in the network.
**Throughput** is measured at the sender as number of Kbits sent per second.
**Goodput** is measured at the sender as number of Kbits sent - number of Kbits resent per second.
**Fairness** is calculated based Jain’s fairness index over the flows that run in parallel.

## 5.3 Chain5: Simulation 1

A chain with five nodes, where the left most node send packets via the gateway 2 hops away to the wired host.

### 5.3.1 Congestion Window

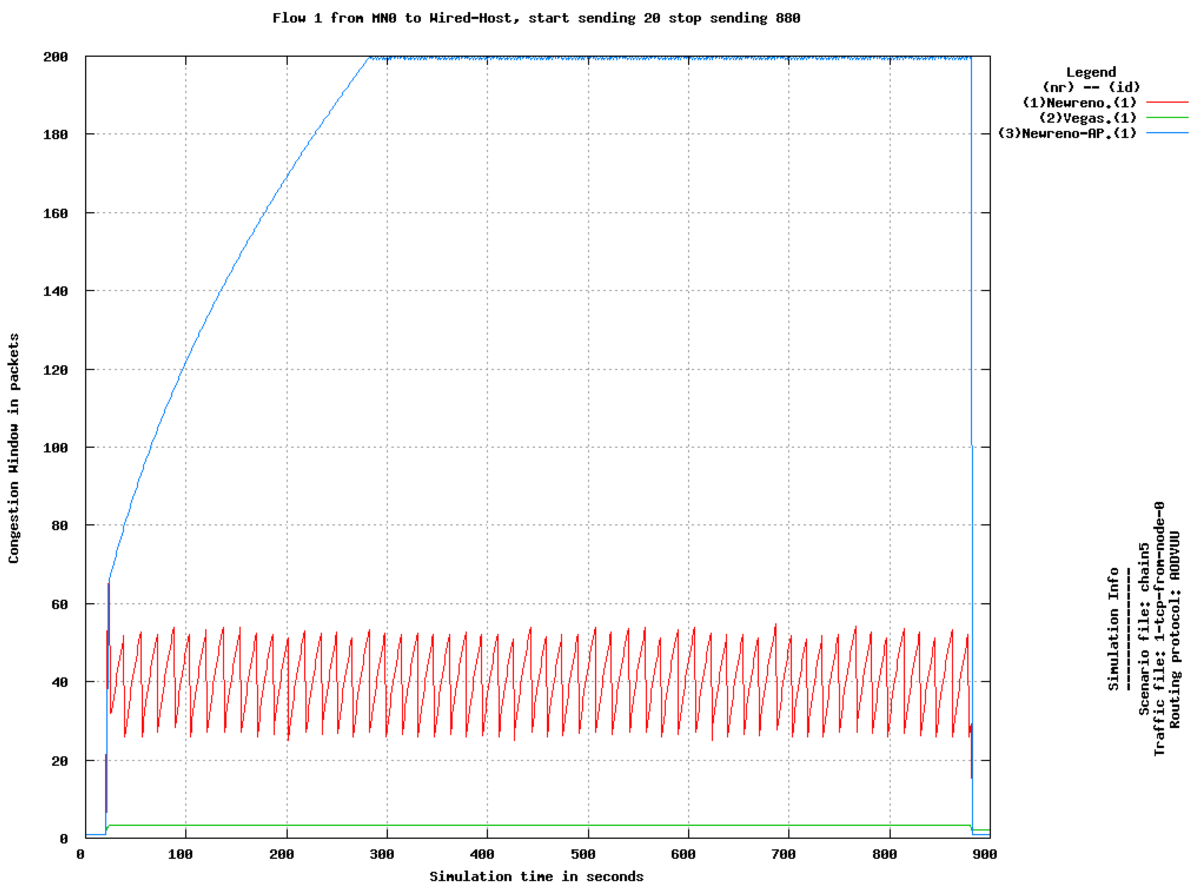

*Figure 14 Congestion window in simulation 1*

In Figure 14 it is clearly shown that in this particular simulation, TCP AP reaches the maximum congestion window and stays there, which indicates that it is not congesting the network. Vegas keeps a stable, not fluctuating, congestion window, indicating a good measurement of how congested the network is. Newreno has a fluctuating congestion window, which indicates that it constantly congests the network and therefore has to reduce its congestion window to compensate for this.

Even if TCP AP does not congest the network it is able to keep a high congestion window, which is most likely due to the pacing mechanism. Vegas must keep a much smaller congestion window to avoid congesting the network. Newreno has a larger congestion window than Vegas but it also, congests the network. The network congestion, which leads to packet drops, can be seen as fluctuations in Newrenos congestion window.

### 5.3.2 Throughput

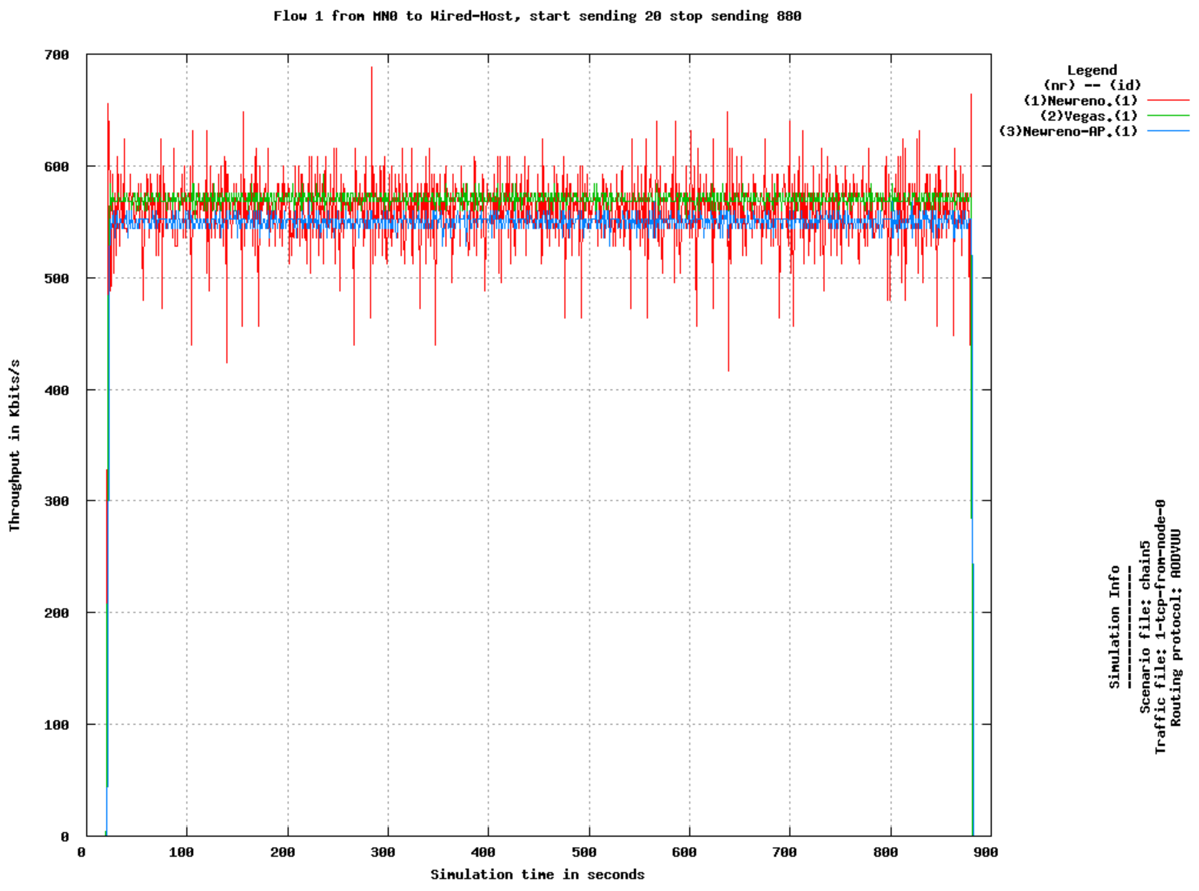

*Figure 15 Throughput simulation 1*

In Figure 15 it is shown that in this particular simulation, the throughput is similar for all three TCP variants. However, TCP AP has a lower average throughput than the others have. Vegas has a higher average throughput than TCP AP, of around 20 Kbits/s. Newreno has higher top peaks throughput but also lower bottom peaks throughput.

### 5.3.3 Goodput

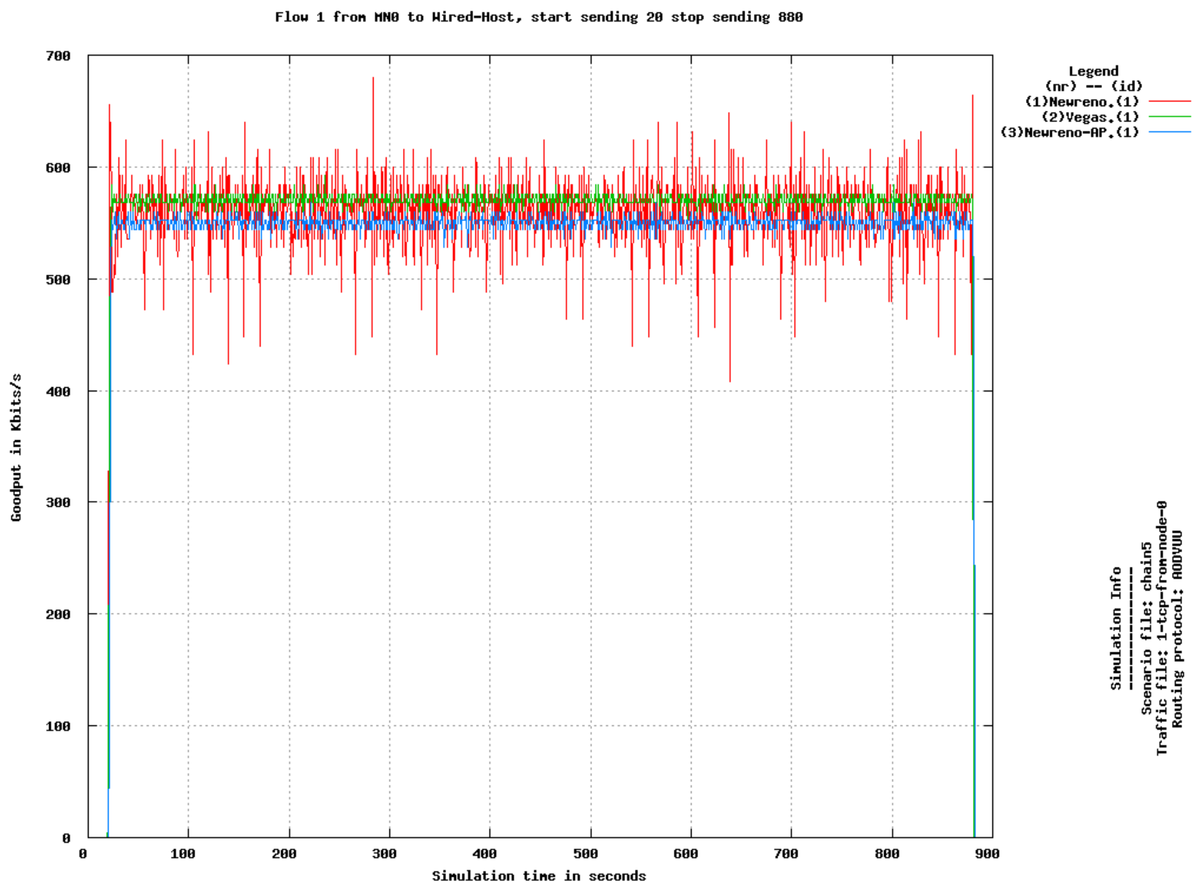

*Figure 16 Goodput in simulation 1*

In Figure 16 it is clearly shown that in this particular simulation, the Goodput is similar for all three TCP variants, and also similar to the throughput displayed in the former graph, which indicates a low amount of retransmissions. As seen, TCP AP has a lower average goodput than the others have. Vegas has a higher average goodput and Newreno has higher top peaks but also lower bottom peaks that the others have.

### 5.3.4 Average and Aggregate

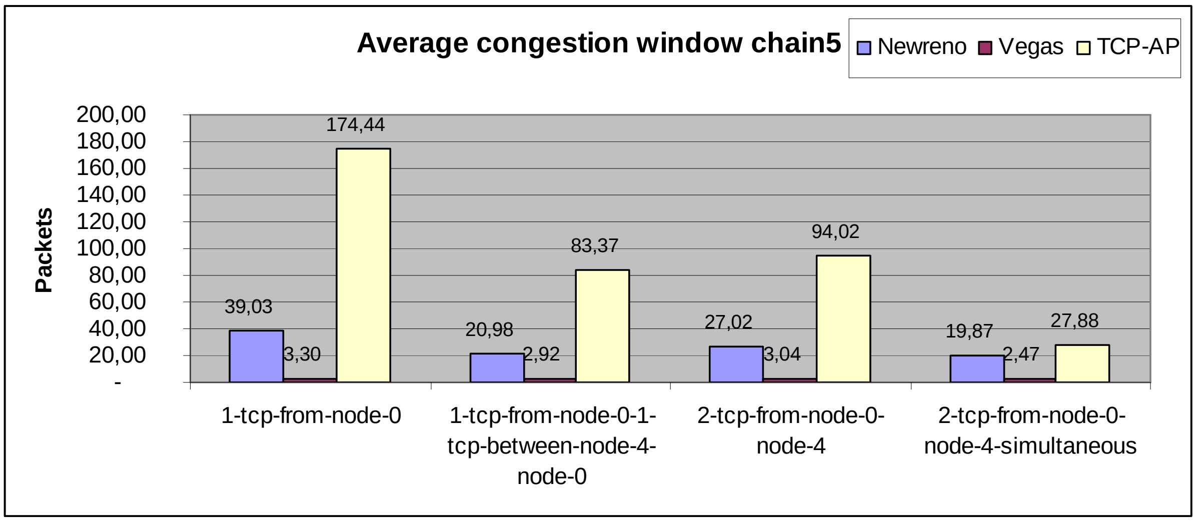

*Figure 17 Average congestion window Chain5*

As it is shown in the previous graphs, depending of the TCP variant the congestion window has fluctuating values, hence it is relevant to compare it in terms of average congestion window. In the traffic files that have more than one flow the congestion window for each flow is smaller than in the scenario with only one, as can be seen in Figure 17.

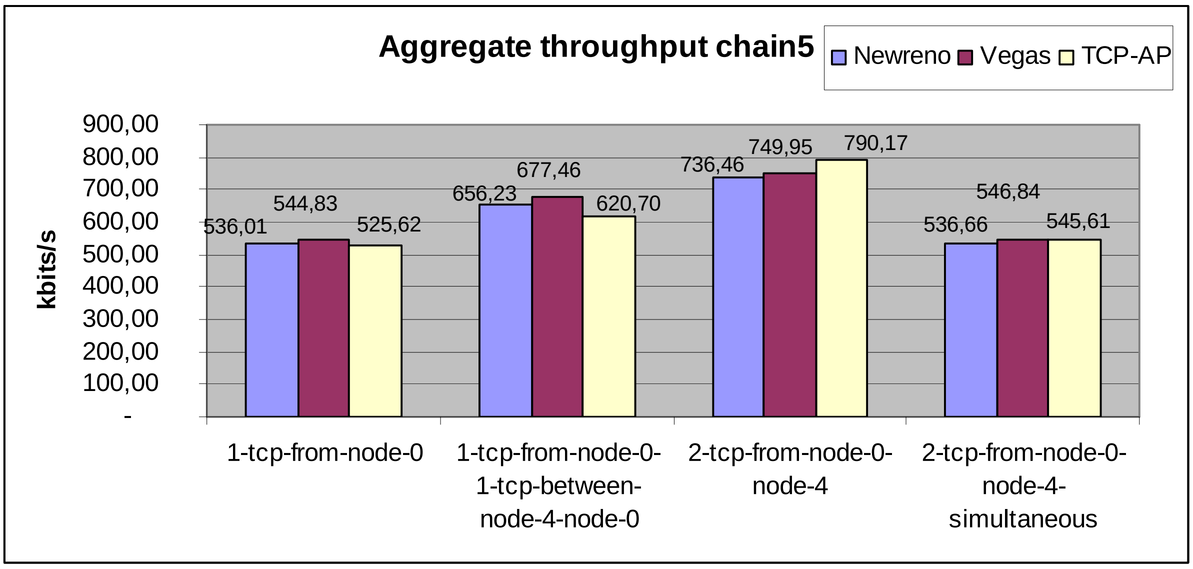

*Figure 18 Aggregate throughput Chain5*

In Figure 18 it is possible to see the throughput in terms of Kbit/s in different traffic scenarios. It is appreciable that in the traffic file where there is only one flow the throughput is lower than in the other two. In general, there is not so big difference between the TCP variants.

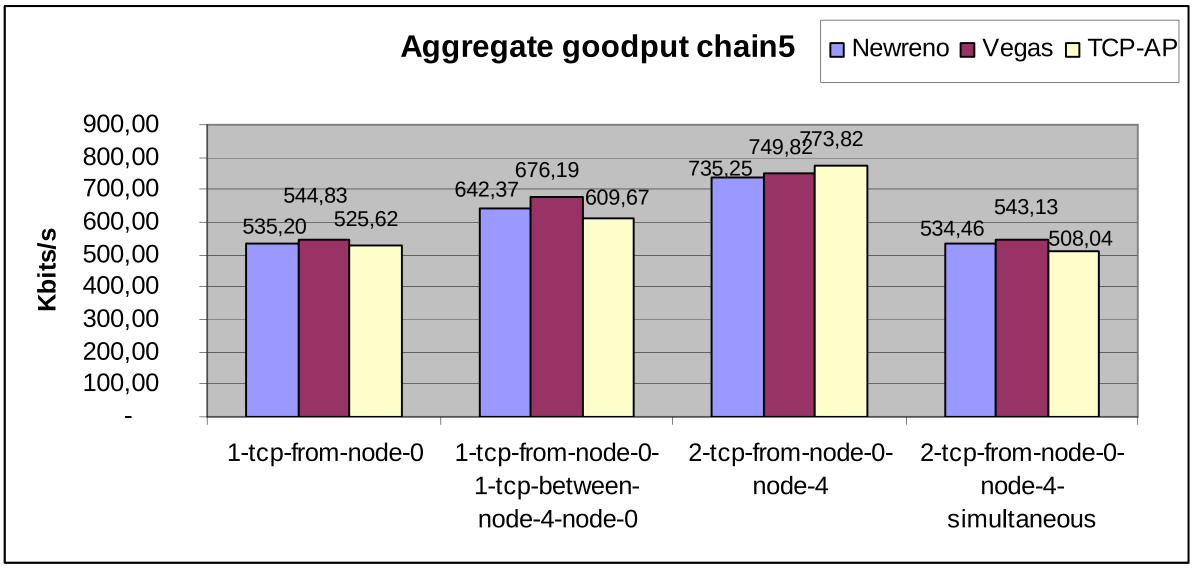

*Figure 19 Aggregate goodput Chain5*

The goodput as can be seen in Figure 19 is similar to Throughput, as there is a small difference between the different TCP variants. In the last traffic scenario when there are two traffic flows that stop and start at the same time, the goodput is clearly lower for all TCP variants than the third scenario where most parts of the two traffic flows run independently of each other.

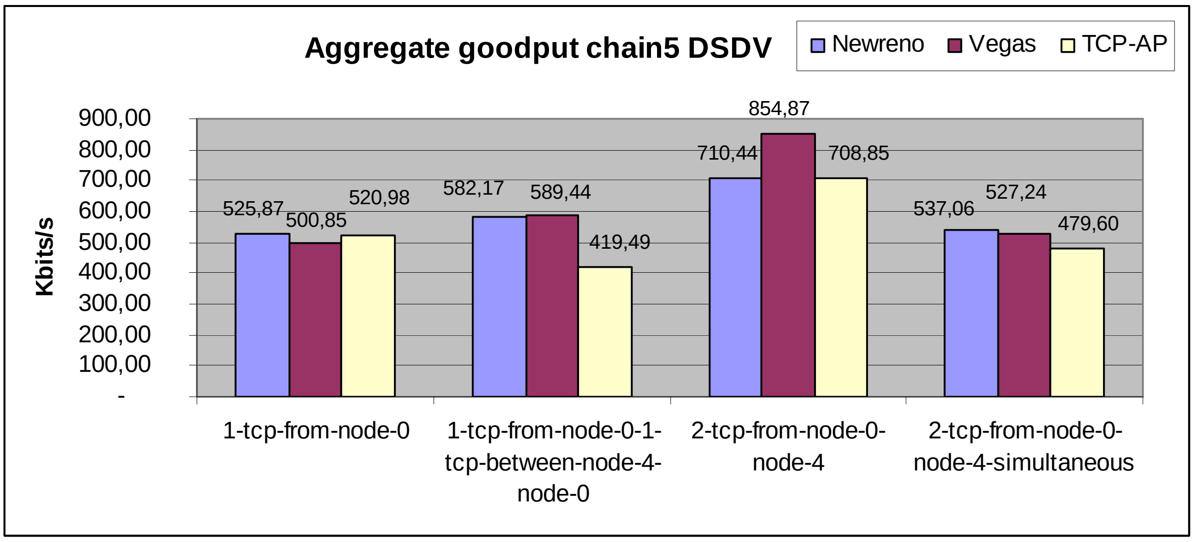

*Figure 20 Aggregate goodput Chain 5 DSDV*

Compared to the values for AODVUU, DSDV values are lower but roughly consistent between the TCP variants, with a slight advantage for Newreno except in the traffic scenario 2-tcp-from-node-0-node-4 where Vegas outperforms the others.

## 5.4 Chain5+1: Simulation 5

To clarify the results of this simulation, *Table 3* and Figure 21 summarizes the speed for Mobile Node 5 over time.

| Start time (s) | Speed (m/s) | Arrival time (s) | Pause (s) |
|---|---|---|---|
| **10** | **20** | **50,00** | **5,00** |
| **55** | **30** | **81,67** | **8,33** |
| **90** | **10** | **170,00** | **0,00** |
| **170** | **20** | **210,00** | **10,00** |
| **220** | **5** | **380,00** | **20,00** |
| **400** | **40** | **420,00** | **10,00** |
| **430** | **60** | **443,33** | **6,67** |
| **450** | **1,5** | **983,33** | **-** |

*Table 3 Speed of Mobile Node 5 over time*

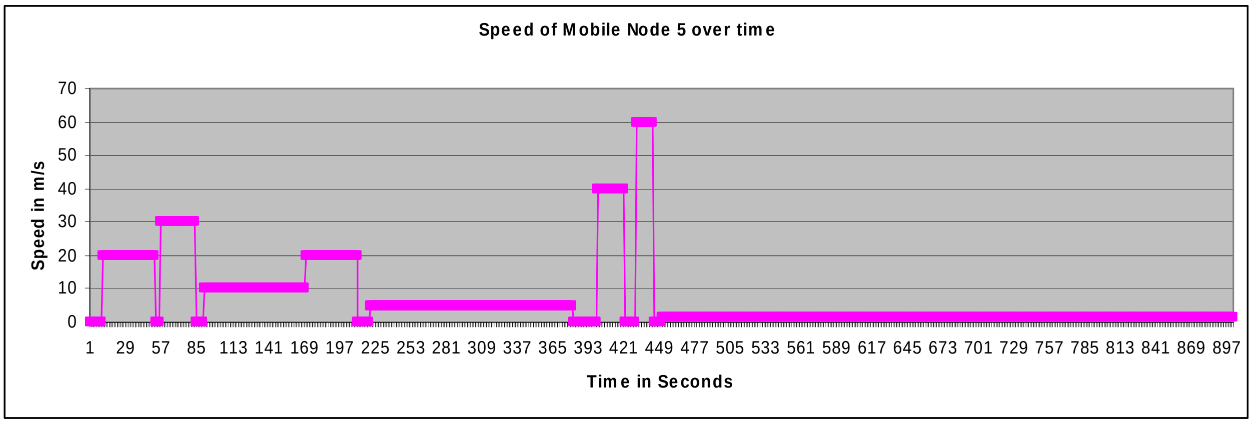

*Figure 21 Speed of Mobile Node 5 over time*

As can be seen in the *Table 4* on next page these movements, provoke route changes and packet loss that influence the congestion window, see Figure 23.

This also means that the number of wireless hops between the gateway and the Mobile Node 5 is changing constantly between 1, 2 and 3 hops. How the number of hops varies over time can be seen in *Table 4*. The figure below, Figure 22, shows an amplification of the first 100 seconds of simulation 5. The time when the different number of hops to the gateway change for TCP Vegas is marked out with thick black lines. The thin horizontal lines show the average lower limit of the throughput for all TCP variants, according to the number of hops. During the First 100 seconds of simulation, of which 80 seconds where used for traffic, Vegas and TCP AP changed the number of hops to the gateway 8 times and Newreno 26 times, due to oscillation.

| Time (s) | Nr of Hops | Time (s) | Nr of Hops |
|---|---|---|---|
| 20.270 | 2 | 250.198 | 2 |
| 27.617 | 1 | 290.065 | 1 |
| 38.136 | 2 | 330.591 | 2 |
| 47.754 | 3 | 370.592 | 3 |
| 60.214 | 2 | 403.984 | 2 |
| 66.747 | 1 | 409.434 | 1 |
| 73.558 | 2 | 413.957 | 2 |
| 80.226 | 3 | 418.995 | 3 |
| 105.224 | 2 | 433.093 | 2 |
| 125.668 | 1 | 435.887 | 1 |
| 145.214 | 2 | 439.374 | 2 |
| 165.622 | 3 | 443.108 | 3 |
| 177.725 | 2 | 550.627 | 2 |
| 188.587 | 1 | 683.436 | 1 |
| 197.730 | 2 | 817.313 | 2 |
| 207.754 | 3 | | |

*Table 4 Number of hops for Mobile Node 5 with TCP Vegas*

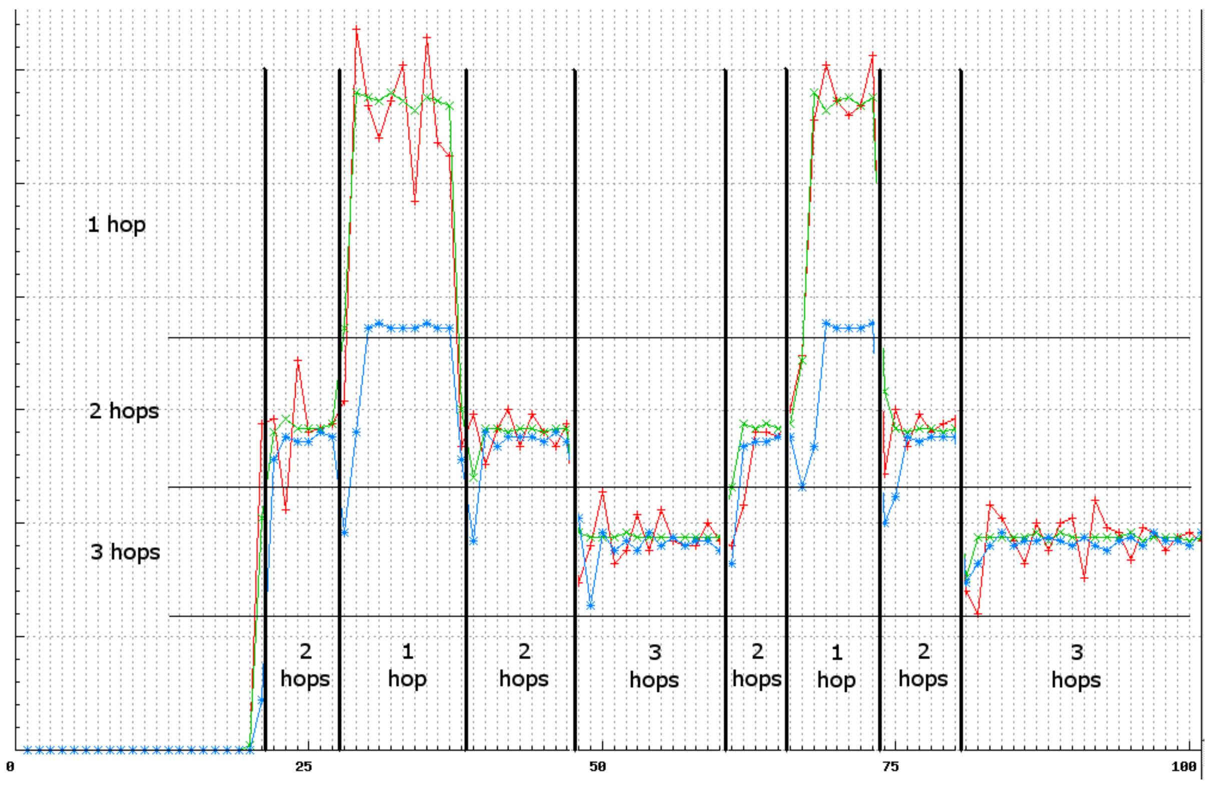

*Figure 22 Magnification of Simulation 5 throughput*

## 5.4.1 Congestion Window

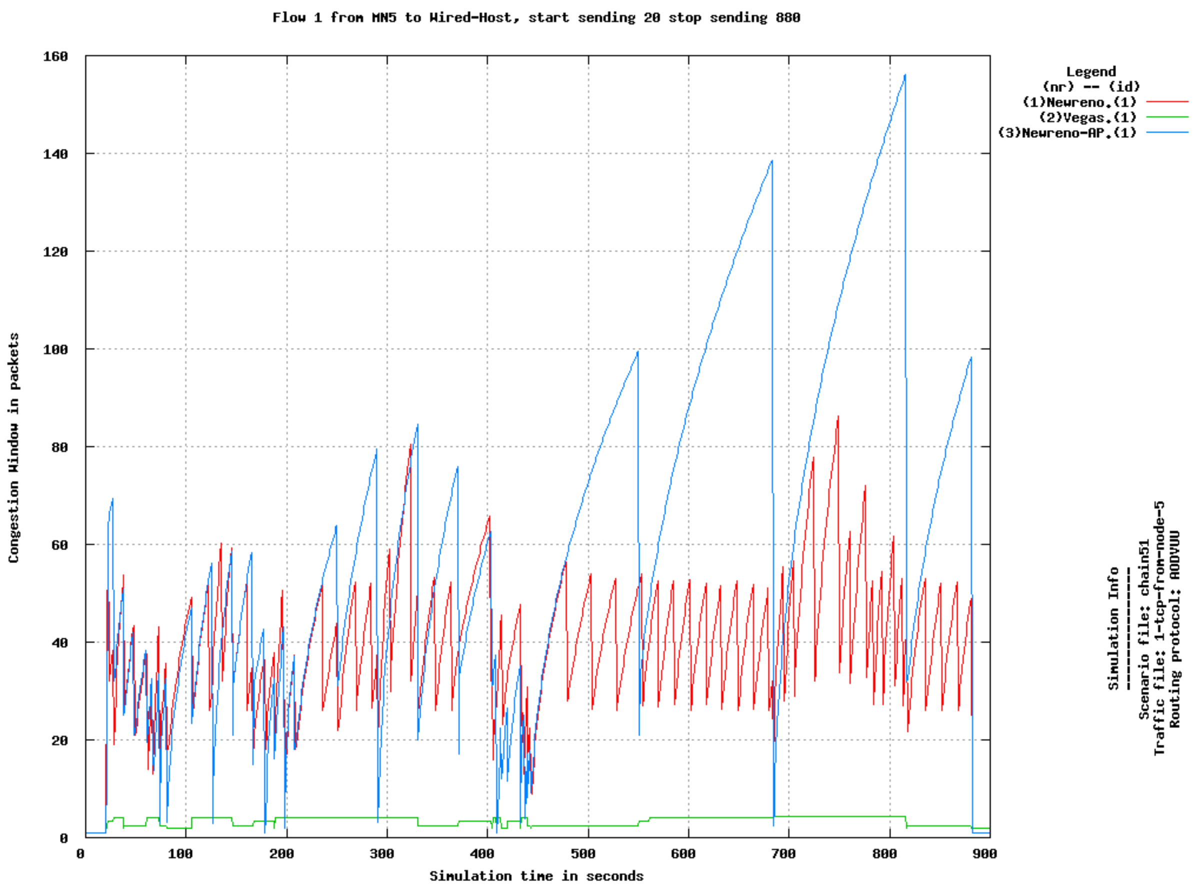

*Figure 23 Congestion window in simulation 5*

In this particular simulation the mobile node above the chain is moving and sending packets to the wired host. Therefore, unlike the former simulation, path breaks and route changes occur. As seen in Figure 23 Vegas keeps a stable, not fluctuating, congestion window indicating a good measurement of how congested the network is. Newreno has a fluctuating congestion window, which indicates that it constantly congests the network and therefore has to reduce its congestion window to compensate for this. However, compared to TCP AP the movement is not affecting Newreno's Congestion window as much as it does to TCP AP. As also can be seen at time 400 and 430 where the movement is 40 m/s and 60 m/s the congestion window as expected drops considerably, for Newreno and TCP AP, Vegas is affected but the drop is considerably less. From the time 450 to 900 the node moves slowly, the large drops of congestion window that can be seen from TCP AP is at the time the node change the route and the number of hops to the gateway.

### 5.4.2 Throughput

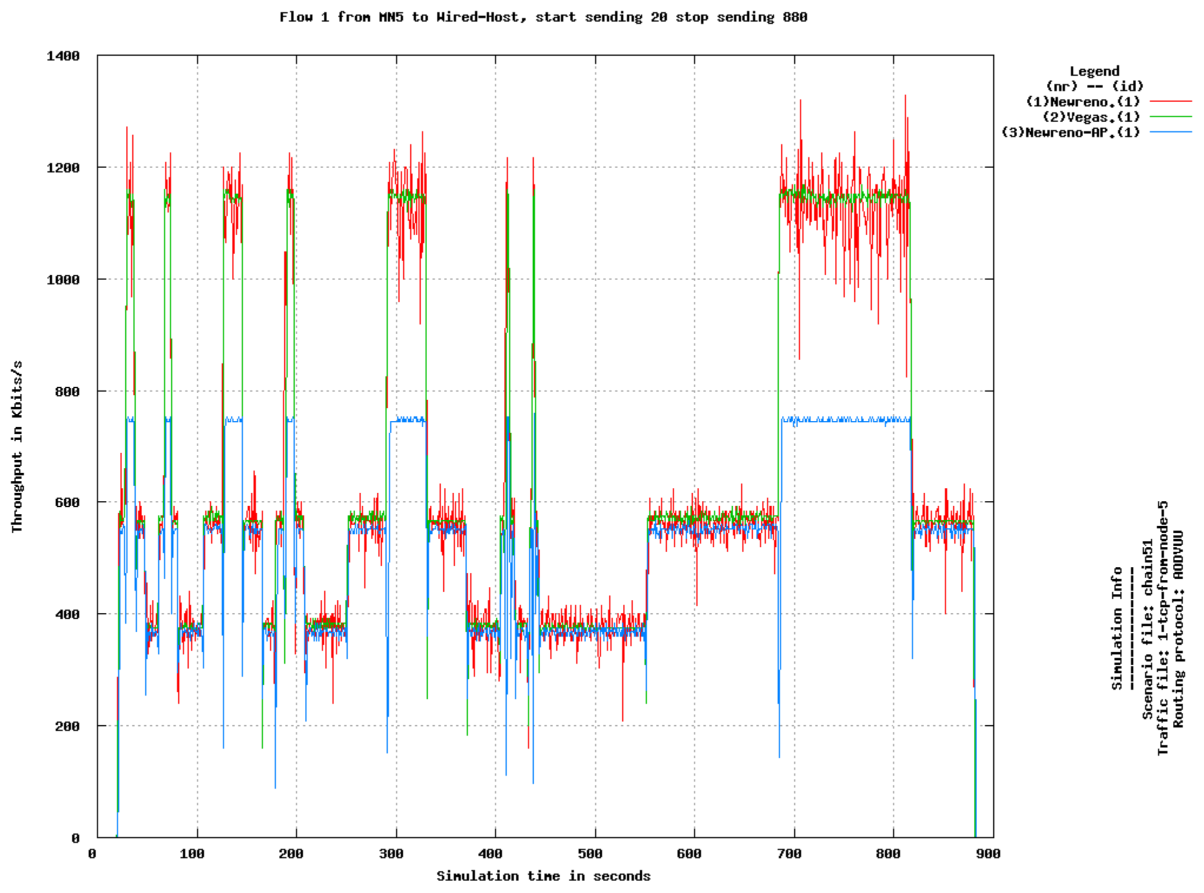

*Figure 24 Throughput simulation 5*

In Figure 24 it is clearly shown that the movement and the number of hops severely affect the throughput. The largest gap between TCP AP throughput and the others is when the gateway is only one hop away. This is most likely a consequence of TCP AP´s pacing mechanism that assumes a multihop environment.

However, TCP AP constantly has a lower average throughput than the others have. Vegas has a higher average throughput than both TCP AP and Newreno. Newreno has higher top peak throughput but also lower bottom peak throughput.

### 5.4.3 Goodput

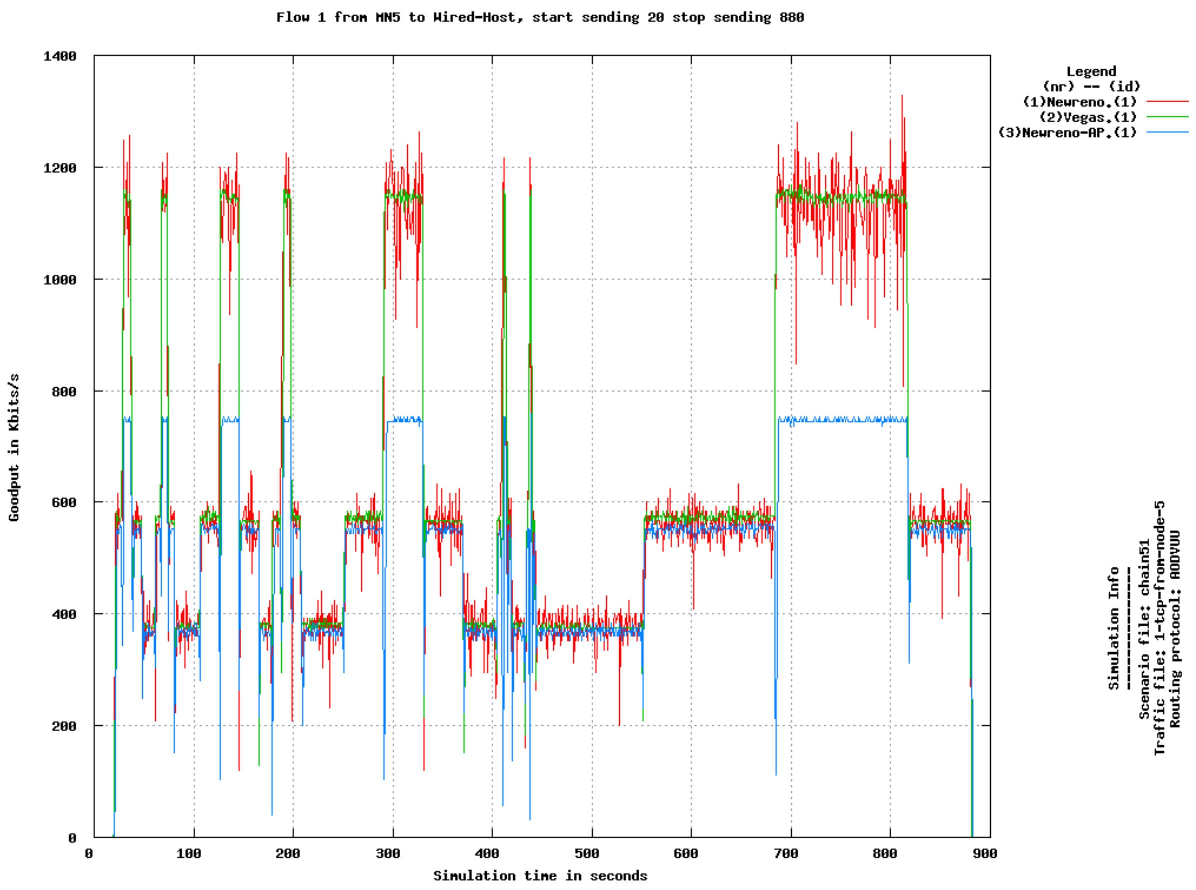

*Figure 25 Goodput in simulation 5*

The goodput follows the same pattern as the throughput. However, as can be seen, in Figure 25, is that just as with throughput TCP AP constantly has a lower average goodput than the others have, but also worth mentioning is that TCP AP's goodput is more stable than Newreno's and Vegas, probably because it underutilizes the network as indicated by lower throughout compared to the other simulations. Vegas have a higher average goodput than Newreno, which have higher top peaks, as seen in the other simulations as well. In this and the former graph it is clearly that the number of hops has a much higher impact on performance than the version of TCP used, as before it is clear that Vegas and Newreno, has the highest goodput and throughput.

### 5.4.4 Average and Aggregate

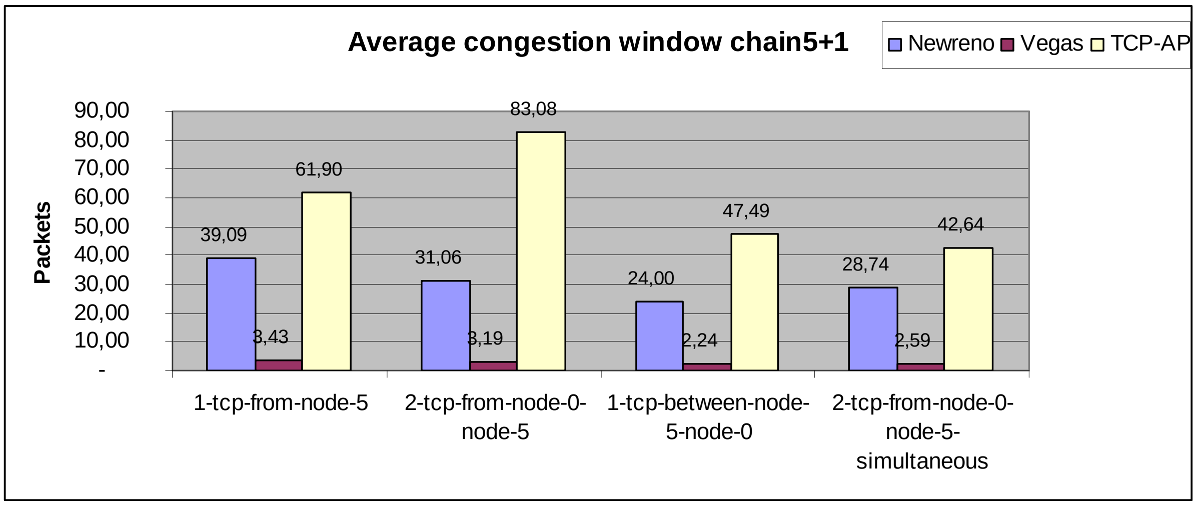

*Figure 26 Average congestion window Chain5+1*

The node movement causes a reduction in the congestion window for TCP AP but as in the previous Mobility scenario, the congestion window of TCP AP is higher than for the other TCP variants, as seen in Figure 26.

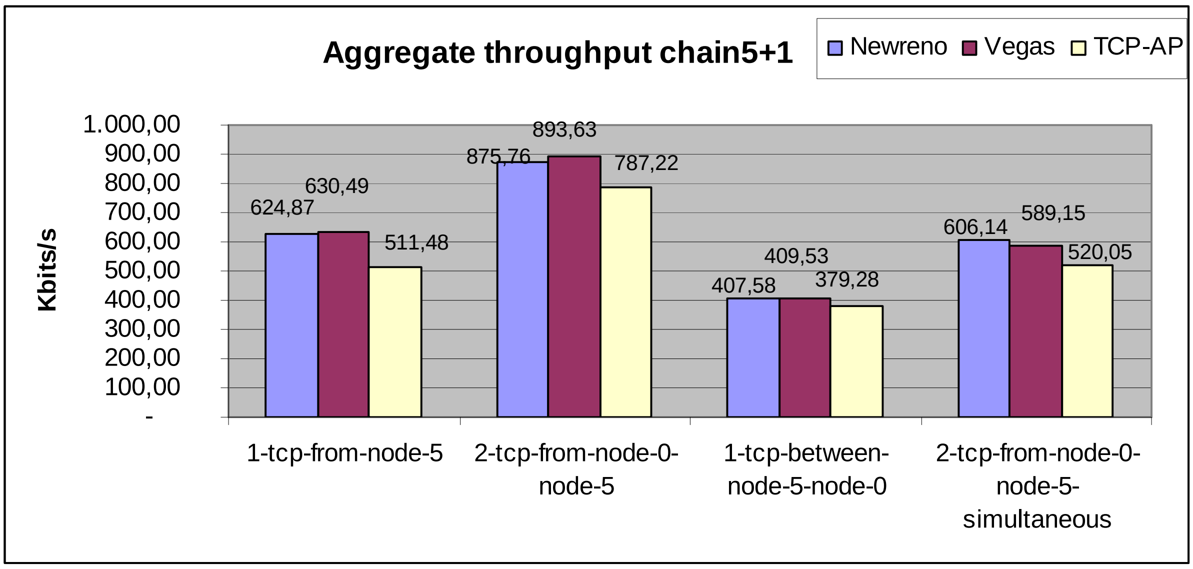

*Figure 27 Aggregate throughput Chain5+1*

The throughput of the different TCP variants is very similar except for TCP AP, which is slightly lower, as seen in Figure 27. Compared to the previous mobility scenario, Chain5, the throughput is also higher for Vegas and Newreno but lower for TCP AP. This can maybe be explained by the fact that the number of hops between the gateway and the mobile node is always equal or shorter than in the previous static scenario and that Vegas and Newreno can benefit more from this as they both send packets as fast as possible when they can, but TCP AP always send with a pace.

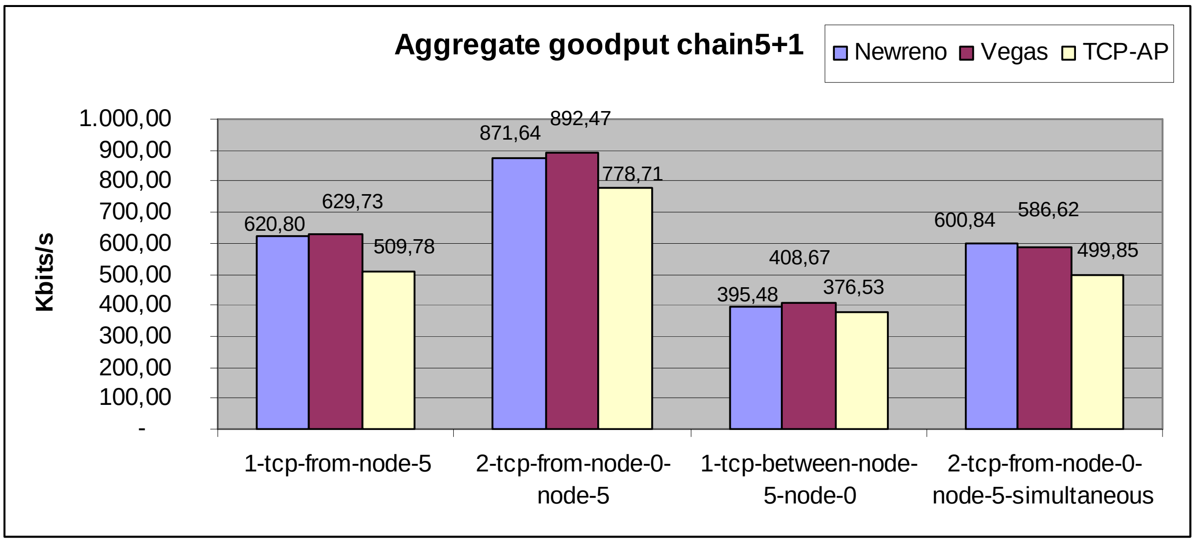

*Figure 28 Aggregate goodput Chain5+1*

As seen before the goodput is only slightly lower than the throughput, although the best throughput/goodput ratio does Vegas achieve with almost no retransmissions, see Figure 28.

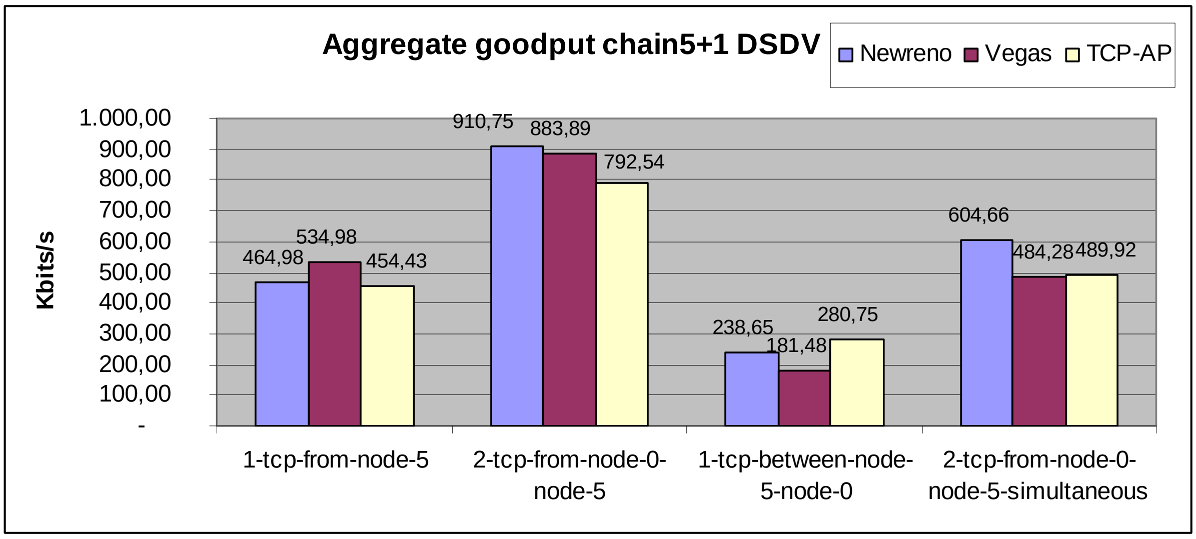

*Figure 29 Aggregate goodput Chain5+1 DSDV*

Once again does the change from AODVUU to DSDV shift which TCP variant performs better for the same traffic scenarios. The movement is also making a difference as the goodput values for DSDV is beginning to decline in almost all traffic scenarios in comparison to AODVUU, see Figure 29.

## 5.5 Grid7x7: Simulation 9

A grid with 48 nodes and 1 gateway, where the left bottom most node send packets via the gateway 4 hops away to the wired host. The number of hops to the gateway is at least 4, which can explain the low average performance for all the TCP variants.

### 5.5.1 Congestion Window

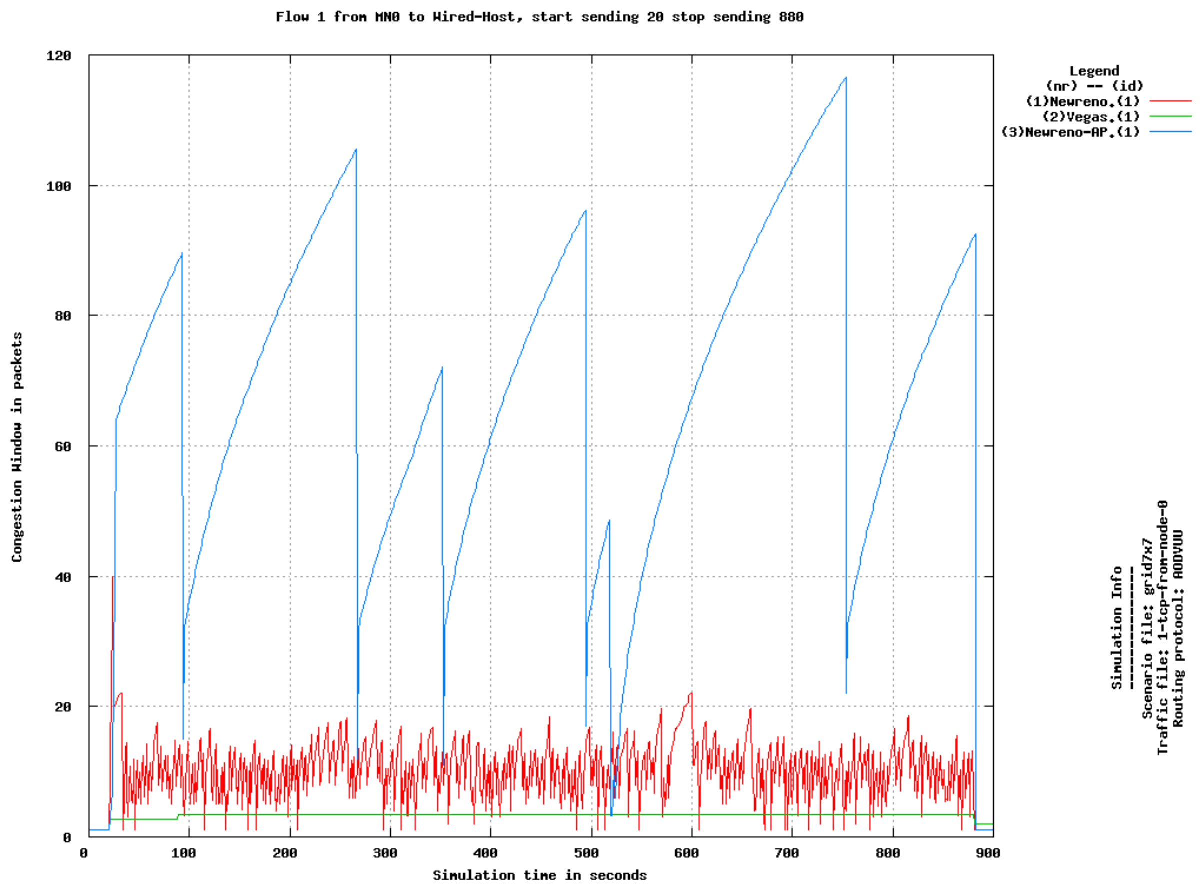

*Figure 30 Congestion window in simulation 9*

This graph, Figure 30, represent the congestion window in a grid7x7 scenario. For TCP AP the window is fluctuating and it reach a top peak around 115 packets. Vegas as in chain5 keep a stable congestion window. Newreno on the other hand has a fluctuating congestion window. Because it is working by sending burst of packets which congest the network, Newreno has to wait until the link is free, before it can send packets again. The curve in the graph has not a perfect behaviour as in chain5. Because in Grid7x7, although the nodes are static, there are some route changes during the transmission, that affect the congestion windows

### 5.5.2 Throughput

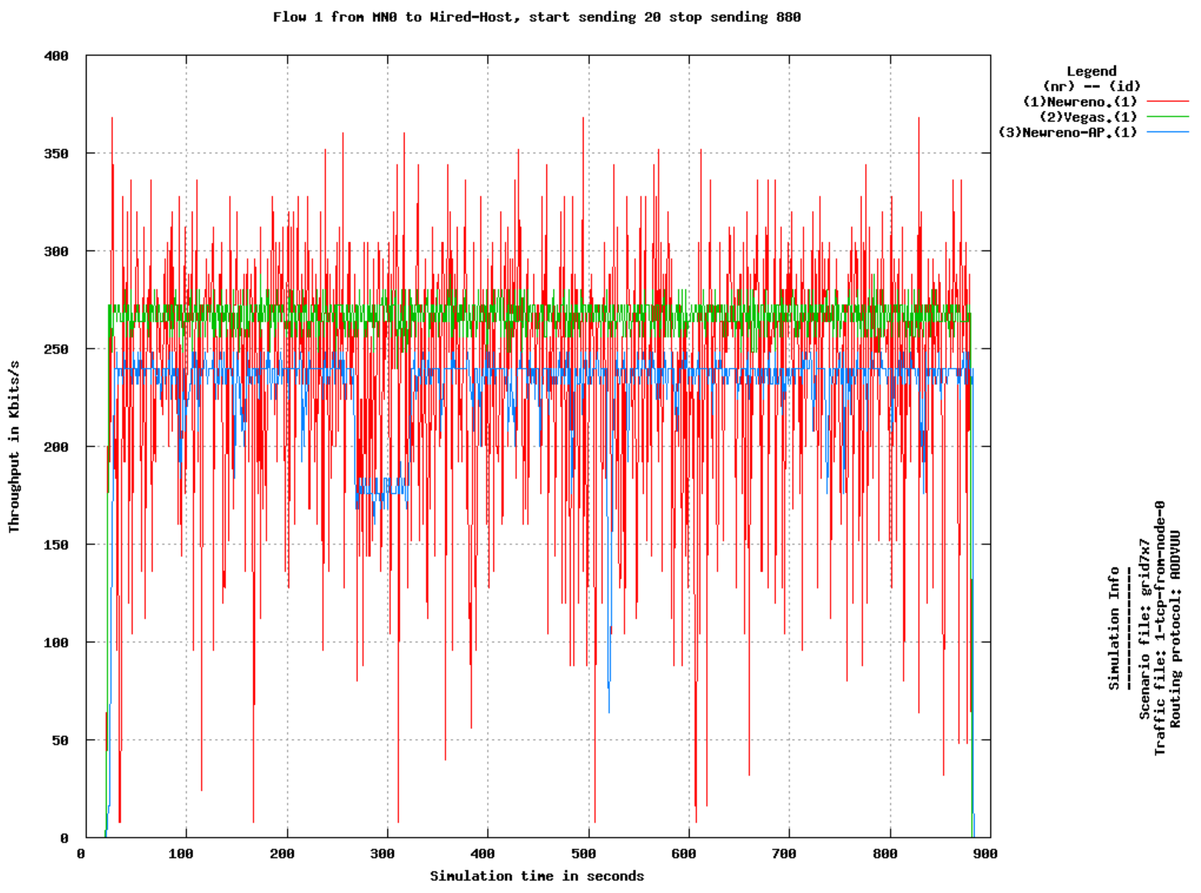

*Figure 31 Throughput in simulation 9*

In the graph, Figure 31, it is shown that in this simulation, the throughput is unstable, especially for Newreno, which has high peaks in both directions. The other two alternatives have similar values, although TCP AP has a drop of values between 250 and 300 seconds of the simulation. In general terms TCP AP has the lowest throughput average.

### 5.5.3 Goodput

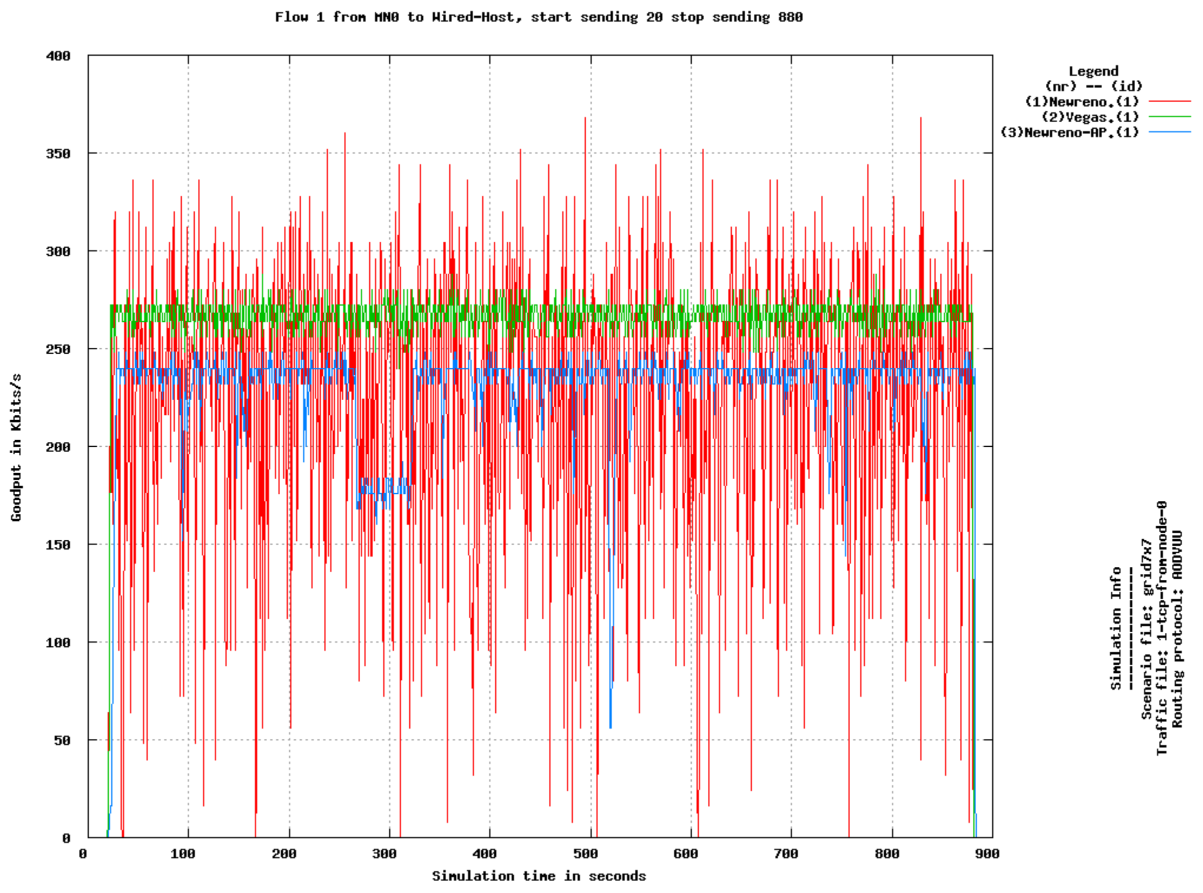

*Figure 32 Goodput in simulation 9*

In Figure 32 it is clearly shown that for this simulation the data follows the same structure that for the throughput, the curves are almost the same. Newreno is fluctuating, Vegas and TCP AP, both have much more stable curves. TCP AP has a stable but lower goodput than Vegas, while Newreno has a fluctuating rate, with very high bottom and top peaks.

The average goodput for Newreno and TCP AP is actually quite similar. However, Vegas is the one that performs better in this scenario.

### 5.5.4 Average and Aggregate

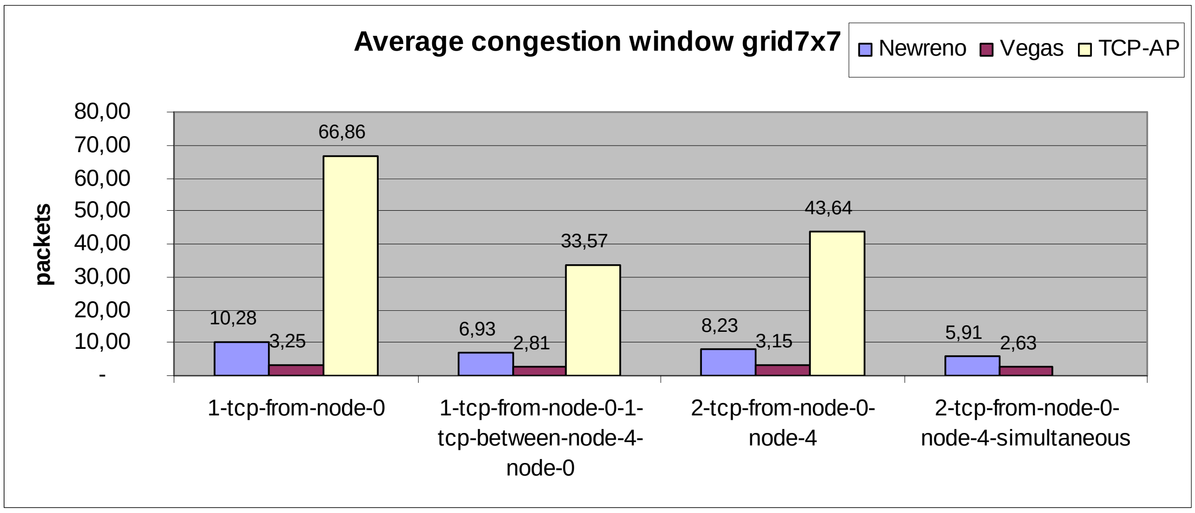

*Figure 33 Average congestion window Grid 7x7*

Figure 33 reflects the average congestion window in a Grid7x7 scenario for different traffic files. If the results are compared with the values previously presented for chain 5, is appreciable the decrease of packets in average. The only variant that is not affected is Vegas because it keeps a constant value during all the simulation time. Its average is quite low and it is independent from other external factors. In addition, TCP AP has a fixed limit, due to implementation constrains, of how many packets can be sent at one time and this “maximum packets to send” limit was exceeded in the last traffic scenario so TCP AP could not complete the simulation.

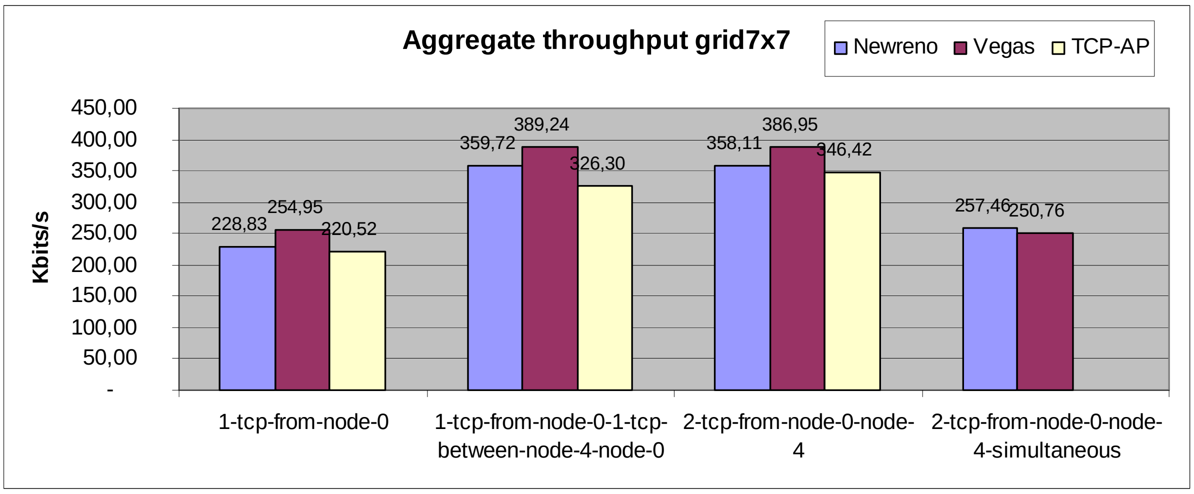

*Figure 34 Aggregate throughput Grid 7x7*

In Figure 34 it is noticeable that in a Grid7x7 scenario, TCP AP is the variant that performs worst in terms of throughput (Kbits/s), respect the other alternatives. Vegas is the one that in all scenarios, except the last, has the best performance. Newreno and TCP AP have similar values, a little bit lower than Vegas.

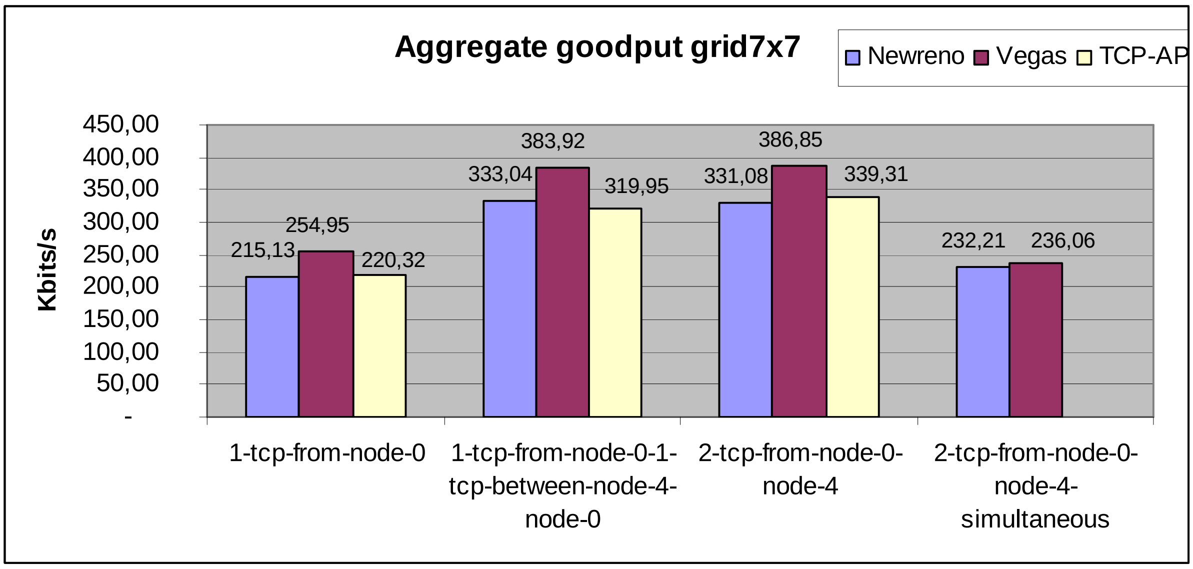

*Figure 35 Aggregate goodput Grid7x7*

As can be seen from Figure 35, Newreno and TCP AP have similar goodput but Vegas is ahead of the other two. This can be because Vegas more precisely determine the congestion window and in this scenario, it will benefit from that because it does not cause route updates due to a congested network as Newreno and TCP AP might do.

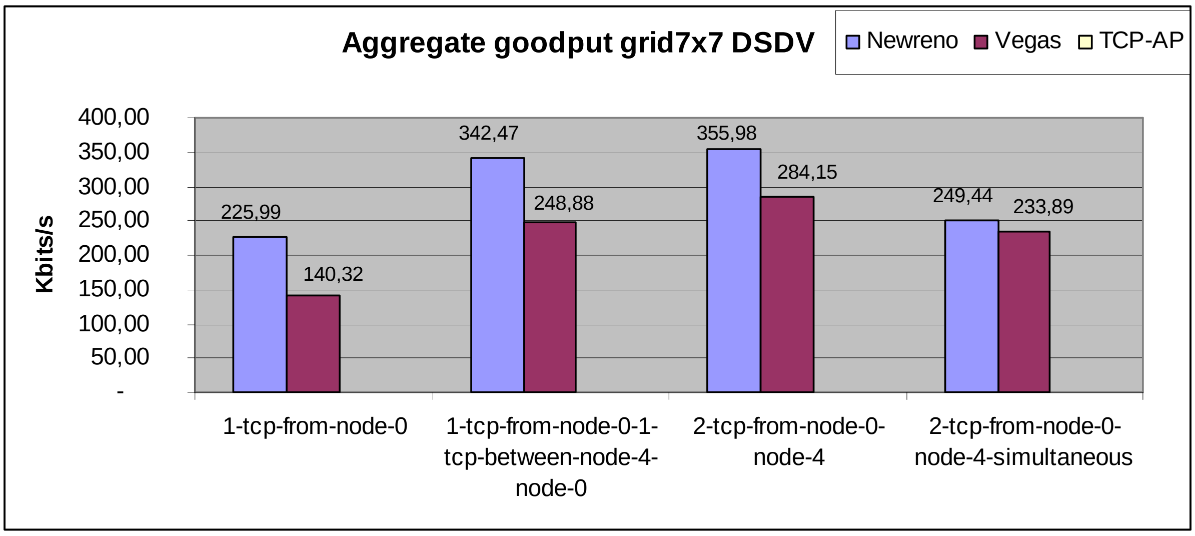

*Figure 36 Aggregate goodput Grid7x7 DSDV*

In this static scenario DSDV with Newreno has an advantage over AODVUU as the goodput values are higher in Figure 36. Vegas on the other hand is not performing as good as it did with AODVUU. TCP AP exceeded in all mobility scenarios the “maximum packets to send” limit so unfortunately there are no results to compare.

## 5.6 Random48: Simulation 13

As seen in simulation 5, Chapter 5.4.2, the throughput is very much dependent on the number of hops between the gateway and the sending node.

In the Random48 mobility scenario, node 0 changes its routes 2194 and node 4 changes its route 2027 times. In total there are 54650 route changes and 15860 link changes during the simulation with 372 destinations that can not be reached at all times.

### 5.6.1 Congestion Window

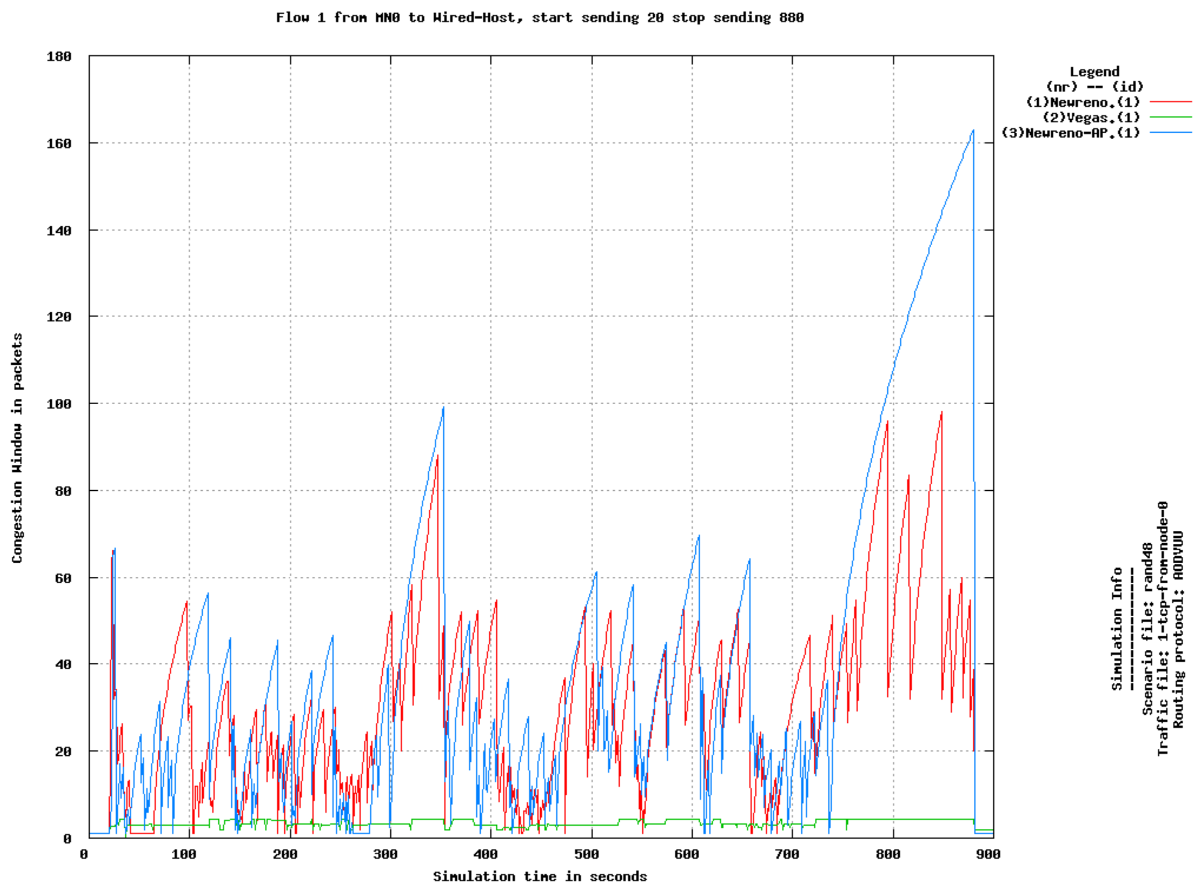

*Figure 37 Congestion window in simulation 13*

In Figure 37 it is shown that only Vegas tries to maintain a constant congestion window during the entire simulation. On the other hand, TCP AP and Newreno have fluctuating congestion window value. The route changes make TCP AP reduce its congestion window, as packets are lost. This is also affecting the other TCP variants but it is more prominent in TCP AP, as it uses a larger congestion window in general than the others.

### 5.6.2 Throughput

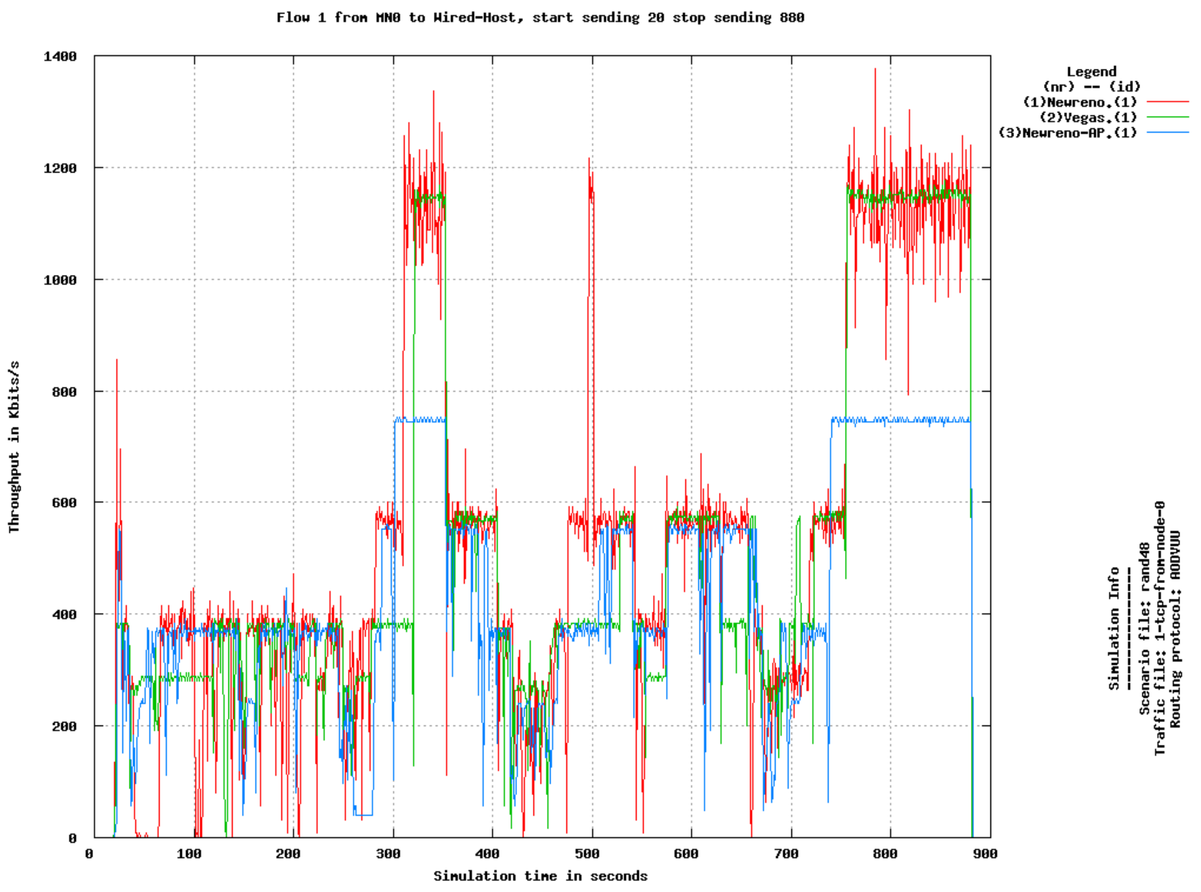

*Figure 38 Throughput in simulation 13*

In Figure 38 it is clearly shown that in the simulation 13, the throughput is unstable for all the three TCP variants. None of the alternatives keeps its value more or less constant; all of them have high peaks. In general, TCP AP has the lowest throughput values. Nevertheless, Newreno is the variant that performs better. It is the one that sends the highest amount of packets from the sender.  The throughput steps in the graph are result of the different number of hops to the gateway and the sharp peaks are the result of mobility and route changes.

### 5.6.3 Goodput

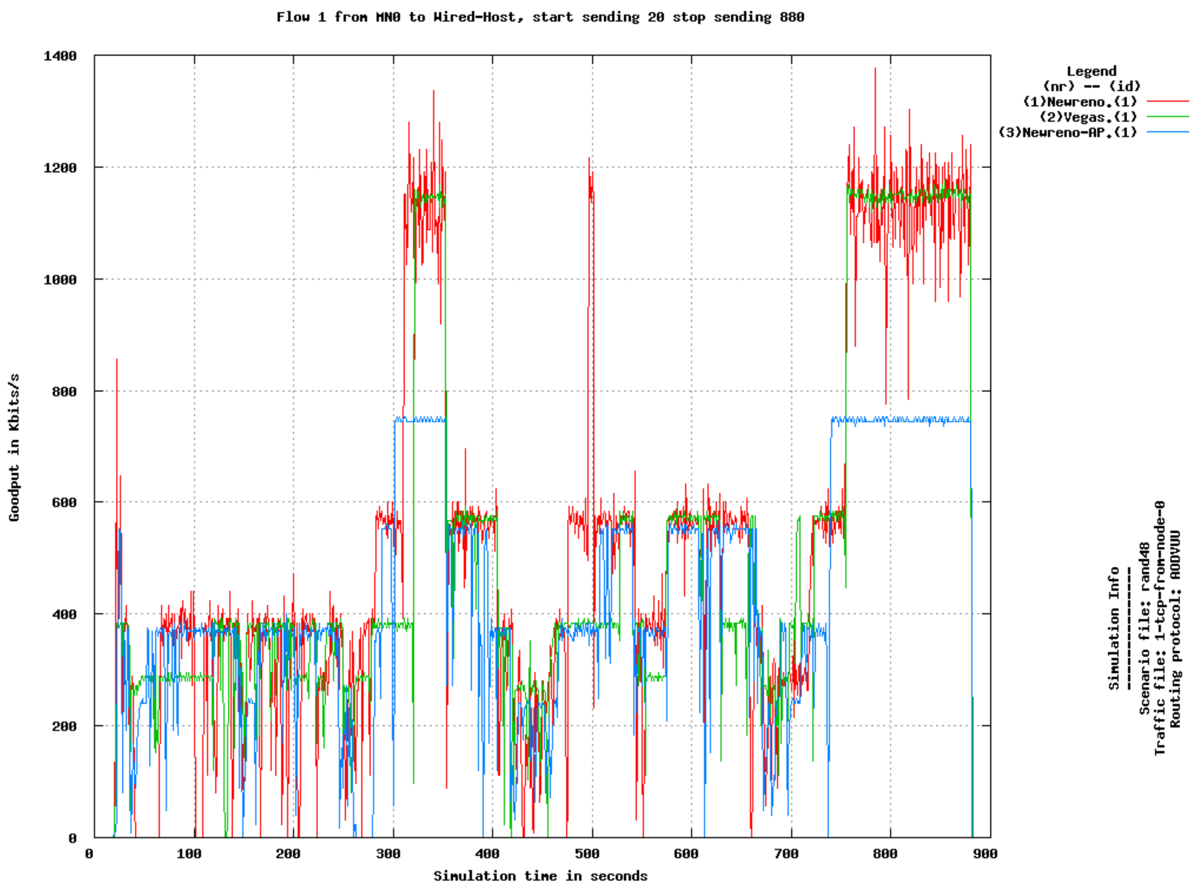

*Figure 39 Goodput in simulation 13*

The goodput in this simulation keeps the structure of the graph previously presented with almost the same values, which means that there are almost no retransmissions during the simulation. Therefore, throughput and goodput have almost the same values, see Figure 39 .

### 5.6.4 Average and Aggregate

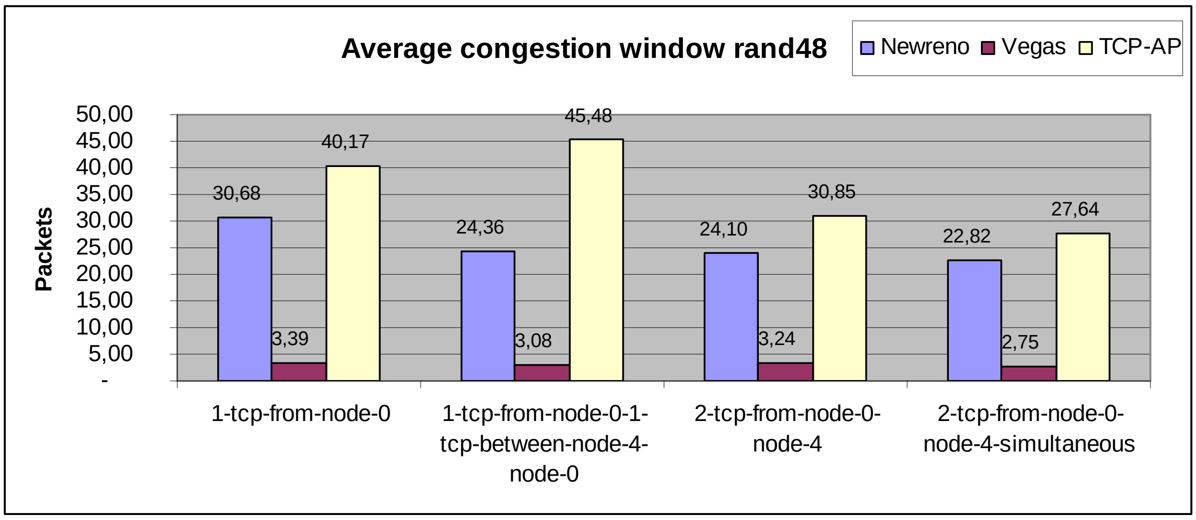

*Figure 40 Average congestion window Random 48*

In this simulation the difference between Newreno and TCP AP is much smaller than in the other scenarios, this might be due to the fact that in this scenario more of the lost packets is because of mobility and not for that TCP congesting the network. As in all simulations Vegas keeps a low and stable congestion window in all scenarios, as can be seen in Figure 40.

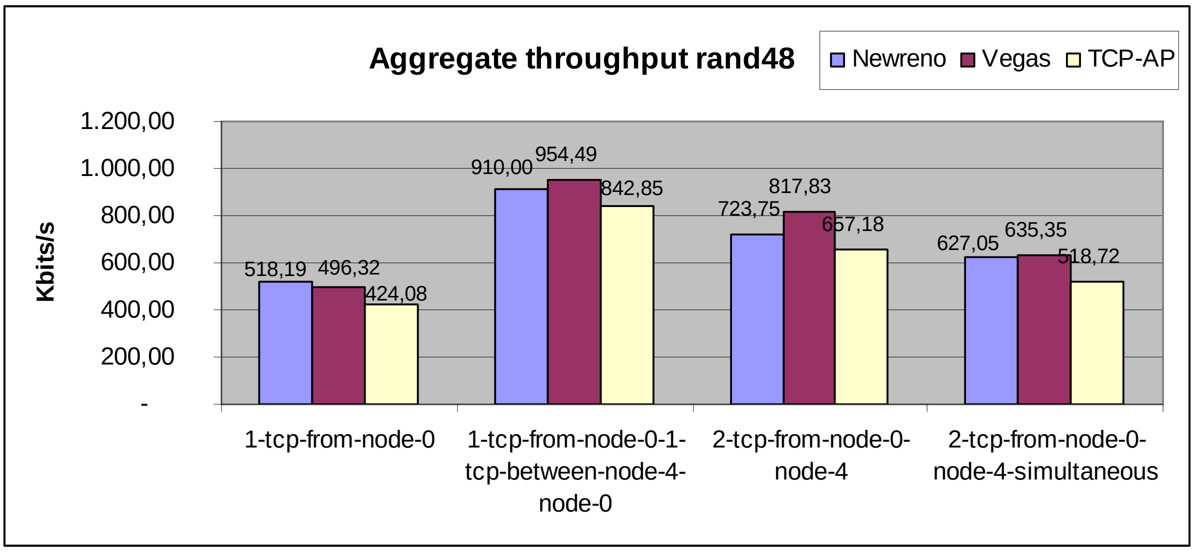

*Figure 41 Aggregate throughput Random 48*

In Figure 41 it shows that with two flows the throughput is higher than in all the other mobility scenarios. This is probably mainly because the two flows can run in parallel; the flows are not forced to share the same hops as in the other mobility scenarios. With one flow the throughput is as expected lower than in the chain5 scenario. The reason that the throughput is higher than in grid7x7 could be that the nodes are moving in an 800x800 meters square which means that they are never more than 600 meters away from the gateway. This also means that the node will have direct connection with the gateway during certain periods of time.

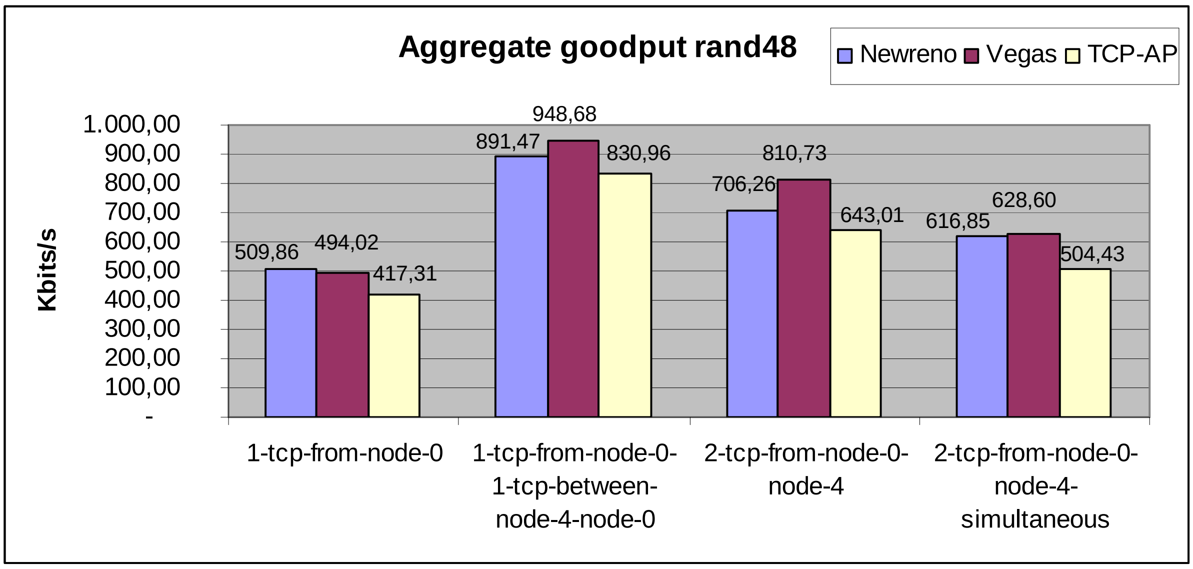

*Figure 42 Aggregate goodput Random 48*

As in all the other mobility scenarios, there are almost no retransmissions. Therefore the goodput and throughput have almost the same values, as shown in Figure 42.

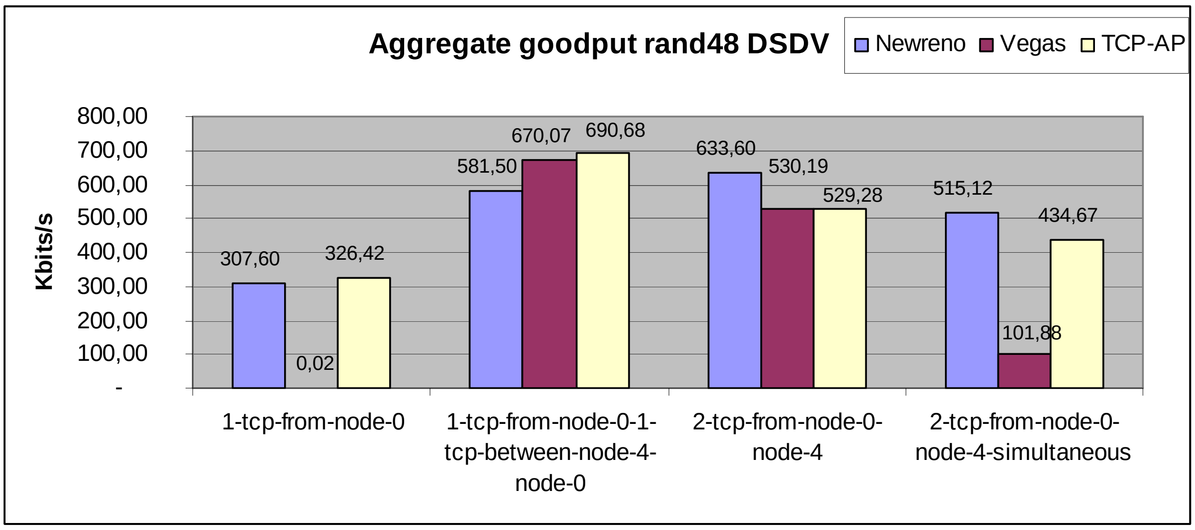

*Figure 43 Aggregate goodput rand48 DSDV*

The mobility is penalising DSDV's proactive nature in this mobility scenario, with lower goodput than for AODVUU, especially noteworthy is the goodput drop for Vegas in almost all traffic scenarios compared to AODVUU, shown in Figure 43. Most prominent is this in

"1-tcp-from-node-0", where Vegas perform very badly. The reasons behind Vegas low performance in this traffic scenario need to be more investigated in detail.

## 5.7 Jain's Fairness Index for all Mobility Scenarios

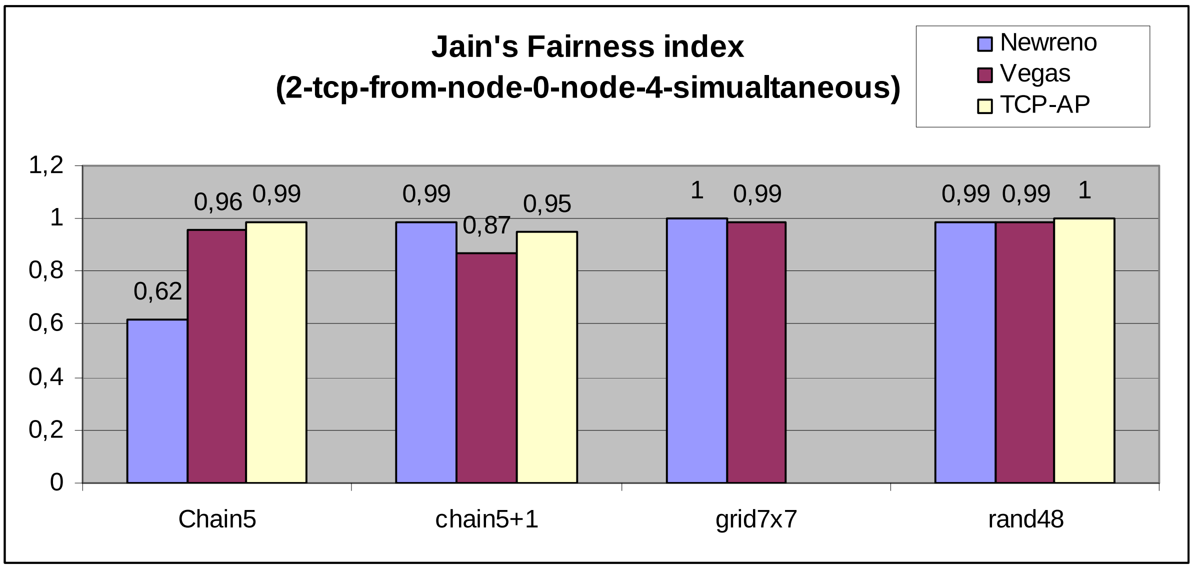

*Figure 44 Jain's Fairness index*

The Fairness is good in all the tested scenarios except chain5 with Newreno where one of the flows capture almost all the channel during the entire simulation. TCP AP is the most fair of the TCP variants. In Grid7x7 with traffic scenario 2-tcp-from-node-0-node-4-simultaneous the simulation with TCP AP could not be completed, where Newreno's and Vegas' fairness depends on the mobility scenario used as can be seen in Figure 44. As it is seen in the graphs, Figure 44 and Figure 45, TCP AP is the fairest.

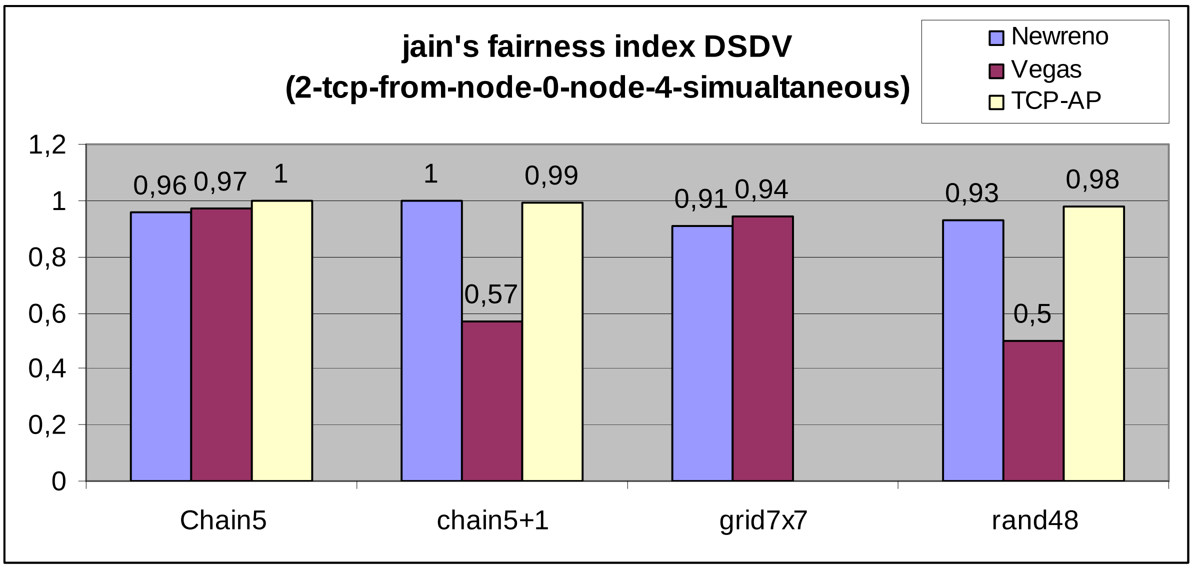

*Figure 45 Jain's Fairness index DSDV*

When the mobility is high, as in chain5+1 or rand48, and DSDV is used, Vegas drops its fairness to almost 50 %. While Newreno, improve its fairness, especially for the chain5 scenario.

## 5.8 Summary

This Chapter 5 presents the results obtained from the simulations already described in Chapter 4. To save space and resources not all the simulations have been commented and analyzed, only the template simulations, which try to represent the most significant situations. Some of the parameters considered are: throughput, congestion window and goodput displayed as a graph over time. Average congestion window and aggregate throughput and goodput is also displayed for comparison between the different TCP variants. In almost all simulations the throughput and goodput are higher for Vegas when AODVUU is used as a routing protocol. When DSDV is used, the advantage of Vegas is not so clear. In mobility scenario rand48 the goodput and throughput dropped drastically for Vegas. The same simulations are also conducted with a wired-bandwidth of 756Kbits and a delay of 25ms. As can be seen below in Figure 46 this has almost no effect at all on Vegas and Newreno.

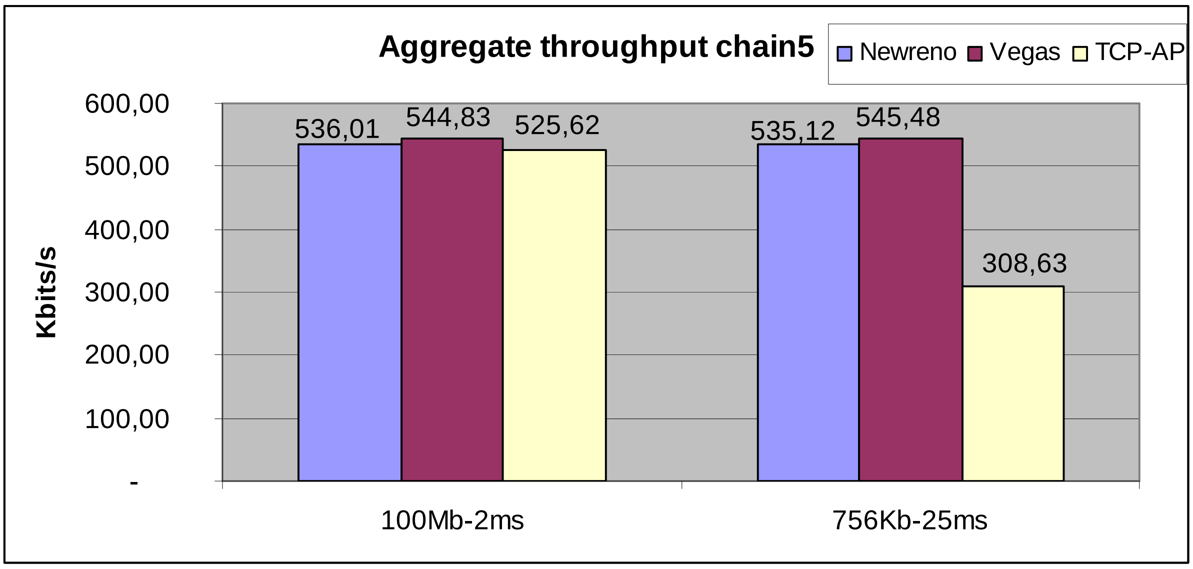

*Figure 46 Comparison between two different wired-bandwidths in simulation 1*

Another difference that could be noted between the simulations with the different fixed network bandwidths and delays are that in general Vegas increased its average congestion window quite drastically, from 3.3 to 8.19 in the above Mobility scenario, Chain5, while Newreno's increase is more subtle and TCP AP actually decrease the average congestion window. As a comment it can be said that the simulation was run for 900 seconds so eventual effects of an "initialization phase" should not be a factor. In the simulations above, it takes TCP AP around 200 seconds to reach the maximum congestion window in the simulation. However, with 756 Kb and 25ms it takes almost 450 seconds, half the simulation time, to reach the same maximum, which explains the decrease of  throughput and average congestion window.

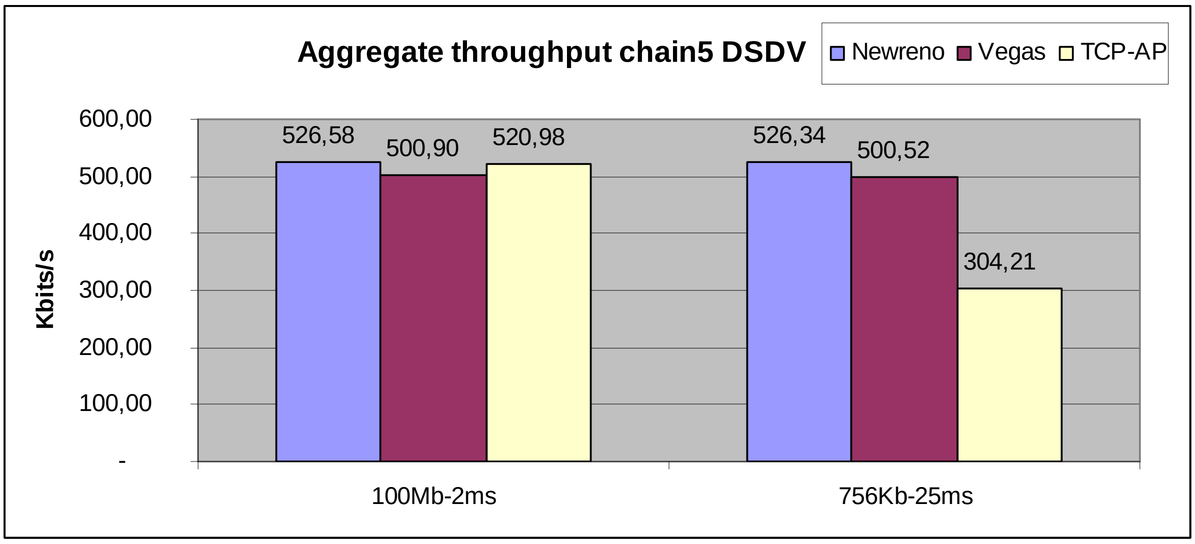

*Figure 47 Comparison between two different wired-bandwidth in simulation 1 DSDV*

The result is similar, with an increase of delay and decrease of wired-bandwidth TCP AP drops its throughput, even when DSDV is used, as can be seen in Figure 47.
An important reflection to remember is that the number of hops to the gateway has more impact on performance than the TCP variants and routing protocol used as seen in simulation 5.

In general, the simulations conducted show that with AODVUU, TCP Vegas achieves similar or higher throughput and goodput in all simulations, while keeping a stable congestion window.

TCP Newreno on the other side shows, 0- 20 Kbits/s less throughput, compared to Vegas but at a cost of fluctuations in the traffic flow.

TCP – AP's congestion window is more stable than Newreno. Therefore, it does not congest the network as Newreno does, even so TCP – AP performs at pair with Newreno in the simulations where the nodes are static, but drops around 10 – 100 Kbits/s compared to Newreno when there are mobility involved. An important factor is that TCP AP only utilizes around ½ of the available bandwidth compared to Vegas and Newreno when there is one hop to the gateway. The fairest TCP variant of those evaluated is however TCP AP.

With 25 ms delay the congestion window increases more slowly than with 2ms delay, therefore TCP AP will not be able to reach a high congestion window fast. With mobility the situation becomes worse as the constant route changes forces TCP AP to reduce its congestion window.

When the routing protocol is changed from AODVUU to DSDV, performance is reduced in roughly all simulations, mostly prominent in the simulations involving node movement, the exception is simulation 4 and 6 (2 tcp flows to the wired host in mobility scenario chain5 and chain5+1).

There is also a shift between the TCP variants so when DSDV is used there is advantage of using TCP Newreno.

TCP Vegas has a very unpredictable performance with DSDV, from performing very well in simulation 5 to average performance in all simulation with grid7x7 to very bad in simulation 13 where 1 mobile node is sending with mobility scenario Random48. More investigation is necessary to evaluate this phenomenon.

TCP – AP is following the same pattern as when using AODVUU and has roughly around 10 – 100 Kbits/s less Goodput than Newreno in almost all simulations.

# 6 Conclusions and Future Work

In this chapter some conclusions from the theoretical overview and an evaluation of the results described in Chapter 5, will be presented with a suggestion of future work needed.

## 6.1 Conclusions

In this thesis we have looked in to several aspects of TCP performance in a hybrid MANET, using a simulation based approach, where mobile nodes connect to a wired host through a gateway.

The evaluation was conducted as a comparison between three TCP variants: TCP Newreno, TCP Vegas and TCP AP, and two different routing protocols: AODVUU and DSDV, which support gateway interconnection.

AODVUU is using the half-tunnelling approach and proxy RREP's find and to route packets to the wired network, while DSDV is using default route and next hop routing.

The evaluation of the simulations shows that AODVUU with TCP Vegas achieves at pair or higher throughput and goodput in almost all simulations, while having the same or almost the same fairness as TCP AP.

From the theoretical part, we conclude some details, although all these conclusions are not based on the results obtained in our simulations.

MobileIP is very useful to be able to refer a node independently of the gateway or network to which it is attached, the drawbacks is routing overhead and added complexity in the routing protocol.

Half-tunnelling can be used in every network because no special requisite is required from the network. Intermediate nodes in the transmission just forward the data as a normal packet in the MANET; they do not have to constantly update their routing tables as needed with default route; however the routing protocol must be changed at the sending node and gateway to allow for handling of the extra routing header. Handovers are necessary to maintain the communication with the network when nodes are forced to change gateway because of mobility. Optimizing handovers could be very useful to reduce the amount of forced handovers which are more costly, but it is important to choose the optimal point when it has to be done, to not saturate the network with handovers. Several TCP variants have been presented in Chapter 3, each one with different characteristics, as modified congestion detection and pacing of the transmission. One interesting TCP variant, because of its ability to not congest the network is TCP Few, which use a fractional window scheme to adapt better in a network with a low BWD product, as a MANET.

As stated before, the focus on this thesis is to evaluate AODVUU and TCP AP, the other TCP variants and routing protocol are used for comparison.

An important reflection to remember is that the number of hops to the gateway has more impact on performance than the TCP variants.

In general, the simulations conducted show that with AODVUU, TCP Vegas achieves at pair or higher Throughput and Goodput in all simulations, while keeping a stable congestion window, which implies a good interpretation of the network congestion. The drawback of having a low congestion window is of course the need to send a lot of ACK packets.

TCP Newreno on the other side performs almost as Vegas but at a cost of fluctuations in the traffic flow. This congests the network and forces a reduction of the sending speed, which is also reflected in the heavily fluctuating congestion window.

TCP AP performs at pair with Newreno in the simulations where the nodes are static, but drops when there is mobility involved. An important factor is that TCP AP only utilizes around ½ of the available bandwidth compared to Vegas and Newreno when there is one hop to the gateway. The fairest TCP variant of those evaluated is however TCP AP.

With 25 ms delay the congestion window increases more slowly than with 2ms delay, this is reflected in TCP AP as lower average throughput and goodput.

When the routing protocol is changed from AODVUU to DSDV, performance is reduced in roughly all simulations.

There is also a shift between the TCP variants so when DSDV is used there is advantage of using TCP Newreno as TCP Vegas has a very unpredictable performance with DSDV.

There are for sure more subtle interactions between the routing protocols and the TCP variants that need to be further investigated. However, with the simulations conducted in this thesis and the result thereof produced, our conclusion is therefore to use TCP Vegas in combination with AODVUU for the fastest and most stable performance.

TCP AP for the fairest performance with a low amount of traffic burst.
In the simulations there is evidently so that the number of hops to the gateway have a great impact on performance, and unfortunately TCP AP does not fully utilize this information.

## 6.2 Future work

An interesting extension of this work could be to test TCP-FeW performance with the same simulations, mobility and traffic scenarios.

Another modification to the simulations would be to add more gateways and measure the performance during handover. Traffic flows that come from the wired part could also be interesting to evaluate.

Future tests could also be done to compare the results obtained against more generic gateway discovery mechanisms as [16] and [37] to see how beneficial it is to integrate the gateway discovery in the routing protocol as it is done with AODVUU and DSDV. This would also allow for comparisons with other routing protocols like DSR or OLSR.

Modify TCP AP, so that it does not need to have a fixed value, or at least a larger value, of the number of packets that can be on queue for sending. This would make TCP AP work in more scenarios.

Another improvement for TCP AP would be to modify the protocol so it does not need such large congestion window to fully utilize the bandwidth or alternatively make the congestion window respond more quickly to changes in the network. Further enhancement to TCP AP would be to make it actively take advantage of that the number of wireless hops is one. ACK thinning, to reduce or delay the acks, could also be investigated as this has shown to be beneficial for Vegas and Newreno [7]. Change the values of α and β, in Vegas, to investigate the performance impact they have in a hybrid MANET environment.

A further investigation of how ELFN could benefit all TCP variants is also a viable way to achieve improvement.

To further enlighten the results in this thesis, a more in depth investigation of the number of hops, as when they occur and how they are affecting the performance, would be interesting. Also interesting would be to investigate the interaction with more traffic flows and in a mixed scenario with both UDP and TCP flows. Further investigation could also evaluate the routing dependency in a more complex scenario with multiple gateways and multihop handovers.

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# 8 Appendix

## A Common Abbreviations

| | |
|---|---|
| AODV | Ad-hoc On-demand Distance Vector |
| AODV-UU | Uppsala University implementation of AODV |
| DSDV | Destination-Sequenced Distance Vector |
| DSR | Dynamic Source Routing |
| ELFN | Explicit Link Failure Notification |
| GW | Gateway |
| IEEE | Institute of Electrical and Electronics Engineers |
| IETF | Internet Engineering Task Force |
| IP | Internet Protocol |
| MN | Mobile Node |
| NAM | Network AniMator |
| NAT | Network Address Translation |
| OLSR | Optimized Link State Routing Protocol |
| RFC | Request for Comments |
| TCL | Tool Command Language |
| TCP | Transmission Control Protocol |
| TCP AP | TCP variant with Adaptive Pacing |
| TCP FeW | TCP variant with a Fractional increment of TCP congestion window |
| ZRP | Zone Routing Protocol |

*Table 5 Abbreviations*

# B Template Simulation details

**Simulation 1**

*Scenario (chain5.dst):*

- *Area* : *1200x1200m*
- *Wireless nodes*
  - *Nr of nodes* :*4*
  - *Positions* : *In a chain, 200m distance.*
- *Gateway*
  - *Nr of gateways* : *1*
  - *Position(s)* : *400x0 (3º position in the chain)*

*Traffic (1_tcp-from_node_0):*

- *Traffic* : *1 FTP flow*
  - *Flow 1* : *From MN0 to Wired Host*
    - *Start time* : *20*
    - *Stop time* : *880*

**Simulation 2**

*Scenario (chain5.dst):*

- *Area* : *1200x1200m*
- *Wireless nodes*
  - *Nr of nodes* :*4*
  - *Positions* : *In a chain, 200m distance.*
- *Gateway*
  - *Nr of gateways* : *1*
  - *Position(s)* : *400x0 (3º position in the chain)*

*Traffic (1-tcp-from-node-0-1-tcp-between-node-4-node-0):*

- *Traffic* : *2 FTP flows*
  - *Flow 1* : *From MN 0 to Wired Host*
    - *Start time* : *20*
    - *Stop time* : *440*

- o *Flow 2* : *From MN4 to MN0*
    - *Start time* : *220*
    - *Stop time* : *880*

**Simulation 3**

*Scenario (chain5.dst):*

- *Area* : *1200x1200m*
- *Wireless nodes*
  - o *Nr of nodes* :*4*
  - o *Positions* : *In a chain, 200m distance.*
- *Gateway*
  - o *Nr of gateways* : *1*
  - o *Position(s)* : *400x0 (3º position in the chain)*

*Traffic (2-tcp-from-node-0-node-4-simultaneous):*

- *Traffic* : *2 FTP flows*
  - o *Flow 1* : *From MN 0 to Wired Host*
    - *Start time* : *20*
    - *Stop time* : *880*

  - o *Flow 2* : *From MN 4 to Wired Host*
    - *Start time* : *20*
    - *Stop time* : *880*

**Simulation 4**

*Scenario (chain5.dst):*

- *Area* : *1200x1200m*
- *Wireless nodes*
  - o *Nr of nodes* :*4*
  - o *Positions* : *In a chain, 200m distance.*
- *Gateway*
  - o *Nr of gateways* : *1*
  - o *Position(s)* : *400x0 (3º position in the chain)*

*Traffic (2_tcp-from_node_0_node4):*

- *Traffic* : *2 FTP flows*
  - o *Flow 1* : *From MN 0 to Wired Host*
    - *Start time* : *20*
    - *Stop time* : *440*

  - o *Flow 2* : *From MN 4 to Wired Host*
    - *Start time* : *220*
    - *Stop time* : *880*

**Simulation 5**

*Scenario (chain51.dst):*

- *Area* : *1200x1200m*
- *Wireless nodes*
  - o *Nr of nodes* :*5*
  - o *Positions* : *chain, 200m distance. one 200 m above moving*
- *Gateway*
  - o *Nr of gateways* : *1*
  - o *Position(s)* : *400x0 (3º position in the chain)*

*Traffic (1_tcp-from_node_5):*

- *Traffic* : *1 FTP flows*
  - o *Flow 1* : *From MN5 to Wired Host.*
    - *Start time* : *20*
    - *Stop time* : *880*

**Simulation 6**

*Scenario (chain51.dst):*

- *Area* : *1200x1200m*
- *Wireless nodes*
  - o *Nr of nodes* :*5*
  - o *Positions* : *chain, 200m distance. one 200 m above moving*
- *Gateway*
  - o *Nr of gateways* : *1*

- *Position(s) : 400x0 (3º position in the chain)*

*Traffic (2-tcp-from-node-0-node-5):*

- *Traffic : 2 FTP flows*
  - *Flow 1 : From MN0 to Wired Host.*
    - *Start time : 20*
    - *Stop time : 440*
  - *Flow 2 : From MN5 to Wired Host.*
    - *Start time : 220*
    - *Stop time : 880*

**Simulation 7**

*Scenario (chain51.dst):*

- *Area : 1200x1200m*
- *Wireless nodes*
  - *Nr of nodes :5*
  - *Positions : chain, 200m distance. one 200 m above moving*
- *Gateway*
  - *Nr of gateways : 1*
  - *Position(s) : 400x0 (3º position in the chain)*

*Traffic (1_tcp-between_node_5-node_0):*

- *Traffic : 1 FTP flows*
  - *Flow 1 : From MN5 to MN0.*
    - *Start time : 20*
    - *Stop time : 880*

**Simulation 8**

*Scenario (chain51.dst):*

- *Area : 1200x1200m*
- *Wireless nodes*
  - *Nr of nodes :5*
  - *Positions : chain, 200m distance. one 200 m above moving*
- *Gateway*
  - *Nr of gateways : 1*
  - *Position(s) : 400x0 (3º position in the chain)*

*Traffic (2-tcp-from-node-0-node-5-simultaneous):*

- *Traffic : 2 FTP flows*
  - *Flow 1 : From MN0 to Wired Host*
    - *Start time : 20*
    - *Stop time : 880*
  - *Flow 2 : From MN 5 to Wired Host*
    - *Start time : 20*
    - *Stop time : 880*

**Simulation 9**

*Scenario (grid7x7.dst):*

- *Area : 1200x1200m*
- *Wireless nodes*
  - *Nr of nodes : 48*
  - *Positions : Grid 7x7, 200m distance (X,Y)*
- *Gateway*
  - *Nr of gateways : 1*
  - *Position(s) : 400x400 (position 16 in grid)*

*Traffic (1_tcp-from_node_0):*

- *Traffic : 1 FTP flow*
  - *Flow 1 : From MN0 to Wired Host*
    - *Start time : 20*
    - *Stop time : 880*

**Simulation 10**

*Scenario (grid7x7.dst):*

- *Area : 1200x1200m*
- *Wireless nodes*
  - *Nr of nodes : 48*
  - *Positions : Grid 7x7, 200m distance (X,Y)*
- *Gateway*
  - *Nr of gateways : 1*
  - *Position(s) : 400x400 (position 16 in grid)*

*Traffic (1-tcp-from-node-0-1-tcp-between-node-4-node-0):*

- *Traffic : 2 FTP flows*
  - *Flow 1 : From MN 0 to Wired Host*
    - *Start time : 20*
    - *Stop time : 440*
  - *Flow 2 : From MN4 to MN0*
    - *Start time : 220*
    - *Stop time : 880*

**Simulation 11**

*Scenario (grid7x7.dst):*

- *Area : 1200x1200m*
- *Wireless nodes*
  - *Nr of nodes : 48*
  - *Positions : Grid 7x7, 200m distance (X,Y)*
- *Gateway*
  - *Nr of gateways : 1*
  - *Position(s) : 400x400 (position 16 in grid)*

*Traffic (2-tcp-from-node-0-node-4-simultaneous):*

- *Traffic : 2 FTP flows*
  - *Flow 1 : From MN 0 to Wired Host*
    - *Start time : 20*
    - *Stop time : 880*
  - *Flow 2 : From MN 4 to Wired Host*
    - *Start time : 20*
    - *Stop time : 880*

**Simulation 12**

*Scenario (grid7x7.dst):*

- *Area : 1200x1200m*
- *Wireless nodes*

- Nr of nodes : 48
- Positions : Grid 7x7, 200m distance (X,Y)

*•Gateway*

- *Nr of gateways : 1*
- *Position(s) : 400x400 (position 16 in grid)*

*Traffic (2_tcp-from_node_0_node4):*

- *Traffic : 2 FTP flows*
  - *Flow 1 : From MN 0 to Wired Host*
    - *Start time : 20*
    - *Stop time : 440*

  - *Flow 2 : From MN 4 to Wired Host*
    - *Start time : 220*
    - *Stop time : 880*

**Simulation 13**

*Scenario (rand48.dst):*

- *Area : 1200x1200m*
- *Wireless nodes*
  - *Nr of nodes : 48*
  - *Positions : Grid 7x7, 200m distance (X,Y)*
- *Gateway*
  - *Nr of gateways : 1*
  - *Position(s) : 400x400 (position 16 in grid)*

*Traffic (1_tcp-from_node_0):*

- *Traffic : 1 FTP flow*
  - *Flow 1 : From MN0 to Wired Host*
    - *Start time : 20*
    - *Stop time : 880*

**Simulation 14**

*Scenario (rand48.dst):*

- *Area : 1200x1200m*
- *Wireless nodes*

- *Nr of nodes : 48*
- *Positions : Random in a 800x800 area (X,Y)*

- *Gateway*
  - *Nr of gateways : 1*
  - *Position(s) : 400x400*

*Traffic (1-tcp-from-node-0-1-tcp-between-node-4-node-0):*

- *Traffic : 2 FTP flows*
  - *Flow 1 : From MN 0 to Wired Host*
    - *Start time : 20*
    - *Stop time : 440*

  - *Flow 2 : From MN4 to MN0*
    - *Start time : 220*
    - *Stop time : 880*

**Simulation 15**

*Scenario (rand48.dst):*

- *Area : 1200x1200m*
- *Wireless nodes*
  - *Nr of nodes : 48*
  - *Positions : Random in a 800x800 area (X,Y)*
- *Gateway*
  - *Nr of gateways : 1*
  - *Position(s) : 400x400*

*Traffic (2-tcp-from-node-0-node-4-simultaneous):*

- *Traffic : 2 FTP flows*
  - *Flow 1 : From MN 0 to Wired Host*
    - *Start time : 20*
    - *Stop time : 880*

  - *Flow 2 : From MN 4 to Wired Host*
    - *Start time : 20*
    - *Stop time : 880*

**Simulation 16**

*Scenario (rand48.dst):*

- *Area : 1200x1200m*
- *Wireless nodes*
  - *Nr of nodes : 48*
  - *Positions : Random in a 800x800 area (X,Y)*
- *Gateway*
  - *Nr of gateways : 1*
  - *Position(s) : 400x400*

*Traffic (2_tcp-from_node_0_node4):*

- *Traffic : 2 FTP flows*
  - *Flow 1 : From MN 0 to Wired Host*
    - *Start time : 20*
    - *Stop time : 440*

  - *Flow 2 : From MN 4 to Wired Host*
    - *Start time : 220*
    - *Stop time : 880*

# C Simulation scripts

## C.1 Variables

In this section some crucial variables, to understand the simulation script, will be presented.

All of these variables,, except the ones defined in the traffic files, can be changed by giving command line options to the main scrip, e.g. `–variable value,` if no command line option is given the default value is used.

### C.1.1 Traffic files

**Code Sample Main script**

```
set opt(traffic)              "1-tcp-from-node-0"
```

The variable opt(traffic) determines which traffic scenario to load.

**Code Sample of traffic-file 2-tcp-from-node-0-node-4**

```
#Variables
set src(node-1)    $node_(0)
set dst(node-1)    $host_(0)
set src(node-2)    $node_(4)
set dst(node-2)    $host_(0)

set opt(start-src1) $opt(flow-delay)
set opt(stop-src1)  [expr(($opt(stop)-$opt(flow-delay))/2.0)]
set opt(start-src2) [expr  (($opt(stop)-$opt(flow-delay))/4.0)]
set opt(stop-src2)  [expr  ($opt(stop)-$opt(flow-delay))]
#Flow 1
set src(agt-1) [new Agent/$opt(tcp_version)]
set dst(agt-1) [new Agent/TCPSink]
$ns_ attach-agent $src(node-1) $src(agt-1)
$ns_ attach-agent $dst(node-1) $dst(agt-1)
$ns_ connect $src(agt-1) $dst(agt-1)
```

```
$src(agt-1) set fid_ 1
set ftp [new Application/FTP]
$ftp attach-agent $src(agt-1)
$ns_ at $opt(start-src1) "$ftp start"
$ns_ at $opt(stop-src1) "$ftp stop"
...skipped code for flow 2
```

Quick definition of variables:

| | |
|---|---|
| • src(node-1) | First Source Node |
| • dst(node-1) | First Destination Node |
| • src(node-2) | Second Source Node |
| • dst(node-2) | Second Destination Node |
| • opt(start-src1) | Start of first Flow |
| • opt(stop-src1) | Stop of first Flow |
| • opt(start-src2) | Start of second Flow |
| • opt(stop-src2) | Stop of second Flow |
| • opt(flow-delay) | The buffer time before the traffic is allowed to start, and the time it must stop. Calculated from start of simulation and end of simulation |

### C.1.2 TCP variants

The code samples below shows where it is determined which variable combination that yields the different TCP variant.

**Code sample main script**

```
set opt(tcp_name)   "Newreno"          ;#Newreno, Vegas
set opt(tcp_ext)     "none"            ;#AP Only works with Newreno
```

For TCP AP the parameter opt(tcp_name) must be set to Newreno and opt(tcp_ext) to AP.

## C.2 Calculations and Measurements

**Code sample of Jain's Fairness index calculation:**

```
#==================================================================
# Jains fairness index   = (Z Xi)^2 / i * Z Xi^2
#==================================================================
proc fairnessbt { thr i } {
global btthr_
 set btthr_($i) $thr
 set temproof 0
 set tempfloor 0

 for { set z 1 } { $z <= $i } { incr z } {
  set temproof [expr ($temproof + $btthr_($z))]
  set tempfloor [expr ($tempfloor + $btthr_($z) * $btthr_($z))]
  set roof [expr ($temproof * $temproof)]
  set floor [expr ($z * $tempfloor)]

  if { $floor != 0 && $i >= 2 } {
   set retur [expr ($roof * 1.0 / $floor)]
  } else {
   set retur 0
  }
 }
 return $retur
}
```

**Code Sample of Goodput calculation:**

```
#==================================================================
# Goodput calc = (tx - retx)/time
#==================================================================
proc goodput { tx retx dur } {
    set diff        [expr ($tx - $retx)]
    set gp          [expr ($diff * 1.0 /$dur)]
    return $gp
}
```

**Code sample of congestion window measurement:**

```
set cwnd_src-$i [$src(agt-$i) set cwnd_]
```

**Code sample of Throughput calculation:**

```
#===================================================================
# Throughput
#===================================================================
proc throughput { amount dur } {
    set retur [expr ($amount * 1.0/$dur)]
    return $retur
}
```

# D Code

## D.1 Main script

This script is the actual simulations script that controls the entire simulation.

```
# ======================================================================
# Define options
# ======================================================================
#TCP version and upper bound on congestion window
set opt(tcp_name)     "Newreno"            ;#FeW Newreno, Reno, Tahoe
set opt(tcp_ext)       ""                            ;#AP Only works with
Newreno
set opt(max_cwnd)     199                            ;# < 200 for TCP AP
set opt(max_win)      64                             ;# < 200 for TCP AP

#Scenario files
set opt(scenario)       "chain5"
set opt(traffic)        "1-tcp-from-node-0"
#set opt(traffic)        "tcp"
           ;#"tcp","udp","mobiletcp" or traffic file
set opt(src-node)      4                             ;#Only used if no
traffic file. src-node must exist
;#Destination is wired host or mobile node_(0) (if mobiletcp)
## Various parameters
#Wireless
set opt(rp)             AODVUU                          ;# DSDV, AODVUU
set opt(Wireless-rate)          2e6
#Wired
set opt(Wired-Bandwidth) 100Mb
set opt(Wired-Delay)   2ms
#Start and stop parameters
set opt(stop)          900.0
set opt(start-trace)   1.0
set opt(flow-delay)    20
#Clock in tracfiles
set opt(granularity)   1.0

##Static Variables
#Dirs
set opt(result-dir)    "./result"
set opt(traffic-dir)   "./traffic"
set opt(scenario-dir)  "./scenario"

##Wireless Network Interface Characteristics
set opt(chan)                Channel/WirelessChannel    ;# channel type
set opt(prop)           Propagation/TwoRayGround   ;# radio-propagation
model
set opt(netif)          Phy/WirelessPhy            ;# network interface
type
set opt(mac)            Mac/802_11                 ;# MAC type
set opt(ifq)            Queue/DropTail/PriQueue    ;# interface queue type
set opt(ll)             LL                         ;# link layer type
set opt(ant)            Antenna/OmniAntenna        ;# antenna model
set opt(ifqlen)         50                        ;# max packet in ifq

#Set up the topography
set opt(x)               1200
set opt(y)               1200


#Graph drawing variables
set opt(same-x-axis)  1
set opt(xlabel)                  "Simulation time in seconds"
set opt(yformat)      "%g"
set opt(xformat)      "%g"
set opt(ylabel-win)   "Congestion Window in packets"
set opt(ylabel-bt)    "Throughput in Kbits/s"
set opt(ylabel-btgp)  "Goodput in Kbits/s"
set opt(ylabel-pkt)   "Throughput in pkts/s"
set opt(ylabel-pktgp)           "Throughput in pkts/s"
set opt(ylabel-fair)  "Jain's Fairness Index procent"
set opt(afterburner)  -1


# ======================================================================
# Main
# ======================================================================
proc main {} {
    global opt ns_ file_ argc argv
#----Define some colors in NAM--------#
set ns_ [new Simulator]
$ns_ color 0 Brown
$ns_ color 1 Blue
$ns_ color 2 Yellow
$ns_ color 3 Green
$ns_ color 4 Purple
$ns_ color 5 Red

#Load command line options
getopt $argc $argv
#$ns_ use-newtrace

#Initialize variables that might have changed via cmd line
initvar

#Create dirs
set val(result_dir) "$opt(result-
dir)/$opt(scenario)/$opt(traffic)/$opt(rp)-$opt(tcp_name)"
exec mkdir -p "$val(result_dir)"

#----Remove old tracefile and open new one----------#
set tracefile "$val(result_dir)/trace"
exec rm -f "$tracefile.*"

#For NS
set file_(tr) [open "$tracefile.tr" w]
$ns_ trace-all $file_(tr)

#For NAM
set file_(nam) [open "$tracefile.nam" w]
#$ns_ namtrace-all-wireless $file_(nam) $opt(x) $opt(y)

#For Cwnd trace
set file_(win) [open "$tracefile.win" w]
```

```
#For Bytes trace
set file_(bt) [open "$tracefile.bt" w]

#For Packet trace
set file_(pkt) [open "$tracefile.pkt" w]

#For Movment trace
plotMovement                    ;#Write output in ns tracefile

#----Call the procedure that create topology, setup the traffic etc.---#
create-topo-nodes
set-traffic

#----------------------- Run Simulation -------------------------
$ns_ at $opt(stop).0001 "finish $tracefile $val(result_dir)"
$ns_ at 0.0 "$ns_ set-animation-rate 15ms"
#Starting the logging
$ns_ at $opt(start-trace) "plotPktByteWin $file_(pkt) $file_(bt)
$file_(win) 0.0"
# For tracegraph
puts $file_(tr) "mixed12 ip hex"

puts "Starting simulation..."
puts "Please wait..."
$ns_ run

}

# ======================================================================
# End of Simulation
# ======================================================================
proc finish { tracefile result_dir } {
    global ns_ opt node_ host_ file_ dst src val

    #Statistics about simulation
    statPktByteWin $file_(pkt) $file_(bt) $file_(win)

    #--For NAM ----#
    #The Wired Host
    $ns_ at $opt(stop).01 "$host_(0) reset";

    #The Wireless nodes + Gateway (remeber node_(X) = gw1)
    for {set i 0} {$i < [expr $opt(wirelessNodes) + $opt(gatewayNodes)]}
{incr i} {
        $ns_ at $opt(stop).01 "$node_($i) reset";
    }

    #Stop Animation
    $ns_ at $opt(stop).01 "$ns_ nam-end-wireless $opt(stop)"

    #------Stop simulation------#
    $ns_ at $opt(stop).0002 "$ns_ halt"

    #Flush and close tracefiles
    $ns_ flush-trace
    flush $file_(tr)
    flush $file_(nam)
    flush $file_(win)
    flush $file_(bt)
    flush $file_(pkt)
```

```
        close $file_(tr)
        close $file_(nam)
        close $file_(win)
        close $file_(bt)
        close $file_(pkt)

        #-----------Run NAM ------------#
        #puts "Running nam with $tracefile.nam ... "
        #exec nam "$tracefile.nam" &

        #-----------Post processin ------------#
        set post_dir "$result_dir/postprocess"
        exec mkdir -p "$post_dir"
        exec rm -f "$post_dir/*"

        puts "Running post-processing scripts ... "
        postProcessing $tracefile $post_dir $result_dir

       #writing the dir in afterburner file
       if { $opt(afterburner) != -1 } {
              set ab [open "$opt(afterburner)" a]
              puts $ab "$result_dir/$opt(afterburner)"
              flush $ab
              close $ab
       }
       #------------End post processing -----------#
       exit 0
}

# ====================================================================
# Setup Scenario and Nodes
# ====================================================================
proc create-topo-nodes {} {
    global ns_ opt node_ gw_ host_ god_

    #create a topology object and define topology
    set topo [new Topography]
    $topo load_flatgrid $opt(x) $opt(y)

    create-nodes $topo

    #In scenario rand48 this is the gateways position
    if { $opt(scenario) == "rand48" } {
        $gw_(0) set X_ $opt(gw-pos-X)
        $gw_(0) set Y_ $opt(gw-pos-Y)
        $gw_(0) set Z_ $opt(gw-pos-Z)
    }

    #Load Scenario file
    if { $opt(scenario) == "" } {
        puts "*** NOTE: no scenario file specified."
        set opt(scenario) "none"
    } else {
        puts "Loading scenario file..."
        source "$opt(scenario-dir)/$opt(scenario).dst"
        puts "Load complete..."
    }

    #---Label Mobile and Fixed hosts in NAM--------------"
    $ns_ at 0.0 "$host_(0) label \"Wired Host([$host_(0) id])\""
    puts "Wired Host = Node_ID([$host_(0) id])"
    $ns_ at 0.0 "$gw_(0) label \"GATEWAY([$gw_(0) id])\""
    puts "GATEWAY = Node_ID([$gw_(0) id])"
    for {set i 0} {$i < [expr $opt(wirelessNodes) + $opt(gatewayNodes)]  }
{incr i} {
        if { $i != $opt(gwNode) } {
            $ns_ at 0.0 "$node_($i) label \"MN $i ([$node_($i) id])\""
               puts "MN $i = Node_ID([$node_($i) id])"
            $ns_ initial_node_pos $node_($i) 20
        }
    }

    $host_(0) color blue
    $host_(0) shape box

    $gw_(0) color red
    $gw_(0) shape hexagon

    #----- For Nam Wired Links----------#
    $ns_ duplex-link-op $host_(0) $gw_(0) orient up
}

# ======================================================================
# Create nodes
# ======================================================================
proc create-nodes { topo } {
    global ns_ opt node_ gw_ host_ god_

    #------------Create God Object-------------#
    set god_ [create-god [expr $opt(wirelessNodes)+$opt(gatewayNodes)]]

    #---------Addressing---------#
    #For mixed simulations we need to use hierarchical routing in order to
    #route packets. Must be put before addressing starts.
    $ns_ node-config -addressType hierarchical

    #Number of domains
    #2 domains
    AddrParams set domain_num_ 2

    #Number of clusters in each domain
    #2 clusters
    #1 cluster in domain 0
    #1 cluster in domain 1
    AddrParams set cluster_num_ {1 1}

    #Number of nodes in each cluster
    #1 nodes in domain 0 in cluster 0: host1 0.0.0
    #Wireless + gateway node in domain 1 in cluster 0
    lappend nr_of_nodes_in_each_domain 1  [expr
$opt(wirelessNodes)+$opt(gatewayNodes)]
    AddrParams set nodes_num_  $nr_of_nodes_in_each_domain

    #-----Create Nodes--------------------#
    ### Create wired nodes
    set host_(0) [$ns_ node 0.0.0]


    # Configure mobile nodes and gateways
    $ns_ node-config -adhocRouting $opt(rp) \
            -llType $opt(ll) \
            -macType $opt(mac) \
            -ifqType $opt(ifq) \
            -ifqLen $opt(ifqlen) \
            -antType $opt(ant) \
            -propType $opt(prop) \
            -phyType $opt(netif) \
            -channel [new $opt(chan)] \
            -topoInstance $topo \
            -wiredRouting ON \
            -agentTrace ON \
            -routerTrace OFF \
            -macTrace OFF \
            -movementTrace OFF

    #Set wireless sending rate
    $opt(mac) set basicRate_ $opt(Wireless-rate)
    $opt(mac) set dataRate_ $opt(Wireless-rate)
    $opt(netif) set bandwidth_ $opt(Wireless-rate)
    $opt(netif) set Rb_ $opt(Wireless-rate)


    ### Create gateway
    set gw_(0) [$ns_ node 1.0.$opt(gwNode)]
    $gw_(0) random-motion 0     ;# disable random motion
    #----- Create Wired Links----------#
    $ns_ duplex-link $host_(0) $gw_(0) $opt(Wired-Bandwidth) $opt(Wired-
Delay) DropTail

    #set ragent [$ns_ create-noah-agent $gw1]

    #If AODVUU is used tell this node that it is a gateway and use half
tunneling
    if { $opt(rp) == "AODVUU" } {
        set r [$gw_(0) set ragent_]
        $r set internet_gw_mode_ 1
    }

    #In all scenarios except rand48 the gateway's position
    ##is defined in the sceanrio file as node_(X)
    set node_($opt(gwNode)) $gw_(0)

    # Configure for mobile nodes
    $ns_ node-config -wiredRouting OFF

    ### Create mobile nodes
    for {set i 0} {$i < [expr $opt(wirelessNodes) + $opt(gatewayNodes)] }
{incr i} {
           if { $i != $opt(gwNode) } {                ;#Gateway node is
already created
            set node_($i) [$ns_ node 1.0.$i]
            $node_($i) random-motion 0
            $node_($i) base-station [AddrParams addr2id [$gw_(0) node-
addr]] ;# assign gw_(0) as gateway for this node
        }
    }
}


# ==========================================================================
# Setup Traffic
# ==========================================================================
proc set-traffic { } {
    global ns_ opt node_ gw_ host_ src dst

    if { $opt(max_cwnd) != -1 } {
        Agent/$opt(tcp_version) set maxcwnd_ $opt(max_cwnd)
    }
    if { $opt(max_win) != -1 } {
        Agent/$opt(tcp_version) set window_ $opt(max_win)
    }

    #---------Improve perfomance as stated in---------#
    ##Improving TCP Performance for Multihop Wireless Networks,#
    ##Sherif M. ElRakabawy, Christoph Lindemann, Mary K. Vernon#
    if { $opt(tcp_version) == "TCP/vegas"  }  {
        Agent/$opt(tcp_version) set v_alpha_ 2
        Agent/$opt(tcp_version) set v_beta_ 2
    }

    #---------Improve perfomance as stated in---------#
    ##TCP with Adaptive Pacing for Multihop Wireless Networks,#
    ##Sherif M. ElRakabawy, Christoph Lindemann, Mary K. Vernon#
    if { $opt(tcp_version) == "TCP/Newreno/AP"  }  {
        Agent/$opt(tcp_version) set history_ 50
           Agent/$opt(tcp_version) set alpha_ 0.7
           #for changeing the wireless rate
           Agent/$opt(tcp_version) set ll_bandwidth_ $opt(Wireless-rate)
    }

    #----Load traffic file if exist and not is tcp or udp or mobile tcp ---
---#
    if {$opt(traffic) == "tcp" && $opt(traffic) == "udp" && $opt(traffic)
== "mobiletcp"} {
           simpleTraffic
    } else {
        if { $opt(traffic) == "" } {
            puts "*** NOTE: no traffic file specified."
            exit -1
        } else {
            puts "Loading traffic file..."
            source "$opt(traffic-dir)/$opt(traffic)"
            puts "Load complete..."

        }

    }
}


#---------------------Tracing-----------------------------------------
#

#
=============================================================================
# Movement trace
#
=============================================================================
proc plotMovement { } {
    global logtimer ns_ ns opt
    set ns $ns_

    source /sim/ns-allinone-2.29/ns-2.28/tcl/mobility/timer.tcl
    Class LogTimer -superclass Timer
    LogTimer instproc timeout {} {
        global opt node_;

        for {set i 0} {$i < [expr $opt(wirelessNodes) +
$opt(gatewayNodes)]} {incr i} {
            $node_($i) log-movement
        }
        $self sched $opt(granularity)
    }
}

#
===========================================================================
# Packet/Byte/Win trace
#
===========================================================================
proc plotPktByteWin { trfilepkts trfilebytes trfilewin oldnow} {
    global ns_ src dst opt agg_ val host_ gw_ node_

    set now [$ns_ now]
    set dur [expr ($now - $oldnow)]
           for { set i 1 } { [info exist src(node-$i)] } { incr i } {
           if { $now >= [expr ($opt(start-src$i) - $opt(flow-delay))] &&
$now <= [expr ($opt(stop-src$i)+$opt(flow-delay))] } {
               global header_
               if { ![info exist agg_(times_$i)] } {
                      set agg_(times_$i) 0
                      set agg_(thrbytes_$i) 0
                      set agg_(thrpkts_$i) 0
                      set agg_(gpbytes_$i) 0
                      set agg_(gppkts_$i) 0
                      set agg_(win_$i) 0
                      set agg_(bytes_$i) 0
                      set agg_(rebytes_$i) 0
                      set agg_(pkts_$i) 0
                      set agg_(repkts_$i) 0
                      set agg_(recvbytes_$i) 0
                   }

                      set sent_bytes_src [expr ([$src(agt-$i) set
ndatabytes_] - $agg_(bytes_$i))]
                      set resent_bytes_src [expr ([$src(agt-$i) set
nrexmitbytes_] - $agg_(rebytes_$i))]

                set sent_pkts_src [expr ([$src(agt-$i) set ndatapack_] -
$agg_(pkts_$i))]
                set resent_pkts_src [expr ([$src(agt-$i) set nrexmitpack_]
- $agg_(repkts_$i))]

                set cwnd_src [$src(agt-$i) set cwnd_]

#                     $src(agt-$i) set ndatabytes_ 0
#                     $src(agt-$i) set nrexmitbytes_ 0
#                     $src(agt-$i) set ndatapack_ 0
#                     $src(agt-$i) set nrexmitpack_ 0


                #set recv_pkts_dst-$i [expr ([$dst(agt-$i) set npkts_] -
$old(recv_pkts_dst_$i))];# funkar endast med lossmonitor som sink?
```

```
                set recv_bytes_dst [expr ([$dst(agt-$i) set bytes_] -
$agg_(recvbytes_$i))]


                      #Throughput
                      set thrbytes [expr ([throughput $sent_bytes_src $dur]
* 8.0 /1000.0)]
                      set thrpkts [throughput $sent_pkts_src $dur]


                #Goodput calc = (tx bytes - retx bytes)/time
#                     set gpbytes [expr ([throughput $recv_bytes_dst $dur]
* 8.0 /1000.0)]
                set gpbytes [expr ([goodput $sent_bytes_src
$resent_bytes_src $dur] * 8.0 /1000.0)]
                set gppkts  [goodput $sent_pkts_src $resent_pkts_src $dur]




                      set agg_(thrbytes_$i) [expr ($agg_(thrbytes_$i) +
$thrbytes)]
                      set agg_(thrpkts_$i) [expr ($agg_(thrpkts_$i) +
$thrpkts)]
                      set agg_(gpbytes_$i) [expr ($agg_(gpbytes_$i) +
$gpbytes)]
                      set agg_(gppkts_$i) [expr ($agg_(gppkts_$i) +
$gppkts)]
                      set agg_(win_$i)  [expr ($cwnd_src + $agg_(win_$i))]
                      set agg_(bytes_$i) [expr ($agg_(bytes_$i) +
$sent_bytes_src)]
                      set agg_(rebytes_$i) [expr ($agg_(rebytes_$i) +
$resent_bytes_src)]
                      set agg_(pkts_$i) [expr ($agg_(pkts_$i) +
$sent_pkts_src)]
                      set agg_(repkts_$i) [expr ($agg_(repkts_$i) +
$resent_pkts_src)]

                      set agg_(recvbytes_$i) [expr ($agg_(recvbytes_$i) +
$recv_bytes_dst)]

                      set agg_(times_$i) [expr ($agg_(times_$i) + 1)]

                      #is true once for every flow
                      if {  ![info exist header_($i)] } {
                          set header_($i) 1
                          #-----Flow $i -----------#
                          set val(flowid-$i) [$src(agt-$i) set fid_]

                          #Source $i
                          set nodeid_src_ [$src(node-$i) id]
                          #Destinatin $i
                          set nodeid_dst_ [$dst(node-$i) id]
                          #Find out which node is sender

                          if { $nodeid_src_ == [$host_(0) id] } {
                                 set val(nodeid_src-$i) "Wired-Host"
                          } elseif { $nodeid_src_ == [$gw_(0) id] } {
                                 set val(nodeid_src-$i) "Gateway"
                          } else {
                                 for {set k 0} {$k < [expr
$opt(wirelessNodes) + $opt(gatewayNodes)]  } {incr k} {
                                     if { $k != $opt(gwNode) } {
                                 if { [$node_($k) id] == $nodeid_src_ } {
                                                 set val(nodeid_src-$i)
"MN$k"
                                     }
                                            }
                              }
                          }
                          # find out wich node is dst
                          if { $nodeid_dst_ == [$host_(0) id]} {
                                 set val(nodeid_dst-$i) "Wired-Host"
                          } elseif { $nodeid_dst_ == [$gw_(0) id] } {
                                 set val(nodeid_dst-$i) "Gateway"
                          } else {
                                 for {set k 0} {$k < [expr
$opt(wirelessNodes) + $opt(gatewayNodes)]  } {incr k} {
                                     if { $k != $opt(gwNode) } {
                                 if { [$node_($k) id] == $nodeid_dst_ } {
                                                 set val(nodeid_dst-$i)
"MN$k"
                                     }
                                            }
                              }
                          }
                          puts "Flow $val(flowid-$i), Start $opt(start-
src$i) : $val(nodeid_src-$i) -> $val(nodeid_dst-$i) : Stop  $opt(stop-
src$i)"
                          set val(title-win_$i) "Congestion Window
$val(nodeid_src-$i), start sending $opt(start-src$i) stop sending
$opt(stop-src$i)"
                          set val(title-bt_$i) "Flow $val(flowid-$i) from
$val(nodeid_src-$i) to $val(nodeid_dst-$i), start sending $opt(start-src$i)
stop sending $opt(stop-src$i)"
                          set val(title-pkt_$i) "Flow $val(flowid-$i) from
$val(nodeid_src-$i) to  $val(nodeid_dst-$i), start sending $opt(start-
src$i) stop sending $opt(stop-src$i)"
                          puts $trfilewin "Title $val(title-win_$i)"
                    puts $trfilepkts  "Title $val(title-pkt_$i)"
                    puts $trfilebytes "Title $val(title-bt_$i)"
                          puts $trfilepkts  "Comment Flow_id Time
Throughput and Goodput in pkts/s"
                          puts $trfilebytes  "Comment Flow_id Time
Throughput and Goodput in Kbit/s"
                }

                      #Write output
                puts $trfilewin "$val(nodeid_src-$i) $now $cwnd_src"
                      puts $trfilepkts  "$val(flowid-$i) $now $thrpkts
$gppkts"
                puts $trfilebytes "$val(flowid-$i) $now $thrbytes $gpbytes"
               }
           }
    $ns_ at [expr ($now + $opt(granularity))] "plotPktByteWin $trfilepkts
$trfilebytes $trfilewin $now"
}

#
==========================================================================
# Packet/Byte/Win statistic calc and trace
```

```
#
===========================================================================
proc statPktByteWin {trfilepkts trfilebytes trfilewin} {
           global agg_ src val opt

           set thrbytes_tot 0
           set thrpkts_tot 0
           set gpbytes_tot 0
           set gpkts_tot        0
           set win_tot  0
           for { set i 1 } { [info exist src(node-$i)] } { incr i } {
                      set thrbytes [expr
($agg_(thrbytes_$i)*1.0/(1.0*$agg_(times_$i)))]
                      set thrpkts [expr
($agg_(thrpkts_$i)*1.0/(1.0*$agg_(times_$i)))]
                      set gpbytes [expr
($agg_(gpbytes_$i)*1.0/(1.0*$agg_(times_$i)))]
                set gppkts [expr
($agg_(gppkts_$i)*1.0/(1.0*$agg_(times_$i)))]
                      set avgwin [expr
($agg_(win_$i)*1.0/(1.0*$agg_(times_$i)))]
                      set thrbytes_tot [expr ($thrbytes_tot + $thrbytes)]
                      set thrpkts_tot [expr ($thrpkts_tot + $thrpkts)]
                      set gpbytes_tot [expr ($gpbytes_tot + $gpbytes)]
                      set gpkts_tot [expr ($gpkts_tot + $gppkts)]
                      set win_tot  [expr ($win_tot + $avgwin)]

                      set val(stat-pkt_$i) "[format "Avg Thru:%.2fpkts/s"
$thrpkts]"
                      set val(stat-bt_$i) "[format "Avg Thru:%.2fKbit/s"
$thrbytes]"
                      set val(stat-pktgp_$i) "[format "Avg GP:%.2fpkts/s"
$gppkts]"
                      set val(stat-btgp_$i) "[format "Avg GP:%.2fKbit/s"
$gpbytes]"
                      set val(stat-win_$i) "[format "Avg Cwnd:%.2fpkt"
$avgwin]"
                      puts $trfilepkts  "Statistic Flow $val(flowid-$i)
$val(stat-pkt_$i), $val(stat-pktgp_$i)"
                      puts $trfilebytes "Statistic Flow $val(flowid-$i)
$val(stat-bt_$i), $val(stat-btgp_$i)"
                      puts $trfilewin "Statistic $val(nodeid_src-$i)
$val(stat-win_$i)"
           }


           set val(nr-flows) [expr ($i-1)]
           set fair [fairnessbt $val(nr-flows)]
           set val(stat-fair) "[format "Jain's Fairness Index:%.2f" $fair]
for $val(nr-flows) flows"
           set val(stat-pkt_agg) "[format "Aggregate Thr:%.2fpkts/s"
$thrpkts_tot] for $val(nr-flows) flows"
           set val(stat-bt_agg) "[format "Aggregate Thr:%.2fKbits/s"
$thrbytes_tot] for $val(nr-flows) flows"
           set val(stat-pktgp_agg) "[format "Aggregate GP:%.2fpkts/s"
$gpkts_tot] for $val(nr-flows) flows"
           set val(stat-btgp_agg) "[format "Aggregate GP:%.2fKbits/s"
$gpbytes_tot] for $val(nr-flows) flows"
           set val(stat-win_agg) "[format "Aggregate Cwnd:%.2fpkts"
$win_tot] for $val(nr-flows) nodes"
```

```
           puts $trfilebytes  "Statistic $val(stat-bt_agg), $val(stat-
btgp_agg), $val(stat-fair)"
           puts $trfilepkts "Statistic $val(stat-pkt_agg), $val(stat-
pktgp_agg), $val(stat-fair)"
           puts $trfilewin "Statistic $val(stat-win_agg)"
}

#--Subroutines for "simulation"--------------------------------------------
#
#-----------Calculations----------------------------------------------#
# ====================================================================
# Throughput  & goodput at receiver
# ====================================================================
proc throughput { amount dur } {
    set retur         [expr ($amount * 1.0/$dur)]
    return $retur
}

# ====================================================================
# Goodput calc = (tx - retx)/time
# ====================================================================
proc goodput { tx retx dur } {
    set diff          [expr ($tx - $retx)]
    set gp            [expr ($diff * 1.0 /$dur)]
    return $gp
}


# ====================================================================
# Jains fairness index   = (Z Xi)^2 / i * Z Xi^2
# ====================================================================
proc fairnessbt { i } {
    global agg_
    set temproof 0
    set tempfloor 0
    for { set z 1 } { $z <= $i } { incr z } {
        set temproof [expr ($temproof + $agg_(thrbytes_$z))]
           set tempfloor [expr ($tempfloor + $agg_(thrbytes_$z) *
$agg_(thrbytes_$z))]
           }

           set roof [expr ($temproof * $temproof)]
        set floor [expr ($i * $tempfloor)]

           if { $floor != 0} {
                      set retur [expr ($roof * 1.0 / $floor)]
        } else {
                      set retur 1
           }
    return $retur
}
#----Load command line options, init variables ect--------------------#
# ====================================================================
# Load command line options
# ====================================================================
proc getopt {argc argv} {
    global opt
    for {set i 0} {$i < $argc} {incr i} {
        set arg [lindex $argv $i]

        if {[string range $arg 0 0] != "-"} {
            continue
        }
        set name [string range $arg 1 end]
        set opt($name) [lindex $argv [expr $i+1]]
        puts "opt($name) = $opt($name)"
    }
    if { $argc == 0 } {
        puts "Using defaults"
    }
}
# ========================================================================
# Initialize variables
# ========================================================================
proc initvar { } {
    global opt
#Start and stop traffic Observe these variables can be overwritten in the
traffic file
set opt(start-src1)    $opt(flow-delay)
set opt(stop-src1)     [expr ($opt(stop) - $opt(flow-delay))]
set opt(start-src2)    [expr ($opt(stop) + 1)]
set opt(stop-src2)     [expr ($opt(stop) + 2)]

if { $opt(tcp_name) == "FeW"  || $opt(tcp_name) == "Tahoe"} {
    set opt(tcp_version)         "TCP"                    ;#TCP, TCP/Vegas,
TCP/Reno, TCP/Tahoe
} else {
    set opt(tcp_version)         "TCP/$opt(tcp_name)"                ;#TCP,
TCP/Vegas, TCP/Reno, TCP/Tahoe
}

if { !($opt(tcp_ext) == "" || $opt(tcp_ext) == "none") } {
    set opt(tcp_version)         "TCP/$opt(tcp_name)/$opt(tcp_ext)"
                        ;#TCP, TCP/Vegas, TCP/Reno, TCP/Tahoe
    set opt(tcp_name)            "$opt(tcp_name)-$opt(tcp_ext)"
              ;#TCP, TCP/Vegas, TCP/Reno, TCP/Tahoe
}
if { $opt(scenario) == "grid7x7" } {
    set opt(wirelessNodes)   48
    set opt(gatewayNodes)    1
    set opt(gwNode)              16
}
if { $opt(scenario) == "chain5" } {
    set opt(wirelessNodes)   4
    set opt(gatewayNodes)    1
    set opt(gwNode)              2
}
if { $opt(scenario) == "chain51" } {
    set opt(wirelessNodes)   5
    set opt(gatewayNodes)    1
    set opt(gwNode)              2
}
if { $opt(scenario) == "rand48" } {
    set opt(wirelessNodes)   48
    set opt(gatewayNodes)    1
    set opt(gwNode)    $opt(wirelessNodes) ;# Must be the last of the
wireless + 1
    set opt(gw-pos-X)  200.0
    set opt(gw-pos-Y)  200.0
    set opt(gw-pos-Z)  0.0
}
if { $opt(same-x-axis) == 1} {
    set opt(xlabel-bt)                    $opt(xlabel)
    set opt(xlabel-btgp)        $opt(xlabel)
    set opt(xlabel-pkt)                   $opt(xlabel)
    set opt(xlabel-pktgp)       $opt(xlabel)
    set opt(xlabel-win)                   $opt(xlabel)
    set opt(xlabel-fair)        $opt(xlabel)
    }
}

# ========================================================================
# simpleTraffic Scenario
# ========================================================================
proc simpleTraffic { } {
    #Simple UDP constant bitrate from MANET to Wired
    if {$opt(traffic) == "udp"} {
        set src(node-1) $node_($opt(src-node))
        set dst(node-1) $host_(0)

        set src(agt-1) [new Agent/UDP]
        set dst(agt-1) [new Agent/Null]
        $ns_ attach-agent $src(node-1) $src(agt-1)
        $ns_ attach-agent $dst(node-1) $dst(agt-1)
        $ns_ connect $src(agt-1) $dst(agt-1)

        set cbr [new Application/Traffic/CBR]
        $cbr attach-agent $src(agt-1)
        $cbr set packetSize_ 512
        $cbr set interval_ 0.1
        #$cbr set packetSize_ 1000
        #$cbr set interval_ 0.0178571429

        $ns_ at $opt(start-src1) "$cbr start"
        $ns_ at $opt(stop-src1) "$cbr stop"
    }

    #Simple TCP Newreno from MANET to Wired
    if {$opt(traffic) == "tcp"} {
        set src(node-1) $node_($opt(src-node))
        set dst(node-1) $host_(0)

        set src(agt-1) [new Agent/$opt(tcp_version)]
        set dst(agt-1) [new Agent/TCPSink]
        $ns_ attach-agent $src(node-1) $src(agt-1)
        $ns_ attach-agent $dst(node-1) $dst(agt-1)
        $ns_ connect $src(agt-1) $dst(agt-1)

        $src(agt-1) set fid_ 1
        set ftp [new Application/FTP]
        $ftp attach-agent $src(agt-1)

        $ns_ at $opt(start-src1) "$ftp start"
        $ns_ at $opt(stop-src1) "$ftp stop"
    }

    #Simple TCP Newreno between MANET nodes
    if {$opt(traffic) == "mobiletcp"} {
        set src(node-1) $node_($opt(src-node))
        set dst(node-1) $node_(0)

        set src(agt-1) [new Agent/$opt(tcp_version)]
        set dst(agt-1) [new Agent/TCPSink]
        $ns_ attach-agent $src(node-1) $src(agt-1)
        $ns_ attach-agent $dst(node-1) $dst(agt-1)
        $ns_ connect $src(agt-1) $dst(agt-1)

        $src(agt-1) set fid_ 1
        set ftp [new Application/FTP]
        $ftp attach-agent $src(agt-1)

        $ns_ at $opt(start-src1) "$ftp start"
        $ns_ at $opt(stop-src1) "$ftp stop"

    }

}


#-- Helper sub routines has nothing todo with actual simulation or
traceing-#
#
==============================================================================
# Post processing
#
==============================================================================
proc postProcessing {filename1 post_dir trace_dir} {
    global src dst opt val

  for { set i 1 } { $i <= $val(nr-flows) } { incr i } {

           set file_name_bt_($i) "Througput-byte-flow-$val(flowid-$i)"
           set file_name_pkt_($i) "Througput-packet-flow-$val(flowid-$i)"
           set file_name_bt_gp($i) "Goodput-byte-flow-$val(flowid-$i)"
           set file_name_pkt_gp($i) "Goodput-packet-flow-$val(flowid-$i)"
           set file_name_($i) "Cwnd-node-$val(nodeid_src-$i)"
           exec perl postprocess.pl "$filename1.bt" $val(flowid-$i)
Throughput > "$post_dir/$file_name_bt_($i)"
           exec perl postprocess.pl "$filename1.pkt" $val(flowid-$i)
Throughput > "$post_dir/$file_name_pkt_($i)"
           exec perl postprocess.pl "$filename1.bt" $val(flowid-$i) Goodput
> "$post_dir/$file_name_bt_gp($i)"
           exec perl postprocess.pl "$filename1.pkt" $val(flowid-$i)
Goodput > "$post_dir/$file_name_pkt_gp($i)"
           exec perl postprocess.pl "$filename1.win" $val(nodeid_src-$i)
Window > "$post_dir/$file_name_($i)"


           useGnuplot $file_name_bt_($i) "" $file_name_bt_($i) $post_dir
"$val(title-bt_$i), $val(stat-bt_$i)" "$opt(scenario)\\n$opt(rp)-
$opt(tcp_name)\\n$opt(traffic)" $opt(ylabel-bt) $opt(xlabel-bt)
$opt(xformat) $opt(yformat)
           useGnuplot $file_name_pkt_($i) "" $file_name_pkt_($i) $post_dir
"$val(title-pkt_$i), $val(stat-pkt_$i)" "$opt(scenario)\\n$opt(rp)-
$opt(tcp_name)\\n$opt(traffic)" $opt(ylabel-pkt) $opt(xlabel-pkt)
$opt(xformat) $opt(yformat)
           useGnuplot $file_name_bt_gp($i) "" $file_name_bt_gp($i)
$post_dir "$val(title-bt_$i), $val(stat-btgp_$i)"
"$opt(scenario)\\n$opt(rp)-$opt(tcp_name)\\n$opt(traffic)" $opt(ylabel-
btgp) $opt(xlabel-btgp) $opt(xformat) $opt(yformat)
           useGnuplot $file_name_pkt_gp($i) "" $file_name_pkt_gp($i)
$post_dir "$val(title-pkt_$i), $val(stat-pktgp_$i)"
"$opt(scenario)\\n$opt(rp)-$opt(tcp_name)\\n$opt(traffic)" $opt(ylabel-
pktgp) $opt(xlabel-pktgp) $opt(xformat) $opt(yformat)
```

```
           useGnuplot $file_name_($i) "" $file_name_($i) $post_dir
"$val(title-win_$i), $val(stat-win_$i)" "$opt(scenario)\\n$opt(rp)-
$opt(tcp_name)\\n$opt(traffic)" $opt(ylabel-win) $opt(xlabel-win)
$opt(xformat) $opt(yformat)

    if { $i >= 2 } {
               useGnuplot $file_name_bt_(1) $file_name_bt_($i)
"$file_name_bt_(1)_and_$file_name_bt_($i)" $post_dir "$val(title-bt_1),
$val(stat-bt_1)\\n$val(title-bt_$i), $val(stat-bt_$i)"
"$opt(scenario)\\n$opt(rp)-$opt(tcp_name)\\n$opt(traffic)" $opt(ylabel-bt)
$opt(xlabel-bt) $opt(xformat) $opt(yformat)
               useGnuplot $file_name_pkt_(1) $file_name_pkt_($i)
"$file_name_pkt_(1)_and_$file_name_pkt_($i)" $post_dir "$val(title-pkt_1),
$val(stat-pkt_1)\\n$val(title-pkt_$i), $val(stat-pkt_$i)"
"$opt(scenario)\\n$opt(rp)-$opt(tcp_name)\\n$opt(traffic)" $opt(ylabel-pkt)
$opt(xlabel-pkt) $opt(xformat) $opt(yformat)
               useGnuplot $file_name_bt_gp(1) $file_name_bt_gp($i)
"$file_name_bt_gp(1)_and_$file_name_bt_gp($i)" $post_dir "$val(title-bt_1),
$val(stat-btgp_1)\\n$val(title-bt_$i), $val(stat-btgp_$i)"
"$opt(scenario)\\n$opt(rp)-$opt(tcp_name)\\n$opt(traffic)" $opt(ylabel-
btgp) $opt(xlabel-btgp) $opt(xformat) $opt(yformat)
               useGnuplot $file_name_pkt_gp(1) $file_name_pkt_gp($i)
"$file_name_pkt_gp(1)_and_$file_name_pkt_gp($i)" $post_dir "$val(title-
pkt_1), $val(stat-pktgp_1)\\n$val(title-pkt_$i), $val(stat-pktgp_$i)"
"$opt(scenario)\\n$opt(rp)-$opt(tcp_name)\\n$opt(traffic)" $opt(ylabel-
pktgp) $opt(xlabel-pktgp) $opt(xformat) $opt(yformat)
           }

           if { $opt(afterburner) != -1 } {
           append flow "-FLOW-$i-------------------------------------------
---\n" \
                      "Flowid_$i=$val(flowid-$i)\n" \
                      "Nodeid_src_$i=$val(nodeid_src-$i)\n" \
                   "Nodeid_dst_$i=$val(nodeid_dst-$i)\n" \
                      "Start_$i=$opt(start-src$i)\n" \
                      "Stop_$i=$opt(start-src$i)\n" \
                   "Throughput_byte_filename_$i=$file_name_bt_($i)\n" \
                      "Throughput_byte_title_$i=$val(title-bt_$i)\n" \
                      "Throughput_byte_ylabel_$i=$opt(ylabel-bt)\n" \
                      "Throughput_byte_xlabel_$i=$opt(xlabel-bt)\n" \
                      "Throughput_byte_stat_$i=$val(stat-bt_$i)\n" \
                      "Goodput_byte_filename_$i=$file_name_bt_gp($i)\n" \
                      "Goodput_byte_title_$i=$val(title-bt_$i)\n" \
                      "Goodput_byte_ylabel_$i=$opt(ylabel-btgp)\n" \
                      "Goodput_byte_xlabel_$i=$opt(xlabel-btgp)\n" \
                      "Goodput_byte_stat_$i=$val(stat-btgp_$i)\n" \
                      "Throughput_pkt_filename_$i=$file_name_pkt_($i)\n" \
                      "Throughput_pkt_title_$i=$val(title-pkt_$i)\n" \
                      "Throughput_pkt_ylabel_$i=$opt(ylabel-pkt)\n" \
                      "Throughput_pkt_xlabel_$i=$opt(xlabel-pkt)\n" \
                      "Throughput_pkt_stat_$i=$val(stat-pkt_$i)\n" \
                      "Goodput_pkt_filename_$i=$file_name_pkt_gp($i)\n" \
                      "Goodput_pkt_title_$i=$val(title-pkt_$i)\n" \
                      "Goodput_pkt_ylabel_$i=$opt(ylabel-pktgp)\n" \
                      "Goodput_pkt_xlabel_$i=$opt(xlabel-pktgp)\n" \
                      "Goodput_pkt_stat_$i=$val(stat-pktgp_$i)\n" \
                      "Window_filename_$i=$file_name_($i)\n" \
                      "Window_title_$i=$val(title-bt_$i)\n" \
                      "Window_ylabel_$i=$opt(ylabel-win)\n" \
                      "Window_xlabel_$i=$opt(xlabel-win)\n" \
                      "Window_stat_$i=$val(stat-win_$i)\n" \
                      "-END-FLOW-$i----------------------------------------
---\n"
           }

}

   if { $opt(afterburner) != -1 } {
    set afterburner [open "$trace_dir/$opt(afterburner)" w]
    set afterpost_dir [string range $post_dir [expr ([string last "/"
$post_dir] + 1)] end]

    append header "-HEADER------------------------------------------------
\n" \
                      "Dir=$trace_dir\n" \
                      "Time=$opt(stop)\n" \
                      "Outdir=$afterpost_dir\n" \
                      "Window_tracefile=$filename1.win\n" \
                      "Throughput_byte_tracefile=$filename1.bt\n" \
                      "Throughput_pkt_tracefile=$filename1.pkt\n" \
                      "Goodput_pkt_tracefile=$filename1.pkt\n" \
                      "Goodput_byte_tracefile=$filename1.bt\n" \
                      "Scenario=$opt(scenario)\n" \
                      "Traffic=$opt(traffic)\n" \
                      "Rp=$opt(rp)\n" \
                      "Tcp=$opt(tcp_name)\n" \
                      "Xformat=$opt(xformat)\n" \
                      "Yformat=$opt(yformat)\n" \
                      "Throughput_byte_stat_agg=$val(stat-bt_agg)\n" \
                      "Throughput_pkt_stat_agg=$val(stat-pkt_agg)\n" \
                      "Goodput_pkt_stat_agg=$val(stat-pktgp_agg)\n" \
                      "Goodput_byte_stat_agg=$val(stat-btgp_agg)\n" \
                      "Window_stat_agg=$val(stat-win_agg)\n" \
                      "Fairness_stat=$val(stat-fair)\n" \
                      "Nr_Flows=$val(nr-flows)\n" \
                      "-END-HEADER-----------------------------------------
---\n"

    append out $header $flow
    puts $afterburner $out
    flush $afterburner
    close $afterburner
    }
    for { set i 1 } { $i <= $val(nr-flows) } { incr i } {
               exec rm -f "$post_dir/$file_name_bt_($i)"
               exec rm -f "$post_dir/$file_name_pkt_($i)"
               exec rm -f "$post_dir/$file_name_bt_gp($i)"
               exec rm -f "$post_dir/$file_name_pkt_gp($i)"
               exec rm -f "$post_dir/$file_name_($i)"
           }
}


#-----------Plotting---------------------------------------------------#
# ====================================================================
# Draw the Graphs Gnuplot way
# ====================================================================
proc useGnuplot { infile1 infile2 outfile dir Title label ylabel xlabel
yformat xformat } {
    set old_dir [pwd]
    cd $dir
    set gnuplot_cmd "$outfile.cmd"
    exec rm -f $gnuplot_cmd

    set gnuplot_cmd_file [open "$gnuplot_cmd" w]
    puts $gnuplot_cmd_file "set terminal png enhanced size 1024,768"
    puts $gnuplot_cmd_file "set output \"$outfile.png\""
    puts $gnuplot_cmd_file "set xlabel \"$xlabel\""
    puts $gnuplot_cmd_file "set ylabel \"$ylabel\""
    puts $gnuplot_cmd_file "set label  \"Simulation Info\\n-----------
\\n$label\" at screen 0.92,0.3 center rotate"
    puts $gnuplot_cmd_file "set format x \"$xformat\""
    puts $gnuplot_cmd_file "set format y \"$yformat\""
    puts $gnuplot_cmd_file "set yrange \[*:*\]"
    puts $gnuplot_cmd_file "set xrange \[*:*\]"
    puts $gnuplot_cmd_file "set grid"
    puts $gnuplot_cmd_file "set key right outside title \"Legend\\n--------
\""
    puts $gnuplot_cmd_file "set title \"$Title\""

    if { $infile2 == "" } {
           puts $gnuplot_cmd_file "plot \"$infile1\" title \" $infile1\"
with linespoints"
    } else {
           puts $gnuplot_cmd_file "plot \"$infile1\" title \" $infile1\"
with linespoints, \"$infile2\" title \" $infile2\" with linespoints"
    }

    flush $gnuplot_cmd_file
    close $gnuplot_cmd_file
    set status 0
    catch {
           exec gnuplot $gnuplot_cmd
           }

    exec rm -f $gnuplot_cmd
    cd $old_dir
}

# ====================================================================
# Draw the graphs Xgraph way
# ====================================================================
proc useXgraph { infile1 infile2 outfile dir Title label ylabel xlabel
yformat xformat } {
    set old_dir [pwd]
    cd $dir
    if { $infile2 == "" } {
    exec xgraph -device ps -M -nb \
           -fmtx "$xformat" -fmty "  $yformat" -x $xlabel -y $ylabel \
           -t "$Title $label" \
           -O $outfile.ps \
           $infile1
    } else {
    exec xgraph -device ps -M -nb \
           -fmtx "%d Sec" -fmty "  %d" -x $xlabel -y $ylabel \
           -t "$Title $label" \
           -O $outfile.ps \
           $infile1 $infile2
    }

    exec ps2pdf $outfile.ps $outfile.pdf

    if { $infile2 == "" } {
```

```
    exec xgraph -device ps -M -nb \
           -fmtx "$xformat" -fmty "  $yformat" -x $xlabel -y $ylabel \
           -t "$Title $label" \
           -o $outfile.eps \
           $infile1
    } else {
    exec xgraph -device ps -M -nb \
           -fmtx "%d Sec" -fmty "  %d" -x $xlabel -y $ylabel \
           -t "$Title $label" \
           -o $outfile.eps \
           $infile1 $infile2
    }
    cd $old_dir
}


main
```

## D.2 Simulation runner

This script “runs”, give the correct command line options the main script and later call postprocessing script ….

```
for ($x = 0; $x <= $#ARGV;$x++) {
        last if $ARGV[$x]=~/-/;
           if ($ARGV[$x]=~/[0-9]|all/i) {
                      push(@whatsim,$ARGV[$x]);
                      }
}

$extra= join (" ", @ARGV[$x .. $#ARGV]);



$extra = $extra." -afterburner ab.txt\n";
system("rm -f ab.txt");


@traffic = (          "1-tcp-from-node-0",
                      "2-tcp-from-node-0-node-4-simultaneous",
                      "1-tcp-from-node-0-1-tcp-between-node-4-node-0",
                      "2-tcp-from-node-0-node-4",
                      "2-tcp-from-node-0-node-5-simultaneous",
                      "1-tcp-from-node-5",
                      "2-tcp-from-node-0-node-5",
                      "1-tcp-between-node-5-node-0");

@tcp = (   "Newreno",
                      "Vegas",
                      "Newreno-AP");

@scenario =(          "chain5",
                      "grid7x7",
                      "rand48",
                      "chain51");
```

```
@rp =(                  "AODVUU",
                        "DSDV");


for ($traffici = 4; $traffici <= $#traffic ; $traffici++)  {

           for ($rpi = 0; $rpi <= $#rp ; $rpi++)             {

                      for ($tcpi = 0; $tcpi <= $#tcp; $tcpi++){
                                 ($tcp_name,$tcp_ext) = split('-
',$tcp[$tcpi]);
                                 if ($tcp_ext eq ""){
                                               $tcp_ext = "none";
                                 }
                                 push(@sim,"ns main.tcl -scenario
$scenario[3] -traffic $traffic[$traffici] -rp $rp[$rpi] -tcp_name $tcp_name
-tcp_ext $tcp_ext $extra");
                      }
           }
}


for ($scenarioi = 0; $scenarioi < 3; $scenarioi++){
           for ($traffici = 0; $traffici < 4; $traffici++)  {

                      for ($rpi = 0; $rpi <= $#rp; $rpi++)             {

                                 for ($tcpi = 0; $tcpi <= $#tcp; $tcpi++){
                                            ($tcp_name,$tcp_ext) = split('-
',$tcp[$tcpi]);
                                            if ($tcp_ext eq "") {
                                                $tcp_ext = "none";
                                            }
                                            push(@sim,"ns main.tcl -scenario
$scenario[$scenarioi] -traffic $traffic[$traffici] -rp $rp[$rpi] -tcp_name
$tcp_name -tcp_ext $tcp_ext $extra\n");
                                 }
                      }
           }
}


if ($whatsim[0]=~/all/i) {
           foreach $cmd (@sim) {
           $i++;
           print "\nSimulation $i:\n$cmd";
           system("$cmd");
           }
} else {
           foreach $nr (@whatsim) {
                      print "\nSimulation $nr:\n$sim[$nr-1]";
                      system("$sim[$nr-1]");
           }
}

system ("perl afterburner.pl ab.txt");
```

## D.3 Postprocess

This script**, afterburner.pl**, parses the different simulation output files and statistic files and produce via gnuplot graphs.

```
$file=$ARGV[0];
#             scen , traf, rp  , tcp , mode = [THR-BYTE, GP-BYTE, GP-PKT,
CWND ], legend = TCP

@traffic = (          "1-tcp-from-node-0",
                      "2-tcp-from-node-0-node-4-simultaneous",
                      "1-tcp-from-node-0-1-tcp-between-node-4-node-0",
                      "2-tcp-from-node-0-node-4",
                      "2-tcp-from-node-0-node-5-simultaneous",
                      "1-tcp-from-node-5",
                      "2-tcp-from-node-0-node-5",
                      "1-tcp-between-node-5-node-0");

@tcp = (   "Newreno",
                      "Vegas",
                      "Newreno-AP");

@scenario =(          "chain5",
                      "grid7x7",
                      "rand48",
                      "chain51");

@rp =(                "AODVUU",
                      "DSDV");


@mode  = ( "THR-BYTE", "CWND", "GP-BYTE" );


open (DATA,"<$file") || die "Can't open $file $!";

$myhash;

while (chomp($_=<DATA>)) {
    push (@ab_files,$_);
}
close DATA;

$Nr_of_files = 0;

foreach (@ab_files) {
    open (DATA,"<$_") || die "Can't open $_ $!";

    while (chomp($_=<DATA>)) {
           if (!/^\-/) { ;#Skips the comments
           @line = split('=');
           $myhash { $line[0] } = $line[1];
           }
    }

    $tempdir = $myhash{'Dir'}."/".$myhash{'Outdir'}."/";
#    $myhash{'Nr_Flows'} = 1;
    for ($i = 1;$i <= $myhash{'Nr_Flows'};$i++) {

               $Nr_of_files++;
```

```
		#Actually a static for all $i but for convenice i load them
in all
		#-HEADER---------------------------------------------
		push (@NR_FLOWS,$myhash{'Nr_flows'});
		push (@SCENARIO,$myhash{'Scenario'});
		push (@TRAFFIC,$myhash{'Traffic'});
		push (@RP,$myhash{'Rp'});
		push (@TCP,$myhash{'Tcp'});
		push (@THR_BYTE_STAT_AGG,$myhash
{'Throughput_byte_stat_agg'});
		push (@THR_PKT_STAT_AGG,$myhash
{'Throughput_pkt_stat_agg'});
		push (@GP_BYTE_STAT_AGG,$myhash {'Goodput_byte_stat_agg'});
		push (@GP_PKT_STAT_AGG,$myhash {'Goodput_pkt_stat_agg'});
		push (@THR_BYTE_TRACEFILE,$myhash
{'Throughput_byte_tracefile'});
		push (@GP_BYTE_TRACEFILE,$myhash
{'Goodput_byte_tracefile'});
		push (@THR_PKT_TRACEFILE,$myhash
{'Throughput_pkt_tracefile'});
		push (@GP_PKT_TRACEFILE,$myhash {'Goodput_pkt_tracefile'});
		push (@WINDOW_TRACEFILE,$myhash {'Window_tracefile'});
		push (@WINDOW_STAT_AGG,$myhash {'Window_stat_agg'});
		push (@FAIR_STAT_AVG,$myhash{"Fairness_stat"});
		push (@DIR,$myhash{'Dir'});
		push (@COMPLETE_OUTDIR,$tempdir);
		push (@OUTDIR,$myhash{'Outdir'});
		push (@YFORMAT,$myhash{'Yformat'});
		push (@XFORMAT,$myhash{'Xformat'});
		#-END-HEADER-----------------------------------------
		#Here comes the ones that actually change
		#-FLOW-$i--------------------------------------------
		push (@FLOW_ID,$myhash{"Flowid_$i"});
		push (@NODEID_SRC,$myhash{"Nodeid_src_$i"});
		push (@NODEID_DST,$myhash{"Nodeid_dst_$i"});
		push
(@THR_BYTE_FILENAME,$tempdir.$myhash{"Throughput_byte_filename_$i"});
		push (@THR_BYTE_TITLE,$myhash{"Throughput_byte_title_$i"});
		push
(@THR_BYTE_YLABEL,$myhash{"Throughput_byte_ylabel_$i"});
		push
(@THR_BYTE_XLABEL,$myhash{"Throughput_byte_xlabel_$i"});
		push (@THR_BYTE_STAT,$myhash{"Throughput_byte_stat_$i"});
		push
(@THR_PKT_FILENAME,$tempdir.$myhash{"Throughput_pkt_filename_$i"});
		push (@THR_PKT_TITLE,$myhash{"Throughput_pkt_title_$i"});
		push (@THR_PKT_YLABEL,$myhash{"Throughput_pkt_ylabel_$i"});
		push (@THR_PKT_XLABEL,$myhash{"Throughput_pkt_xlabel_$i"});
		push (@THR_PKT_STAT,$myhash{"Throughput_pkt_stat_$i"});
		push
(@GP_PKT_FILENAME,$tempdir.$myhash{"Goodput_pkt_filename_$i"});
		push (@GP_PKT_TITLE,$myhash{"Goodput_pkt_title_$i"});
		push (@GP_PKT_YLABEL,$myhash{"Goodput_pkt_ylabel_$i"});
		push (@GP_PKT_XLABEL,$myhash{"Goodput_pkt_xlabel_$i"});
		push (@GP_PKT_STAT,$myhash{"Goodput_pkt_stat_$i"});
		push
(@GP_BYTE_FILENAME,$tempdir.$myhash{"Goodput_byte_filename_$i"});
		push (@GP_BYTE_TITLE,$myhash{"Goodput_byte_title_$i"});
		push (@GP_BYTE_YLABEL,$myhash{"Goodput_byte_ylabel_$i"});
		push (@GP_BYTE_XLABEL,$myhash{"Goodput_byte_xlabel_$i"});
		push (@GP_BYTE_STAT,$myhash{"Goodput_byte_stat_$i"});
```

```
               push
(@WINDOW_FILENAME,$tempdir.$myhash{"Window_filename_$i"});
               push (@WINDOW_TITLE,$myhash{"Window_title_$i"});
               push (@WINDOW_YLABEL,$myhash{"Window_ylabel_$i"});
               push (@WINDOW_XLABEL,$myhash{"Window_xlabel_$i"});
               push (@WINDOW_STAT,$myhash{"Window_stat_$i"});
               #-END-FLOW-$i-------------------------------------------

    }
    close DATA;
}

for ($x=0;$x < $Nr_of_files;$x++) {
           system("perl postprocess.pl $THR_BYTE_TRACEFILE[$x] $FLOW_ID[$x]
Throughput > $THR_BYTE_FILENAME[$x]");
           system("perl postprocess.pl $THR_PKT_TRACEFILE[$x] $FLOW_ID[$x]
Throughput > $THR_PKT_FILENAME[$x]");
           system("perl postprocess.pl $GP_BYTE_TRACEFILE[$x] $FLOW_ID[$x]
Goodput > $GP_BYTE_FILENAME[$x]");
           system("perl postprocess.pl $GP_PKT_TRACEFILE[$x] $FLOW_ID[$x]
Goodput > $GP_PKT_FILENAME[$x]");
           system("perl postprocess.pl $WINDOW_TRACEFILE[$x]
$NODEID_SRC[$x] Window > $WINDOW_FILENAME[$x]");
}


           for ($traffici = 4; $traffici <= $#traffic; $traffici++)  {

                      for ($rpi = 0; $rpi <= $#rp; $rpi++)             {

                                 for ($i = 0; $i < 3; $i++){

&plotData($scenario[3],$traffic[$traffici],$rp[$rpi],"all", $mode[$i]);
                                 }
                      }
           }

for ($scenarioi = 0; $scenarioi < 3; $scenarioi++){
           for ($traffici = 0; $traffici <= $#traffic; $traffici++)  {

                      for ($rpi = 0; $rpi <= $#rp; $rpi++)             {

                                 for ($i = 0; $i < 3; $i++){

           &plotData($scenario[$scenarioi],$traffic[$traffici],$rp[$rpi],"a
ll", $mode[$i]);
                                 }
                      }
           }
}


exit(0);


####################################Sub routines
########################################
sub plotData {
#This is very ugly but so are perls subroutines/parameters
    my $mode = pop(@_);
    my ($scenario_file, $traffic_file, $routing, $tcp_version) = @_;
    my @temp = @_;
    my $Label = "";
    my $Title ="";
    my $Ylabel = "";
    my $Xlabel = "";
    my $Yformat = "";
    my $Xformat = "";
    my $Outfile = "$mode--Scenario-".$scenario_file."--Traffic-
".$traffic_file."--Routing-".$routing."--Tcp-".$tcp_version;
    my @files = ();
    my $iterate_legend = "";
    my @iterate_title;
    my @iterate_ylabel;
    my @iterate_xlabel;
    my @iterate_stat;
    my @iterate_filename;
    my @test = (0,0,0,0);
    my $count = 0;

    # here i am iterating over @_ if it is not clear ;-)
    for ($x = 0; $x <= $#temp; $x++) {
               $_ = $temp[$x];
               if ($x == 0) {
                      if($_ ne "all") {
                          $Label = $Label."Scenario file: ".$_."\\n";
                       } else {
                               $test[0] = 1;
                       }
               } elsif ($x == 1) {
                      if($_ ne "all") {
                          $Label = $Label."Traffic file: ".$_."\\n";
                       } else {
                               $test[1] = 1;
                       }
               } elsif ($x == 2 ){
                      if($_ ne "all") {
                          $Label = $Label."Routing protocol: ".$_."\\n";
                       } else {
                               $test[2] = 1;
                       }
               } elsif ($x == 3 ){
                      if($_ ne "all") {
                          $Label = $Label."TCP version: ".$_."\\n";
                       } else {
                               $test[3] = 1;
                       }
               }

     }

    if($Label eq "") {
               $Label = "Using all with all\\n";
    }

    if ($mode eq "THR-BYTE") {
           @iterate_title = @THR_BYTE_TITLE;
           @iterate_ylabel = @THR_BYTE_YLABEL;
           @iterate_xlabel = @THR_BYTE_XLABEL;
           @iterate_stat = @THR_BYTE_STAT;
           @iterate_filename = @THR_BYTE_FILENAME;
    } elsif ($mode eq "CWND") {
           @iterate_title = @WINDOW_TITLE;
           @iterate_ylabel = @WINDOW_YLABEL;
           @iterate_xlabel = @WINDOW_XLABEL;
           @iterate_stat = @WINDOW_STAT;
           @iterate_filename = @WINDOW_FILENAME;
    } elsif ($mode eq "GP-BYTE") {
           @iterate_title = @GP_BYTE_TITLE;
           @iterate_ylabel = @GP_BYTE_YLABEL;
           @iterate_xlabel = @GP_BYTE_XLABEL;
           @iterate_stat = @GP_BYTE_STAT;
           @iterate_filename = @GP_BYTE_FILENAME;
    }

    for ($x=0;$x < $Nr_of_files;$x++) {
           if ($routing=~/^$RP[$x]$|all/ && $tcp_version=~/^$TCP[$x]$|all/
&& $scenario_file=~/^$SCENARIO[$x]$|all/ &&
$traffic_file=~/^$TRAFFIC[$x]$|all/){
#         print "---------------\nX = $x\nRP = $RP[$x]\nTCP =
$TCP[$x]\nSCENARIO = $SCENARIO[$x]\nTRAFFIC =
$TRAFFIC[$x]\nTITLE=$iterate_title[$x]\nYLABEL =
$iterate_ylabel[$x]\nXLABEL = $iterate_xlabel[$x]\nSTAT =
$iterate_stat[$x]\nFILENAME = $iterate_filename[$x]\nXFORMAT
=$XFORMAT[$x]\nYFORMAT=$YFORMAT[$x]\n--------------\n";
           #---------------Legend( file titles) and filename---------------
-------------#
               $count++;
#             print "$test[0] , $test[1] , $test[2], $test[3]\n";
               if ($test[0] == 1) { ;#scenario
                      $iterate_legend = $iterate_legend.$SCENARIO[$x].".";
               }
               if ($test[1] == 1) { ;#traffic
                      $iterate_legend = $iterate_legend.$TRAFFIC[$x].".";
               }
               if ($test[2] == 1) { ;#rp
                      $iterate_legend = $iterate_legend.$RP[$x].".";
               }
               if ($test[3] == 1) { ;#tcp
                      $iterate_legend = $iterate_legend.$TCP[$x].".";
               }
               $iterate_legend = $iterate_legend."($FLOW_ID[$x])";

push(@files,"$iterate_filename[$x]:($count)$iterate_legend");
               $iterate_legend = "";
           #----------------------End files and legend--------------------#


               if ($Title!~/$iterate_title[$x]/) {
                          $Title = $Title.$iterate_title[$x]."\\n";
               }

               if ($Yformat!~/$YFORMAT[$x]/) {
                          $Yformat = $Yformat.$YFORMAT[$x]." ";
               }
               if ($Xformat!~/$XFORMAT[$x]/) {
                          $Xformat = $Xformat.$XFORMAT[$x]." ";
               }
               if ($Ylabel!~/$iterate_ylabel[$x]/) {
                          $Ylabel = $Ylabel.$iterate_ylabel[$x]."\\n";
               }
               if ($Xlabel!~/$iterate_xlabel[$x]/) {
                          $Xlabel = $Xlabel.$iterate_xlabel[$x]."\\n";
```

```
                }
            }

    }

    if ( scalar($#files) != -1) {
            &useGnuplot(\@files, $Outfile , $Title, $Label, $Ylabel,
$Xlabel, $Yformat, $Xformat);
    }

}



sub useGnuplot {
     #my @infiles = @$shift(@_);
     my ($refinfiles, $outfile, $Title, $label1, $ylabel, $xlabel,
$yformat, $xformat) = @_; my @infiles = @$refinfiles;

    my $gnuplot_cmd =  "Banner-9100x768-$outfile.cmd";
    open (GNUPLOT_CMD_FILE,">$gnuplot_cmd") || die "Can't open $file $!";

    my $out = "set terminal png enhanced size 9100,768\n".
               "set output \"Banner-9100x768-$outfile.png\"\n".
               "set xlabel \"$xlabel\"\n".
               "set ylabel \"$ylabel\"\n".
               "set label  \"Simulation Info\\n---------------\\n$label1\"
at screen 0.99,0.3 center rotate\n".
#              "set label  \"Flow Info\\n---------\\n$label2\" at screen
0.98,0.45 left rotate\n".
               "set format x \"$xformat\"\n".
               "set format y \"$yformat\"\n".
               "set yrange \[*:*\]\n".
               "set xrange \[*:*\]\n".
               "set xtics 25\n".
               "set mxtics 25\n".
               "set mytics 5\n".
               "set grid mxtics linewidth 0.5\n".
               "set grid xtics \n".
               "set grid ytics linewidth 0.5\n".
               "set grid ytics \n".
               "set grid\n".
               "set key right outside title \"Legend\\n(nr) -- (id)\"\n".
               "set title \"$Title\"\n";

    $out = $out."plot";
    for ($x = 0; $x <= $#infiles;$x++) {
           my ($file,$title) = split(':', $infiles[$x]);
           if ($x < $#infiles) {
               $out = $out." \"$file\" title \" $title\" with
linespoints,";
           } else {
               $out = $out." \"$file\" title \" $title\" with
linespoints\n";
           }
    }

    print GNUPLOT_CMD_FILE $out;
    close GNUPLOT_CMD_FILE;
    #print $out;
    system("gnuplot $gnuplot_cmd;rm -f $gnuplot_cmd");
```

```
#Start
    my $gnuplot_cmd =  "1024x768-Start-$outfile.cmd";
    open (GNUPLOT_CMD_FILE,">$gnuplot_cmd") || die "Can't open $file $!";

    my $out = "set terminal png enhanced size 1024,768\n".
               "set output \"1024x768-Start-$outfile.png\"\n".
               "set xlabel \"$xlabel\"\n".
               "set ylabel \"$ylabel\"\n".
               "set label  \"Simulation Info\\n---------------\\n$label1\"
at screen 0.925,0.3 center rotate\n".
#              "set label  \"Flow Info\\n---------\\n$label2\" at screen
0.925,0.45 left rotate\n".
               "set format x \"$xformat\"\n".
               "set format y \"$yformat\"\n".
               "set yrange \[*:*\]\n".
               "set xrange \[0:300\]\n".
               "set grid\n".
               "set key right outside title \"Legend\\n(nr) -- (id)\"\n".
               "set title \"$Title\"\n";

    $out = $out."plot";
    for ($x = 0; $x <= $#infiles;$x++) {
           my ($file,$title) = split(':', $infiles[$x]);
           if ($x < $#infiles) {
               $out = $out." \"$file\" title \" $title\" with lines,";
           } else {
               $out = $out." \"$file\" title \" $title\" with lines\n";
           }
    }

    print GNUPLOT_CMD_FILE $out;
    close GNUPLOT_CMD_FILE;
    #print $out;
    system("gnuplot $gnuplot_cmd;rm -f $gnuplot_cmd");
#Middle
    my $gnuplot_cmd =  "1024x768-Middle-$outfile.cmd";
    open (GNUPLOT_CMD_FILE,">$gnuplot_cmd") || die "Can't open $file $!";

    my $out = "set terminal png enhanced size 1024,768\n".
               "set output \"1024x768-Middle-$outfile.png\"\n".
               "set xlabel \"$xlabel\"\n".
               "set ylabel \"$ylabel\"\n".
               "set label  \"Simulation Info\\n---------------\\n$label1\"
at screen 0.925,0.3 center rotate\n".
#              "set label  \"Flow Info\\n---------\\n$label2\" at screen
0.925,0.45 left rotate\n".
               "set format x \"$xformat\"\n".
               "set format y \"$yformat\"\n".
               "set yrange \[*:*\]\n".
               "set xrange \[300:600\]\n".
               "set grid\n".
               "set key right outside title \"Legend\\n(nr) -- (id)\"\n".
               "set title \"$Title\"\n";

    $out = $out."plot";
    for ($x = 0; $x <= $#infiles;$x++) {
           my ($file,$title) = split(':', $infiles[$x]);
           if ($x < $#infiles) {
               $out = $out." \"$file\" title \" $title\" with lines,";
           } else {
               $out = $out." \"$file\" title \" $title\" with lines\n";
```

```
            }
        }

        print GNUPLOT_CMD_FILE $out;
        close GNUPLOT_CMD_FILE;
        #print $out;
        system("gnuplot $gnuplot_cmd;rm -f $gnuplot_cmd");
#End
        my $gnuplot_cmd =  "1024x768-End-$outfile.cmd";
        open (GNUPLOT_CMD_FILE,">$gnuplot_cmd") || die "Can't open $file $!";

        my $out = "set terminal png enhanced size 1024,768\n".
                   "set output \"1024x768-End-$outfile.png\"\n".
                   "set xlabel \"$xlabel\"\n".
                   "set ylabel \"$ylabel\"\n".
                   "set label  \"Simulation Info\\n---------------\\n$label1\"
at screen 0.925,0.3 center rotate\n".
#                  "set label  \"Flow Info\\n---------\\n$label2\" at screen
0.925,0.45 left rotate\n".
                   "set format x \"$xformat\"\n".
                   "set format y \"$yformat\"\n".
                   "set yrange \[*:*\]\n".
                   "set xrange \[600:900\]\n".
                   "set grid\n".
                   "set key right outside title \"Legend\\n(nr) -- (id)\"\n".
                   "set title \"$Title\"\n";

        $out = $out."plot";
        for ($x = 0; $x <= $#infiles;$x++) {
               my ($file,$title) = split(':', $infiles[$x]);
               if ($x < $#infiles) {
                   $out = $out." \"$file\" title \" $title\" with lines,";
               } else {
                   $out = $out." \"$file\" title \" $title\" with lines\n";
               }
        }

        print GNUPLOT_CMD_FILE $out;
        close GNUPLOT_CMD_FILE;
        #print $out;
        system("gnuplot $gnuplot_cmd;rm -f $gnuplot_cmd");
#intersect

        my $gnuplot_cmd =  "1024x768-Intersect-$outfile.cmd";
        open (GNUPLOT_CMD_FILE,">$gnuplot_cmd") || die "Can't open $file $!";

        my $out = "set terminal png enhanced size 1024,768\n".
                   "set output \"1024x768-Intersect-$outfile.png\"\n".
                   "set xlabel \"$xlabel\"\n".
                   "set ylabel \"$ylabel\"\n".
                   "set label  \"Simulation Info\\n---------------\\n$label1\"
at screen 0.925,0.3 center rotate\n".
#                  "set label  \"Flow Info\\n---------\\n$label2\" at screen
0.925,0.45 left rotate\n".
                   "set format x \"$xformat\"\n".
                   "set format y \"$yformat\"\n".
                   "set yrange \[*:*\]\n".
                   "set xrange \[150:550\]\n".
                   "set grid\n".
                   "set key right outside title \"Legend\\n(nr) -- (id)\"\n".
                   "set title \"$Title\"\n";
```

```
    $out = $out."plot";
    for ($x = 0; $x <= $#infiles;$x++) {
           my ($file,$title) = split(':', $infiles[$x]);
           if ($x < $#infiles) {
               $out = $out." \"$file\" title \" $title\" with lines,";
           } else {
               $out = $out." \"$file\" title \" $title\" with lines\n";
           }
    }

    print GNUPLOT_CMD_FILE $out;
    close GNUPLOT_CMD_FILE;
    #print $out;
    system("gnuplot $gnuplot_cmd;rm -f $gnuplot_cmd");

    my $gnuplot_cmd =  "1024x768-All-$outfile.cmd";
    open (GNUPLOT_CMD_FILE,">$gnuplot_cmd") || die "Can't open $file $!";

    my $out = "set terminal png enhanced size 1024,768\n".
               "set output \"1024x768-All-$outfile.png\"\n".
               "set xlabel \"$xlabel\"\n".
               "set ylabel \"$ylabel\"\n".
               "set label  \"Simulation Info\\n---------------\\n$label1\"
at screen 0.925,0.3 center rotate\n".
#              "set label  \"Flow Info\\n---------\\n$label2\" at screen
0.925,0.45 left rotate\n".
               "set format x \"$xformat\"\n".
               "set format y \"$yformat\"\n".
               "set yrange \[*:*\]\n".
               "set xrange \[*:*\]\n".
               "set grid\n".
               "set key right outside title \"Legend\\n(nr) -- (id)\"\n".
               "set title \"$Title\"\n";

    $out = $out."plot";
    for ($x = 0; $x <= $#infiles;$x++) {
           my ($file,$title) = split(':', $infiles[$x]);
           if ($x < $#infiles) {
               $out = $out." \"$file\" title \" $title\" with lines,";
           } else {
               $out = $out." \"$file\" title \" $title\" with lines\n";
           }
    }

    print GNUPLOT_CMD_FILE $out;
    close GNUPLOT_CMD_FILE;
    #print $out;
    system("gnuplot $gnuplot_cmd;rm -f $gnuplot_cmd");

    my $gnuplot_cmd =  "640x480-mini-$outfile.cmd";
    open (GNUPLOT_CMD_FILE,">$gnuplot_cmd") || die "Can't open $file $!";

    my $out = "set terminal png enhanced size 640,480\n".
               "set output \"640x480-mini-$outfile.png\"\n".
               "set xlabel \"$xlabel\"\n".
               "set ylabel \"$ylabel\"\n".
#              "set label  \"Simulation Info\\n---------------\\n$label1\"
at screen 0.925,0.3 center rotate\n".
#              "set label  \"Flow Info\\n---------\\n$label2\" at screen
0.925,0.45 left rotate\n".
```

```
                "set format x \"$xformat\"\n".
                "set format y \"$yformat\"\n".
                "set yrange \[*:*\]\n".
                "set xrange \[*:*\]\n".
                "set grid\n".
                "set key right outside title \"Legend\\n(nr) -- (id)\"\n".
                "set title \"$Title\"\n";

    $out = $out."plot";
    for ($x = 0; $x <= $#infiles;$x++) {
           my ($file,$title) = split(':', $infiles[$x]);
           if ($x < $#infiles) {
               $out = $out." \"$file\" title \" $title\" with lines,";
           } else {
               $out = $out." \"$file\" title \" $title\" with lines\n";
           }
    }

    print GNUPLOT_CMD_FILE $out;
    close GNUPLOT_CMD_FILE;
    #print $out;
    system("gnuplot $gnuplot_cmd;rm -f $gnuplot_cmd");


}
```

This script**, hops.pl**, parses the tracefile from simulation with Mobilitty Scenarion Chain5+1 and calculates how the number of hops to the gateway, change over time.

```
  $infile=$ARGV[0];
  $nodenum = $ARGV[1] + 1;
  $node="_". $nodenum."_";

  open (DATA,"<$infile") || die "Can't open $infile $!";
  $oldvalue=-1;
  $oldtime = -1;
  print "Sender Start Stop Difference Nrhops\n";
  while (<DATA>)
  {
       @x = split(' ');

           #checking if protocol is RTR
           if ($x[3] eq 'RTR')
           {
                      #checking if the packet type is encap
                      if ($x[6] eq 'encap')
                      {
                      #checking if it is a forwarding
                      if ($x[0] eq 'f')
                      {
                      #checking if the sender corresponds to arg 1
                      if ($x[2] eq $node)
                      {
                      #checking if from it self
                                 if ($x[8] eq '[0' && $x[9] eq '0' &&
$x[10] eq '0' && $x[11] eq '0]')
                                 {
                                 $hops { $x[5] } = 0;
                                 $start { $x[5] } = $x[1];
                                 }
                      }
                      elsif (defined $hops { $x[5] })
```

```
                          {
                          $hops { $x[5] } = $hops { $x[5] } + 1;
                          }
               }
               elsif ($x[2] eq "_1_" && $x[0] eq 'r' && (defined $hops { $x[5]
}))
               {
               $hops { $x[5] } = $hops { $x[5] } + 1;
               $stop { $x[5] } = $x[1];
               $diff=($stop { $x[5] }) - ($start { $x[5] });
               printf("MN%d %f %f %f %d\n",
ARGV[1],($start{$x[5]}),($stop{$x[5]}),$diff,($hops{$x[5]}));
               }
               }
               }
   }
   close DATA;
   exit(0);
```

# E Traffic Files

## E.1 1-tcp-between-node-5-node-0

```
#Variables
set src(node-1)     $node_(0)
set dst(node-1)     $node_(5)


#Flow 1
set src(agt-1) [new Agent/$opt(tcp_version)]
set dst(agt-1) [new Agent/TCPSink]
$ns_ attach-agent $src(node-1) $src(agt-1)
$ns_ attach-agent $dst(node-1) $dst(agt-1)
$ns_ connect $src(agt-1) $dst(agt-1)

$src(agt-1) set fid_ 1
set ftp [new Application/FTP]
$ftp attach-agent $src(agt-1)
$ns_ at $opt(start-src1) "$ftp start"
$ns_ at $opt(stop-src1) "$ftp stop"
```

## E.2 1-tcp-from-node-0

```
#Variables
set src(node-1) $node_(0)
set dst(node-1) $host_(0)

#Flow 1
set src(agt-1) [new Agent/$opt(tcp_version)]
set dst(agt-1) [new Agent/TCPSink]
$ns_ attach-agent $src(node-1) $src(agt-1)
$ns_ attach-agent $dst(node-1) $dst(agt-1)
$ns_ connect $src(agt-1) $dst(agt-1)

$src(agt-1) set fid_ 1
set ftp [new Application/FTP]
$ftp attach-agent $src(agt-1)
$ns_ at $opt(start-src1) "$ftp start"
$ns_ at $opt(stop-src1) "$ftp stop"
```

## E.3 1-tcp-from-node-0-1-tcp-between-node-4-node-0

```
#Variables
set src(node-1)     $node_(0)
set dst(node-1)     $host_(0)
set src(node-2)     $node_(0)
set dst(node-2)     $node_(4)

set opt(start-src1)           $opt(flow-delay)
set opt(stop-src1)            [expr (($opt(stop)-$opt(flow-
delay))/2.0)]
set opt(start-src2)           [expr (($opt(stop)-$opt(flow-
delay))/4.0)]
set opt(stop-src2)            [expr ($opt(stop)-$opt(flow-delay))]


#Flow 1
set src(agt-1) [new Agent/$opt(tcp_version)]
set dst(agt-1) [new Agent/TCPSink]
$ns_ attach-agent $src(node-1) $src(agt-1)
$ns_ attach-agent $dst(node-1) $dst(agt-1)
$ns_ connect $src(agt-1) $dst(agt-1)

$src(agt-1) set fid_ 1
set ftp [new Application/FTP]
$ftp attach-agent $src(agt-1)
$ns_ at $opt(start-src1) "$ftp start"
$ns_ at $opt(stop-src1) "$ftp stop"

#Flow 2
set src(agt-2) [new Agent/$opt(tcp_version)]
set dst(agt-2) [new Agent/TCPSink]
$ns_ attach-agent $src(node-2) $src(agt-2)
$ns_ attach-agent $dst(node-2) $dst(agt-2)
$ns_ connect $src(agt-2) $dst(agt-2)

$src(agt-2) set fid_ 2
set ftp2 [new Application/FTP]
$ftp2 attach-agent $src(agt-2)
$ns_ at $opt(start-src2) "$ftp2 start"
$ns_ at $opt(stop-src2) "$ftp2 stop"
```

## E.4 1-tcp-from-node-5

```
#Variables
set src(node-1)     $node_(5)
set dst(node-1)     $host_(0)

#Flow 1
set src(agt-1) [new Agent/$opt(tcp_version)]
set dst(agt-1) [new Agent/TCPSink]
$ns_ attach-agent $src(node-1) $src(agt-1)
$ns_ attach-agent $dst(node-1) $dst(agt-1)
$ns_ connect $src(agt-1) $dst(agt-1)

$src(agt-1) set fid_ 1
set ftp [new Application/FTP]
$ftp attach-agent $src(agt-1)
```

```
$ns_ at $opt(start-src1) "$ftp start"
$ns_ at $opt(stop-src1) "$ftp stop"
```

## E.5 2-tcp-from-node-0-node-4

```
#Variables
set src(node-1)     $node_(0)
set dst(node-1)     $host_(0)

set src(node-2)     $node_(4)
set dst(node-2)     $host_(0)

set opt(start-src1)           $opt(flow-delay)
set opt(stop-src1)            [expr (($opt(stop)-$opt(flow-
delay))/2.0)]
set opt(start-src2)           [expr (($opt(stop)-$opt(flow-
delay))/4.0)]
set opt(stop-src2)            [expr ($opt(stop)-$opt(flow-delay))]

#Flow 1
set src(agt-1) [new Agent/$opt(tcp_version)]
set dst(agt-1) [new Agent/TCPSink]
$ns_ attach-agent $src(node-1) $src(agt-1)
$ns_ attach-agent $dst(node-1) $dst(agt-1)
$ns_ connect $src(agt-1) $dst(agt-1)

$src(agt-1) set fid_ 1
set ftp [new Application/FTP]
$ftp attach-agent $src(agt-1)
$ns_ at $opt(start-src1) "$ftp start"
$ns_ at $opt(stop-src1) "$ftp stop"

#Flow 2
set src(agt-2) [new Agent/$opt(tcp_version)]
set dst(agt-2) [new Agent/TCPSink]
$ns_ attach-agent $src(node-2) $src(agt-2)
$ns_ attach-agent $dst(node-2) $dst(agt-2)
$ns_ connect $src(agt-2) $dst(agt-2)

$src(agt-2) set fid_ 2
set ftp2 [new Application/FTP]
$ftp2 attach-agent $src(agt-2)
$ns_ at $opt(start-src2) "$ftp2 start"
$ns_ at $opt(stop-src2) "$ftp2 stop"
```

## E.6 2-tcp-from-node-0-node-4-simultaneous

```
#Variables
set src(node-1)     $node_(0)
set dst(node-1)     $host_(0)
set src(node-2)     $node_(4)
set dst(node-2)     $host_(0)

set opt(start-src1)           $opt(flow-delay)
set opt(stop-src1)            [expr ($opt(stop)-$opt(flow-delay))]
set opt(start-src2)           $opt(start-src1)
set opt(stop-src2)            $opt(stop-src1)


#Flow 1
set src(agt-1) [new Agent/$opt(tcp_version)]
set dst(agt-1) [new Agent/TCPSink]
$ns_ attach-agent $src(node-1) $src(agt-1)
$ns_ attach-agent $dst(node-1) $dst(agt-1)
$ns_ connect $src(agt-1) $dst(agt-1)

$src(agt-1) set fid_ 1
set ftp [new Application/FTP]
$ftp attach-agent $src(agt-1)
$ns_ at $opt(start-src1) "$ftp start"
$ns_ at $opt(stop-src1) "$ftp stop"

#Flow 2
set src(agt-2) [new Agent/$opt(tcp_version)]
set dst(agt-2) [new Agent/TCPSink]
$ns_ attach-agent $src(node-2) $src(agt-2)
$ns_ attach-agent $dst(node-2) $dst(agt-2)
$ns_ connect $src(agt-2) $dst(agt-2)

$src(agt-2) set fid_ 2
set ftp2 [new Application/FTP]
$ftp2 attach-agent $src(agt-2)
$ns_ at $opt(start-src2) "$ftp2 start"
$ns_ at $opt(stop-src2) "$ftp2 stop"
```

## E.7 2-tcp-from-node-0-node-5

```
#Variables
set src(node-1)     $node_(0)
set dst(node-1)     $host_(0)

set src(node-2)     $node_(5)
set dst(node-2)     $host_(0)

set opt(start-src1)           $opt(flow-delay)
set opt(stop-src1)            [expr (($opt(stop)-$opt(flow-
delay))/2.0)]
set opt(start-src2)           [expr (($opt(stop)-$opt(flow-
delay))/4.0)]
set opt(stop-src2)            [expr ($opt(stop)-$opt(flow-delay))]

#Flow 1
set src(agt-1) [new Agent/$opt(tcp_version)]
set dst(agt-1) [new Agent/TCPSink]
$ns_ attach-agent $src(node-1) $src(agt-1)
$ns_ attach-agent $dst(node-1) $dst(agt-1)
$ns_ connect $src(agt-1) $dst(agt-1)

$src(agt-1) set fid_ 1
set ftp [new Application/FTP]
$ftp attach-agent $src(agt-1)
$ns_ at $opt(start-src1) "$ftp start"
$ns_ at $opt(stop-src1) "$ftp stop"

#Flow 2
set src(agt-2) [new Agent/$opt(tcp_version)]
set dst(agt-2) [new Agent/TCPSink]
$ns_ attach-agent $src(node-2) $src(agt-2)
$ns_ attach-agent $dst(node-2) $dst(agt-2)
$ns_ connect $src(agt-2) $dst(agt-2)

$src(agt-2) set fid_ 2
set ftp2 [new Application/FTP]
$ftp2 attach-agent $src(agt-2)
$ns_ at $opt(start-src2) "$ftp2 start"
$ns_ at $opt(stop-src2) "$ftp2 stop"
```

## E.8 2-tcp-from-node-0-node-5-simultaneous

```
#Variables
set src(node-1)    $node_(0)
set dst(node-1)    $host_(0)

set src(node-2)    $node_(5)
set dst(node-2)    $host_(0)

set opt(start-src1)          $opt(flow-delay)
set opt(stop-src1)           [expr ($opt(stop)-$opt(flow-delay))]
set opt(start-src2)          $opt(start-src1)
set opt(stop-src2)           $opt(stop-src1)


#Flow 1
set src(agt-1) [new Agent/$opt(tcp_version)]
set dst(agt-1) [new Agent/TCPSink]
$ns_ attach-agent $src(node-1) $src(agt-1)
$ns_ attach-agent $dst(node-1) $dst(agt-1)
$ns_ connect $src(agt-1) $dst(agt-1)

$src(agt-1) set fid_ 1
set ftp [new Application/FTP]
$ftp attach-agent $src(agt-1)
$ns_ at $opt(start-src1) "$ftp start"
$ns_ at $opt(stop-src1) "$ftp stop"
```

```
#Flow 2
set src(agt-2) [new Agent/$opt(tcp_version)]
set dst(agt-2) [new Agent/TCPSink]
$ns_ attach-agent $src(node-2) $src(agt-2)
$ns_ attach-agent $dst(node-2) $dst(agt-2)
$ns_ connect $src(agt-2) $dst(agt-2)

$src(agt-2) set fid_ 2
set ftp2 [new Application/FTP]
$ftp2 attach-agent $src(agt-2)
$ns_ at $opt(start-src2) "$ftp2 start"
$ns_ at $opt(stop-src2) "$ftp2 stop"
```

# F Scenario files

## F.1 chain5.dst

```
$node_(0) set X_ 0.0
$node_(0) set Y_ 0.0
$node_(0) set Z_ 0.000000000000
$node_(1) set X_ 200.0
$node_(1) set Y_ 0.0
$node_(1) set Z_ 0.000000000000
$node_(2) set X_ 400.0
$node_(2) set Y_ 0.0
$node_(2) set Z_ 0.000000000000
$node_(3) set X_ 600.0
$node_(3) set Y_ 0.0
$node_(3) set Z_ 0.000000000000
$node_(4) set X_ 800.0
$node_(4) set Y_ 0.0
$node_(4) set Z_ 0.000000000000
$god_ set-dist 0 1 1
$god_ set-dist 0 2 2
$god_ set-dist 0 3 3
$god_ set-dist 0 4 4
$god_ set-dist 1 2 1
$god_ set-dist 1 3 2
$god_ set-dist 1 4 3
$god_ set-dist 2 3 1
$god_ set-dist 2 4 2
$god_ set-dist 3 4 1
#
# Destination Unreachables: 0
#
# Route Changes: 0
#
# Link Changes: 0
#
# Node | Route Changes | Link Changes
#    0 |             0 |            0
#    1 |             0 |            0
#    2 |             0 |            0
#    3 |             0 |            0
#    4 |             0 |            0
```

## F.2 chain51.dst

```
$node_(0) set X_ 0.0
```

```
$node_(0) set Y_ 0.0
$node_(0) set Z_ 0.000000000000
$node_(1) set X_ 200.0
$node_(1) set Y_ 0.0
$node_(1) set Z_ 0.000000000000
$node_(2) set X_ 400.0
$node_(2) set Y_ 0.0
$node_(2) set Z_ 0.000000000000
$node_(3) set X_ 600.0
$node_(3) set Y_ 0.0
$node_(3) set Z_ 0.000000000000
$node_(4) set X_ 800.0
$node_(4) set Y_ 0.0
$node_(4) set Z_ 0.000000000000
$node_(5) set X_ 0.0
$node_(5) set Y_ 200.0
$node_(5) set Z_ 0.000000000000
$god_ set-dist 0 1 1
$god_ set-dist 0 2 2
$god_ set-dist 0 3 3
$god_ set-dist 0 4 4
$god_ set-dist 0 5 1
$god_ set-dist 1 2 1
$god_ set-dist 1 3 2
$god_ set-dist 1 4 3
$god_ set-dist 1 5 2
$god_ set-dist 2 3 1
$god_ set-dist 2 4 2
$god_ set-dist 2 5 3
$god_ set-dist 3 4 1
$god_ set-dist 3 5 4
$god_ set-dist 4 5 5
$ns_ at 10.0 "$node_(5) setdest 800.0 200.0 20.0"
$ns_ at 55.0 "$node_(5) setdest 0.1 200.0 30.0"
$ns_ at 90.0 "$node_(5) setdest 800.0 200.0 10.0"
$ns_ at 170.0 "$node_(5) setdest 0.1 200.0 20.0"
$ns_ at 220.0 "$node_(5) setdest 800.0 200.0 5.0"
$ns_ at 400.0 "$node_(5) setdest 0.1 200.0 40.0"
$ns_ at 430.0 "$node_(5) setdest 800.0 200.0 60.0"
$ns_ at 450.0 "$node_(5) setdest 0.1 200.0 1.5"
```

## F.3 grid7x7.dst

```
$node_(0) set X_ 0.0
$node_(0) set Y_ 0.0
$node_(0) set Z_ 0.0
$node_(1) set X_ 200.0
$node_(1) set Y_ 0.0
$node_(1) set Z_ 0.0
$node_(2) set X_ 400.0
$node_(2) set Y_ 0.0
$node_(2) set Z_ 0.0
```

```
$node_(3) set X_ 600.0
$node_(3) set Y_ 0.0
$node_(3) set Z_ 0.0
$node_(4) set X_ 800.0
$node_(4) set Y_ 0.0
$node_(4) set Z_ 0.0
$node_(5) set X_ 1000.0
$node_(5) set Y_ 0.0
$node_(5) set Z_ 0.0
$node_(6) set X_ 1200.0
$node_(6) set Y_ 0.0
$node_(6) set Z_ 0.0

$node_(7) set X_ 0.0
$node_(7) set Y_ 200.0
$node_(7) set Z_ 0.0
$node_(8) set X_ 200.0
$node_(8) set Y_ 200.0
$node_(8) set Z_ 0.0
$node_(9) set X_ 400.0
$node_(9) set Y_ 200.0
$node_(9) set Z_ 0.0
$node_(10) set X_ 600.0
$node_(10) set Y_ 200.0
$node_(10) set Z_ 0.0
$node_(11) set X_ 800.0
$node_(11) set Y_ 200.0
$node_(11) set Z_ 0.0
$node_(12) set X_ 1000.0
$node_(12) set Y_ 200.0
$node_(12) set Z_ 0.0
$node_(13) set X_ 1200.0
$node_(13) set Y_ 200.0
$node_(13) set Z_ 0.0

$node_(14) set X_ 0.0
$node_(14) set Y_ 400.0
$node_(14) set Z_ 0.0
$node_(15) set X_ 200.0
$node_(15) set Y_ 400.0
$node_(15) set Z_ 0.0
$node_(16) set X_ 400.0
$node_(16) set Y_ 400.0
$node_(16) set Z_ 0.0
$node_(17) set X_ 600.0
$node_(17) set Y_ 400.0
$node_(17) set Z_ 0.0
$node_(18) set X_ 800.0
$node_(18) set Y_ 400.0
$node_(18) set Z_ 0.0
$node_(19) set X_ 1000.0
$node_(19) set Y_ 400.0
$node_(19) set Z_ 0.0
$node_(20) set X_ 1200.0
$node_(20) set Y_ 400.0
$node_(20) set Z_ 0.0
```

```
$node_(21) set X_ 0.0
$node_(21) set Y_ 600.0
$node_(21) set Z_ 0.0
$node_(22) set X_ 200.0
$node_(22) set Y_ 600.0
$node_(22) set Z_ 0.0
$node_(23) set X_ 400.0
$node_(23) set Y_ 600.0
$node_(23) set Z_ 0.0
$node_(24) set X_ 600.0
$node_(24) set Y_ 600.0
$node_(24) set Z_ 0.0
$node_(25) set X_ 800.0
$node_(25) set Y_ 600.0
$node_(25) set Z_ 0.0
$node_(26) set X_ 1000.0
$node_(26) set Y_ 600.0
$node_(26) set Z_ 0.0
$node_(27) set X_ 1200.0
$node_(27) set Y_ 600.0
$node_(27) set Z_ 0.0

$node_(28) set X_ 0.0
$node_(28) set Y_ 800.0
$node_(28) set Z_ 0.0
$node_(29) set X_ 200.0
$node_(29) set Y_ 800.0
$node_(29) set Z_ 0.0
$node_(30) set X_ 400.0
$node_(30) set Y_ 800.0
$node_(30) set Z_ 0.0
$node_(31) set X_ 600.0
$node_(31) set Y_ 800.0
$node_(31) set Z_ 0.0
$node_(32) set X_ 800.0
$node_(32) set Y_ 800.0
$node_(32) set Z_ 0.0
$node_(33) set X_ 1000.0
$node_(33) set Y_ 800.0
$node_(33) set Z_ 0.0
$node_(34) set X_ 1200.0
$node_(34) set Y_ 800.0
$node_(34) set Z_ 0.0

$node_(35) set X_ 0.0
$node_(35) set Y_ 1000.0
$node_(35) set Z_ 0.0
$node_(36) set X_ 200.0
$node_(36) set Y_ 1000.0
$node_(36) set Z_ 0.0
$node_(37) set X_ 400.0
$node_(37) set Y_ 1000.0
$node_(37) set Z_ 0.0
$node_(38) set X_ 600.0
$node_(38) set Y_ 1000.0
```

```
$node_(38) set Z_ 0.0
$node_(39) set X_ 800.0
$node_(39) set Y_ 1000.0
$node_(39) set Z_ 0.0
$node_(40) set X_ 1000.0
$node_(40) set Y_ 1000.0
$node_(40) set Z_ 0.0
$node_(41) set X_ 1200.0
$node_(41) set Y_ 1000.0
$node_(41) set Z_ 0.0

$node_(42) set X_ 0.0
$node_(42) set Y_ 1200.0
$node_(42) set Z_ 0.0
$node_(43) set X_ 200.0
$node_(43) set Y_ 1200.0
$node_(43) set Z_ 0.0
$node_(44) set X_ 400.0
$node_(44) set Y_ 1200.0
$node_(44) set Z_ 0.0
$node_(45) set X_ 600.0
$node_(45) set Y_ 1200.0
$node_(45) set Z_ 0.0
$node_(46) set X_ 800.0
$node_(46) set Y_ 1200.0
$node_(46) set Z_ 0.0
$node_(47) set X_ 1000.0
$node_(47) set Y_ 1200.0
$node_(47) set Z_ 0.0
$node_(48) set X_ 1200.0
$node_(48) set Y_ 1200.0
$node_(48) set Z_ 0.0
$node_(48) set Z_ 0.0
…skipped initilaizing of god and end comment
```

## F.4 rand48.dst

Produced by the command “setdest -v 2 -n 48 -s 2 -m 1 -M 20.0  -t 900 -P 1 -p 5.0 -x 800 -y 800 > rand48.dst”, code example only show 10 first lines

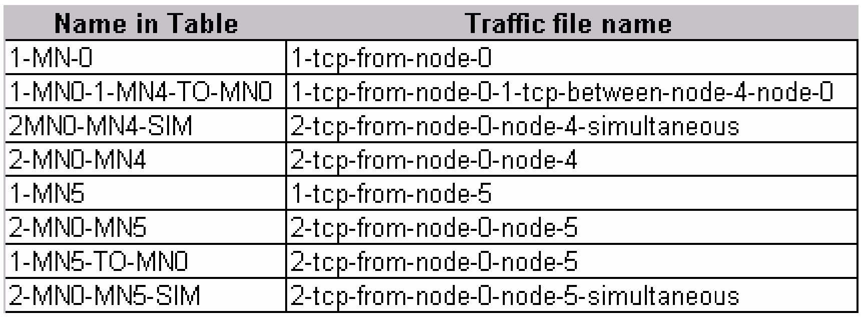
```
#
# nodes: 48, speed type: 2, min speed: 1.00, max speed: 20.00
# avg speed: 7.36, pause type: 1, pause: 5.00, max x: 800.00, max y:
800.00
#
$node_(0) set X_ 688.570440752118
$node_(0) set Y_ 556.044455724127
$node_(0) set Z_ 0.000000000000
$node_(1) set X_ 283.313566196994
$node_(1) set Y_ 533.389390945666
$node_(1) set Z_ 0.000000000000
$node_(2) set X_ 420.308276504307
… rest of file skipped
```

# G Simulation Summary

## G.1 Description of Simulation table

***Table 7*** describes the complete setup of different simulations that have been run. In the table can also be seen the simulation number that sould be used, as a command line option the simulations.pl scipt, to run a specific simulation.

In the traffic scenarios (actually file names) have been abbrivated to save space, to get the complete traffic scenario name the following table must be used.



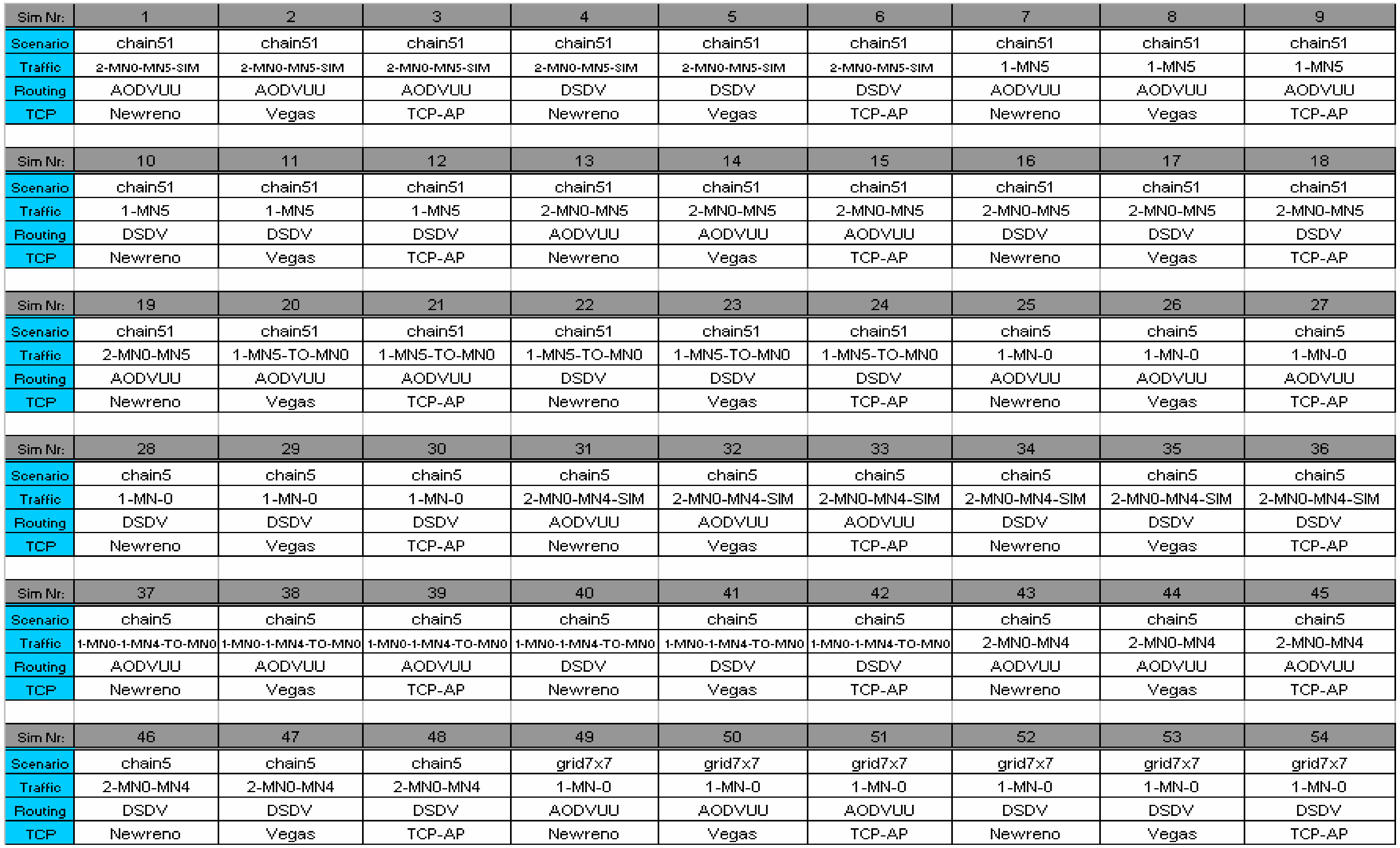
| Name in Table | Traffic file name |
|---|---|
| 1-MN-0 | 1-tcp-from-node-0 |
| 1-MN0-1-MN4-TO-MN0 | 1-tcp-from-node-0-1-tcp-between-node-4-node-0 |
| 2MN0-MN4-SIM | 2-tcp-from-node-0-node-4-simultaneous |
| 2-MN0-MN4 | 2-tcp-from-node-0-node-4 |
| 1-MN5 | 1-tcp-from-node-5 |
| 2-MN0-MN5 | 2-tcp-from-node-0-node-5 |
| 1-MN5-TO-MN0 | 2-tcp-from-node-0-node-5 |
| 2-MN0-MN5-SIM | 2-tcp-from-node-0-node-5-simultaneous |

*Table 6 Abbreviations for Table 7*

## G.2 Description of Simulation Graphs

In Appendix G.4, the output of the all the simulation conducted with a wired bandwidth and delay of 100Mb and 2ms. The simulation information is displayed in the right side of each graph.

## G.3 Summary Table of Simulations



| Sim Nr: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Scenario | chain51 | chain51 | chain51 | chain51 | chain51 | chain51 | chain51 | chain51 | chain51 |
| Traffic | 2-MN0-MN5-SIM | 2-MN0-MN5-SIM | 2-MN0-MN5-SIM | 2-MN0-MN5-SIM | 2-MN0-MN5-SIM | 2-MN0-MN5-SIM | 1-MN5 | 1-MN5 | 1-MN5 |
| Routing | AODVUU | AODVUU | AODVUU | DSDV | DSDV | DSDV | AODVUU | AODVUU | AODVUU |
| TCP | Newreno | Vegas | TCP-AP | Newreno | Vegas | TCP-AP | Newreno | Vegas | TCP-AP |

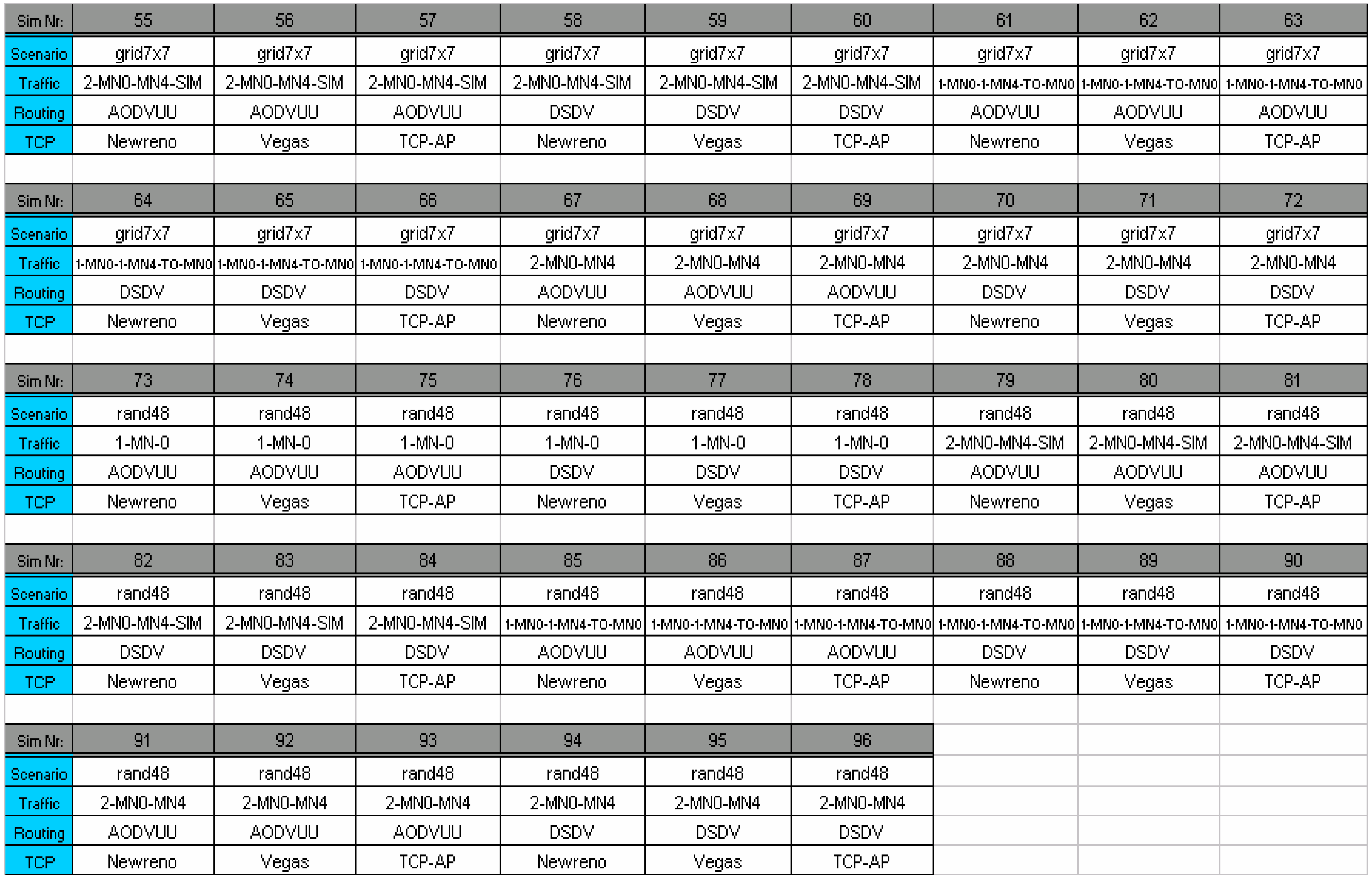
| Sim Nr: | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|
| Scenario | chain51 | chain51 | chain51 | chain51 | chain51 | chain51 | chain51 | chain51 | chain51 |
| Traffic | 1-MN5 | 1-MN5 | 1-MN5 | 2-MN0-MN5 | 2-MN0-MN5 | 2-MN0-MN5 | 2-MN0-MN5 | 2-MN0-MN5 | 2-MN0-MN5 |
| Routing | DSDV | DSDV | DSDV | AODVUU | AODVUU | AODVUU | DSDV | DSDV | DSDV |
| TCP | Newreno | Vegas | TCP-AP | Newreno | Vegas | TCP-AP | Newreno | Vegas | TCP-AP |

| Sim Nr: | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 |
|---|---|---|---|---|---|---|---|---|---|
| Scenario | chain51 | chain51 | chain51 | chain51 | chain51 | chain51 | chain5 | chain5 | chain5 |
| Traffic | 2-MN0-MN5 | 1-MN5-TO-MN0 | 1-MN5-TO-MN0 | 1-MN5-TO-MN0 | 1-MN5-TO-MN0 | 1-MN5-TO-MN0 | 1-MN-0 | 1-MN-0 | 1-MN-0 |
| Routing | AODVUU | AODVUU | AODVUU | DSDV | DSDV | DSDV | AODVUU | AODVUU | AODVUU |
| TCP | Newreno | Vegas | TCP-AP | Newreno | Vegas | TCP-AP | Newreno | Vegas | TCP-AP |

| Sim Nr: | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
|---|---|---|---|---|---|---|---|---|---|
| Scenario | chain5 | chain5 | chain5 | chain5 | chain5 | chain5 | chain5 | chain5 | chain5 |
| Traffic | 1-MN-0 | 1-MN-0 | 1-MN-0 | 2-MN0-MN4-SIM | 2-MN0-MN4-SIM | 2-MN0-MN4-SIM | 2-MN0-MN4-SIM | 2-MN0-MN4-SIM | 2-MN0-MN4-SIM |
| Routing | DSDV | DSDV | DSDV | AODVUU | AODVUU | AODVUU | DSDV | DSDV | DSDV |
| TCP | Newreno | Vegas | TCP-AP | Newreno | Vegas | TCP-AP | Newreno | Vegas | TCP-AP |

| Sim Nr: | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 |
|---|---|---|---|---|---|---|---|---|---|
| Scenario | chain5 | chain5 | chain5 | chain5 | chain5 | chain5 | chain5 | chain5 | chain5 |
| Traffic | 1-MN0-1-MN4-TO-MN0 | 1-MN0-1-MN4-TO-MN0 | 1-MN0-1-MN4-TO-MN0 | 1-MN0-1-MN4-TO-MN0 | 1-MN0-1-MN4-TO-MN0 | 1-MN0-1-MN4-TO-MN0 | 2-MN0-MN4 | 2-MN0-MN4 | 2-MN0-MN4 |
| Routing | AODVUU | AODVUU | AODVUU | DSDV | DSDV | DSDV | AODVUU | AODVUU | AODVUU |
| TCP | Newreno | Vegas | TCP-AP | Newreno | Vegas | TCP-AP | Newreno | Vegas | TCP-AP |

| Sim Nr: | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 |
|---|---|---|---|---|---|---|---|---|---|
| Scenario | chain5 | chain5 | chain5 | grid7x7 | grid7x7 | grid7x7 | grid7x7 | grid7x7 | grid7x7 |
| Traffic | 2-MN0-MN4 | 2-MN0-MN4 | 2-MN0-MN4 | 1-MN-0 | 1-MN-0 | 1-MN-0 | 1-MN-0 | 1-MN-0 | 1-MN-0 |
| Routing | DSDV | DSDV | DSDV | AODVUU | AODVUU | AODVUU | DSDV | DSDV | DSDV |
| TCP | Newreno | Vegas | TCP-AP | Newreno | Vegas | TCP-AP | Newreno | Vegas | TCP-AP |



| Sim Nr: | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 |
|---|---|---|---|---|---|---|---|---|---|
| Scenario | grid7x7 | grid7x7 | grid7x7 | grid7x7 | grid7x7 | grid7x7 | grid7x7 | grid7x7 | grid7x7 |
| Traffic | 2-MN0-MN4-SIM | 2-MN0-MN4-SIM | 2-MN0-MN4-SIM | 2-MN0-MN4-SIM | 2-MN0-MN4-SIM | 2-MN0-MN4-SIM | 1-MN0-1-MN4-TO-MN0 | 1-MN0-1-MN4-TO-MN0 | 1-MN0-1-MN4-TO-MN0 |
| Routing | AODVUU | AODVUU | AODVUU | DSDV | DSDV | DSDV | AODVUU | AODVUU | AODVUU |
| TCP | Newreno | Vegas | TCP-AP | Newreno | Vegas | TCP-AP | Newreno | Vegas | TCP-AP |

| Sim Nr: | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 |
|---|---|---|---|---|---|---|---|---|---|
| Scenario | grid7x7 | grid7x7 | grid7x7 | grid7x7 | grid7x7 | grid7x7 | grid7x7 | grid7x7 | grid7x7 |
| Traffic | 1-MN0-1-MN4-TO-MN0 | 1-MN0-1-MN4-TO-MN0 | 1-MN0-1-MN4-TO-MN0 | 2-MN0-MN4 | 2-MN0-MN4 | 2-MN0-MN4 | 2-MN0-MN4 | 2-MN0-MN4 | 2-MN0-MN4 |
| Routing | DSDV | DSDV | DSDV | AODVUU | AODVUU | AODVUU | DSDV | DSDV | DSDV |
| TCP | Newreno | Vegas | TCP-AP | Newreno | Vegas | TCP-AP | Newreno | Vegas | TCP-AP |

| Sim Nr: | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 | 81 |
|---|---|---|---|---|---|---|---|---|---|
| Scenario | rand48 | rand48 | rand48 | rand48 | rand48 | rand48 | rand48 | rand48 | rand48 |
| Traffic | 1-MN-0 | 1-MN-0 | 1-MN-0 | 1-MN-0 | 1-MN-0 | 1-MN-0 | 2-MN0-MN4-SIM | 2-MN0-MN4-SIM | 2-MN0-MN4-SIM |
| Routing | AODVUU | AODVUU | AODVUU | DSDV | DSDV | DSDV | AODVUU | AODVUU | AODVUU |
| TCP | Newreno | Vegas | TCP-AP | Newreno | Vegas | TCP-AP | Newreno | Vegas | TCP-AP |

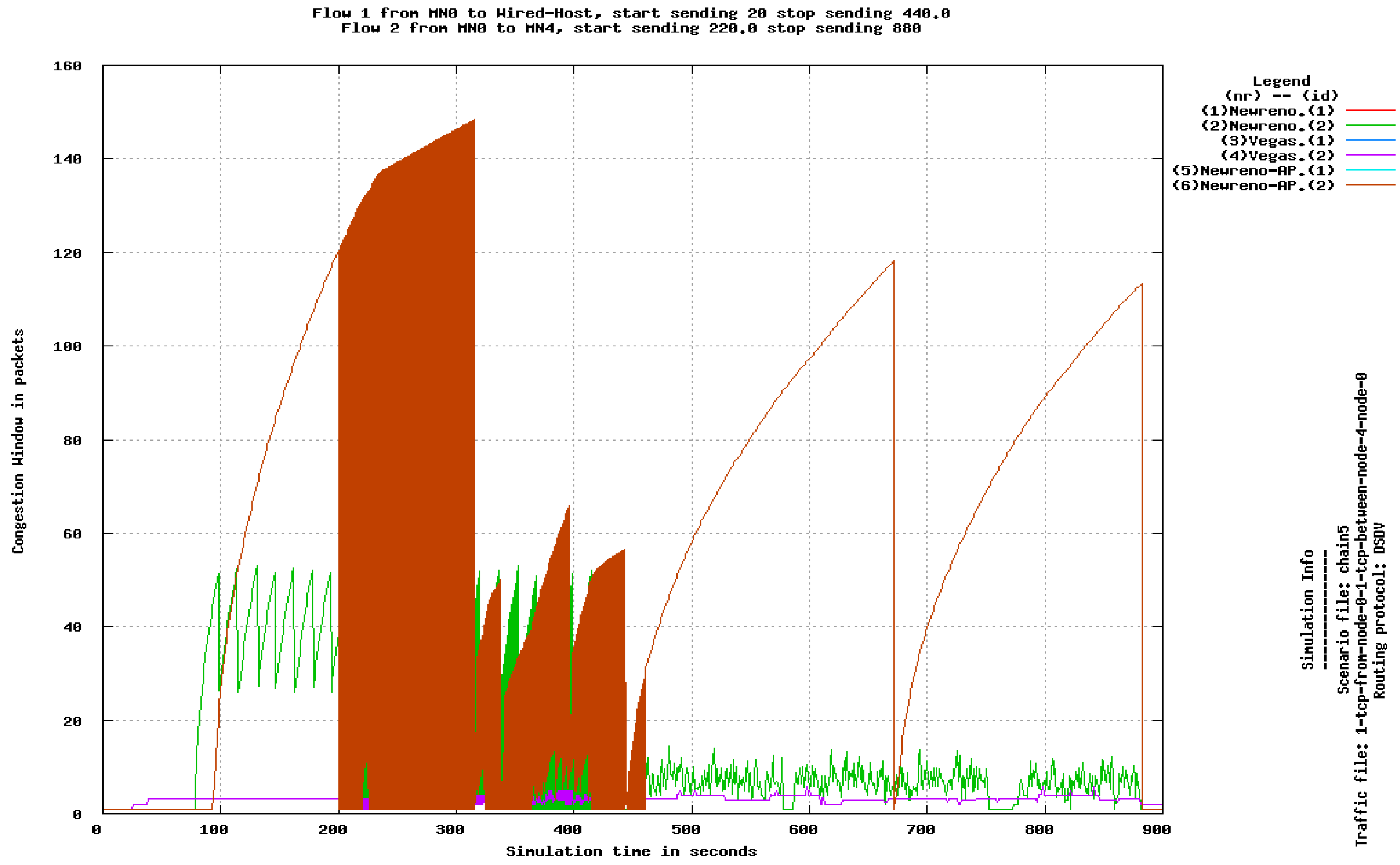
| Sim Nr: | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 |
|---|---|---|---|---|---|---|---|---|---|
| Scenario | rand48 | rand48 | rand48 | rand48 | rand48 | rand48 | rand48 | rand48 | rand48 |
| Traffic | 2-MN0-MN4-SIM | 2-MN0-MN4-SIM | 2-MN0-MN4-SIM | 1-MN0-1-MN4-TO-MN0 | 1-MN0-1-MN4-TO-MN0 | 1-MN0-1-MN4-TO-MN0 | 1-MN0-1-MN4-TO-MN0 | 1-MN0-1-MN4-TO-MN0 | 1-MN0-1-MN4-TO-MN0 |
| Routing | DSDV | DSDV | DSDV | AODVUU | AODVUU | AODVUU | DSDV | DSDV | DSDV |
| TCP | Newreno | Vegas | TCP-AP | Newreno | Vegas | TCP-AP | Newreno | Vegas | TCP-AP |

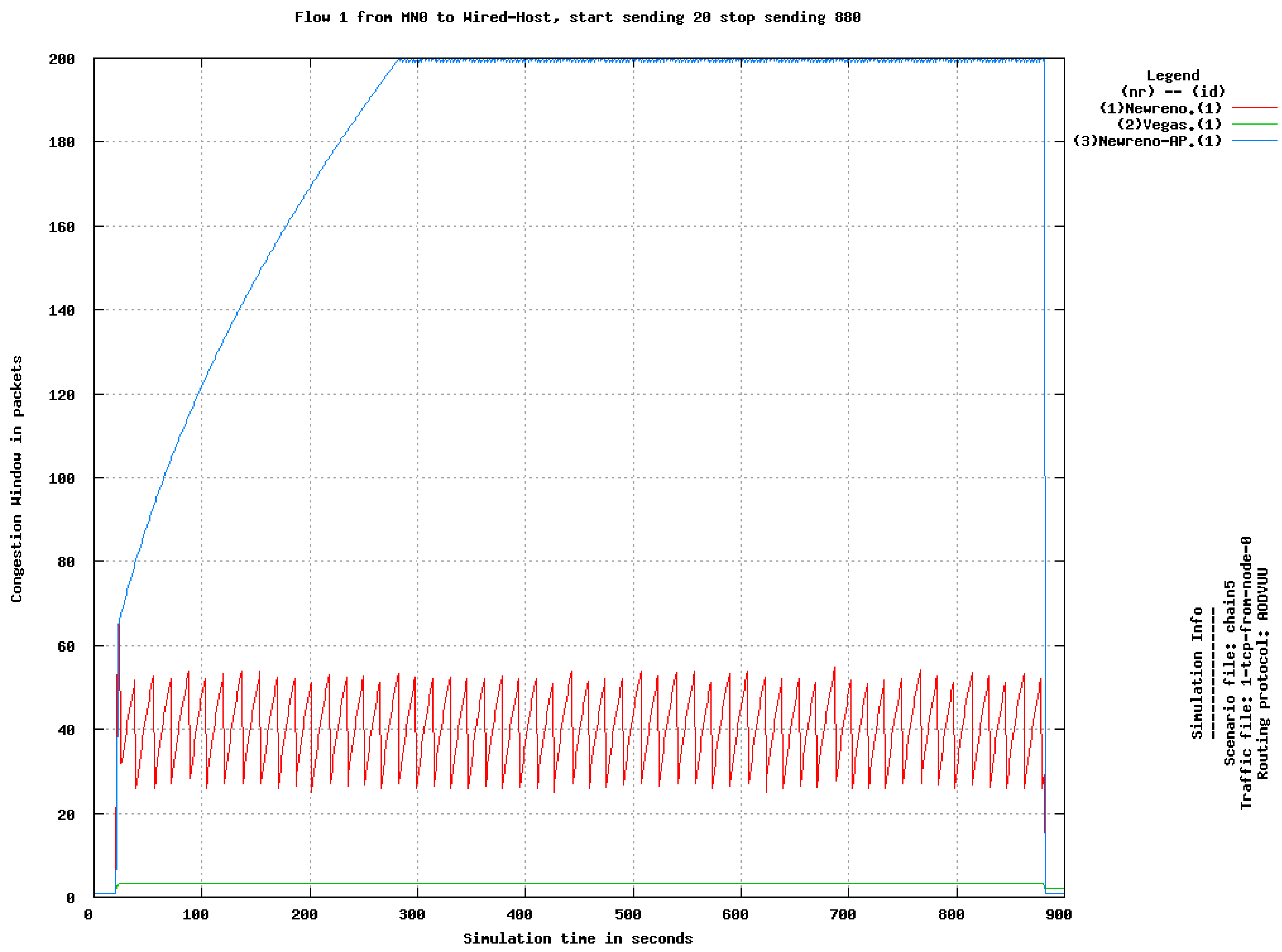
| Sim Nr: | 91 | 92 | 93 | 94 | 95 | 96 |
|---|---|---|---|---|---|---|
| Scenario | rand48 | rand48 | rand48 | rand48 | rand48 | rand48 |
| Traffic | 2-MN0-MN4 | 2-MN0-MN4 | 2-MN0-MN4 | 2-MN0-MN4 | 2-MN0-MN4 | 2-MN0-MN4 |
| Routing | AODVUU | AODVUU | AODVUU | DSDV | DSDV | DSDV |
| TCP | Newreno | Vegas | TCP-AP | Newreno | Vegas | TCP-AP |

*Table 7 Table of Simulations*

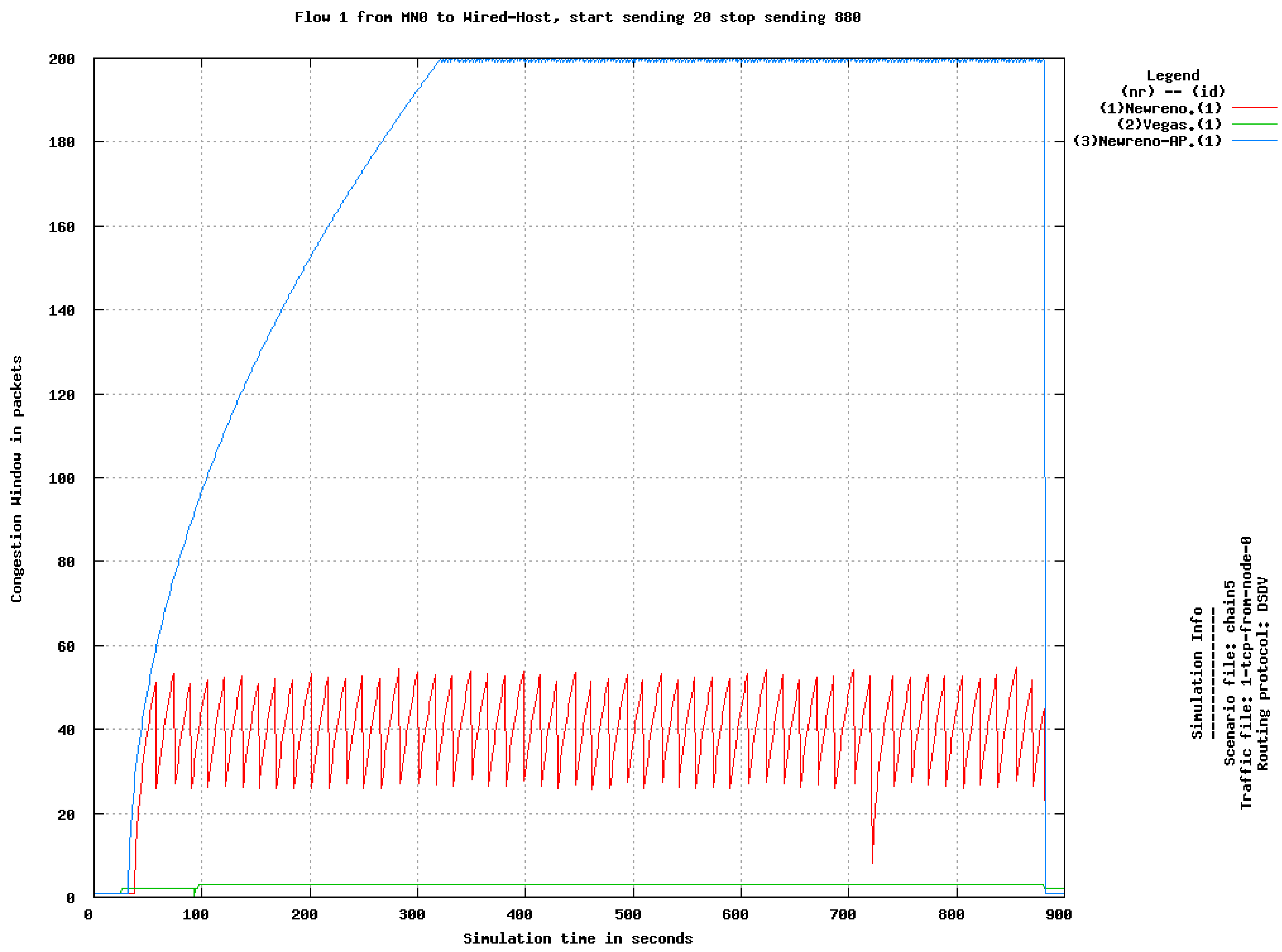
## G.4 Simulation Graphs 100Mb, 2 ms

### G.4.1 Congestion Window

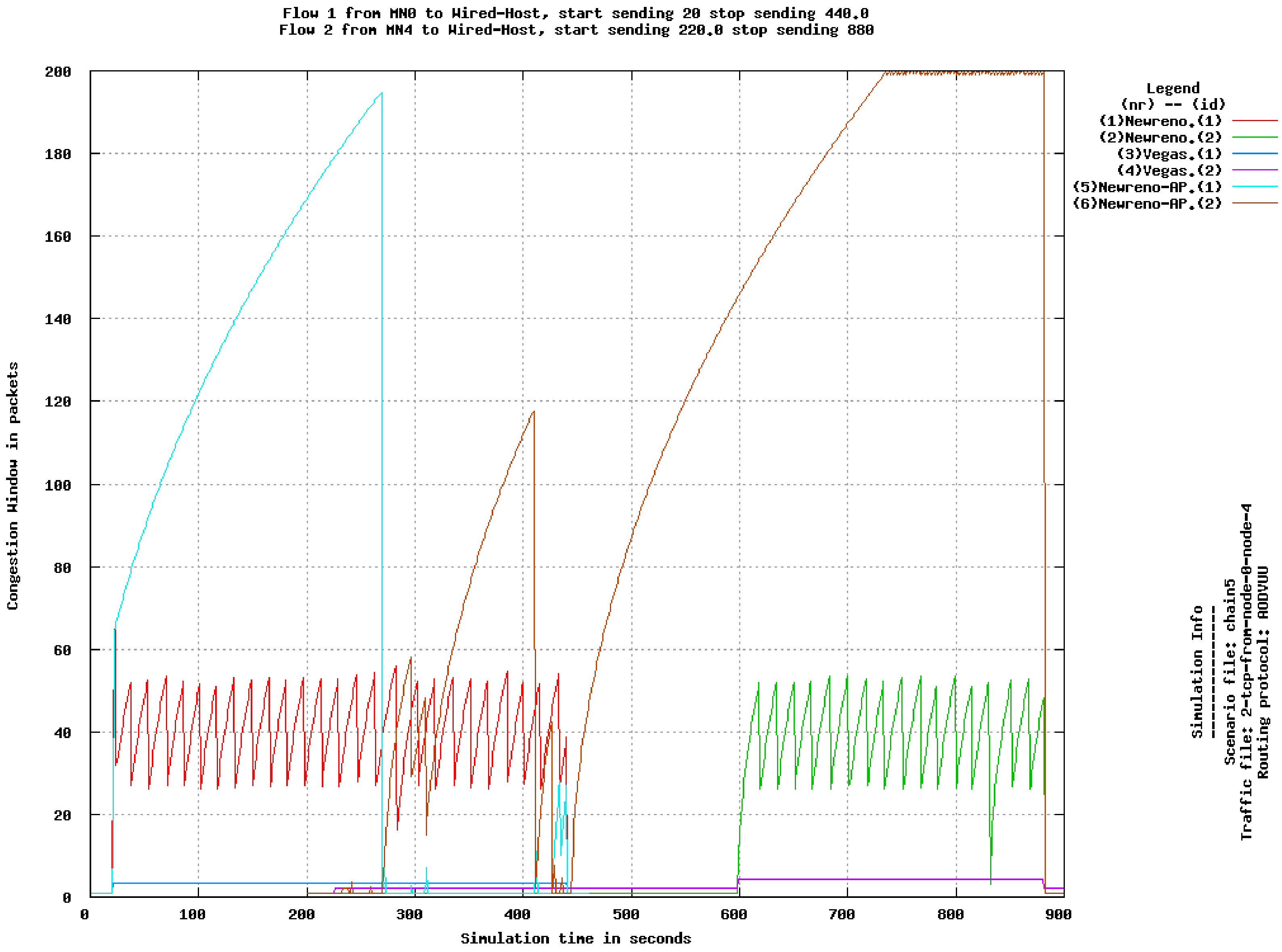




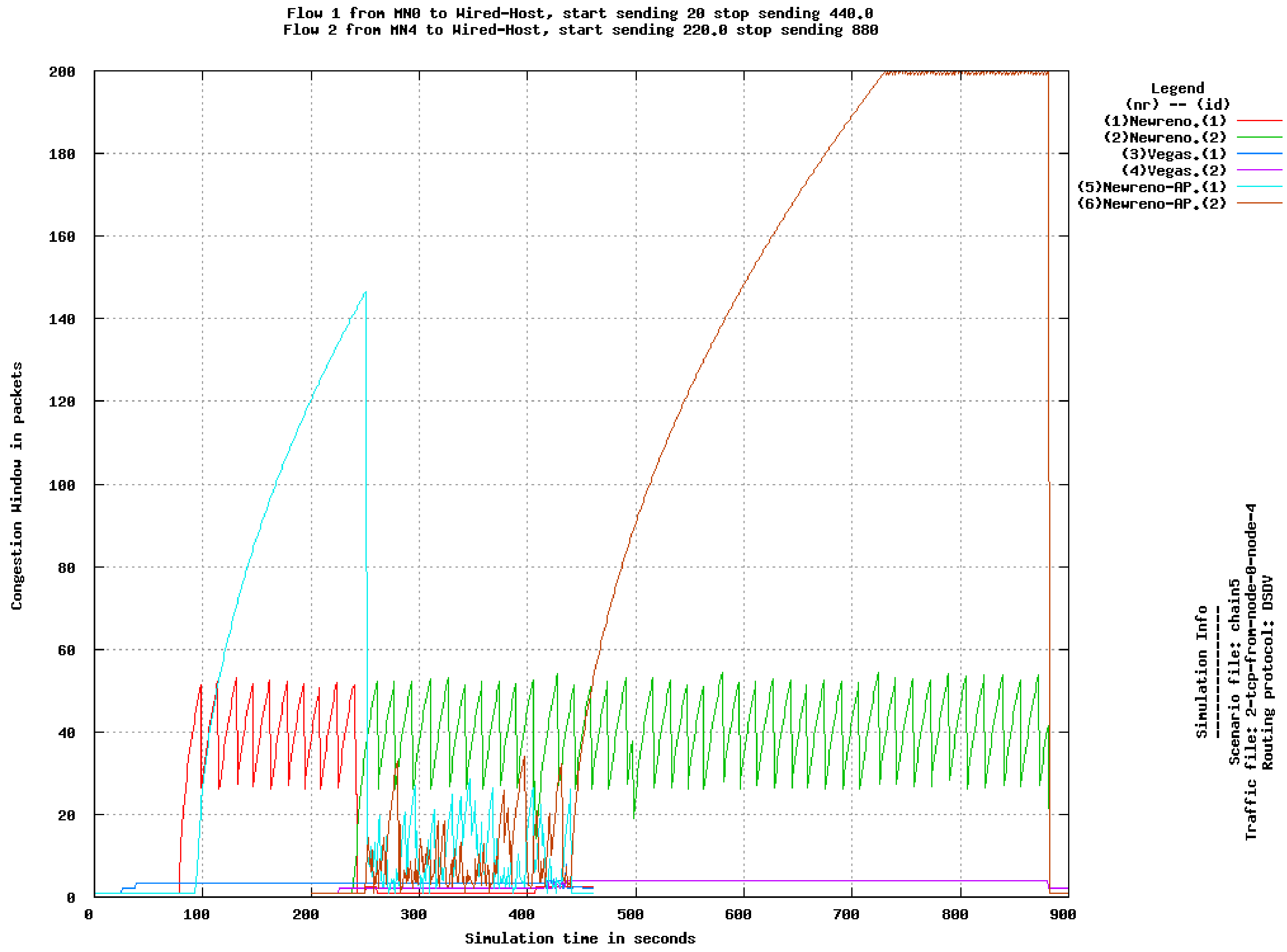
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
20
40
60
80
100
120
140
160
180
200
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
---------------
Scenario file: chain5
Traffic file: 1-tcp-from-node-0
Routing protocol: AODVUU

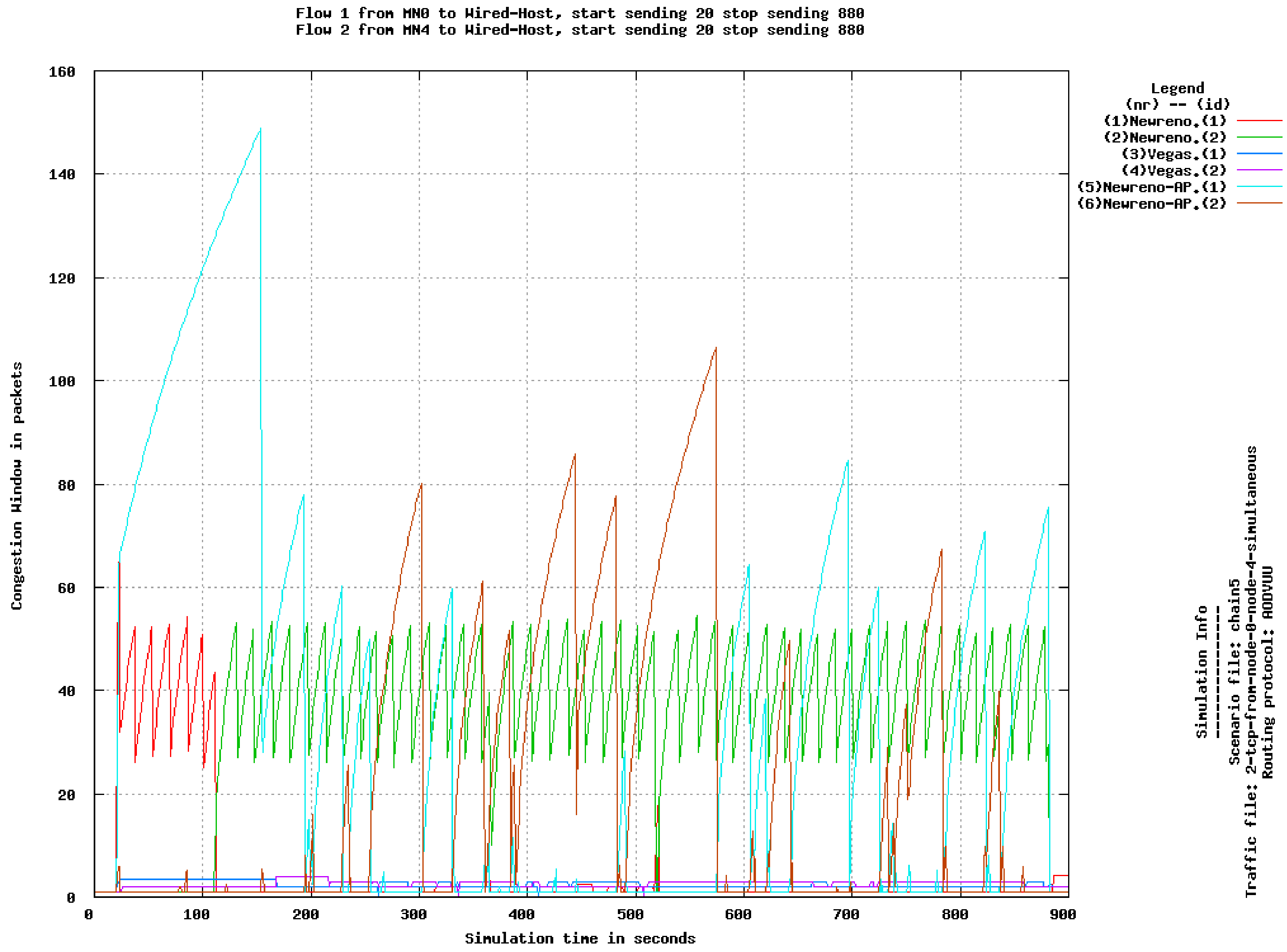


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
20
40
60
80
100
120
140
160
180
200
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
Scenario file: chain5
Traffic file: 1-tcp-from-node-0
Routing protocol: DSDV

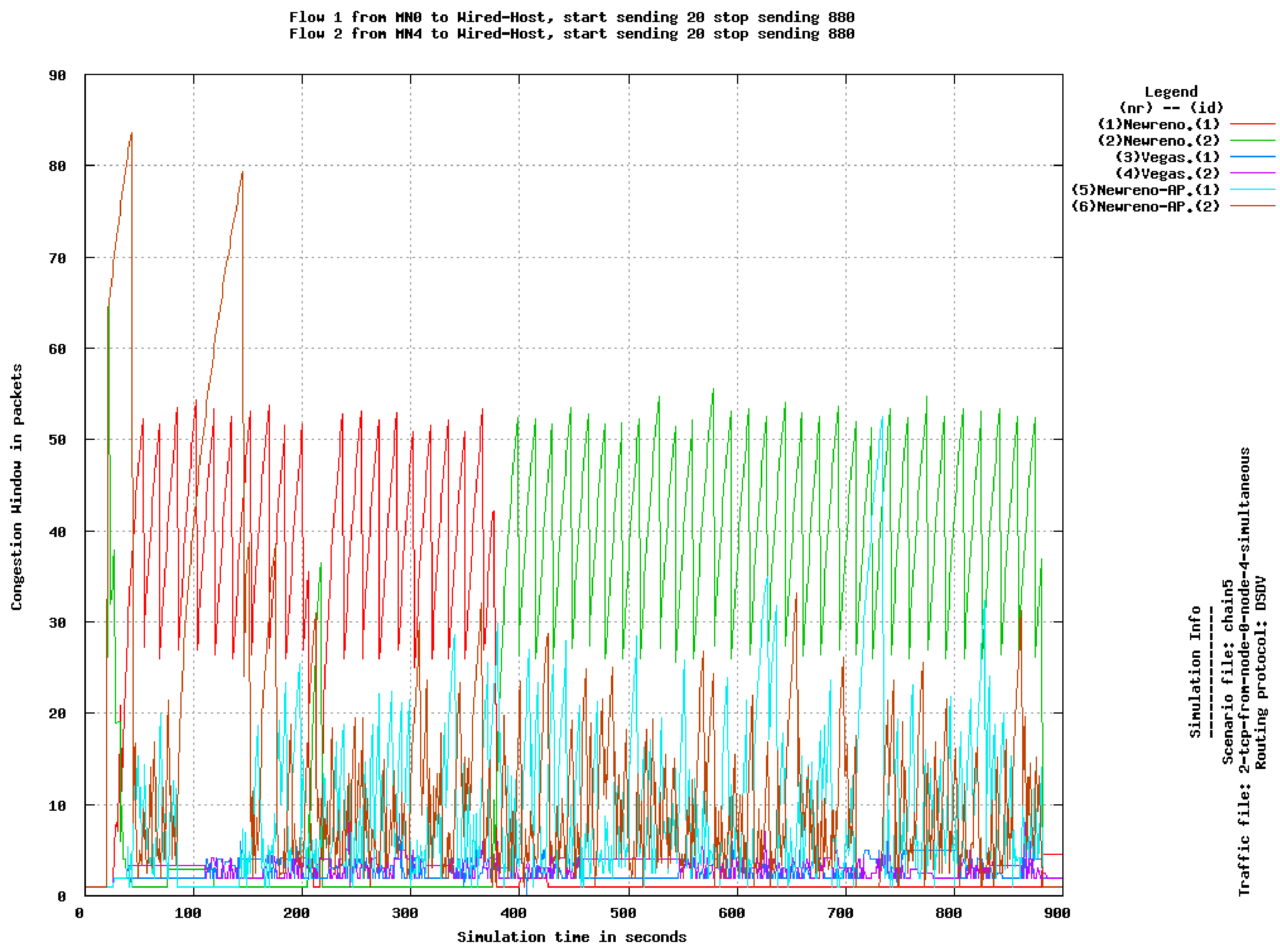


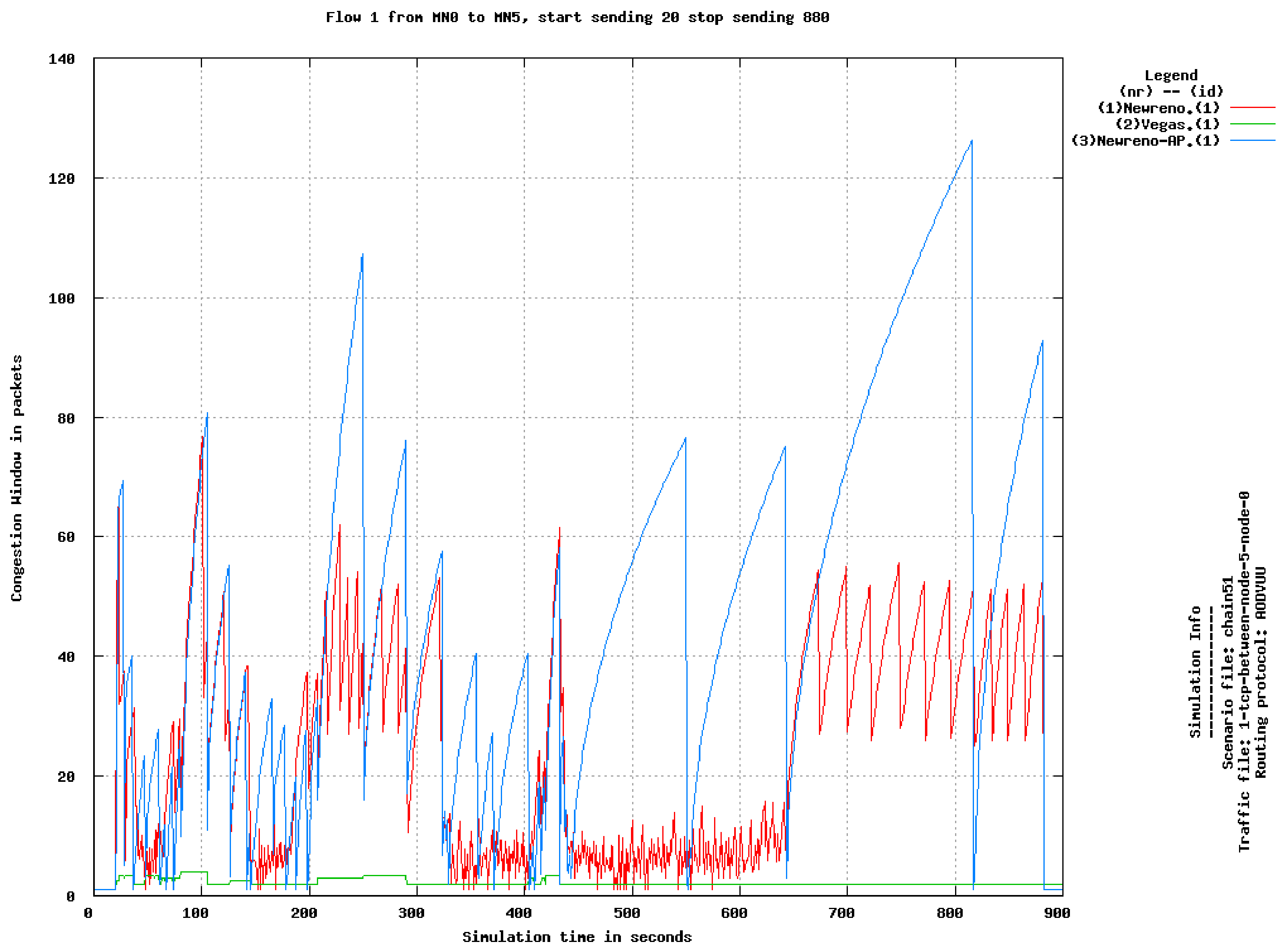
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN4 to Wired-Host, start sending 220.0 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
20
40
60
80
100
120
140
160
180
200
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
---------------
Scenario file: chain5
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: AODVUU


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN4 to Wired-Host, start sending 220.0 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
20
40
60
80
100
120
140
160
180
200
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
---------------
Scenario file: chain5
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: DSDV

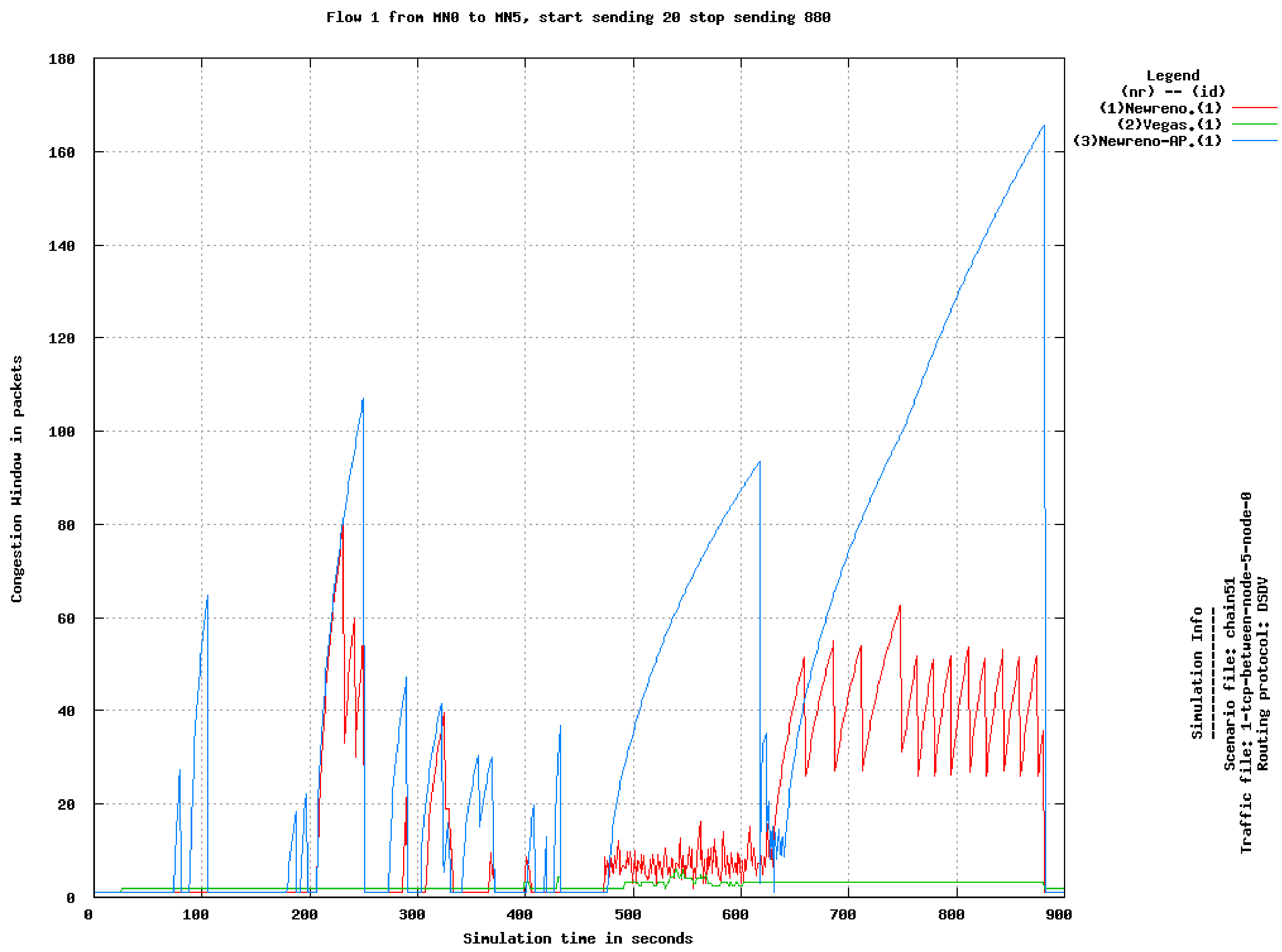


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN4 to Wired-Host, start sending 20 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
20
40
60
80
100
120
140
160
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
---------------
Scenario file: chain5
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: AODVUU

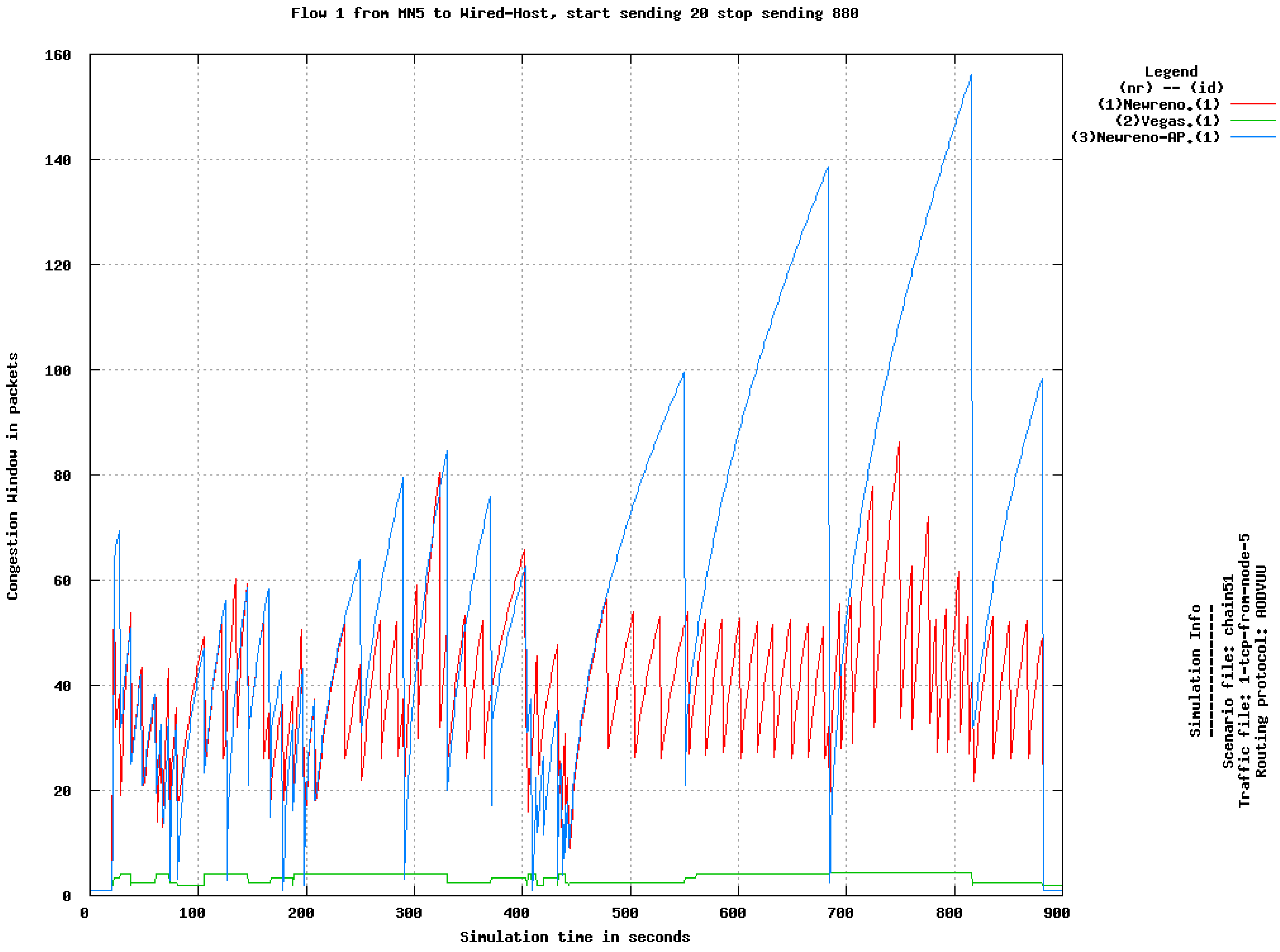

Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN4 to Wired-Host, start sending 20 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
---------------
Scenario file: chain5
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: DSDV



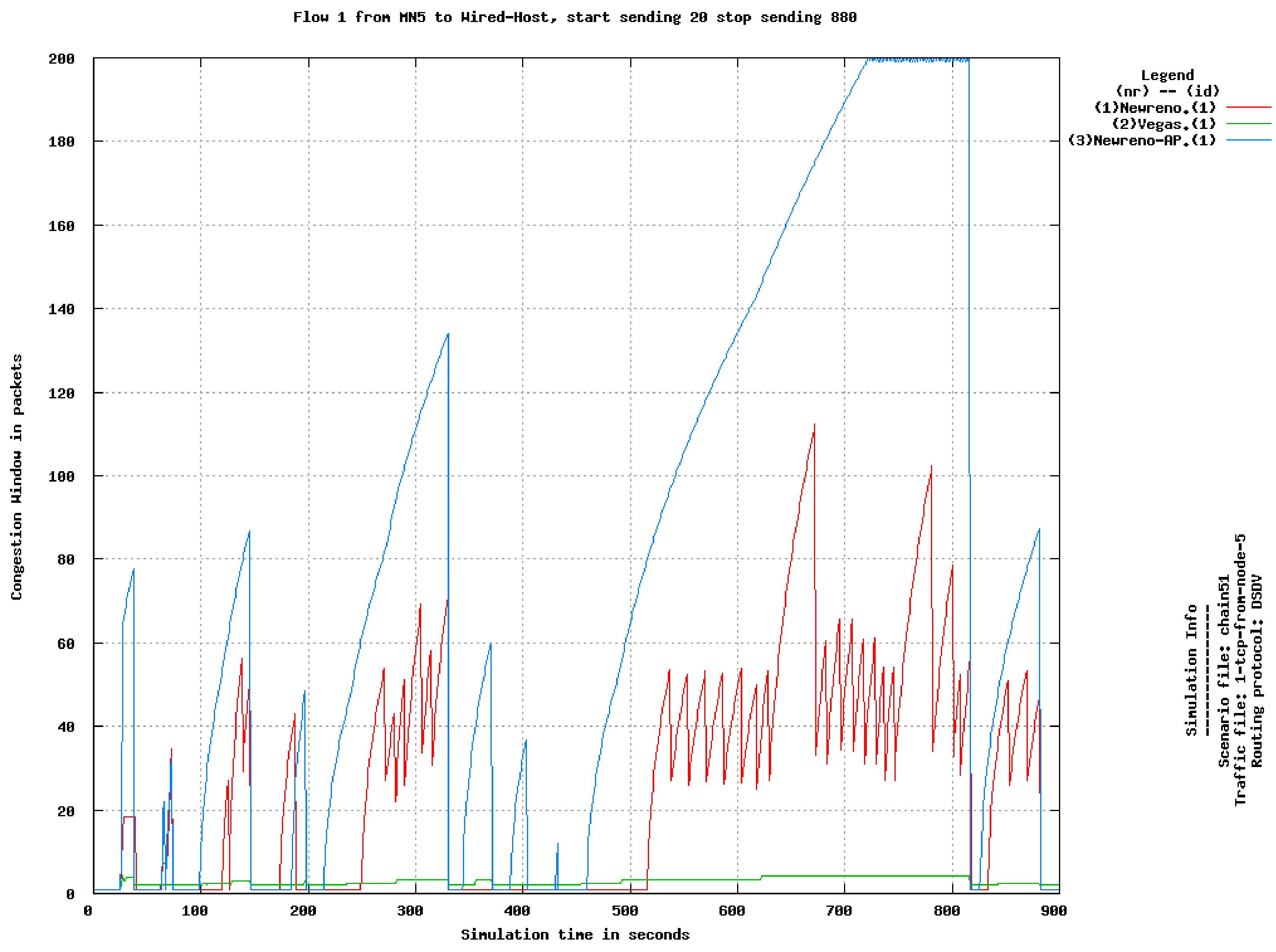
Flow 1 from MN0 to MN5, start sending 20 stop sending 880
Congestion Window in packets
140
120
100
80
60
40
20
0
0
100
200
300
400
500
600
700
800
900
Simulation time in seconds
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
---------------
Scenario file: chain51
Traffic file: 1-tcp-between-node-5-node-0
Routing protocol: AODVUU



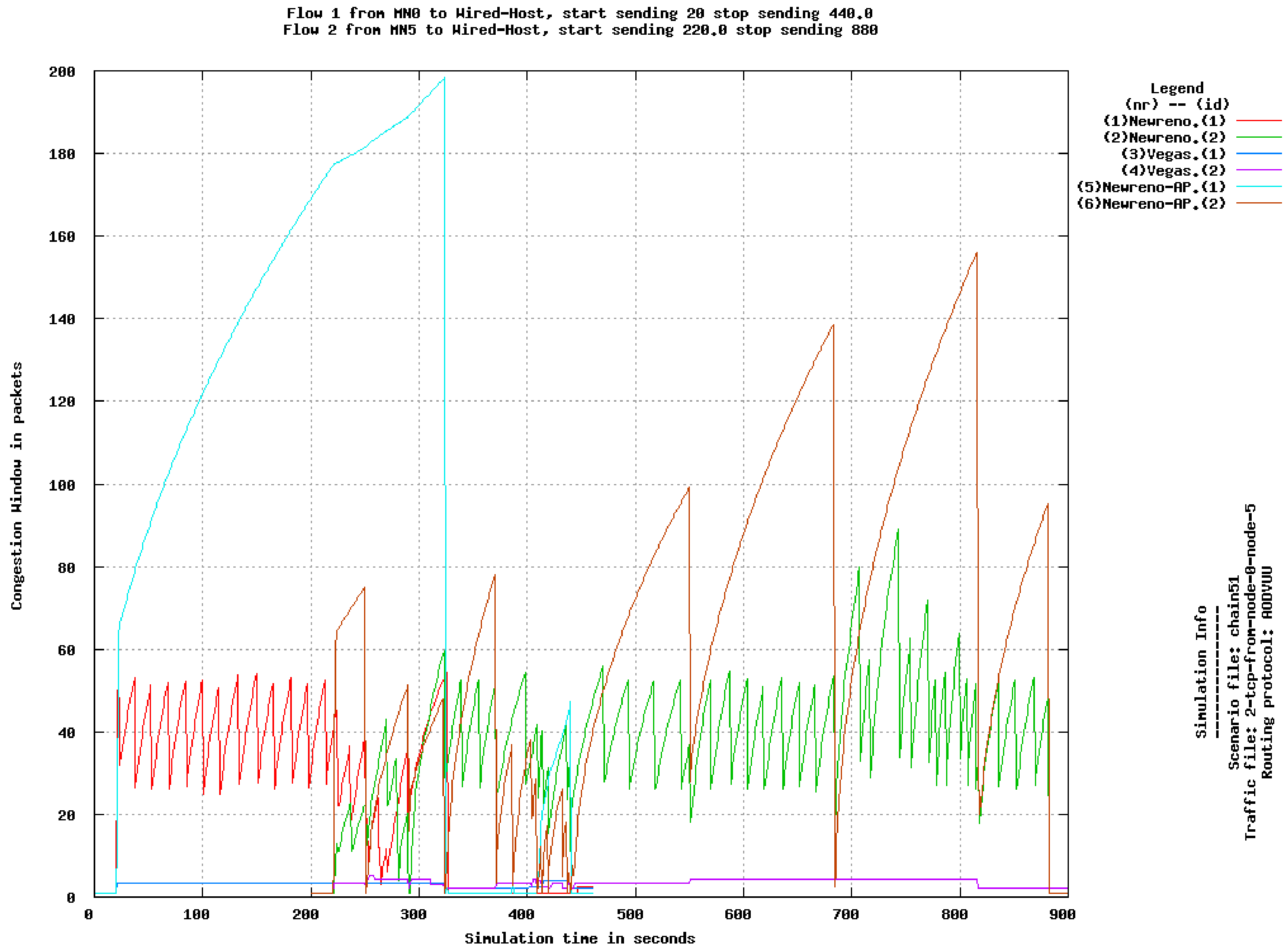
Flow 1 from MN0 to MN5, start sending 20 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
20
40
60
80
100
120
140
160
180
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
Scenario file: chain51
Traffic file: 1-tcp-between-node-5-node-0
Routing protocol: DSDV



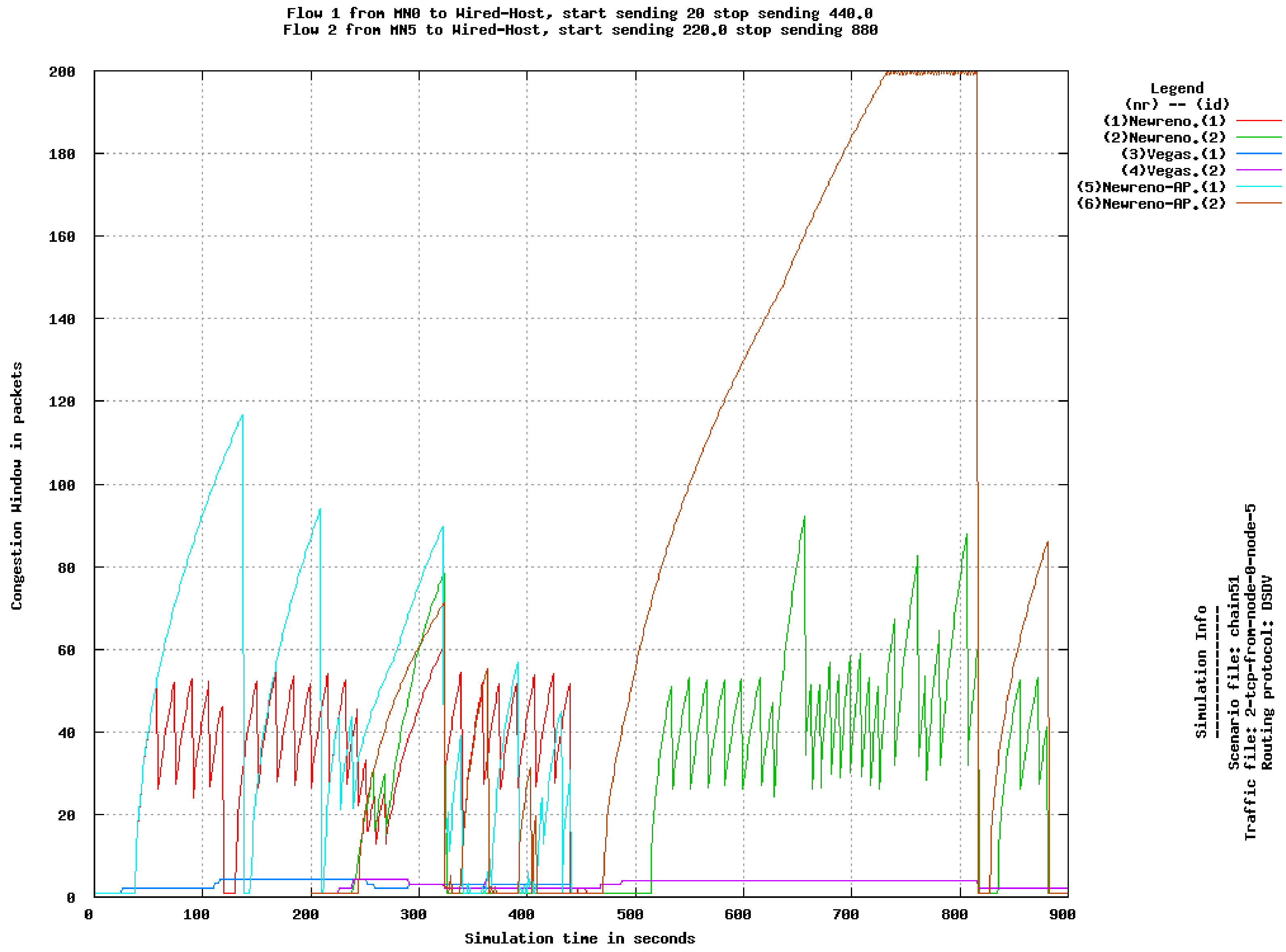
Flow 1 from MN5 to Wired-Host, start sending 20 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
20
40
60
80
100
120
140
160
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
Scenario file: chain51
Traffic file: 1-tcp-from-node-5
Routing protocol: AODVUU

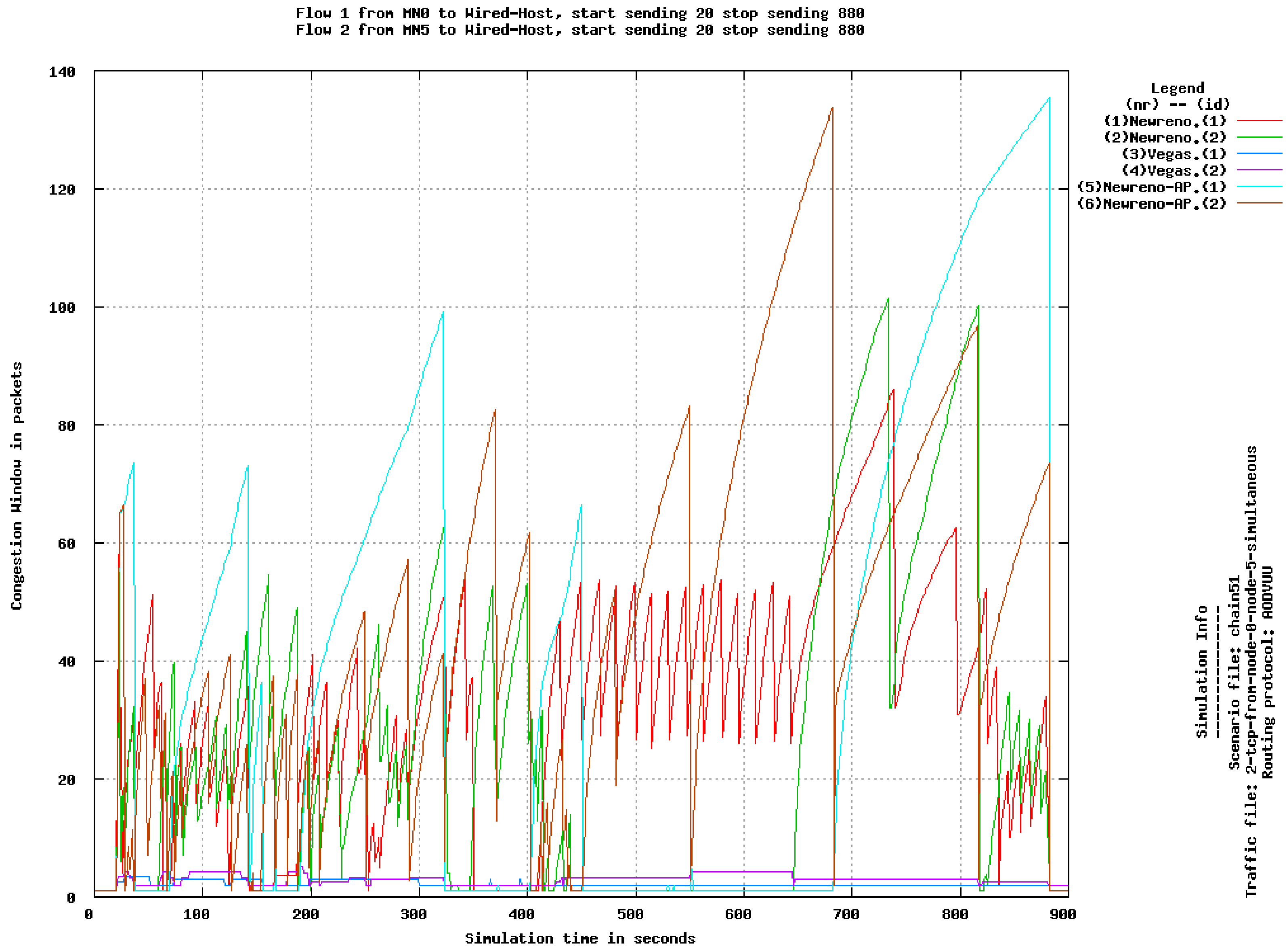


Flow 1 from MN5 to Wired-Host, start sending 20 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
20
40
60
80
100
120
140
160
180
200
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
---------------
Scenario file: chain51
Traffic file: 1-tcp-from-node-5
Routing protocol: DSDV

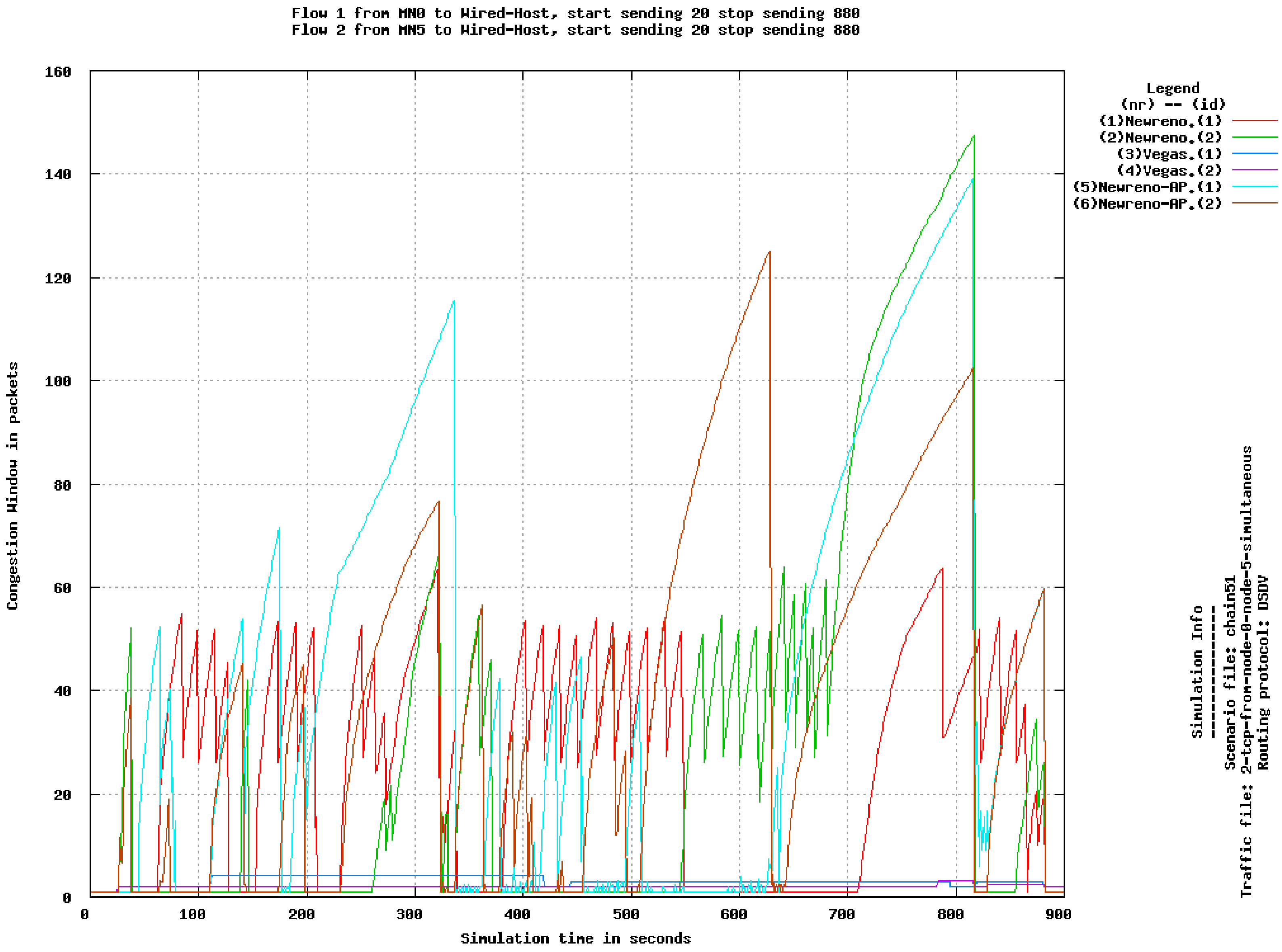


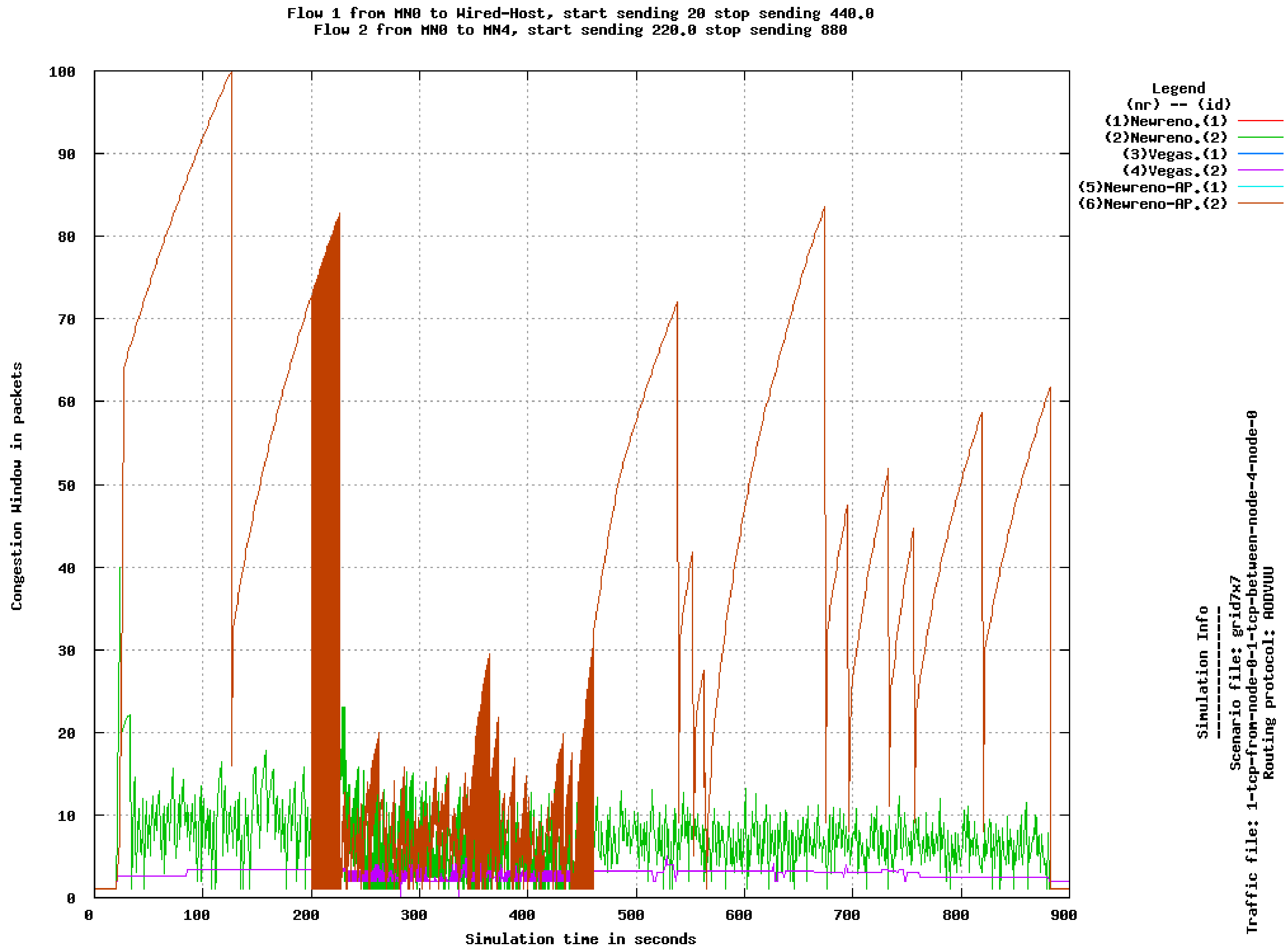
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN5 to Wired-Host, start sending 220.0 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
20
40
60
80
100
120
140
160
180
200
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain51
Traffic file: 2-tcp-from-node-0-node-5
Routing protocol: AODVUU

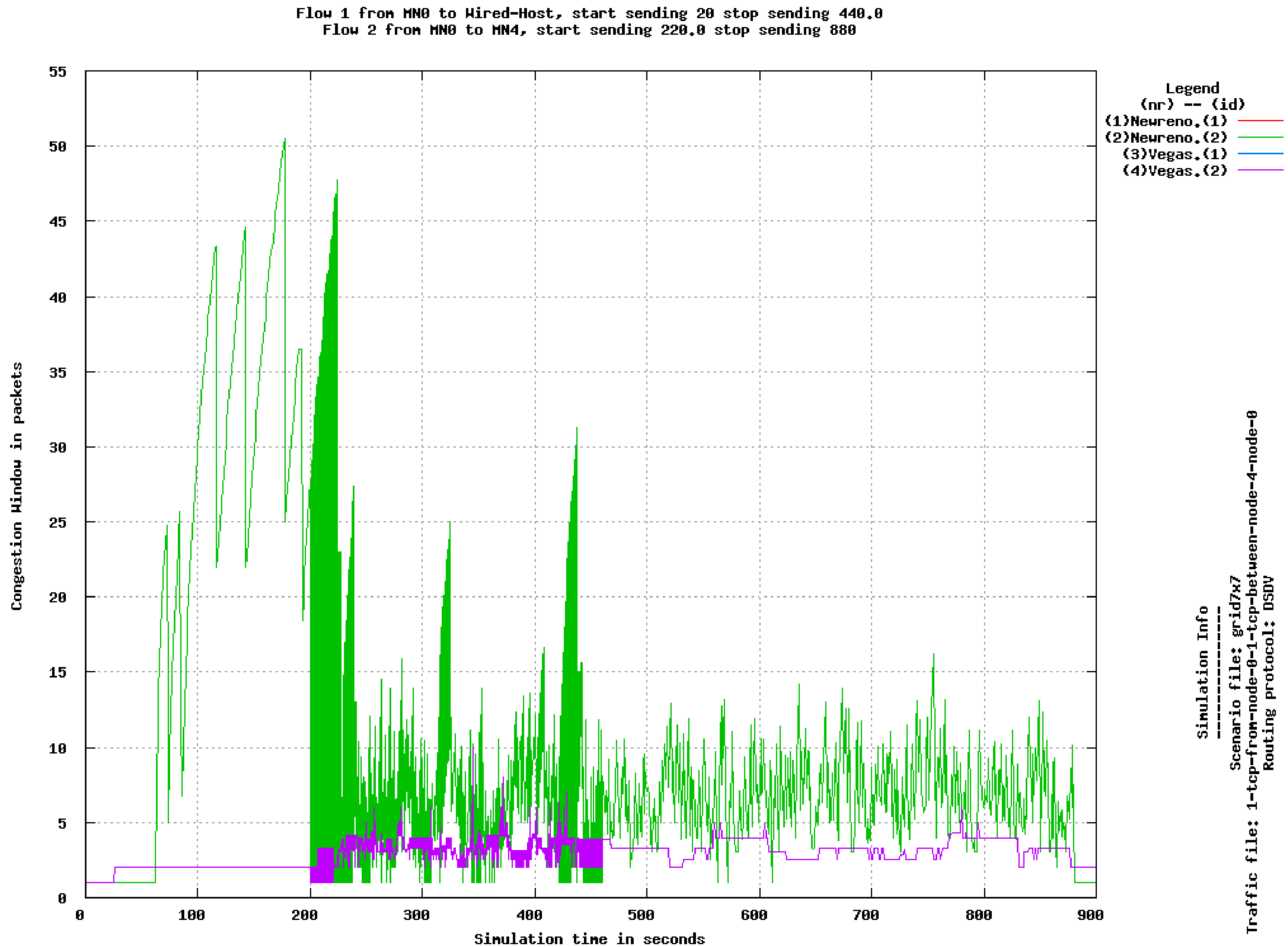

Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN5 to Wired-Host, start sending 220.0 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
20
40
60
80
100
120
140
160
180
200
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain51
Traffic file: 2-tcp-from-node-0-node-5
Routing protocol: DSDV



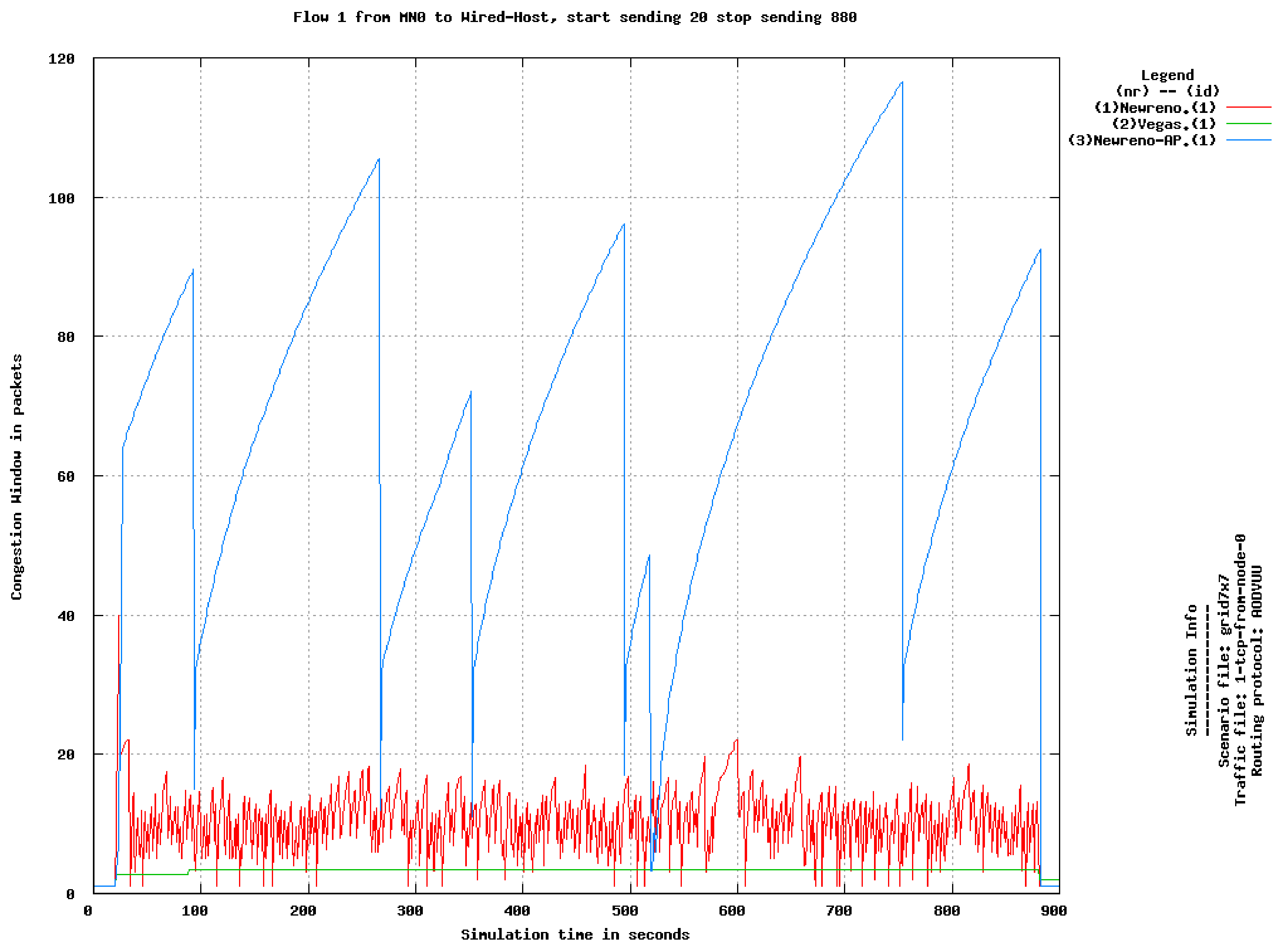
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN5 to Wired-Host, start sending 20 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
20
40
60
80
100
120
140
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno,(1)
(2)Newreno,(2)
(3)Vegas,(1)
(4)Vegas,(2)
(5)Newreno-AP,(1)
(6)Newreno-AP,(2)
Simulation Info
---------------
Scenario file: chain51
Traffic file: 2-tcp-from-node-0-node-5-simultaneous
Routing protocol: AODVUU


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN5 to Wired-Host, start sending 20 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
20
40
60
80
100
120
140
160
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain51
Traffic file: 2-tcp-from-node-0-node-5-simultaneous
Routing protocol: DSDV

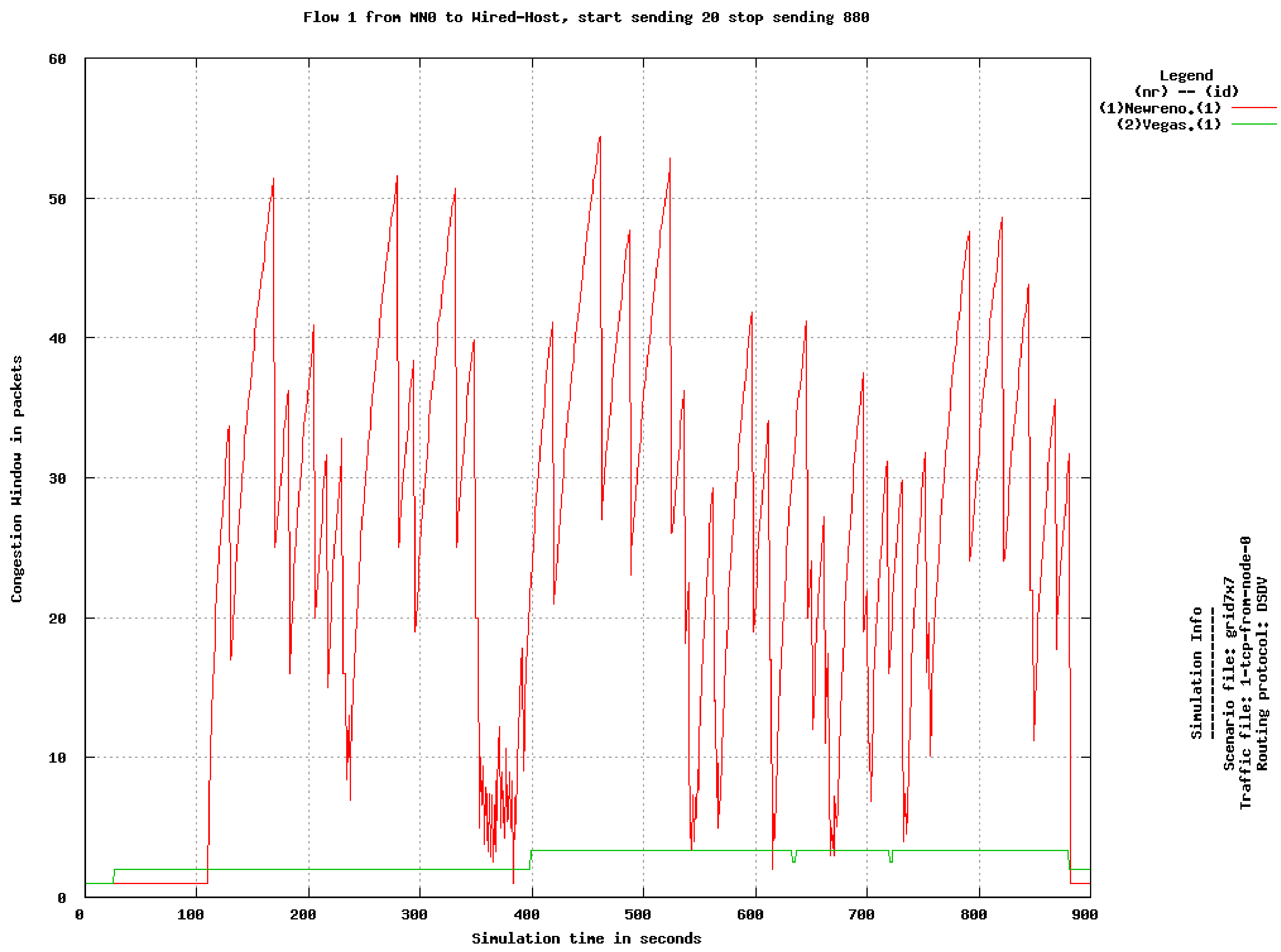

Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN0 to MN4, start sending 220.0 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
10
20
30
40
50
60
70
80
90
100
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: grid7x7
Traffic file: 1-tcp-from-node-0-1-tcp-between-node-4-node-0
Routing protocol: AODVUU



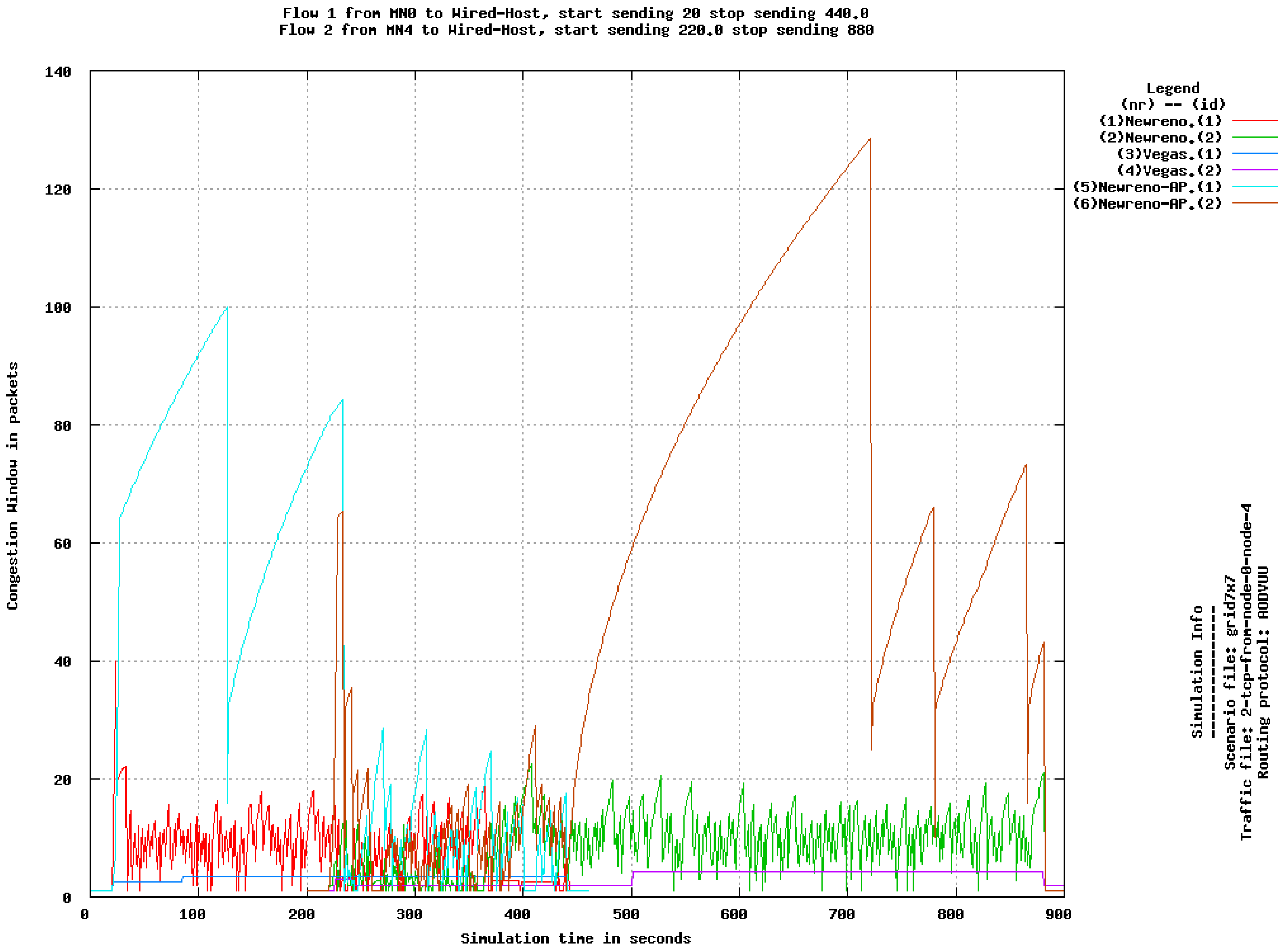
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN0 to MN4, start sending 220.0 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
5
10
15
20
25
30
35
40
45
50
55
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
Simulation Info
Scenario file: grid7x7
Traffic file: 1-tcp-from-node-0-1-tcp-between-node-4-node-0
Routing protocol: DSDV



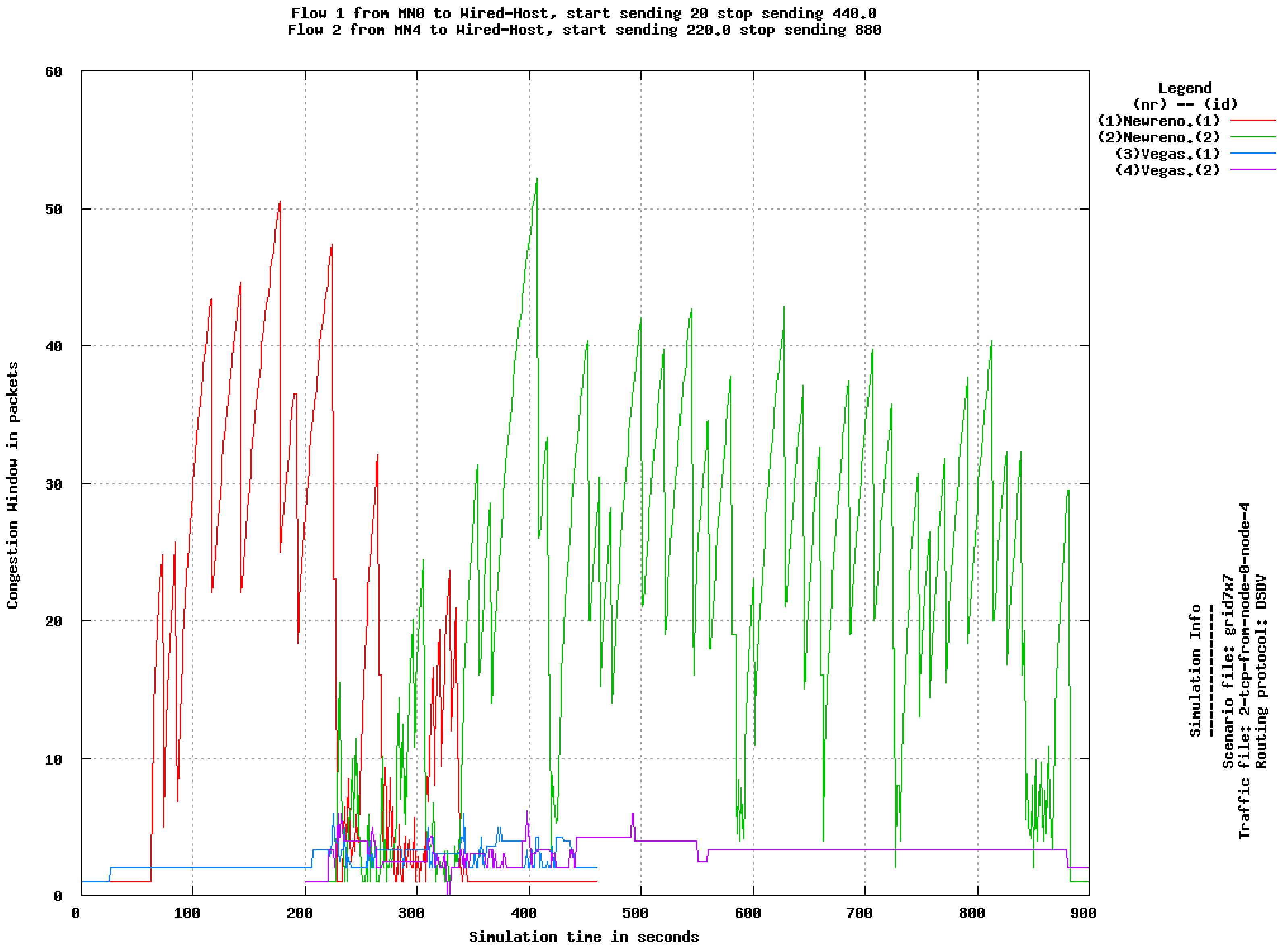
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
20
40
60
80
100
120
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno,(1)
(2)Vegas,(1)
(3)Newreno-AP,(1)
Simulation Info
---------------
Scenario file: grid7x7
Traffic file: 1-tcp-from-node-0
Routing protocol: AODVUU



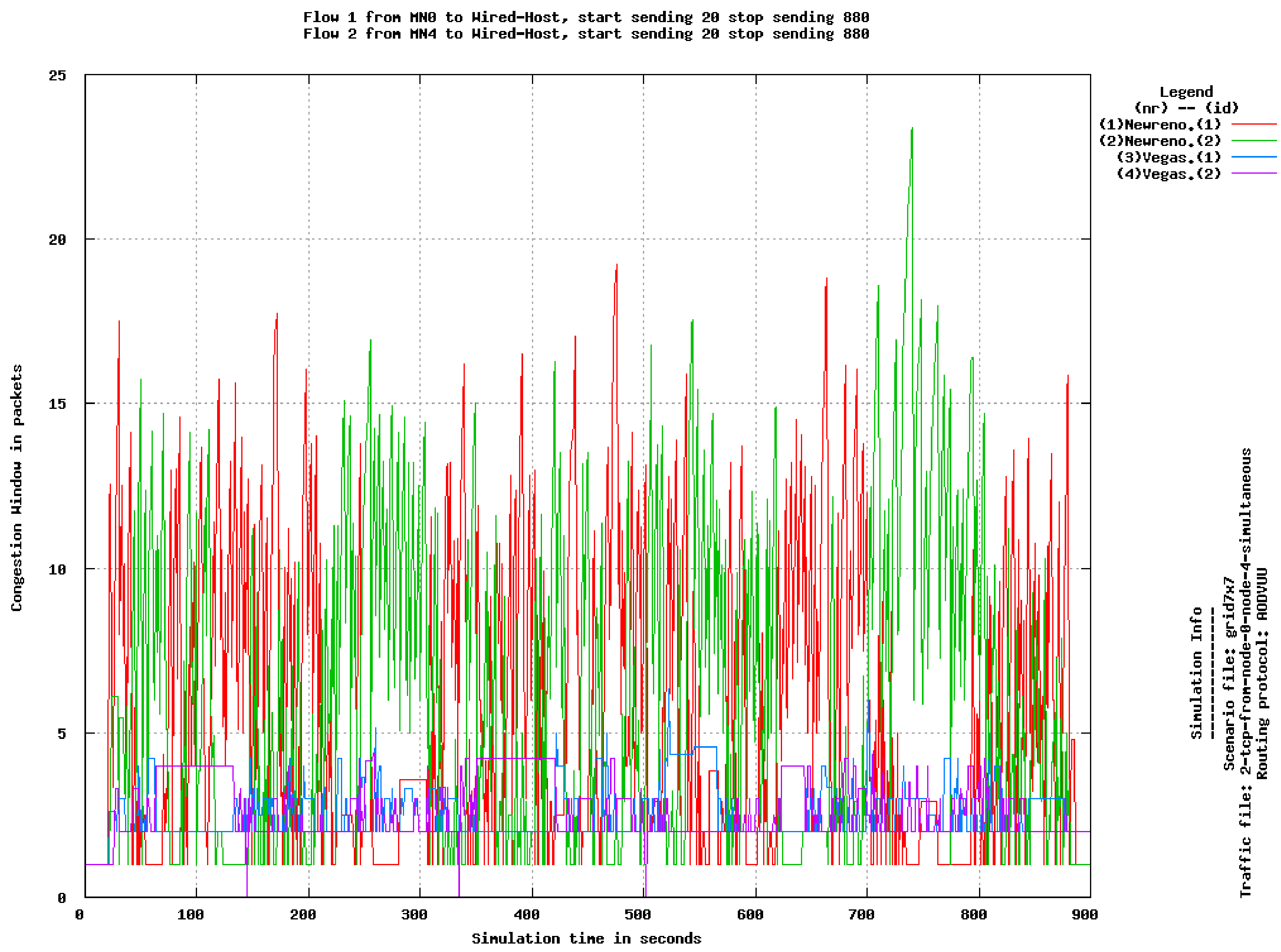
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
10
20
30
40
50
60
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno,(1)
(2)Vegas,(1)
Simulation Info
Scenario file: grid7x7
Traffic file: 1-tcp-from-node-0
Routing protocol: DSDV

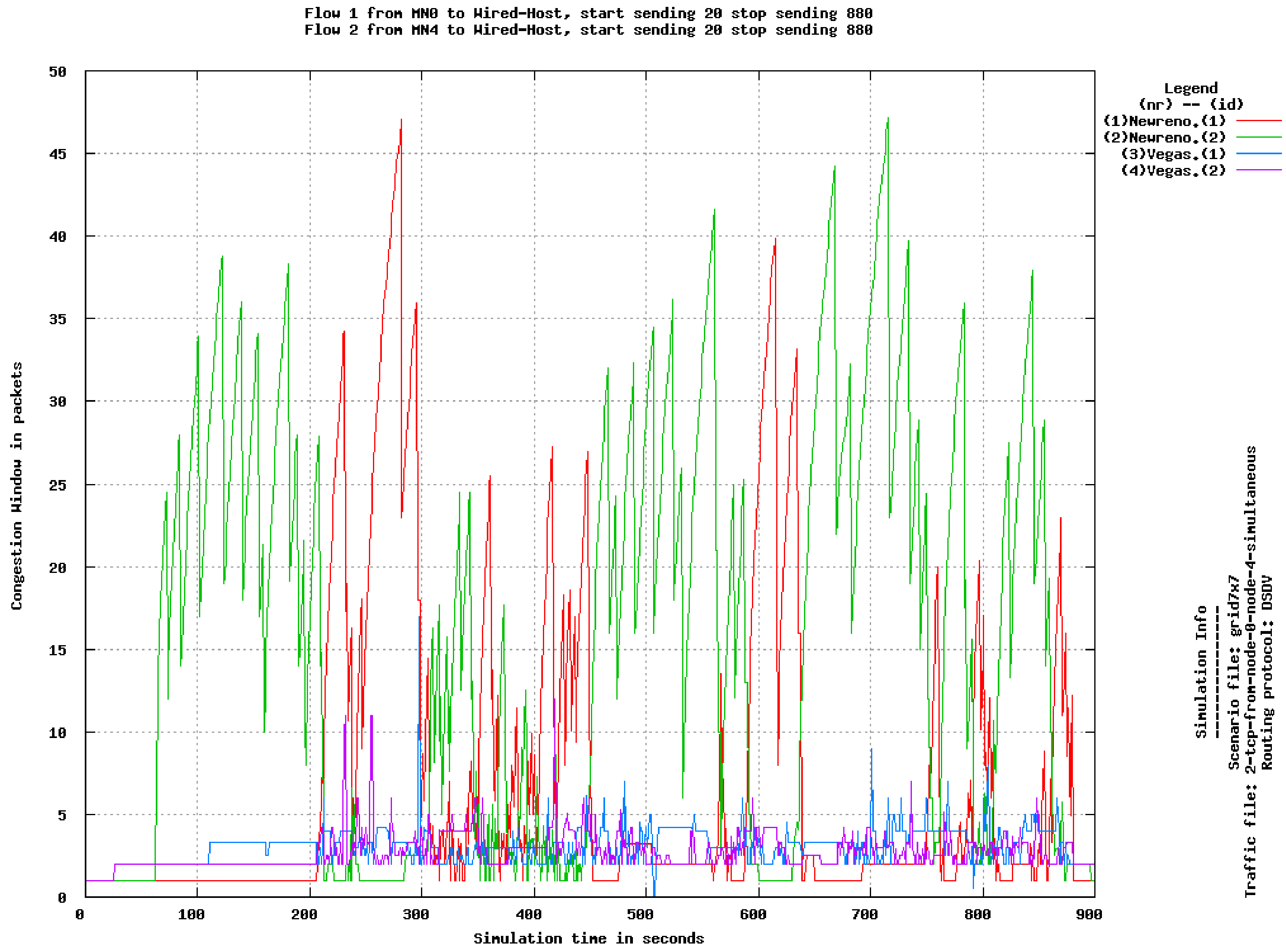


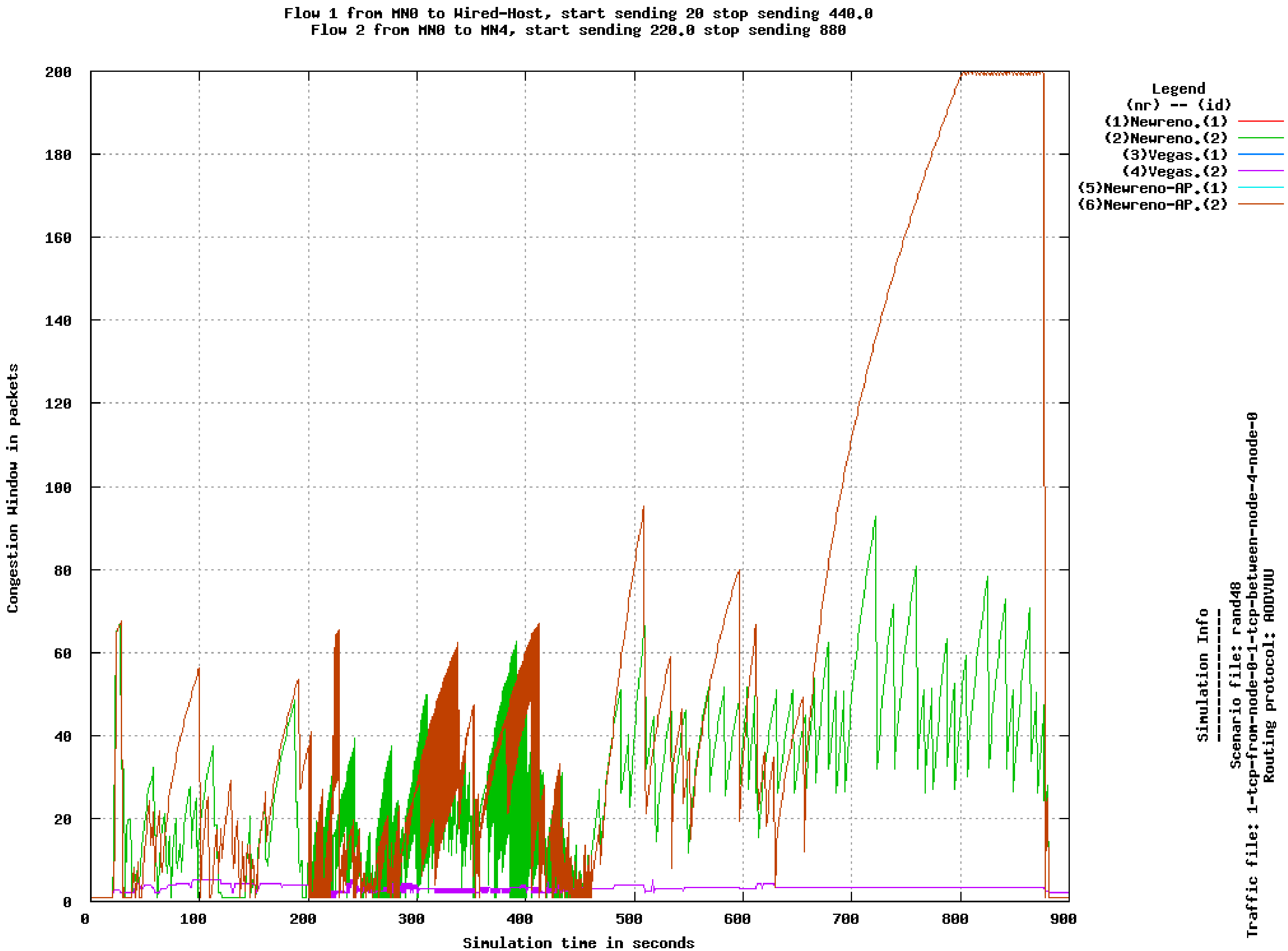
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN4 to Wired-Host, start sending 220.0 stop sending 880
Congestion Window in packets
Simulation time in seconds
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: grid7x7
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: AODVUU



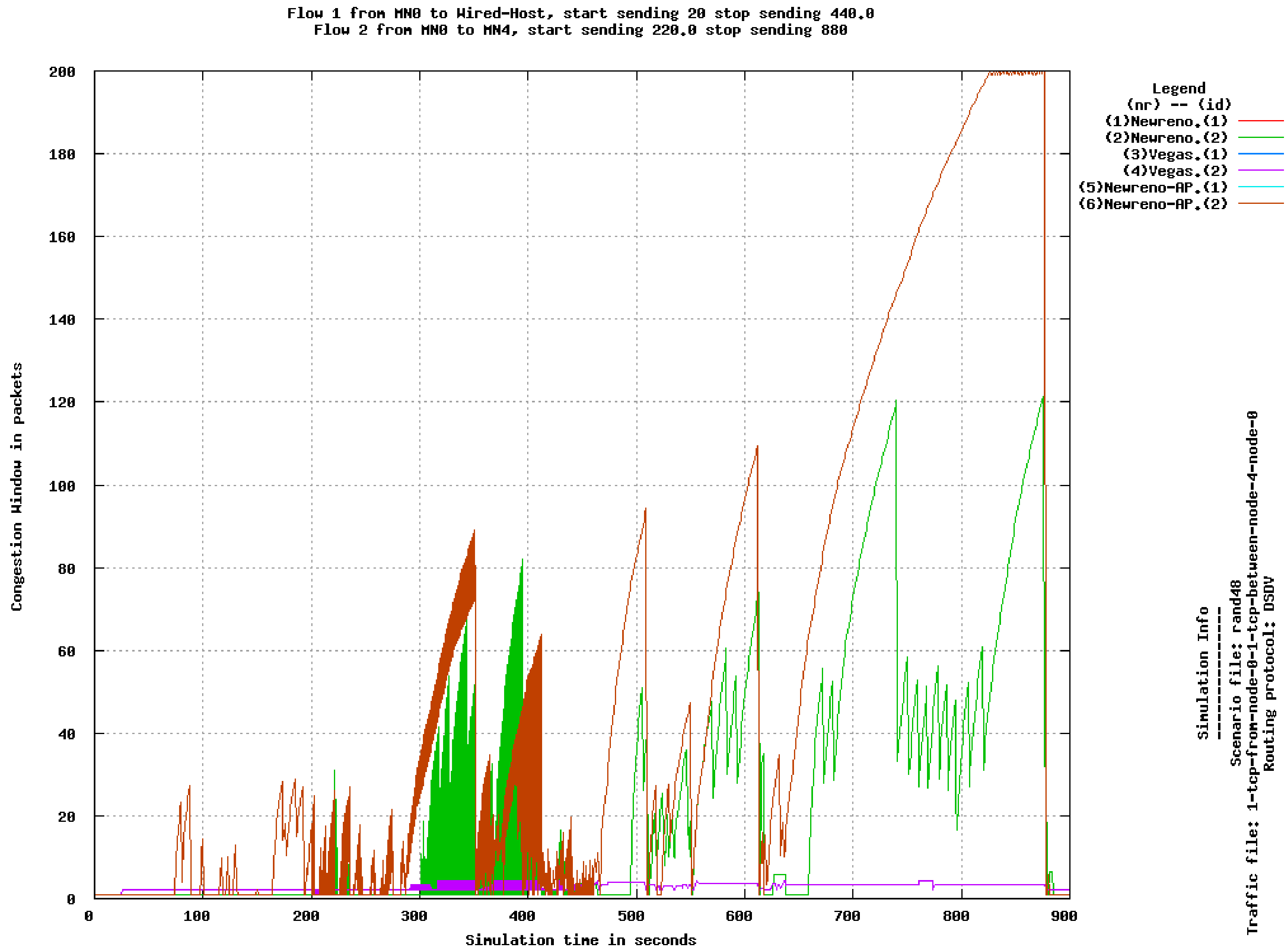
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN4 to Wired-Host, start sending 220.0 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
10
20
30
40
50
60
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
Simulation Info
Scenario file: grid7x7
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: DSDV

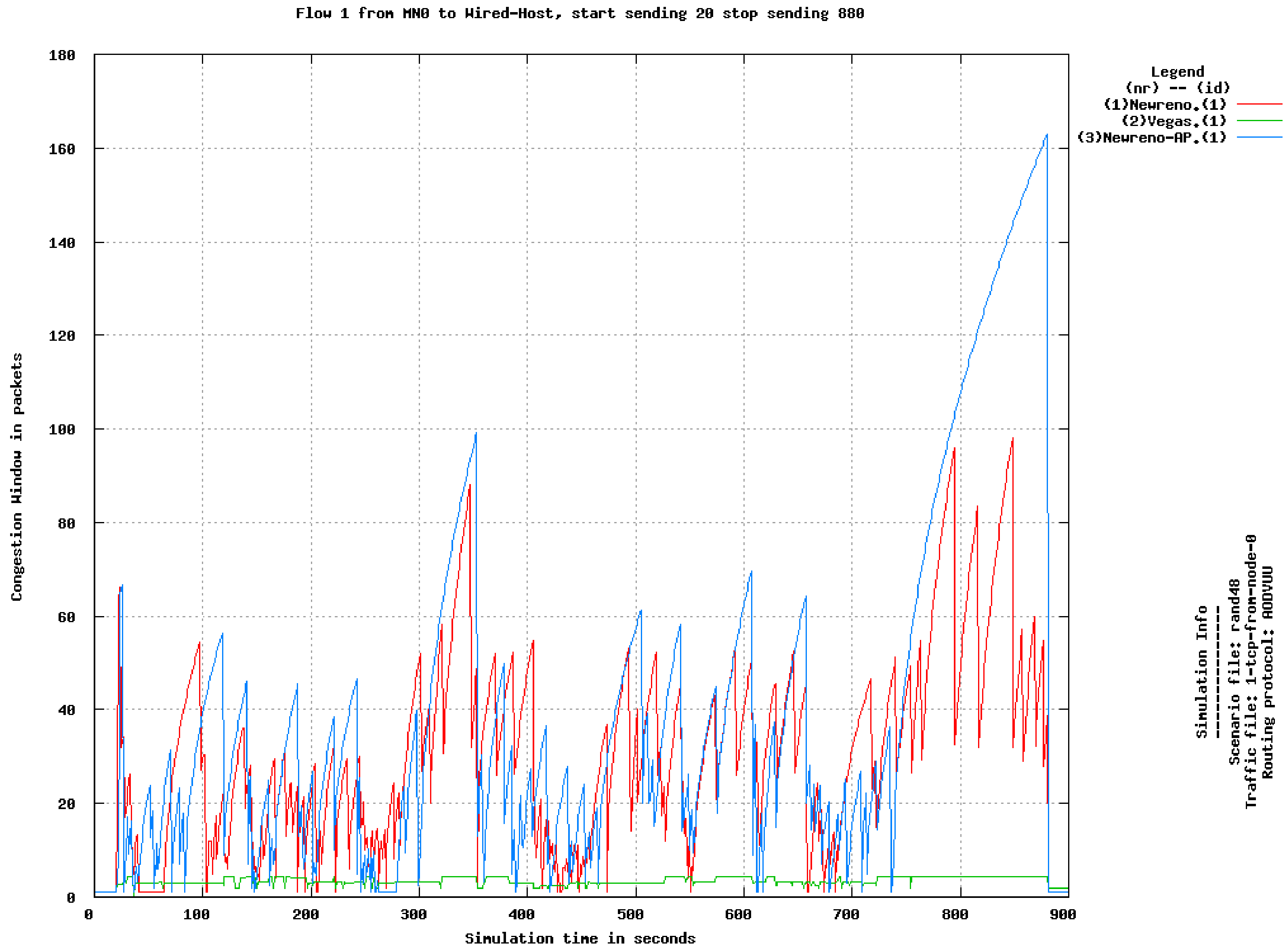

Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN4 to Wired-Host, start sending 20 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
5
10
15
20
25
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno,(1)
(2)Newreno,(2)
(3)Vegas,(1)
(4)Vegas,(2)
Simulation Info
---------------
Scenario file: grid7x7
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: AODVUU


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN4 to Wired-Host, start sending 20 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
5
10
15
20
25
30
35
40
45
50
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno,(1)
(2)Newreno,(2)
(3)Vegas,(1)
(4)Vegas,(2)
Simulation Info
---------------
Scenario file: grid7x7
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: DSDV

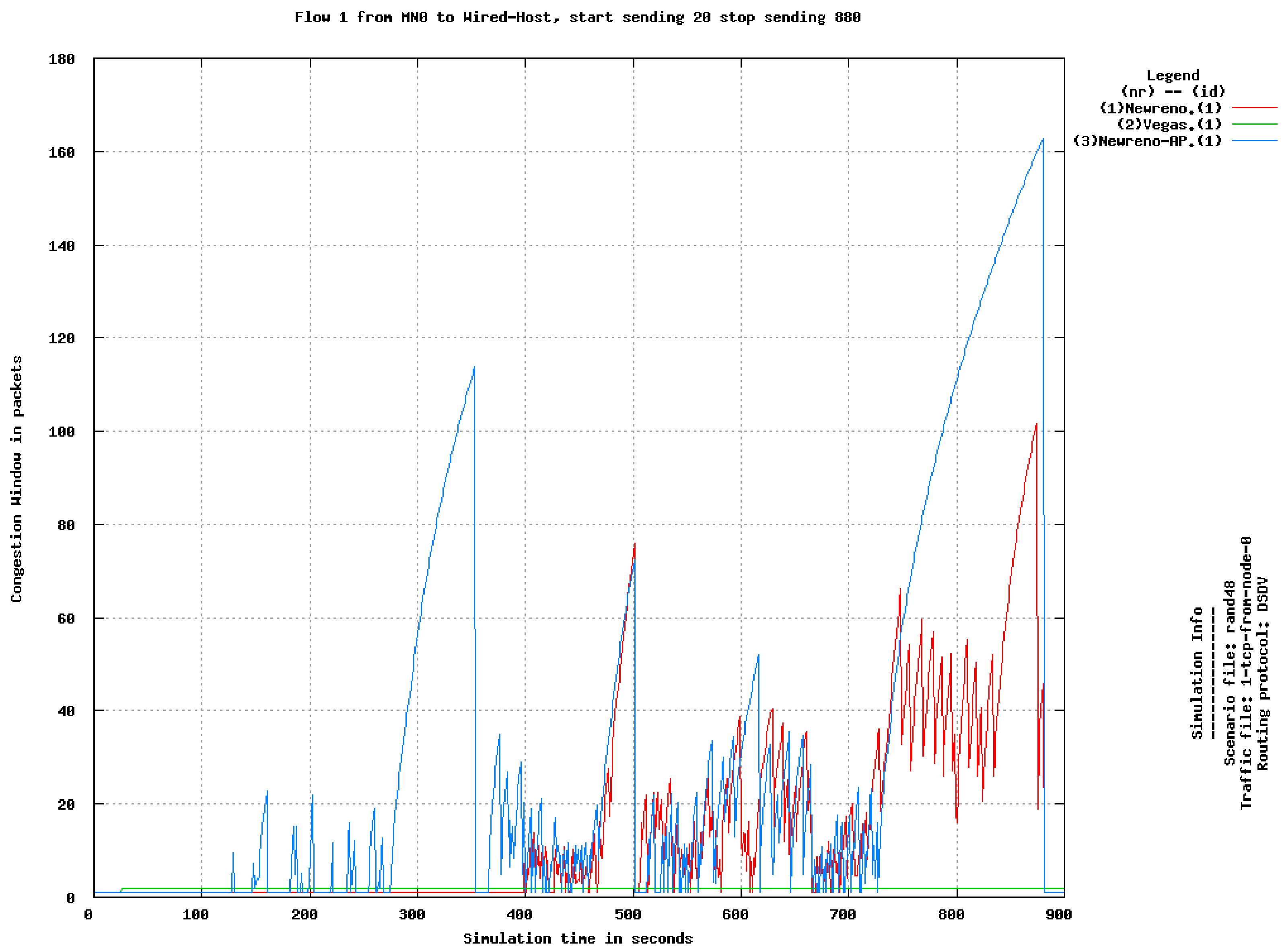


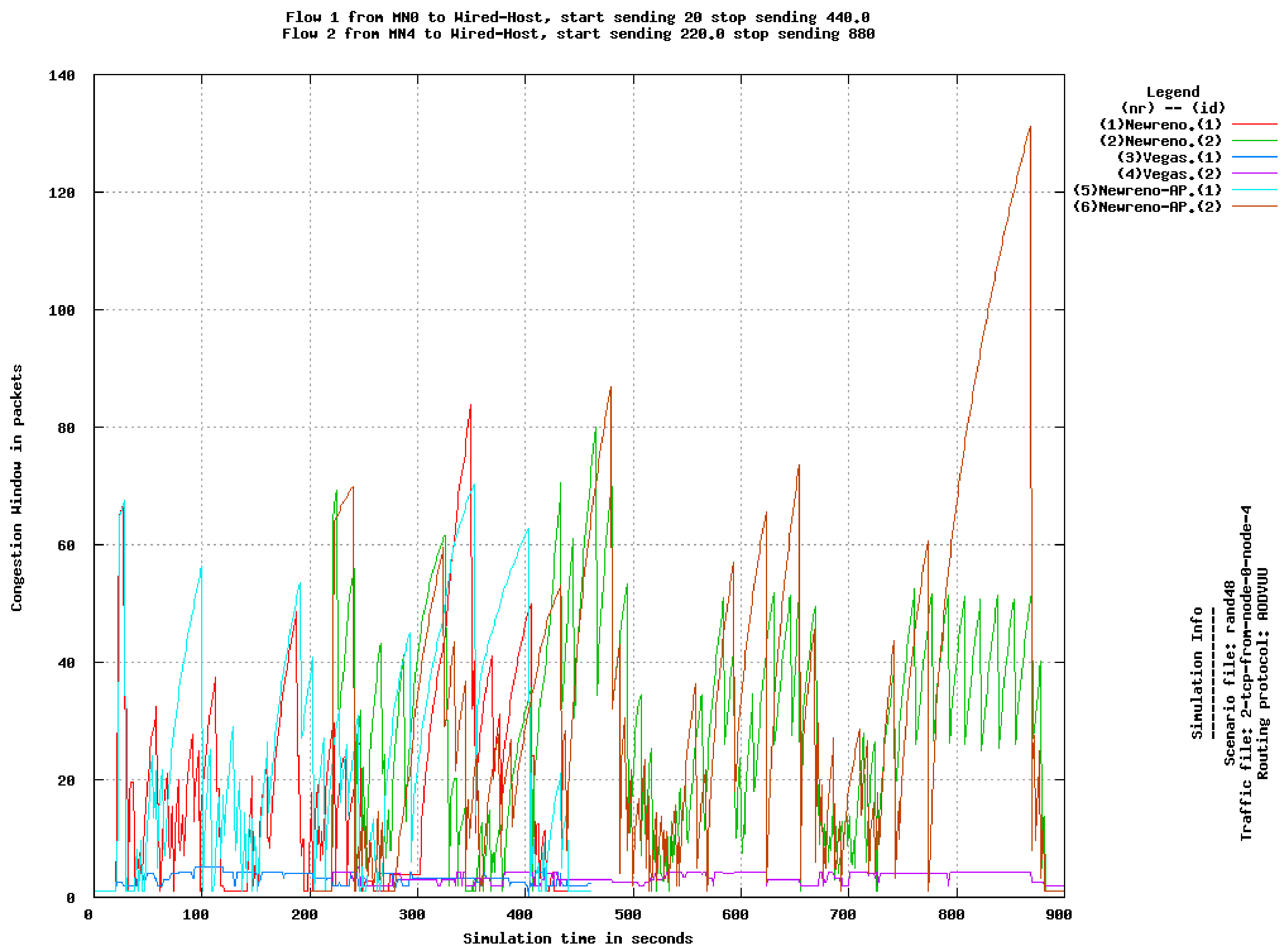
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN0 to MN4, start sending 220.0 stop sending 880
Congestion Window in packets
Simulation time in seconds
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: rand40
Traffic file: 1-tcp-from-node-0-1-tcp-between-node-4-node-0
Routing protocol: AODVUU


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN0 to MN4, start sending 220.0 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
20
40
60
80
100
120
140
160
180
200
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
----------------
Scenario file: rand48
Traffic file: 1-tcp-from-node-0-1-tcp-between-node-4-node-0
Routing protocol: DSDV

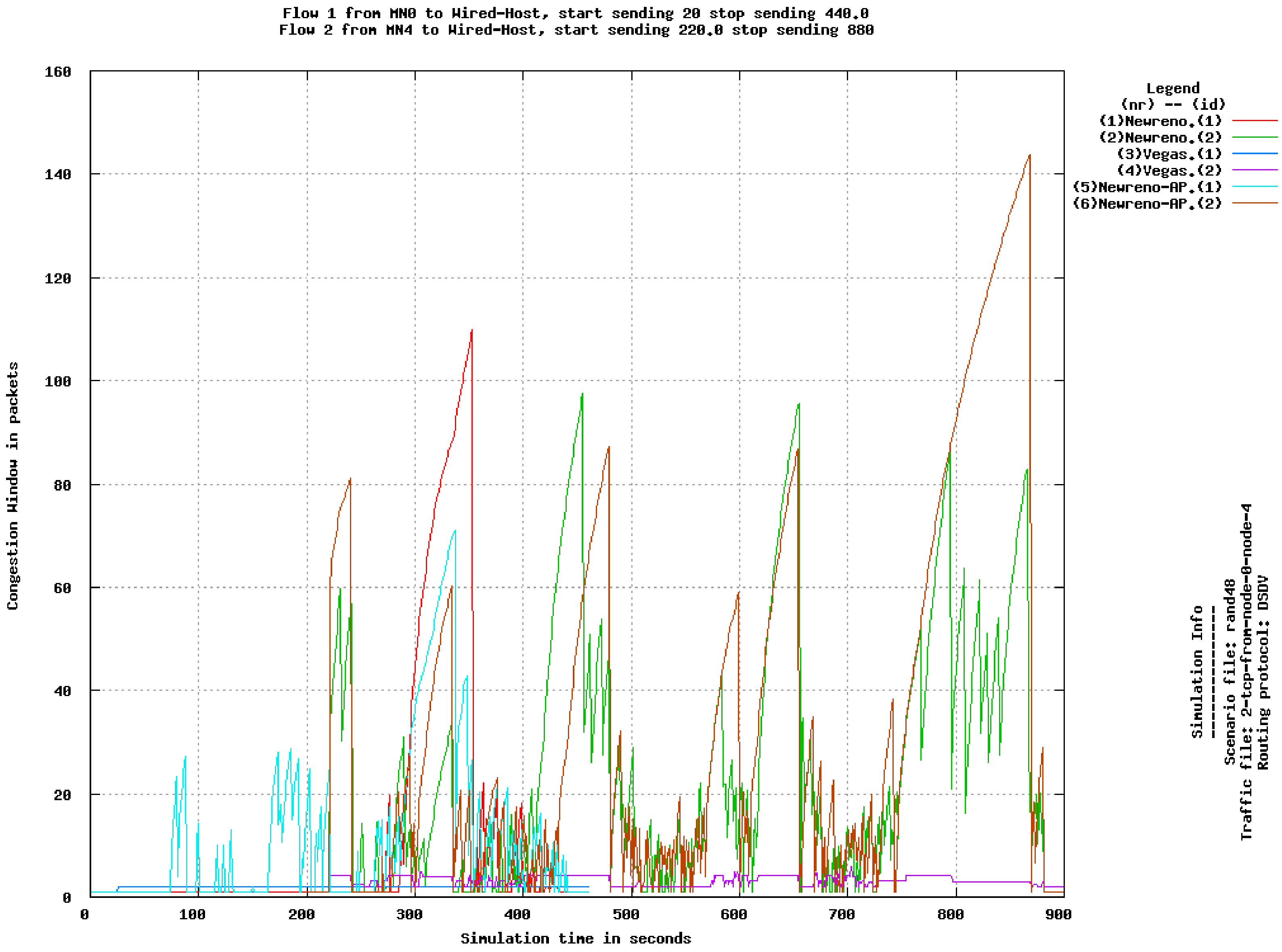


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
20
40
60
80
100
120
140
160
180
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
---------------
Scenario file: rand48
Traffic file: 1-tcp-from-node-0
Routing protocol: AODVUU

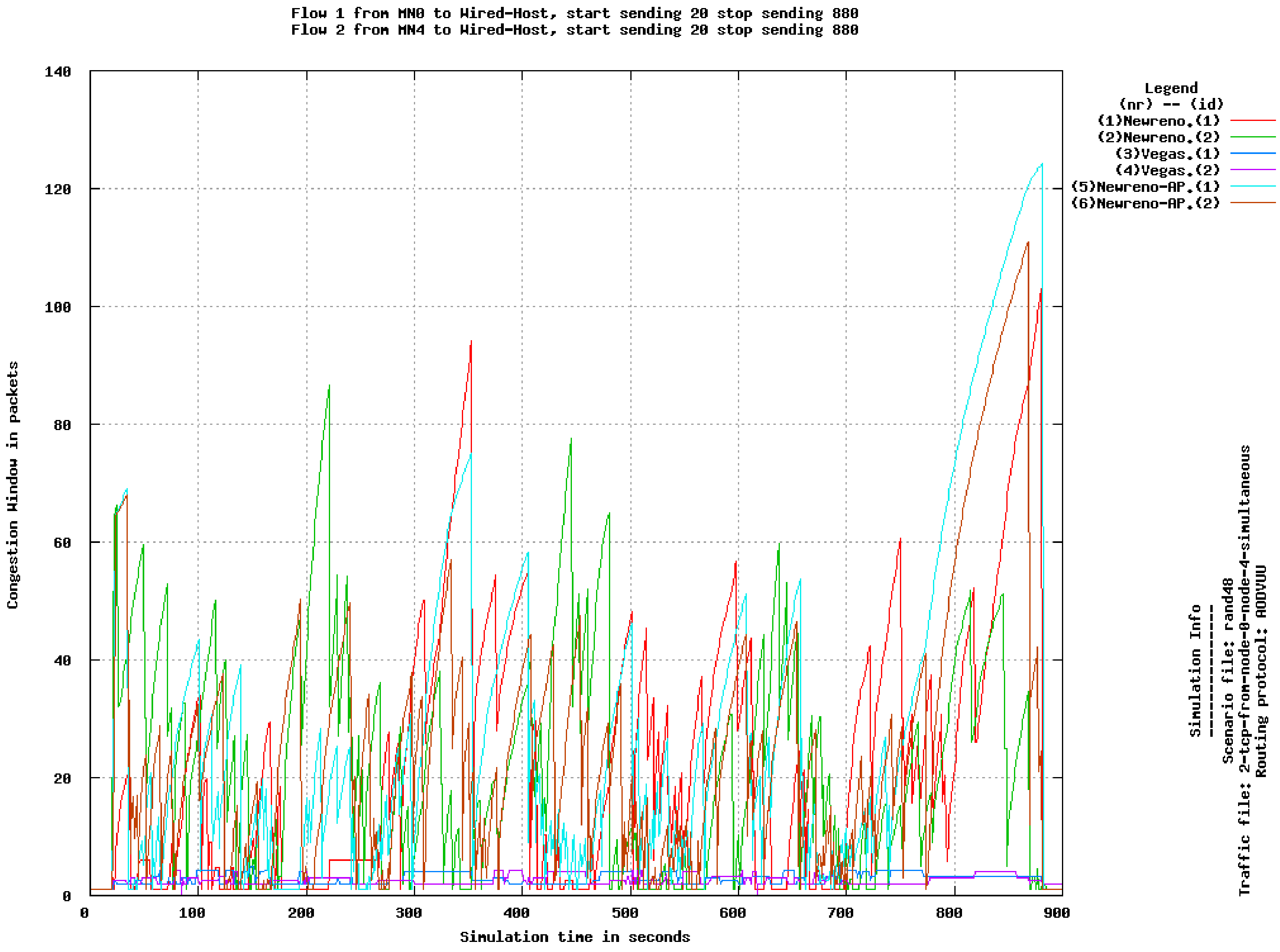

Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
20
40
60
80
100
120
140
160
180
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
---------------
Scenario file: rand48
Traffic file: 1-tcp-from-node-0
Routing protocol: DSDV



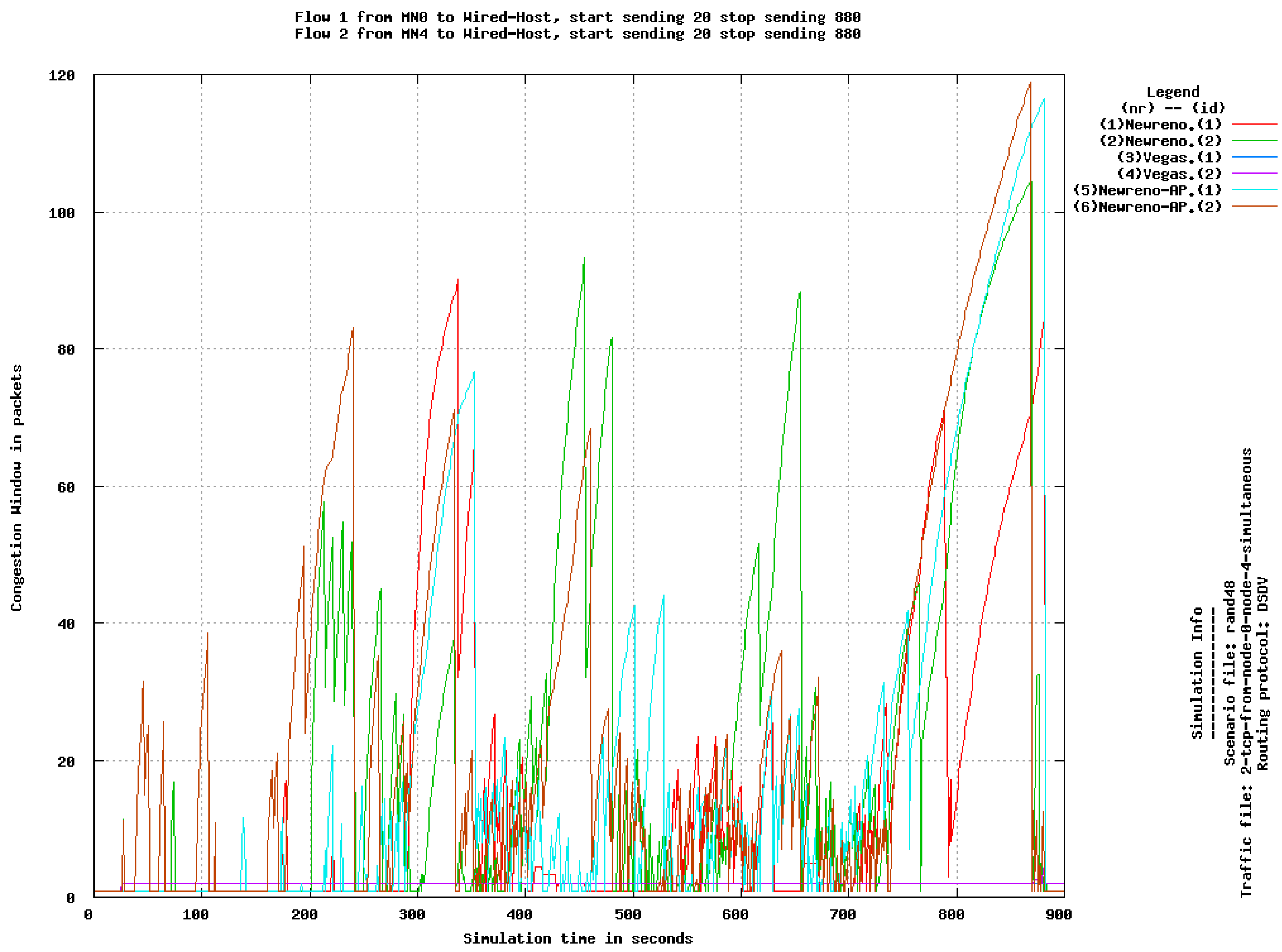
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN4 to Wired-Host, start sending 220.0 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
20
40
60
80
100
120
140
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: rand40
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: AODVUU



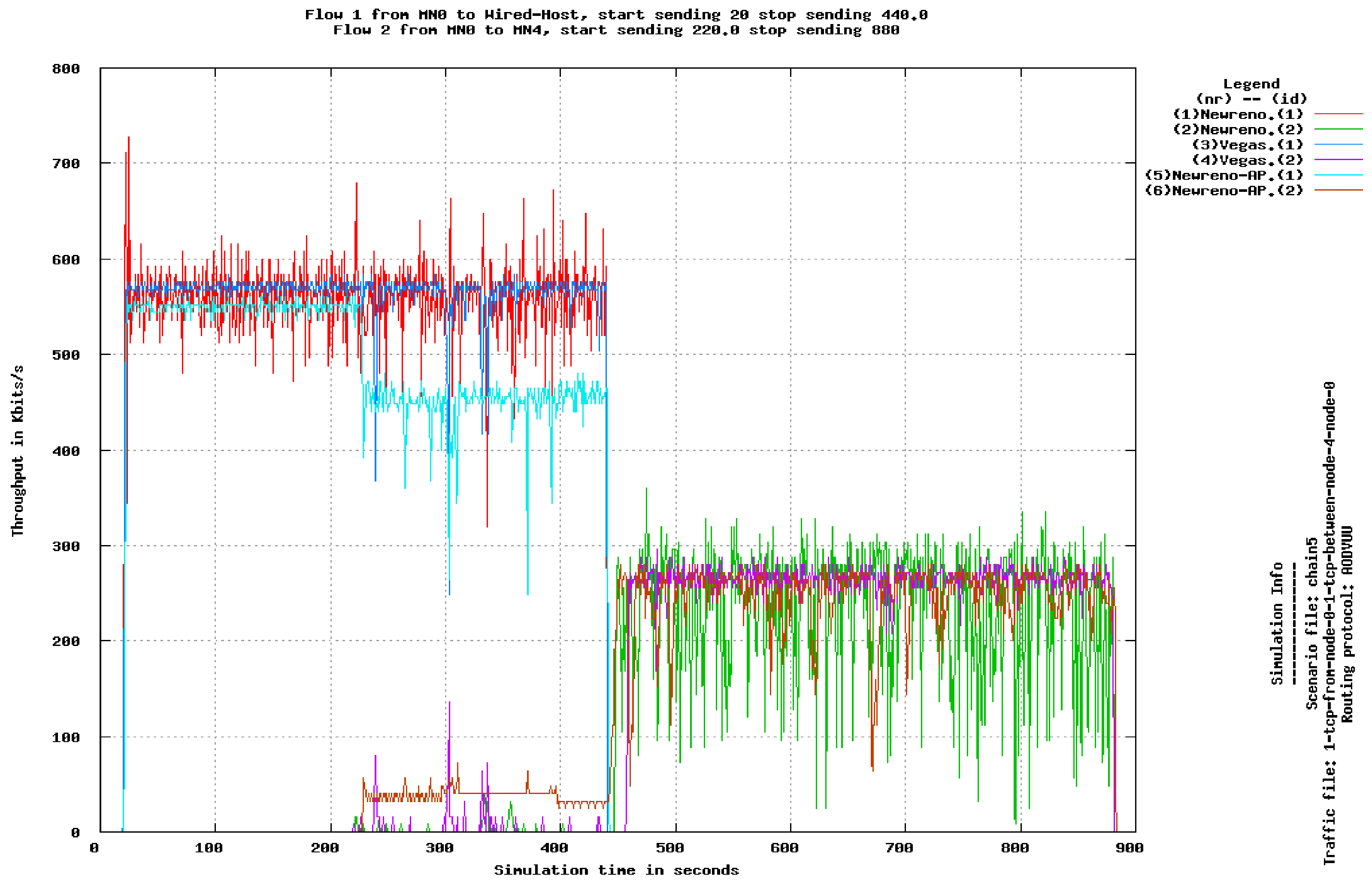
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN4 to Wired-Host, start sending 220.0 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
20
40
60
80
100
120
140
160
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
---------------
Scenario file: rand40
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: DSDV



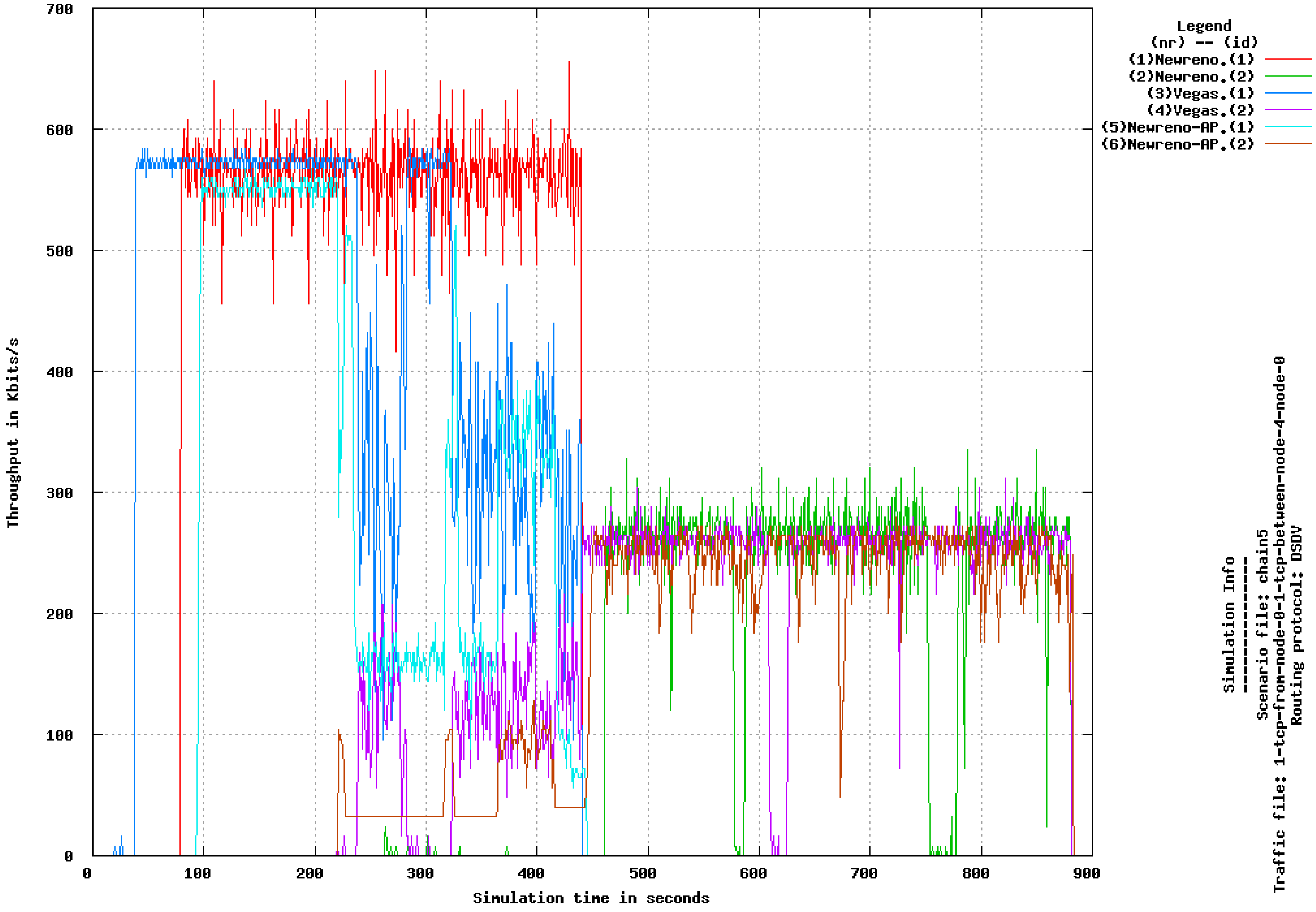
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN4 to Wired-Host, start sending 20 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
20
40
60
80
100
120
140
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno,(1)
(2)Newreno,(2)
(3)Vegas,(1)
(4)Vegas,(2)
(5)Newreno-AP,(1)
(6)Newreno-AP,(2)
Simulation Info
Scenario file: rand48
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: AODVUU

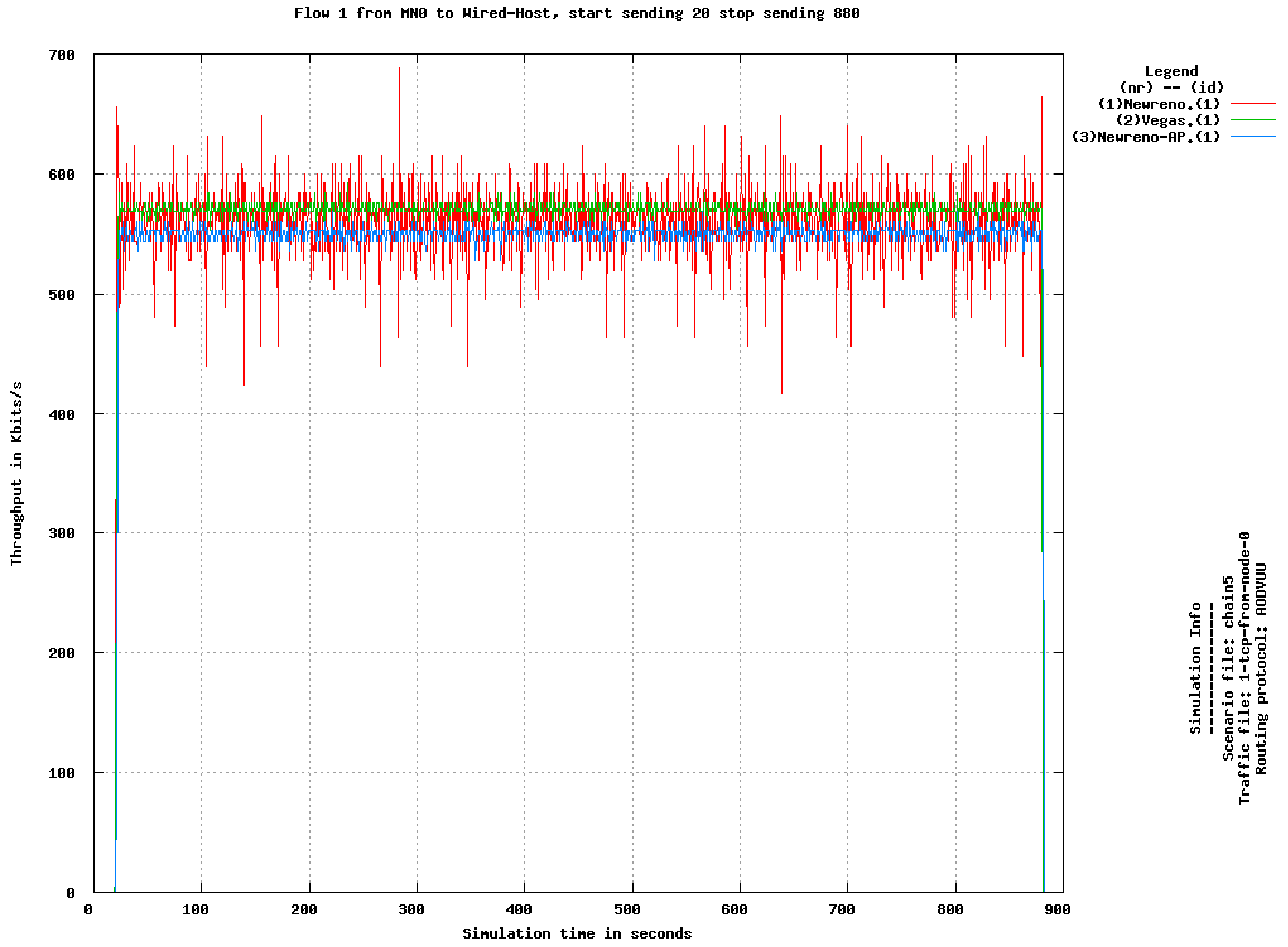

Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN4 to Wired-Host, start sending 20 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
20
40
60
80
100
120
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno,(1)
(2)Newreno,(2)
(3)Vegas,(1)
(4)Vegas,(2)
(5)Newreno-AP,(1)
(6)Newreno-AP,(2)
Simulation Info
---------------
Scenario file: rand48
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: DSDV

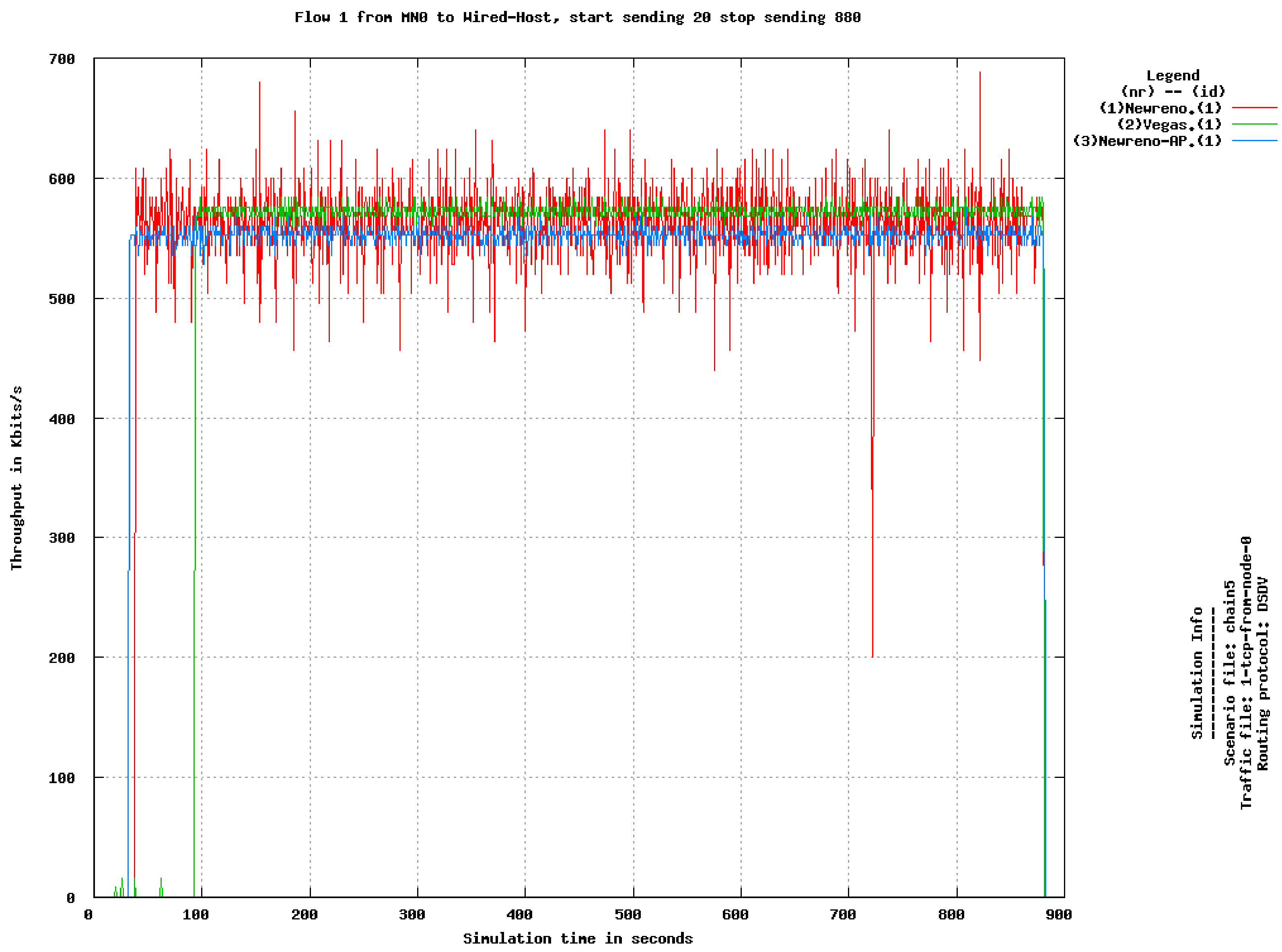
### G.4.2 Throughput



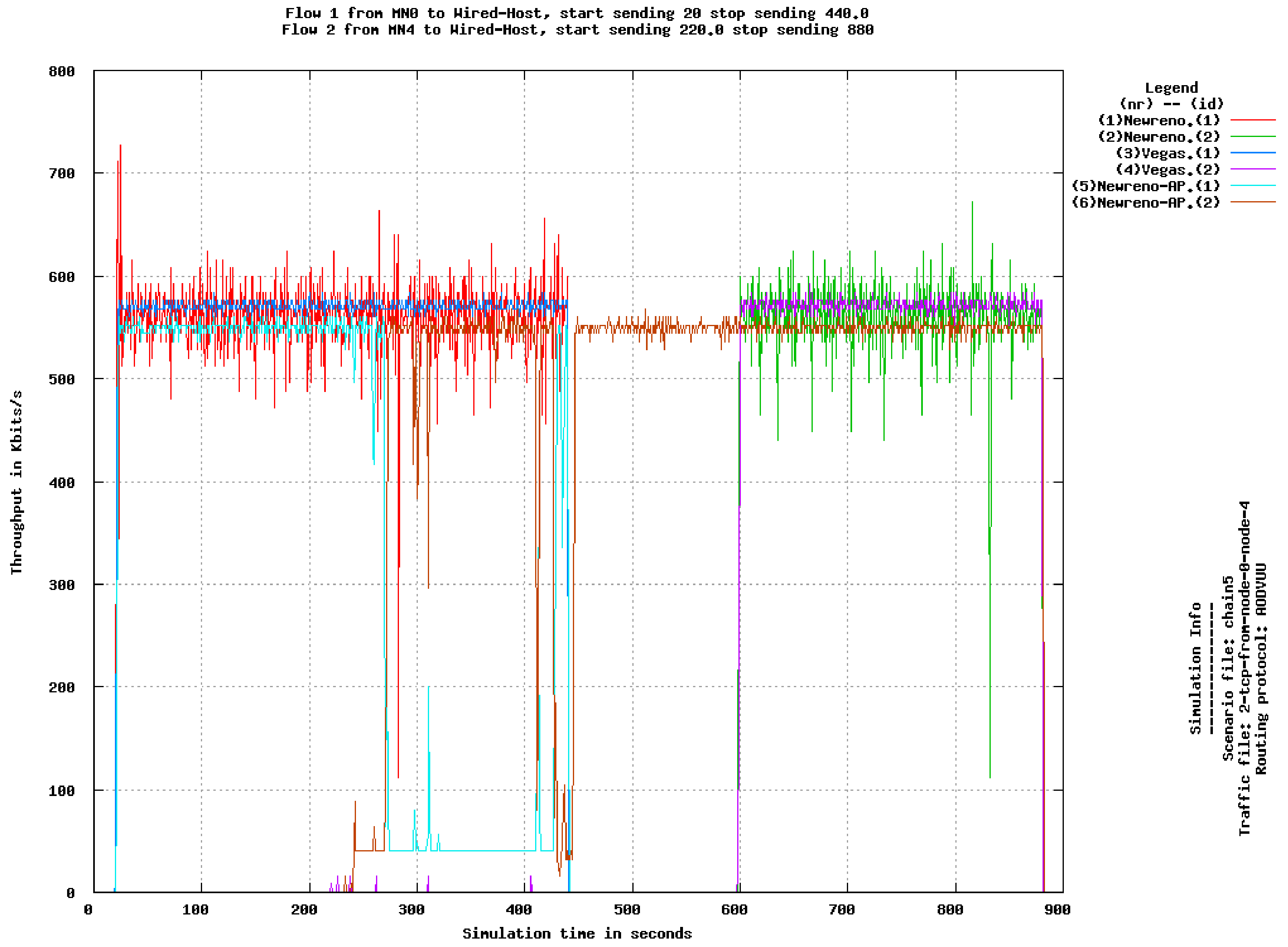
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN0 to MN4, start sending 220.0 stop sending 880



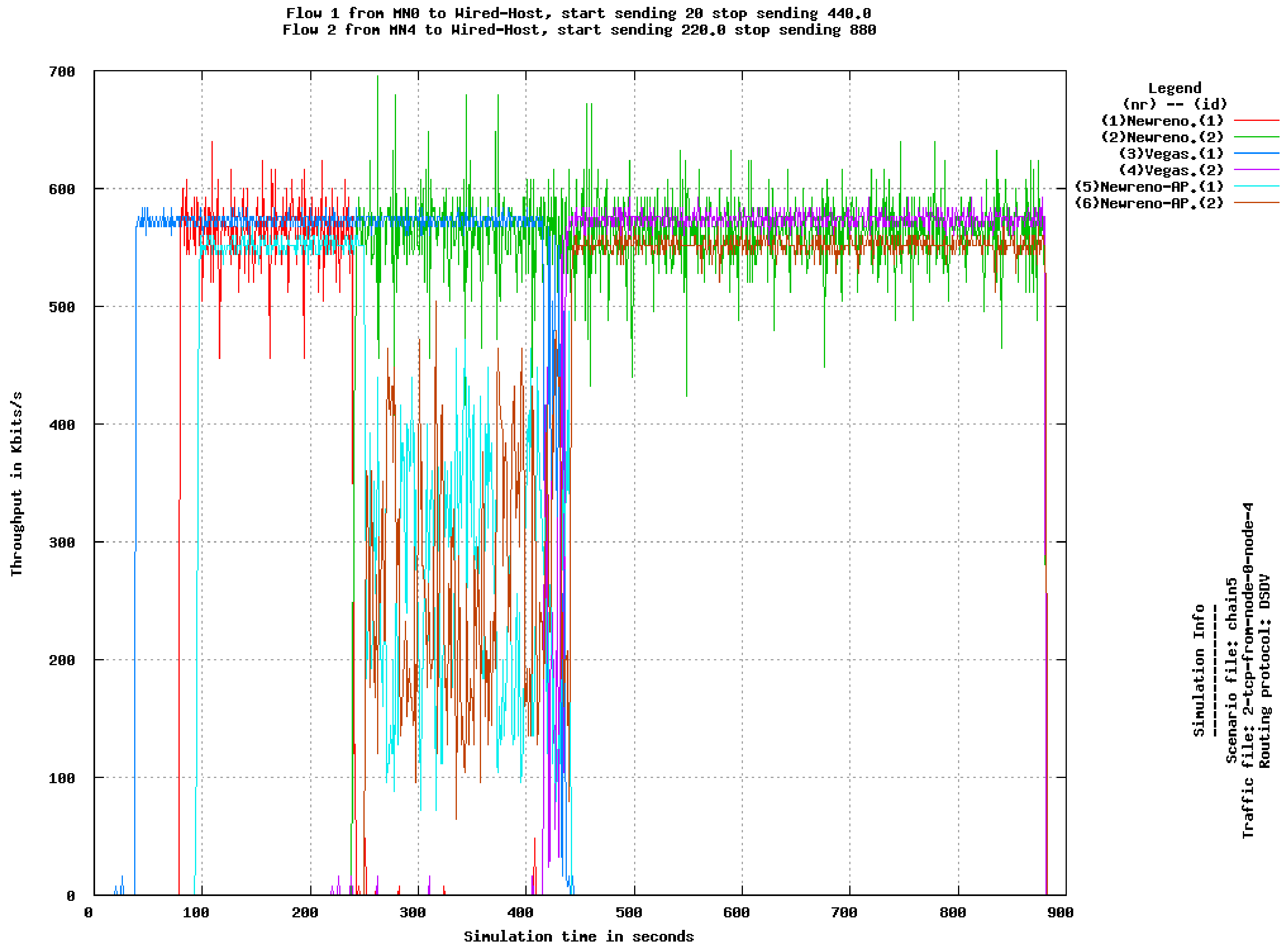

Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
Scenario file: chain5
Traffic file: 1-tcp-from-node-0
Routing protocol: AODVUU

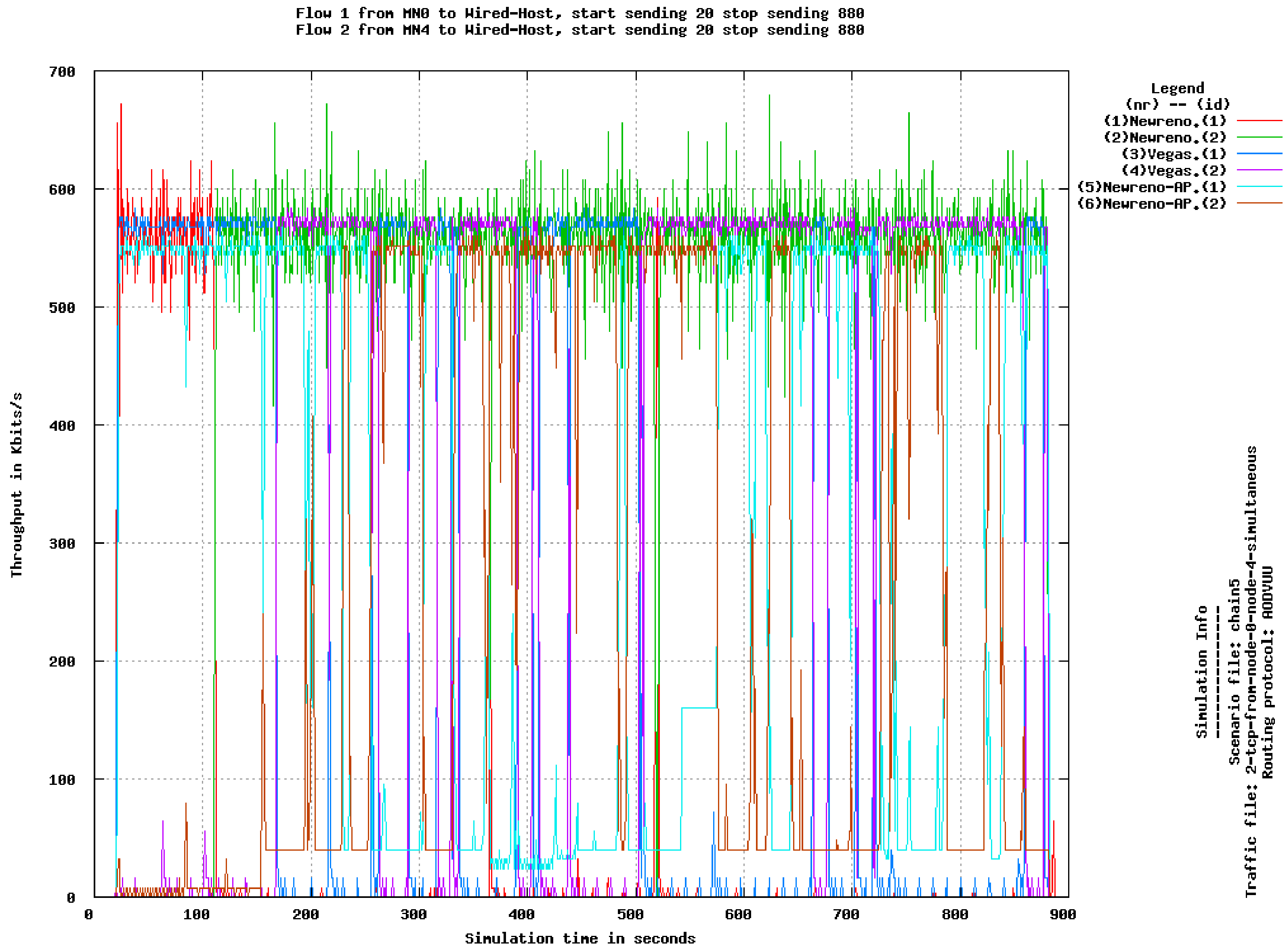


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
Scenario file: chain5
Traffic file: 1-tcp-from-node-0
Routing protocol: DSDV

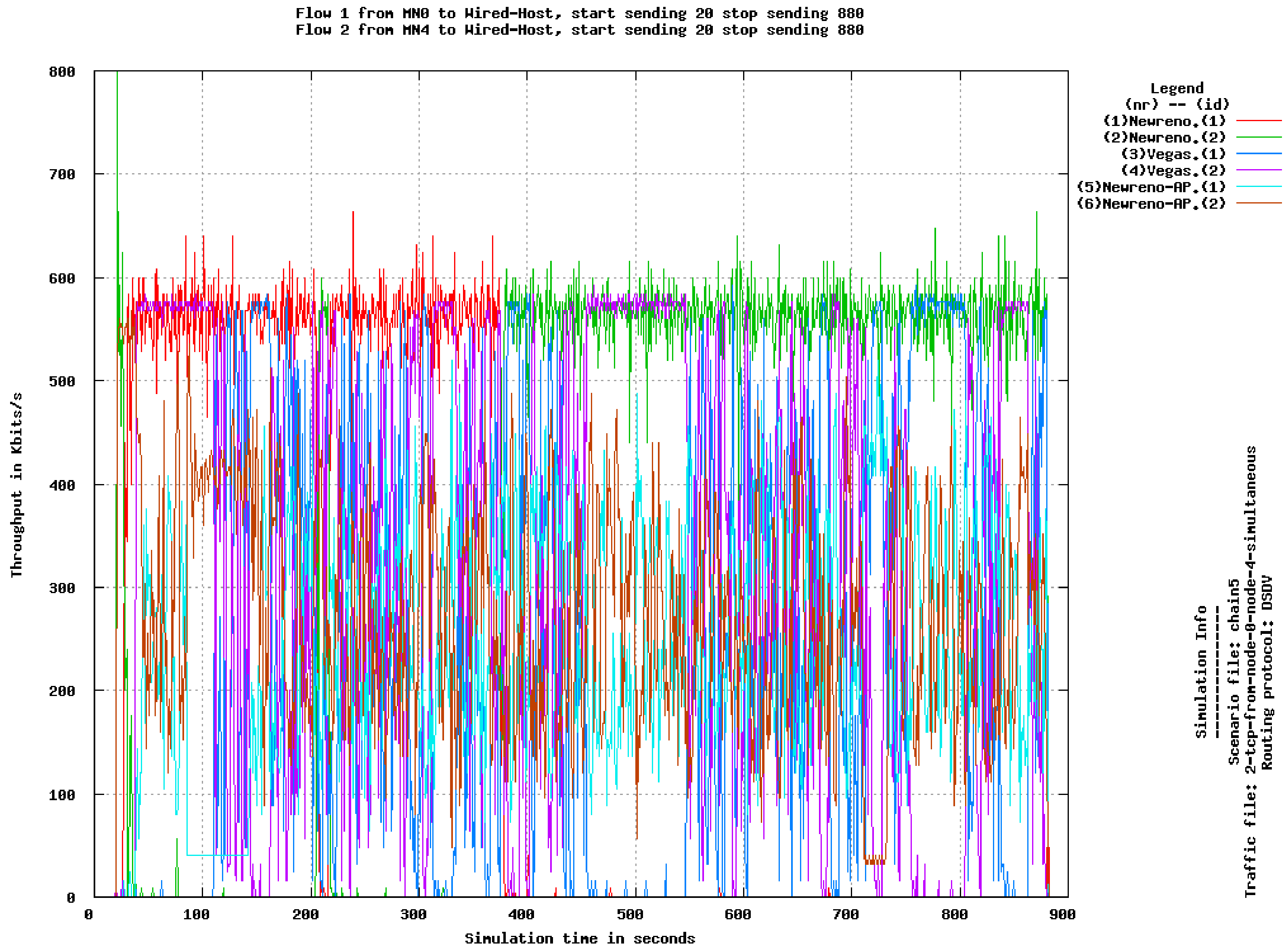


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN4 to Wired-Host, start sending 220.0 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain5
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: AODVUU

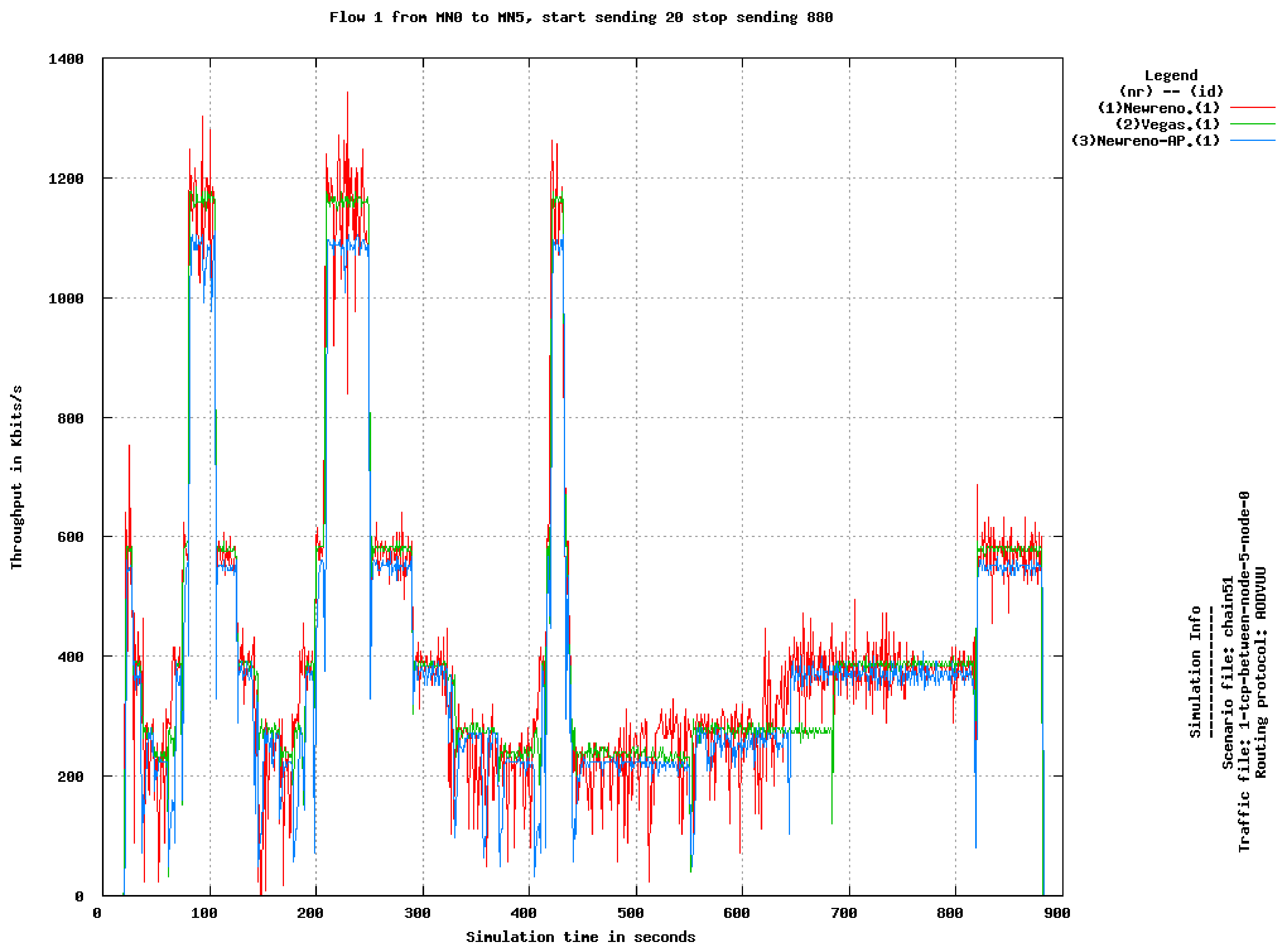

Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN4 to Wired-Host, start sending 220.0 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain5
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: DSDV



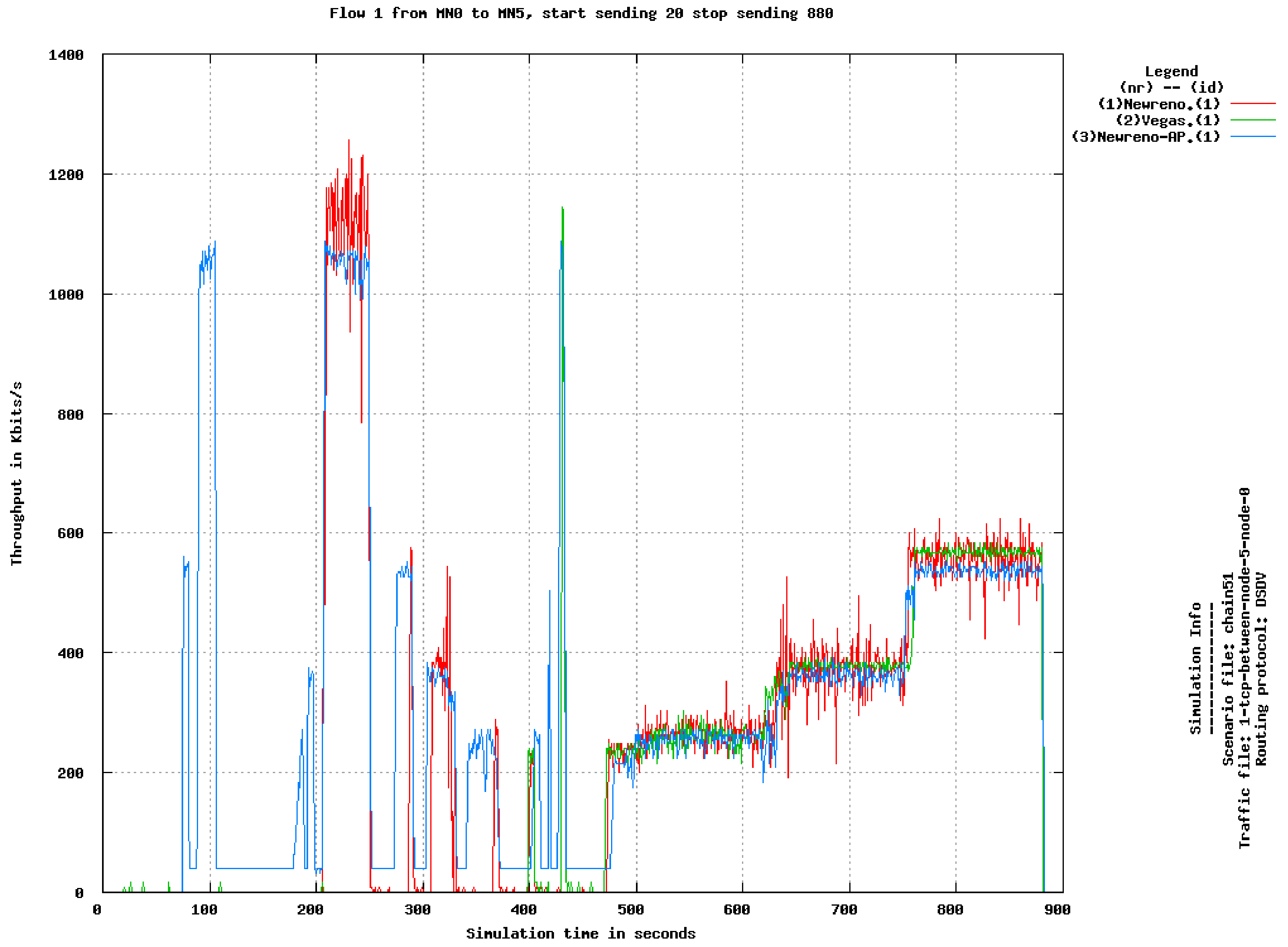
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN4 to Wired-Host, start sending 20 stop sending 880
Throughput in Kbits/s
700
600
500
400
300
200
100
0
0
100
200
300
400
500
600
700
800
900
Simulation time in seconds
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain5
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: AODVUU



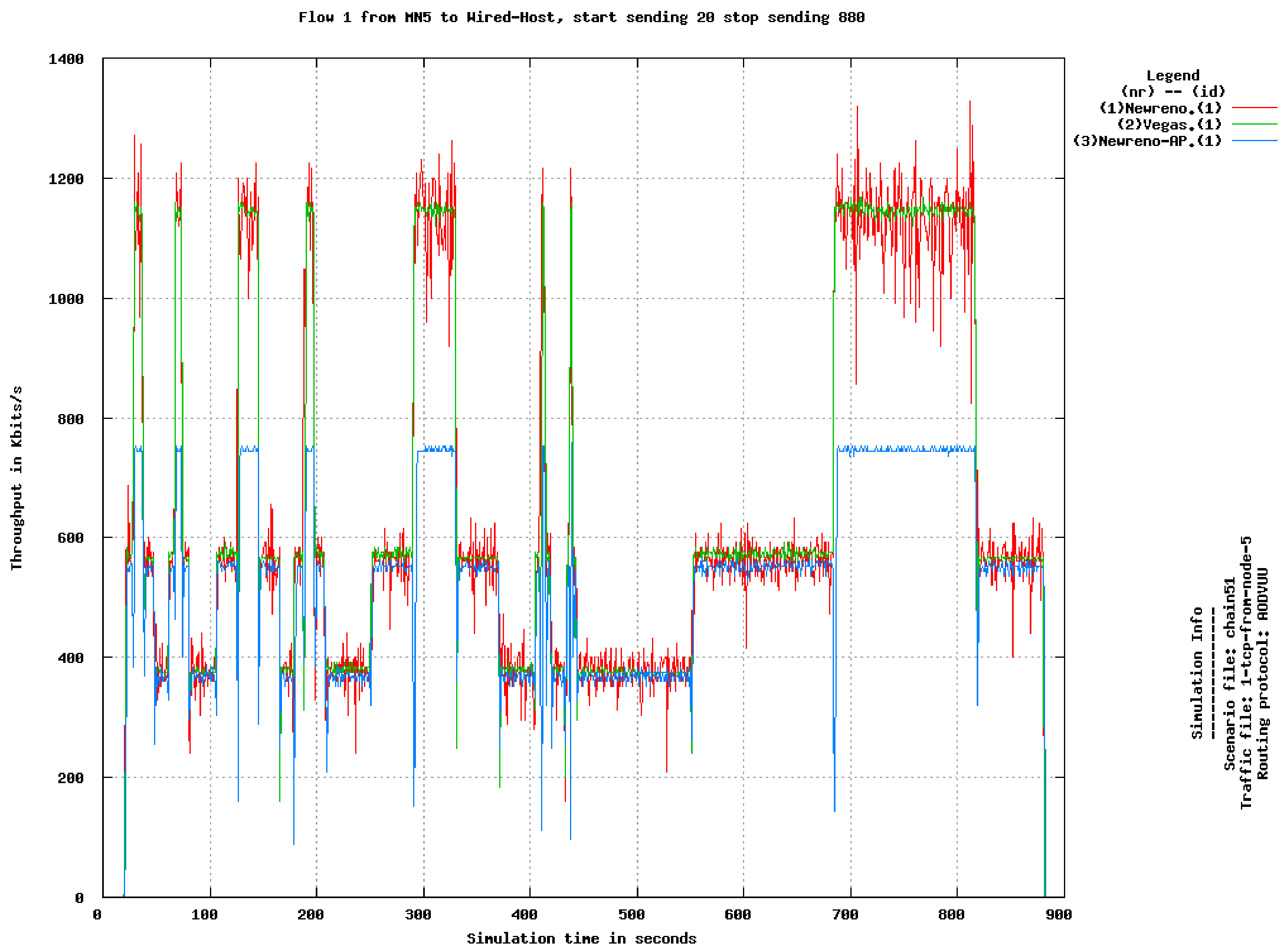
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN4 to Wired-Host, start sending 20 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain5
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: DSDV

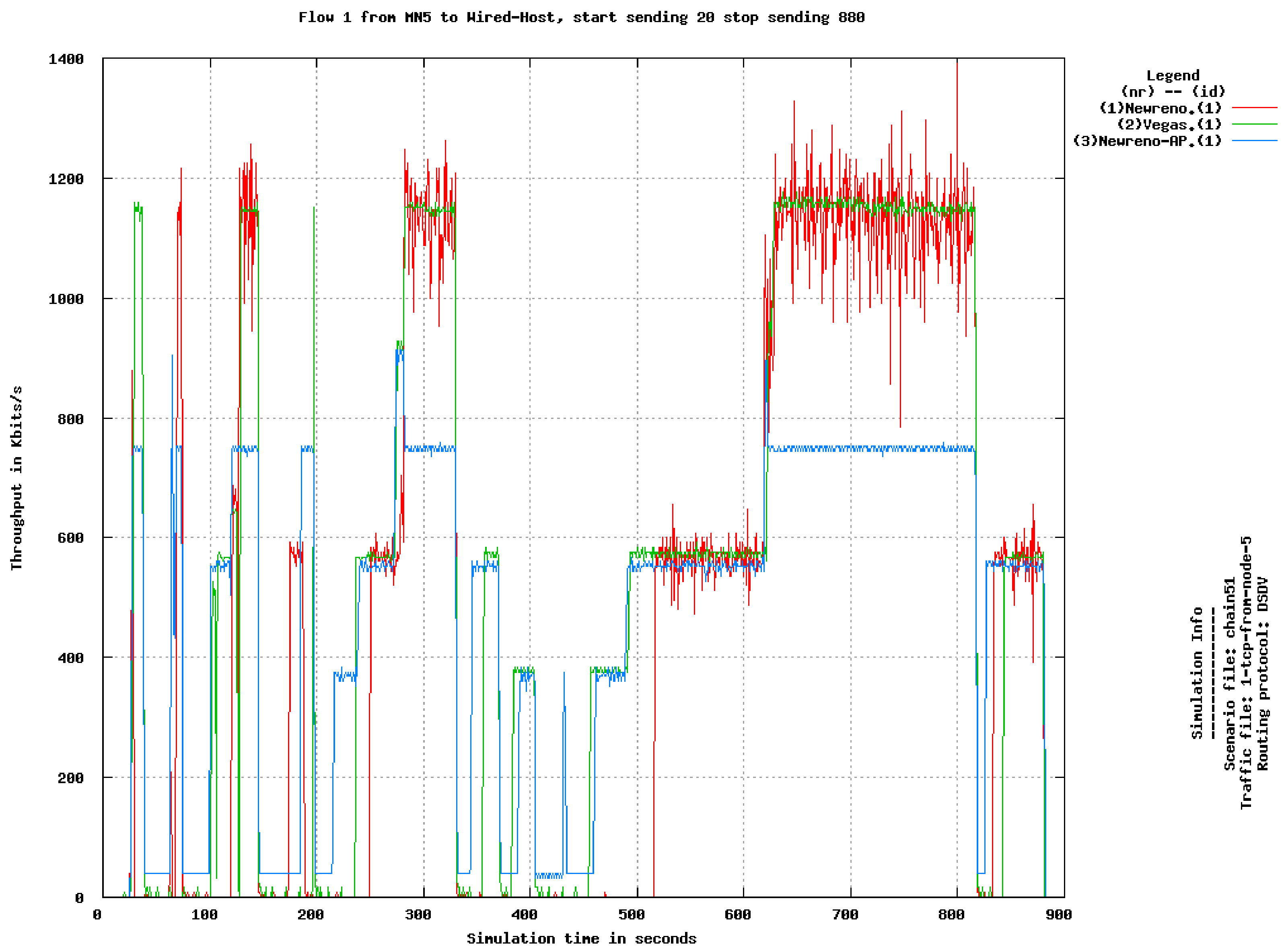


Flow 1 from MN0 to MN5, start sending 20 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
200
400
600
800
1000
1200
1400
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
Scenario file: chain51
Traffic file: 1-tcp-between-node-5-node-0
Routing protocol: AODVUU

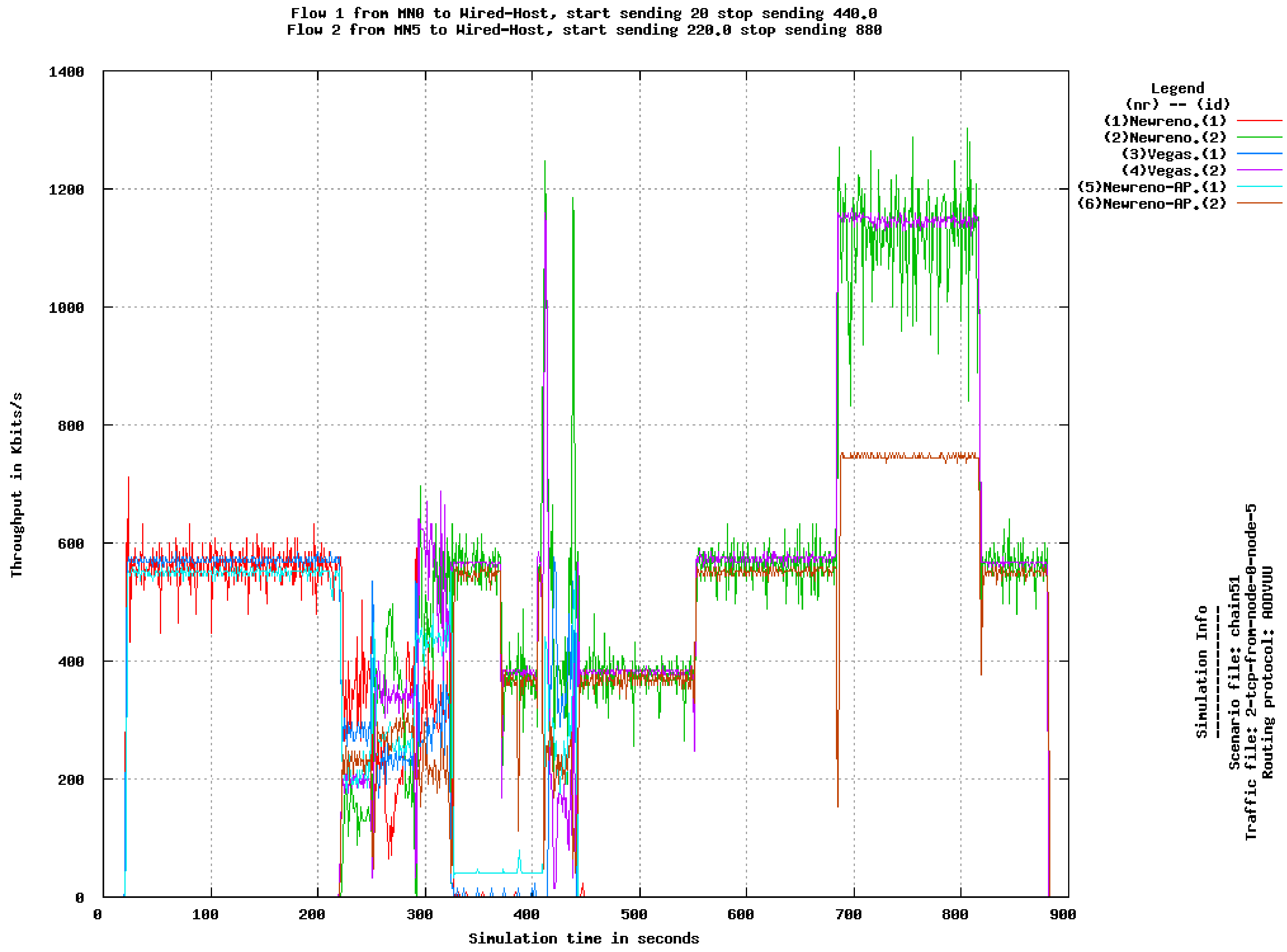


Flow 1 from MN0 to MN5, start sending 20 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
200
400
600
800
1000
1200
1400
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
Scenario file: chain51
Traffic file: 1-tcp-between-node-5-node-0
Routing protocol: DSDV

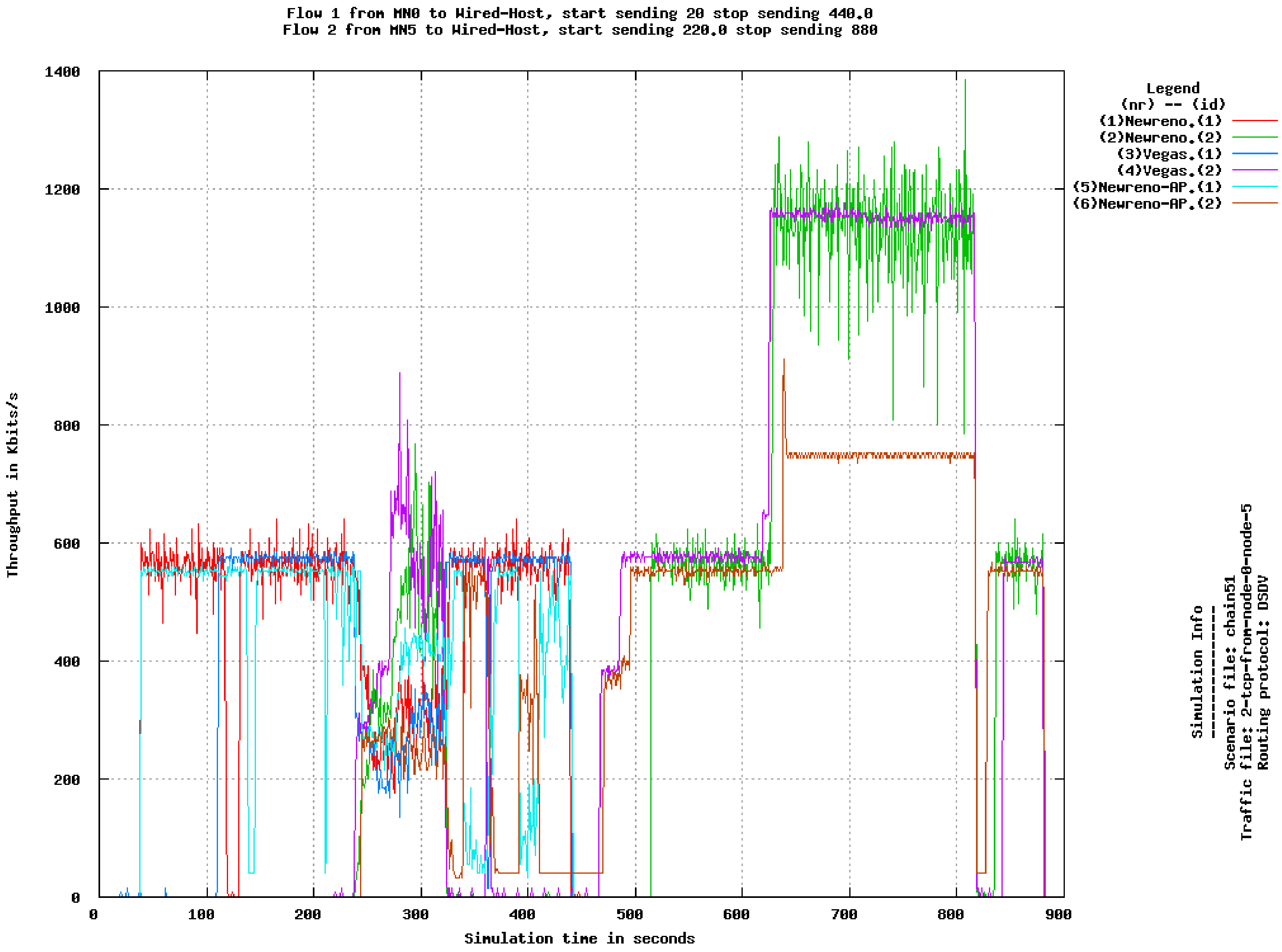

Flow 1 from MN5 to Wired-Host, start sending 20 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
200
400
600
800
1000
1200
1400
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
---------------
Scenario file: chain51
Traffic file: 1-tcp-from-node-5
Routing protocol: AODVUU



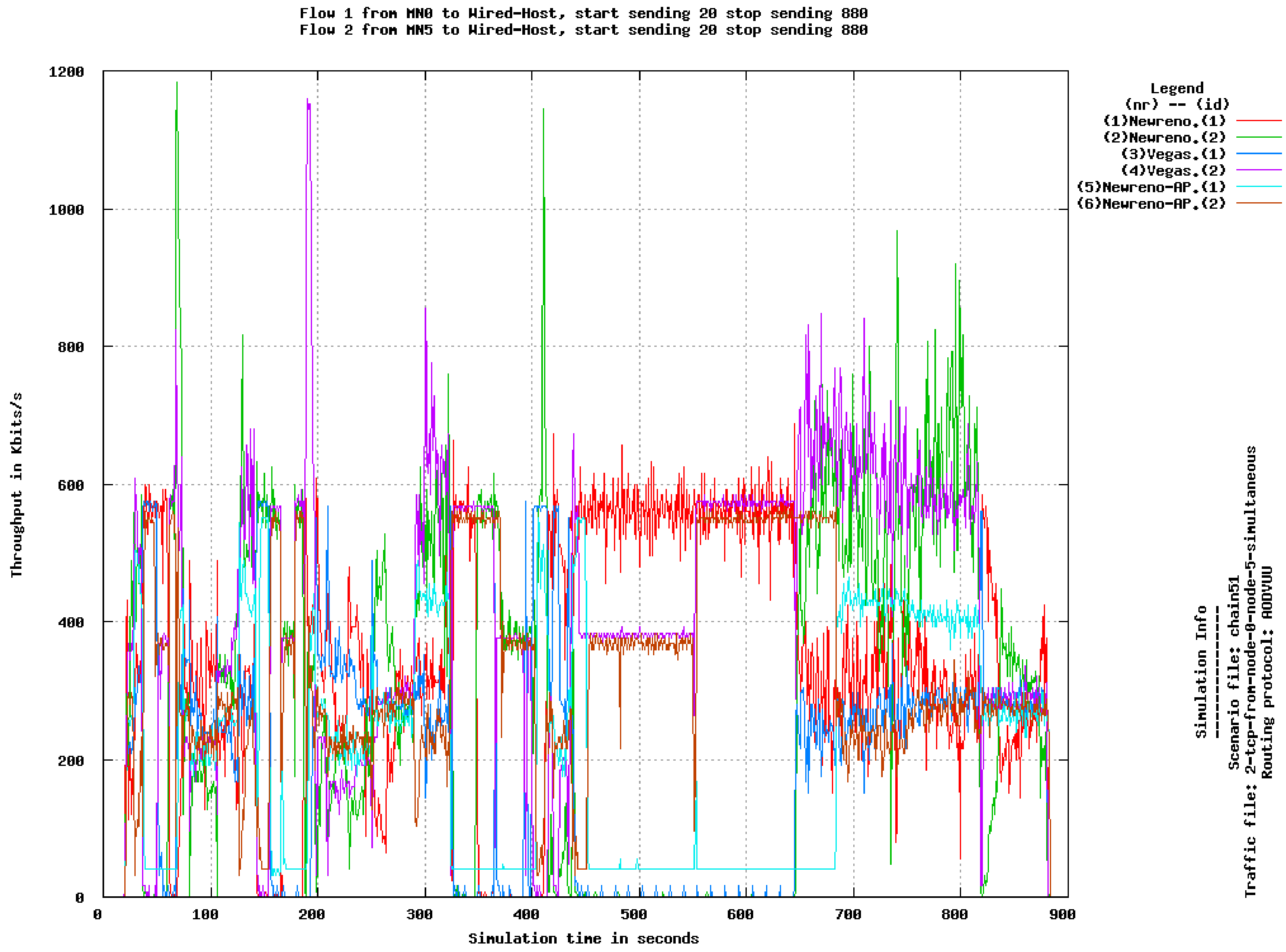
Flow 1 from MN5 to Wired-Host, start sending 20 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
200
400
600
800
1000
1200
1400
100
300
500
700
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
Scenario file: chain51
Traffic file: 1-tcp-from-node-5
Routing protocol: DSDV



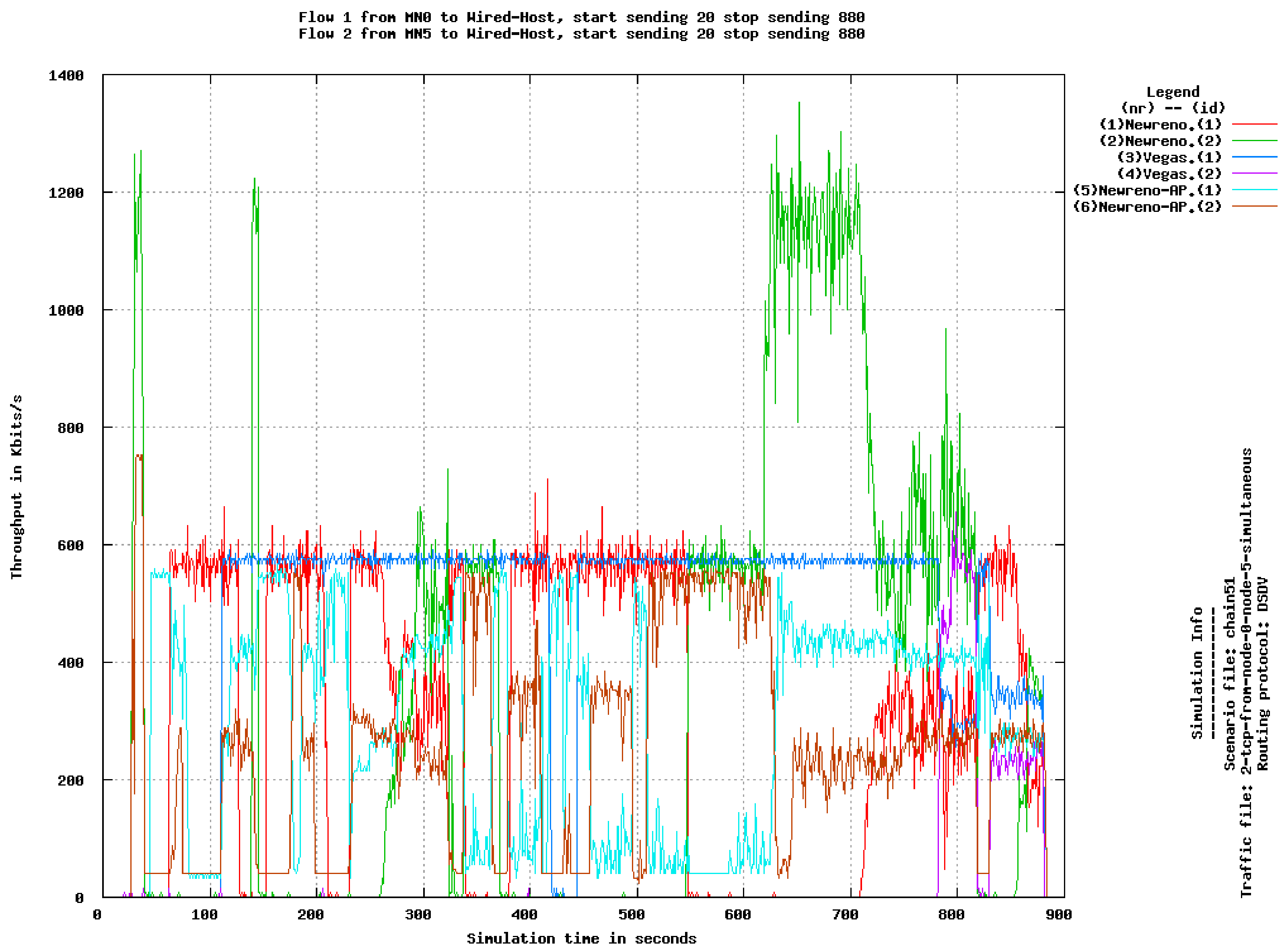
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN5 to Wired-Host, start sending 220.0 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
1400
1200
1000
800
600
400
200
0
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain51
Traffic file: 2-tcp-from-node-0-node-5
Routing protocol: AODVUU

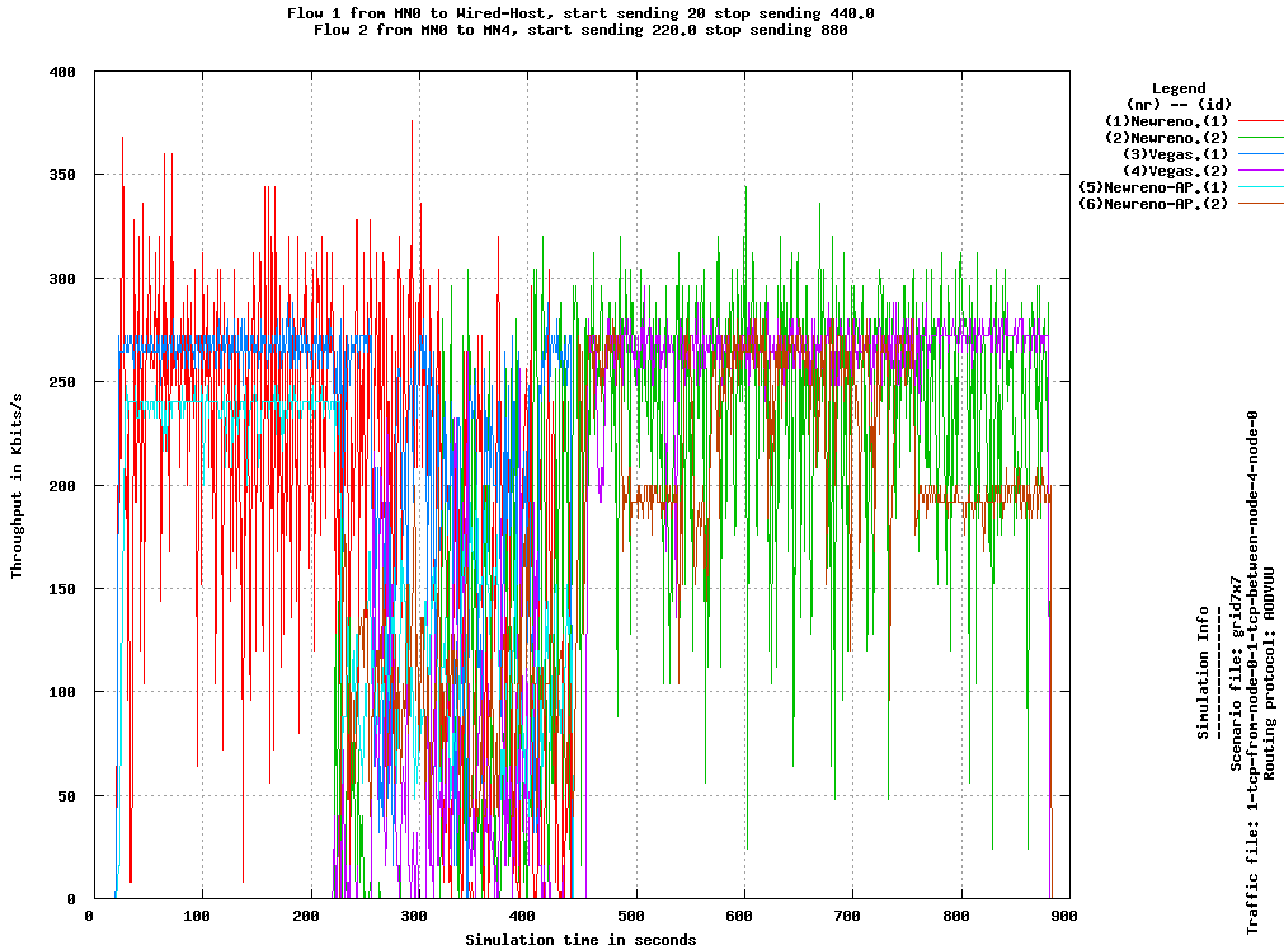


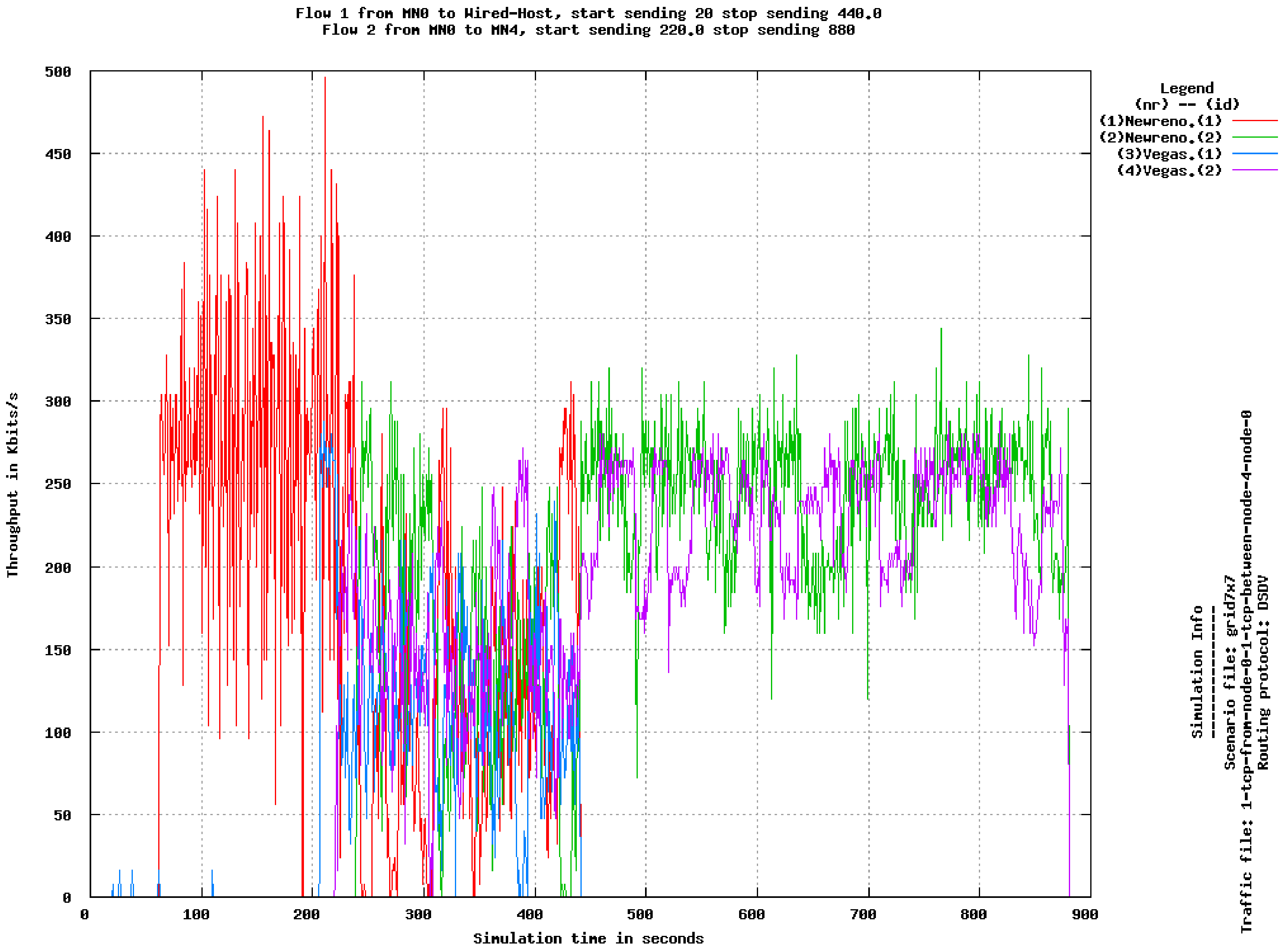
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN5 to Wired-Host, start sending 220.0 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
200
400
600
800
1000
1200
1400
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
---------------
Scenario file: chain51
Traffic file: 2-tcp-from-node-0-node-5
Routing protocol: DSDV



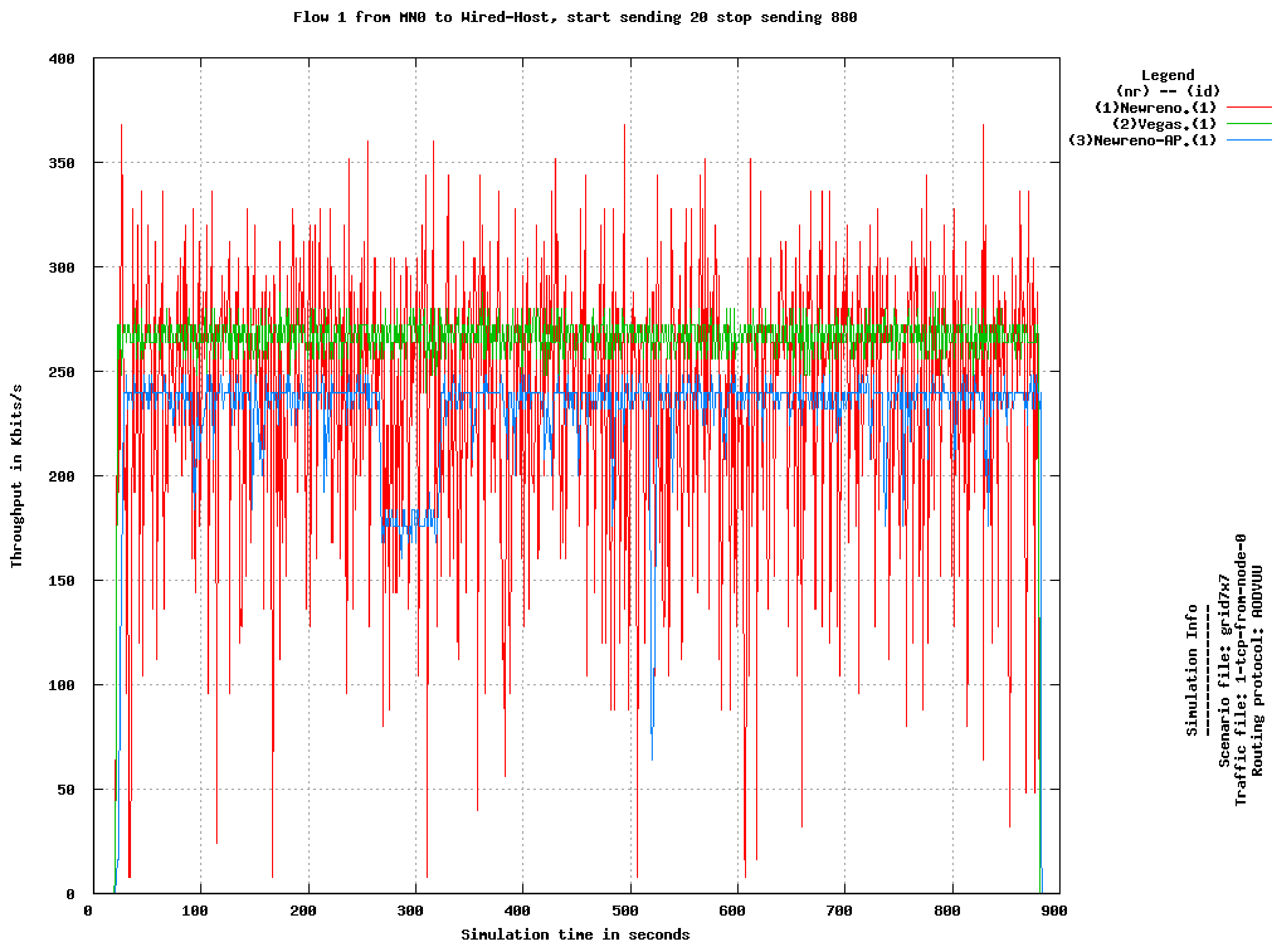
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN5 to Wired-Host, start sending 20 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
200
400
600
800
1000
1200
100
300
500
700
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain51
Traffic file: 2-tcp-from-node-0-node-5-simultaneous
Routing protocol: AODVUU

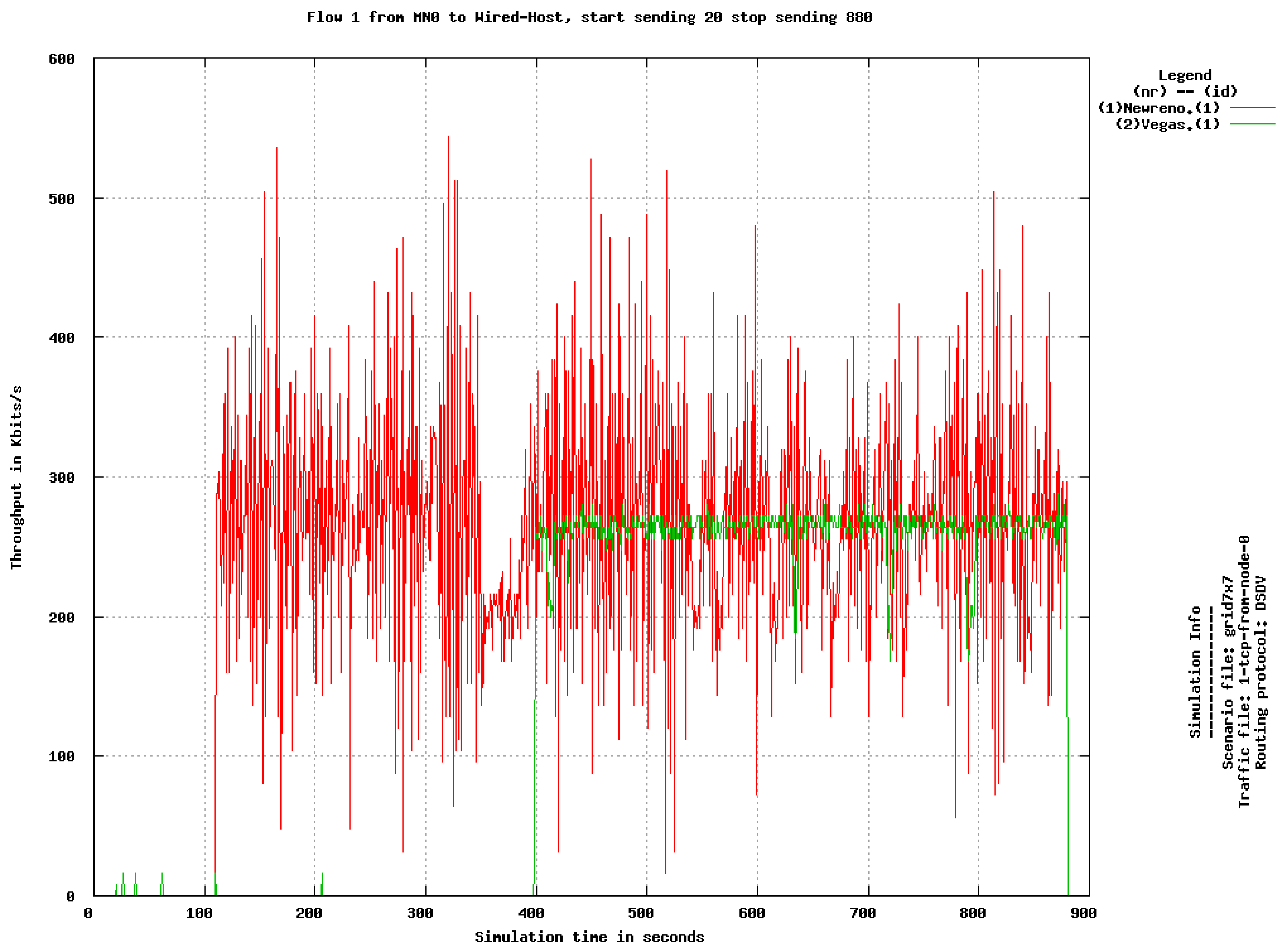

Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN5 to Wired-Host, start sending 20 stop sending 880
Throughput in Kbits/s
0
200
400
600
800
1000
1200
1400
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
---------------
Scenario file: chain51
Traffic file: 2-tcp-from-node-0-node-5-simultaneous
Routing protocol: DSDV

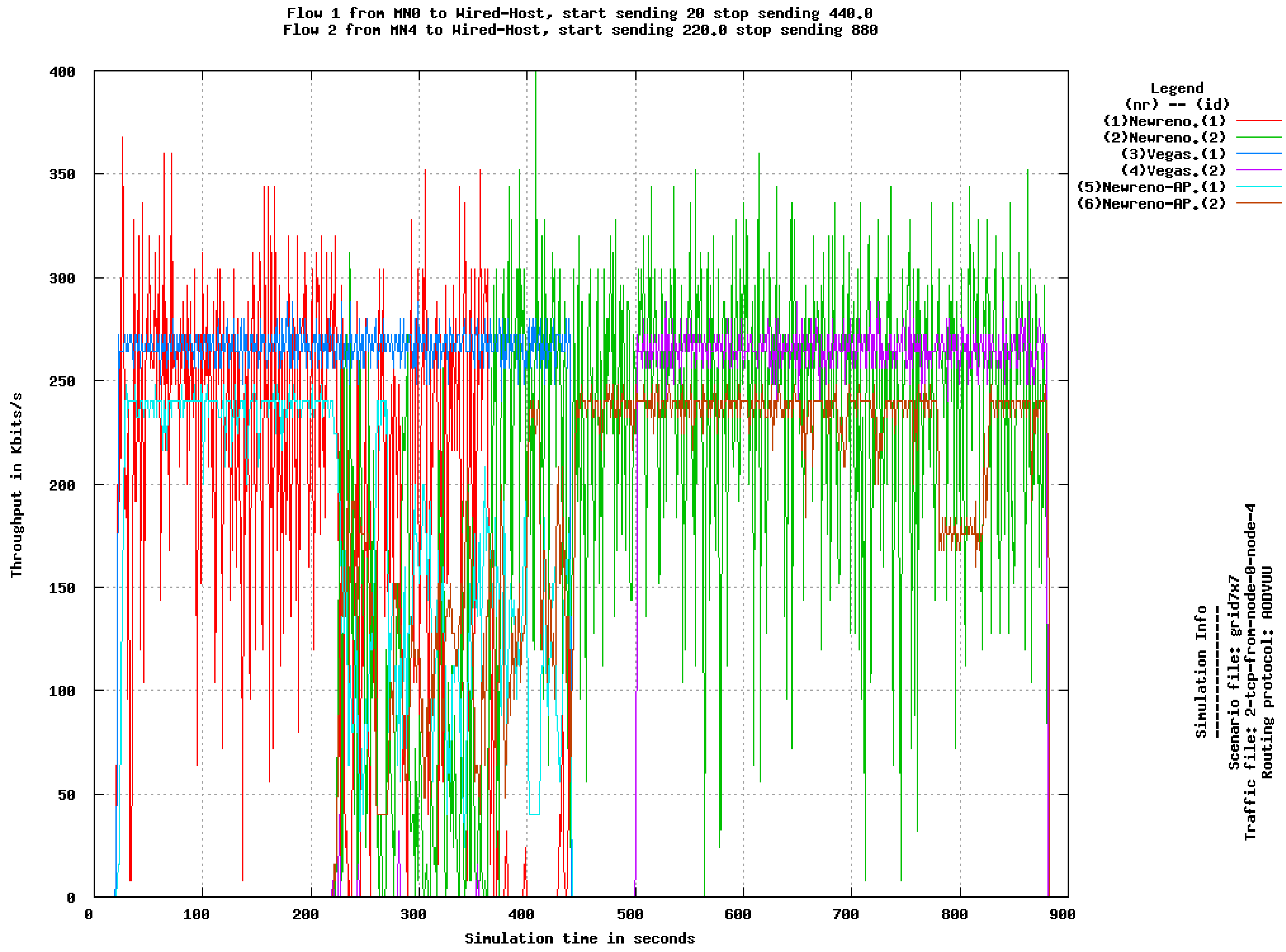

Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN0 to MN4, start sending 220.0 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
50
100
150
200
250
300
350
400
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: grid7x7
Traffic file: 1-tcp-from-node-0-1-tcp-between-node-4-node-0
Routing protocol: AODVUU



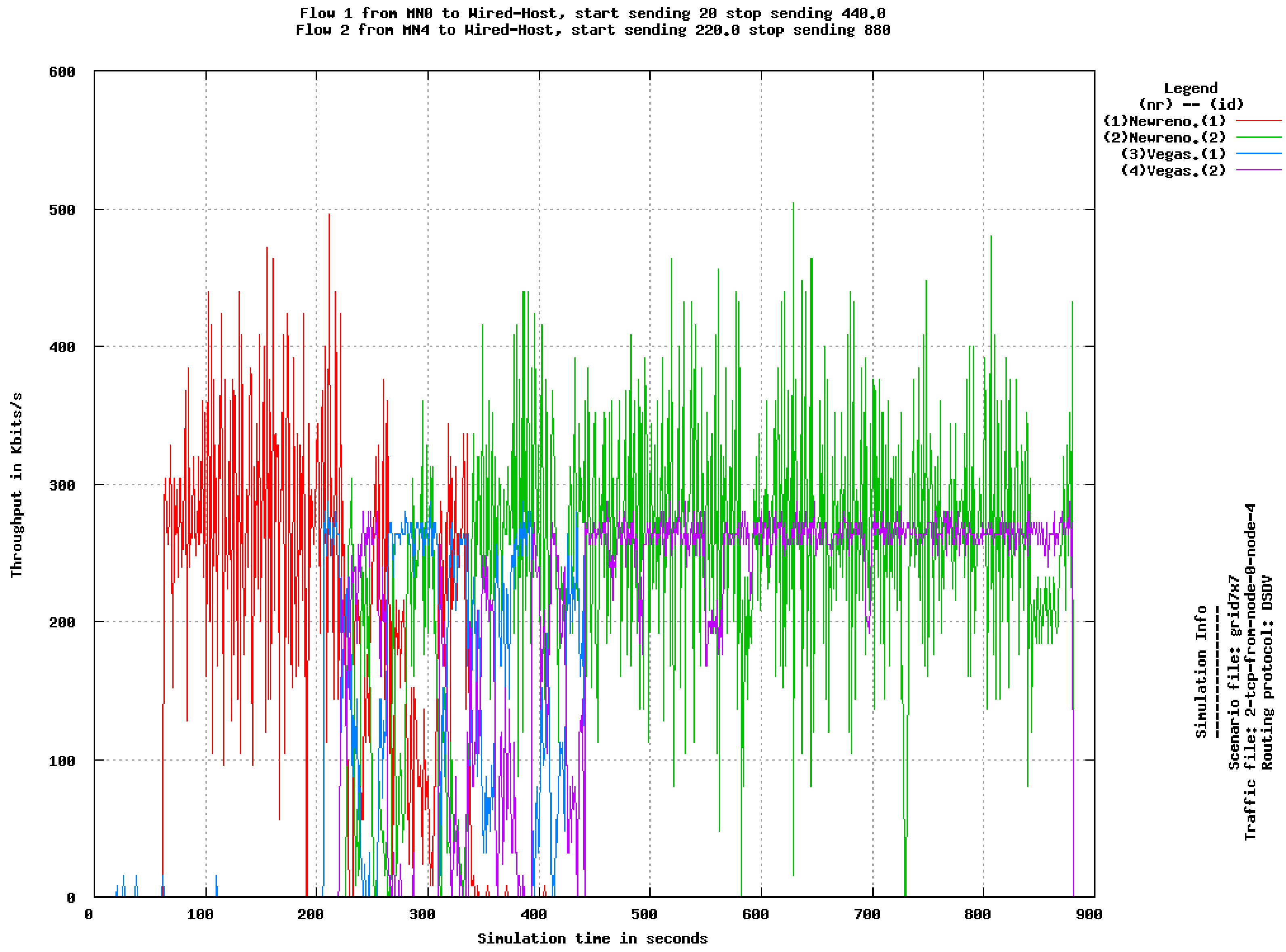
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN0 to MN4, start sending 220.0 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
50
100
150
200
250
300
350
400
450
500
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
Simulation Info
Scenario file: grid7x7
Traffic file: 1-tcp-from-node-0-1-tcp-between-node-4-node-0
Routing protocol: DSDV

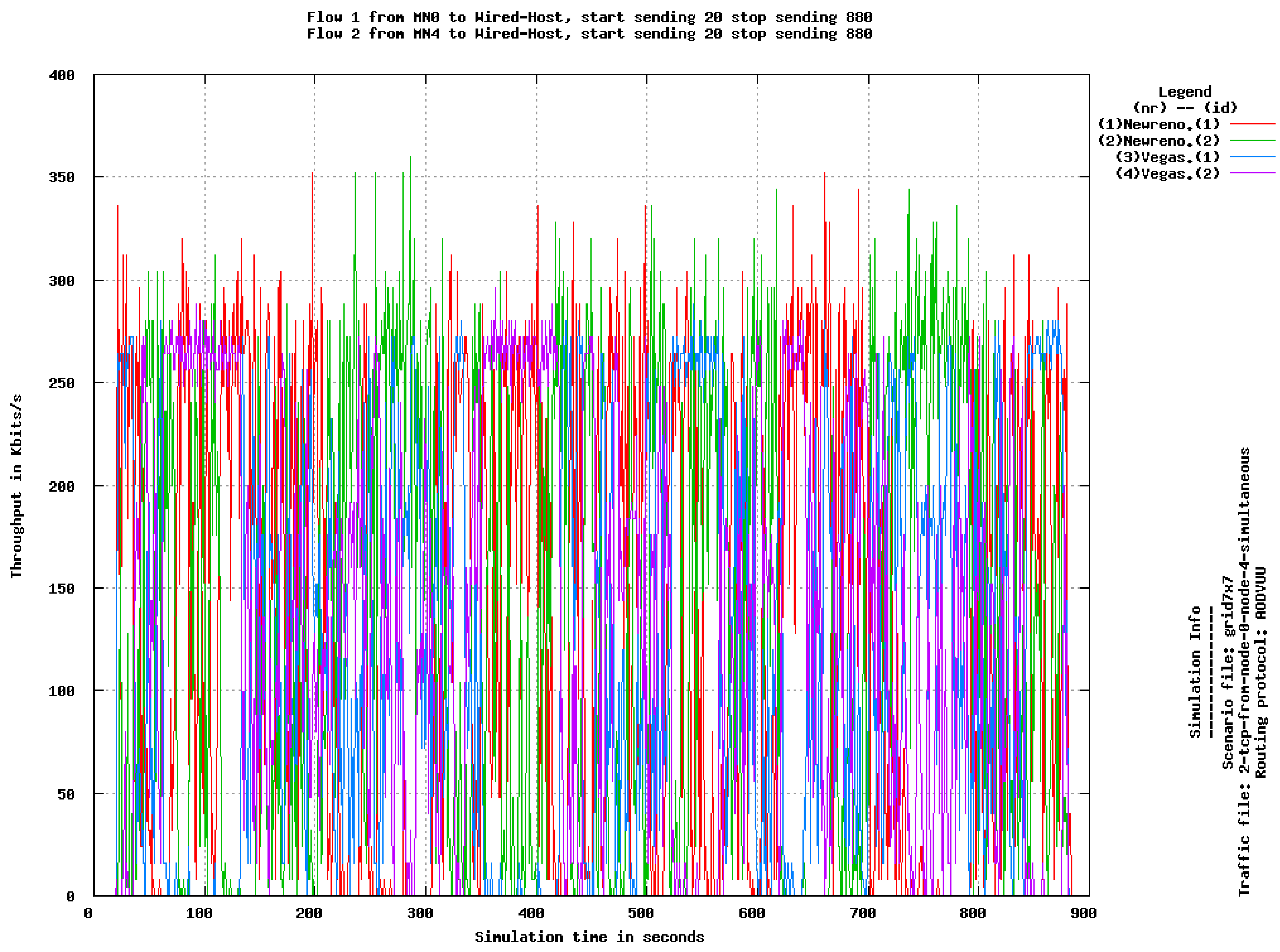

Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
50
100
150
200
250
300
350
400
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
---------------
Scenario file: grid7x7
Traffic file: 1-tcp-from-node-0
Routing protocol: AODVUU


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
Simulation Info
Scenario file: grid7x7
Traffic file: 1-tcp-from-node-0
Routing protocol: DSDV

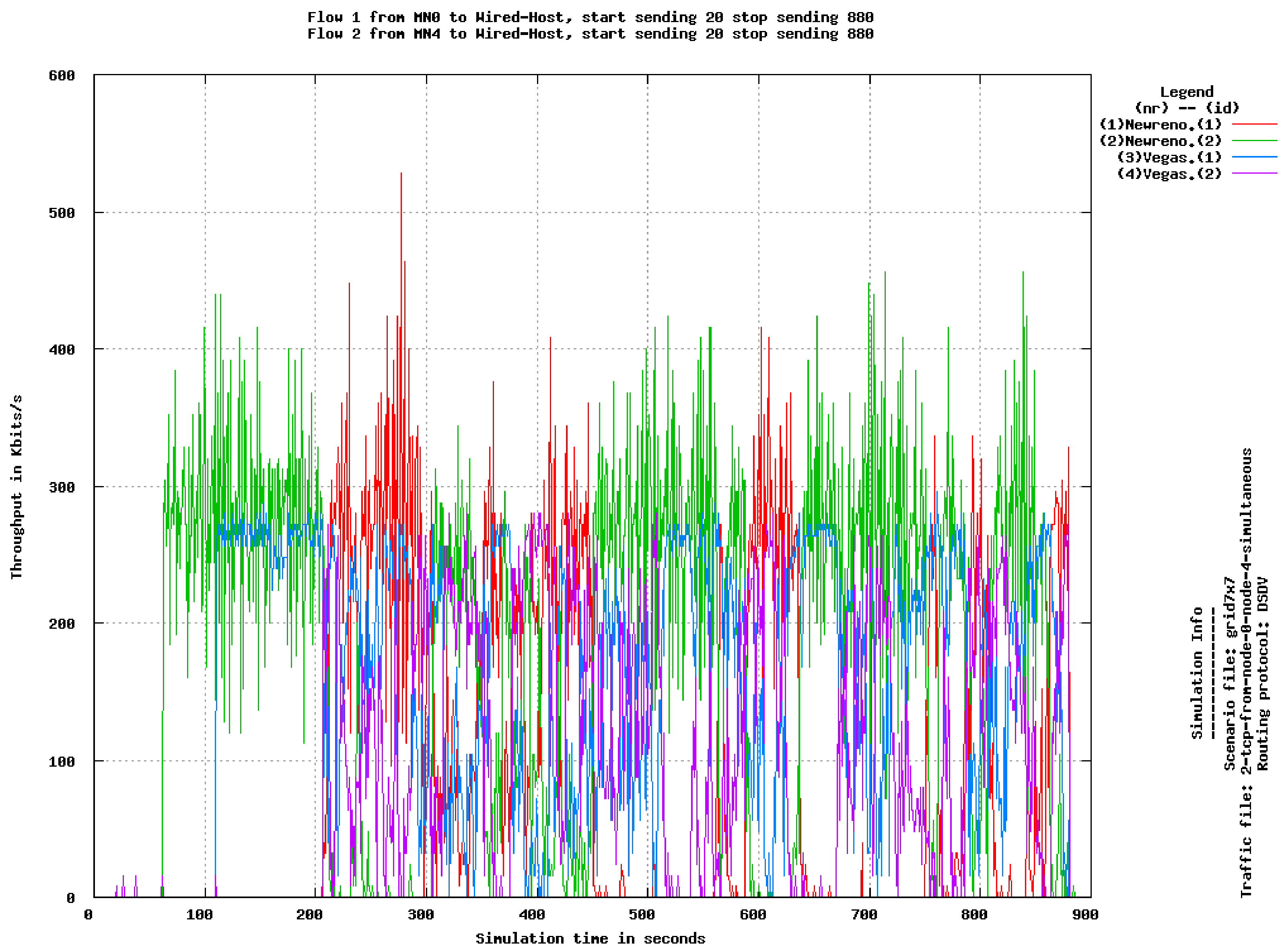


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN4 to Wired-Host, start sending 220.0 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
50
100
150
200
250
300
350
400
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
---------------
Scenario file: grid7x7
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: AODVUU

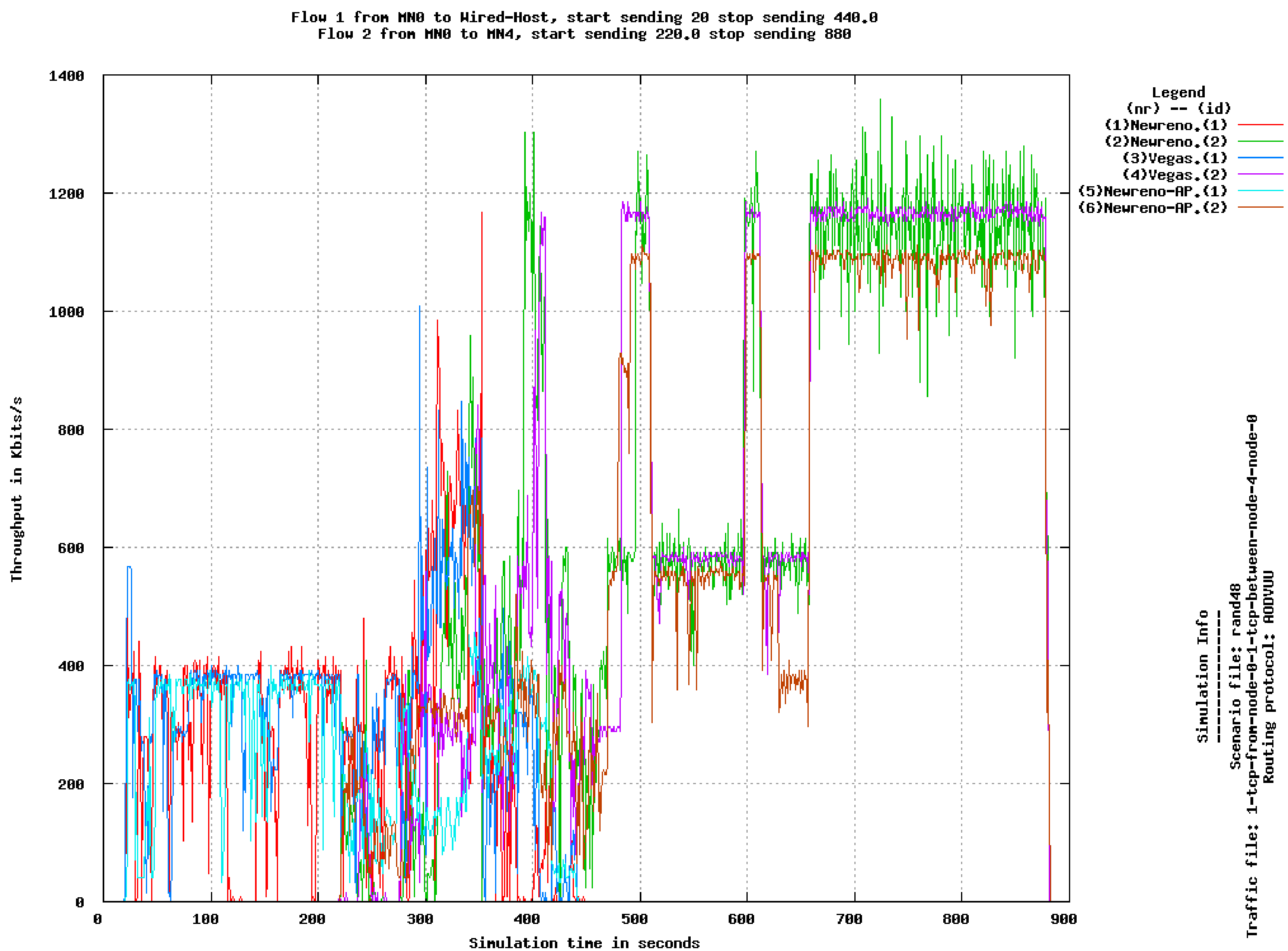

Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN4 to Wired-Host, start sending 220.0 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
600
500
400
300
200
100
0
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
Simulation Info
Scenario file: grid7x7
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: DSDV



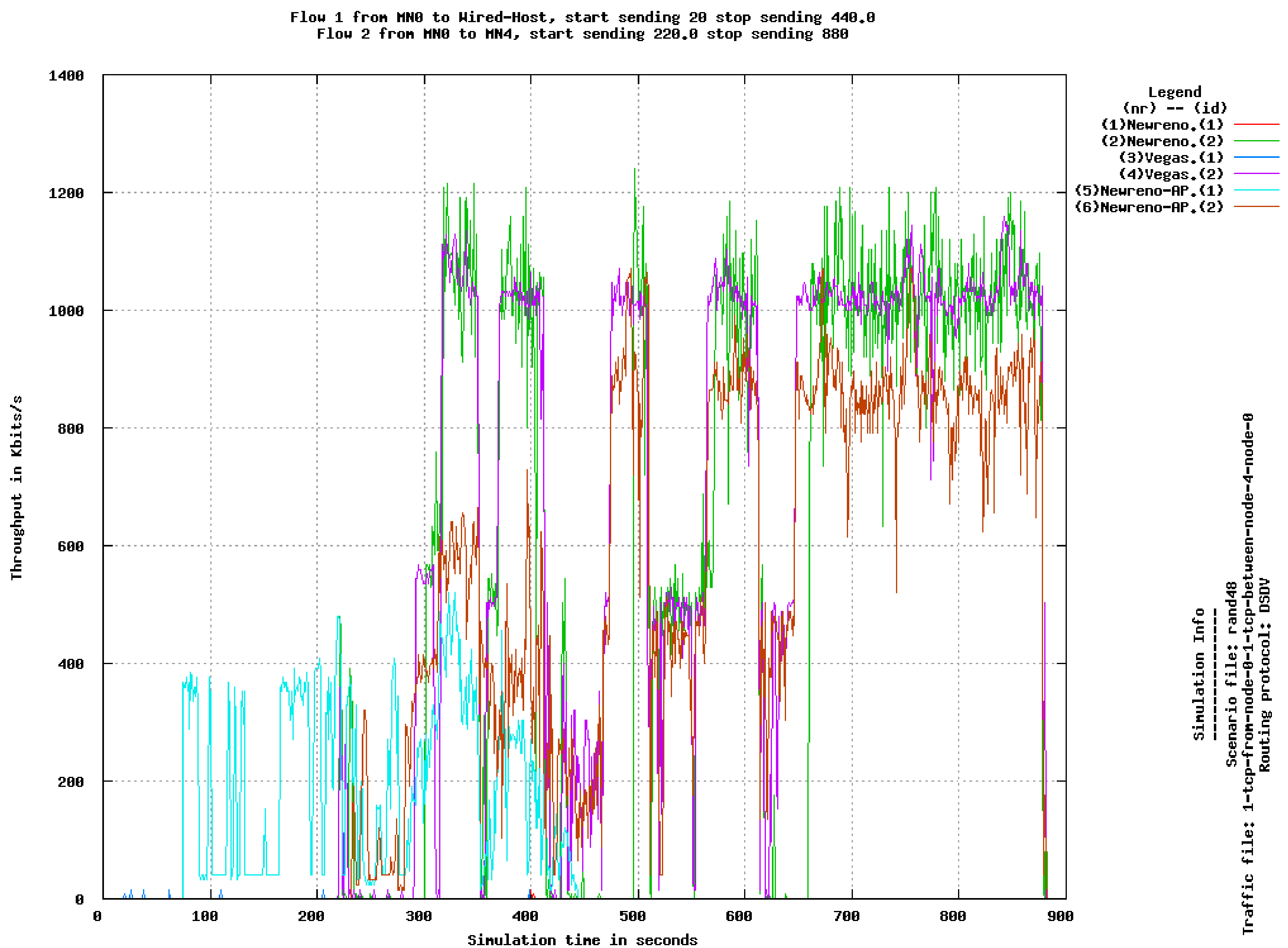
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN4 to Wired-Host, start sending 20 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
50
100
150
200
250
300
350
400
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno,(1)
(2)Newreno,(2)
(3)Vegas,(1)
(4)Vegas,(2)
Simulation Info
Scenario file: grid7x7
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: AODVUU



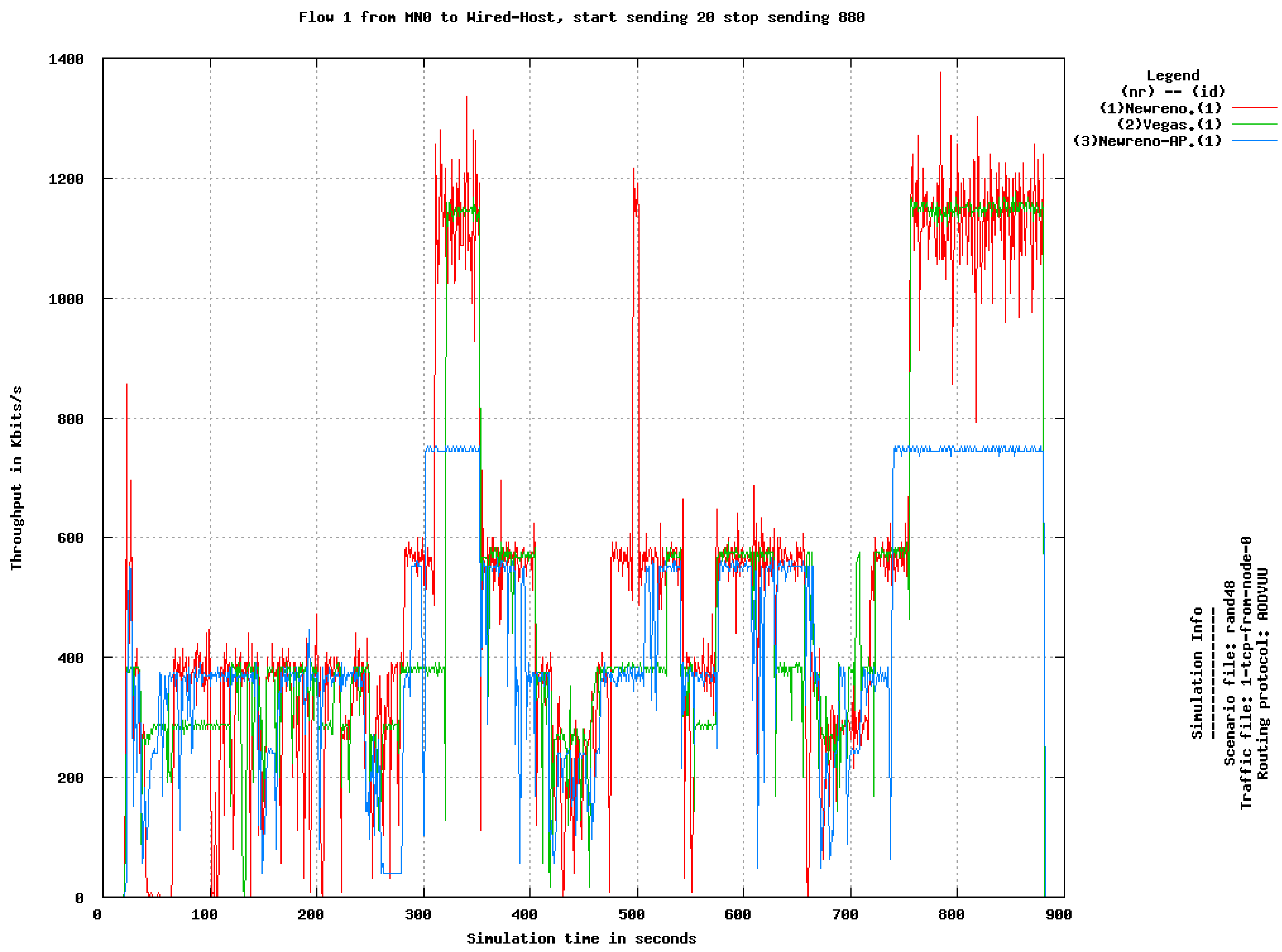
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN4 to Wired-Host, start sending 20 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno,(1)
(2)Newreno,(2)
(3)Vegas,(1)
(4)Vegas,(2)
Simulation Info
Scenario file: grid7x7
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: DSDV



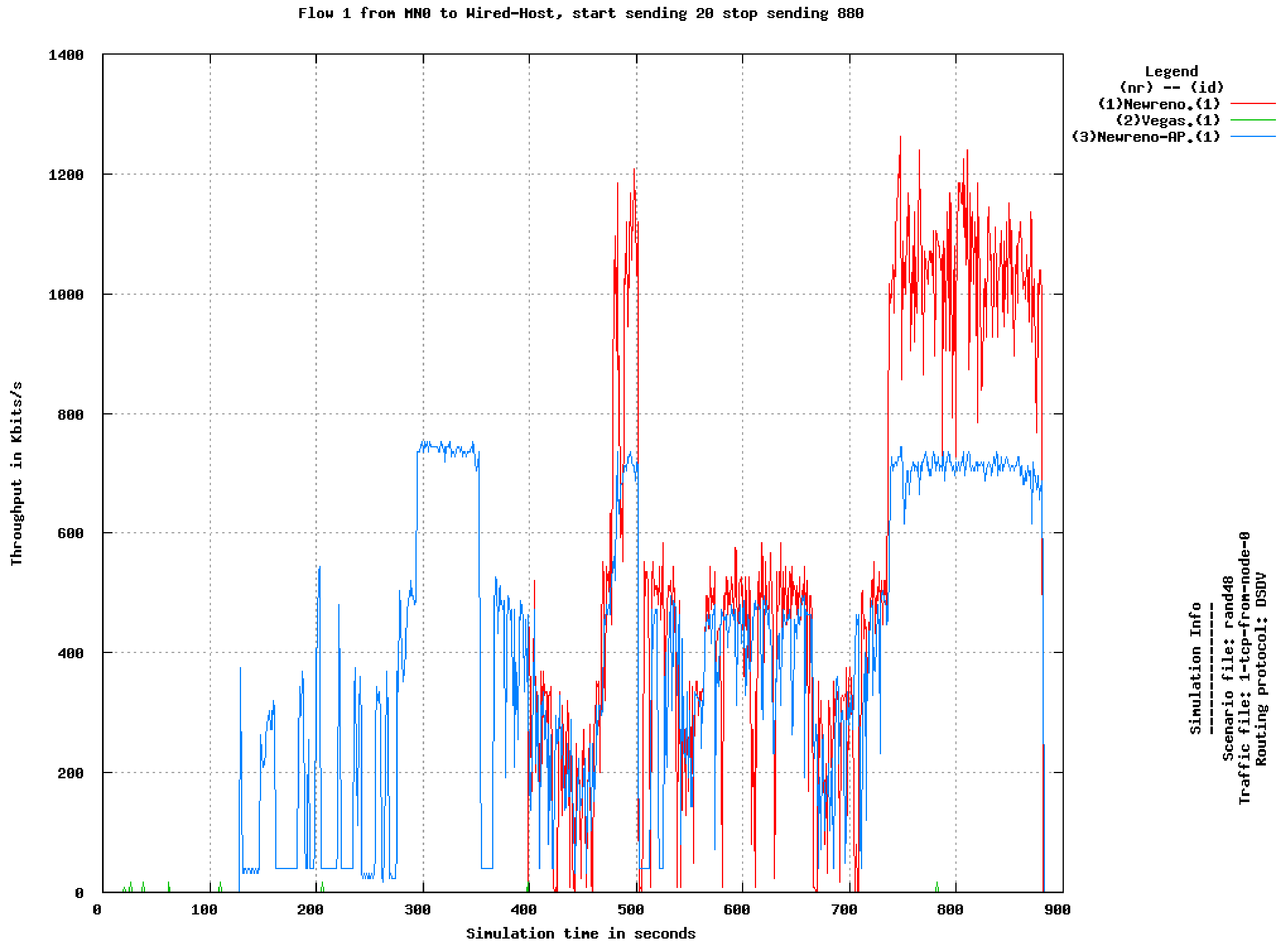
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN0 to MN4, start sending 220.0 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
1400
1200
1000
800
600
400
200
0
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: rand48
Traffic file: 1-tcp-from-node-0-1-tcp-between-node-4-node-0
Routing protocol: AODVUU



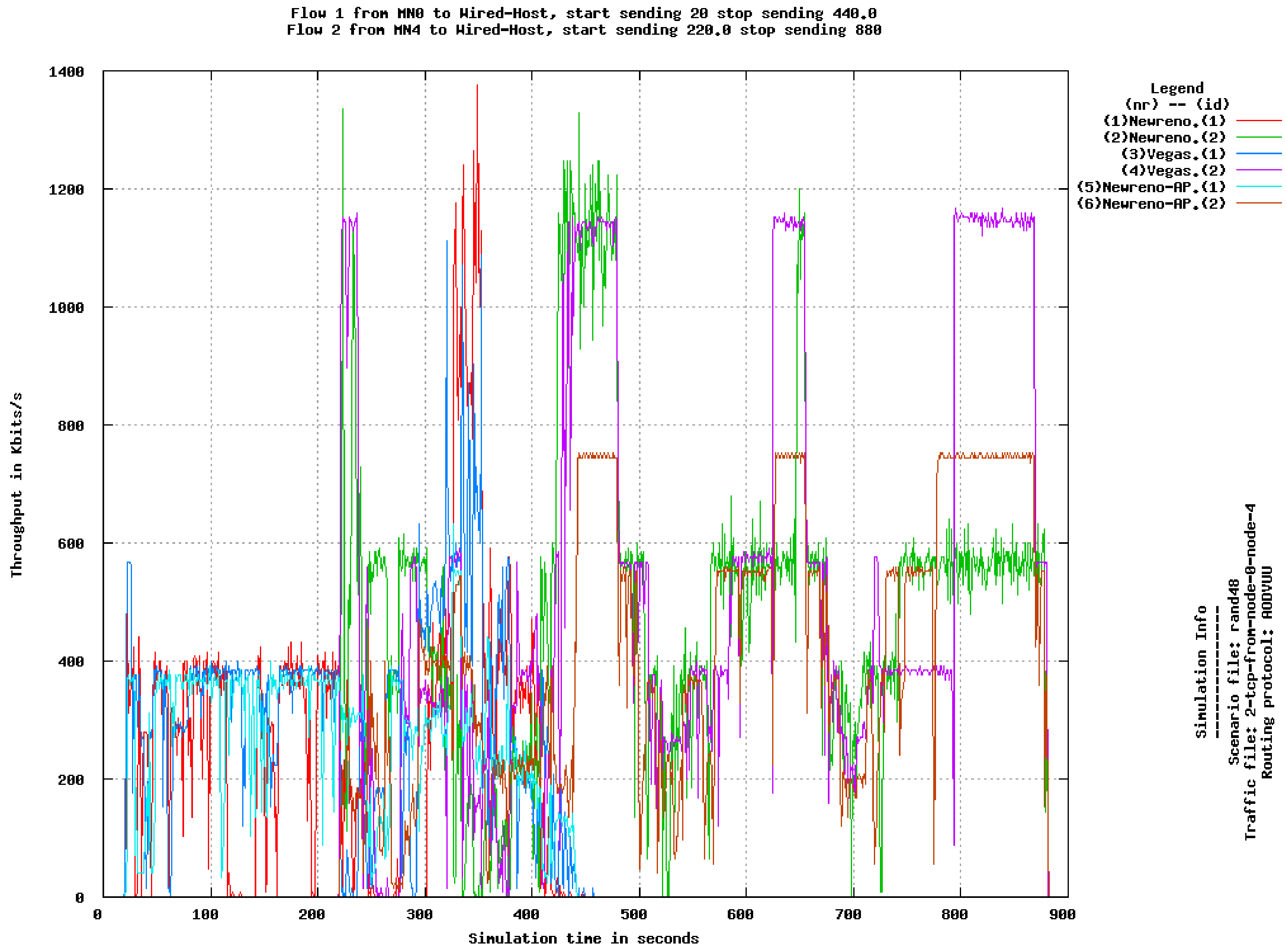
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN0 to MN4, start sending 220.0 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
200
400
600
800
1000
1200
1400
100
300
500
700
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: rand48
Traffic file: 1-tcp-from-node-0-1-tcp-between-node-4-node-0
Routing protocol: DSDV



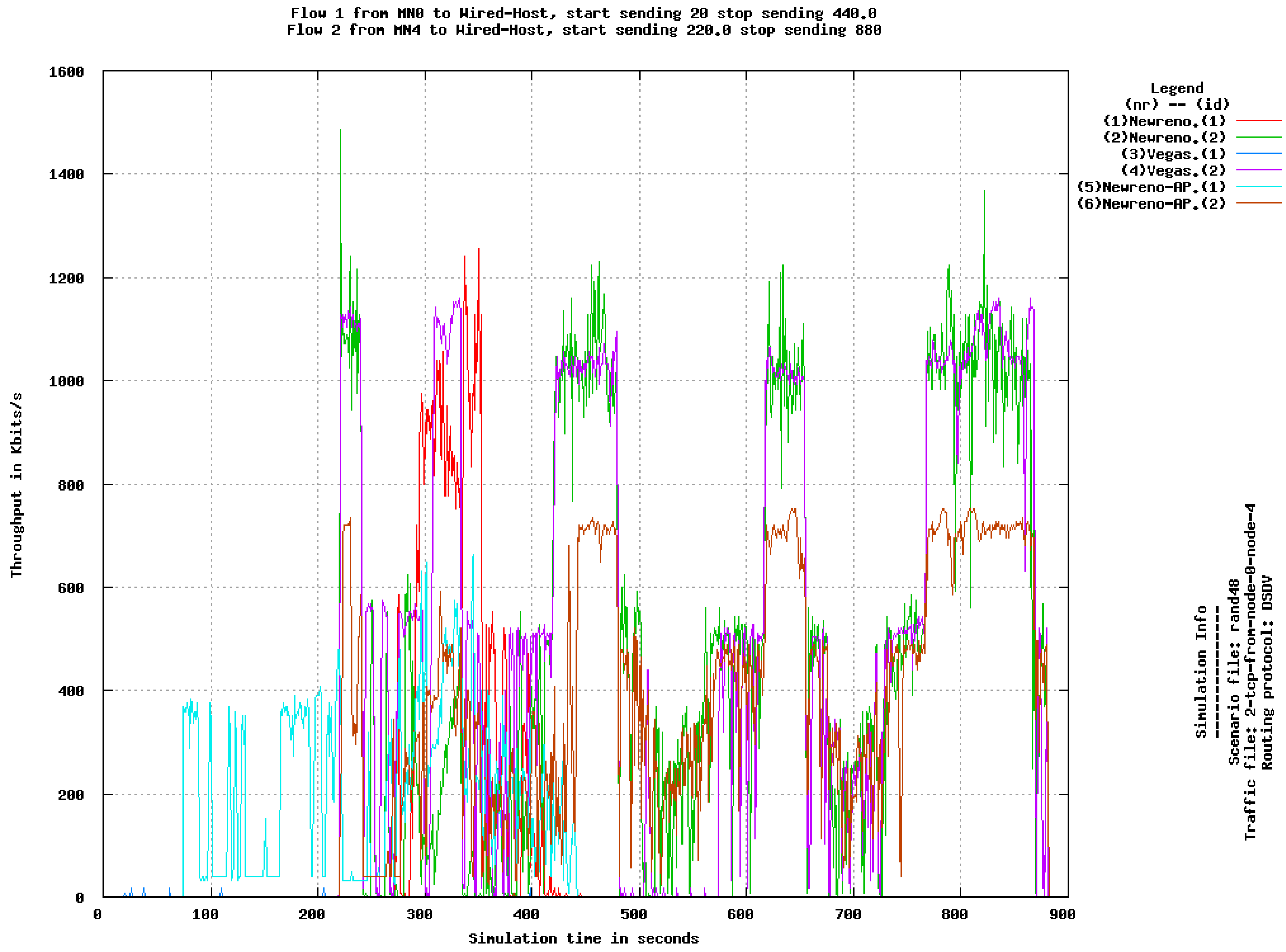
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
200
400
600
800
1000
1200
1400
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
Scenario file: rand48
Traffic file: 1-tcp-from-node-0
Routing protocol: AODVUU



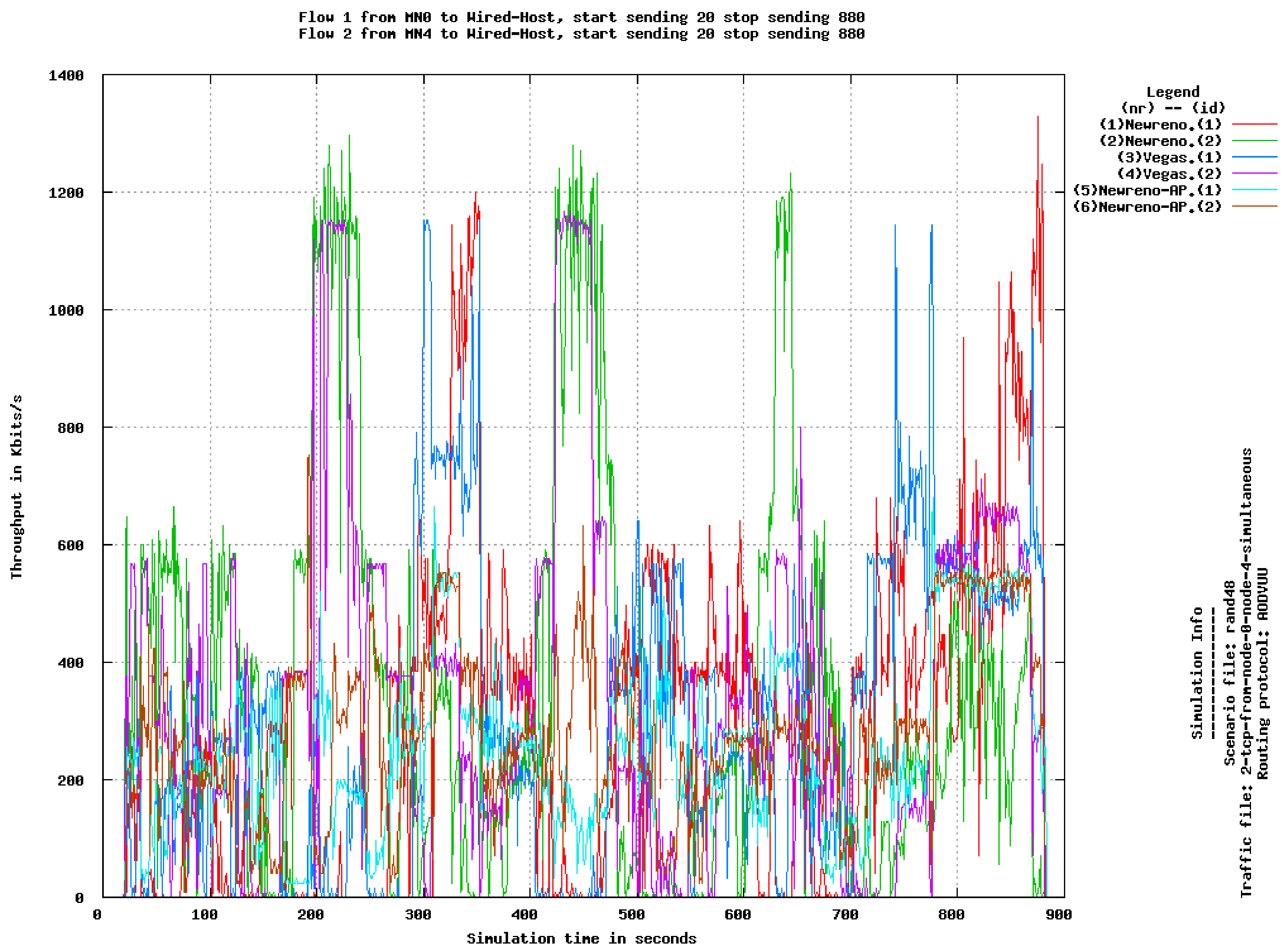
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
200
400
600
800
1000
1200
1400
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
---------------
Scenario file: rand48
Traffic file: 1-tcp-from-node-0
Routing protocol: DSDV

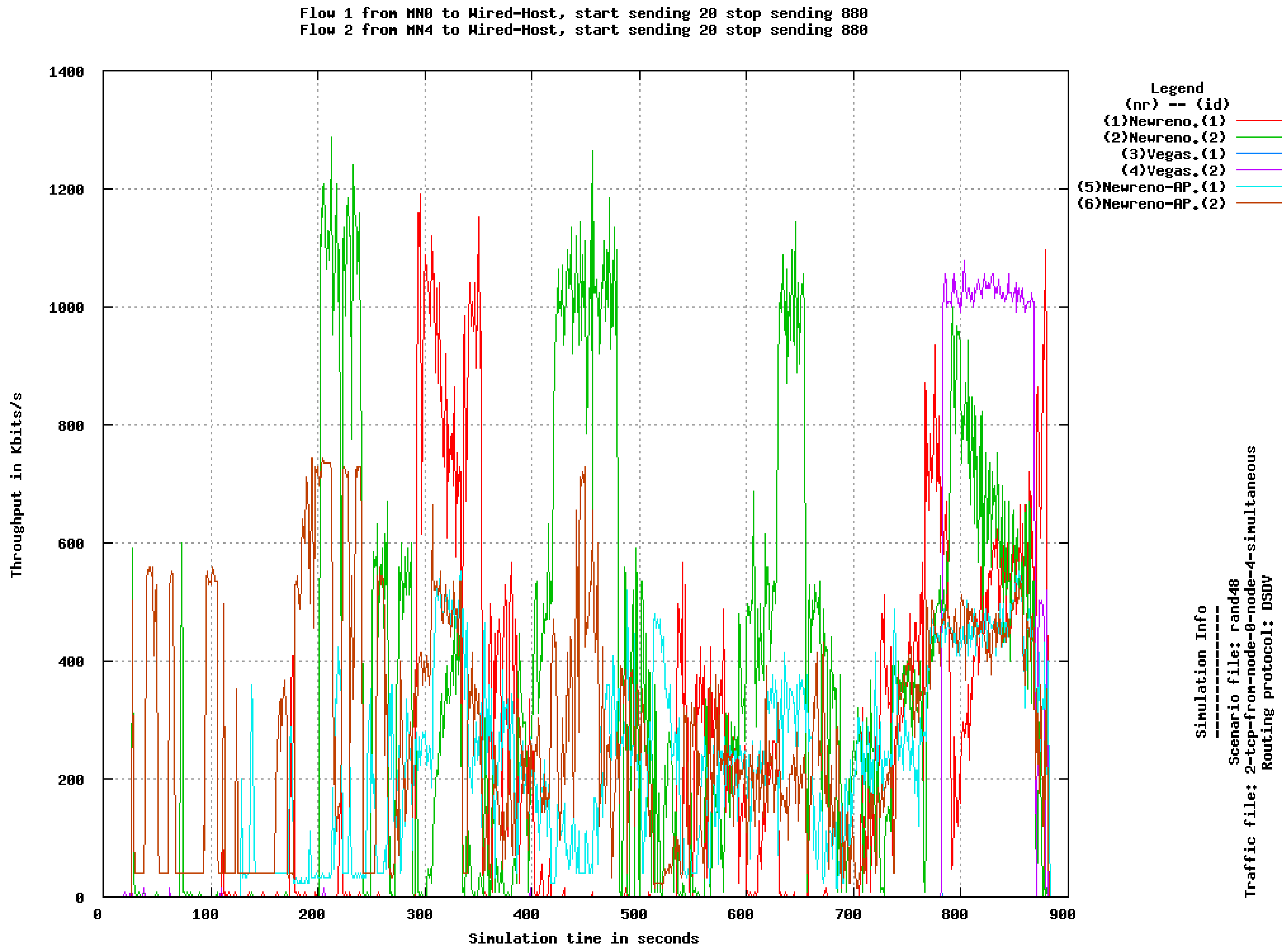


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN4 to Wired-Host, start sending 220.0 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
200
400
600
800
1000
1200
1400
100
300
500
700
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
---------------
Scenario file: rand48
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: AODVUU



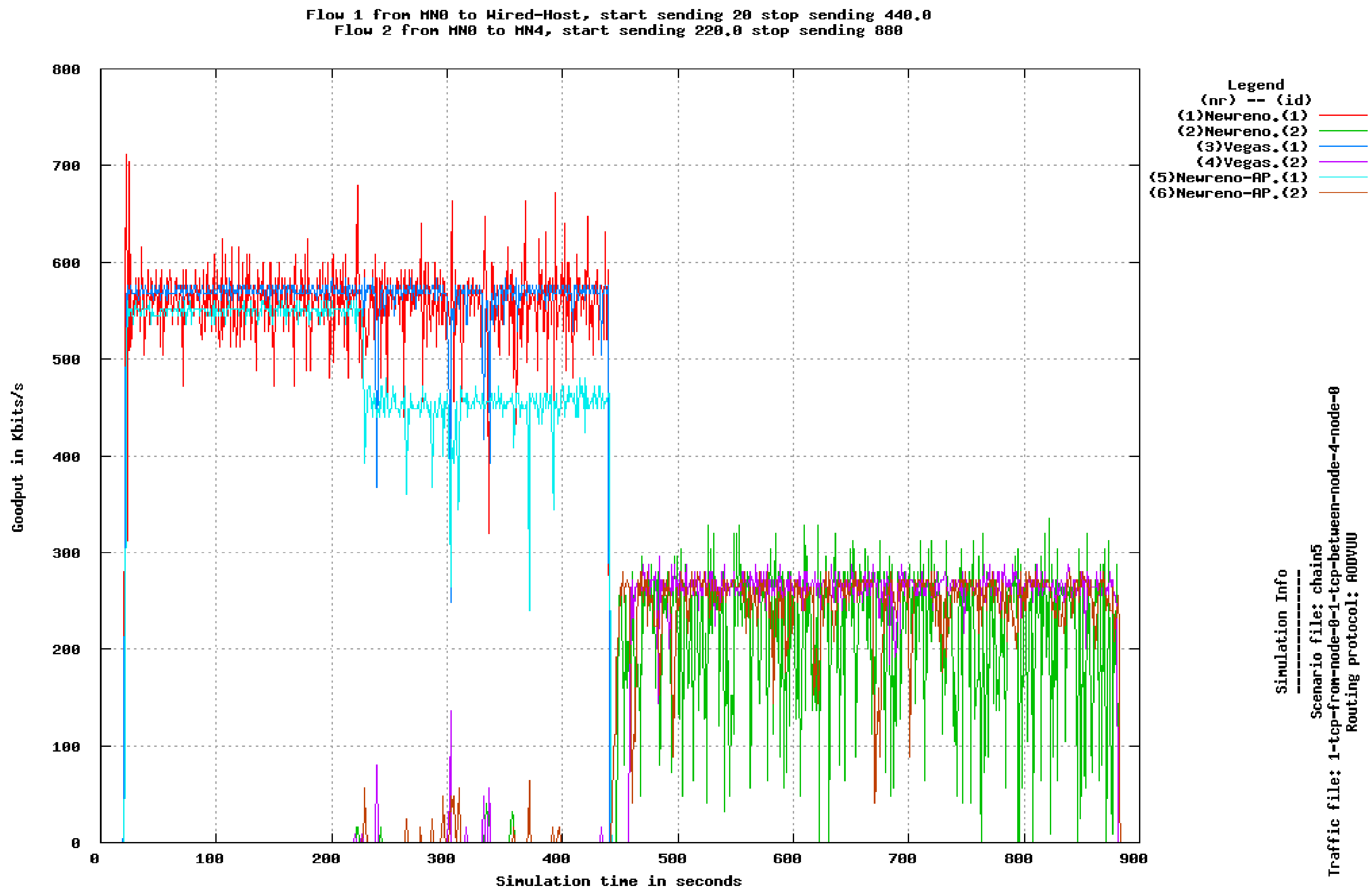
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN4 to Wired-Host, start sending 220.0 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
200
400
600
800
1000
1200
1400
1600
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: rand48
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: DSDV


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN4 to Wired-Host, start sending 20 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
200
400
600
800
1000
1200
1400
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
---------------
Scenario file: rand48
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: AODVUU

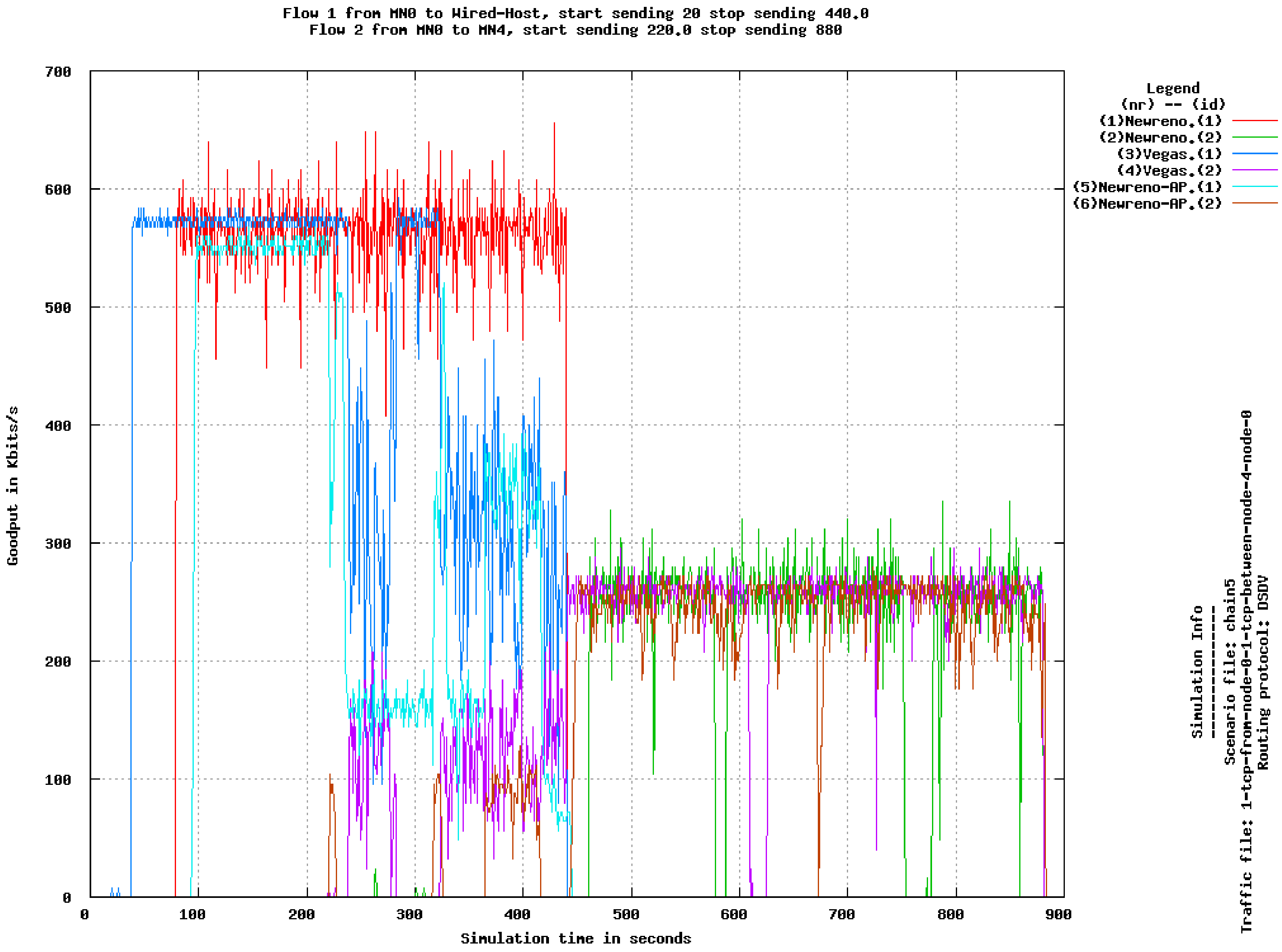


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN4 to Wired-Host, start sending 20 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
200
400
600
800
1000
1200
1400
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
---------------
Scenario file: rand48
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: DSDV

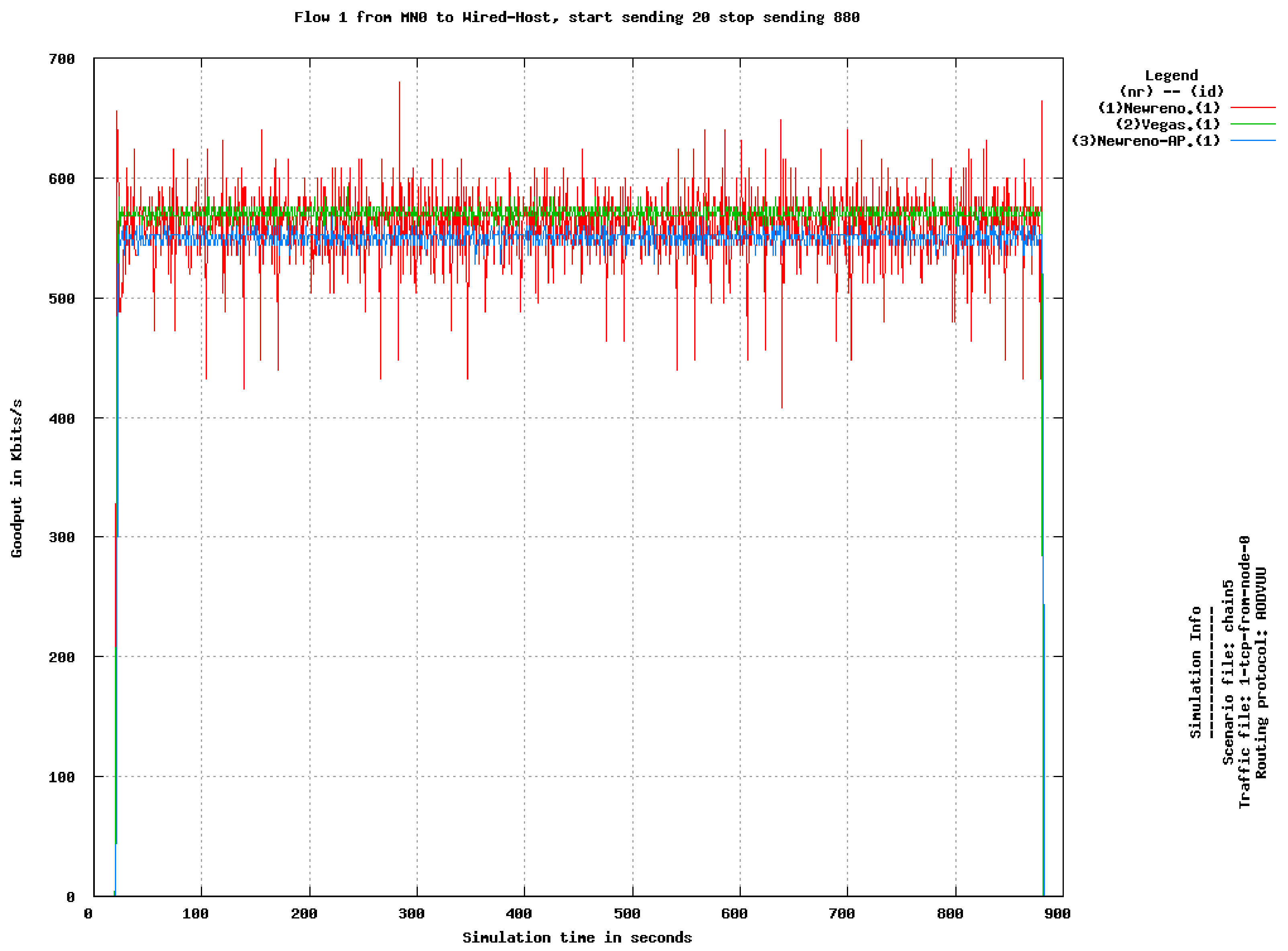
## G.4.3 Goodput



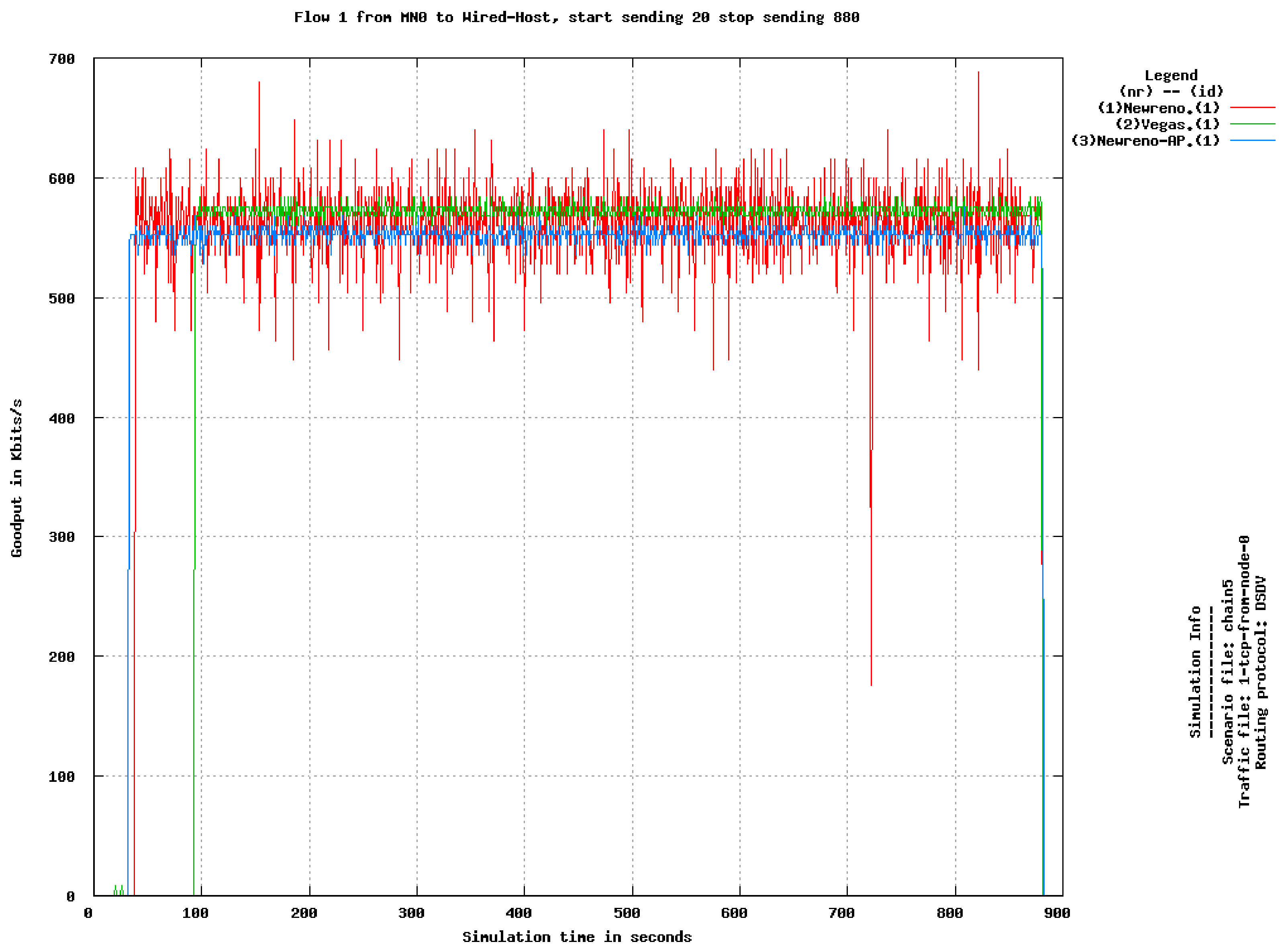
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN0 to MN4, start sending 220.0 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain5
Traffic file: 1-tcp-from-node-0-1-tcp-between-node-4-node-0
Routing protocol: AODVUU

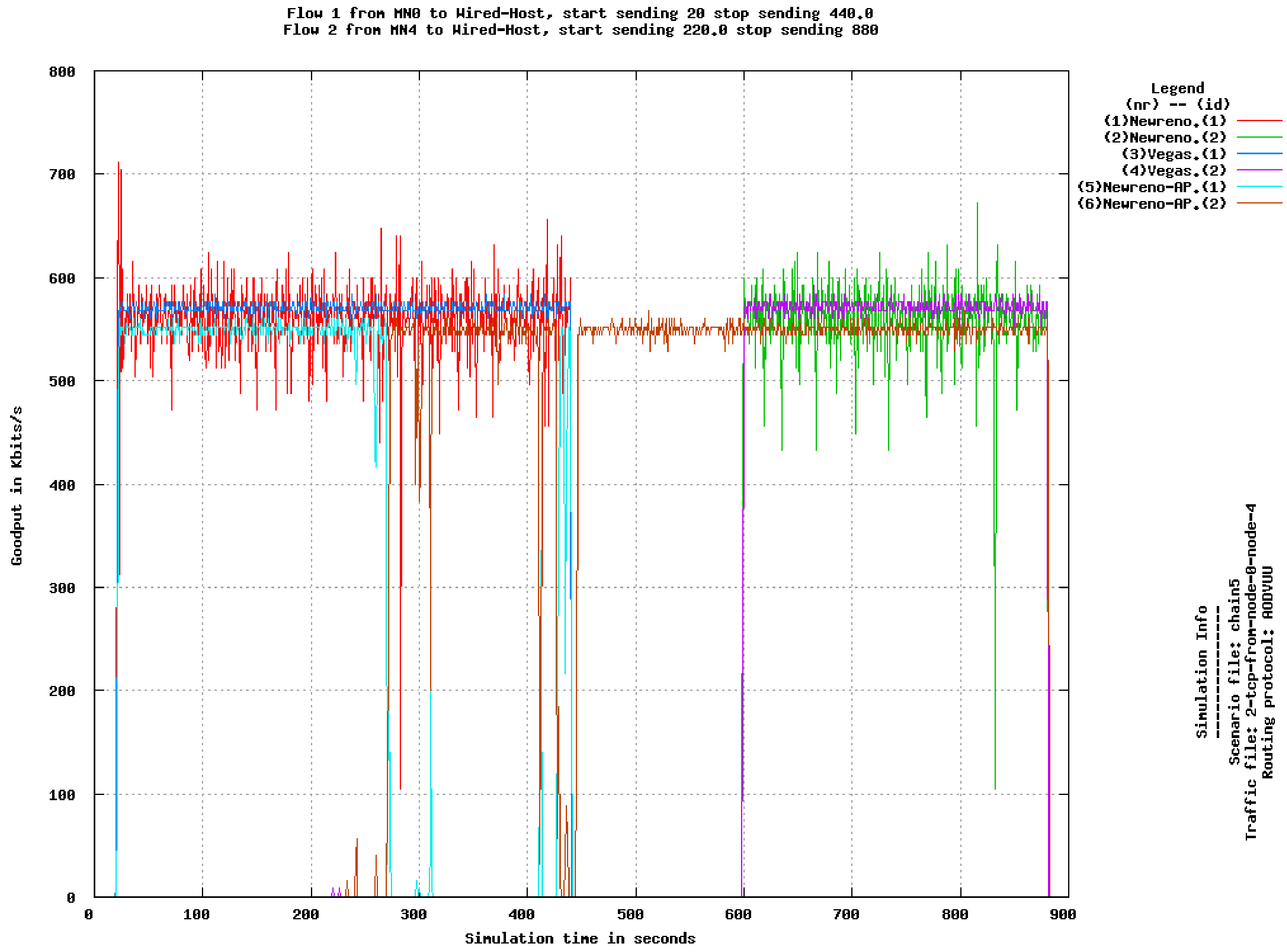


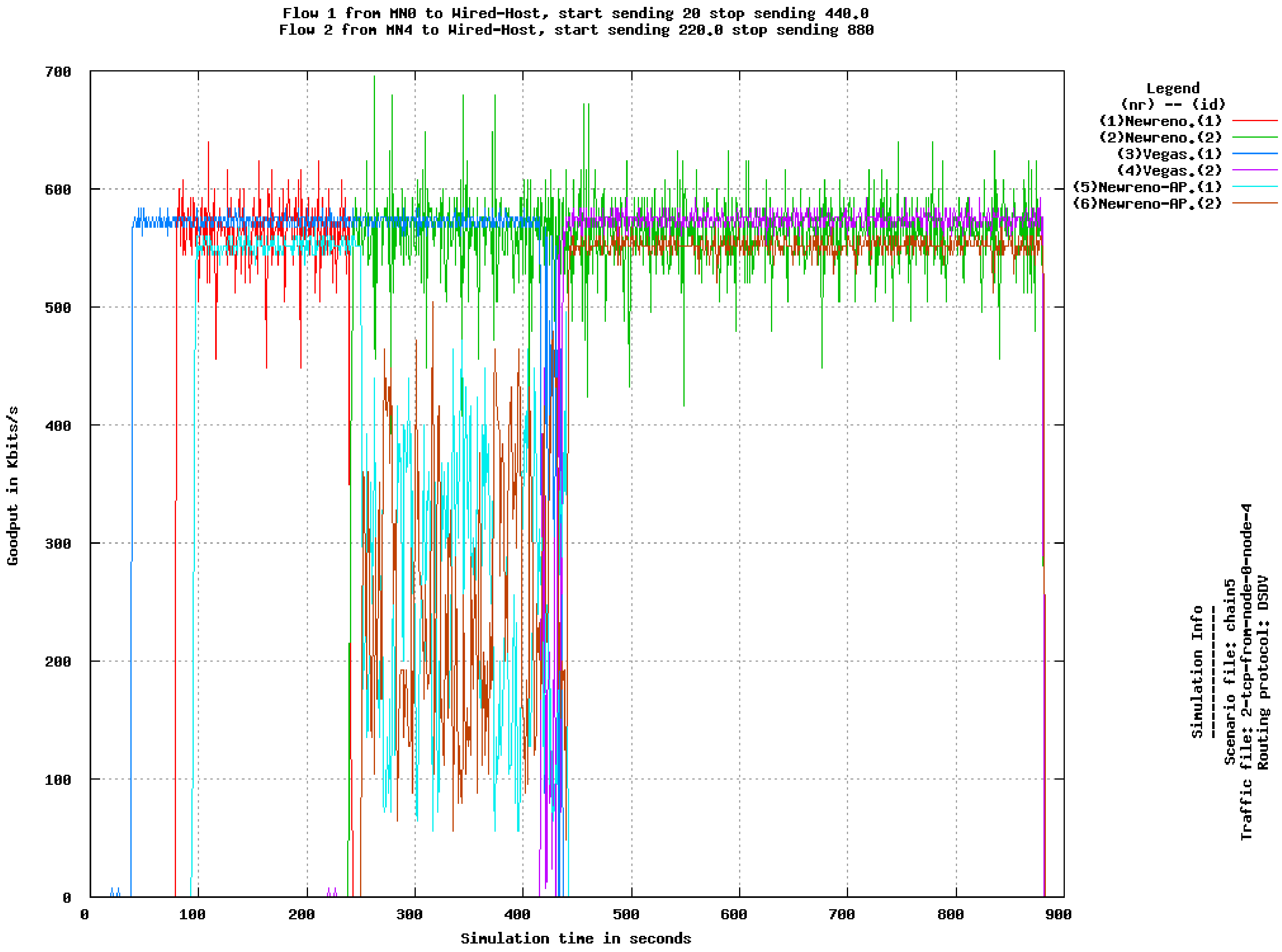
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN0 to MN4, start sending 220.0 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
---------------
Scenario file: chain5
Traffic file: 1-tcp-from-node-0-1-tcp-between-node-4-node-0
Routing protocol: DSDV



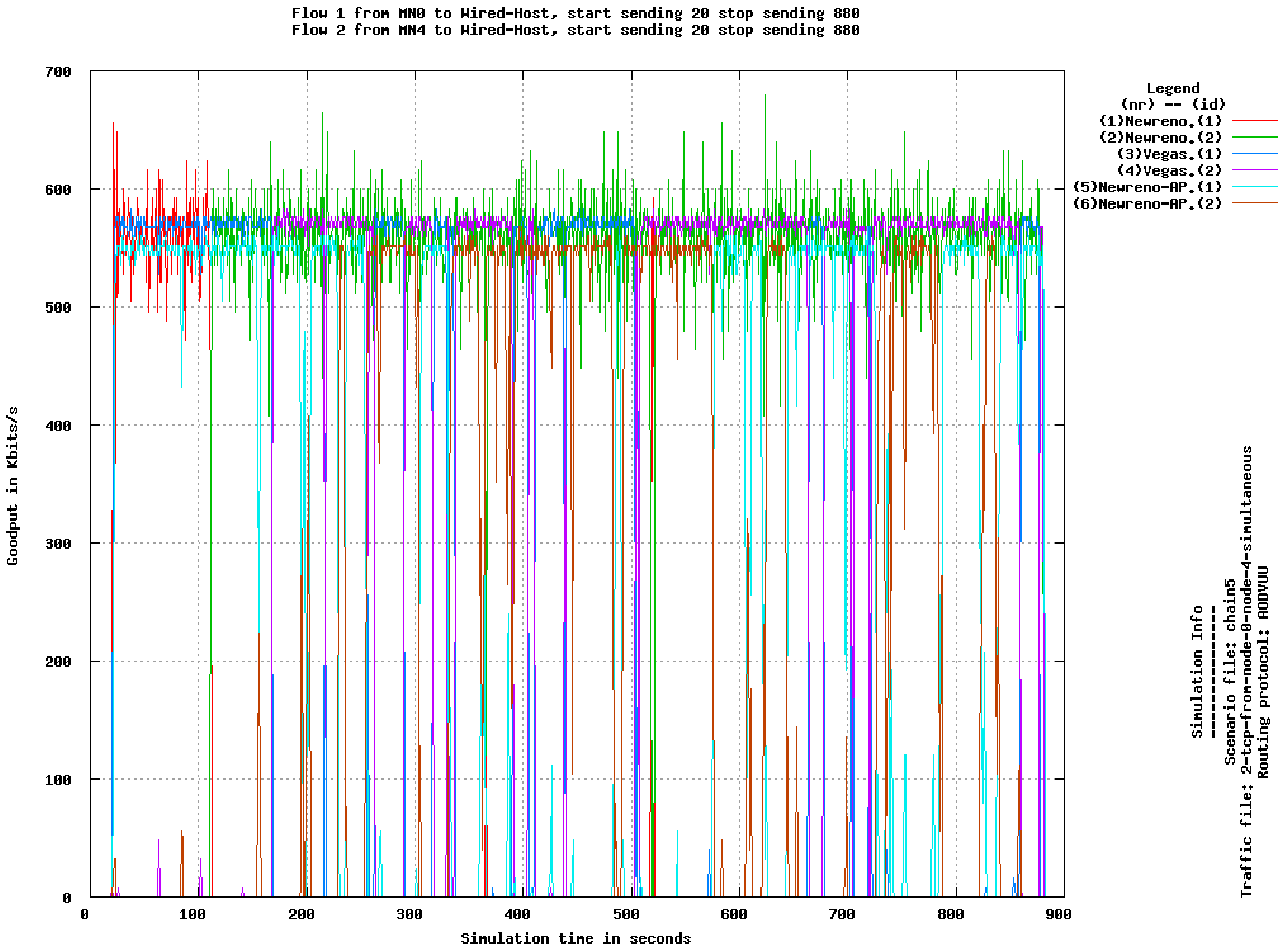
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
Scenario file: chain5
Traffic file: 1-tcp-from-node-0
Routing protocol: AODVUU


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
---------------
Scenario file: chain5
Traffic file: 1-tcp-from-node-0
Routing protocol: DSDV

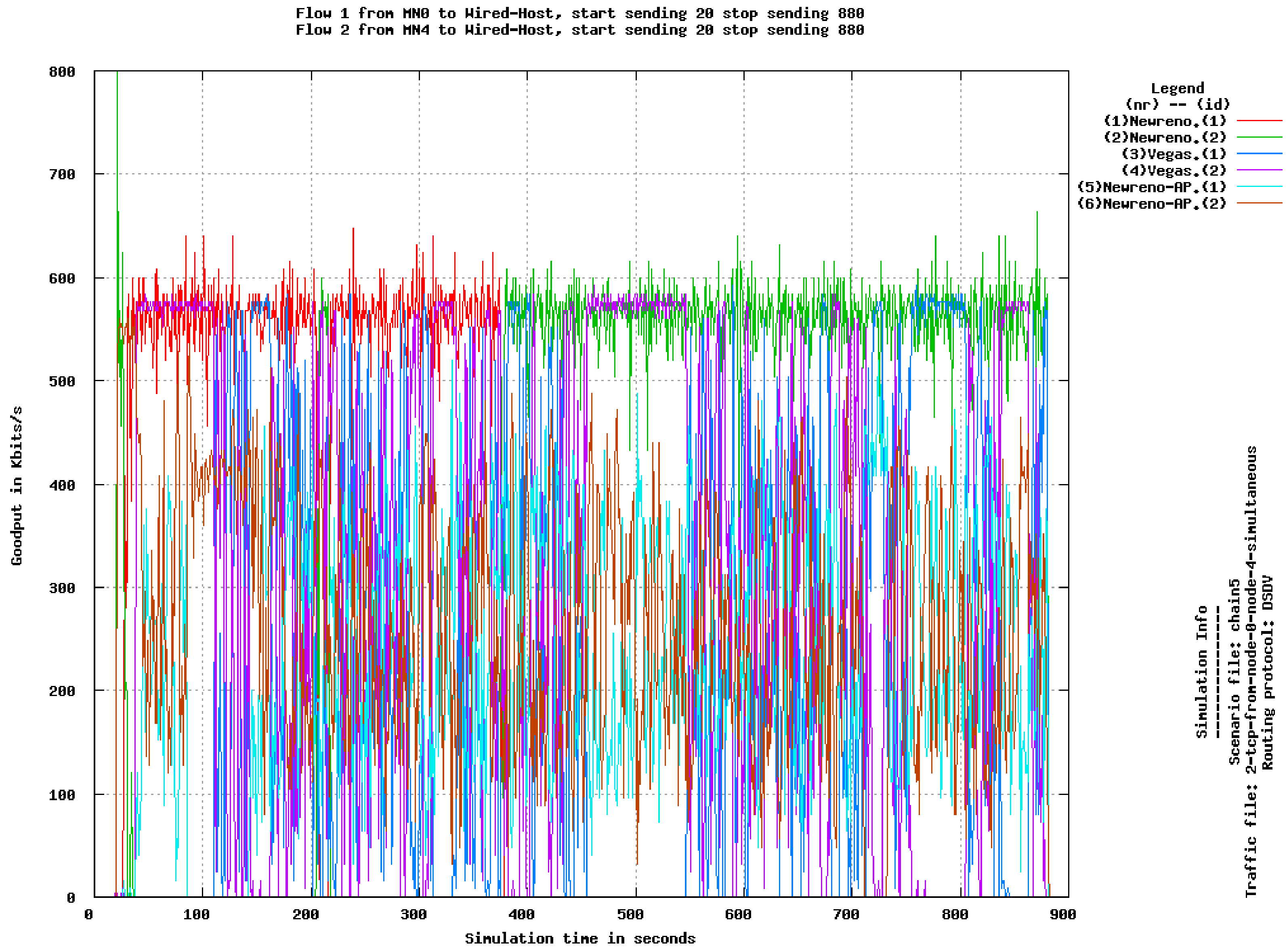

Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN4 to Wired-Host, start sending 220.0 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain5
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: AODVUU



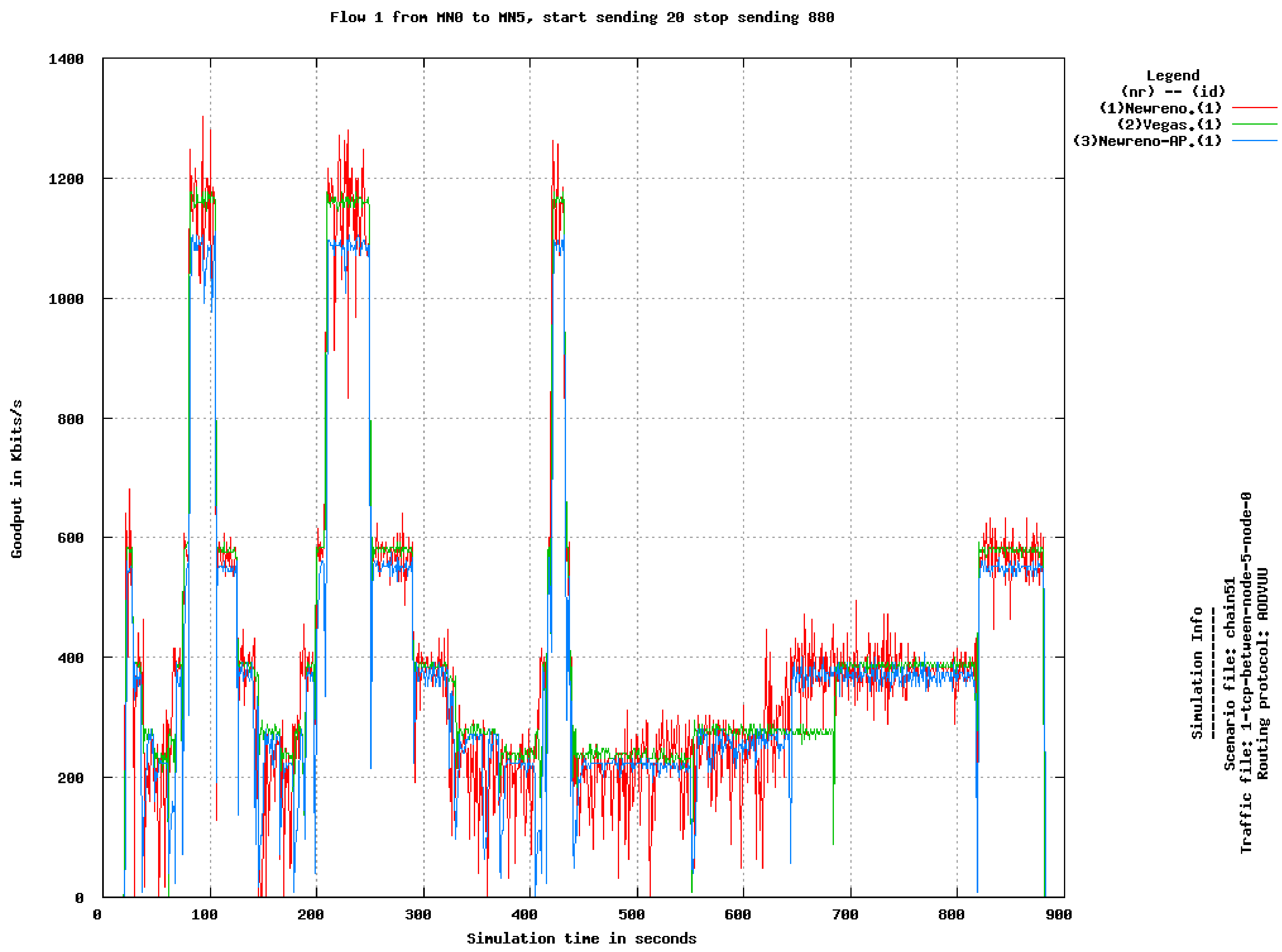
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN4 to Wired-Host, start sending 220.0 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain5
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: DSDV



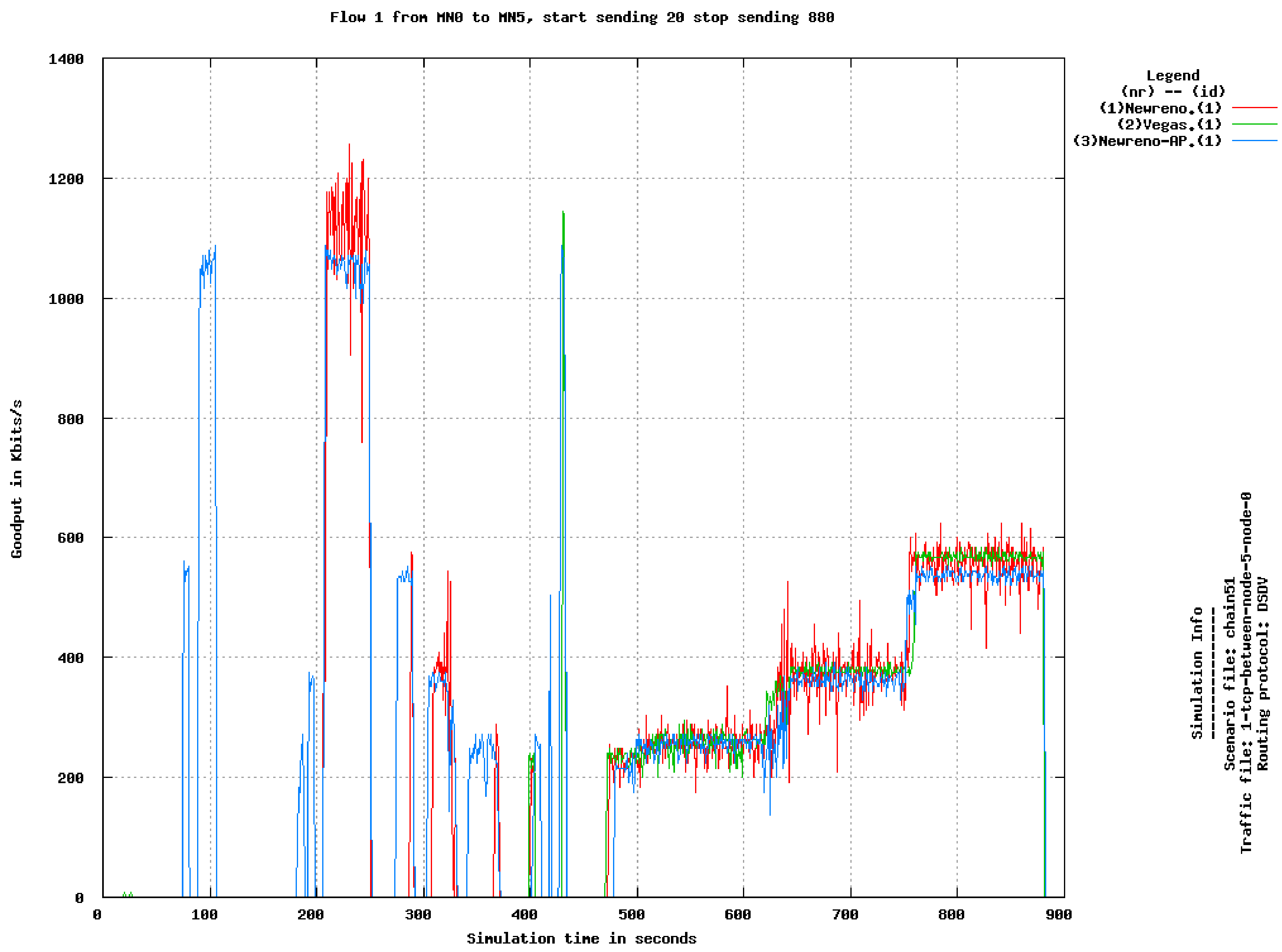
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN4 to Wired-Host, start sending 20 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno,(1)
(2)Newreno,(2)
(3)Vegas,(1)
(4)Vegas,(2)
(5)Newreno-AP,(1)
(6)Newreno-AP,(2)
Simulation Info
Scenario file: chain5
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: AODVUU

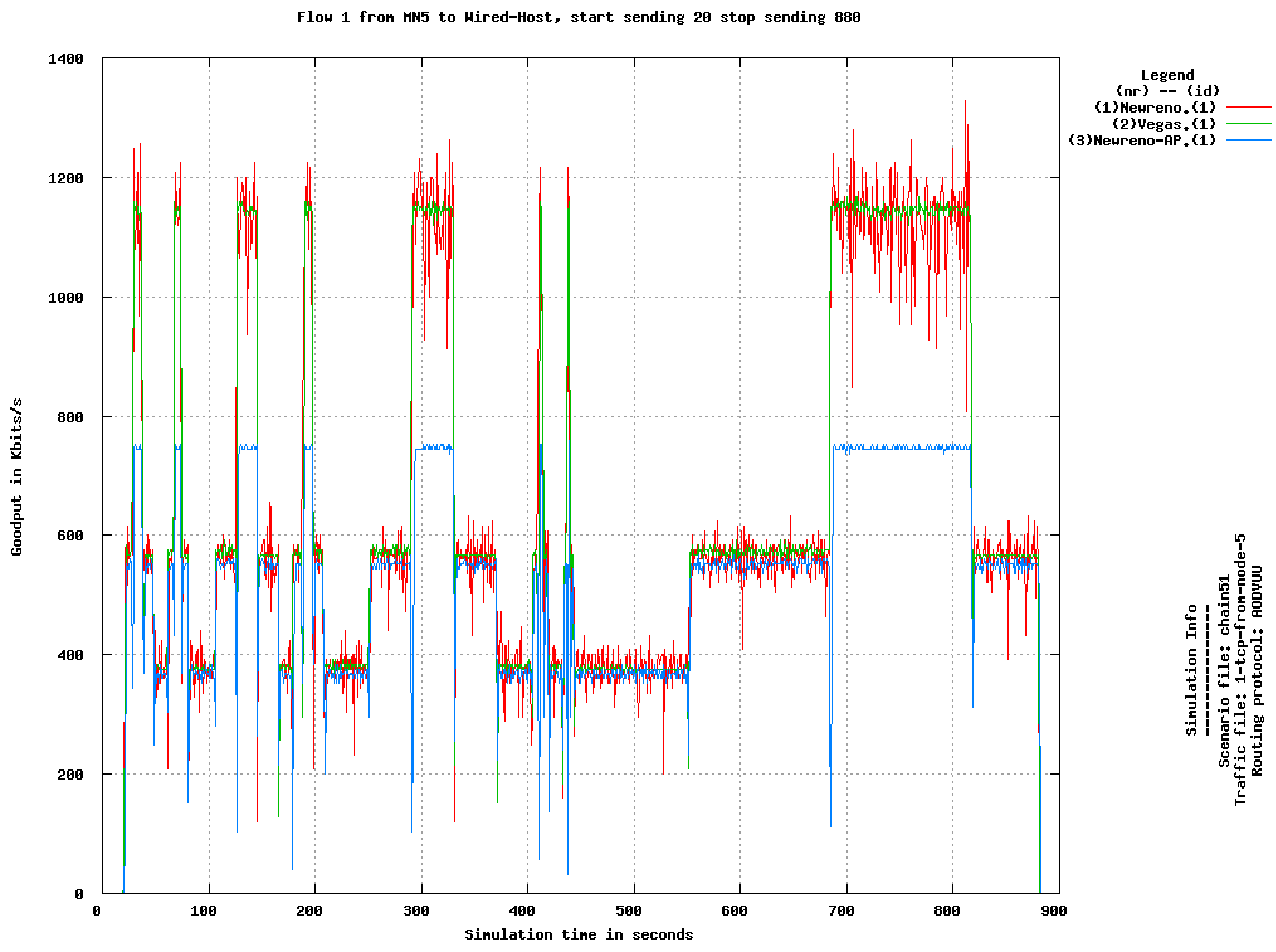


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN4 to Wired-Host, start sending 20 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno,(1)
(2)Newreno,(2)
(3)Vegas,(1)
(4)Vegas,(2)
(5)Newreno-AP,(1)
(6)Newreno-AP,(2)
Simulation Info
Scenario file: chain5
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: DSDV

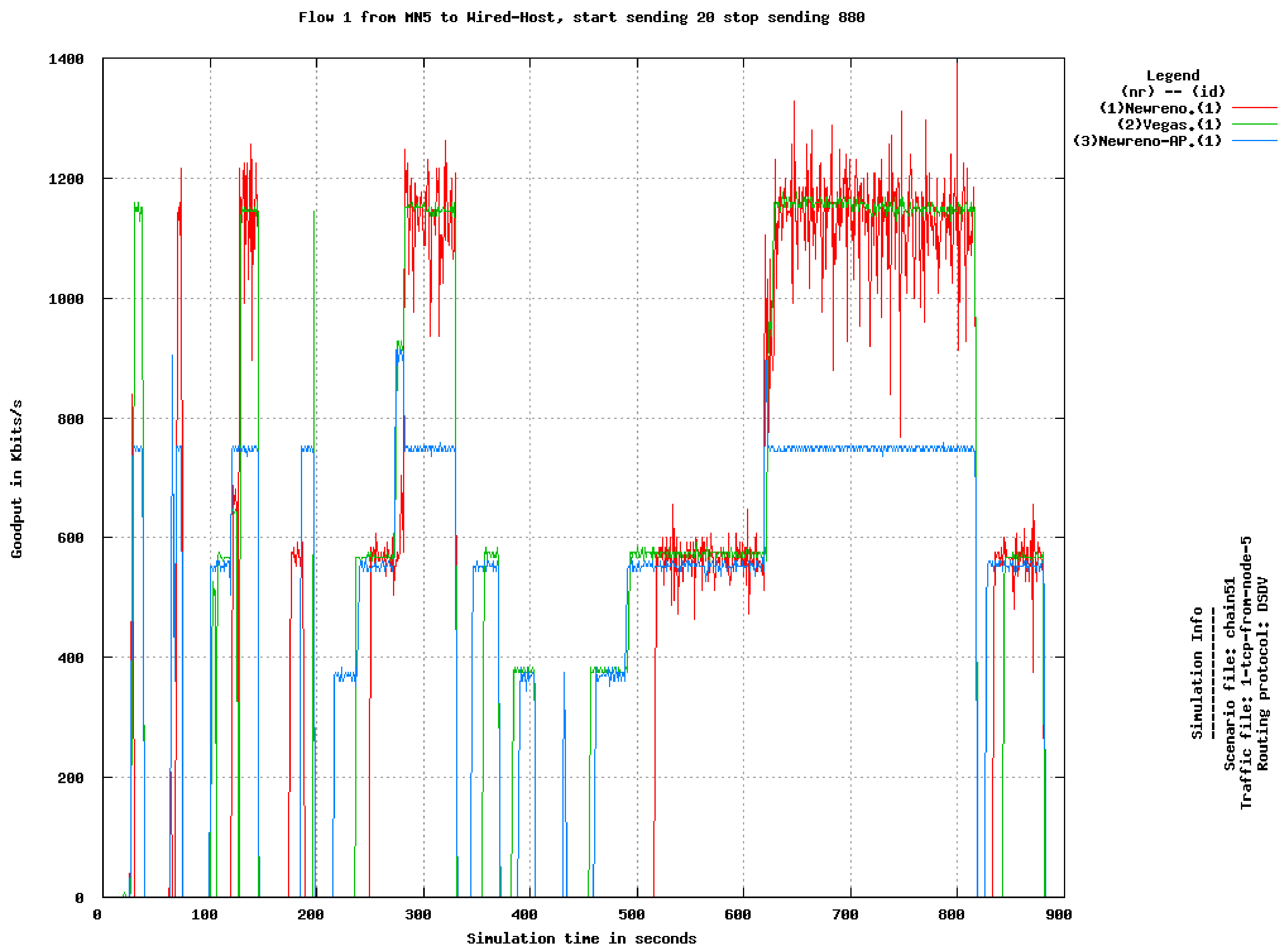


Flow 1 from MN0 to MN5, start sending 20 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
200
400
600
800
1000
1200
1400
100
300
500
700
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
---------------
Scenario file: chain51
Traffic file: 1-tcp-between-node-5-node-0
Routing protocol: AODVUU

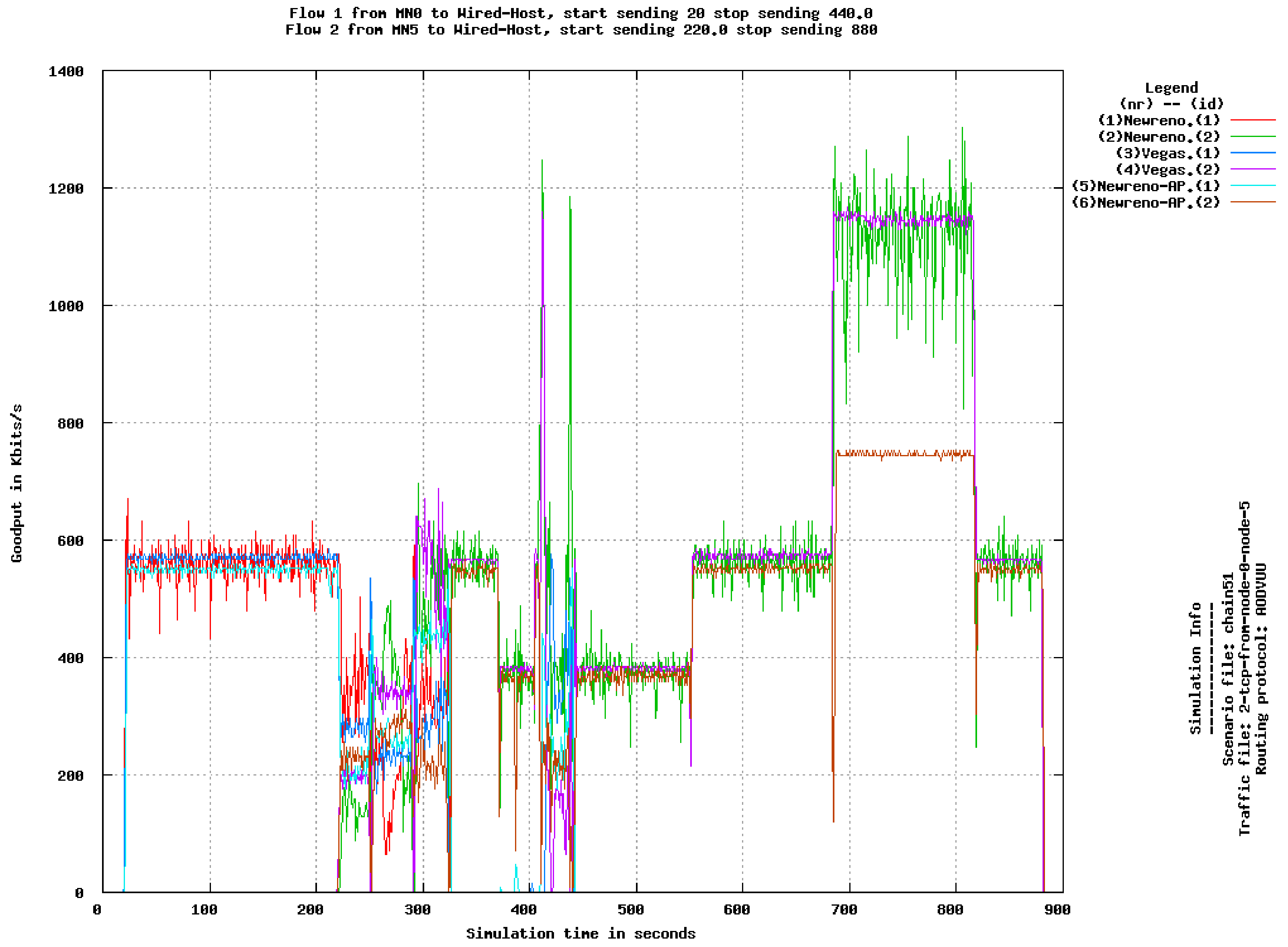

Flow 1 from MN0 to MN5, start sending 20 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
200
400
600
800
1000
1200
1400
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
Scenario file: chain51
Traffic file: 1-tcp-between-node-5-node-0
Routing protocol: DSDV



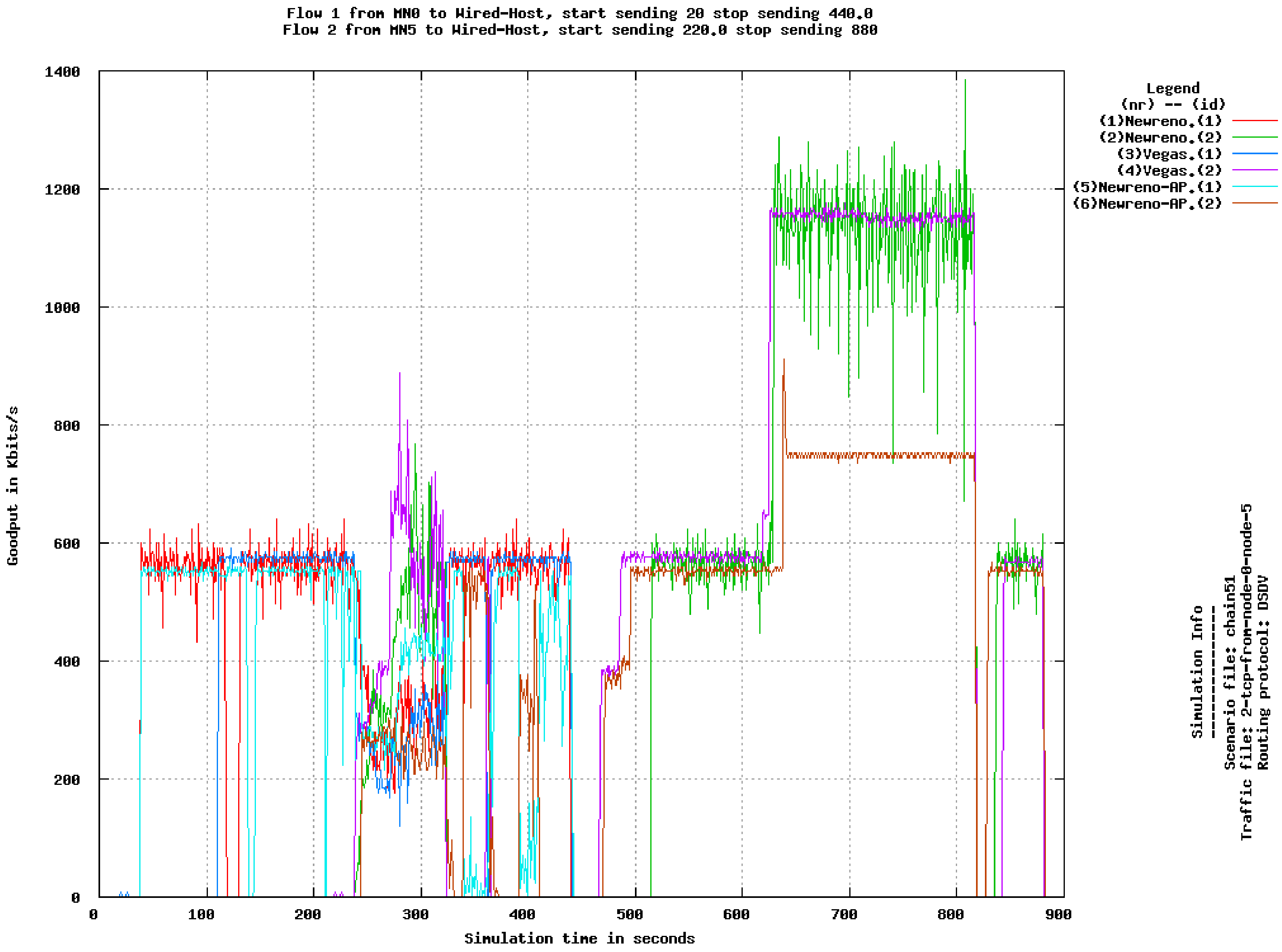
Flow 1 from MN5 to Wired-Host, start sending 20 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
200
400
600
800
1000
1200
1400
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
Scenario file: chain51
Traffic file: 1-tcp-from-node-5
Routing protocol: AODVUU



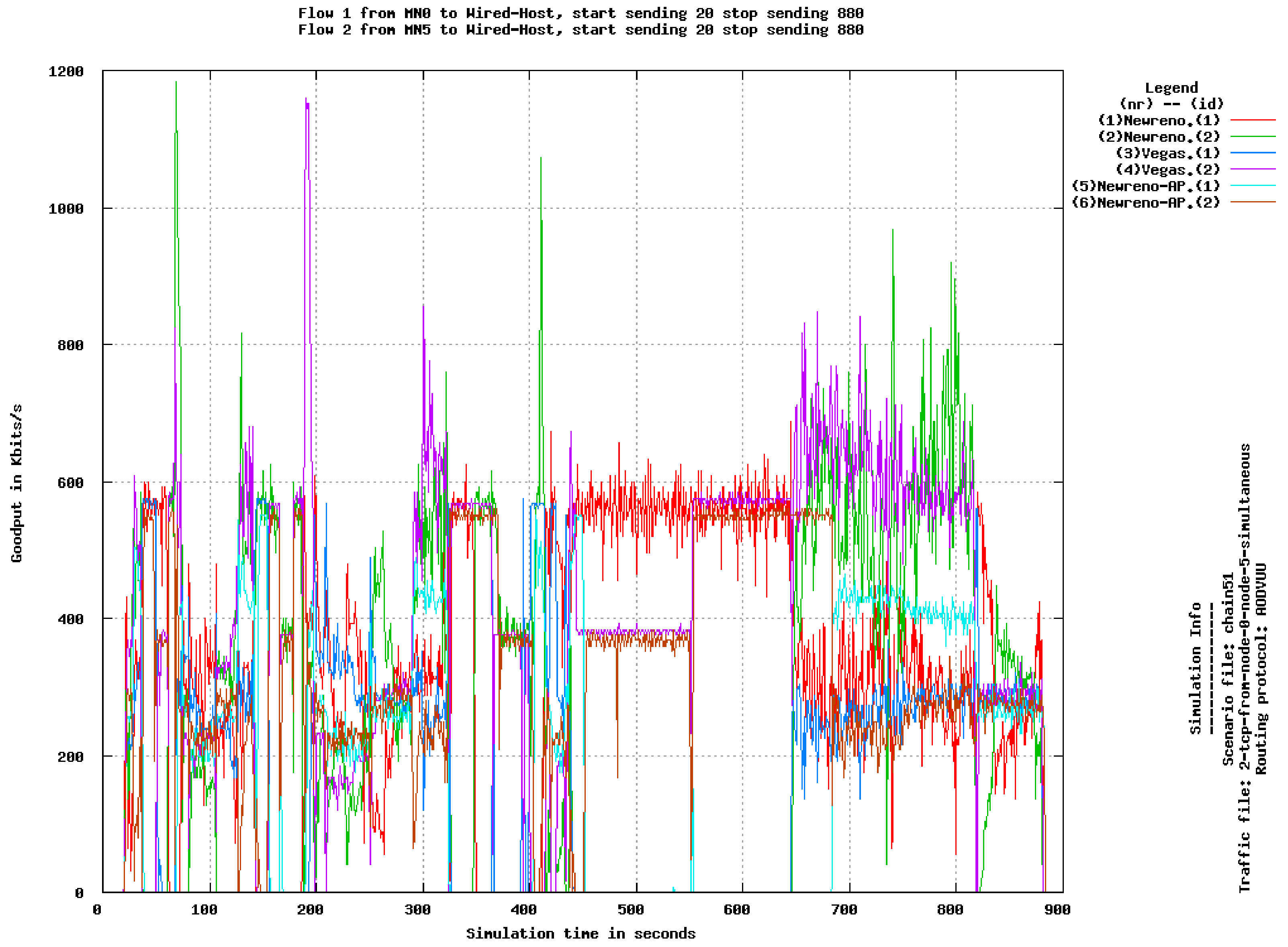
Simulation Info
---------------
Scenario file: chain51
Traffic file: 1-tcp-from-node-5
Routing protocol: DSDV



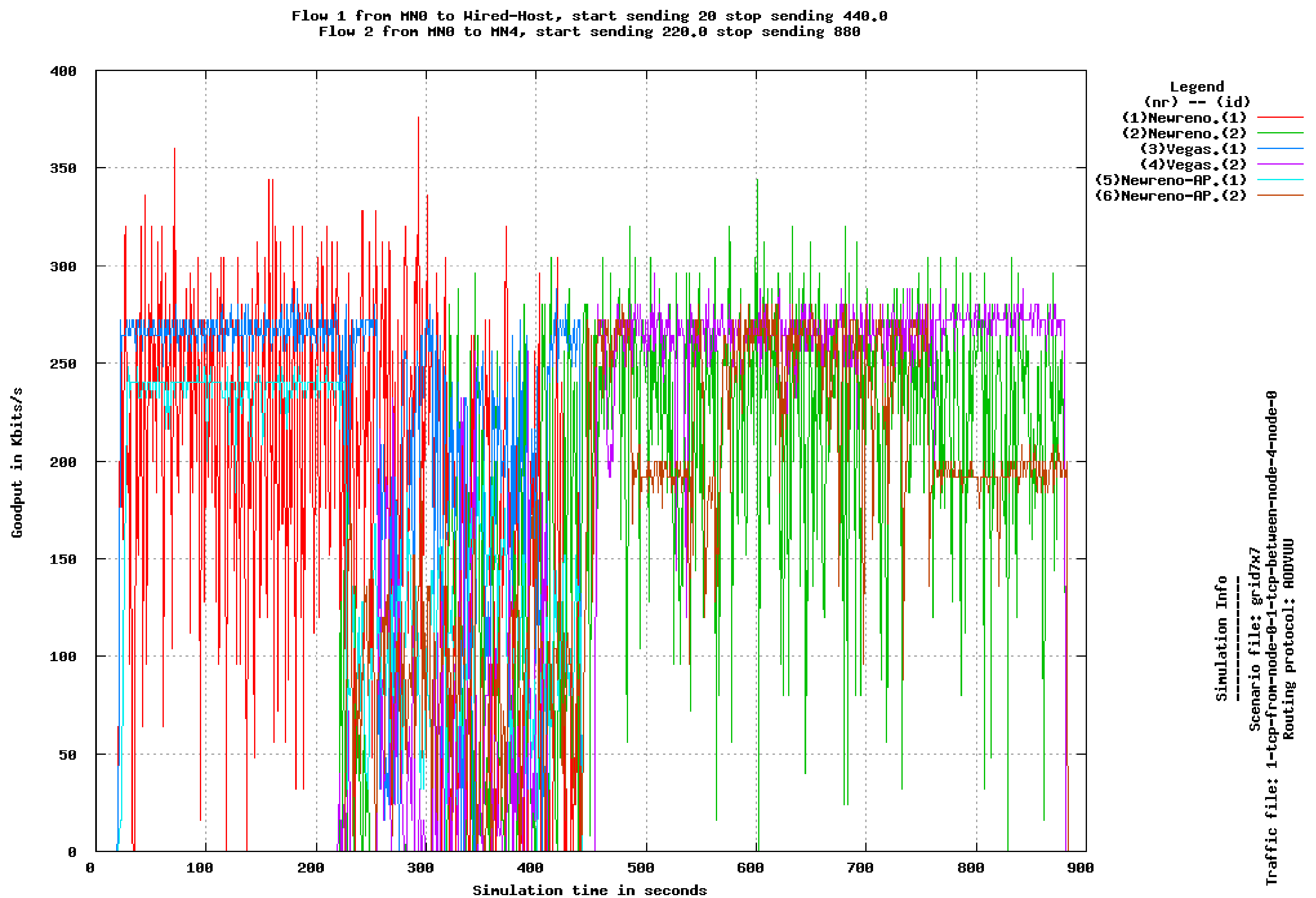
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN5 to Wired-Host, start sending 220.0 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
200
400
600
800
1000
1200
1400
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain51
Traffic file: 2-tcp-from-node-0-node-5
Routing protocol: AODVUU



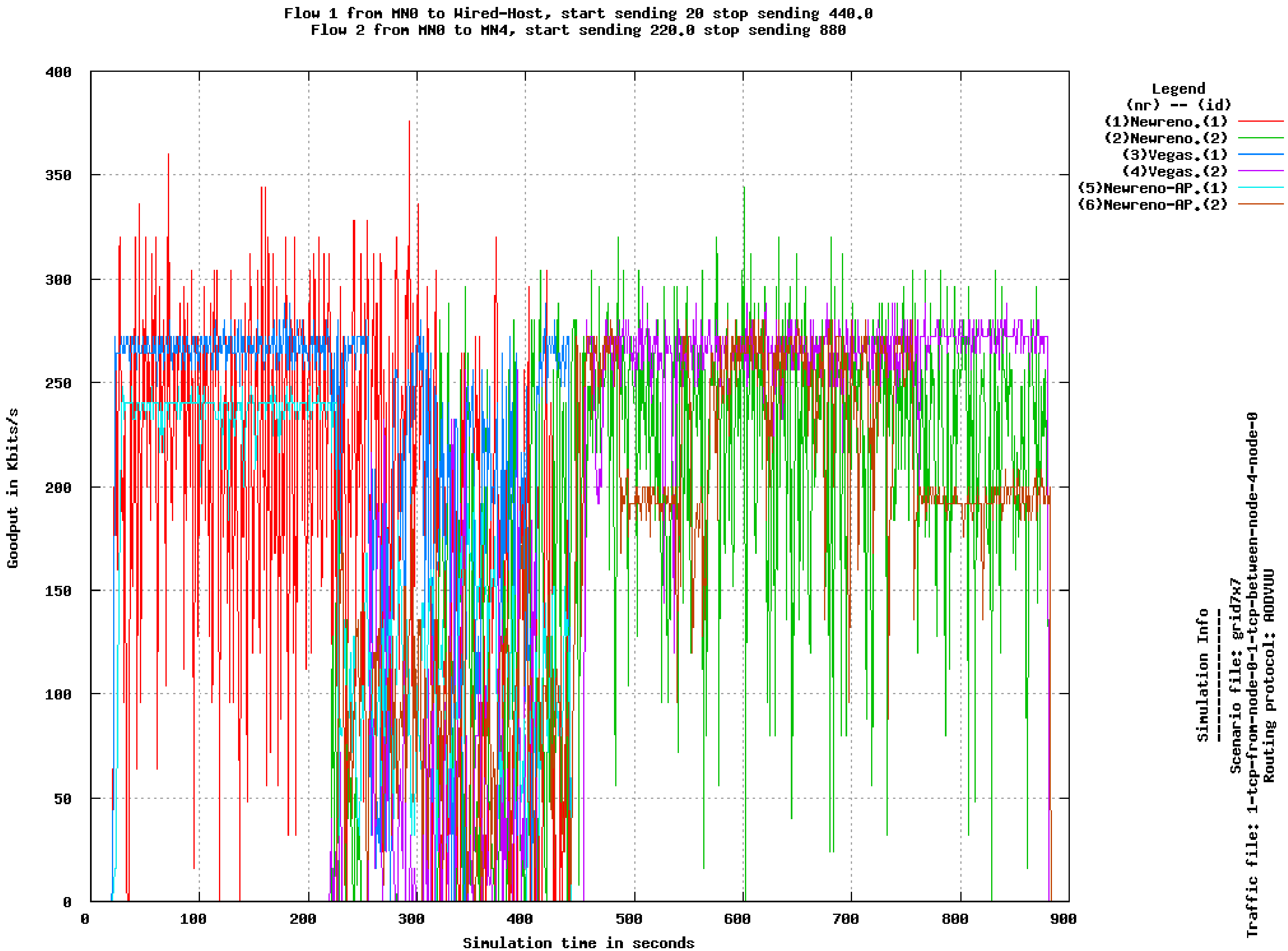
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN5 to Wired-Host, start sending 220.0 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
200
400
600
800
1000
1200
1400
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain51
Traffic file: 2-tcp-from-node-0-node-5
Routing protocol: DSDV

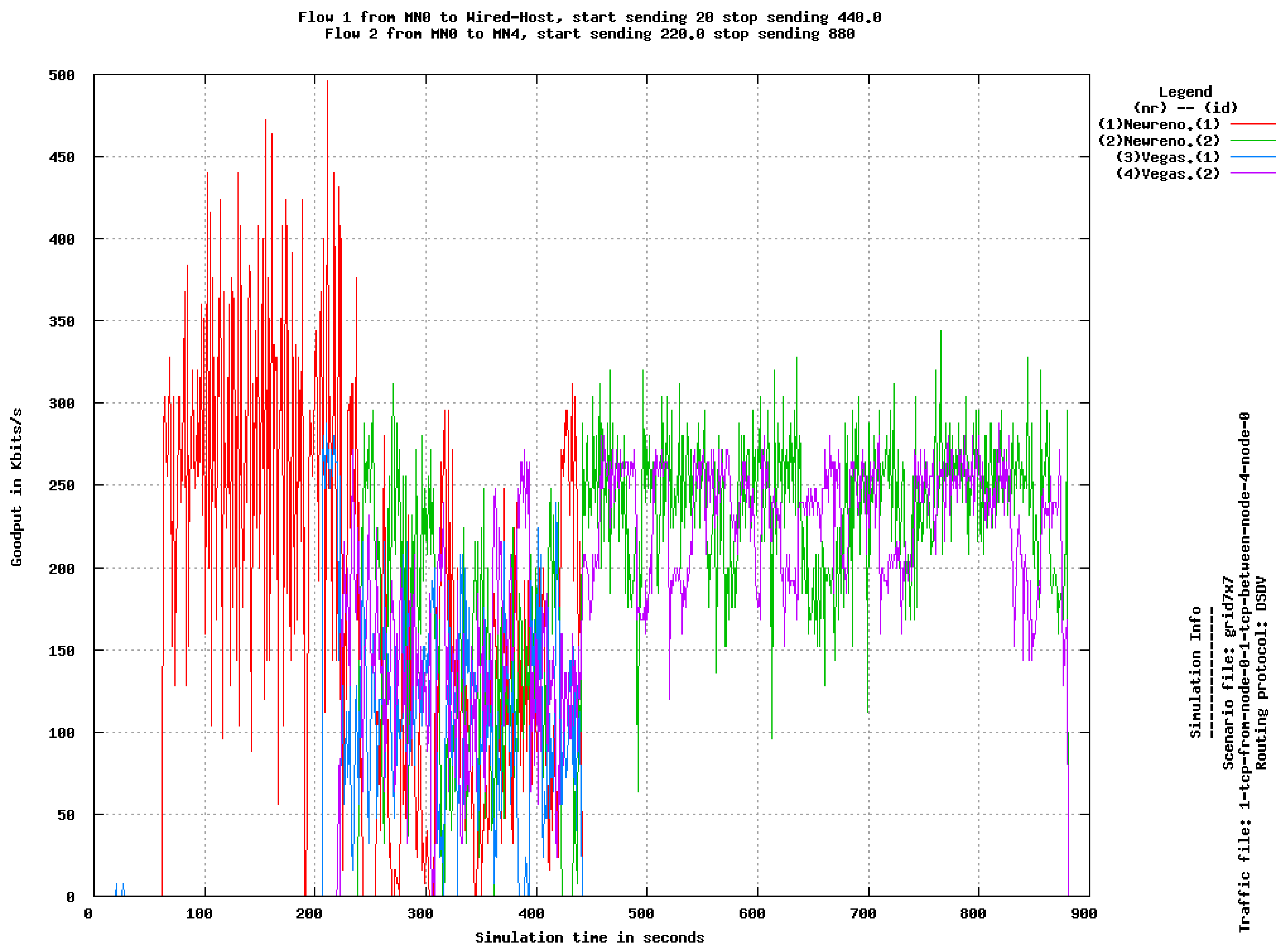


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN5 to Wired-Host, start sending 20 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
200
400
600
800
1000
1200
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno,(1)
(2)Newreno,(2)
(3)Vegas,(1)
(4)Vegas,(2)
(5)Newreno-AP,(1)
(6)Newreno-AP,(2)
Simulation Info
---------------
Scenario file: chain51
Traffic file: 2-tcp-from-node-0-node-5-simultaneous
Routing protocol: AODVUU

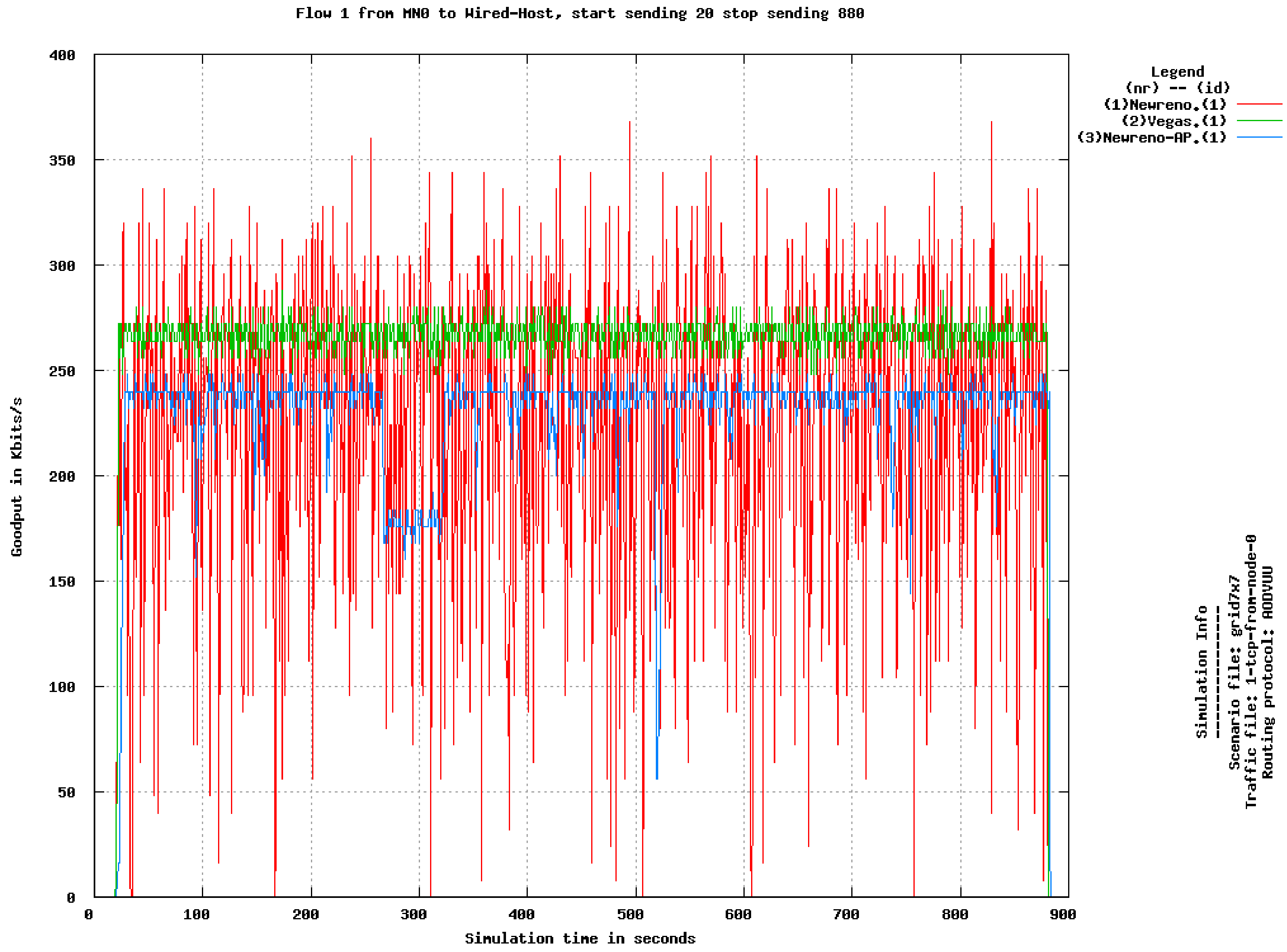


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN0 to MN4, start sending 220.0 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
50
100
150
200
250
300
350
400
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: grid7x7
Traffic file: 1-tcp-from-node-0-1-tcp-between-node-4-node-0
Routing protocol: AODVUU

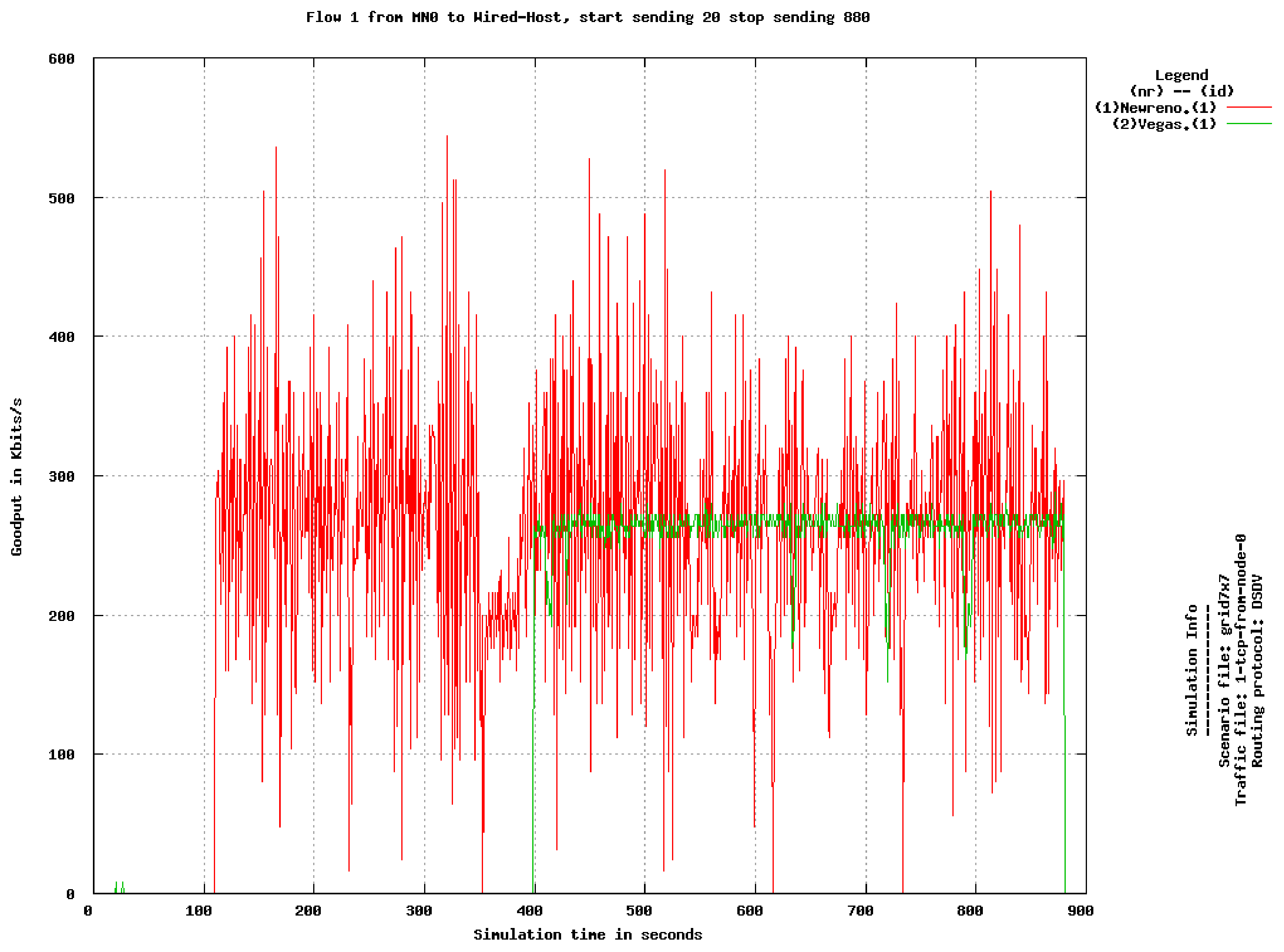

Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN0 to MN4, start sending 220.0 stop sending 880
Goodput in Kbits/s
400
350
300
250
200
150
100
50
0
0
100
200
300
400
500
600
700
800
900
Simulation time in seconds
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: grid7x7
Traffic file: 1-tcp-from-node-0-1-tcp-between-node-4-node-0
Routing protocol: AODVUU



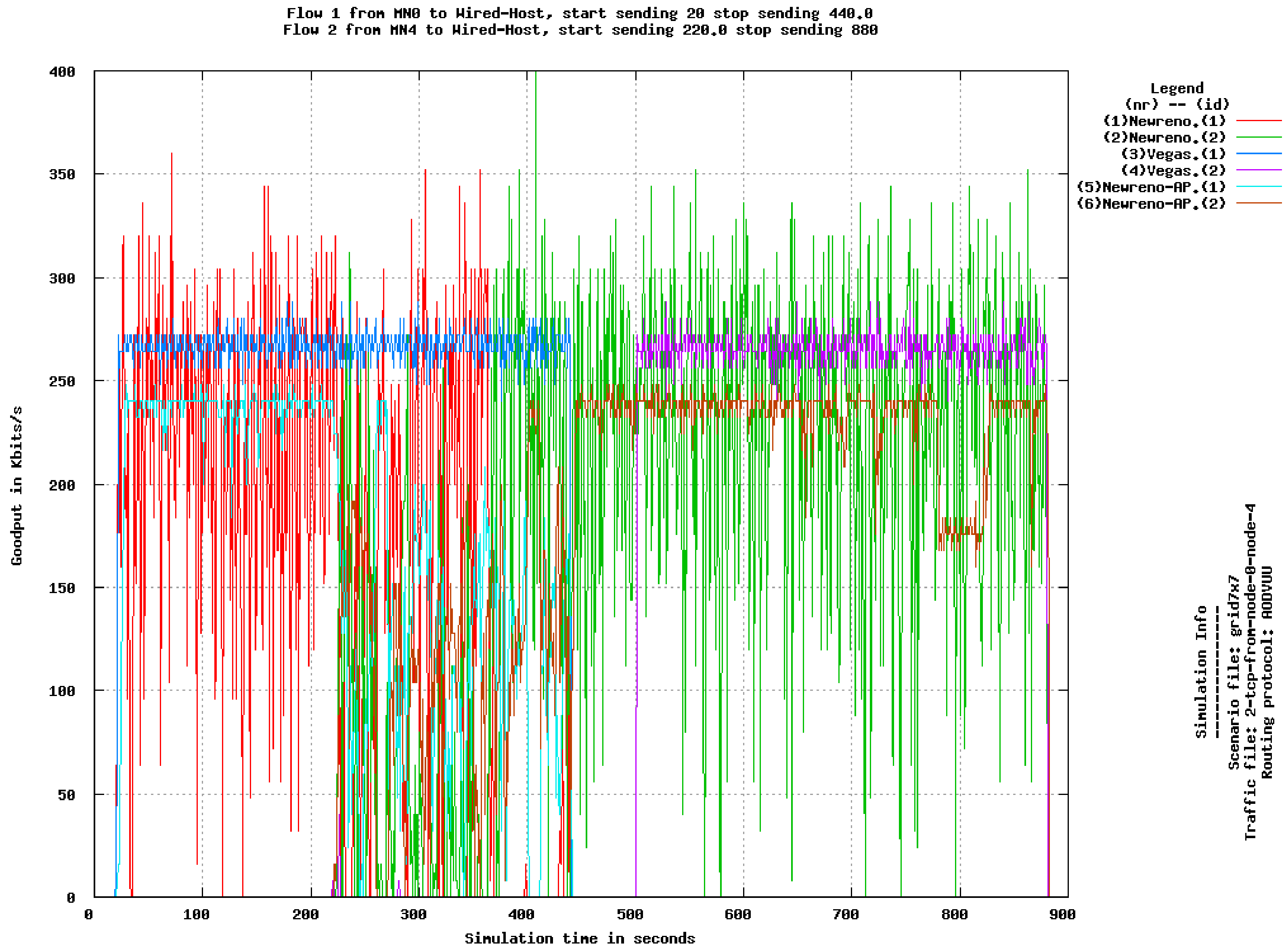
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN0 to MN4, start sending 220.0 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
50
100
150
200
250
300
350
400
450
500
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
Simulation Info
Scenario file: grid7x7
Traffic file: 1-tcp-from-node-0-1-tcp-between-node-4-node-0
Routing protocol: DSDV



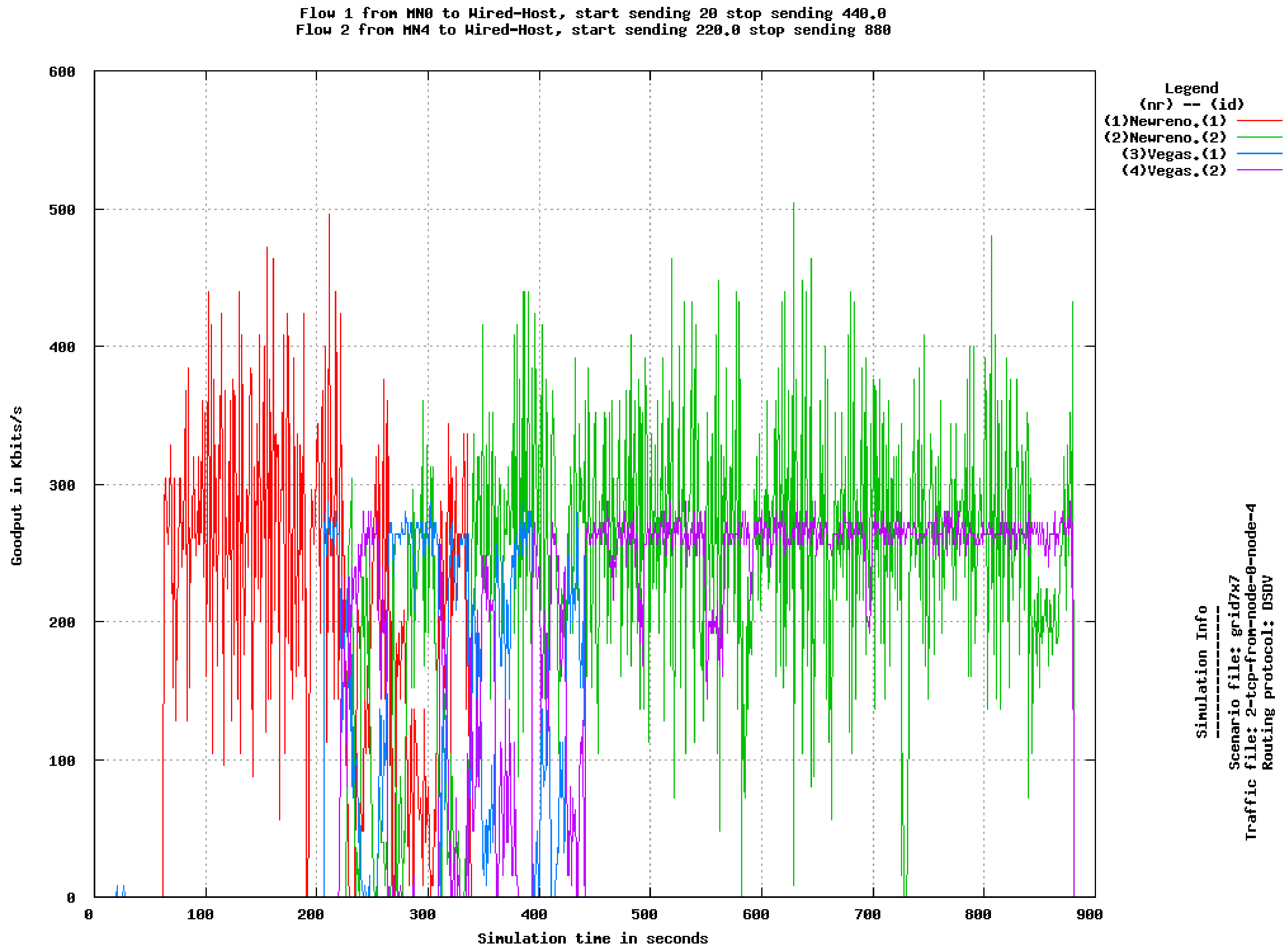
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
50
100
150
200
250
300
350
400
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
---------------
Scenario file: grid7x7
Traffic file: 1-tcp-from-node-0
Routing protocol: AODVUU



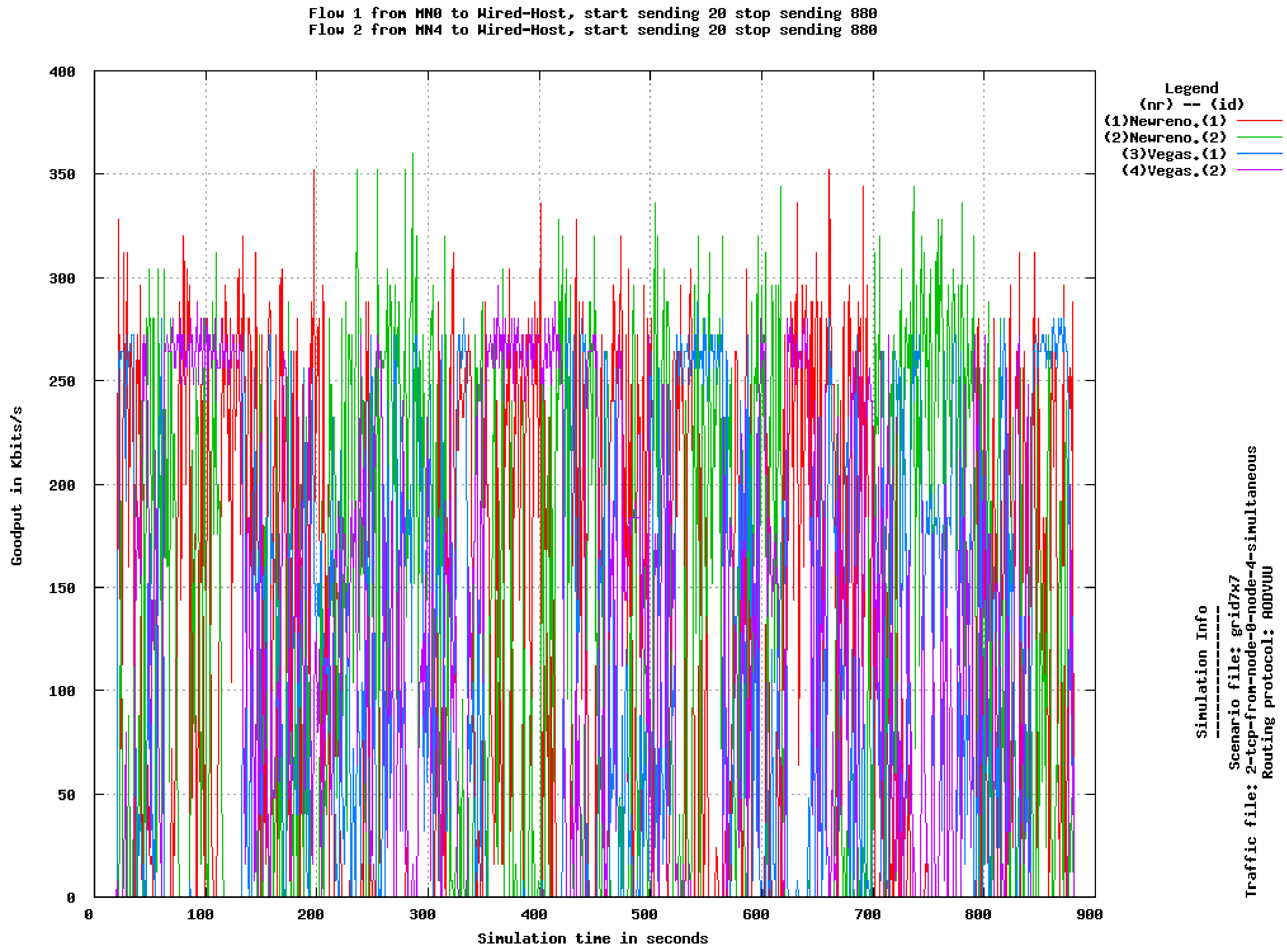
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno,(1)
(2)Vegas,(1)
Simulation Info
Scenario file: grid7x7
Traffic file: 1-tcp-from-node-0
Routing protocol: DSDV



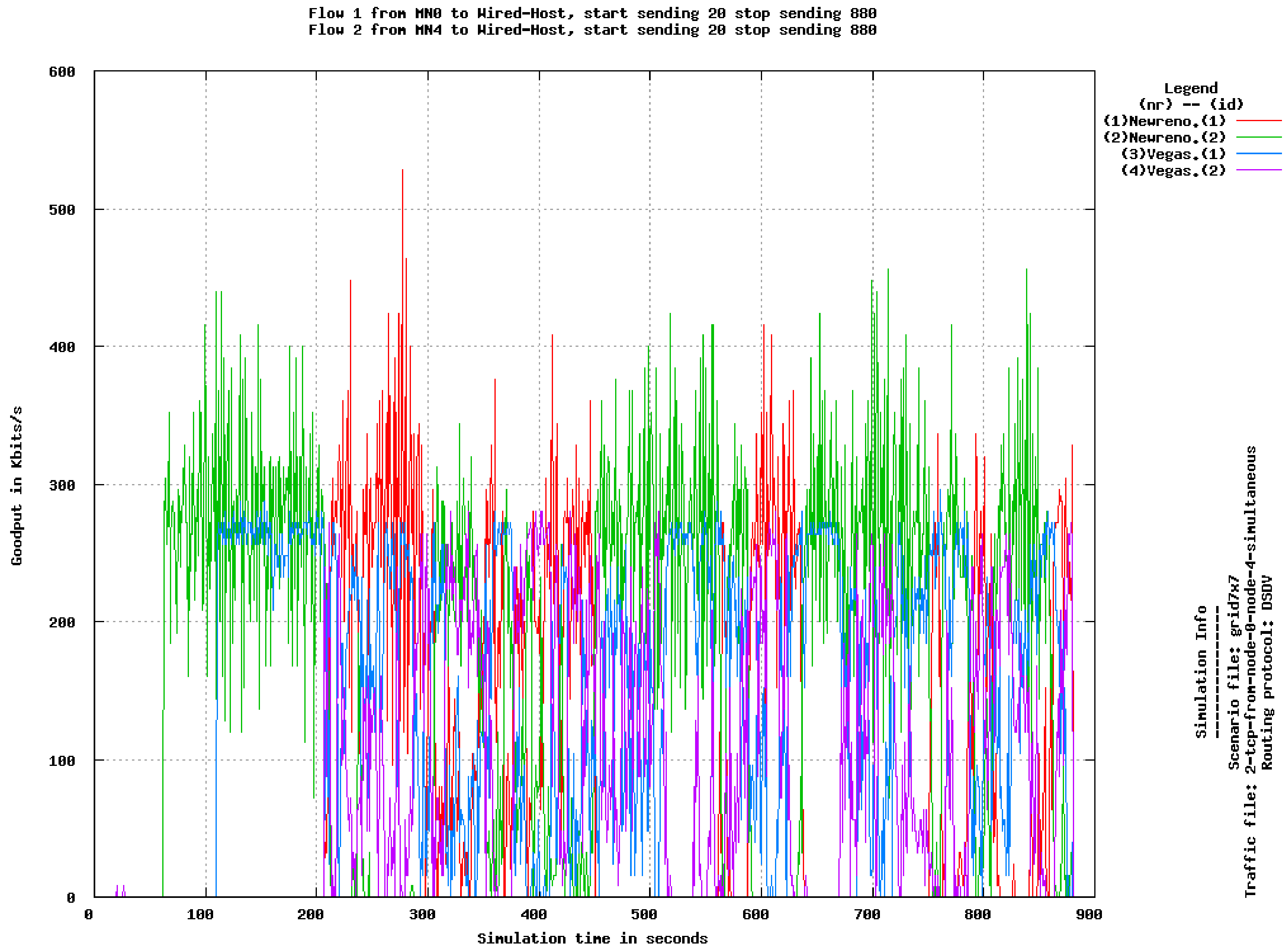
Simulation Info
---------------
Scenario file: grid7x7
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: AODVUU

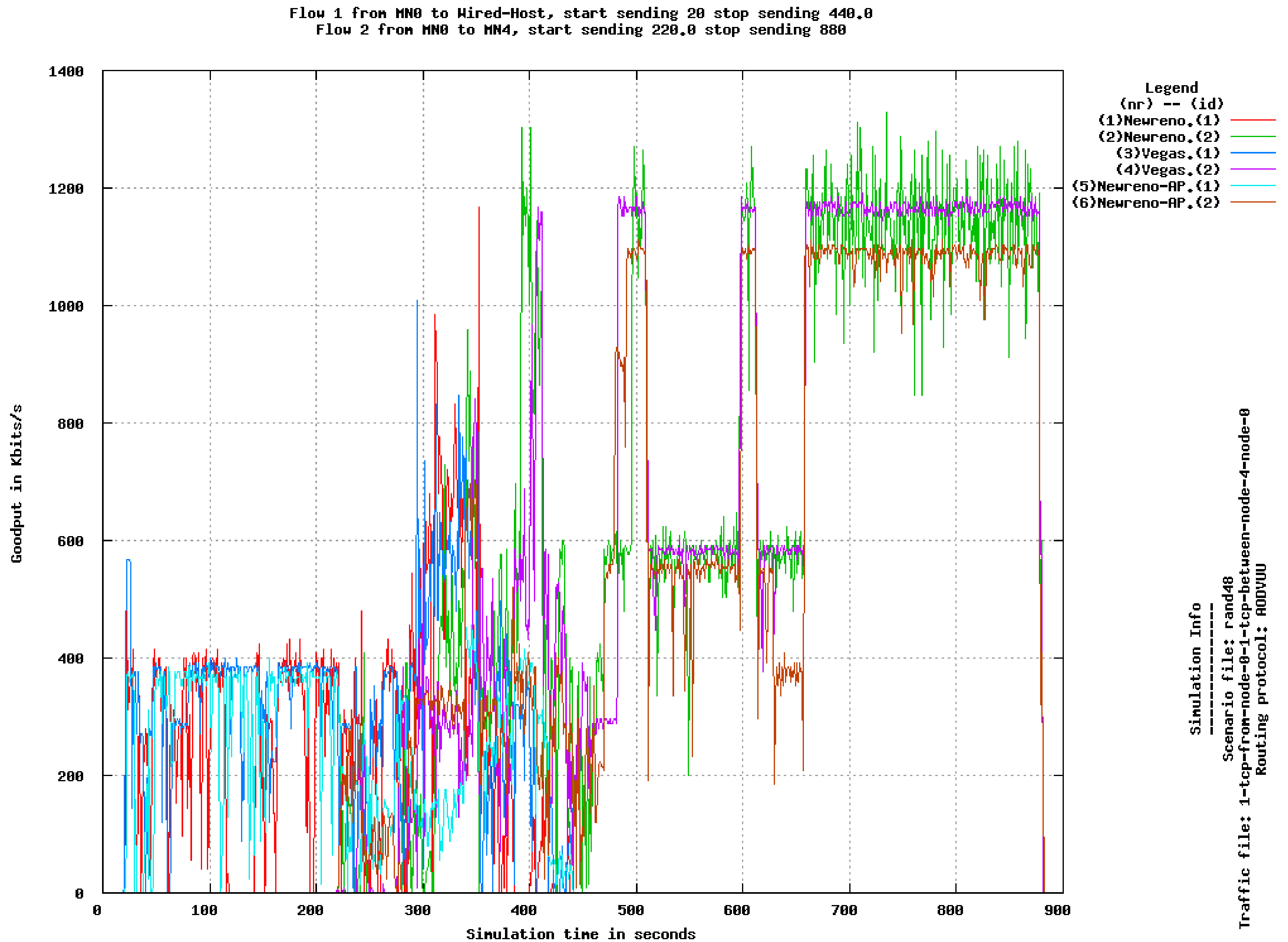


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN4 to Wired-Host, start sending 220.0 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
Simulation Info
Scenario file: grid7x7
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: DSDV

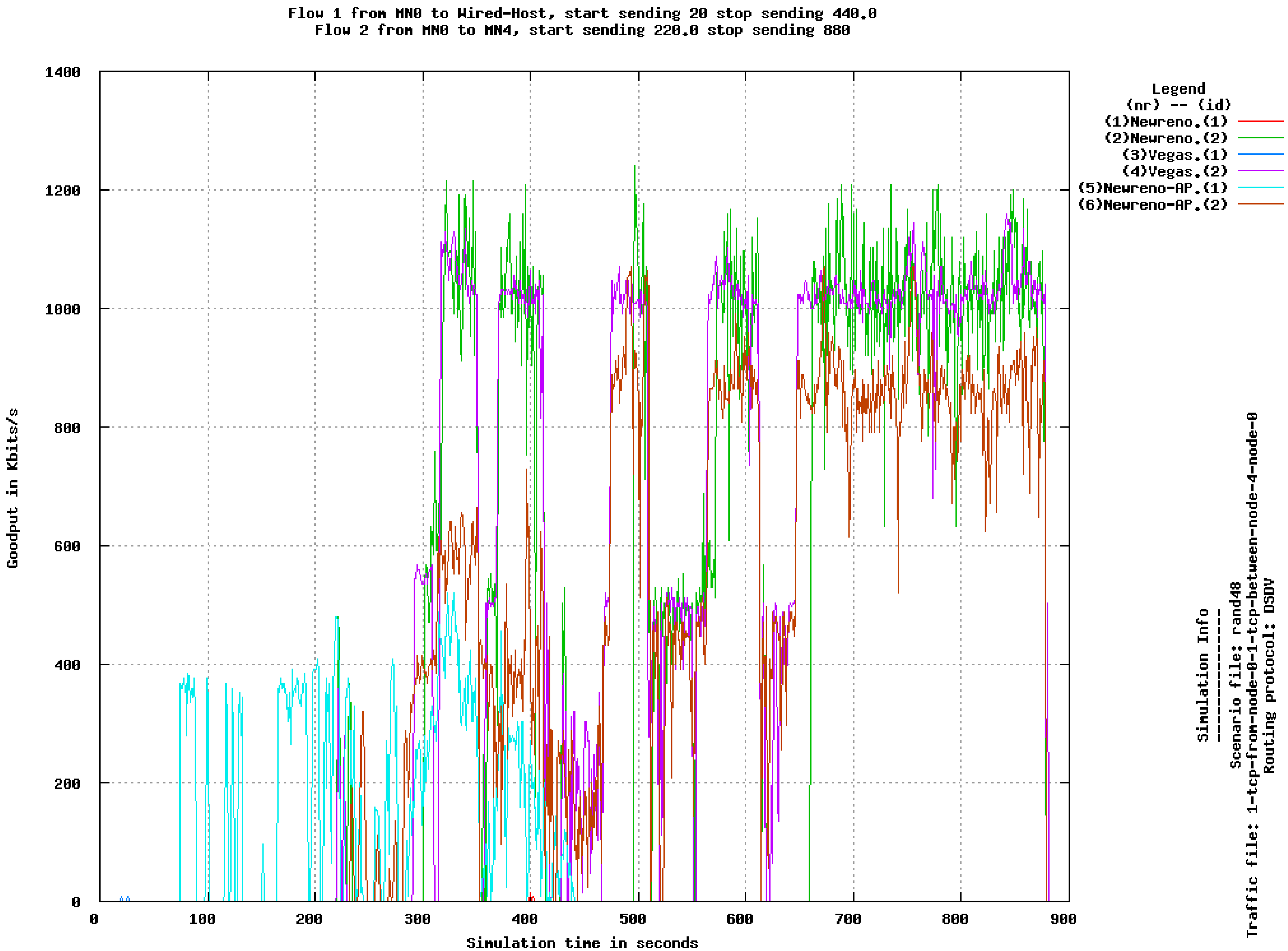


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN4 to Wired-Host, start sending 20 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
50
100
150
200
250
300
350
400
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno,(1)
(2)Newreno,(2)
(3)Vegas,(1)
(4)Vegas,(2)
Simulation Info
---------------
Scenario file: grid7x7
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: AODVUU

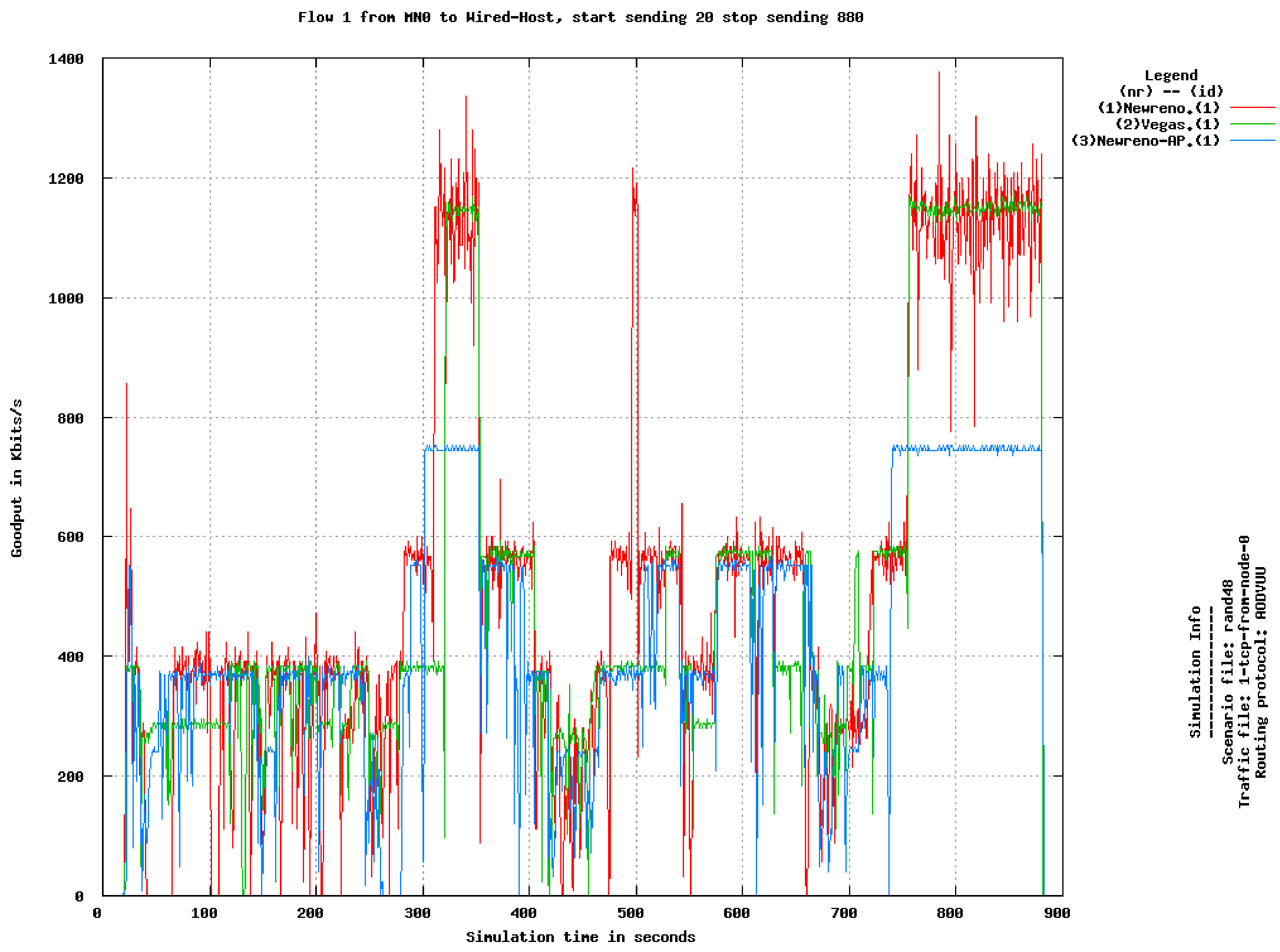

Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN4 to Wired-Host, start sending 20 stop sending 880
Goodput in Kbits/s
600
500
400
300
200
100
0
0
100
200
300
400
500
600
700
800
900
Simulation time in seconds
Legend
(nr) -- (id)
(1)Newreno,(1)
(2)Newreno,(2)
(3)Vegas,(1)
(4)Vegas,(2)
Simulation Info
---------------
Scenario file: grid7x7
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: DSDV

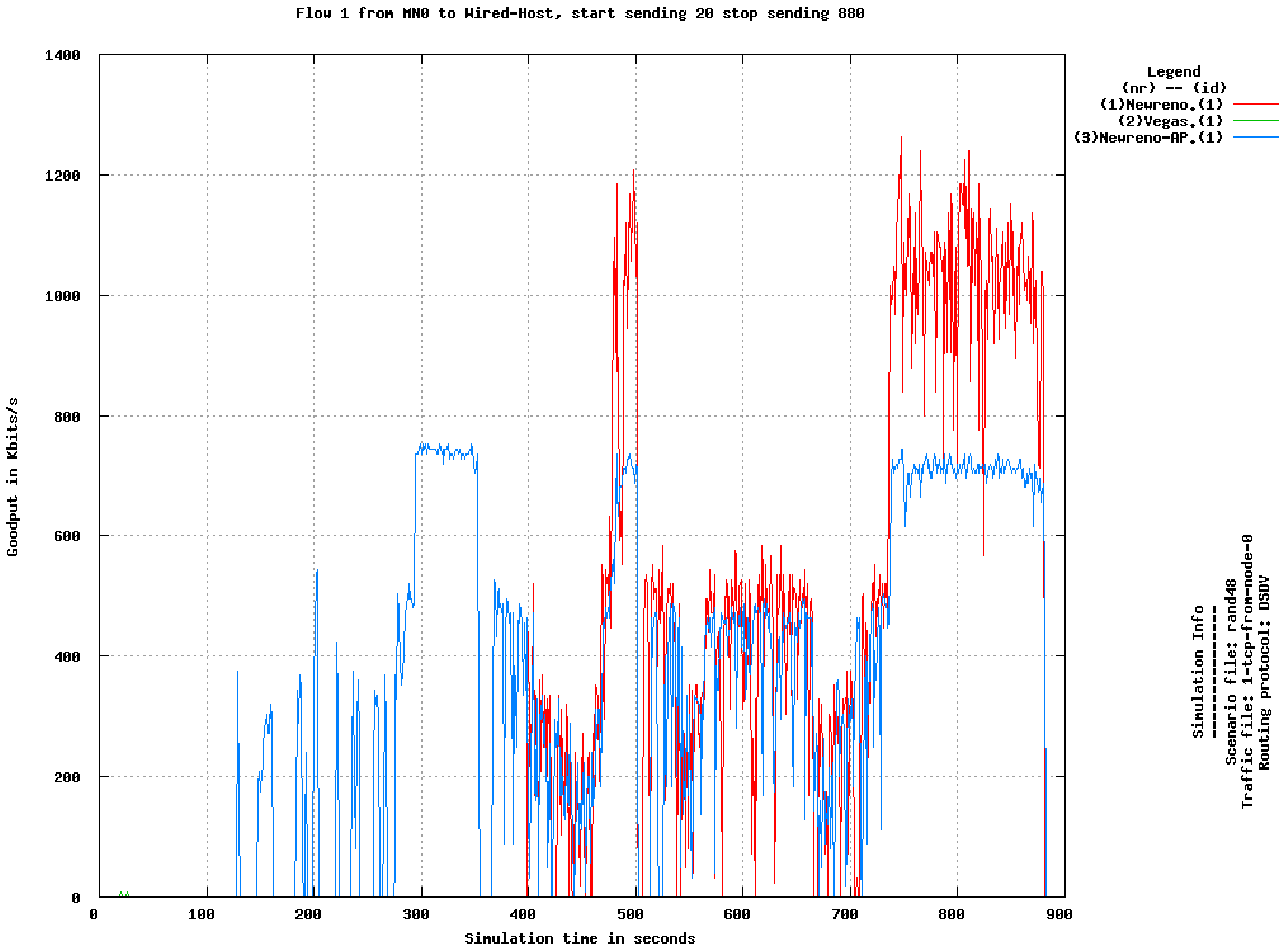


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN0 to MN4, start sending 220.0 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
1400
1200
1000
800
600
400
200
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: rand48
Traffic file: 1-tcp-from-node-0-1-tcp-between-node-4-node-0
Routing protocol: AODVUU

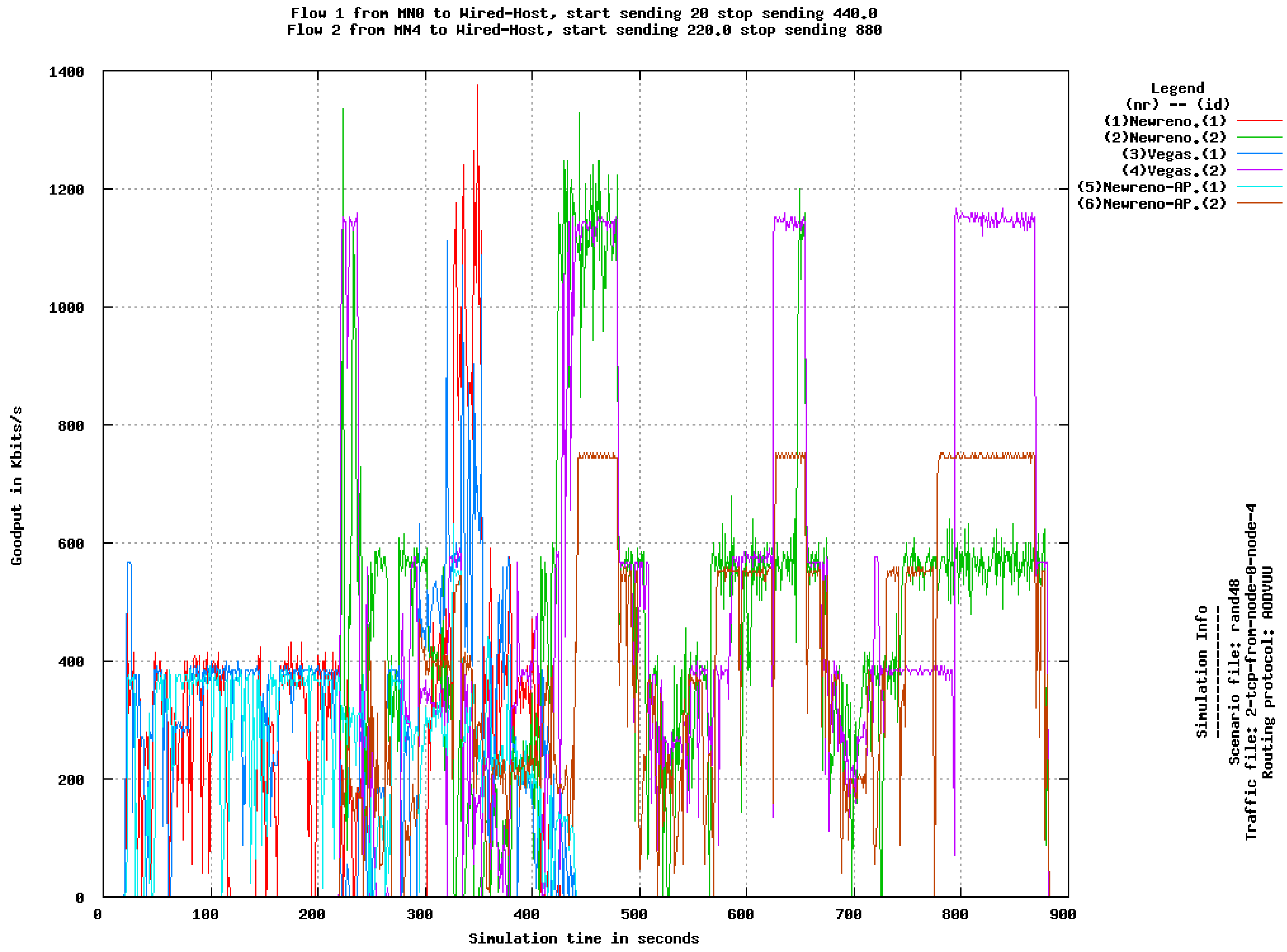


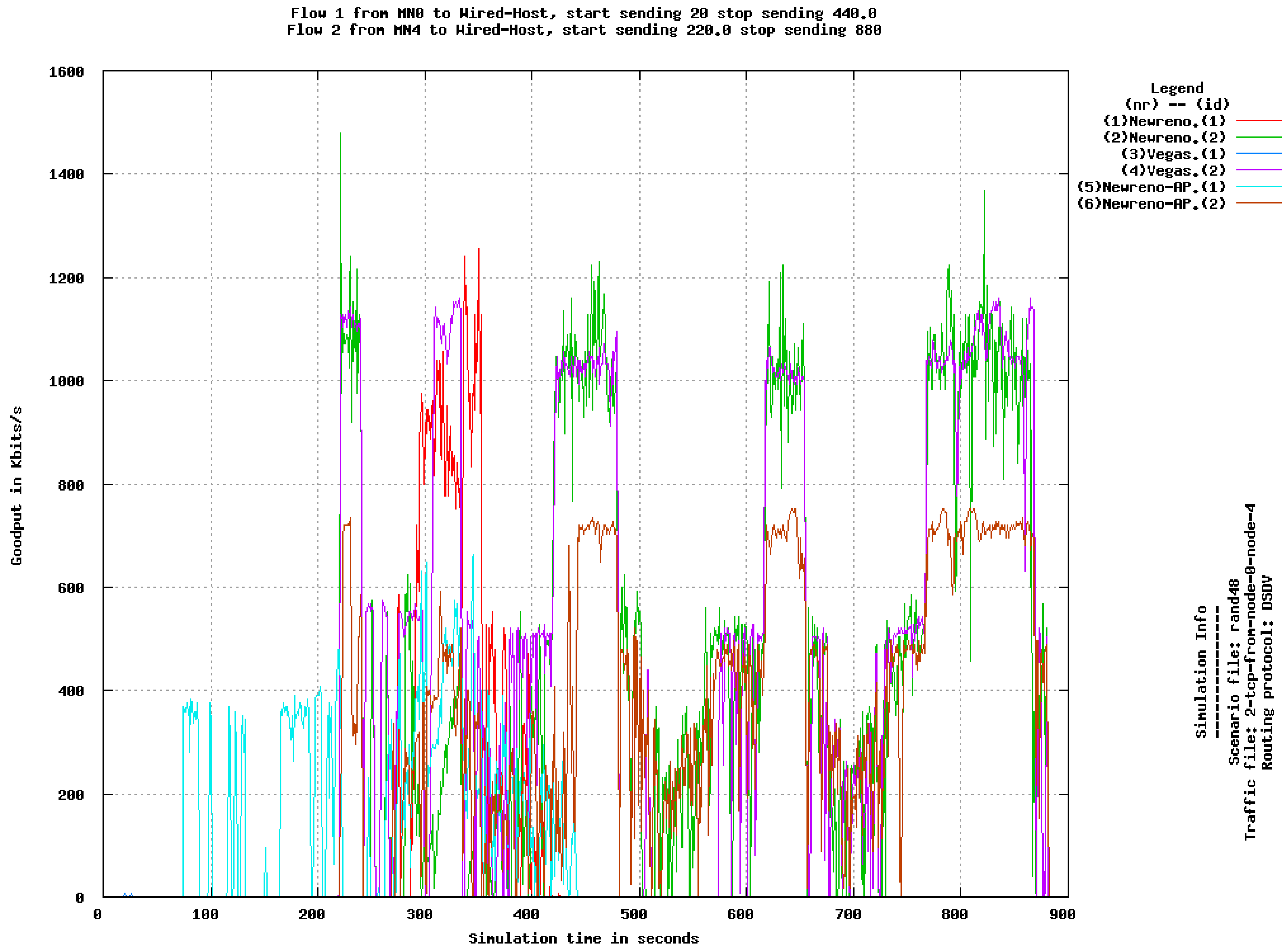
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN0 to MN4, start sending 220.0 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
200
400
600
800
1000
1200
1400
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
---------------
Scenario file: rand48
Traffic file: 1-tcp-from-node-0-1-tcp-between-node-4-node-0
Routing protocol: DSDV


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
200
400
600
800
1000
1200
1400
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
---------------
Scenario file: rand48
Traffic file: 1-tcp-from-node-0
Routing protocol: AODVUU

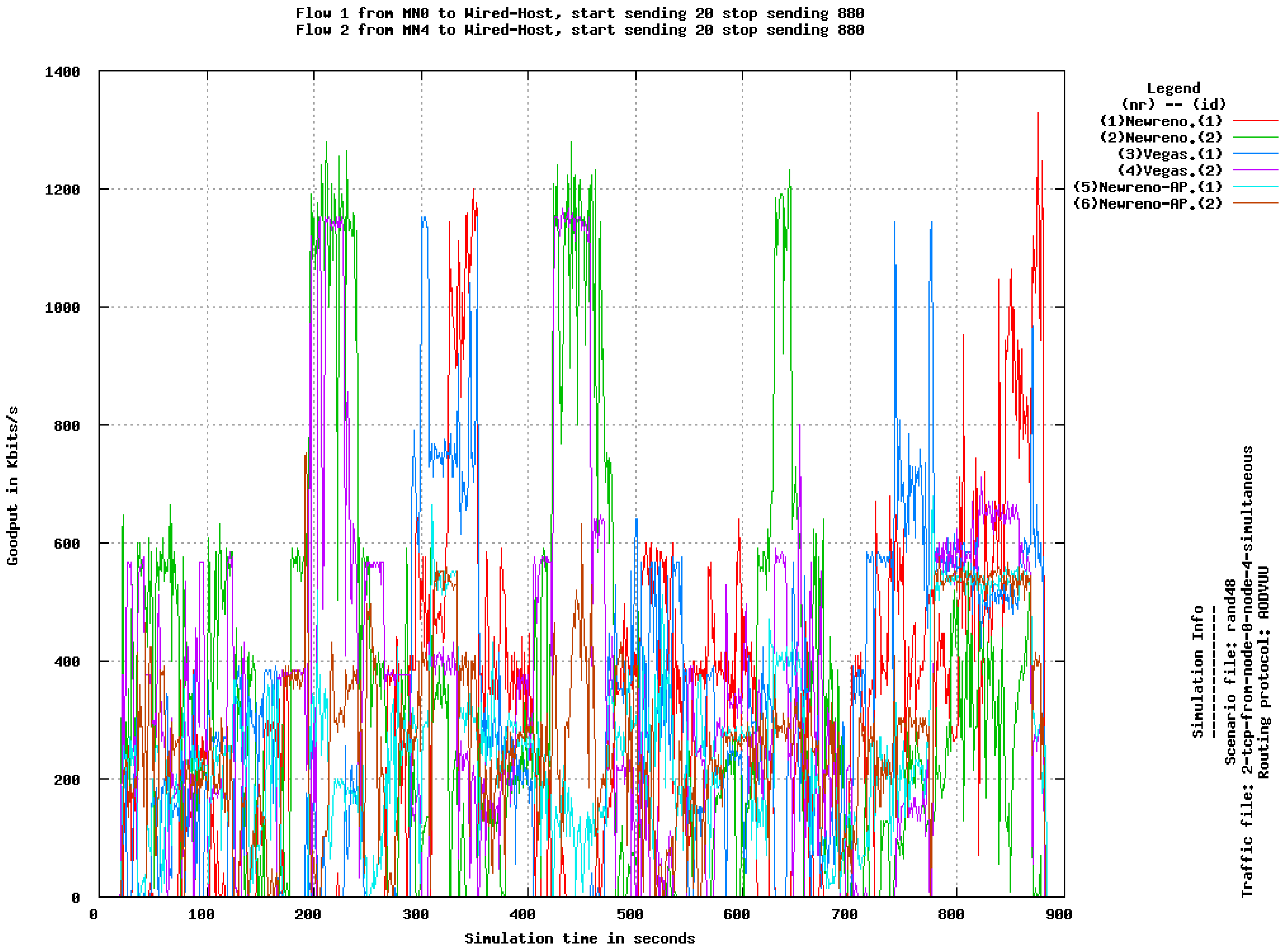


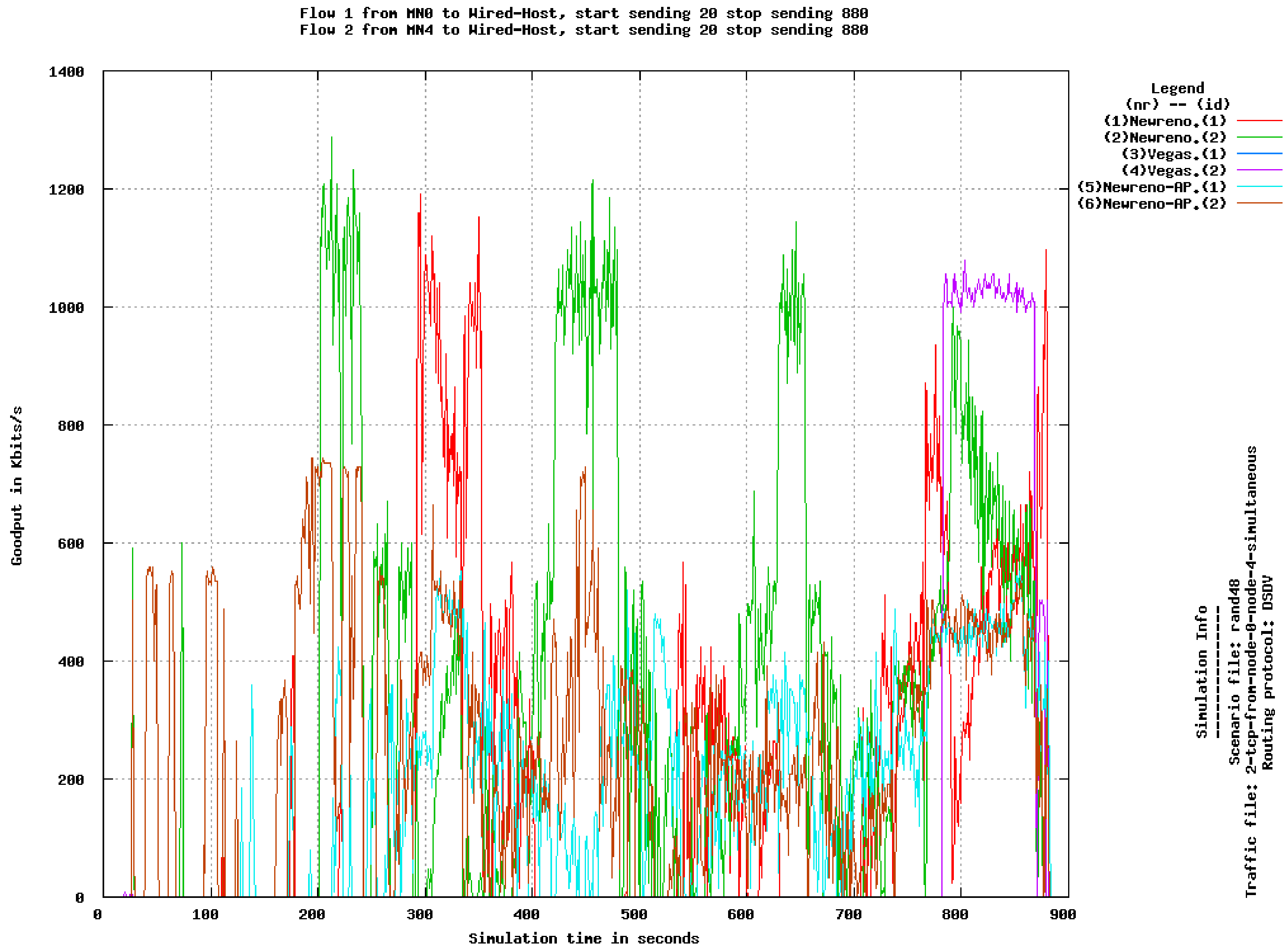
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
200
400
600
800
1000
1200
1400
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
Scenario file: rand48
Traffic file: 1-tcp-from-node-0
Routing protocol: DSDV


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN4 to Wired-Host, start sending 220.0 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
1400
1200
1000
800
600
400
200
0
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
---------------
Scenario file: rand48
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: AODVUU



Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN4 to Wired-Host, start sending 220.0 stop sending 880
1600
1400
1200
1000
800
600
400
200
0
0
100
200
300
400
500
600
700
800
900
Goodput in Kbits/s
Simulation time in seconds
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
---------------
Scenario file: rand48
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: DSDV

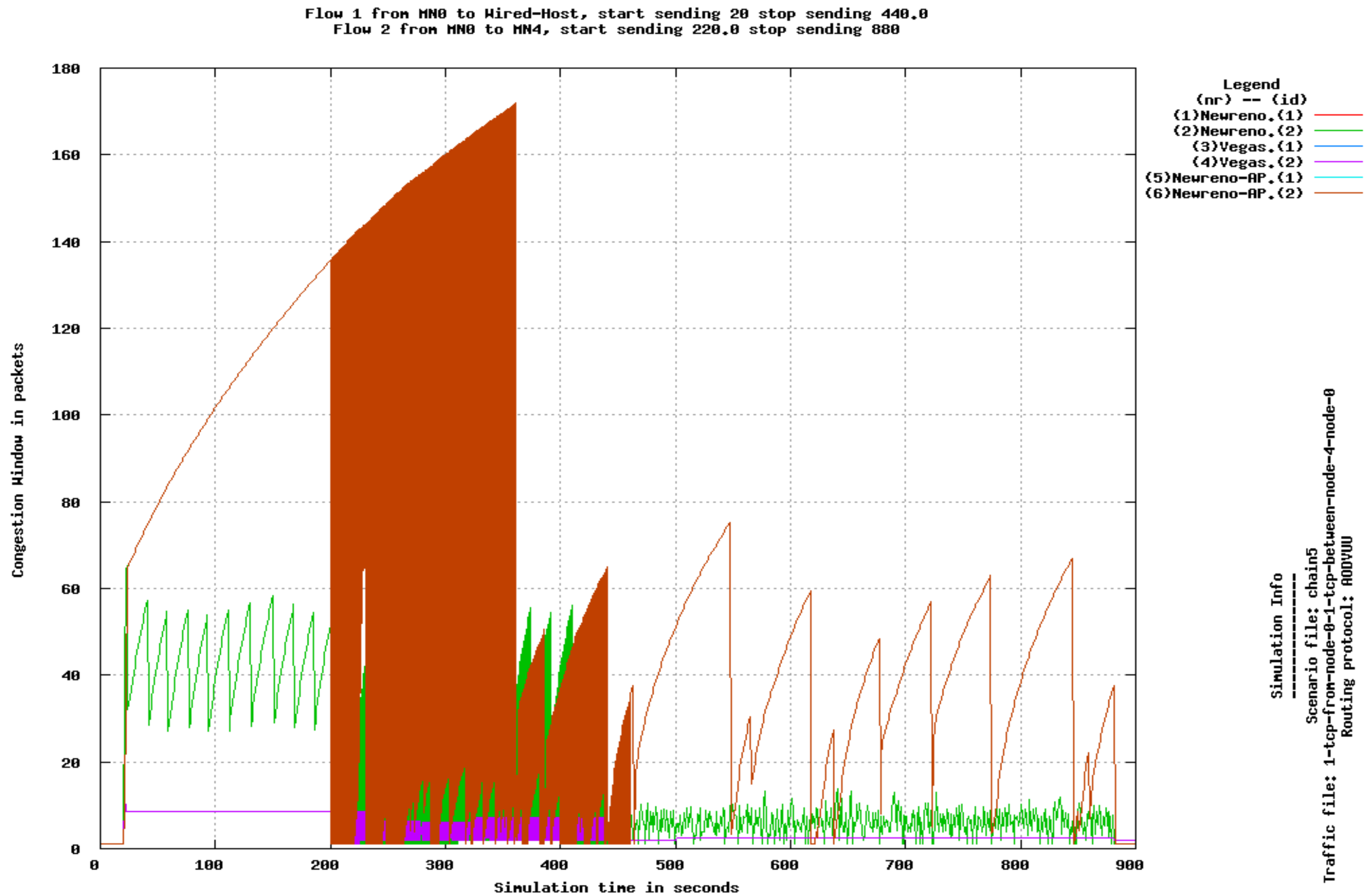

Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN4 to Wired-Host, start sending 20 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
200
400
600
800
1000
1200
1400
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
---------------
Scenario file: rand48
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: AODVUU

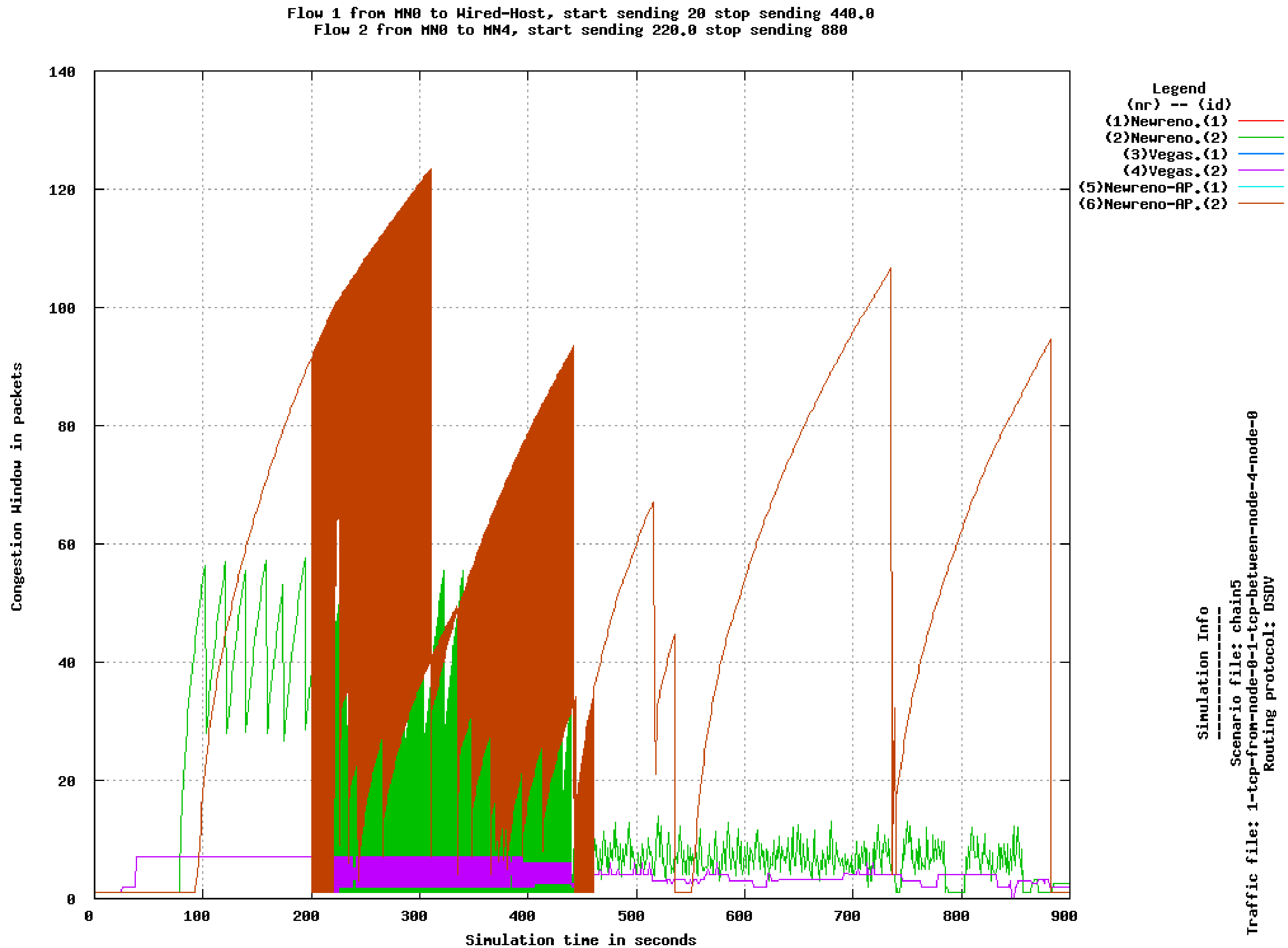


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN4 to Wired-Host, start sending 20 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
200
400
600
800
1000
1200
1400
100
300
500
700
900
Legend
(nr) -- (id)
(1)Newreno,(1)
(2)Newreno,(2)
(3)Vegas,(1)
(4)Vegas,(2)
(5)Newreno-AP,(1)
(6)Newreno-AP,(2)
Simulation Info
Scenario file: rand48
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: DSDV

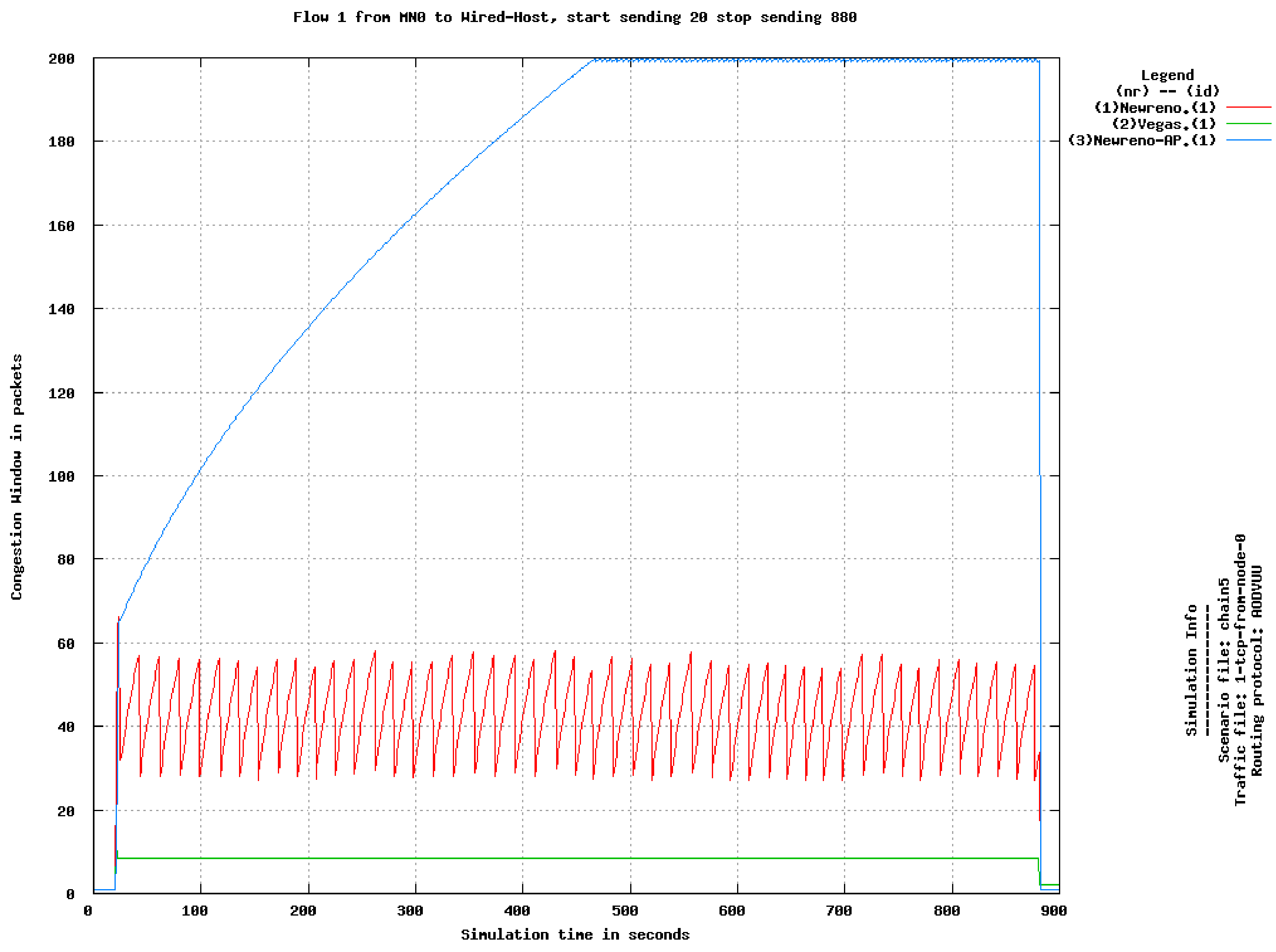
## G.5 Simulation Graphs 756Kb, 25 ms

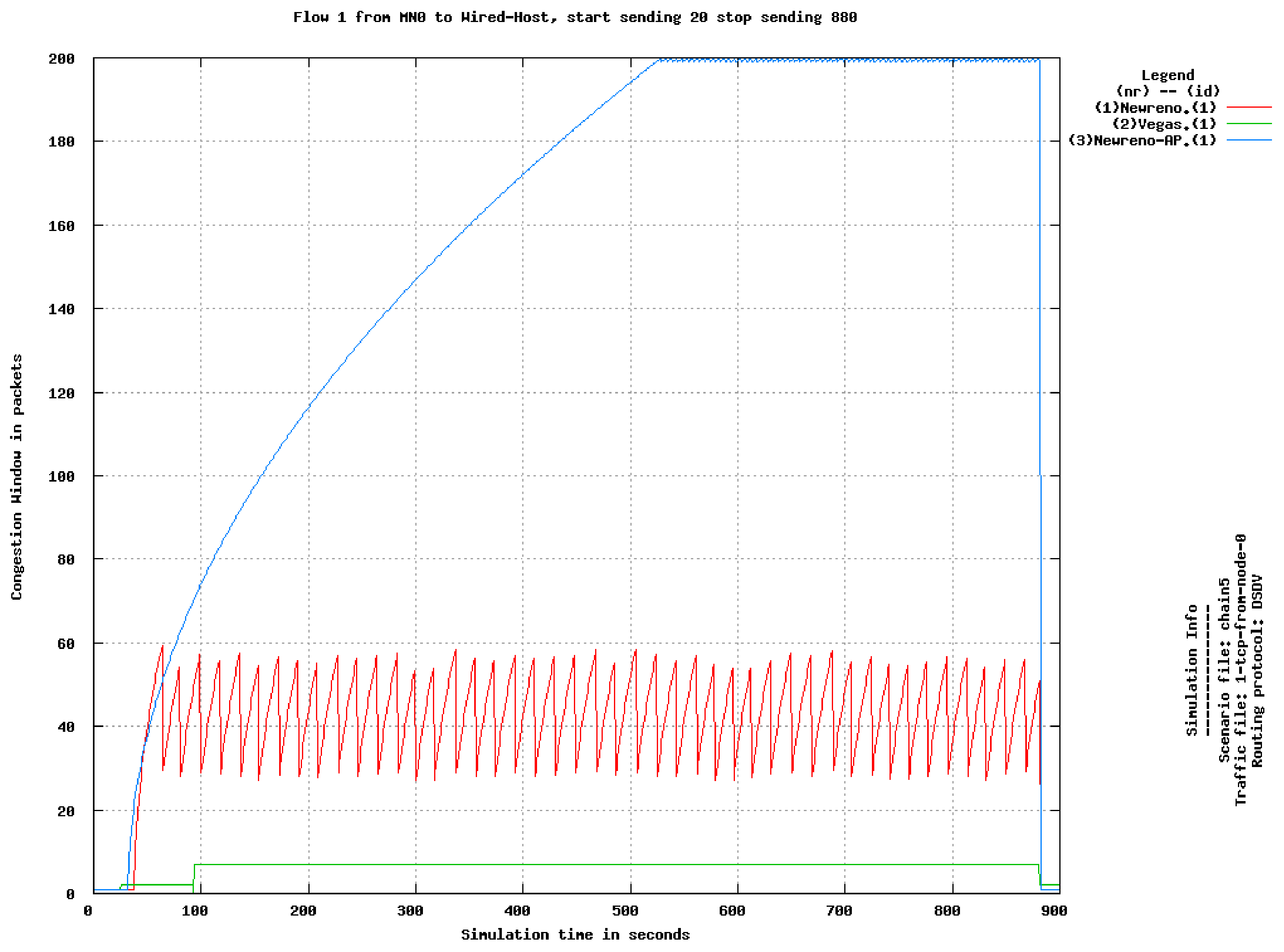
### G.5.1 Congestion Window

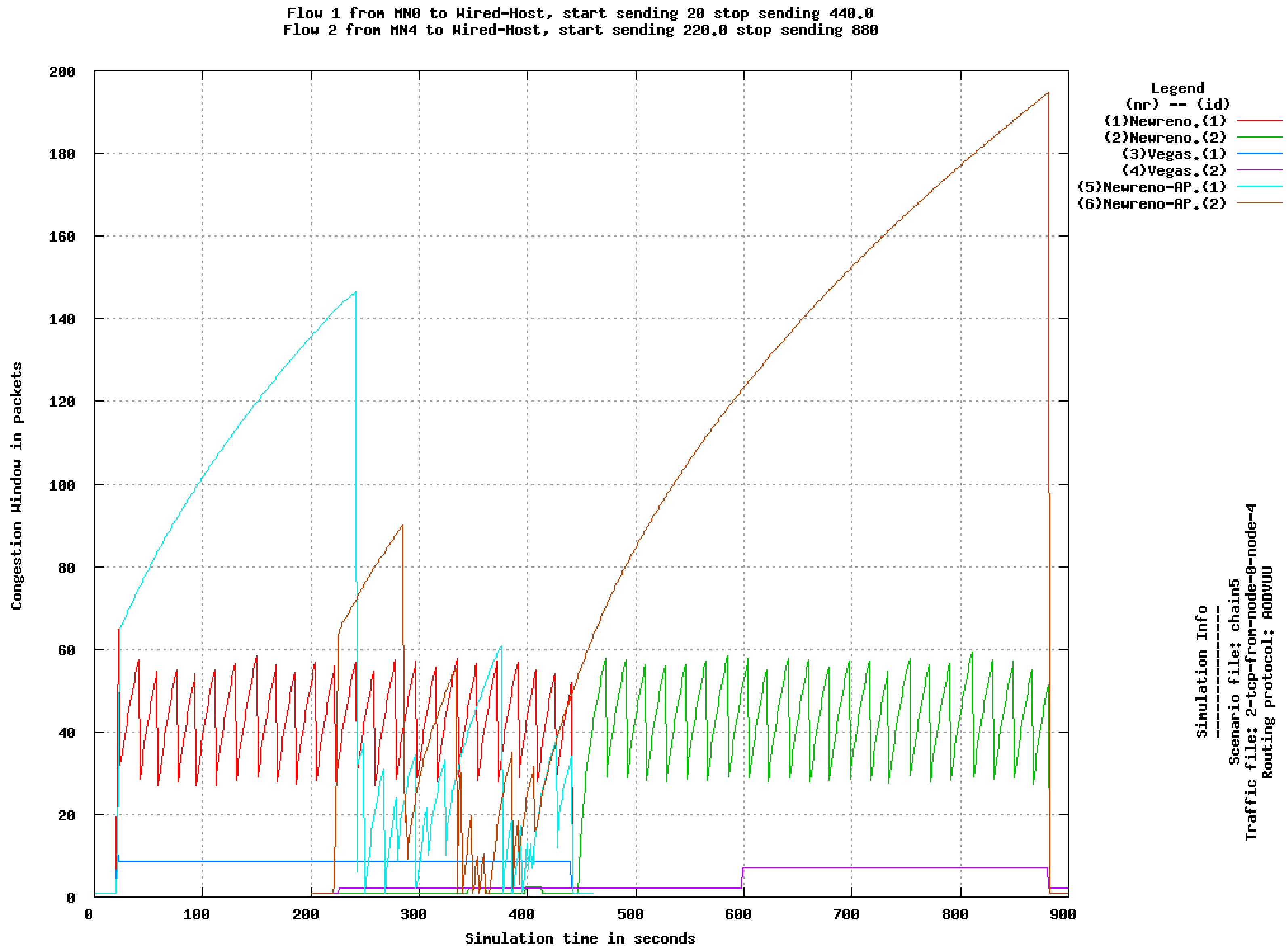


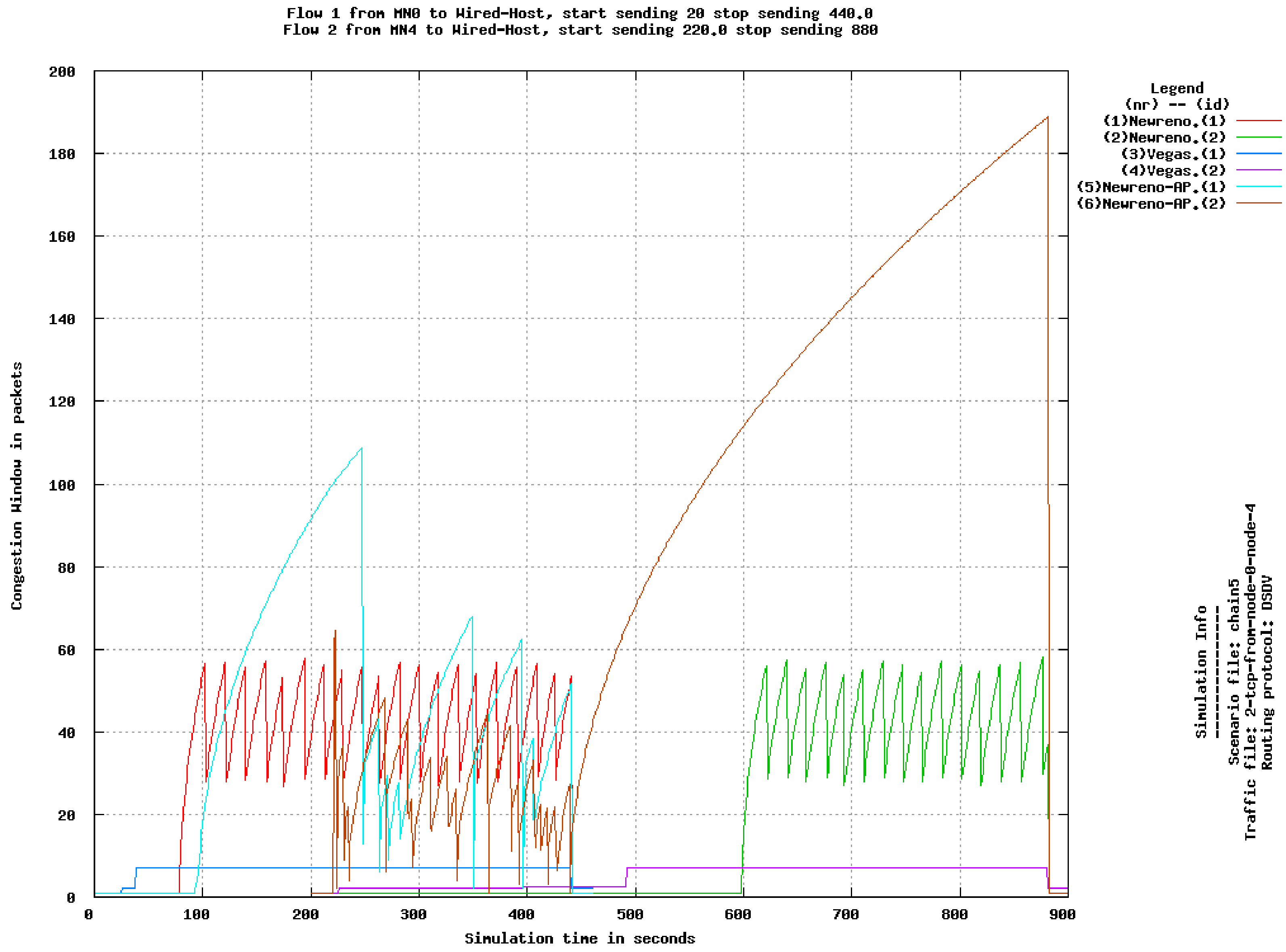


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN0 to MN4, start sending 220.0 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
20
40
60
80
100
120
140
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
----------------
Scenario file: chain5
Traffic file: 1-tcp-from-node-0-1-tcp-between-node-4-node-0
Routing protocol: DSDV

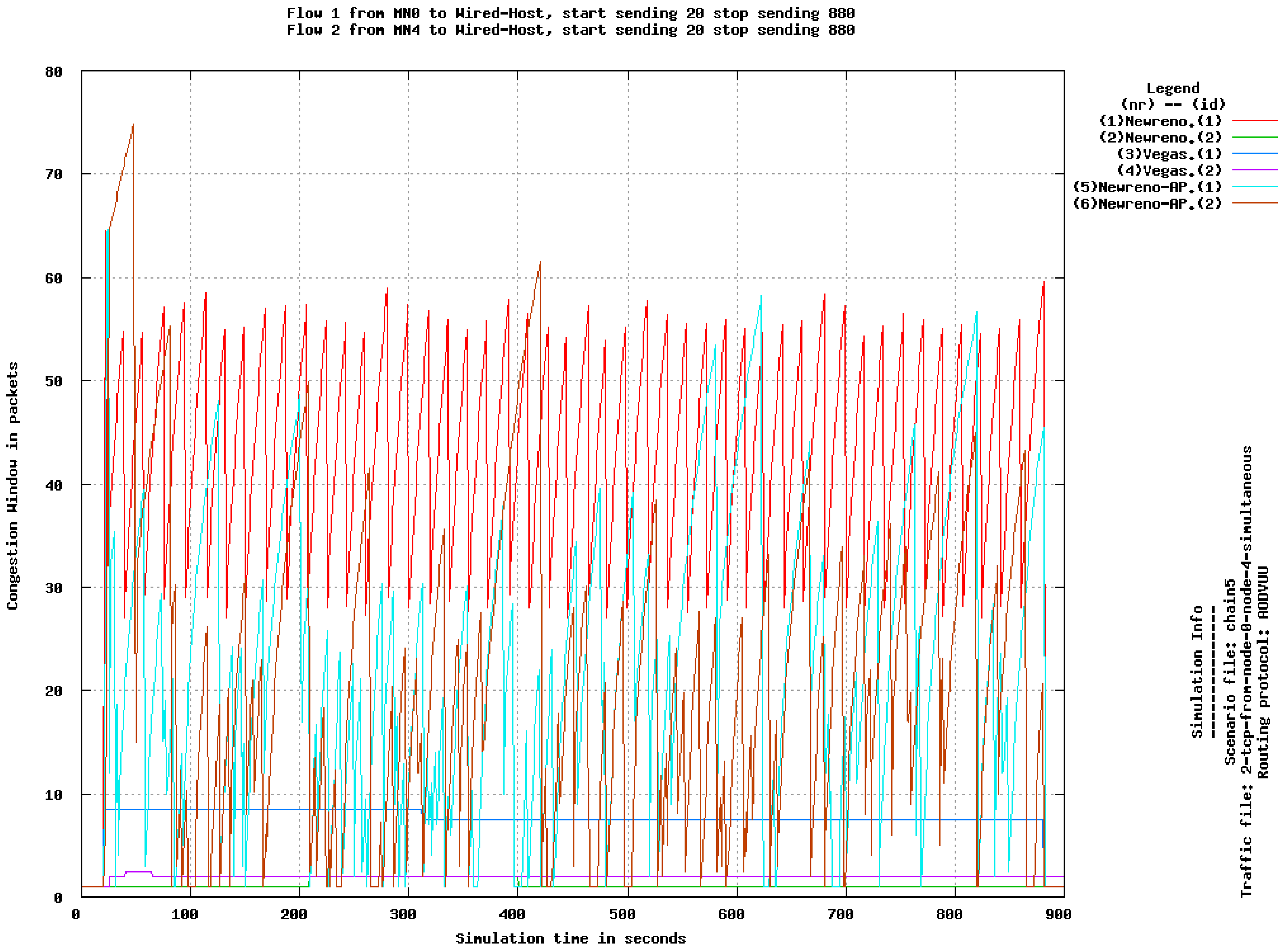

Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
20
40
60
80
100
120
140
160
180
200
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
Scenario file: chain5
Traffic file: 1-tcp-from-node-0
Routing protocol: AODVUU


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
20
40
60
80
100
120
140
160
180
200
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
Scenario file: chain5
Traffic file: 1-tcp-from-node-0
Routing protocol: DSDV

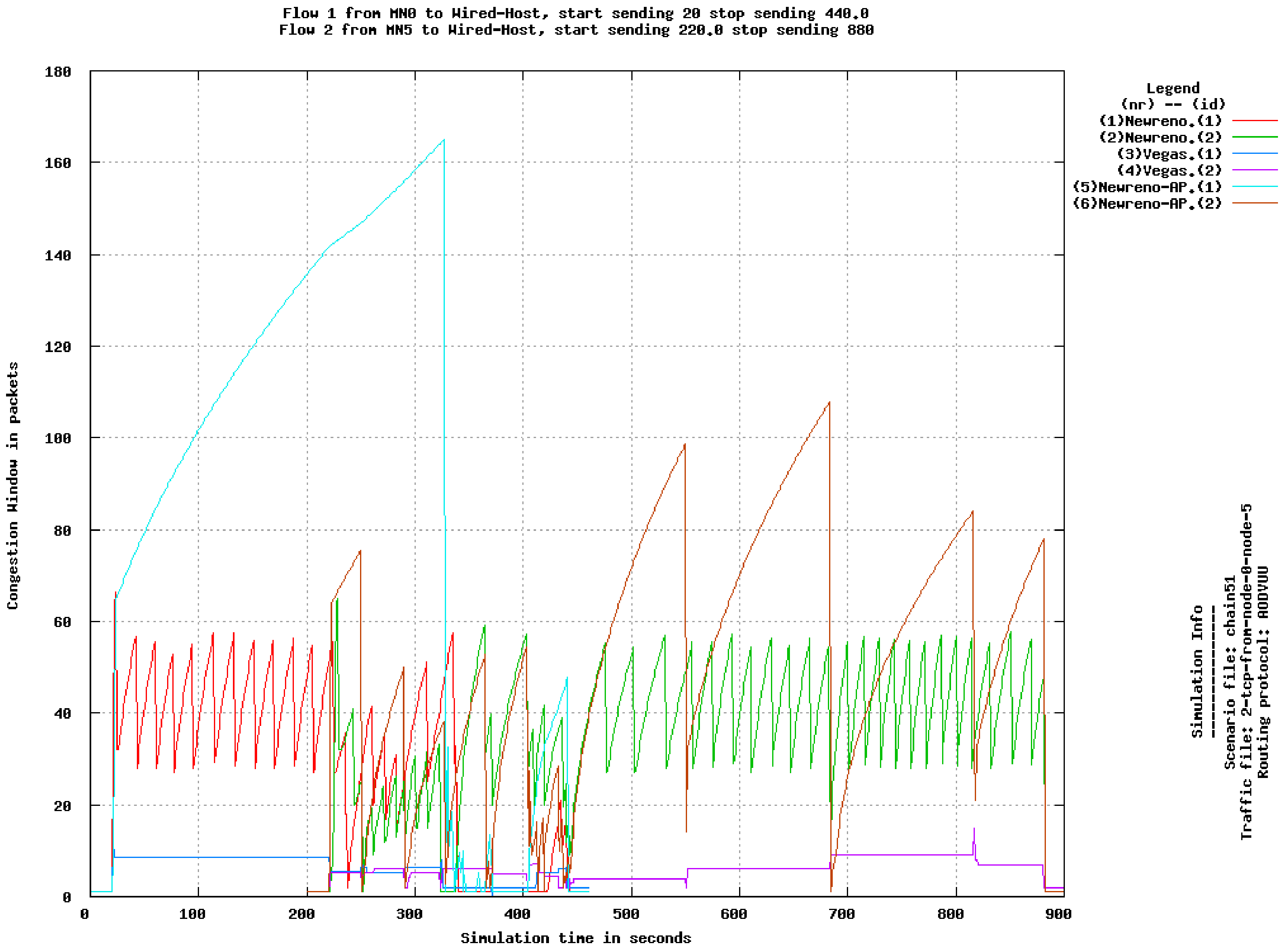

Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN4 to Wired-Host, start sending 220.0 stop sending 880
Congestion Window in packets
Simulation time in seconds
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain5
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: AODVUU



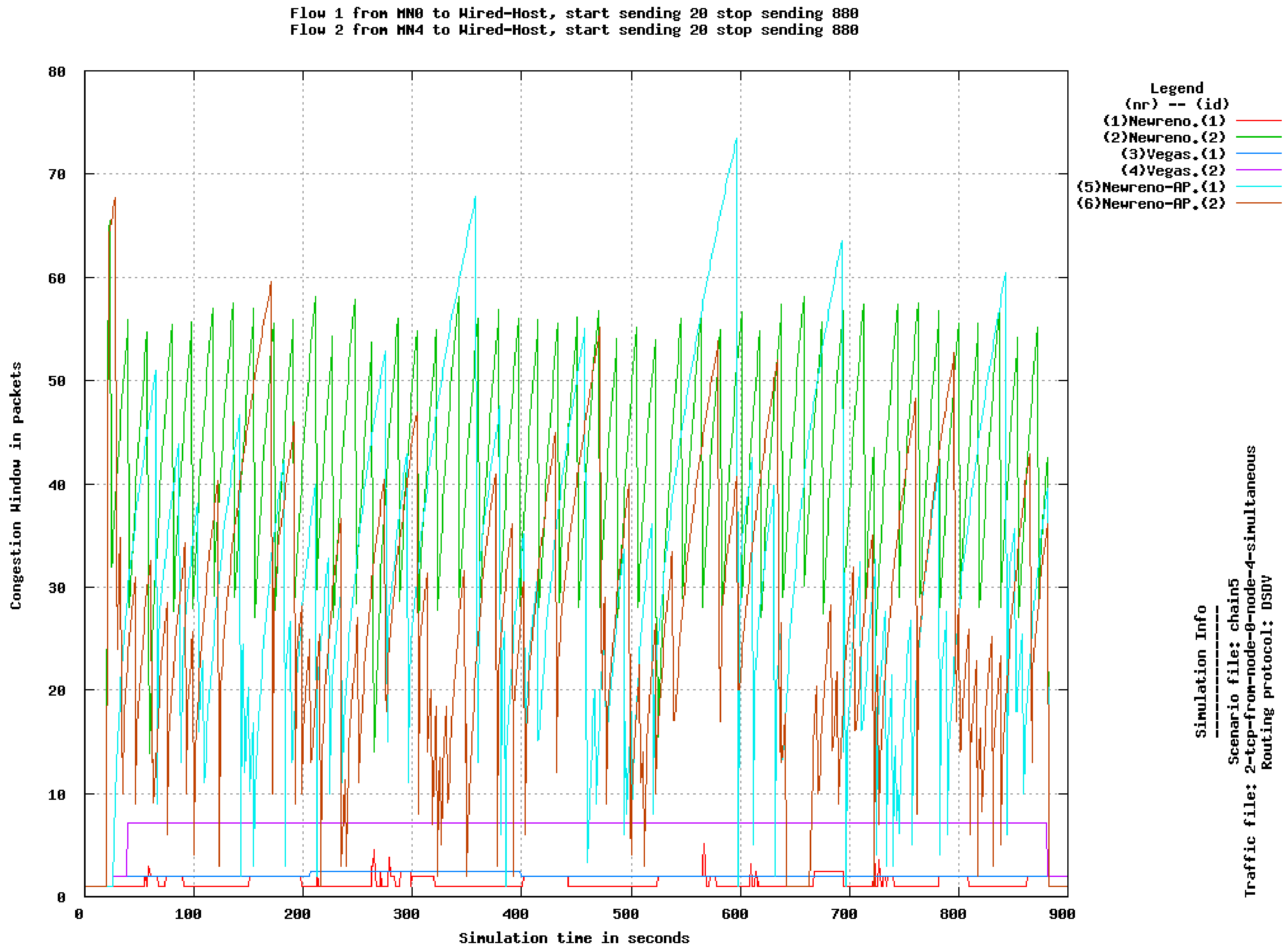
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN4 to Wired-Host, start sending 220.0 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
20
40
60
80
100
120
140
160
180
200
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
----------------
Scenario file: chain5
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: DSDV



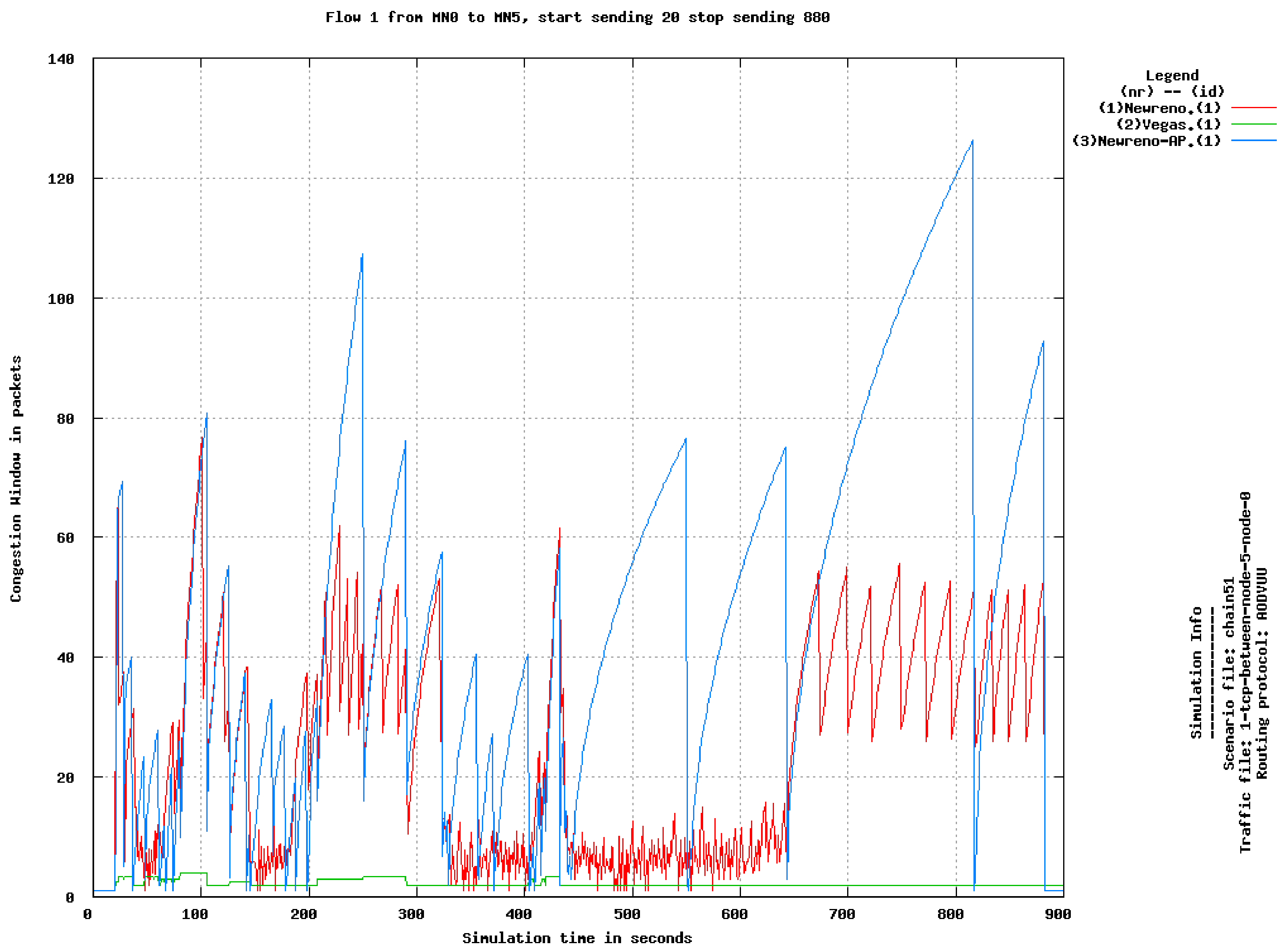
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN4 to Wired-Host, start sending 20 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
10
20
30
40
50
60
70
80
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno,(1)
(2)Newreno,(2)
(3)Vegas,(1)
(4)Vegas,(2)
(5)Newreno-AP,(1)
(6)Newreno-AP,(2)
Simulation Info
Scenario file: chain5
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: AODVUU



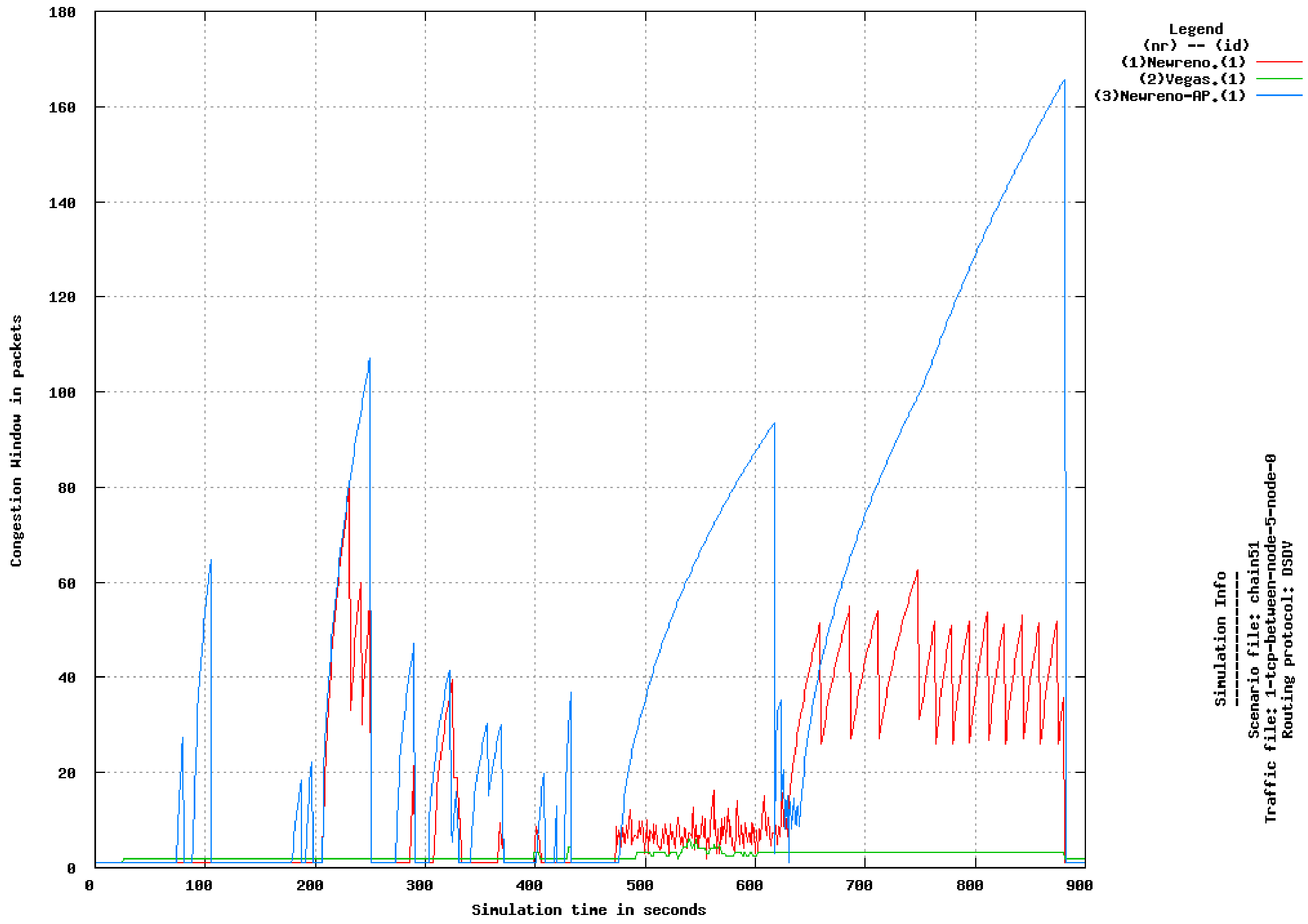
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN5 to Wired-Host, start sending 220.0 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
20
40
60
80
100
120
140
160
180
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain51
Traffic file: 2-tcp-from-node-0-node-5
Routing protocol: AODVUU

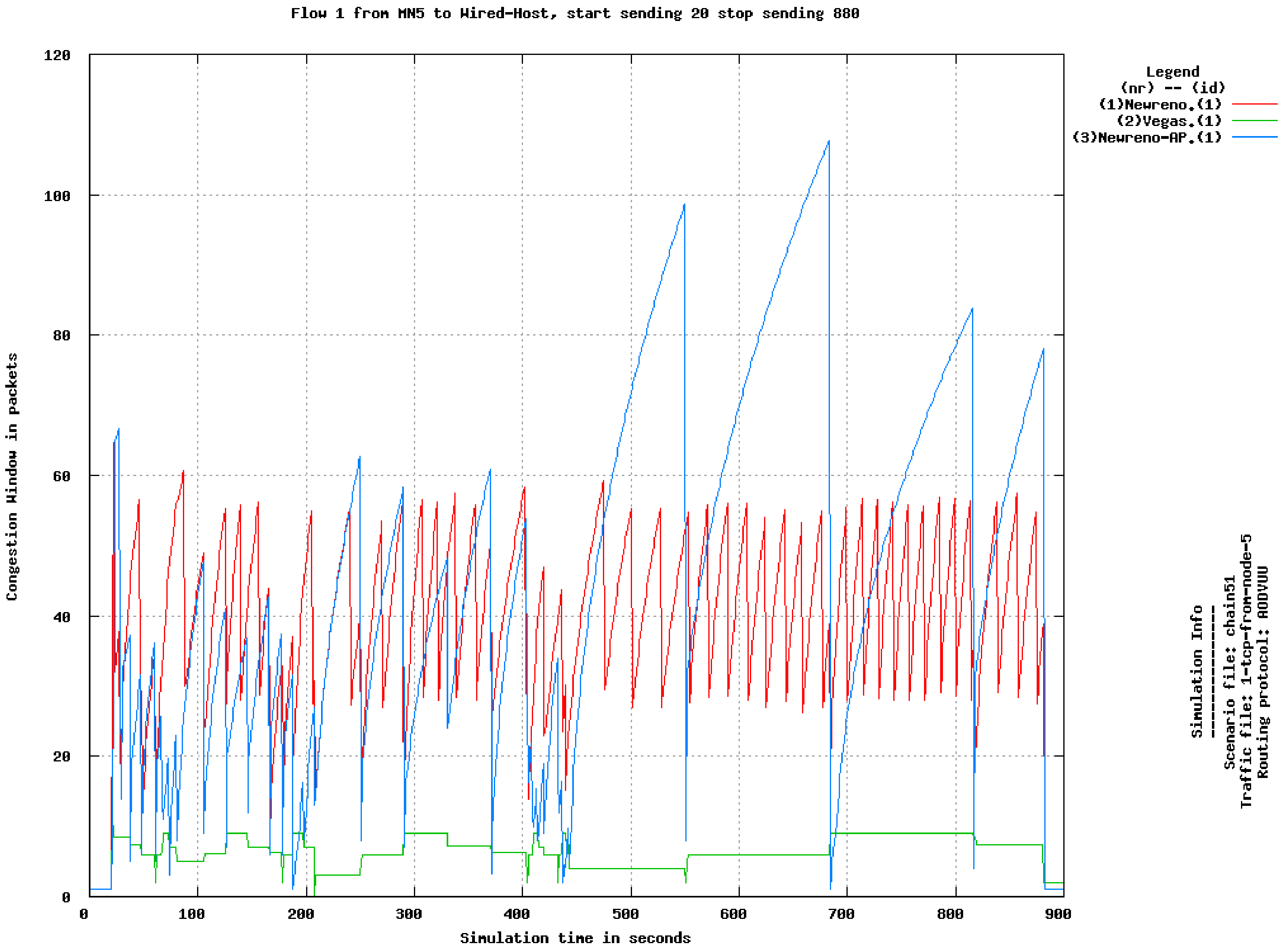


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN4 to Wired-Host, start sending 20 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
10
20
30
40
50
60
70
80
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain5
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: DSDV

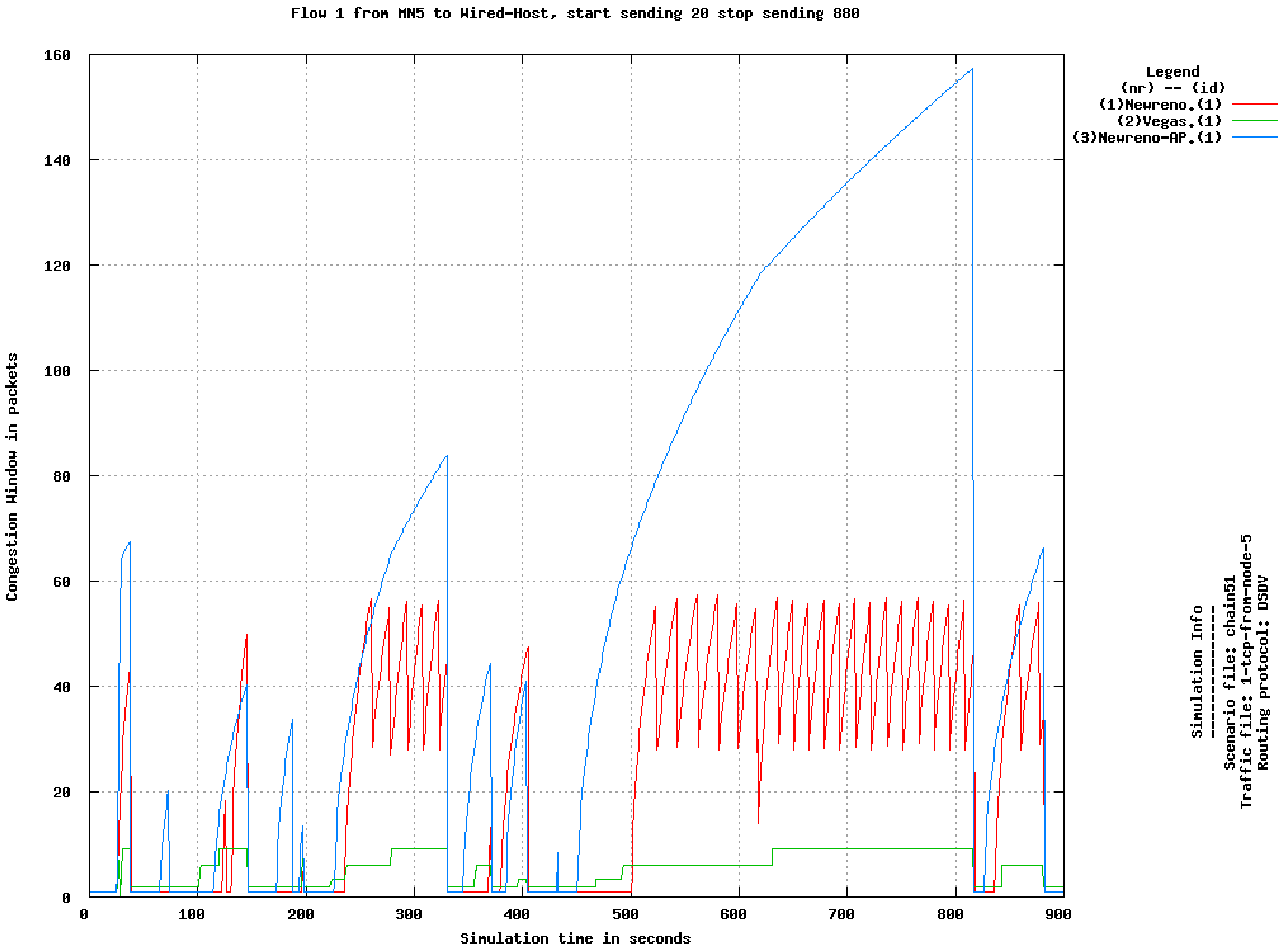

Flow 1 from MN0 to MN5, start sending 20 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
20
40
60
80
100
120
140
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
Scenario file: chain51
Traffic file: 1-tcp-between-node-5-node-0
Routing protocol: AODVUU

Flow 1 from MN0 to MN5, start sending 20 stop sending 880

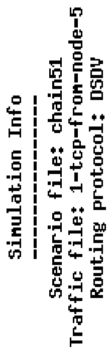




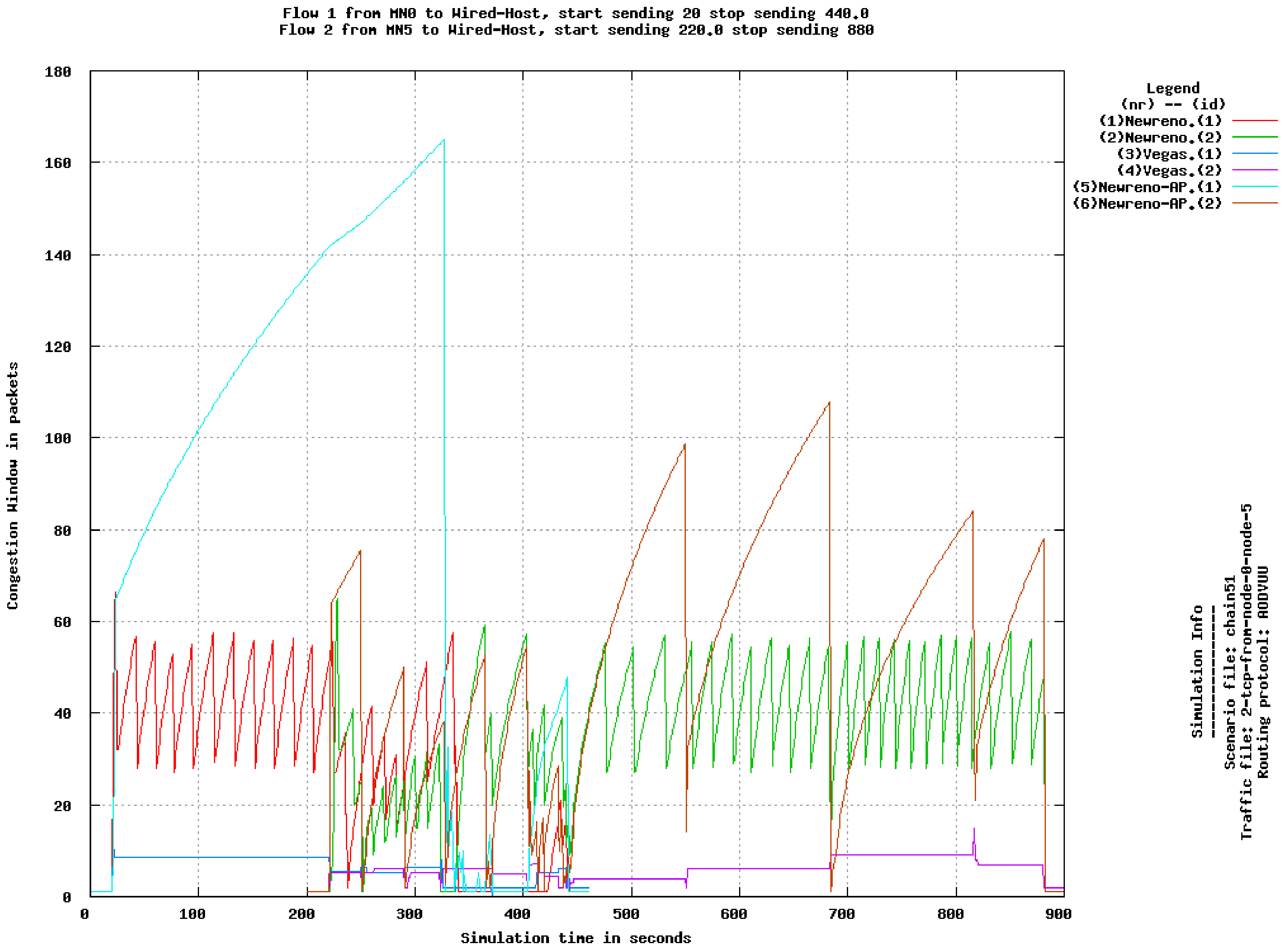
Flow 1 from MN5 to Wired-Host, start sending 20 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
20
40
60
80
100
120
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
Scenario file: chain51
Traffic file: 1-tcp-from-node-5
Routing protocol: AODVUU



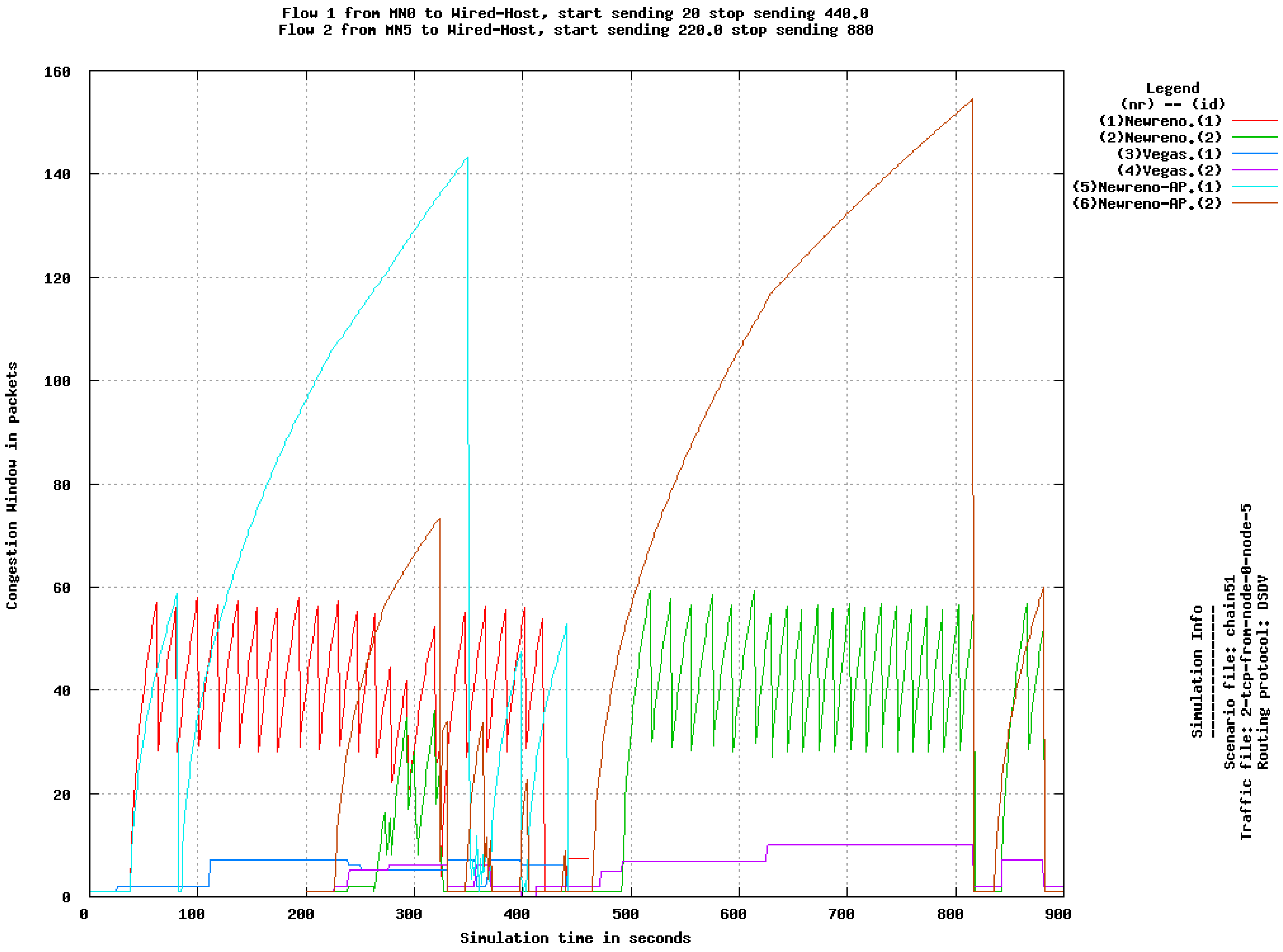
Flow 1 from MN5 to Wired-Host, start sending 20 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
20
40
60
80
100
120
140
160
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)



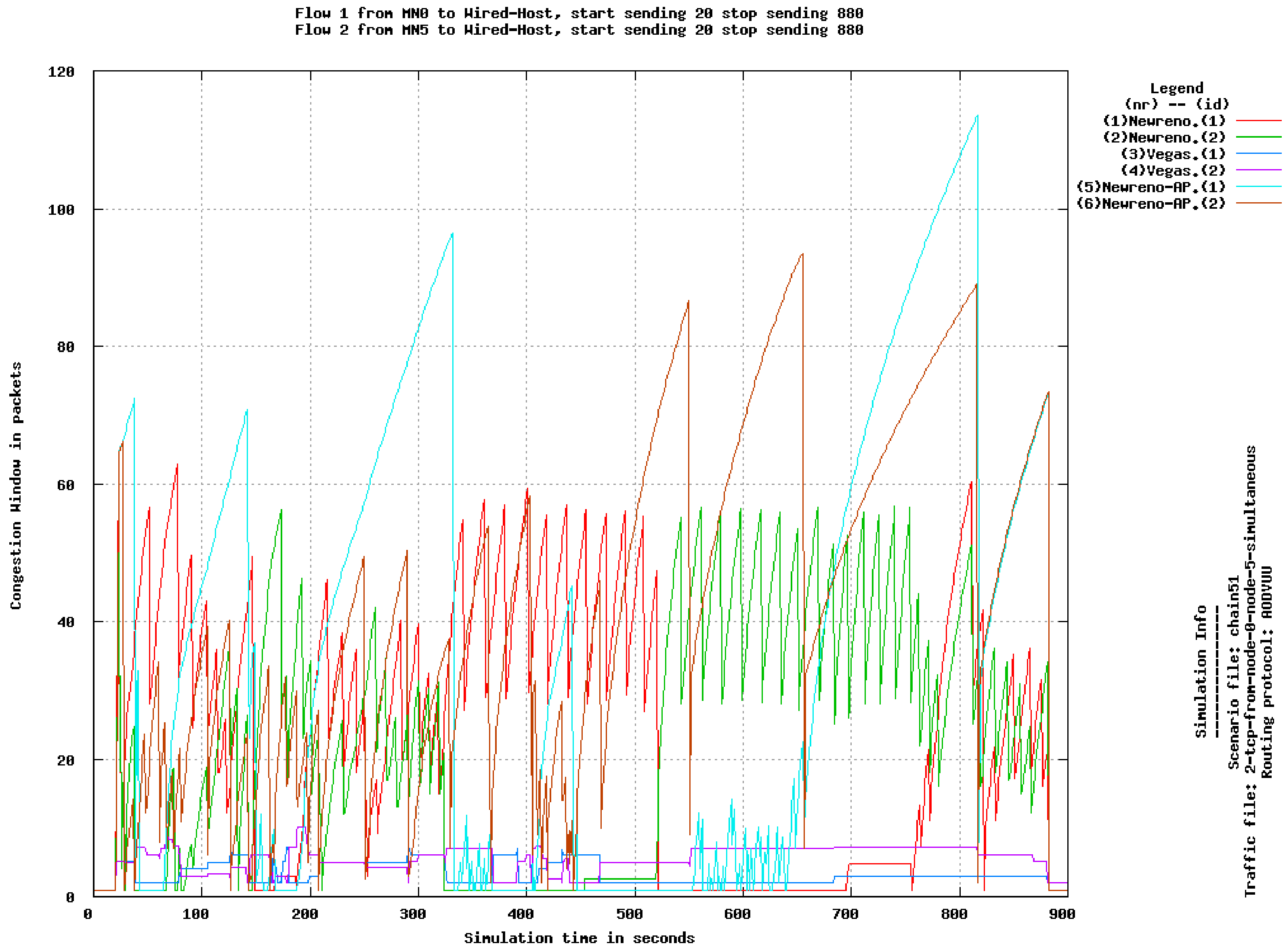
Simulation Info
----------------
Scenario file: chain51
Traffic file: 1-tcp-from-node-5
Routing protocol: DSDV



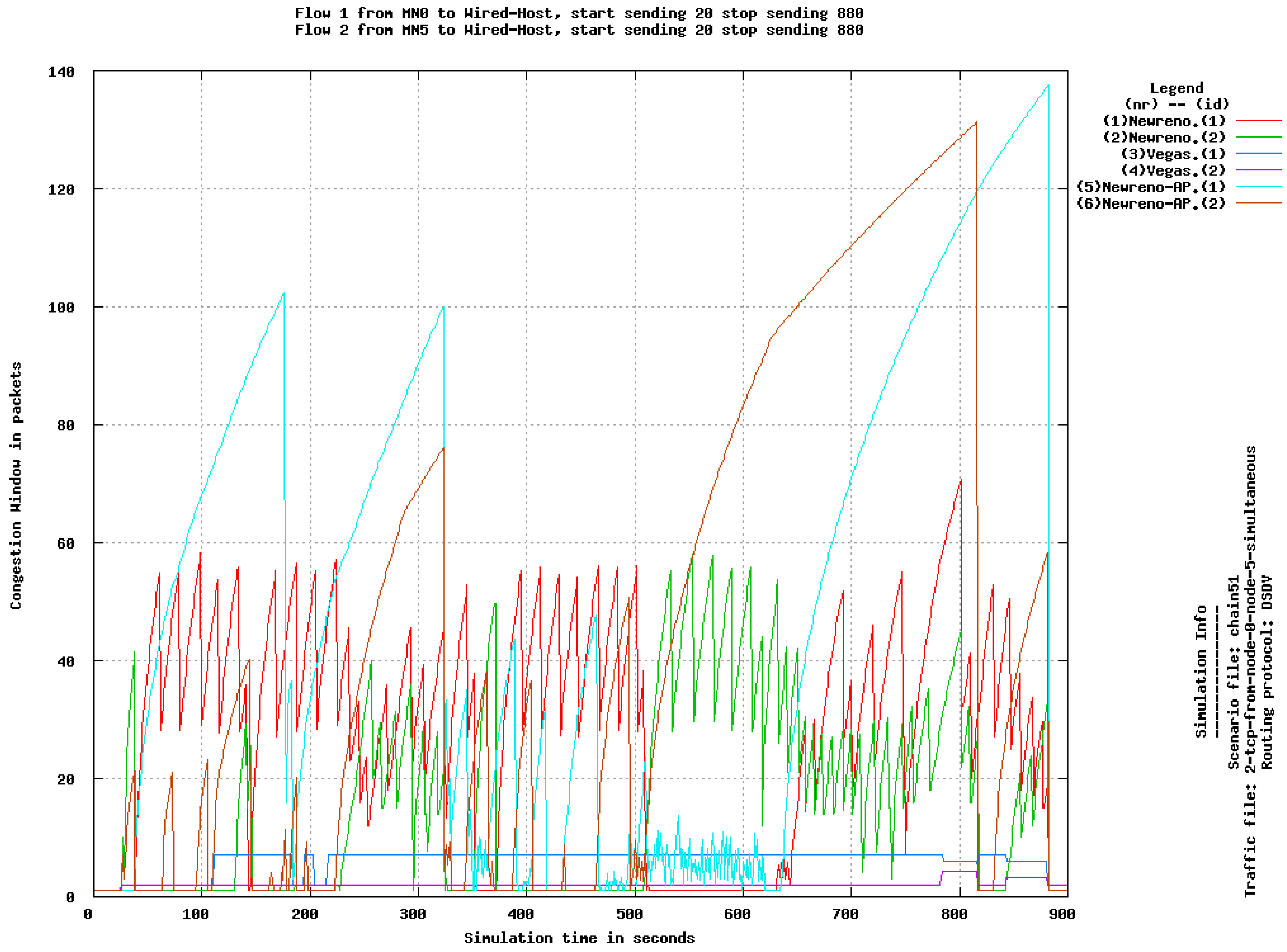
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN5 to Wired-Host, start sending 220.0 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
20
40
60
80
100
120
140
160
180
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
---------------
Scenario file: chain51
Traffic file: 2-tcp-from-node-0-node-5
Routing protocol: AODVUU



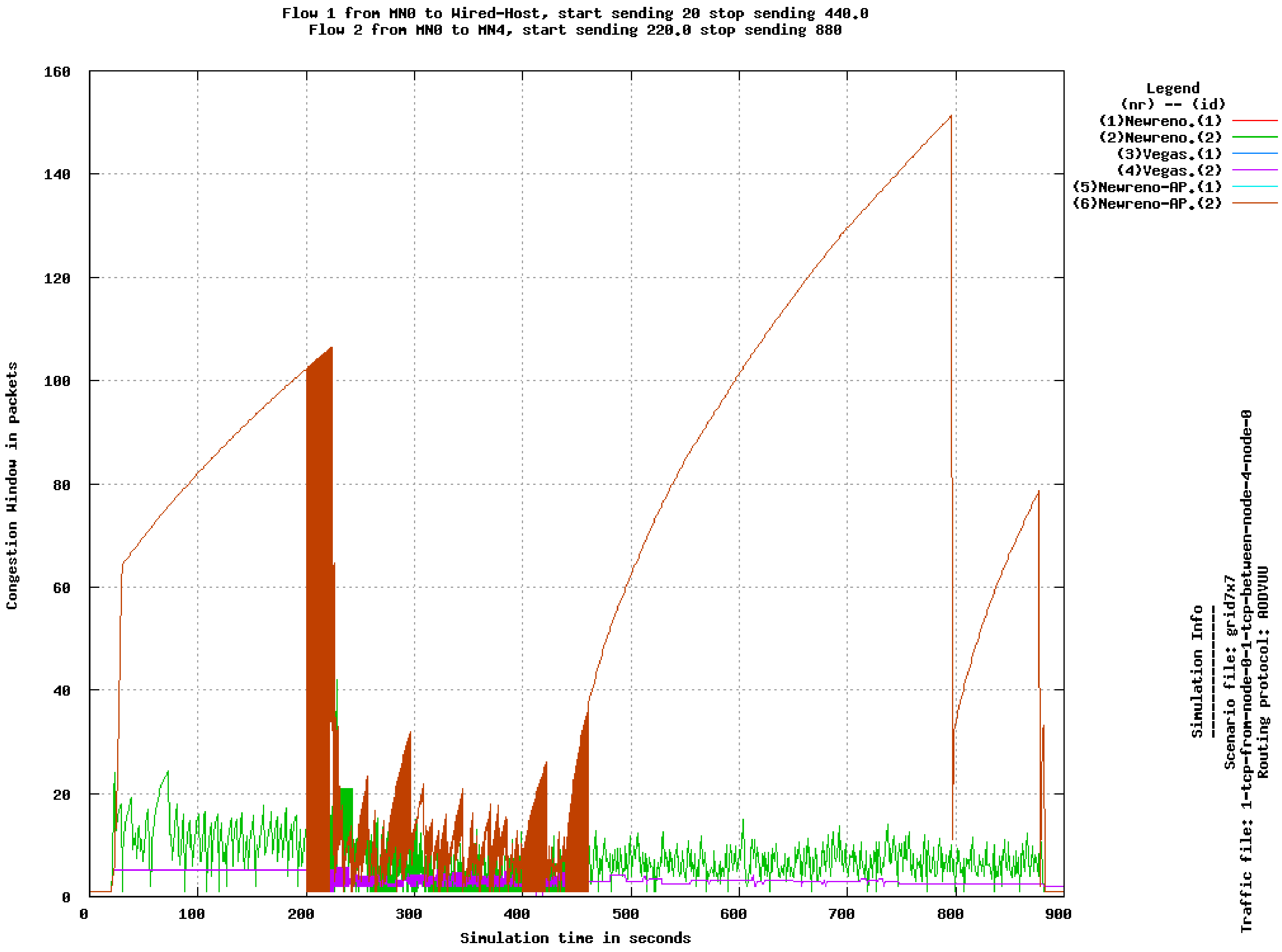
Simulation Info
---------------
Scenario file: chain51
Traffic file: 2-tcp-from-node-0-node-5
Routing protocol: DSDV

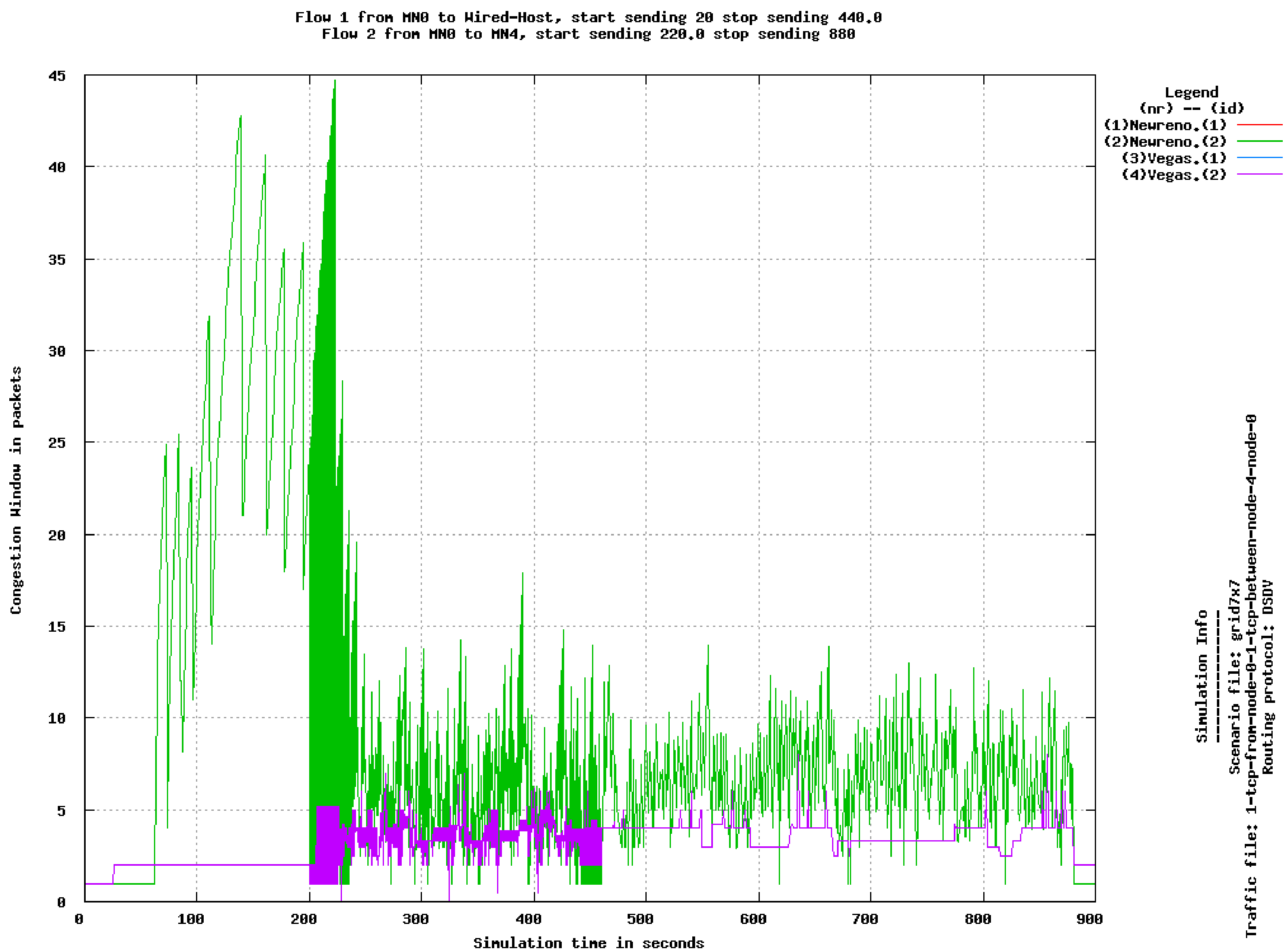


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN5 to Wired-Host, start sending 20 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
20
40
60
80
100
120
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
----------------
Scenario file: chain51
Traffic file: 2-tcp-from-node-0-node-5-simultaneous
Routing protocol: AODVUU

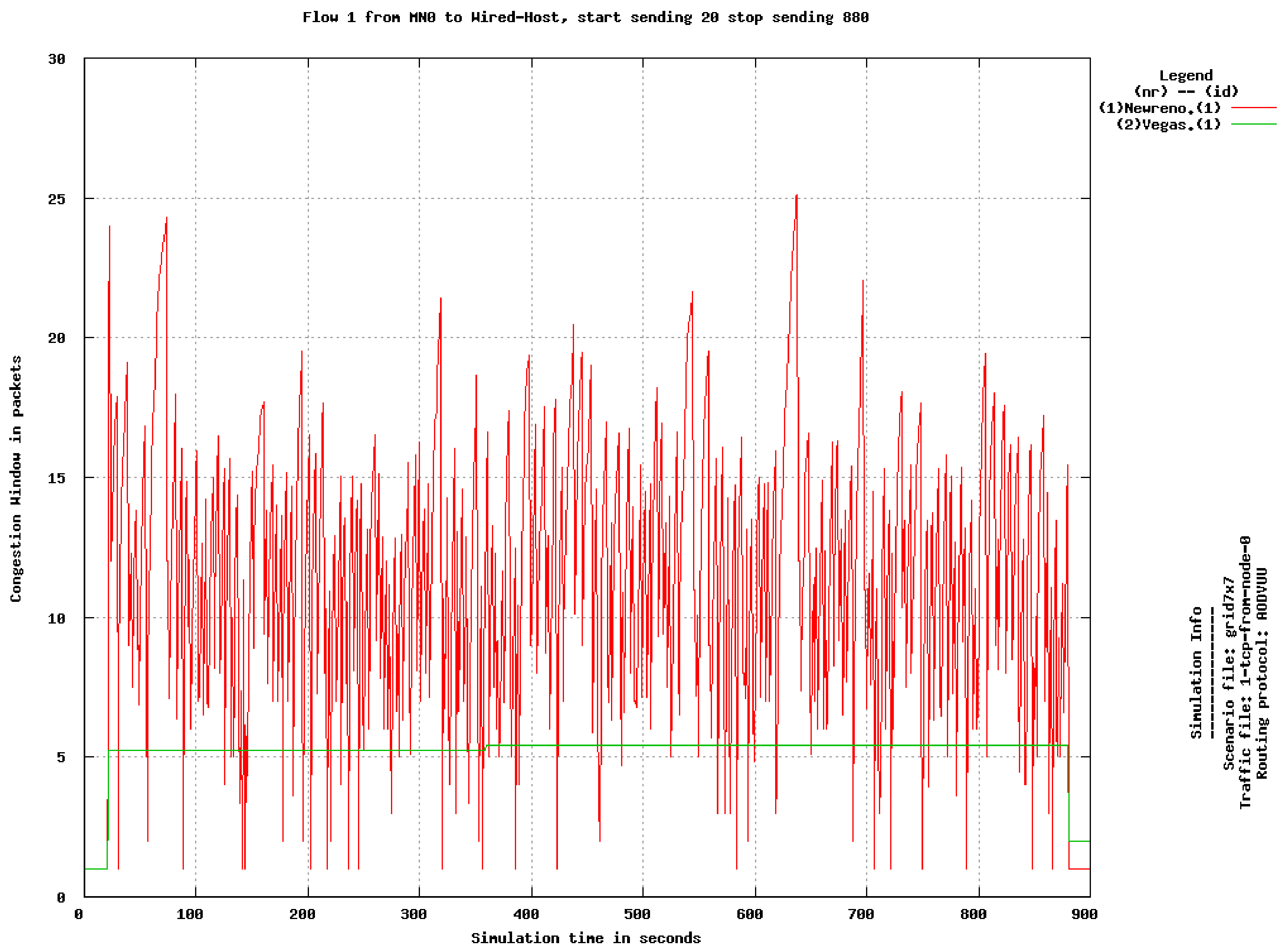


Simulation Info
---------------
Scenario file: chain51
Traffic file: 2-tcp-from-node-0-node-5-simultaneous
Routing protocol: DSDV

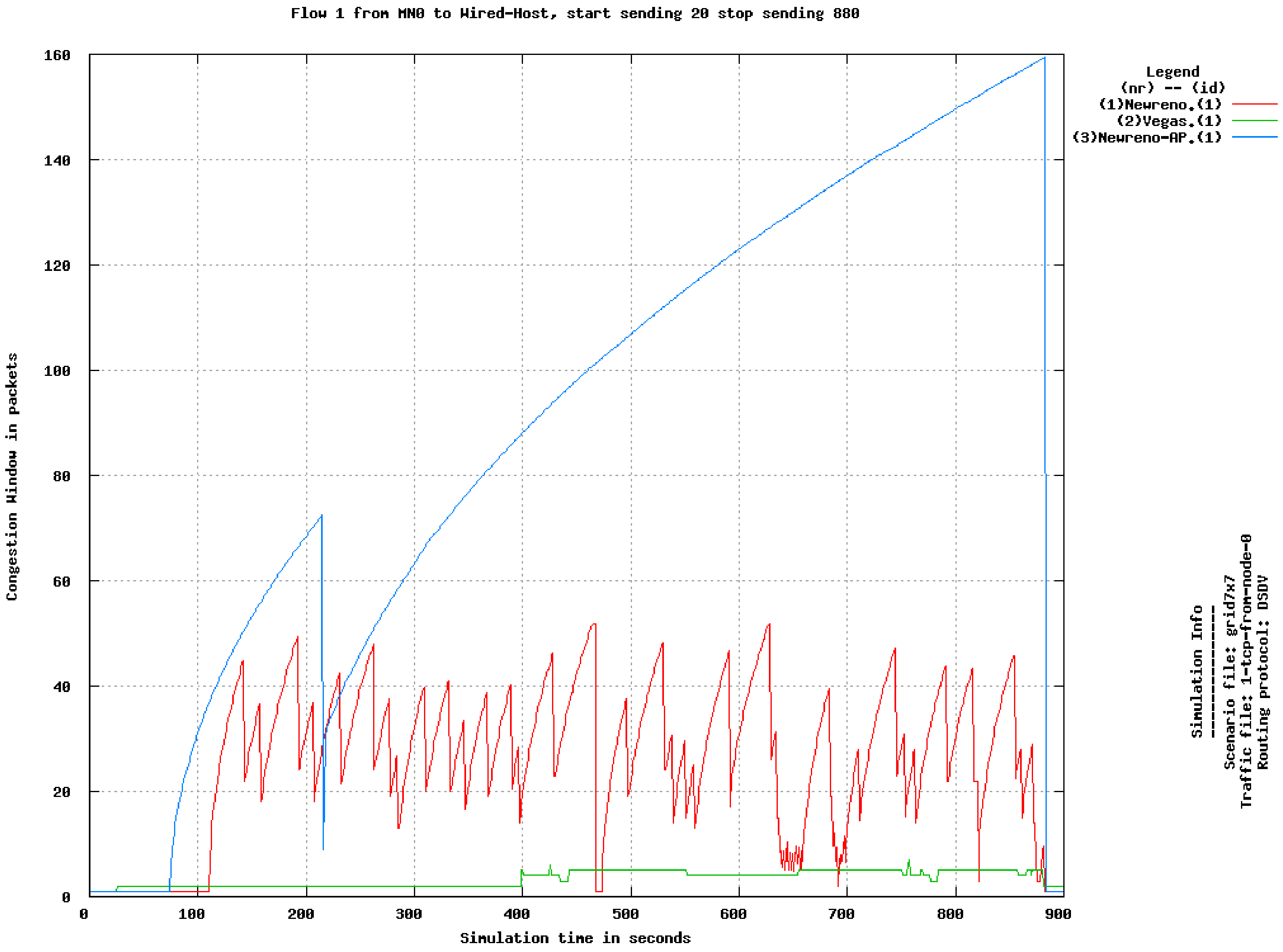

Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN0 to MN4, start sending 220.0 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
20
40
60
80
100
120
140
160
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: grid7x7
Traffic file: 1-tcp-from-node-0-1-tcp-between-node-4-node-0
Routing protocol: AODVUU



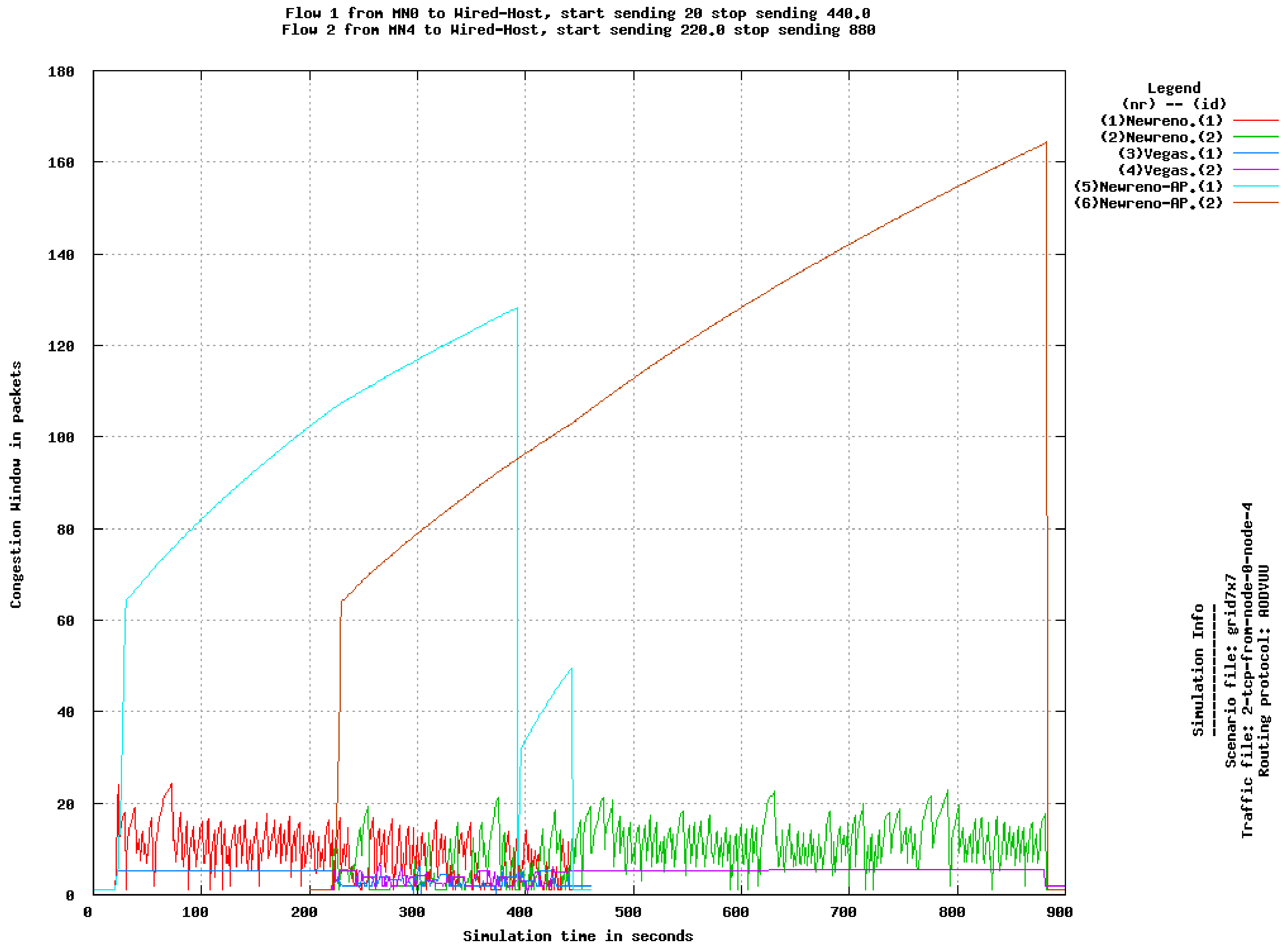
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN0 to MN4, start sending 220.0 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
5
10
15
20
25
30
35
40
45
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
Simulation Info
Scenario file: grid7x7
Traffic file: 1-tcp-from-node-0-1-tcp-between-node-4-node-0
Routing protocol: DSDV



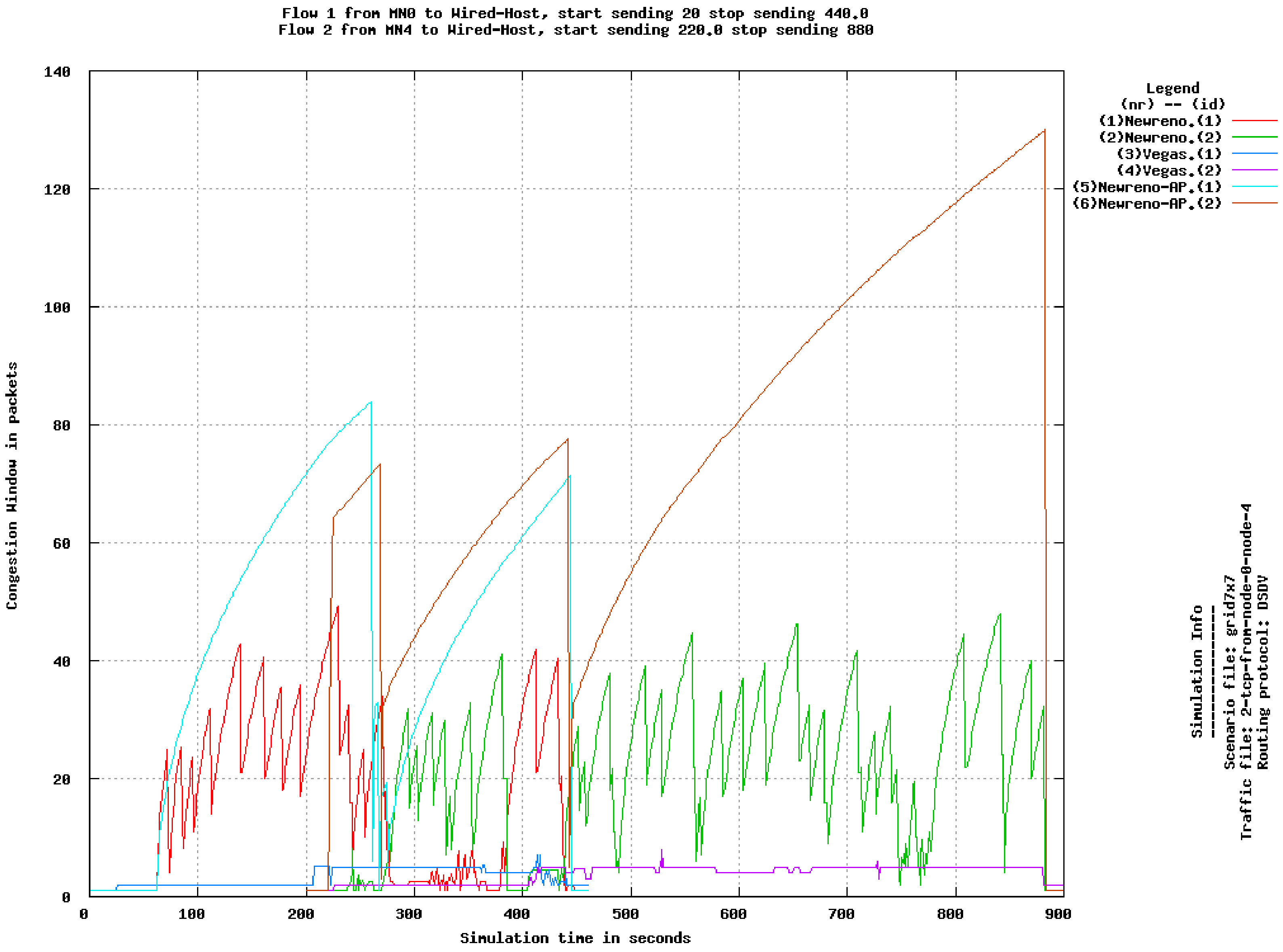
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
5
10
15
20
25
30
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno,(1)
(2)Vegas,(1)
Simulation Info
Scenario file: grid7x7
Traffic file: 1-tcp-from-node-0
Routing protocol: AODVUU

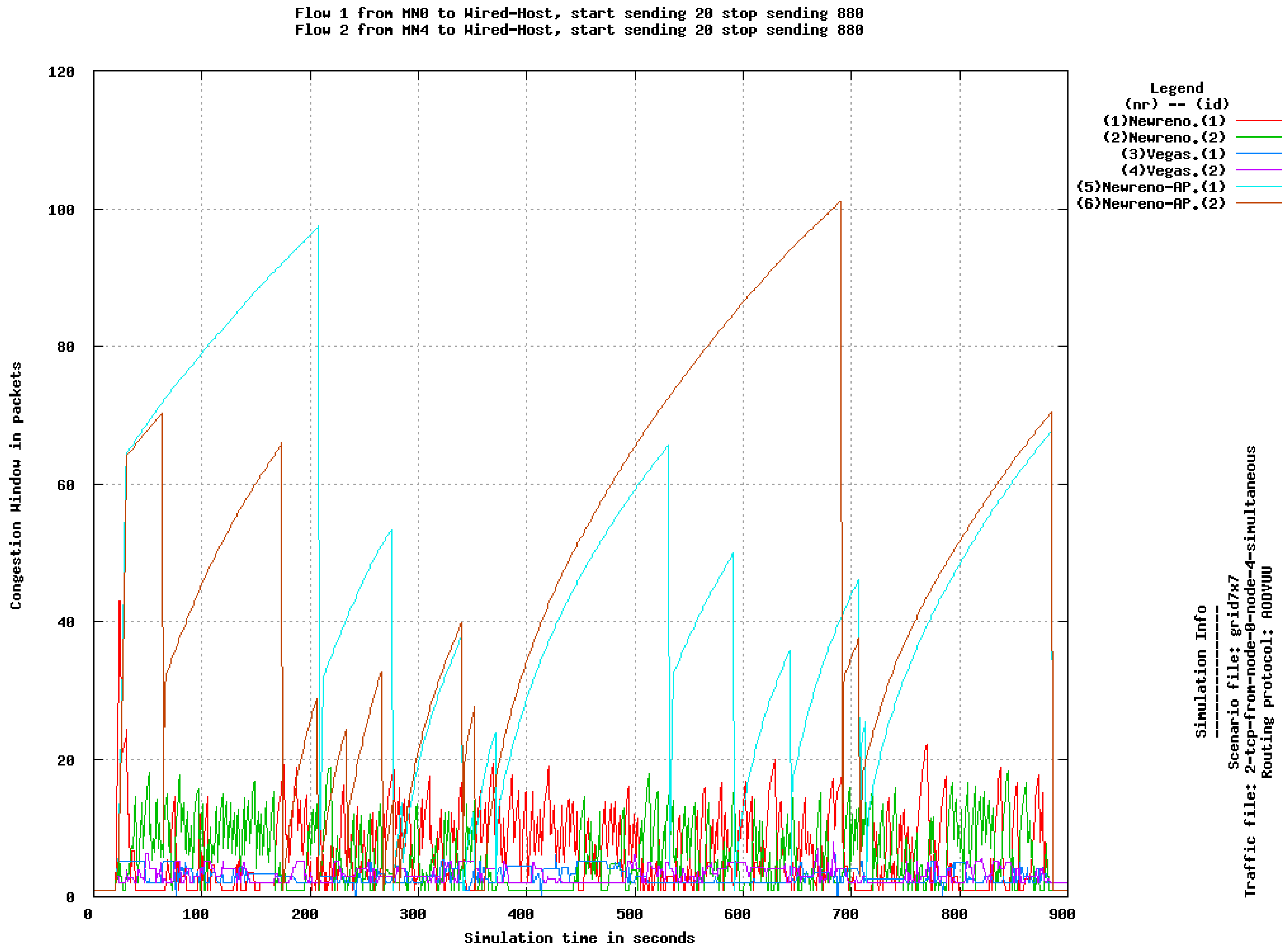


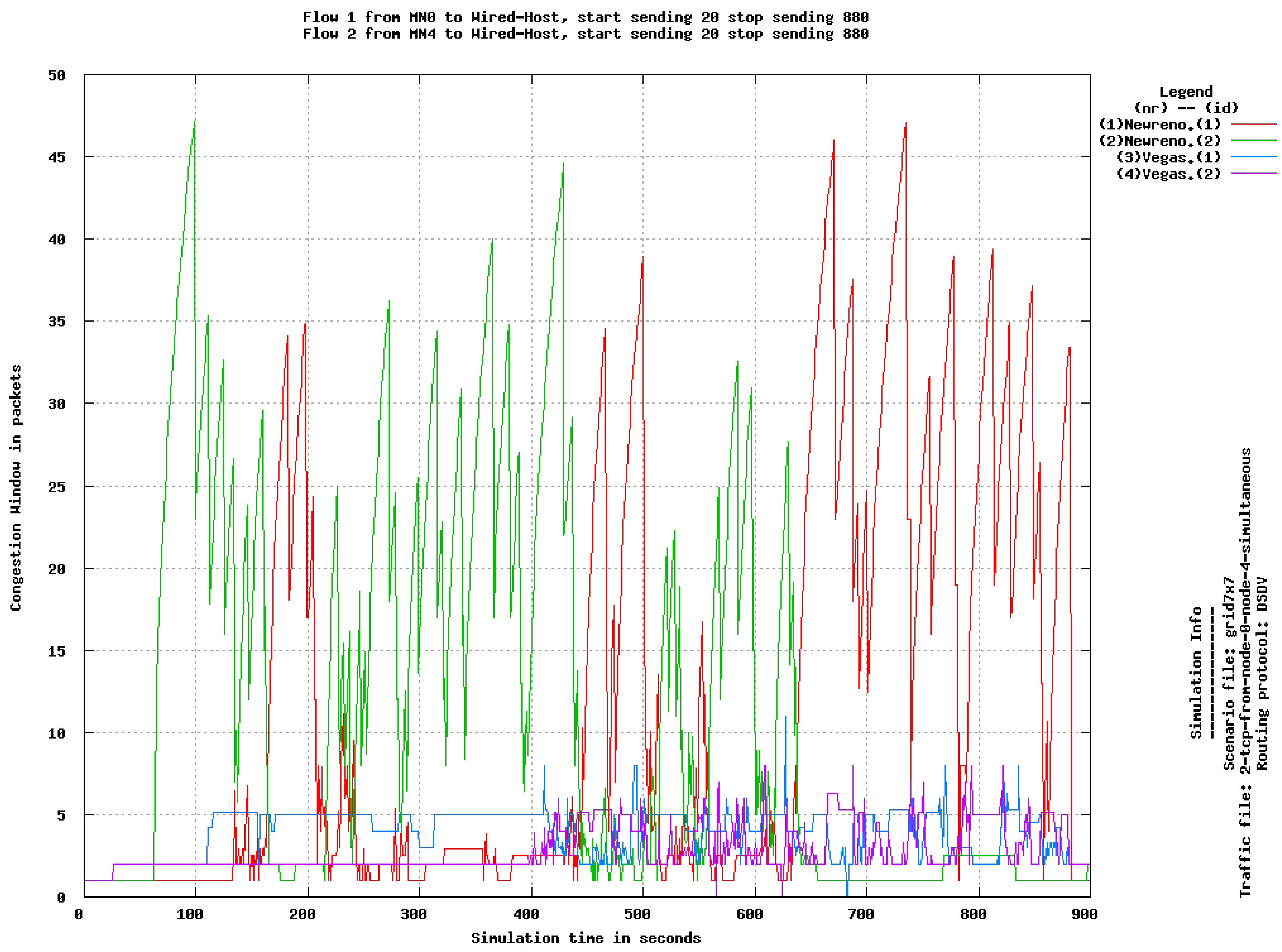
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Congestion Window in packets
Simulation time in seconds
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
Scenario file: grid7x7
Traffic file: 1-tcp-from-node-0
Routing protocol: DSDV
0
20
40
60
80
100
120
140
160
0
100
200
300
400
500
600
700
800
900



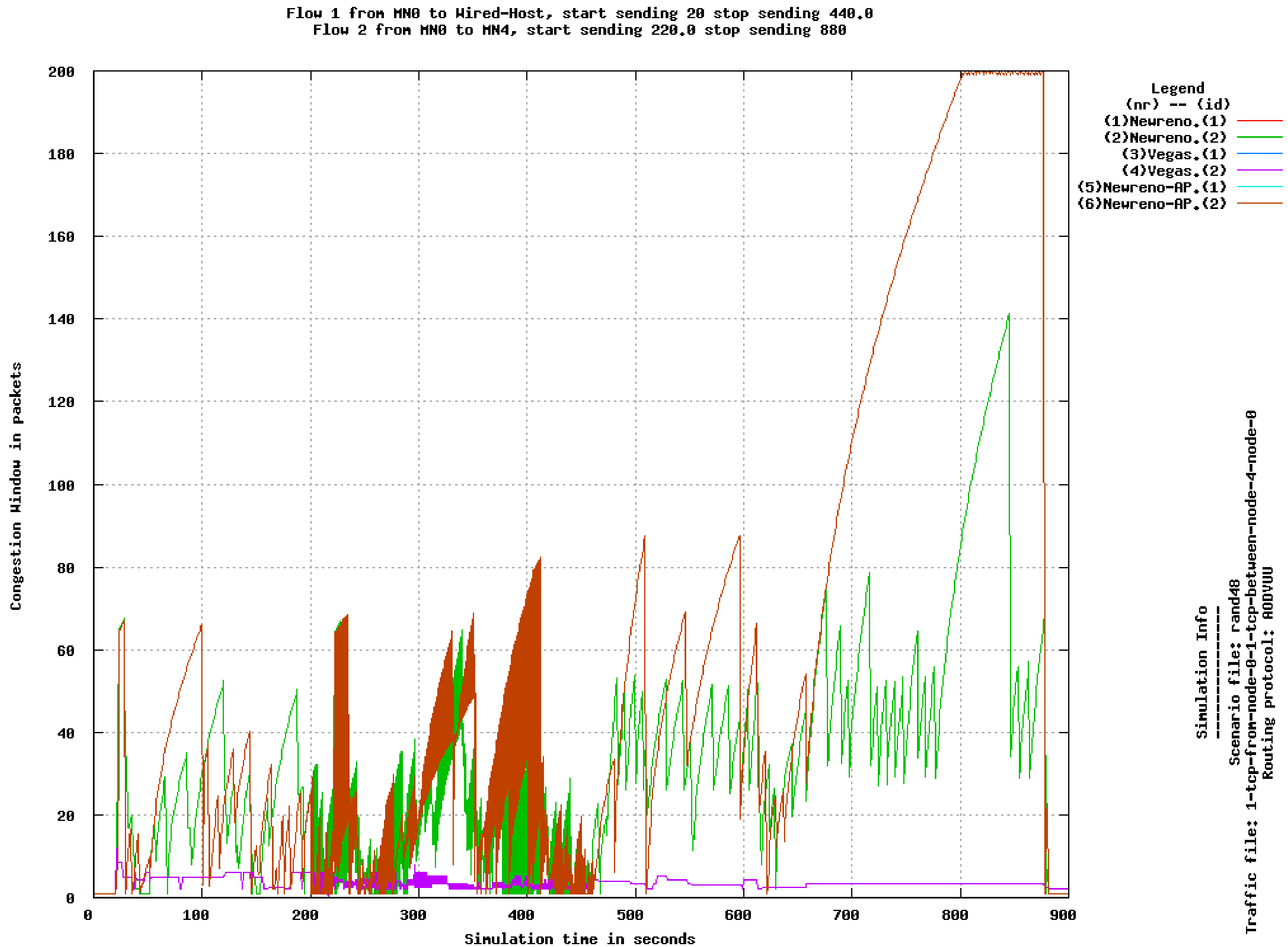
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN4 to Wired-Host, start sending 220.0 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
20
40
60
80
100
120
140
160
180
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: grid7x7
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: AODVUU


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN4 to Wired-Host, start sending 220.0 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
20
40
60
80
100
120
140
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: grid7x7
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: DSDV

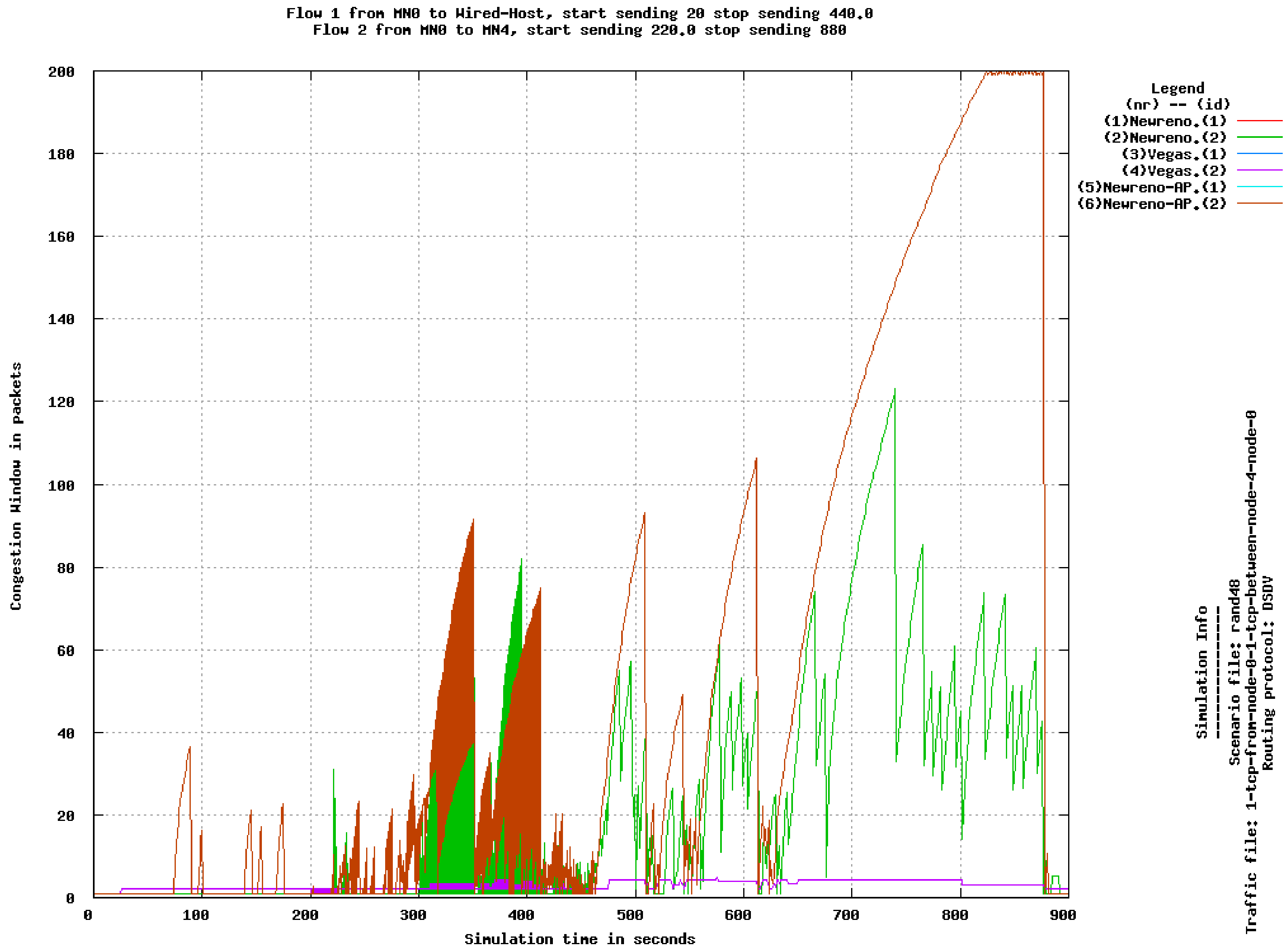

Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN4 to Wired-Host, start sending 20 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
20
40
60
80
100
120
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: grid7x7
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: AODVUU



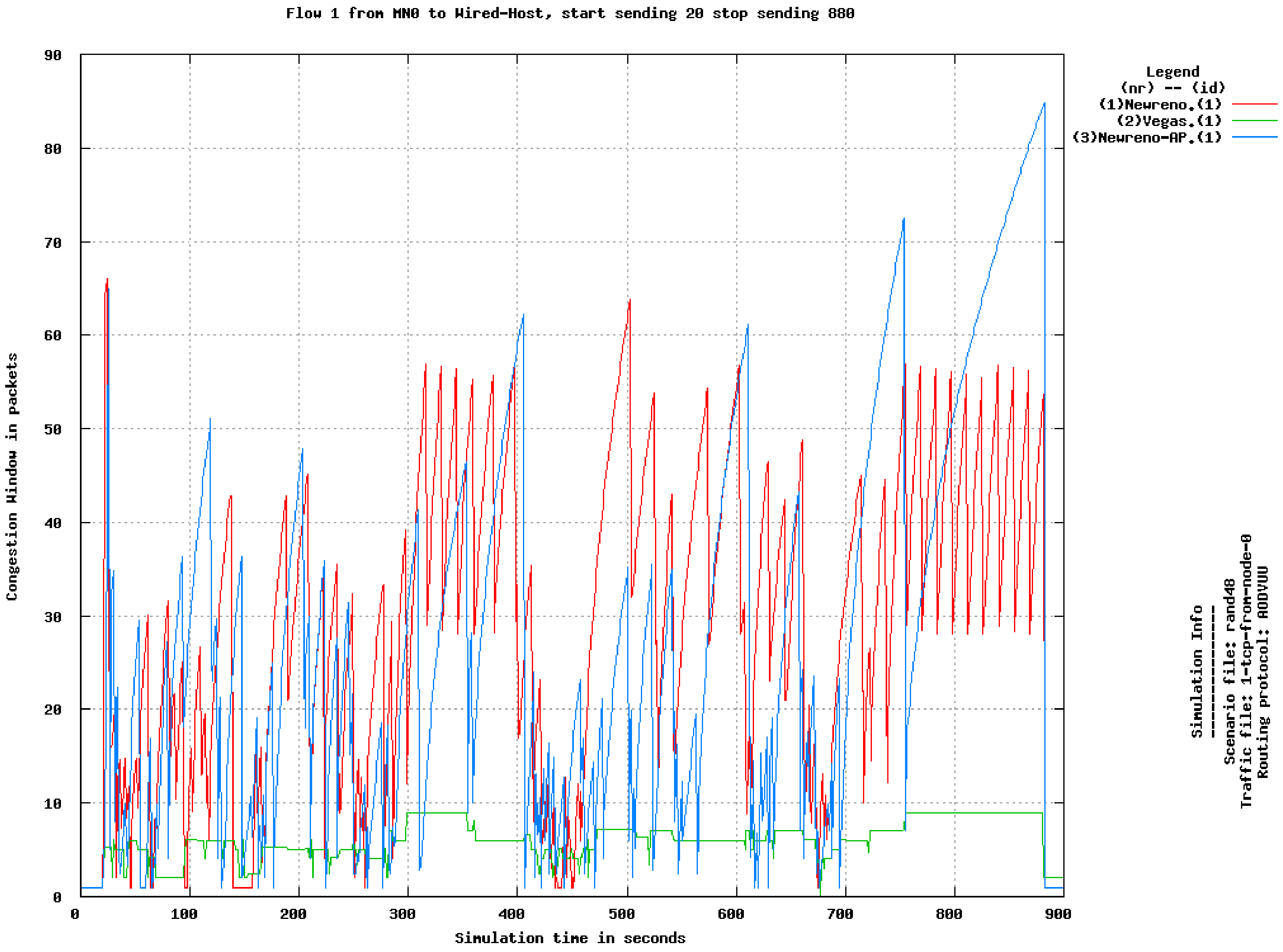
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN4 to Wired-Host, start sending 20 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
5
10
15
20
25
30
35
40
45
50
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
Simulation Info
Scenario file: grid7x7
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: DSDV



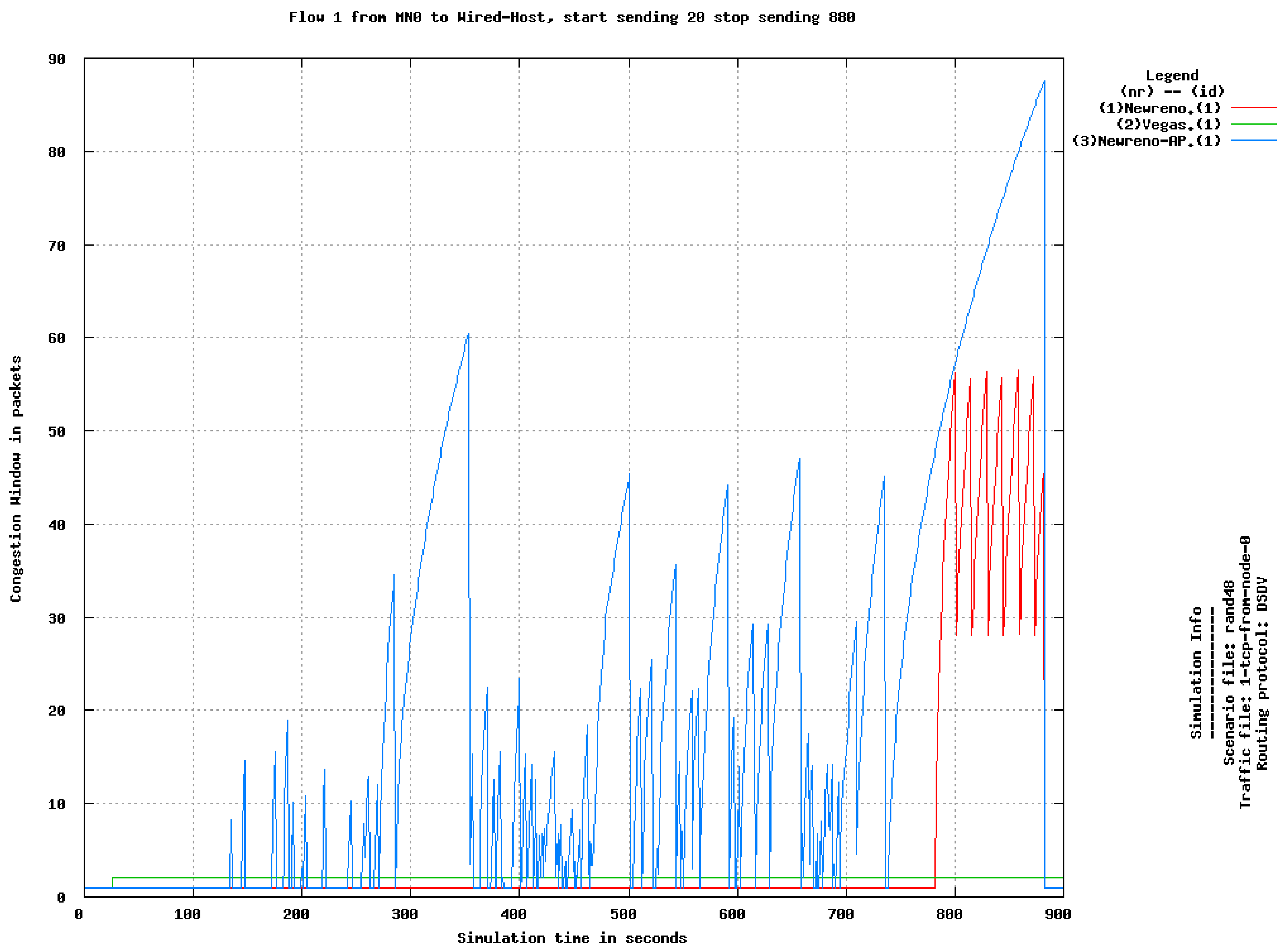
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN0 to MN4, start sending 220.0 stop sending 880
Congestion Window in packets
Simulation time in seconds
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: rand40
Traffic file: 1-tcp-from-node-0-1-tcp-between-node-4-node-0
Routing protocol: AODVUU



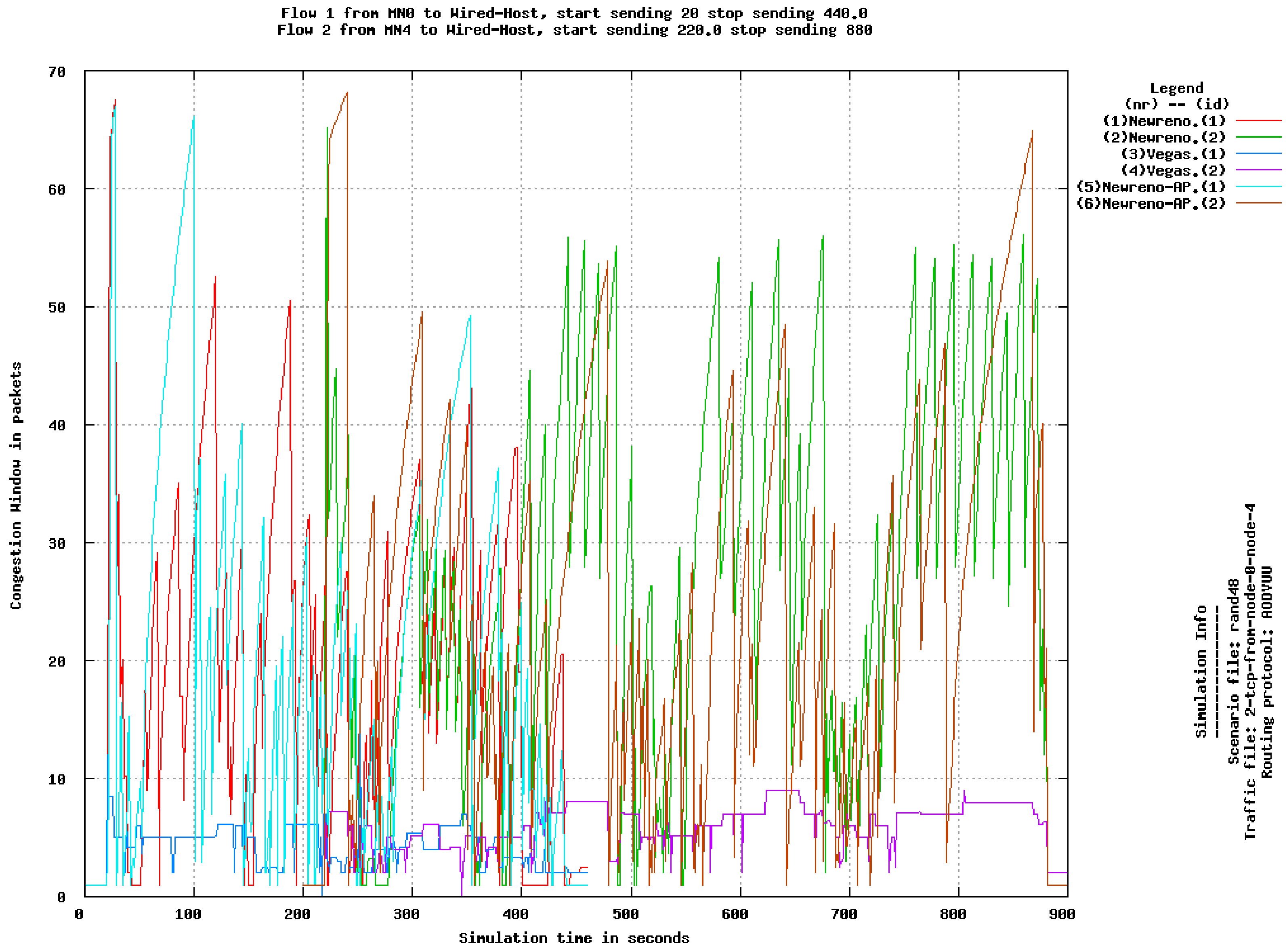
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN0 to MN4, start sending 220.0 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
20
40
60
80
100
120
140
160
180
200
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: rand48
Traffic file: 1-tcp-from-node-0-1-tcp-between-node-4-node-0
Routing protocol: DSDV

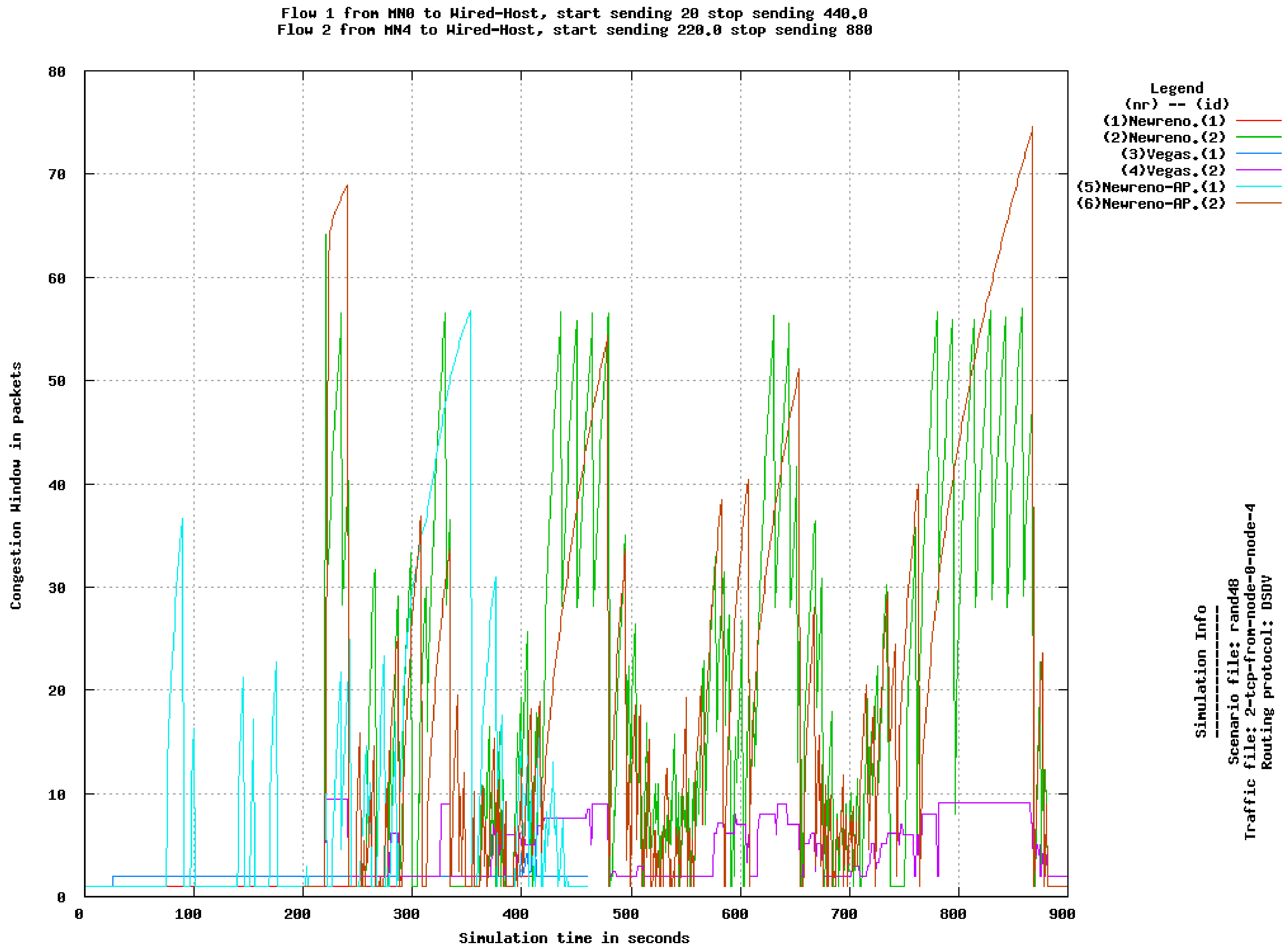


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
10
20
30
40
50
60
70
80
90
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
Scenario file: rand40
Traffic file: 1-tcp-from-node-0
Routing protocol: AODVUU

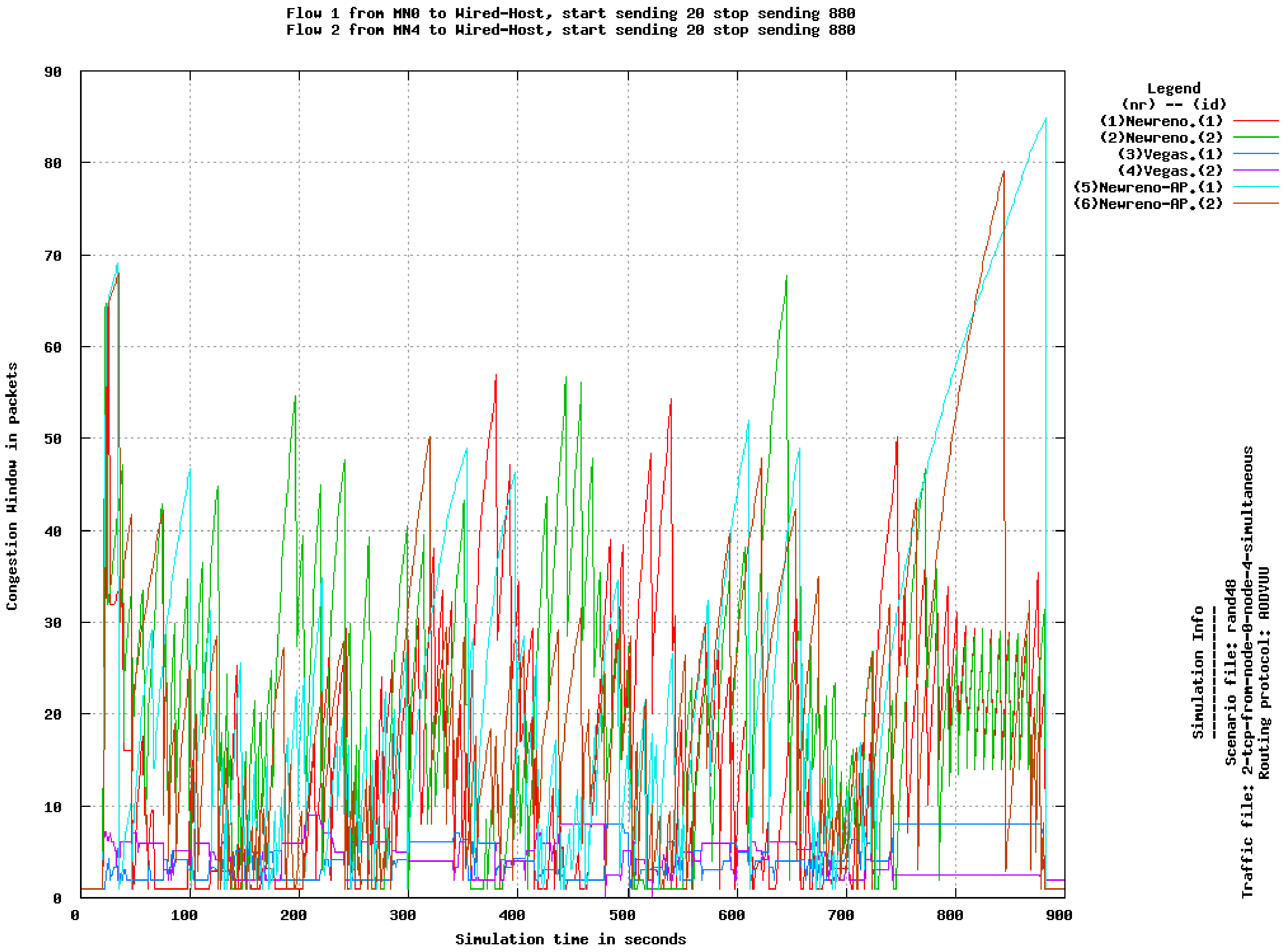


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
10
20
30
40
50
60
70
80
90
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
Scenario file: rand48
Traffic file: 1-tcp-from-node-0
Routing protocol: DSDV

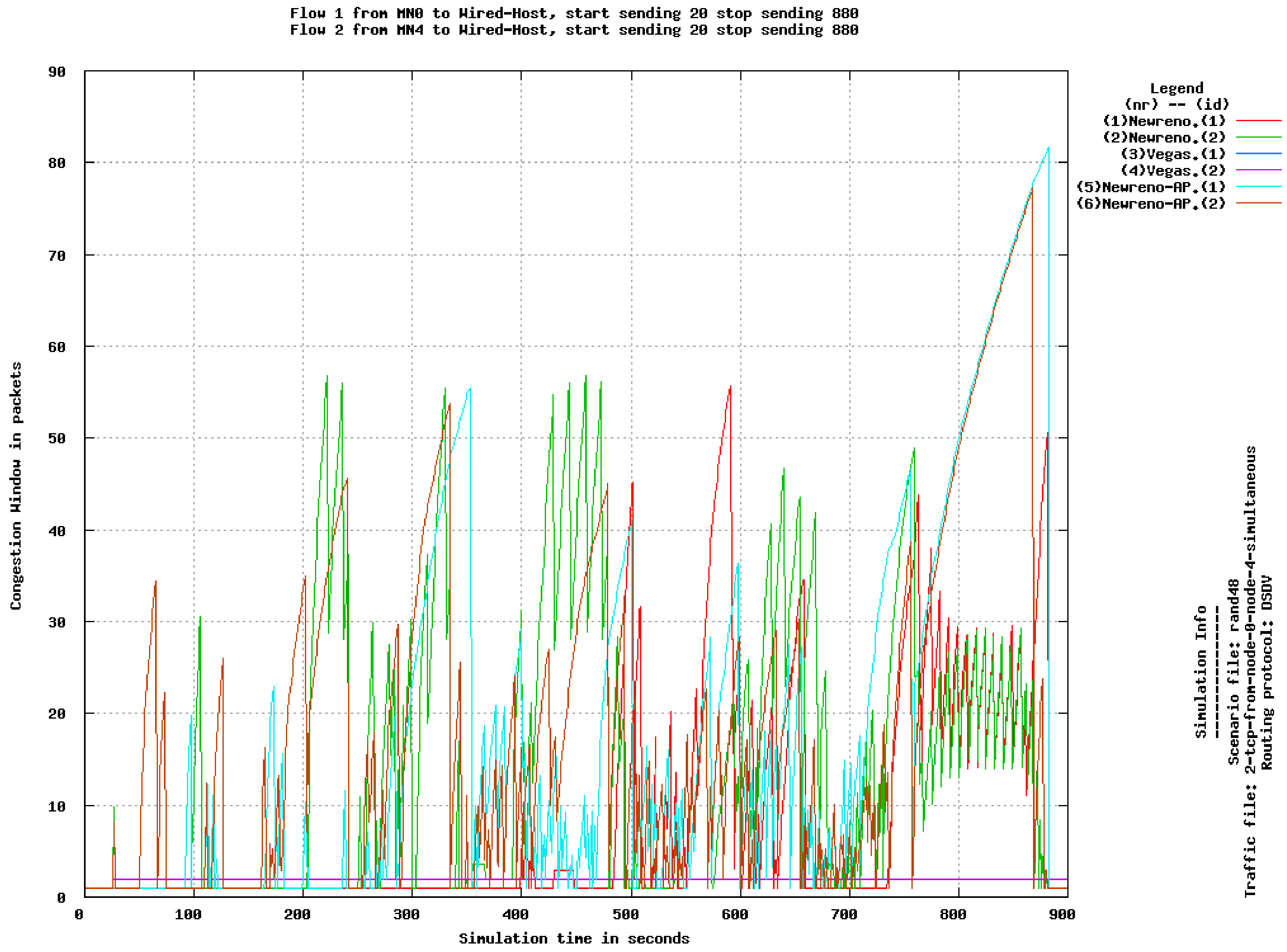

Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN4 to Wired-Host, start sending 220.0 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
10
20
30
40
50
60
70
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
-------------
Scenario file: rand48
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: AODVUU



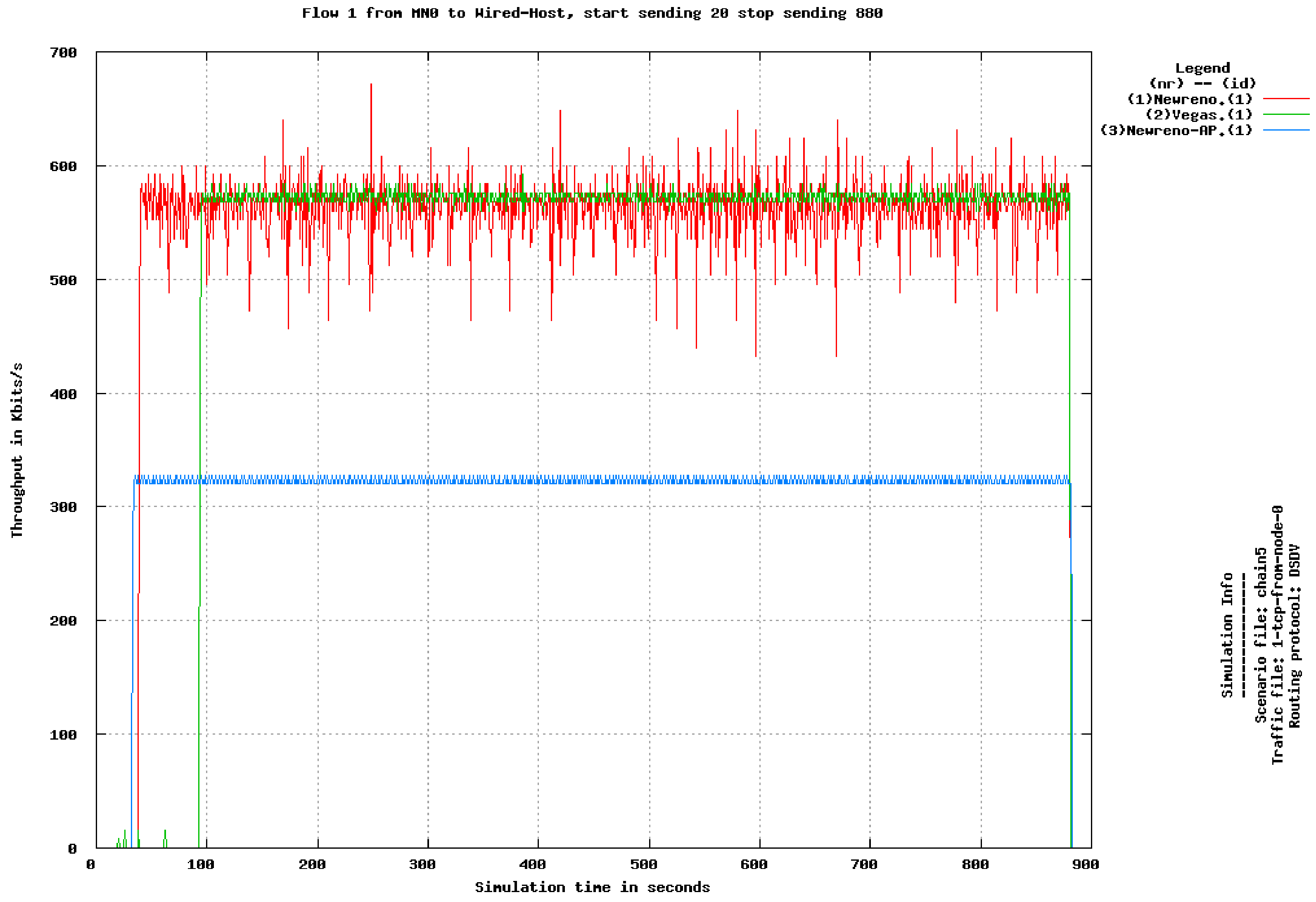
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN4 to Wired-Host, start sending 220.0 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
10
20
30
40
50
60
70
80
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: rand48
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: DSDV

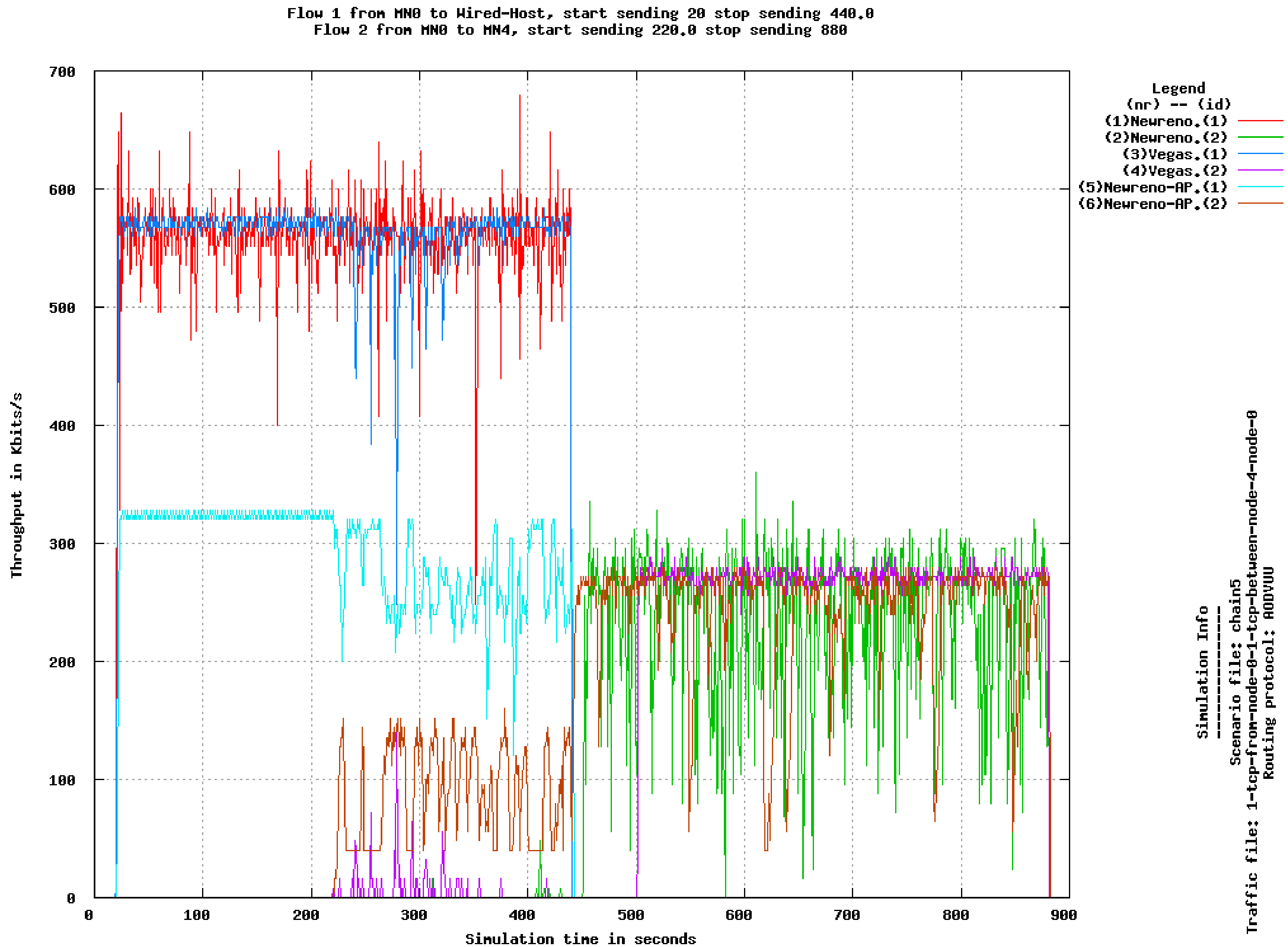


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN4 to Wired-Host, start sending 20 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: rand48
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: AODVUU

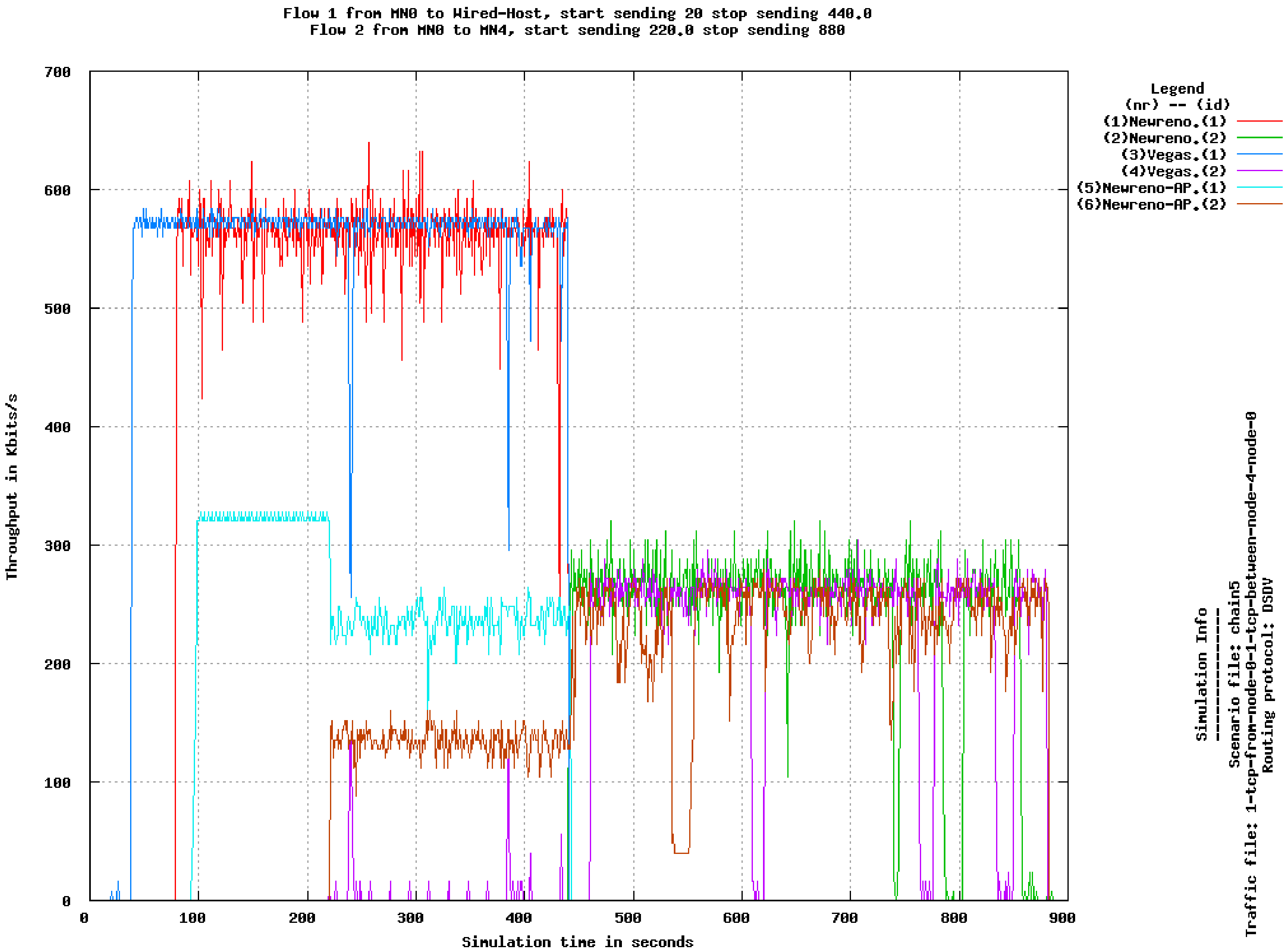

Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN4 to Wired-Host, start sending 20 stop sending 880
Congestion Window in packets
Simulation time in seconds
0
10
20
30
40
50
60
70
80
90
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: rand48
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: DSDV

## G.5.2 Throughput

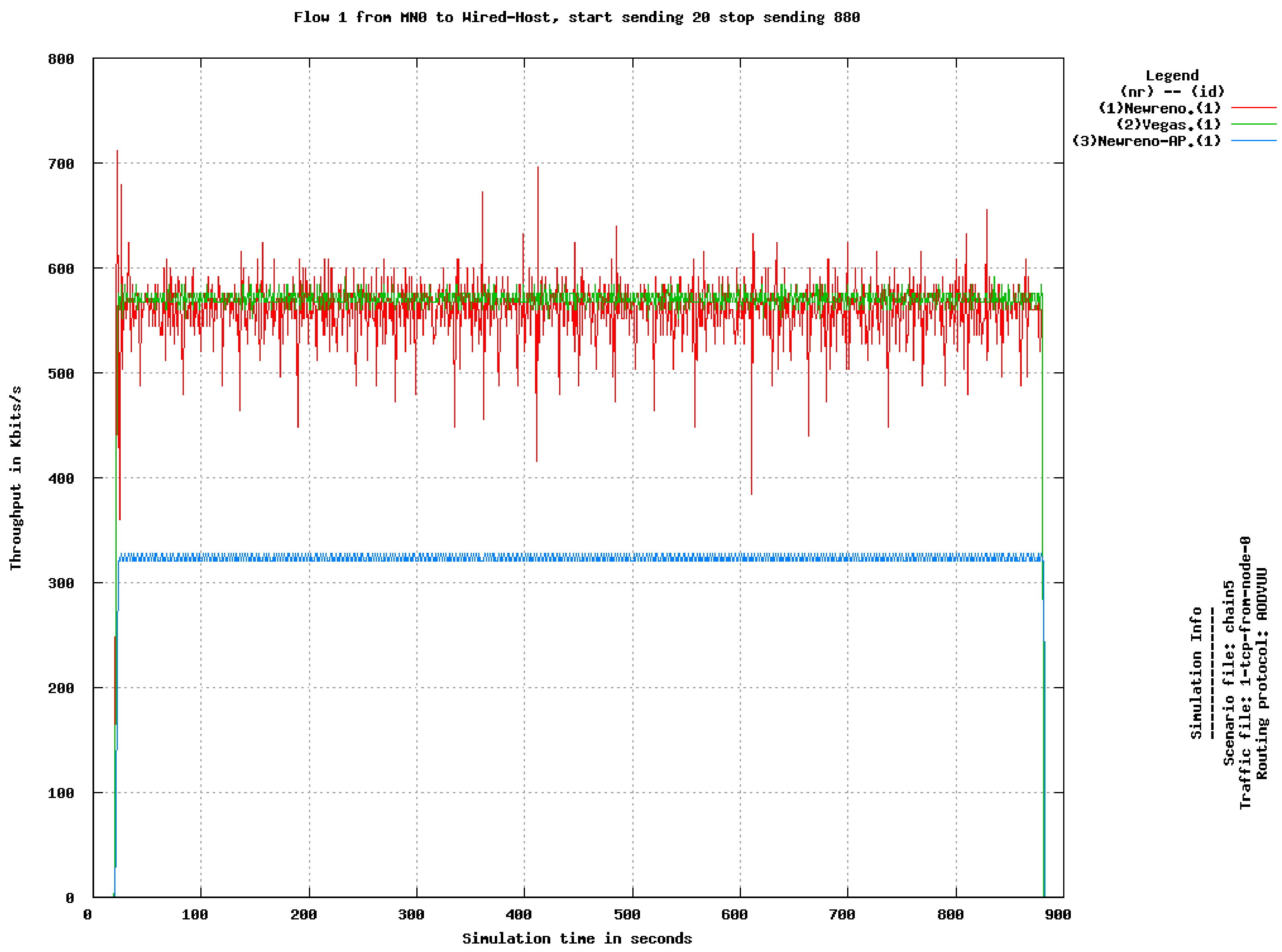




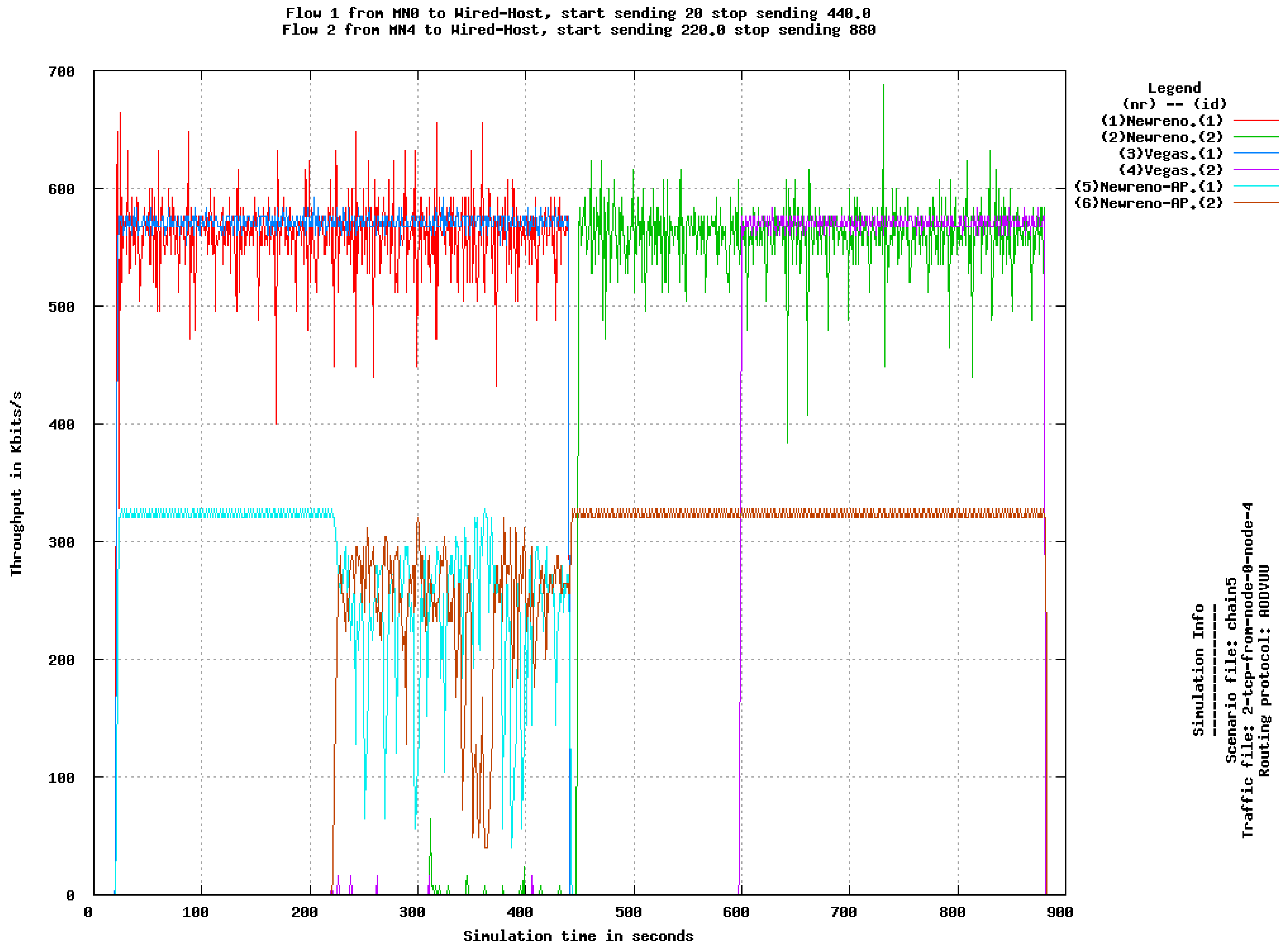
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN0 to MN4, start sending 220.0 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain5
Traffic file: 1-tcp-from-node-0-1-tcp-between-node-4-node-0
Routing protocol: AODVUU



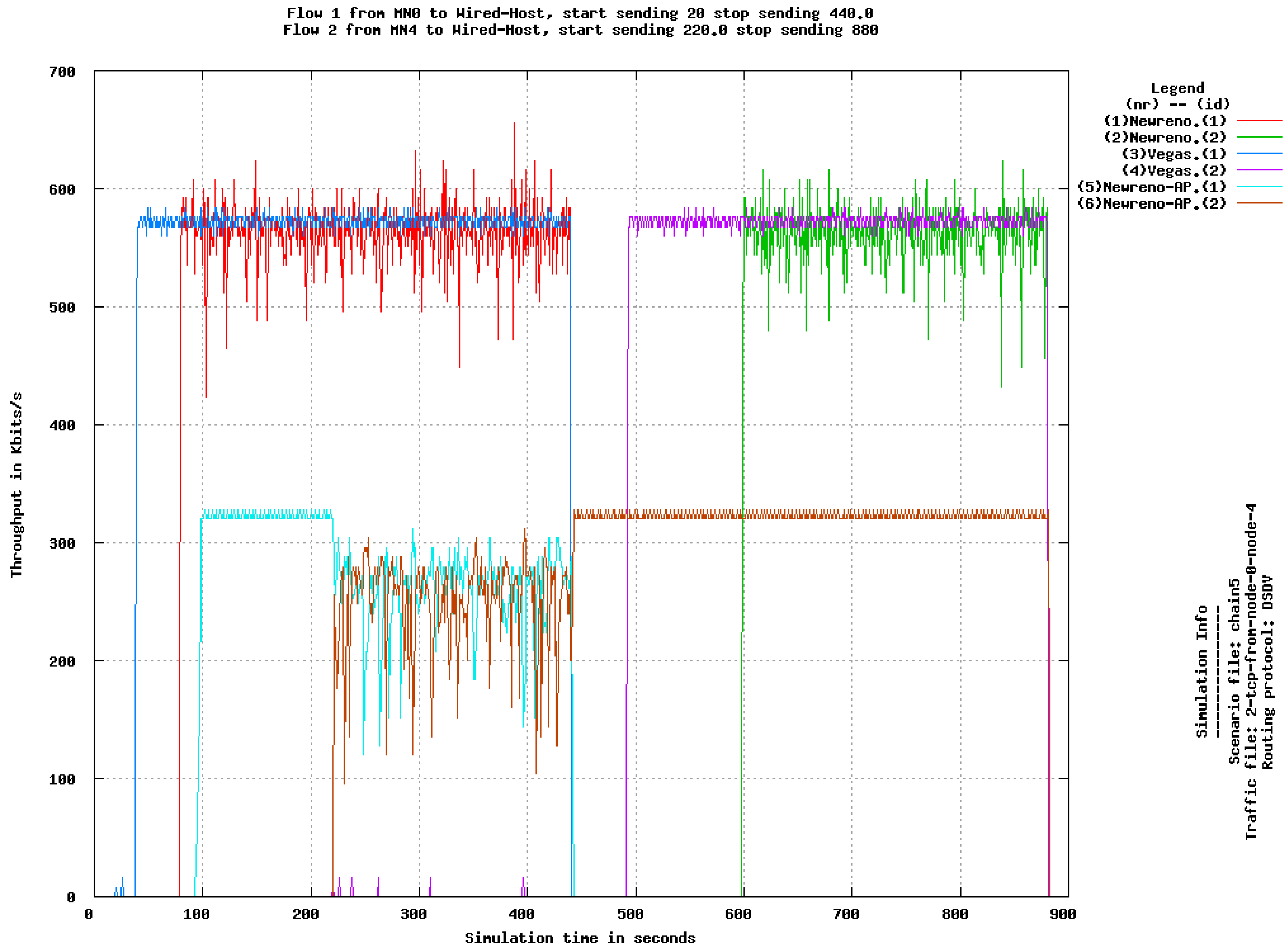
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN0 to MN4, start sending 220.0 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain5
Traffic file: 1-tcp-from-node-0-1-tcp-between-node-4-node-0
Routing protocol: DSDV



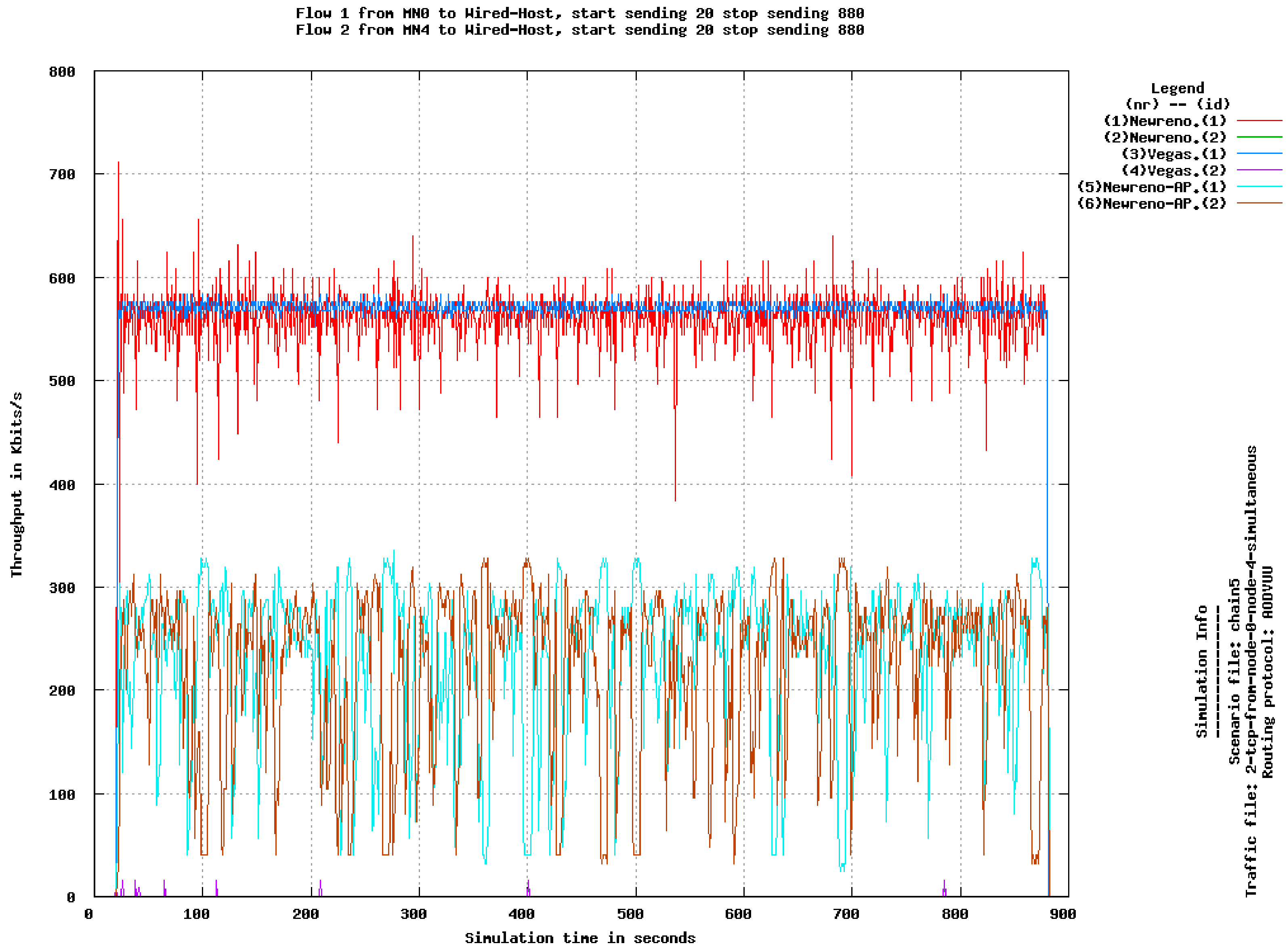
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
Scenario file: chain5
Traffic file: 1-tcp-from-node-0
Routing protocol: AODVUU



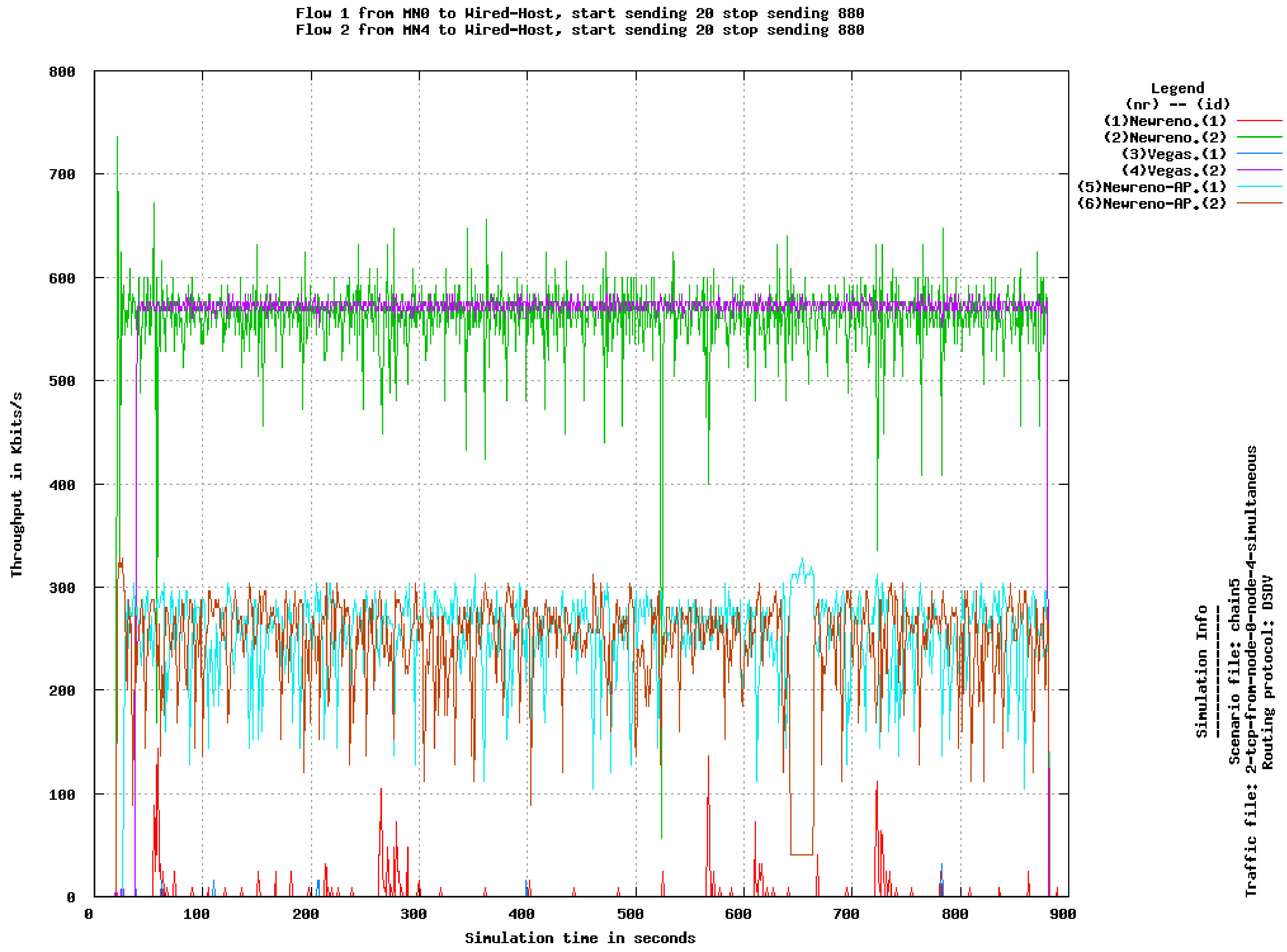
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN4 to Wired-Host, start sending 220.0 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain5
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: AODVUU

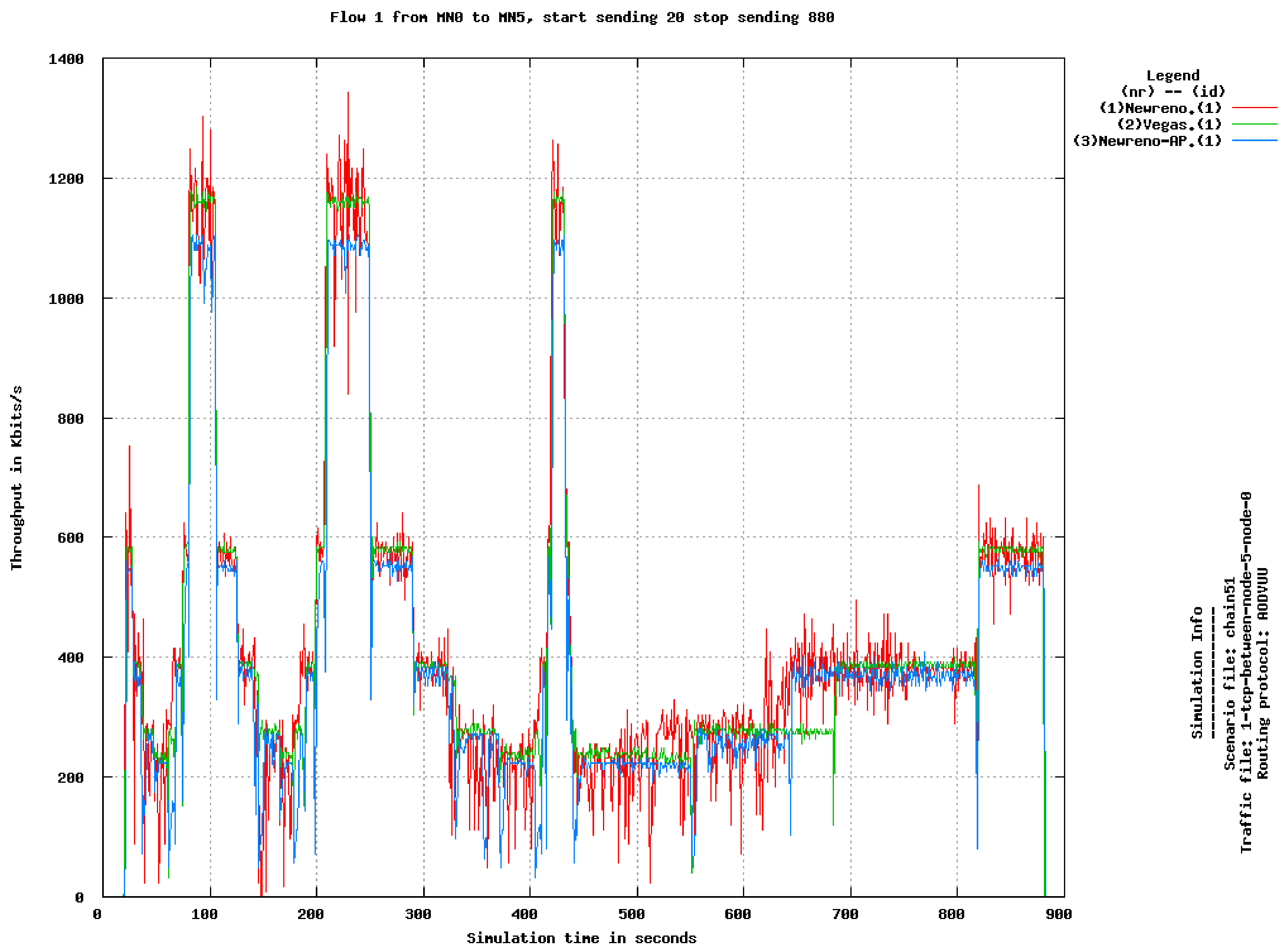


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN4 to Wired-Host, start sending 220.0 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain5
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: DSDV

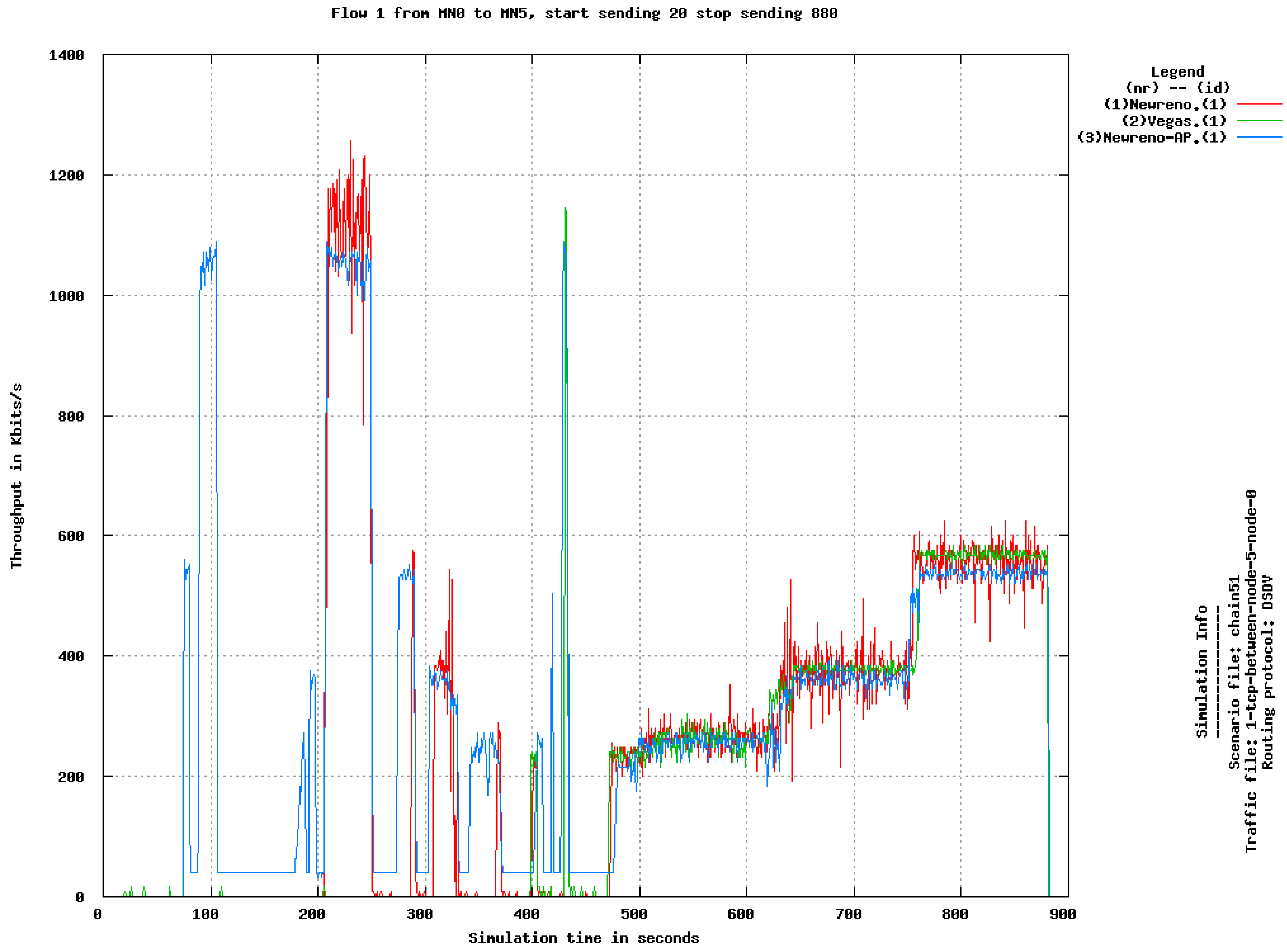


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN4 to Wired-Host, start sending 20 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain5
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: AODVUU

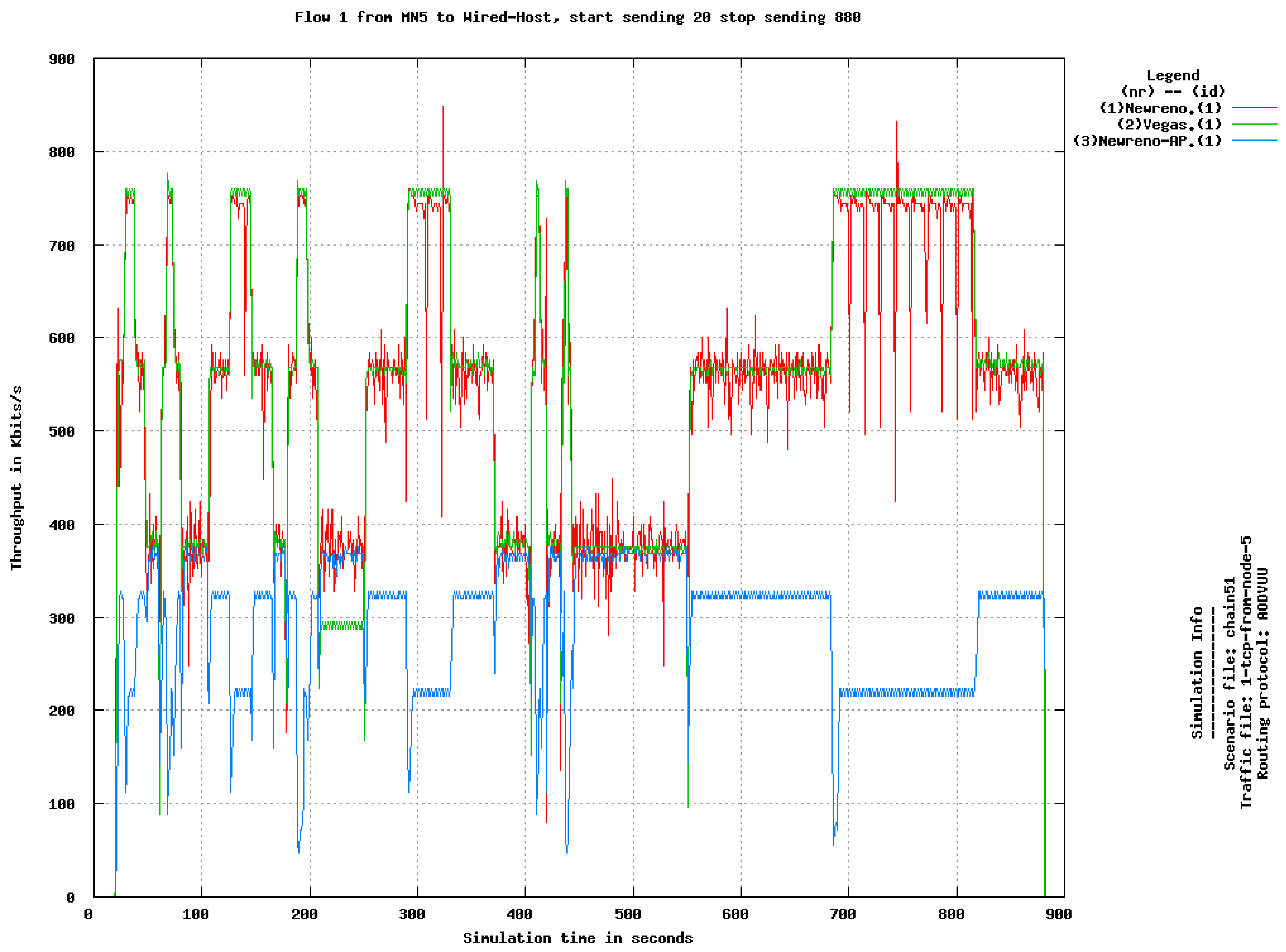

Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN4 to Wired-Host, start sending 20 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain5
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: DSDV



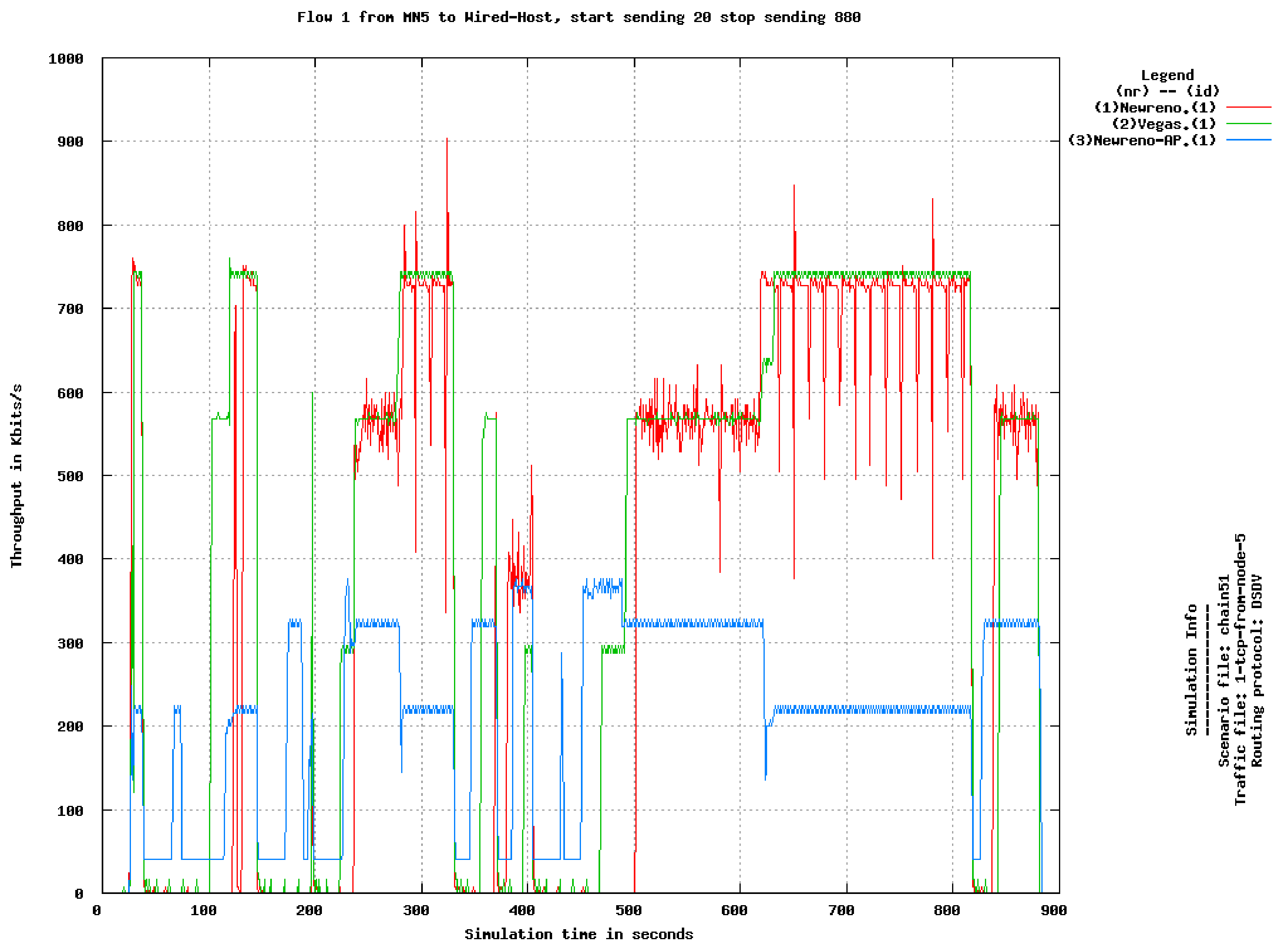
Flow 1 from MN0 to MN5, start sending 20 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
200
400
600
800
1000
1200
1400
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno,(1)
(2)Vegas,(1)
(3)Newreno-AP,(1)
Simulation Info
Scenario file: chain51
Traffic file: 1-tcp-between-node-5-node-0
Routing protocol: AODVUU

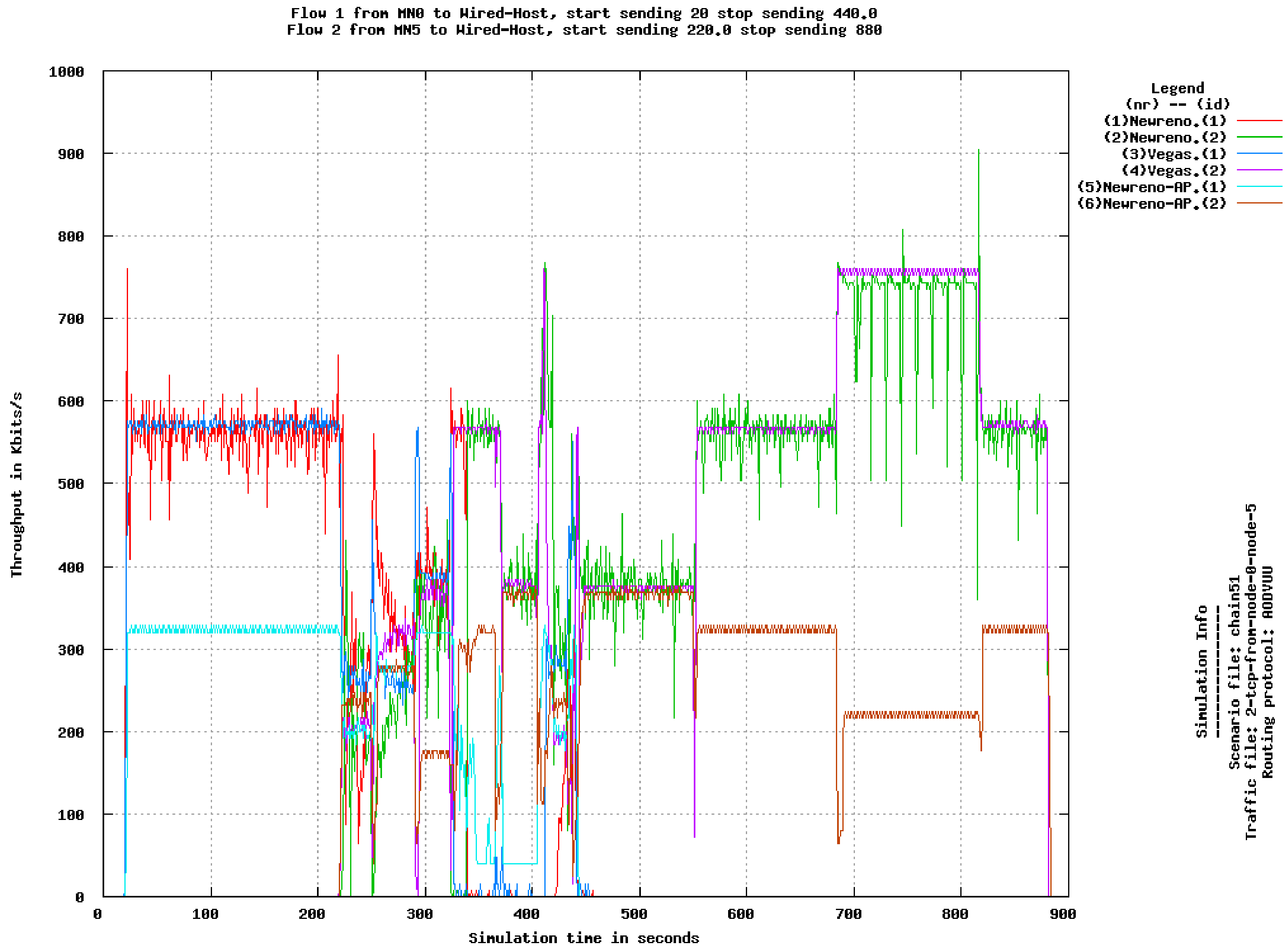


Flow 1 from MN0 to MN5, start sending 20 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
1400
1200
1000
800
600
400
200
0
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno,(1)
(2)Vegas,(1)
(3)Newreno-AP,(1)
Simulation Info
Scenario file: chain51
Traffic file: 1-tcp-between-node-5-node-0
Routing protocol: DSDV

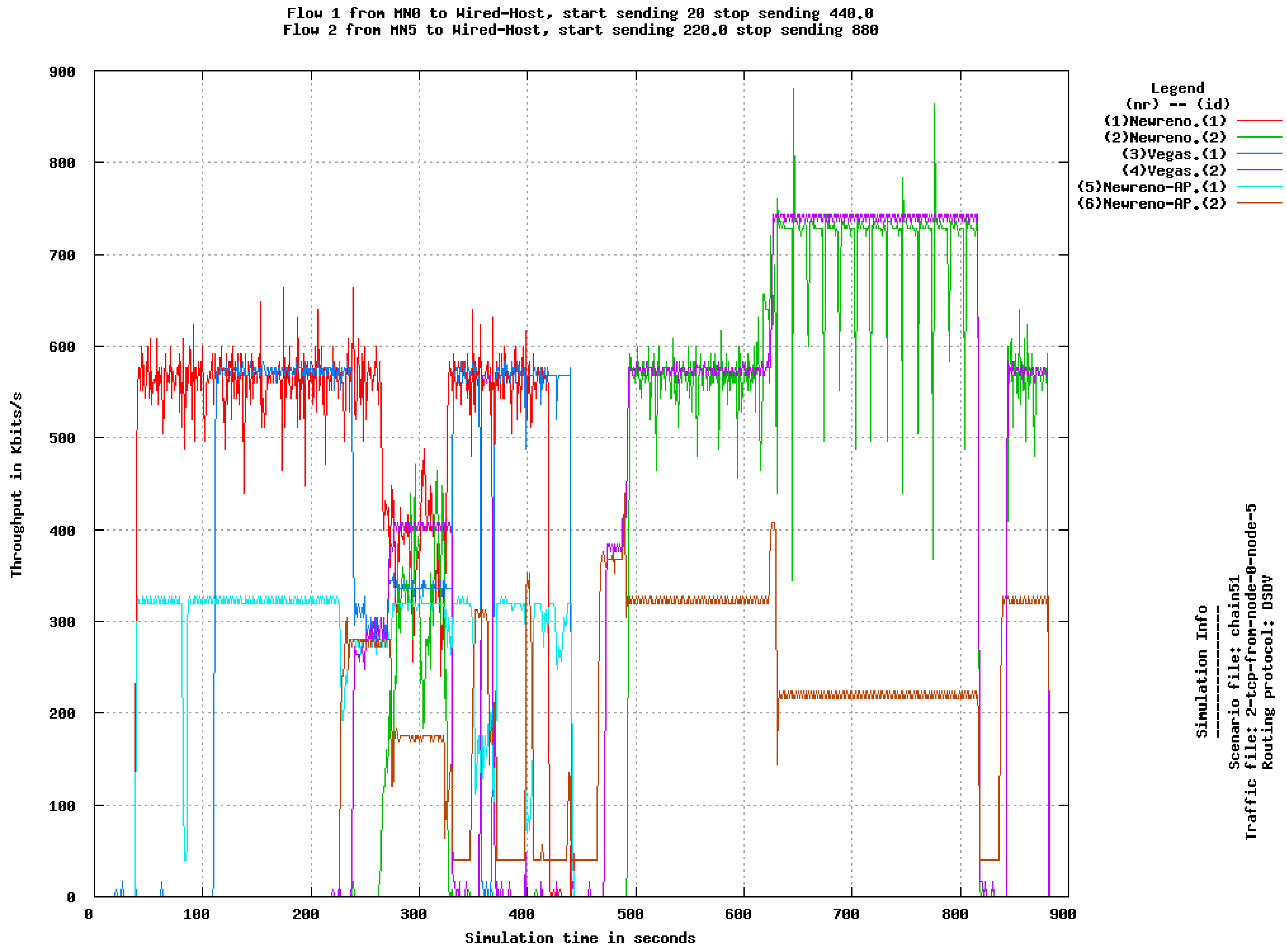


Flow 1 from MN5 to Wired-Host, start sending 20 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
Scenario file: chain51
Traffic file: 1-tcp-from-node-5
Routing protocol: AODVUU

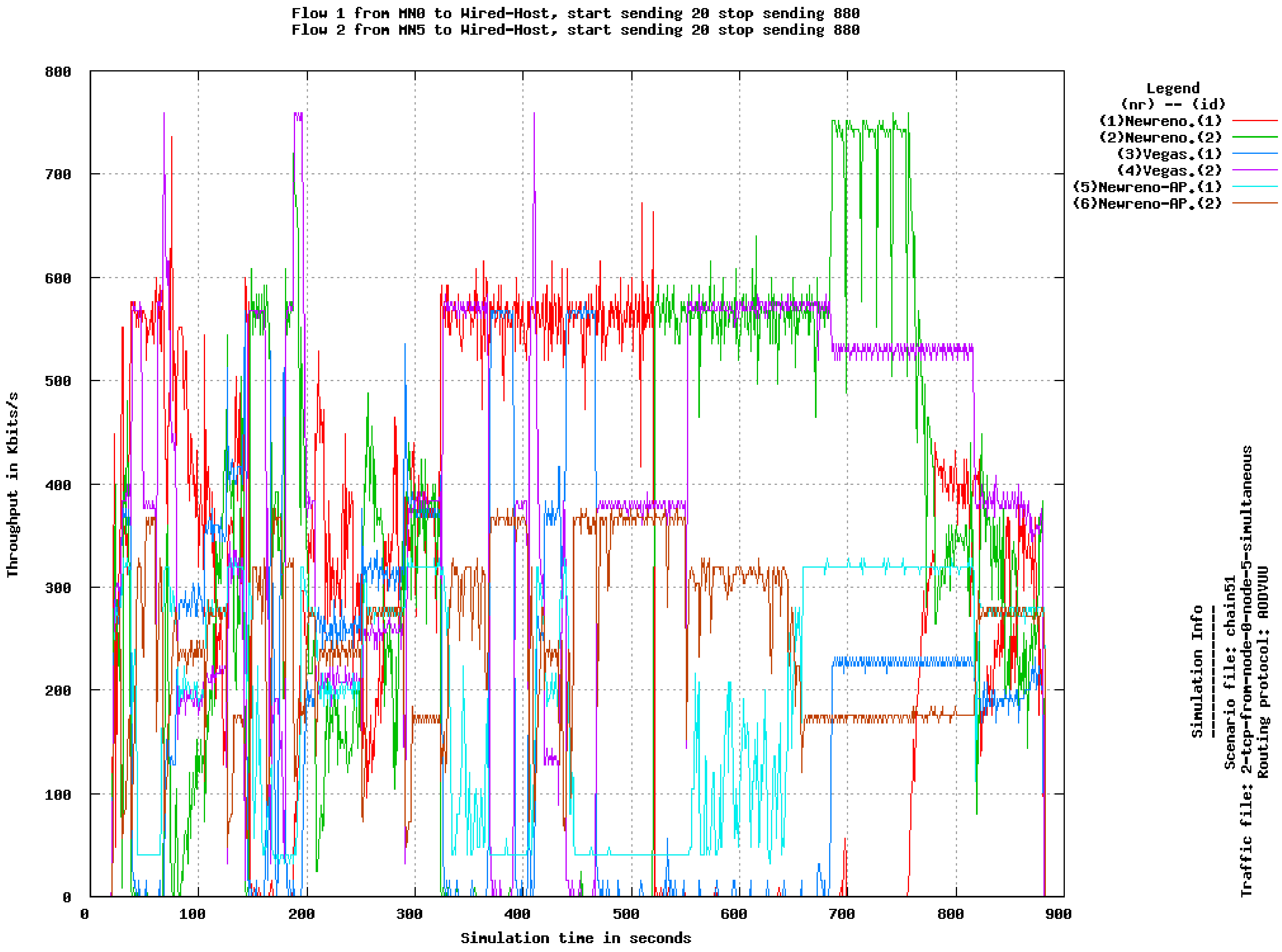

Flow 1 from MN5 to Wired-Host, start sending 20 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
1000
Legend
(nr) -- (id)
(1)Newreno,(1)
(2)Vegas,(1)
(3)Newreno-AP,(1)
Simulation Info
Scenario file: chain51
Traffic file: 1-tcp-from-node-5
Routing protocol: DSDV

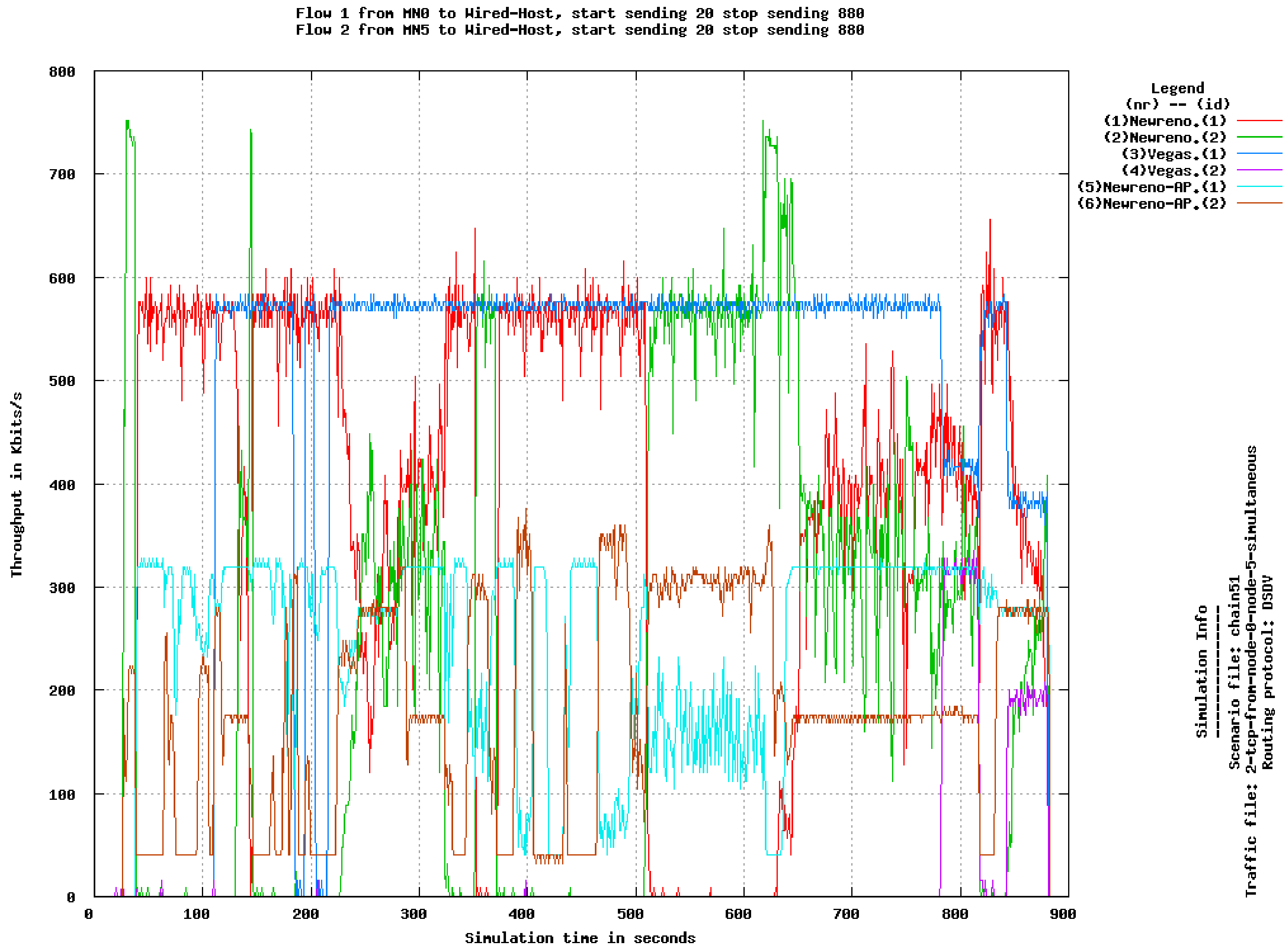


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN5 to Wired-Host, start sending 220.0 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
1000
Legend
(nr) -- (id)
(1)Newreno.(2)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain51
Traffic file: 2-tcp-from-node-0-node-5
Routing protocol: AODVUU

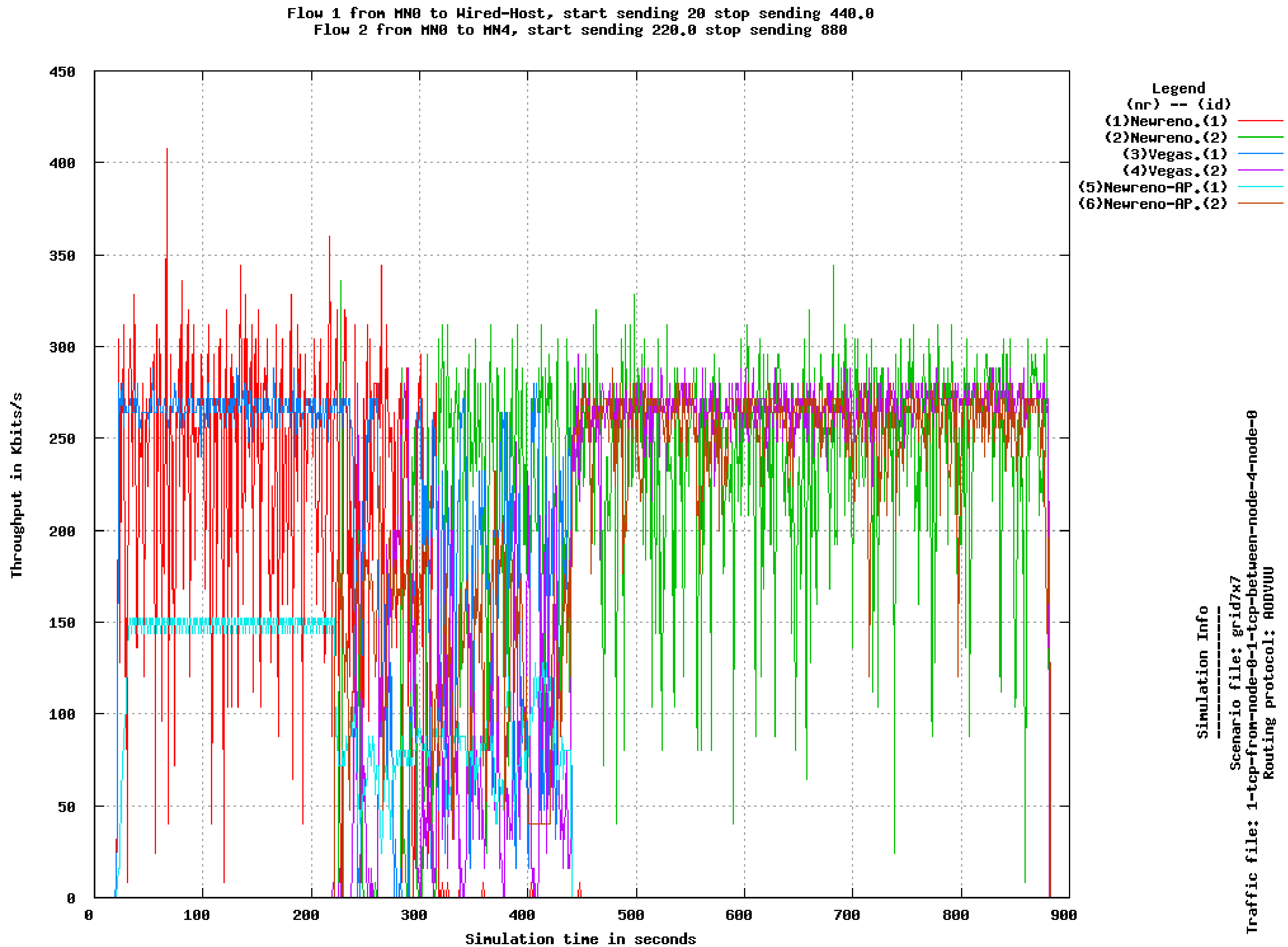


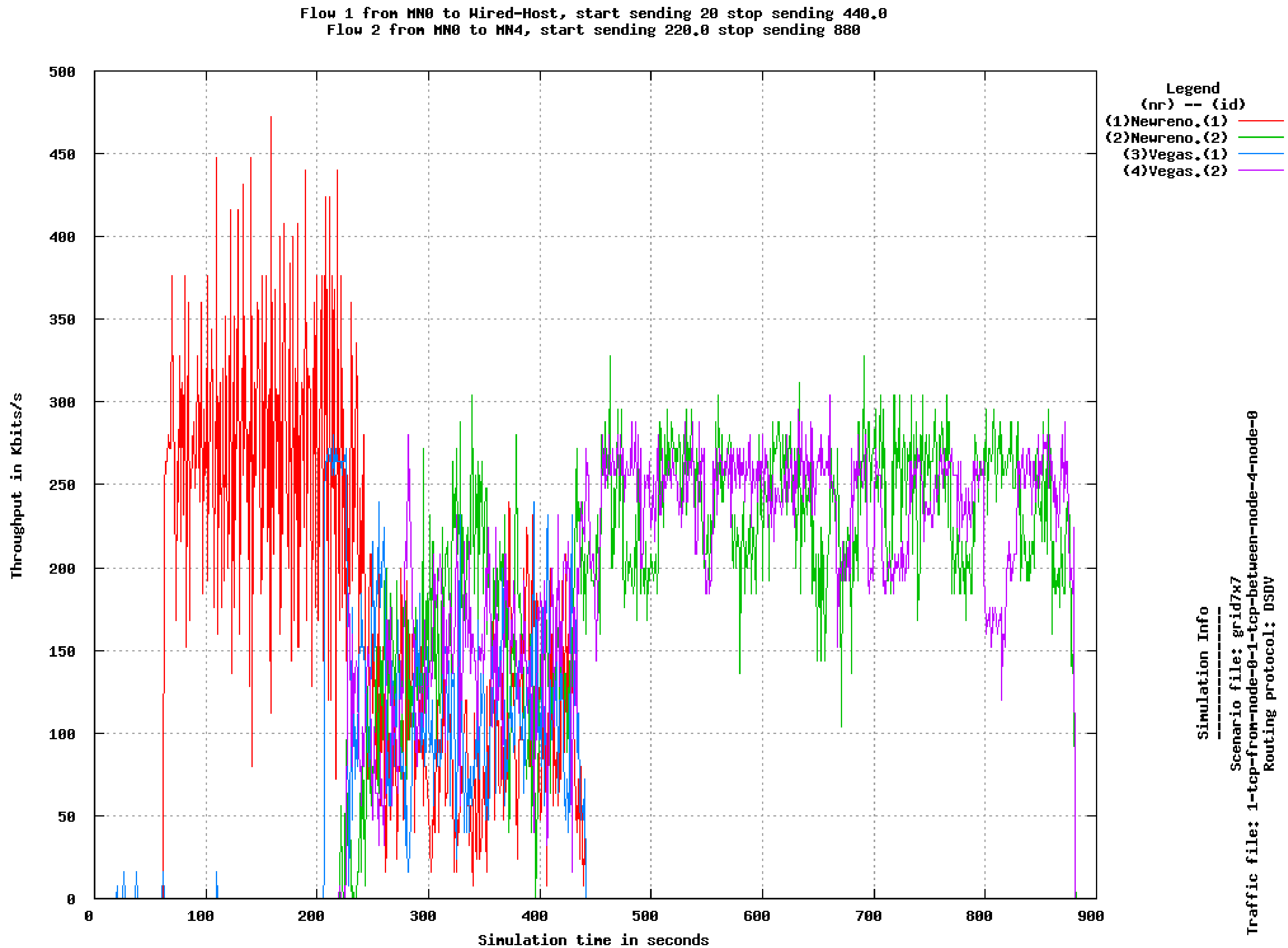
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN5 to Wired-Host, start sending 220.0 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain51
Traffic file: 2-tcp-from-node-0-node-5
Routing protocol: DSDV


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN5 to Wired-Host, start sending 20 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
---------------
Scenario file: chain51
Traffic file: 2-tcp-from-node-0-node-5-simultaneous
Routing protocol: AODVUU

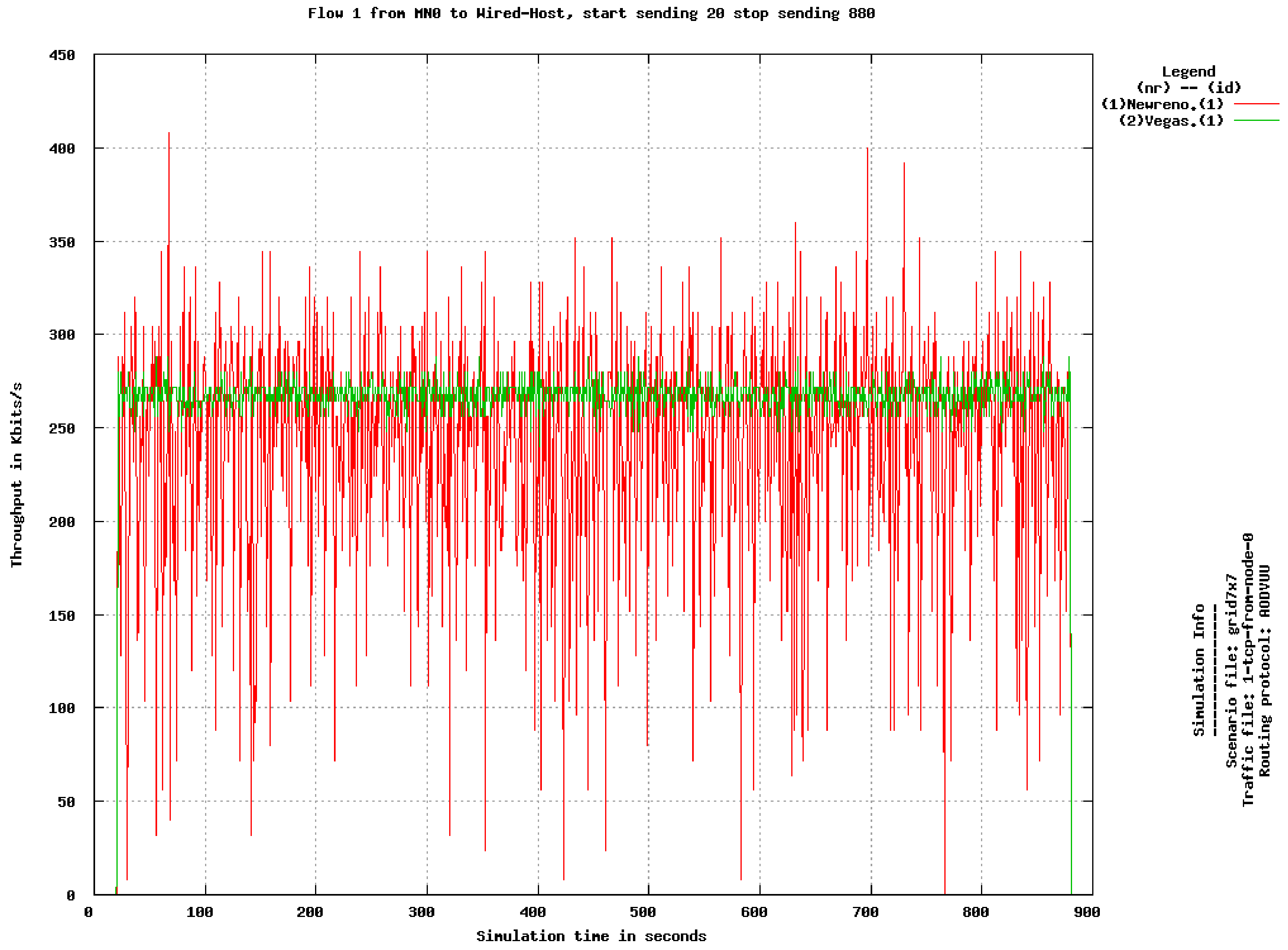


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN5 to Wired-Host, start sending 20 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain51
Traffic file: 2-tcp-from-node-0-node-5-simultaneous
Routing protocol: DSDV

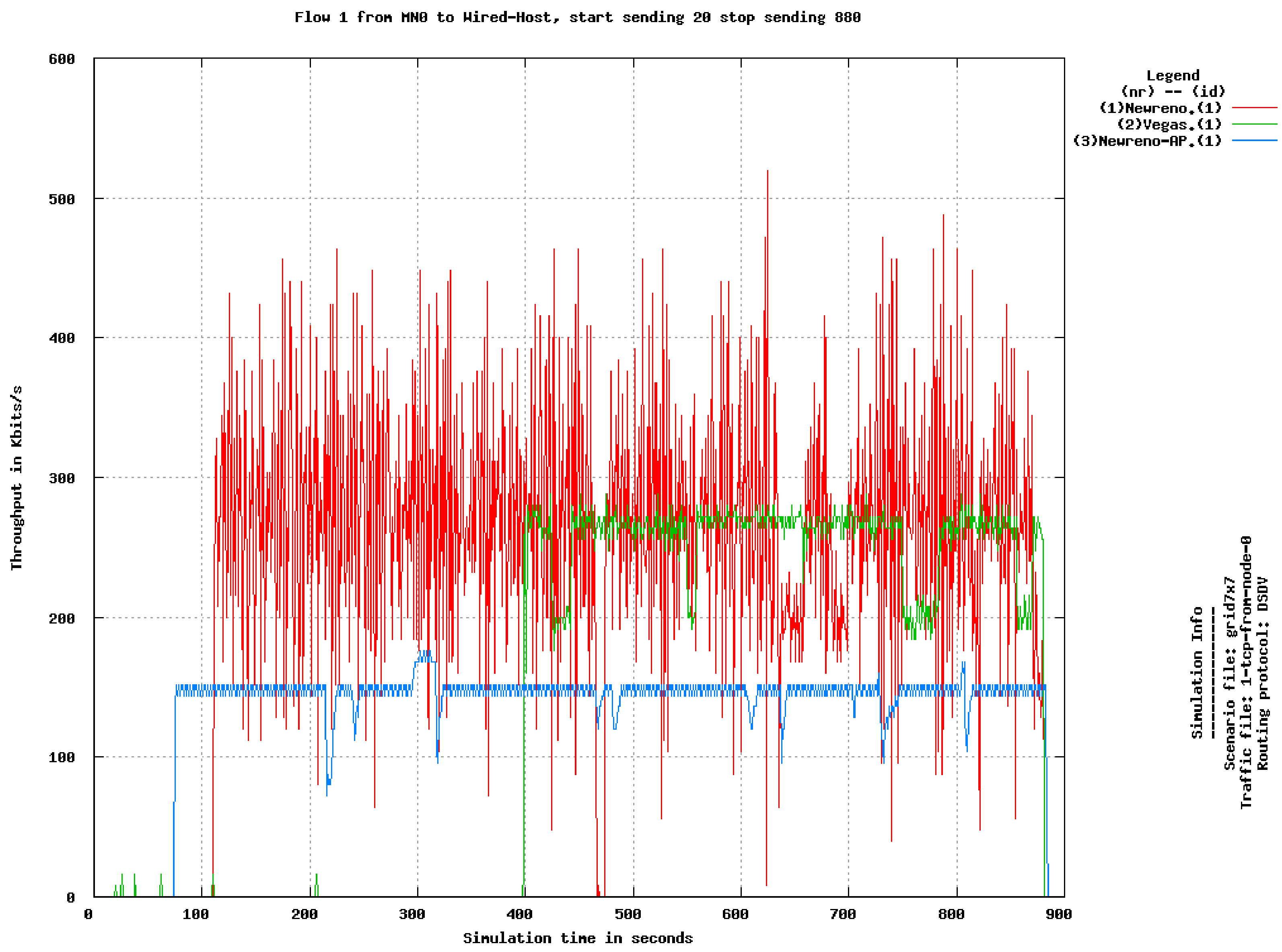

Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN0 to MN4, start sending 220.0 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
50
100
150
200
250
300
350
400
450
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: grid7x7
Traffic file: 1-tcp-from-node-0-1-tcp-between-node-4-node-0
Routing protocol: AODVUU



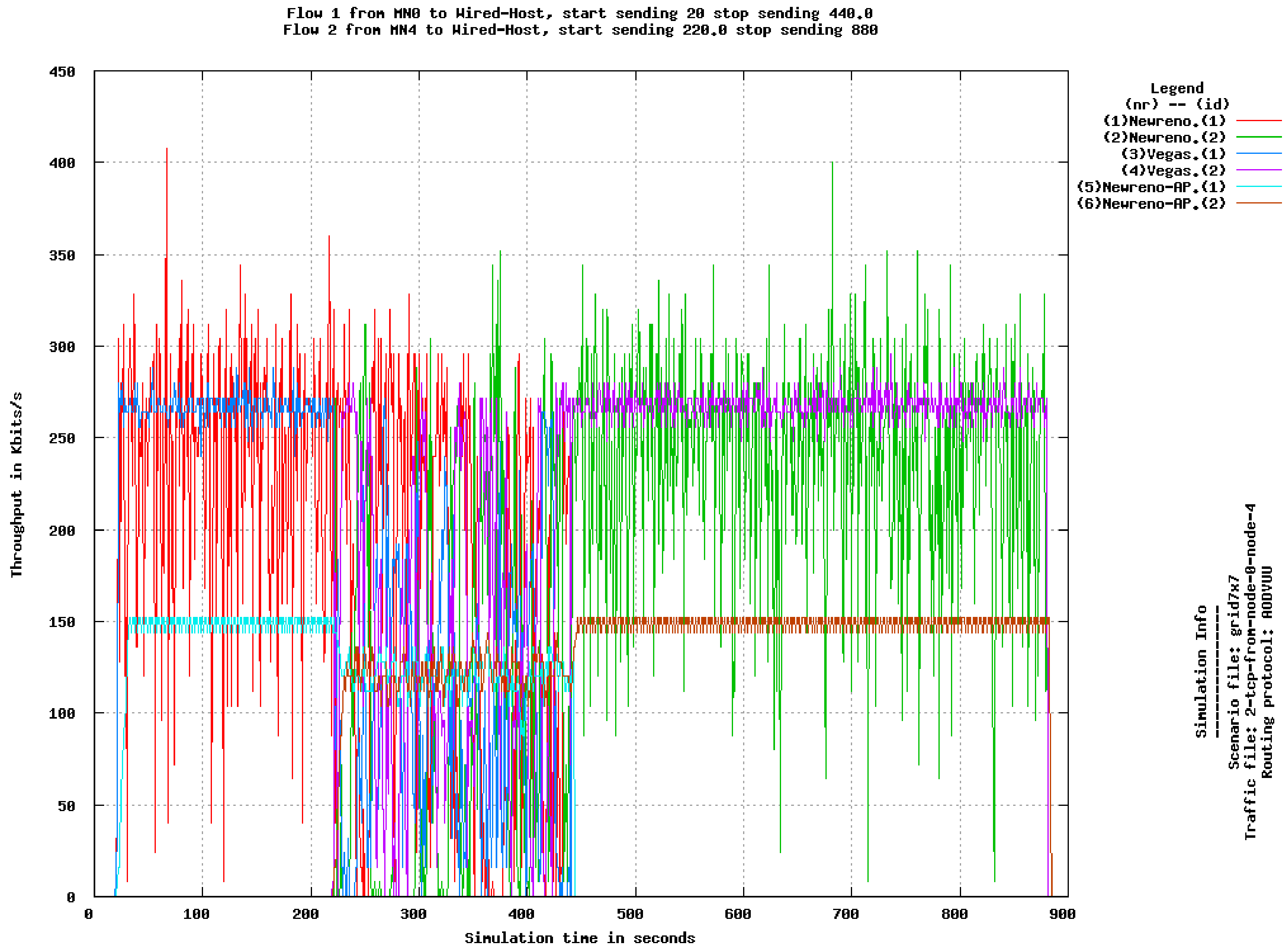
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN0 to MN4, start sending 220.0 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
50
100
150
200
250
300
350
400
450
500
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
Simulation Info
---------------
Scenario file: grid7x7
Traffic file: 1-tcp-from-node-0-1-tcp-between-node-4-node-0
Routing protocol: DSDV

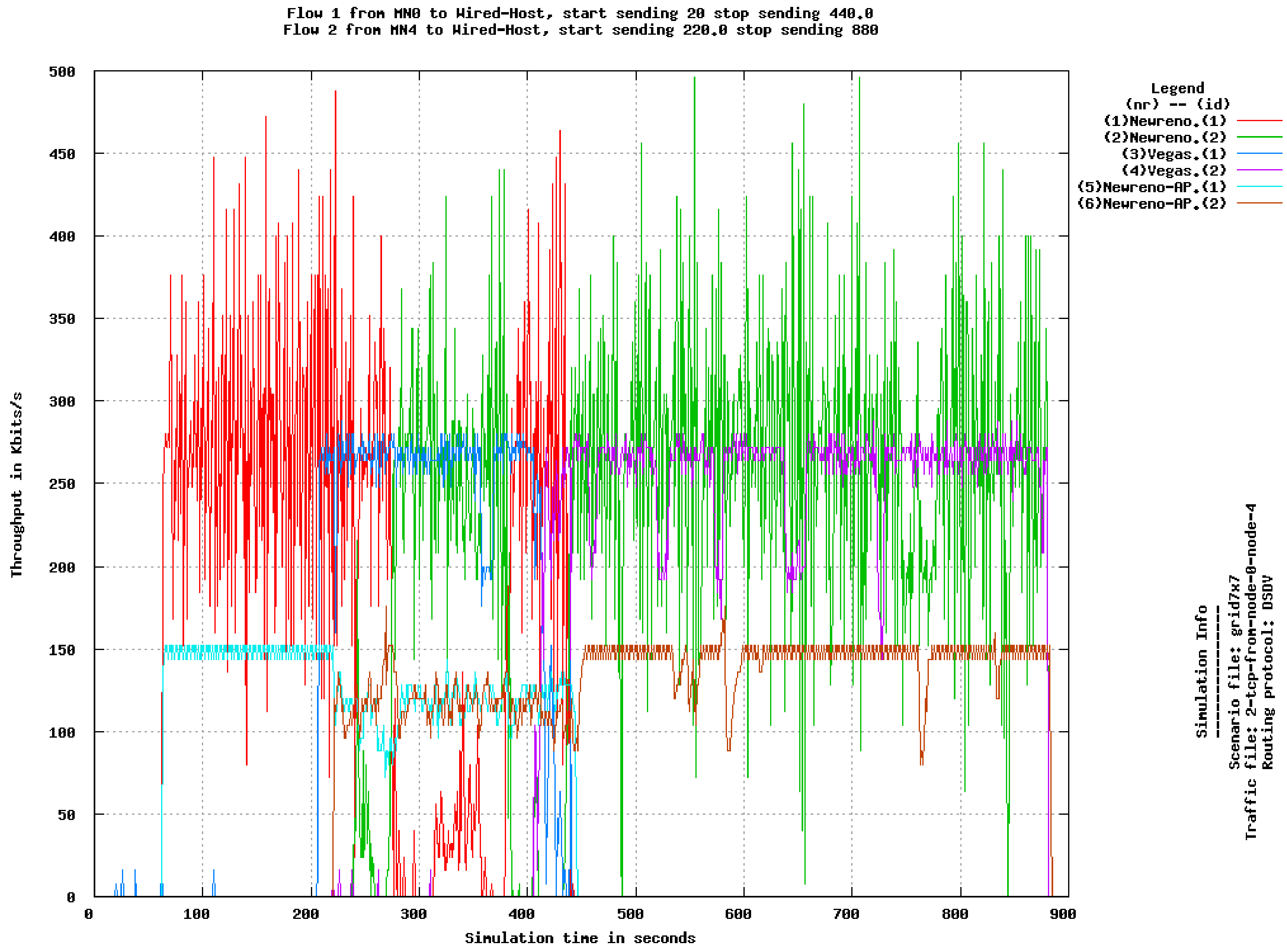


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
50
100
150
200
250
300
350
400
450
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno,(1)
(2)Vegas,(1)
Simulation Info
---------------
Scenario file: grid7x7
Traffic file: 1-tcp-from-node-0
Routing protocol: AODVUU

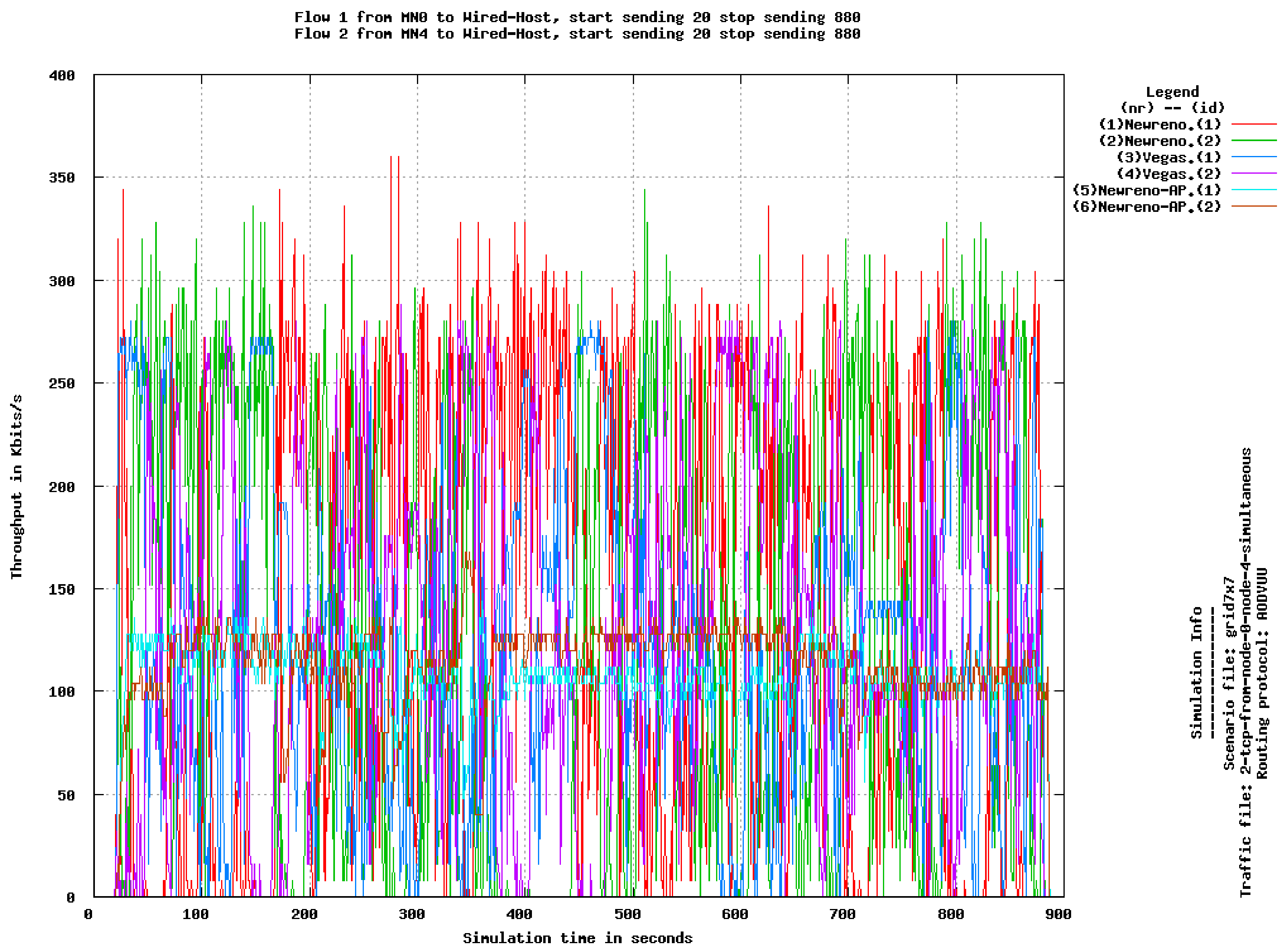


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
Scenario file: grid7x7
Traffic file: 1-tcp-from-node-0
Routing protocol: DSDV

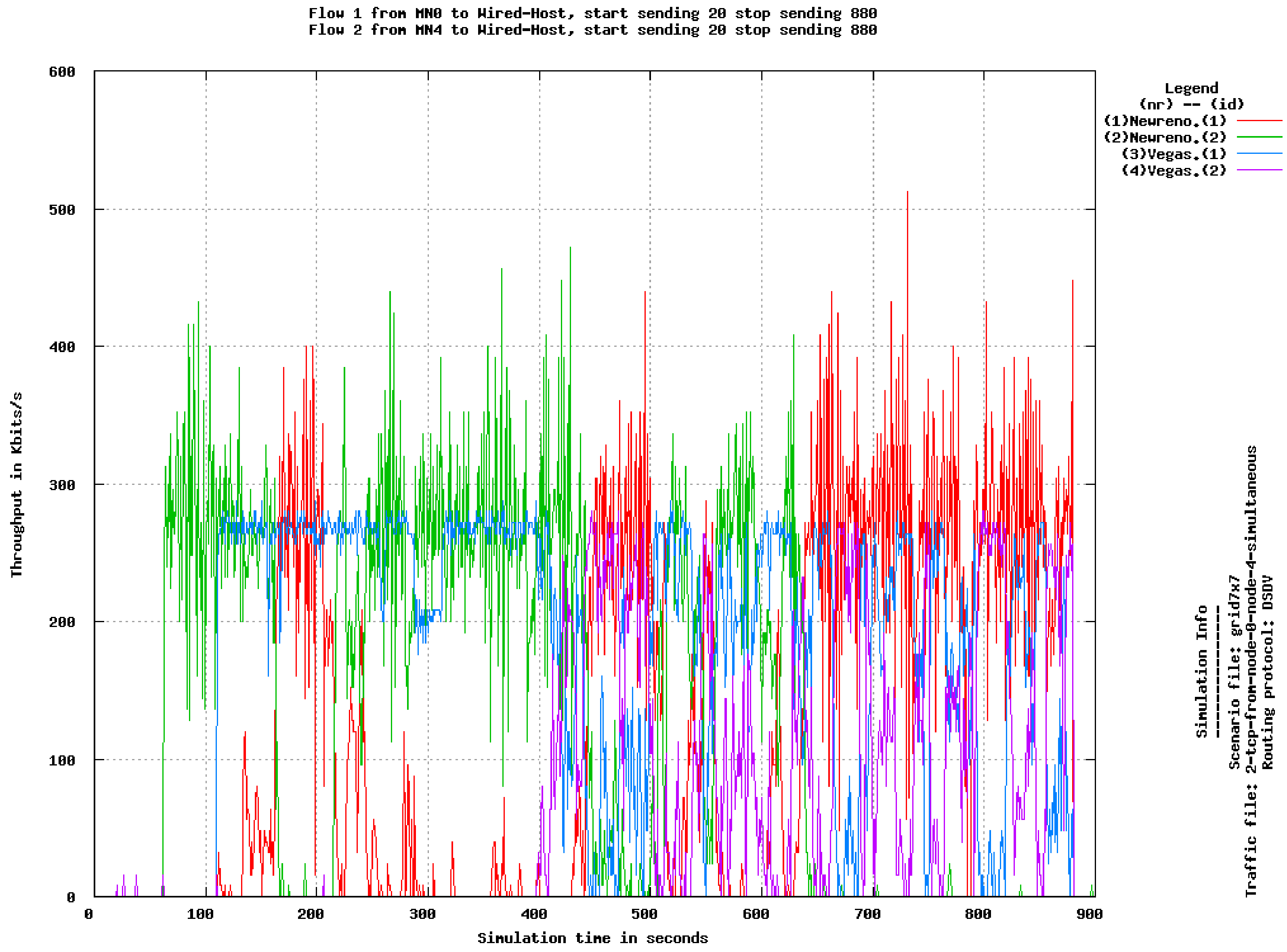

Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN4 to Wired-Host, start sending 220.0 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
50
100
150
200
250
300
350
400
450
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: grid7x7
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: AODVUU

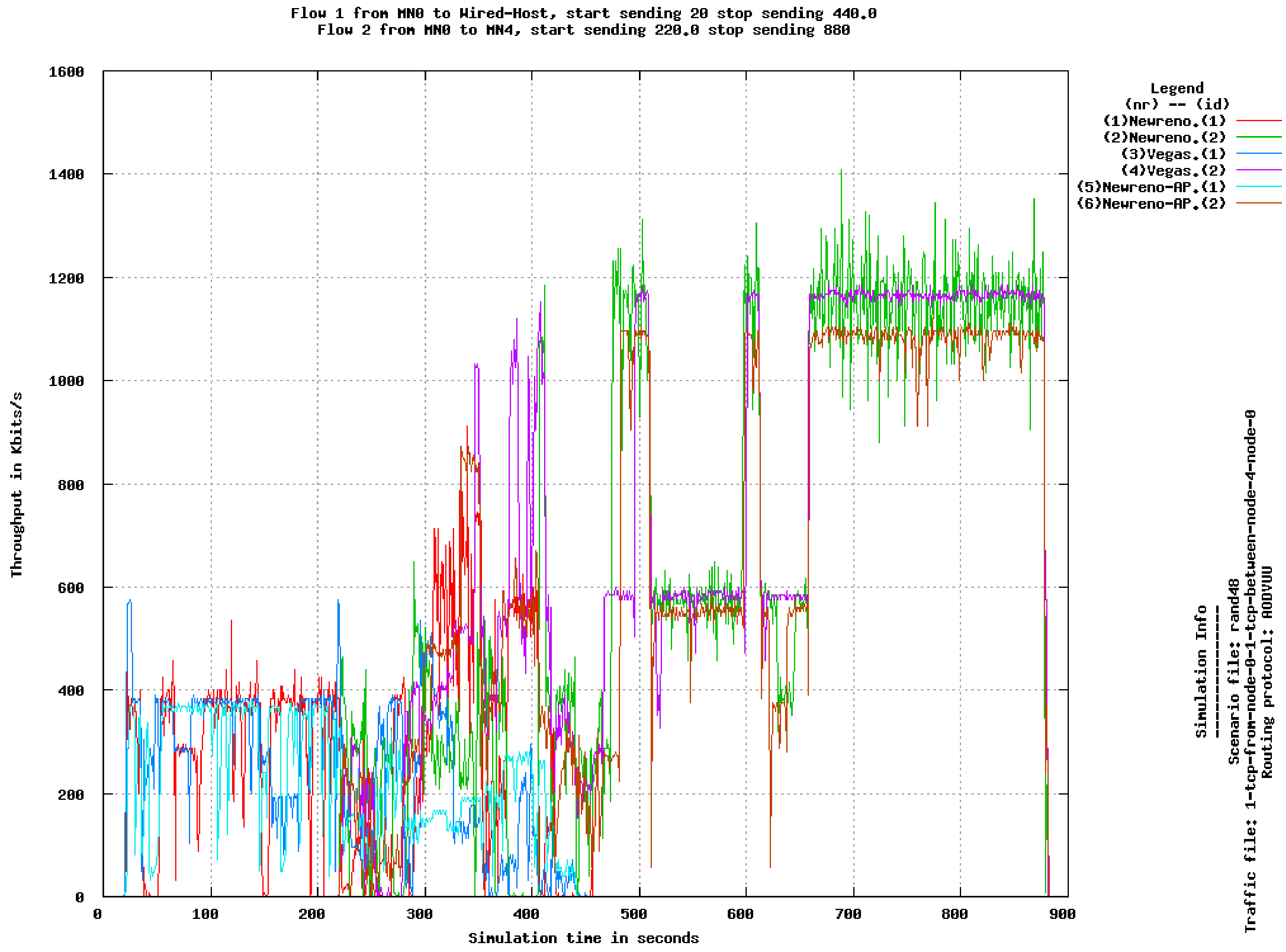


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN4 to Wired-Host, start sending 220.0 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
50
100
150
200
250
300
350
400
450
500
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: grid7x7
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: DSDV

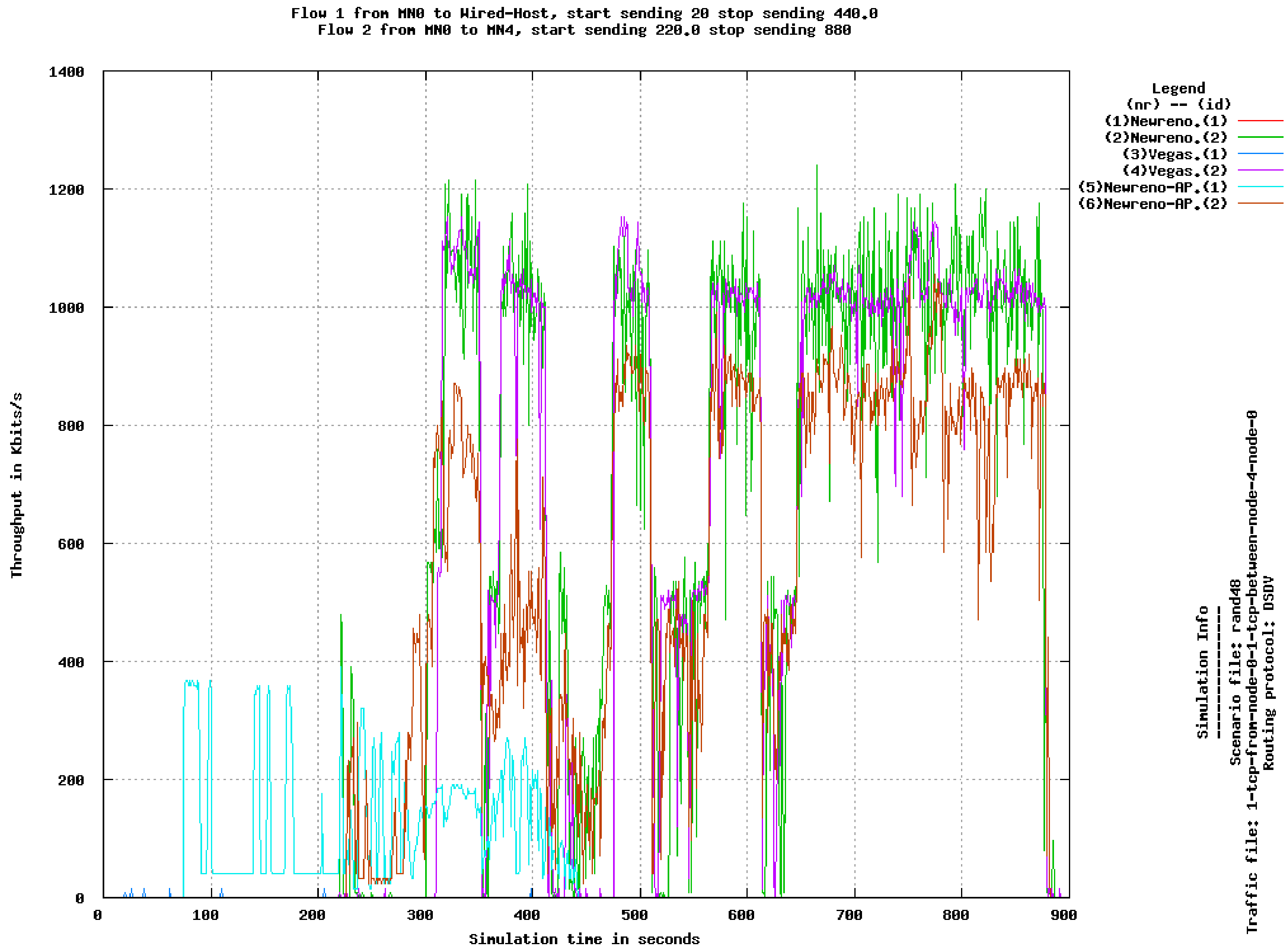


Simulation Info
---------------
Scenario file: grid7x7
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: AODVUU

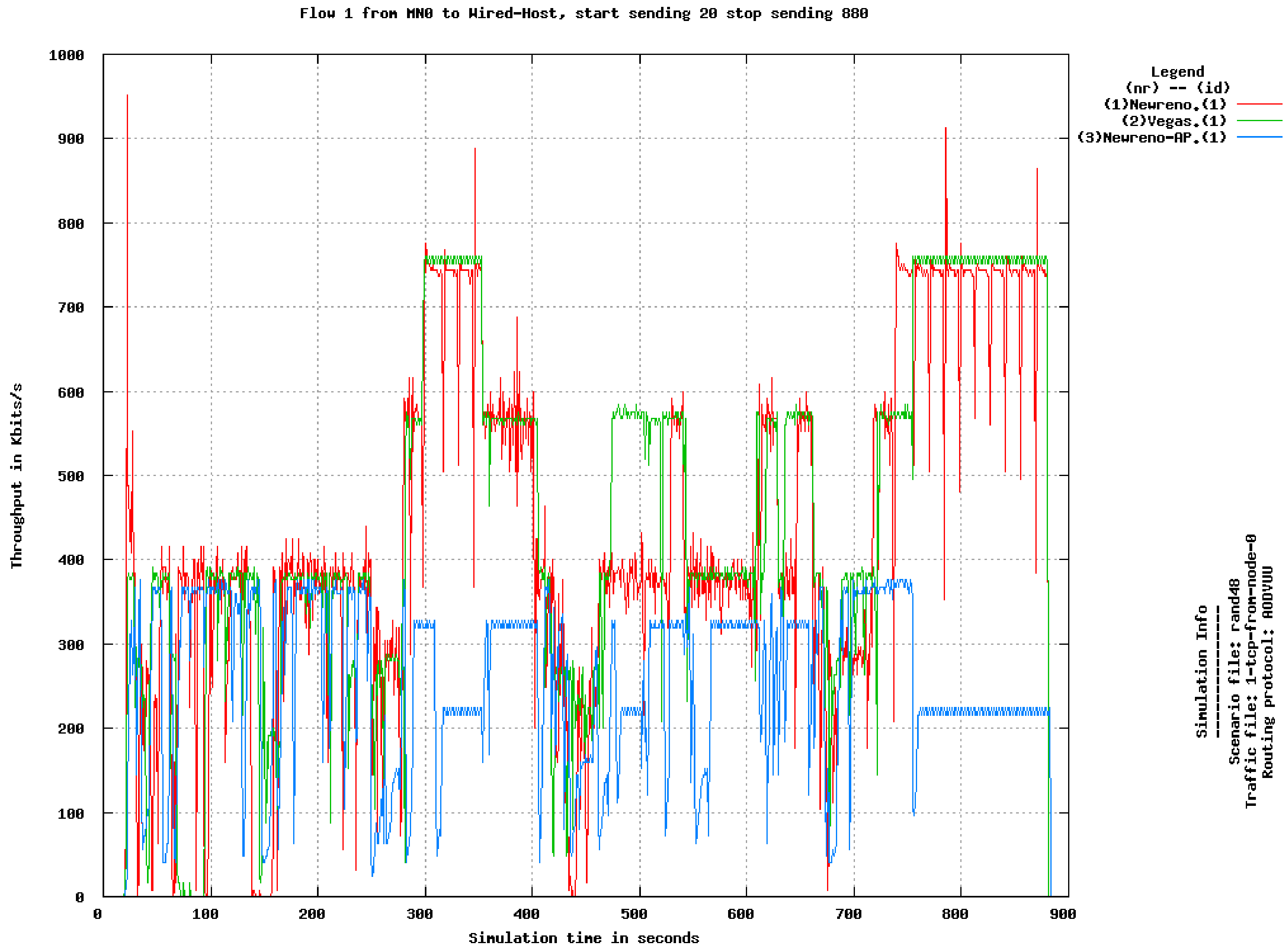

Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN4 to Wired-Host, start sending 20 stop sending 880
Throughput in Kbits/s
0
100
200
300
400
500
600
0
100
200
300
400
500
600
700
800
900
Simulation time in seconds
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
Simulation Info
---------------
Scenario file: grid7x7
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: DSDV



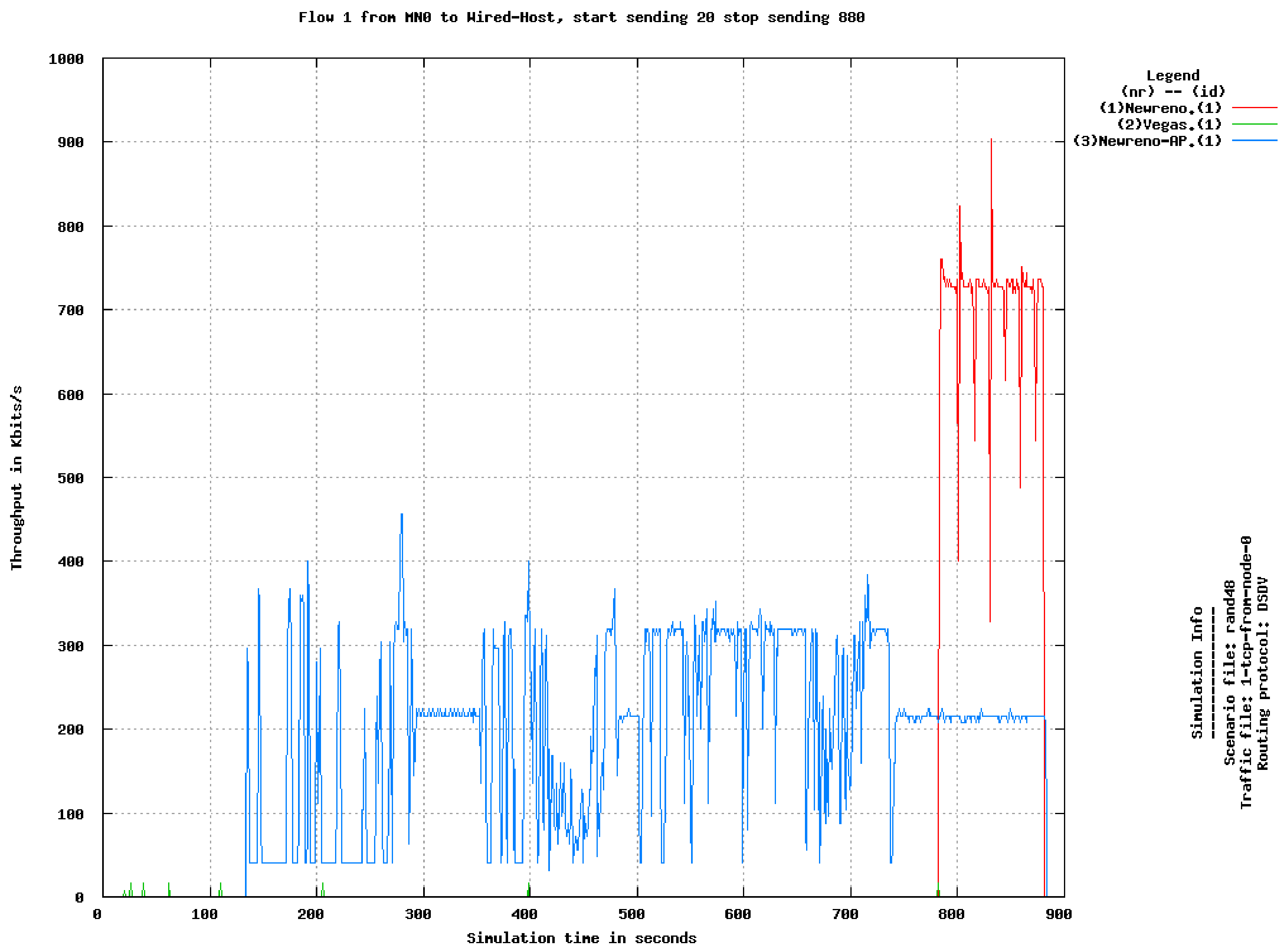
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN0 to MN4, start sending 220.0 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
200
400
600
800
1000
1200
1400
1600
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: rand40
Traffic file: 1-tcp-from-node-0-1-tcp-between-node-4-node-0
Routing protocol: AODVUU



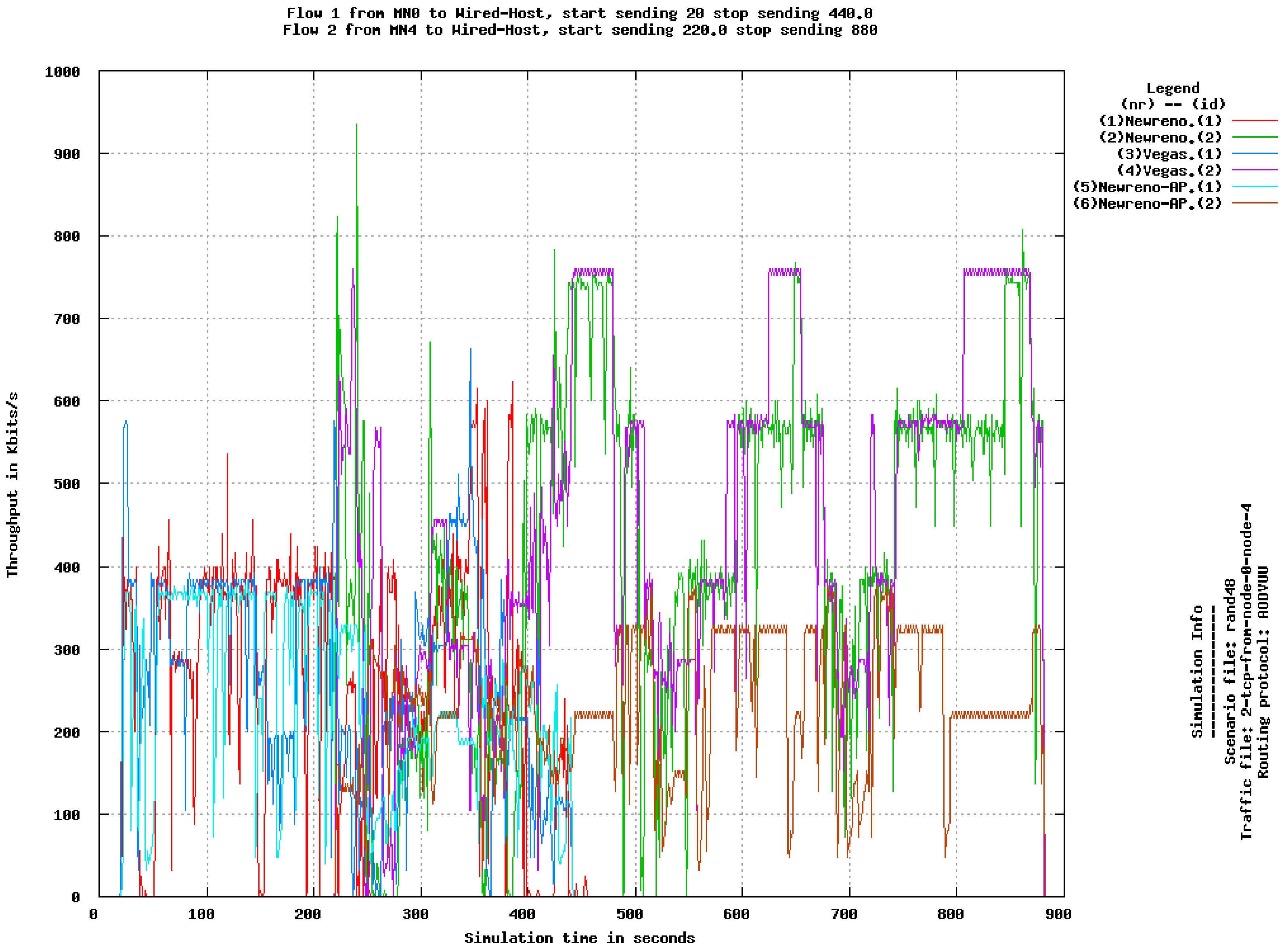
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN0 to MN4, start sending 220.0 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
200
400
600
800
1000
1200
1400
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: rand48
Traffic file: 1-tcp-from-node-0-1-tcp-between-node-4-node-0
Routing protocol: DSDV



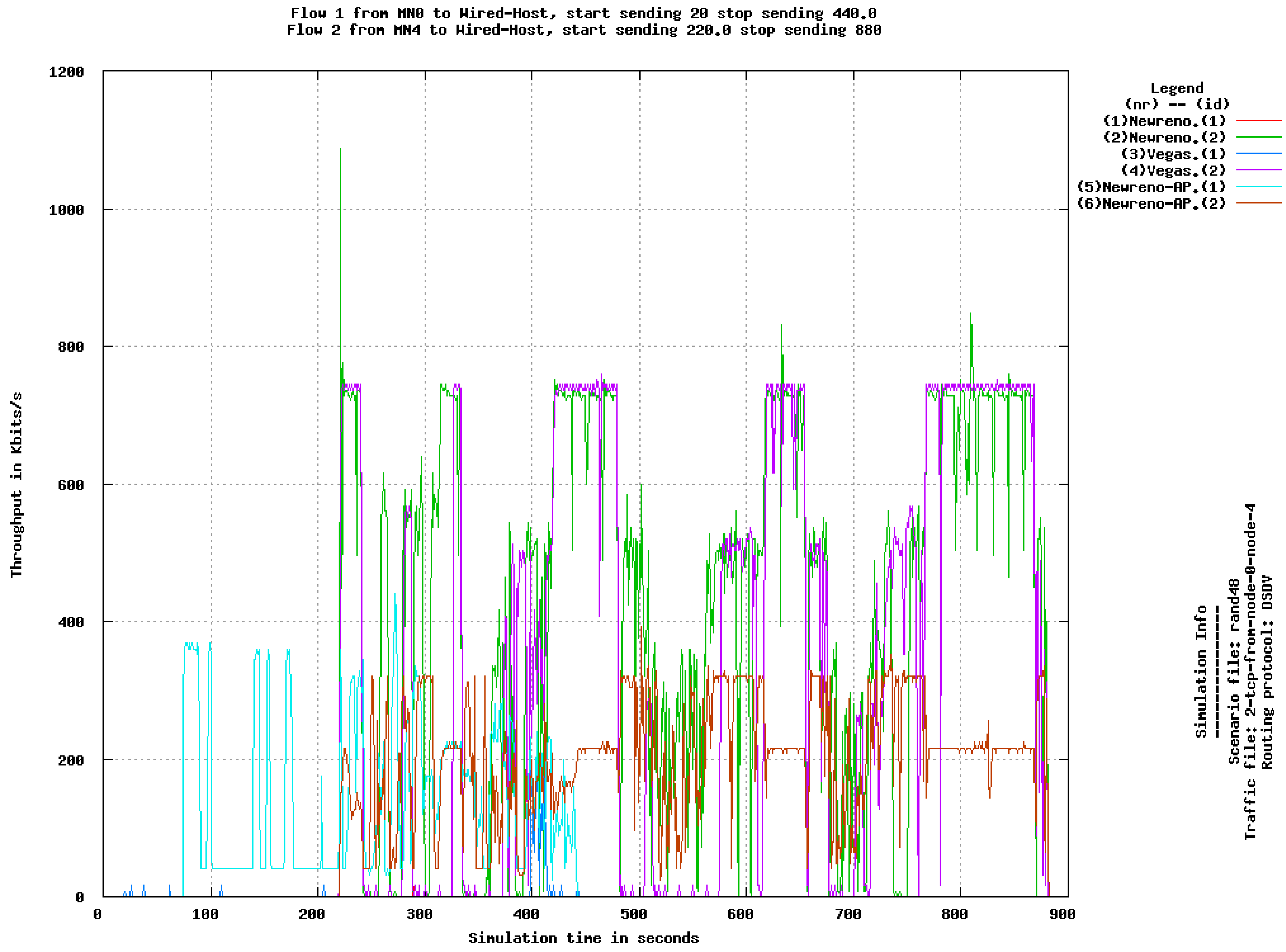
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
1000
Legend
(nr) -- (id)
(1)Newreno,(1)
(2)Vegas,(1)
(3)Newreno-AP,(1)
Simulation Info
Scenario file: rand48
Traffic file: 1-tcp-from-node-0
Routing protocol: AODVUU



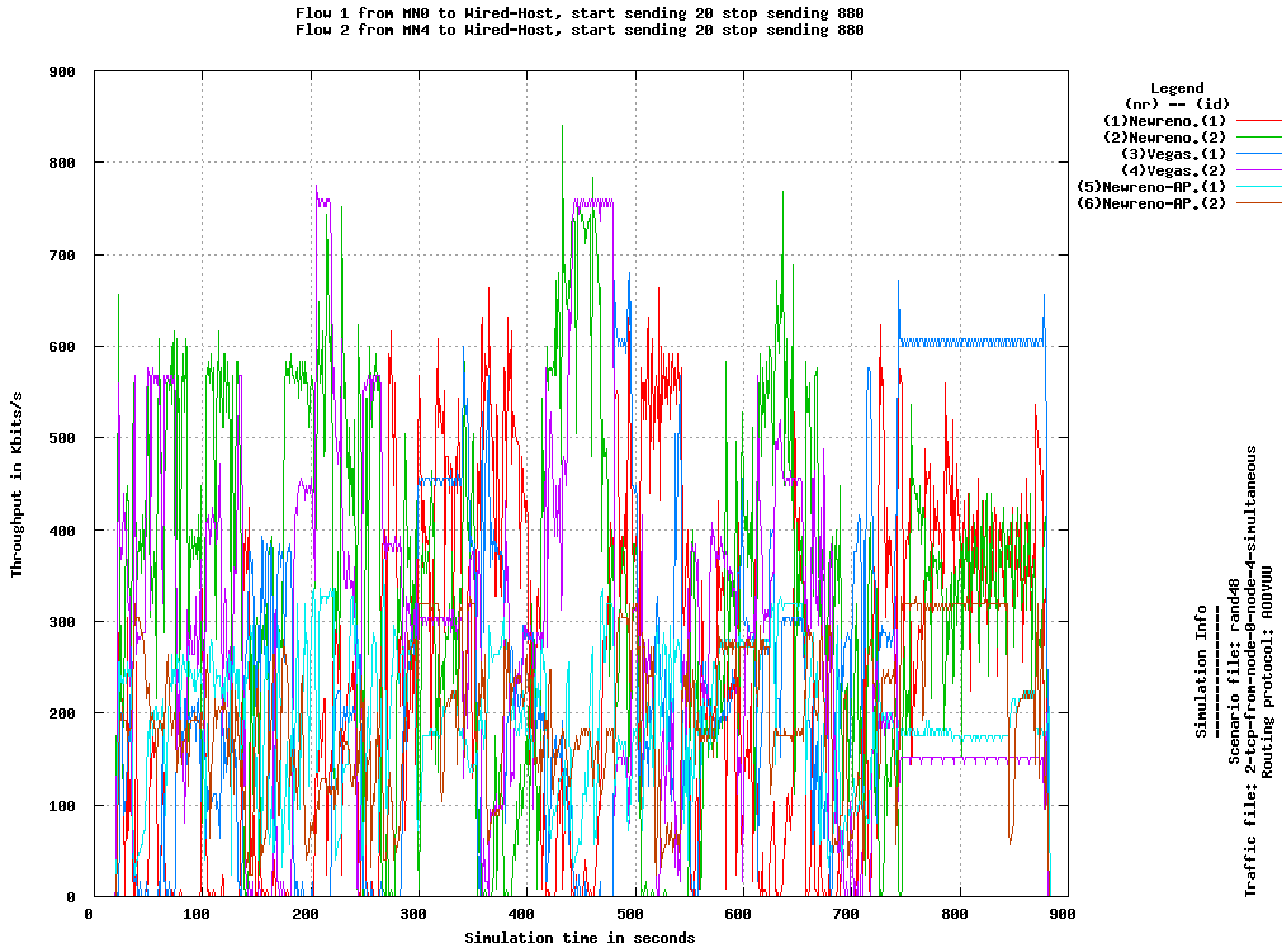
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
1000
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
---------------
Scenario file: rand48
Traffic file: 1-tcp-from-node-0
Routing protocol: DSDV



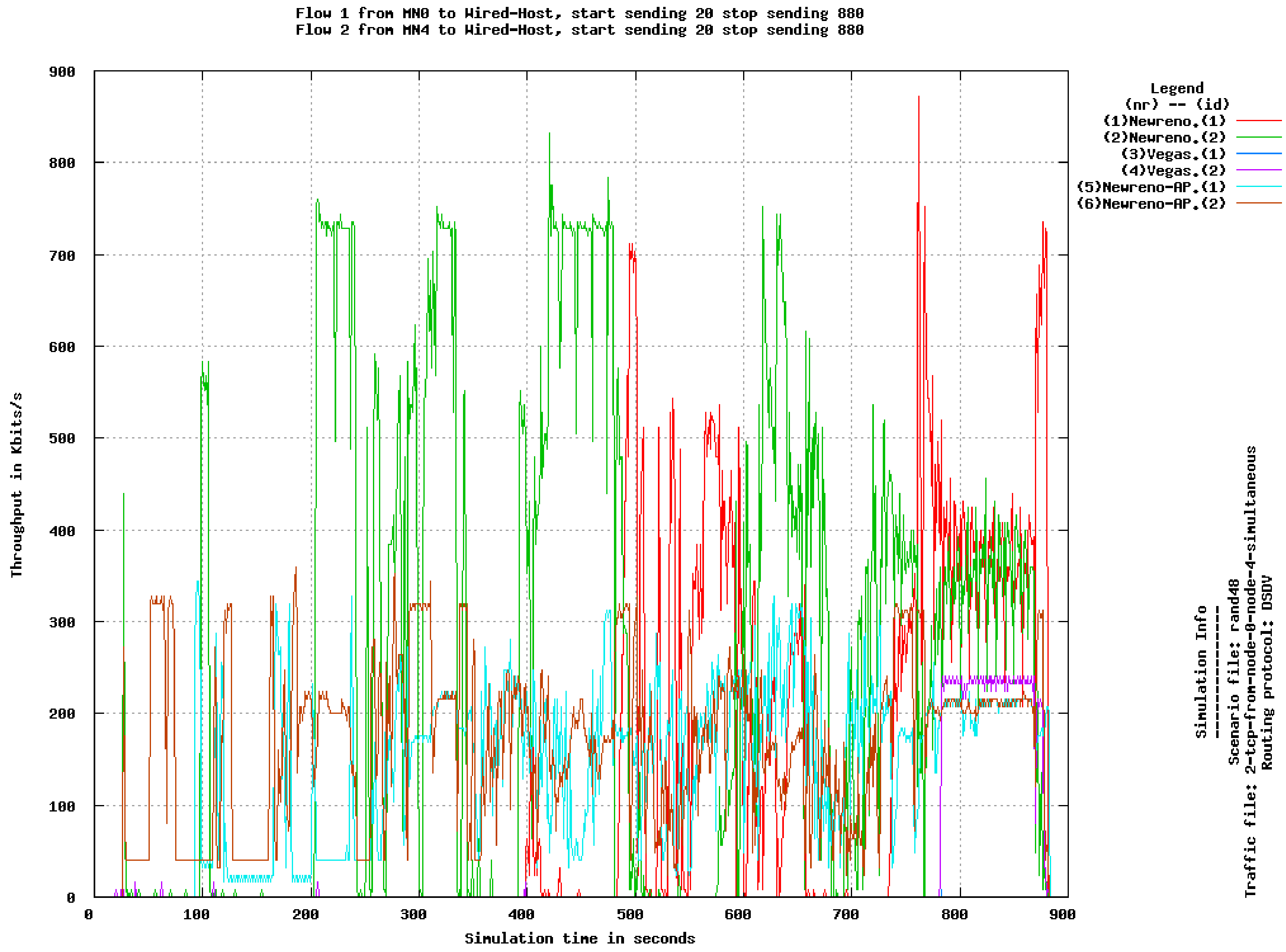
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN4 to Wired-Host, start sending 220.0 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
1000
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
---------------
Scenario file: rand48
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: AODVUU



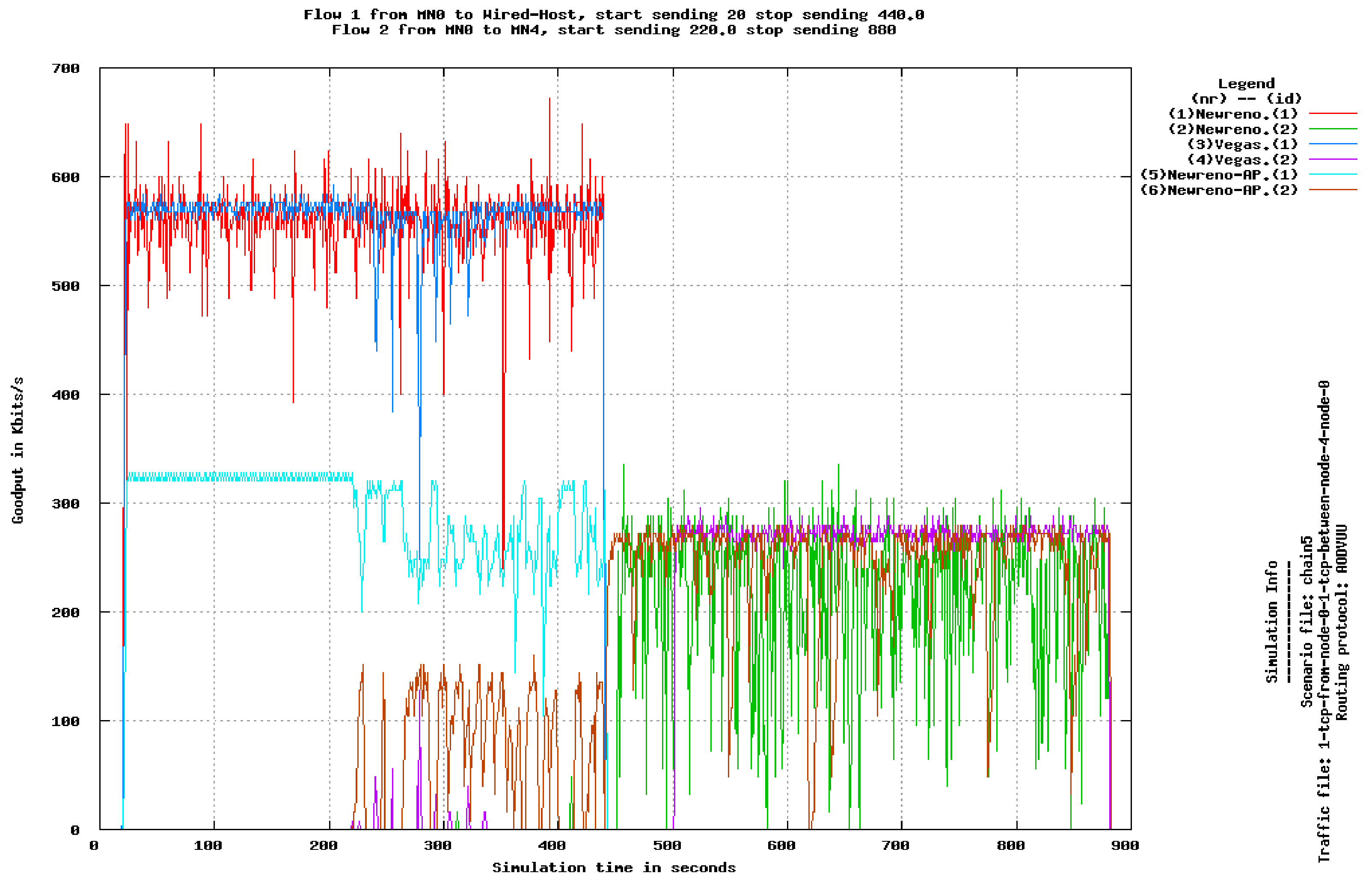
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN4 to Wired-Host, start sending 220.0 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
200
400
600
800
1000
1200
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: rand48
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: DSDV



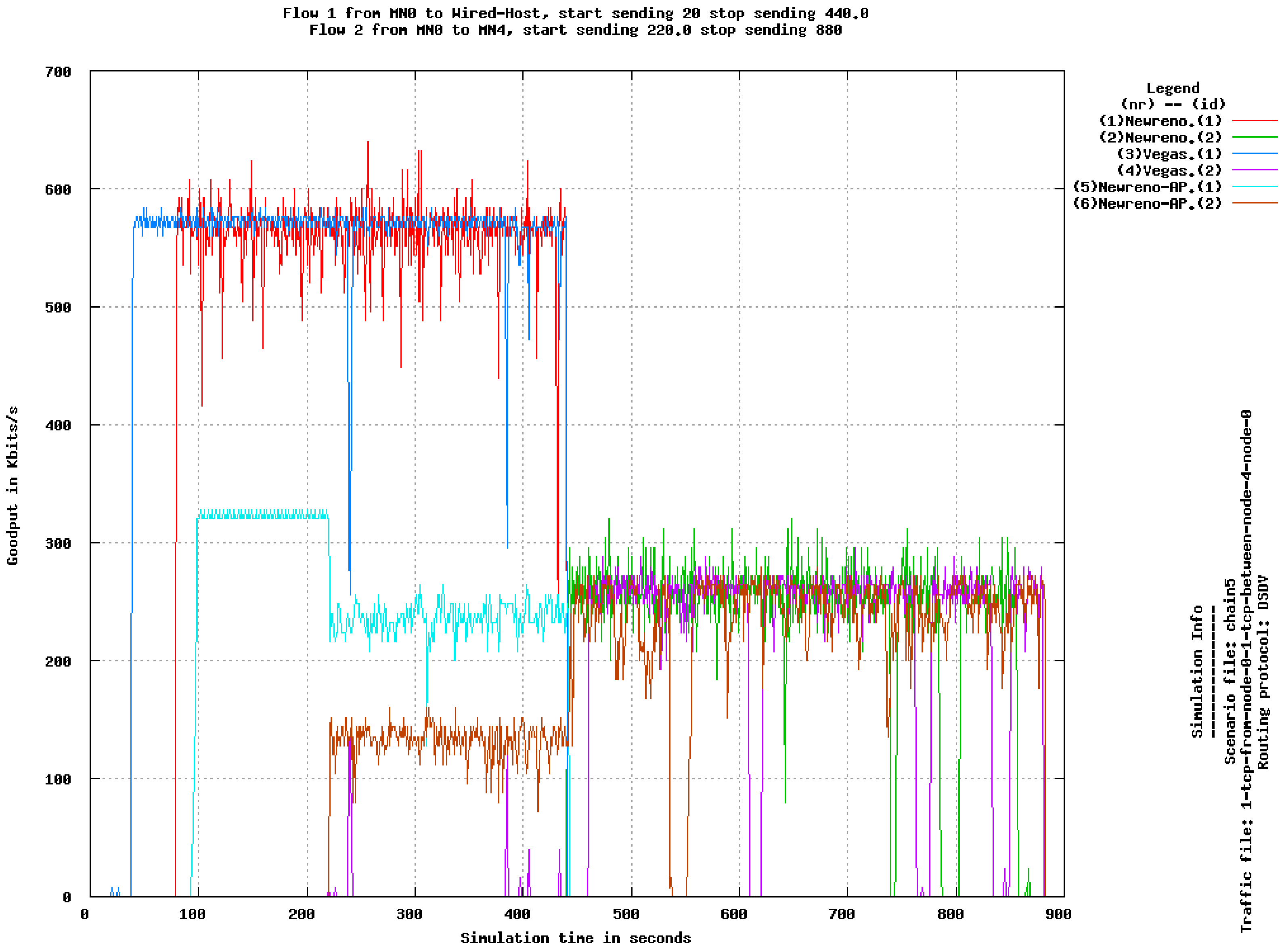
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN4 to Wired-Host, start sending 20 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
---------------
Scenario file: rand48
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: AODVUU


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN4 to Wired-Host, start sending 20 stop sending 880
Throughput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: rand40
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: DSDV

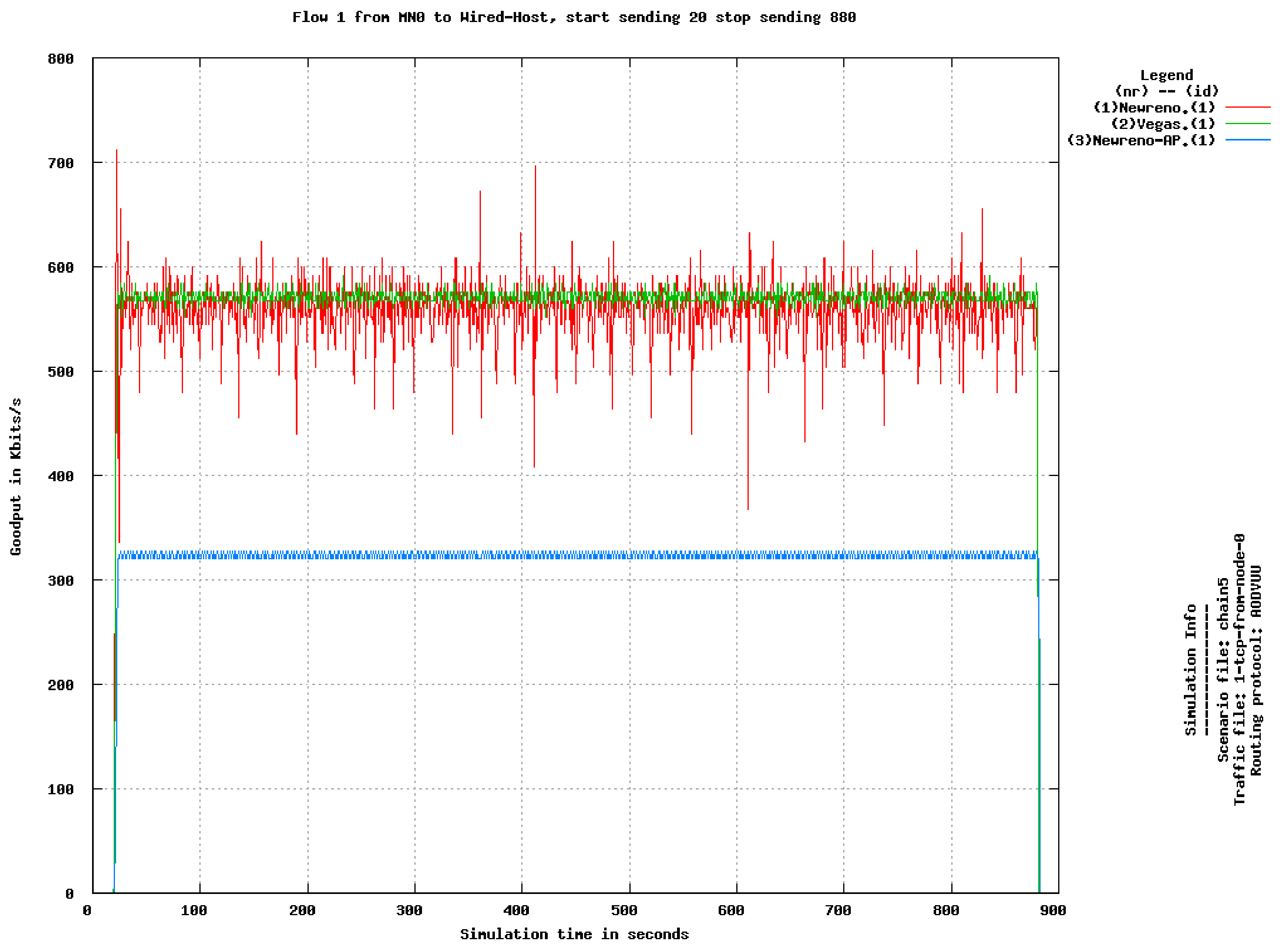
## G.5.3 Goodput

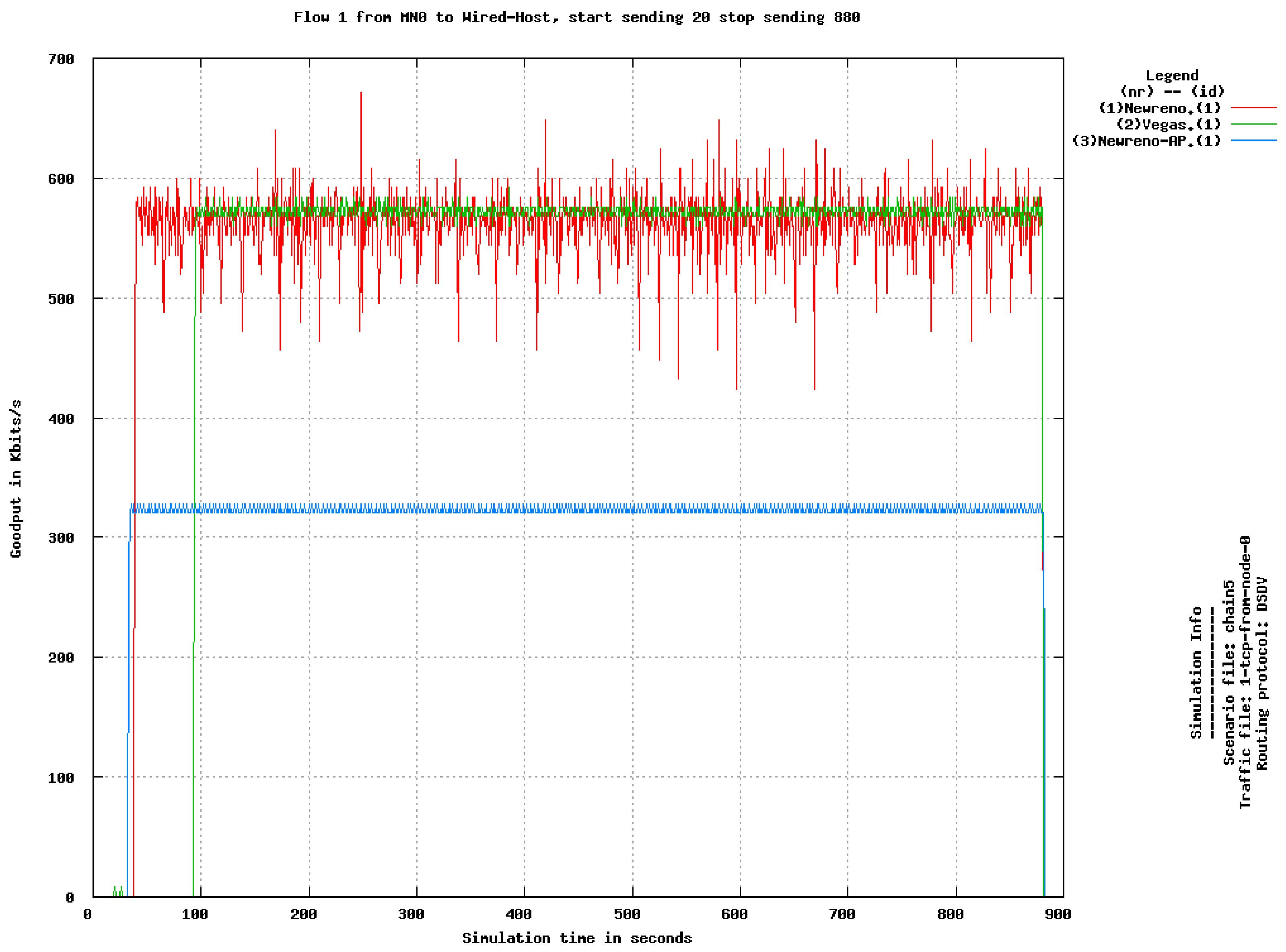


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN0 to MN4, start sending 220.0 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain5
Traffic file: 1-tcp-from-node-0-1-tcp-between-node-4-node-0
Routing protocol: AODVUU

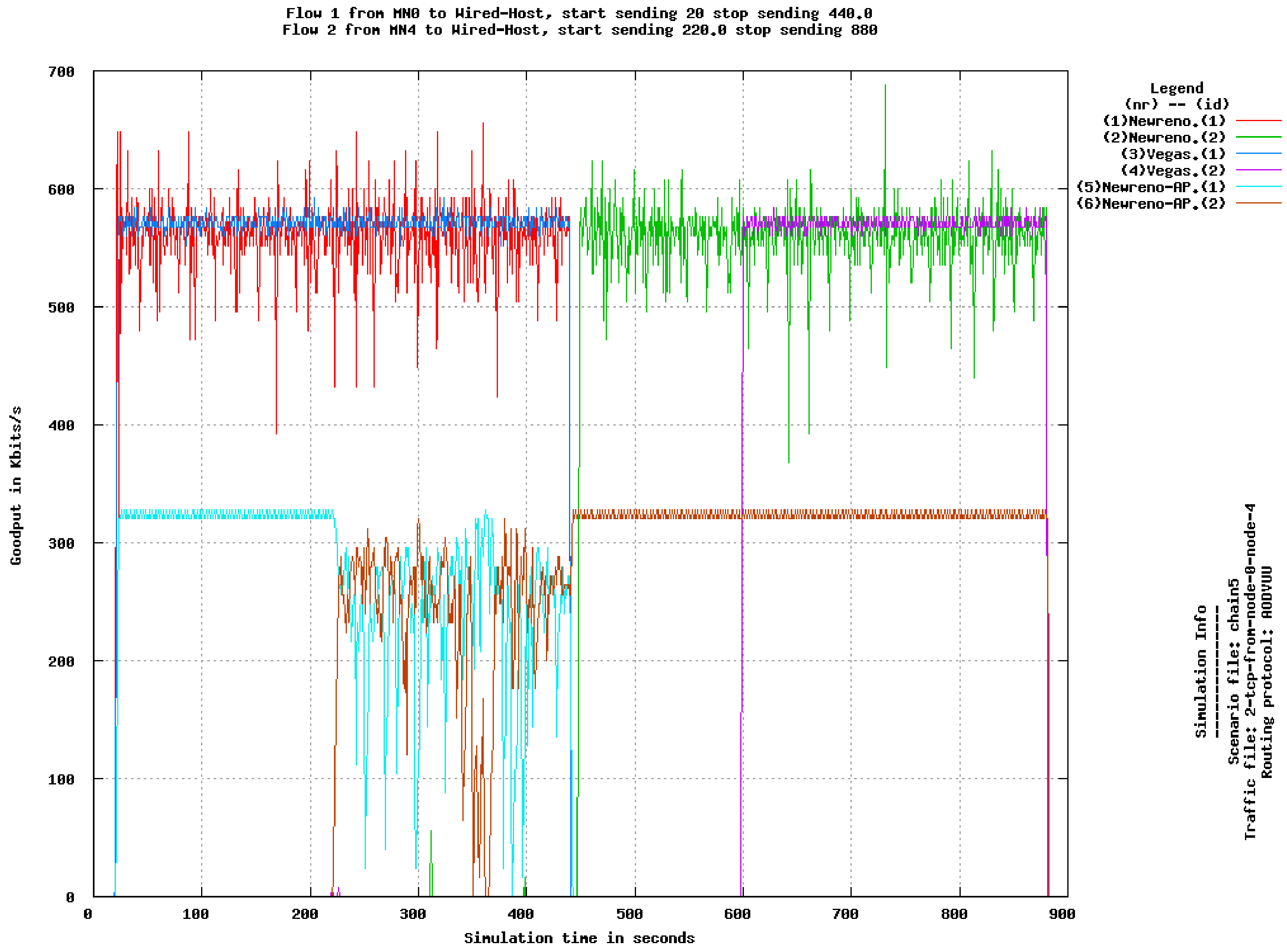


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN0 to MN4, start sending 220.0 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain5
Traffic file: 1-tcp-from-node-0-1-tcp-between-node-4-node-0
Routing protocol: DSDV

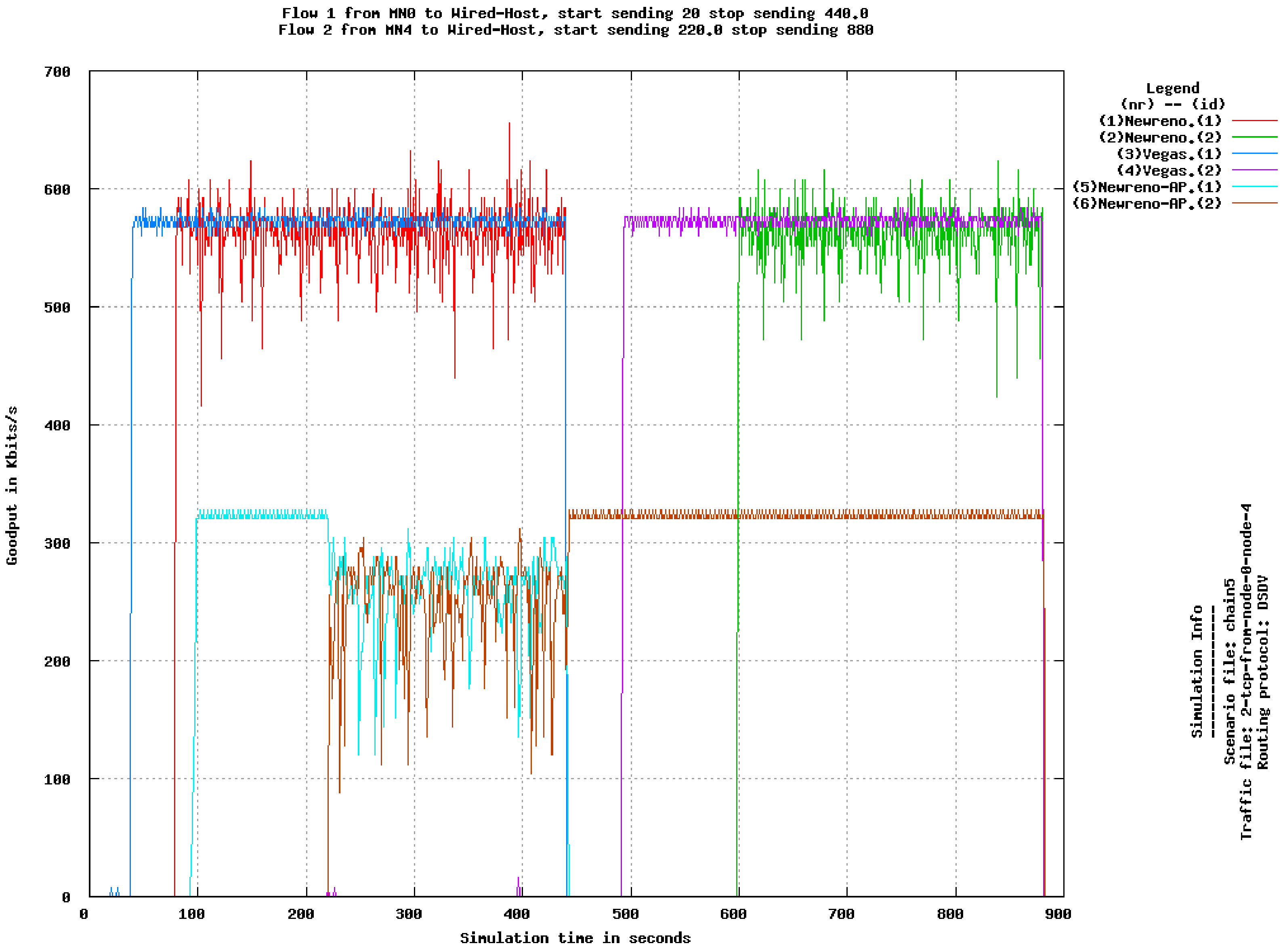

Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
Scenario file: chain5
Traffic file: 1-tcp-from-node-0
Routing protocol: AODVUU

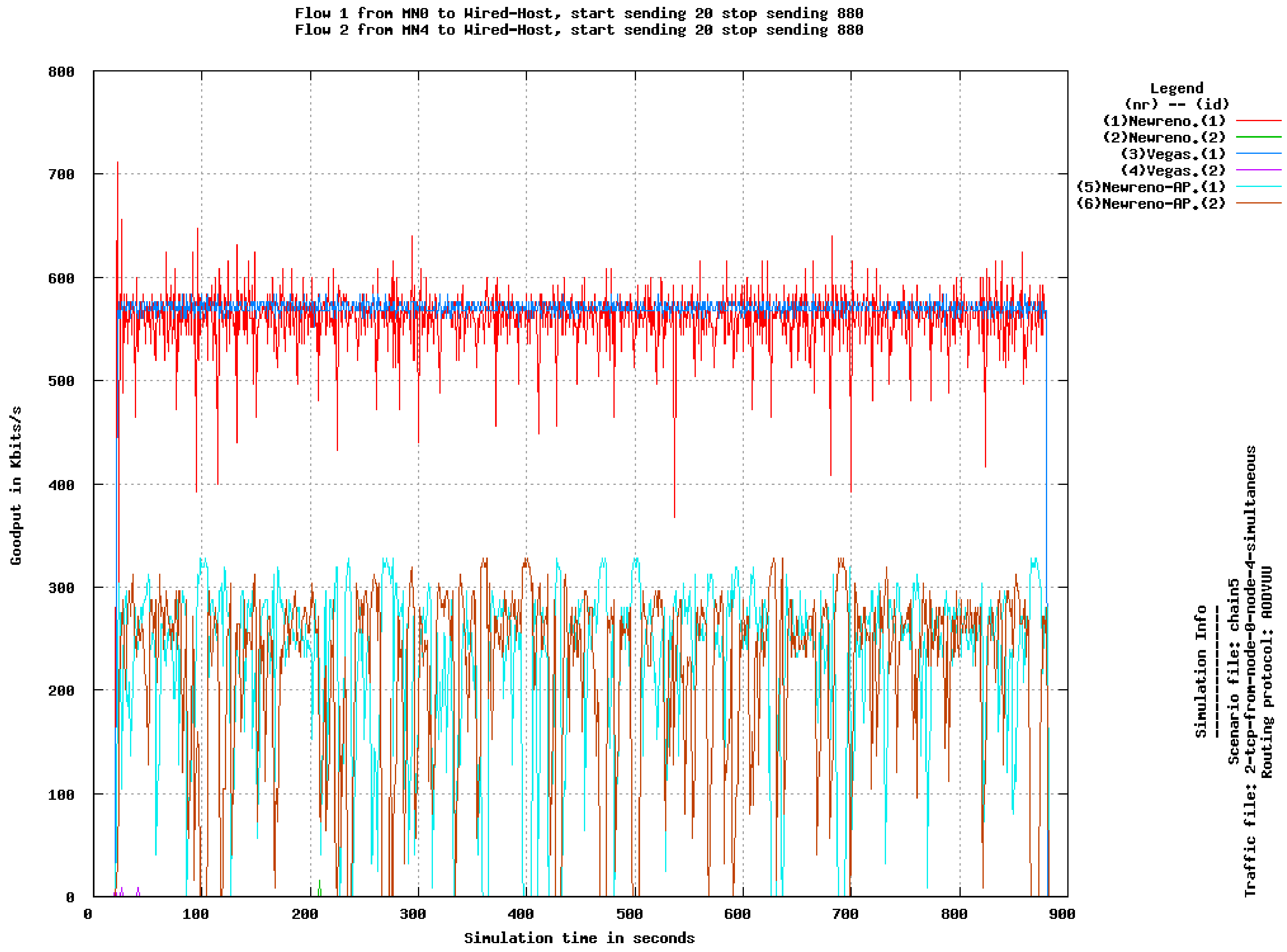


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
Scenario file: chain5
Traffic file: 1-tcp-from-node-0
Routing protocol: DSDV

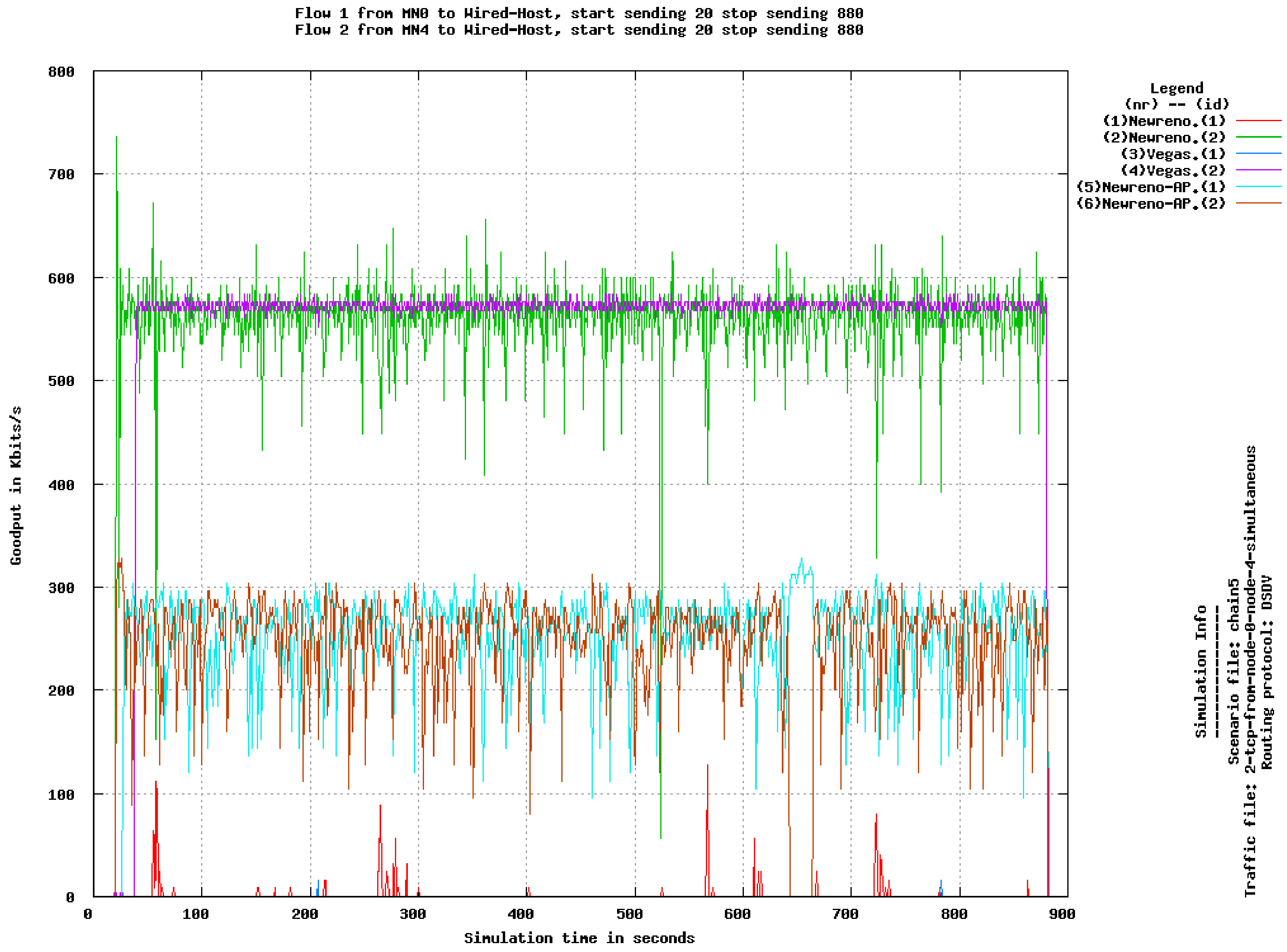


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN4 to Wired-Host, start sending 220.0 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain5
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: AODVUU

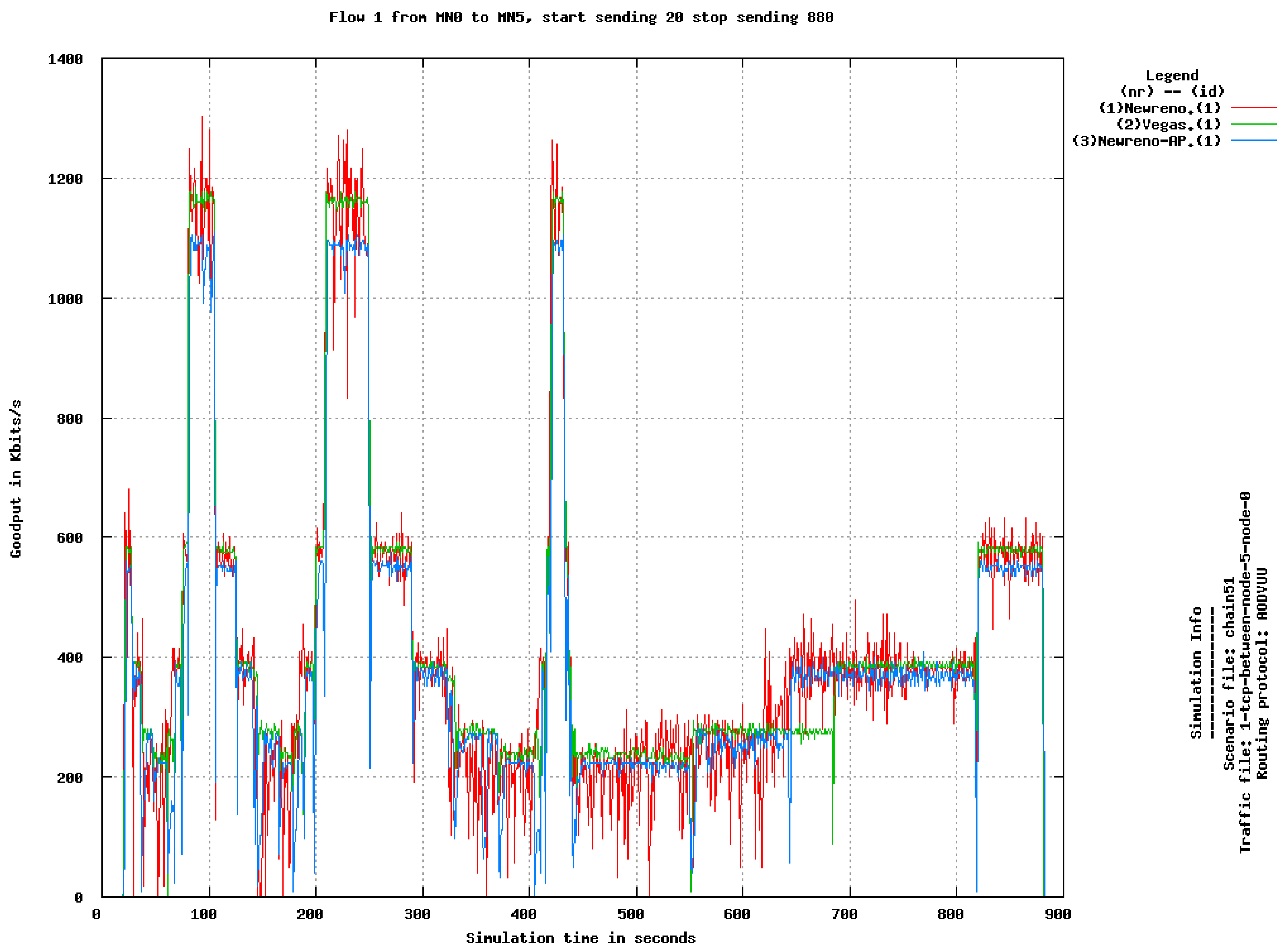

Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN4 to Wired-Host, start sending 220.0 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain5
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: DSDV

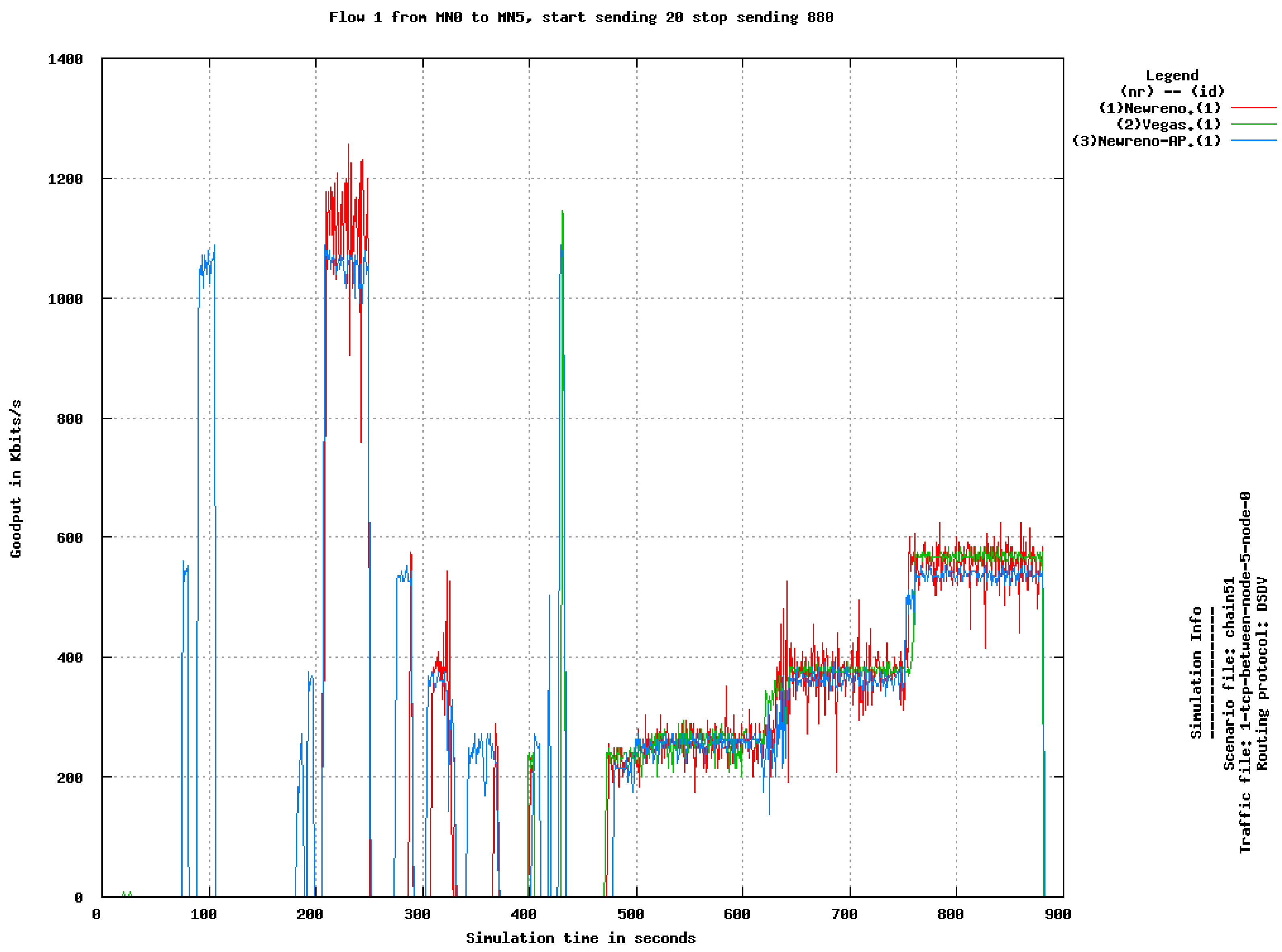


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN4 to Wired-Host, start sending 20 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain5
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: AODVUU

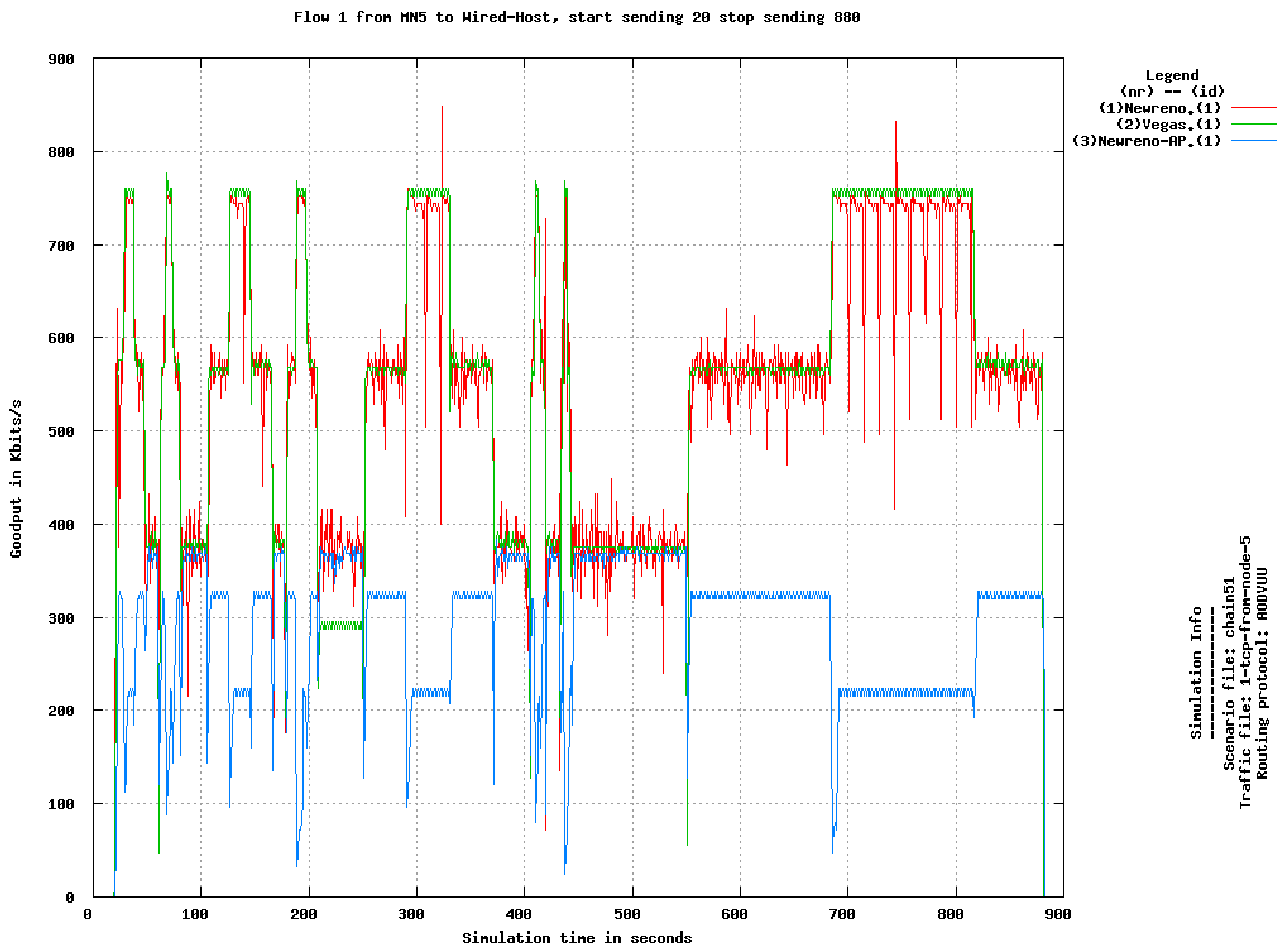


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN4 to Wired-Host, start sending 20 stop sending 880
Goodput in Kbits/s
800
700
600
500
400
300
200
100
0
0
100
200
300
400
500
600
700
800
900
Simulation time in seconds
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
---------------
Scenario file: chain5
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: DSDV

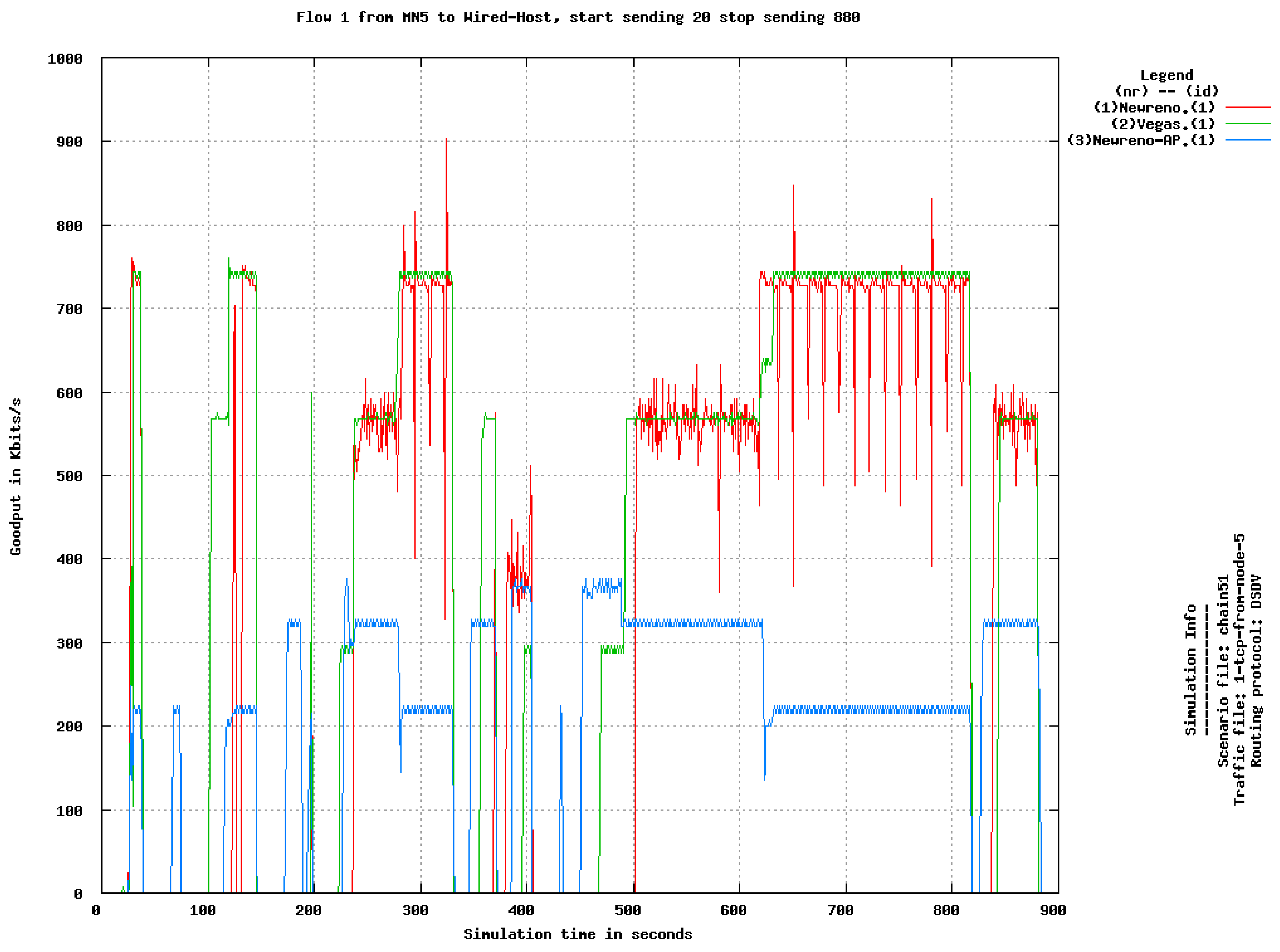

Flow 1 from MN0 to MN5, start sending 20 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
200
400
600
800
1000
1200
1400
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
---------------
Scenario file: chain51
Traffic file: 1-tcp-between-node-5-node-0
Routing protocol: AODVUU



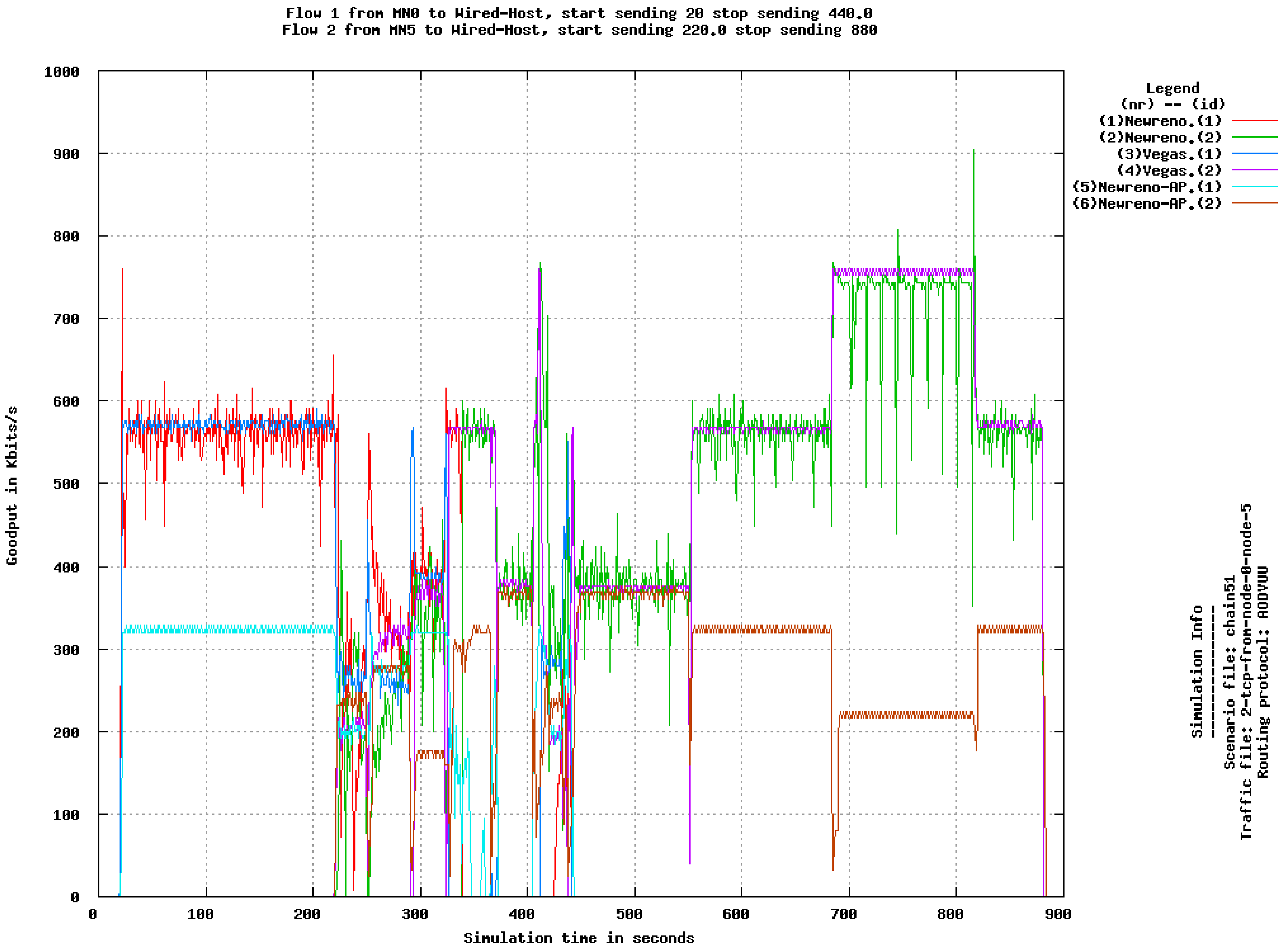
Flow 1 from MN0 to MN5, start sending 20 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
200
400
600
800
1000
1200
1400
100
300
500
700
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
Scenario file: chain51
Traffic file: 1-tcp-between-node-5-node-0
Routing protocol: DSDV



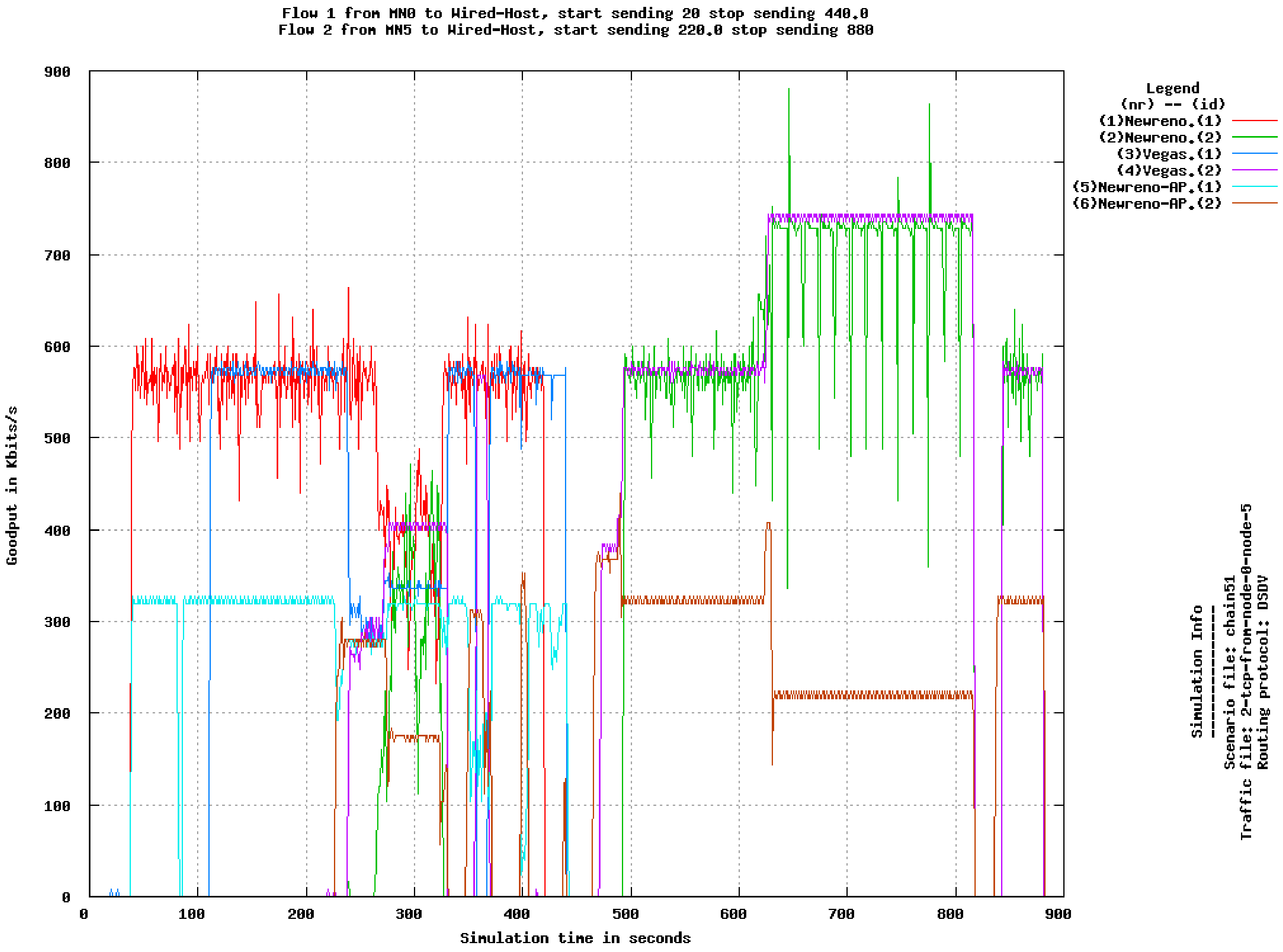
Flow 1 from MN5 to Wired-Host, start sending 20 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
Scenario file: chain51
Traffic file: 1-tcp-from-node-5
Routing protocol: AODVUU

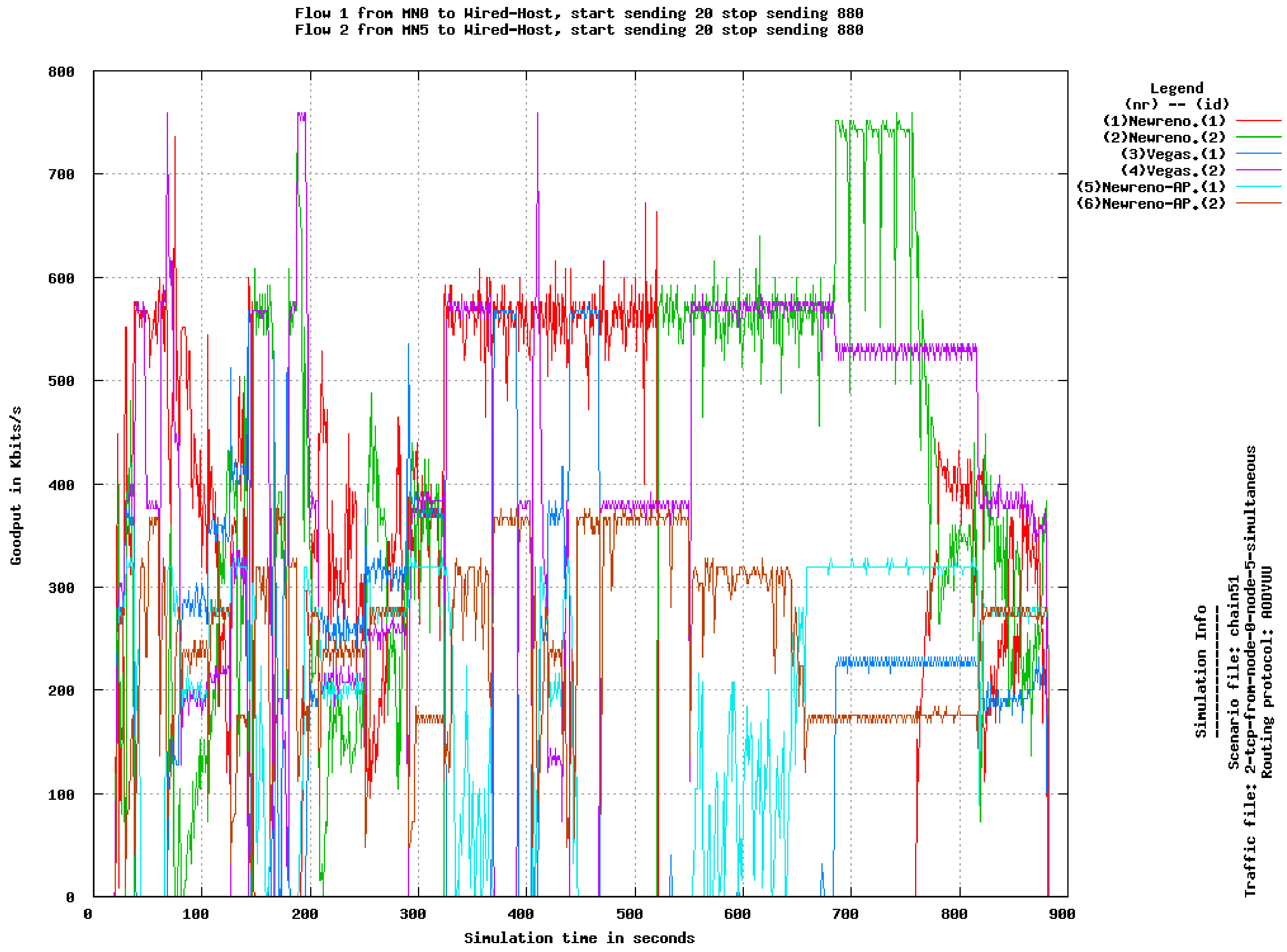


Simulation Info
---------------
Scenario file: chain51
Traffic file: 1-tcp-from-node-5
Routing protocol: DSDV

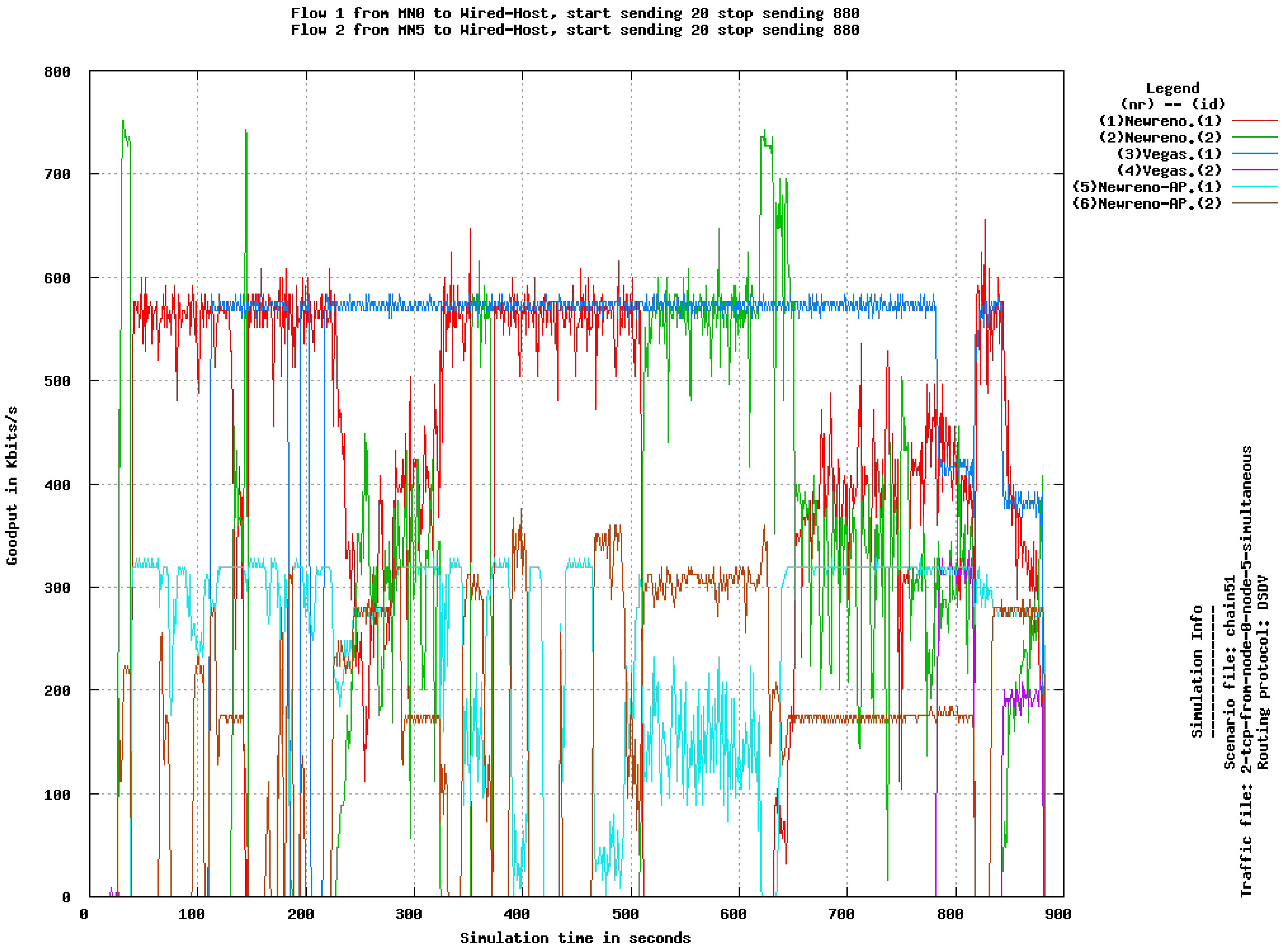


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN5 to Wired-Host, start sending 220.0 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
1000
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain51
Traffic file: 2-tcp-from-node-0-node-5
Routing protocol: AODVUU

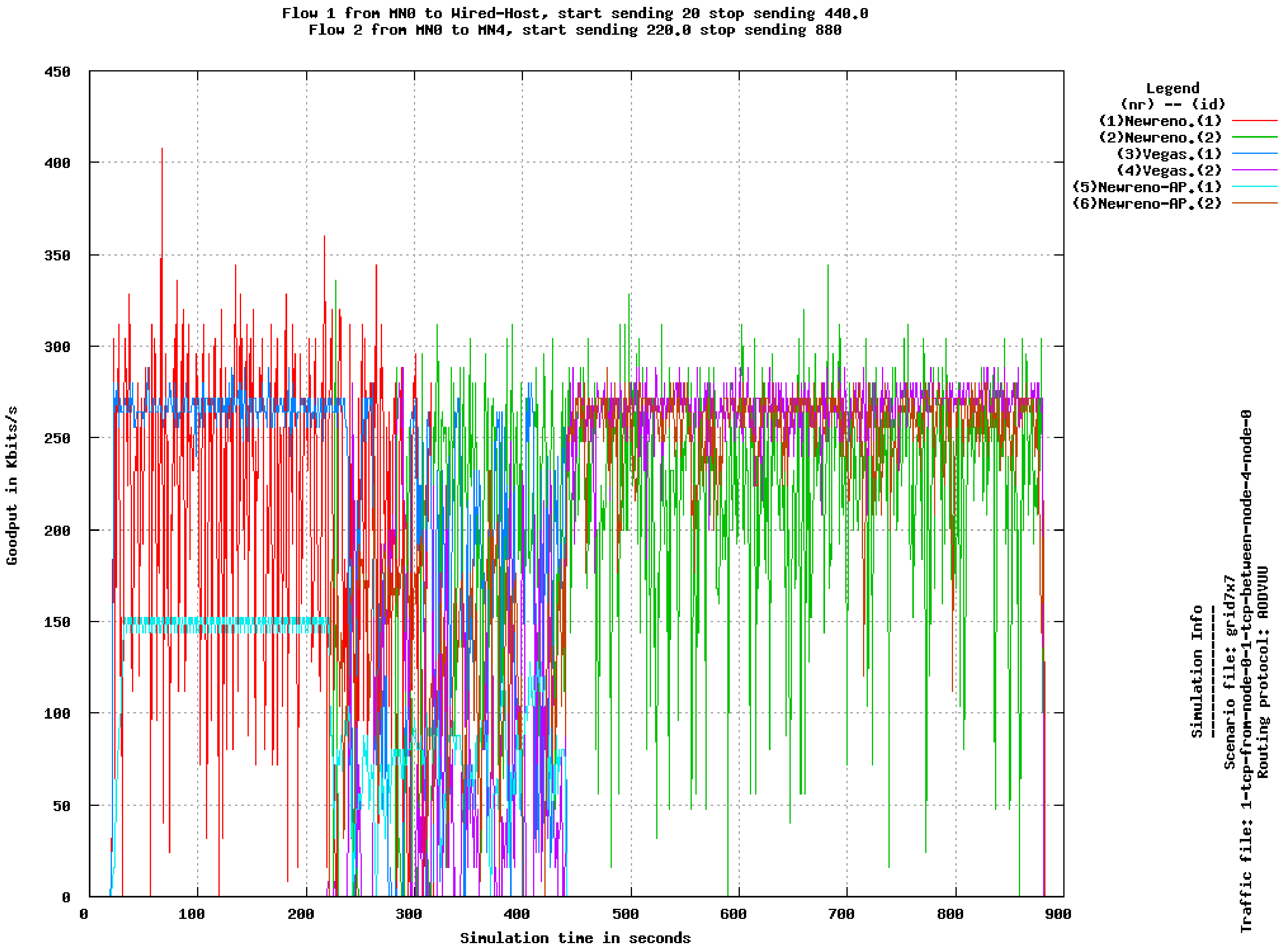

Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN5 to Wired-Host, start sending 220.0 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain51
Traffic file: 2-tcp-from-node-0-node-5
Routing protocol: DSDV

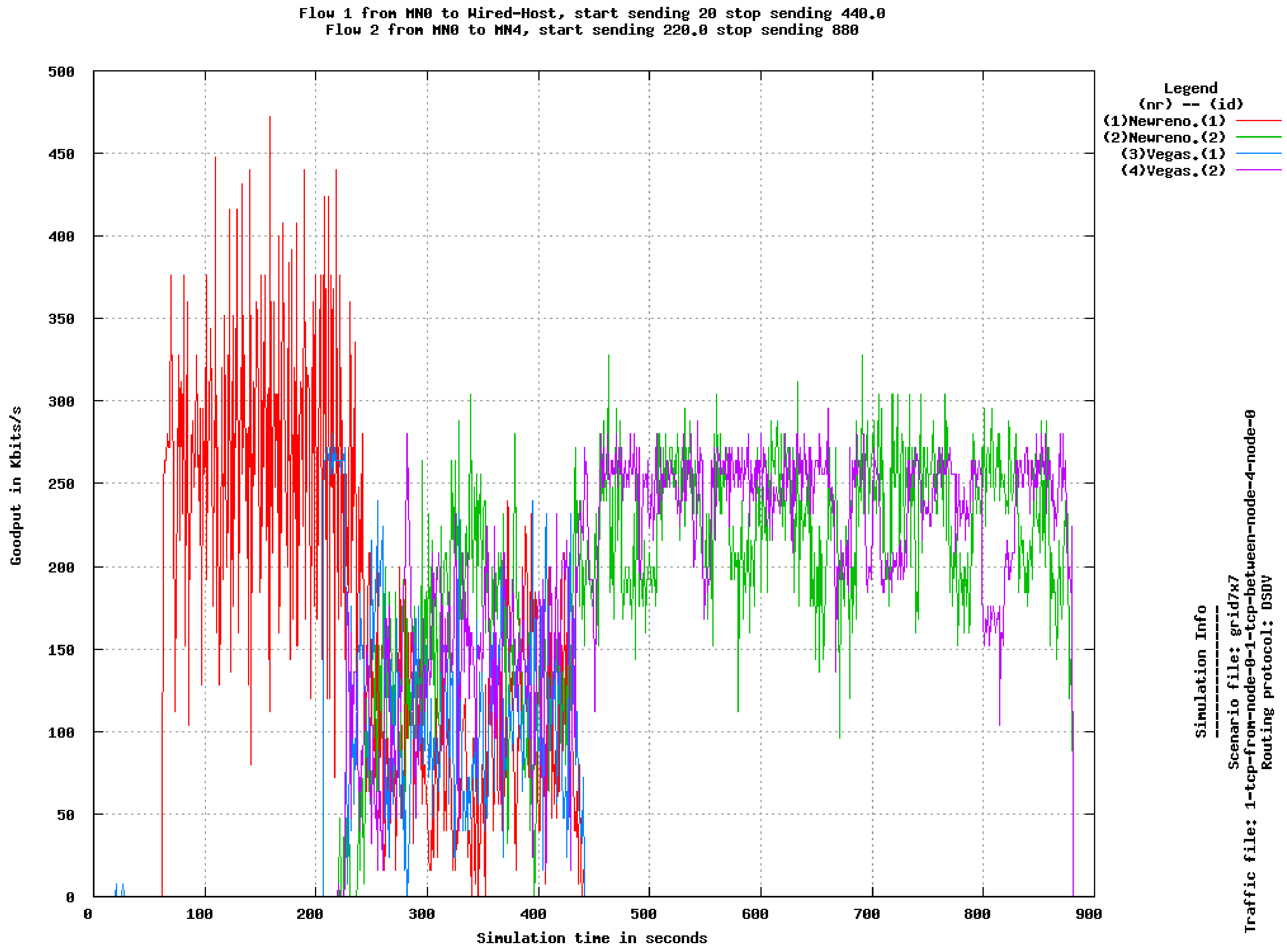


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN5 to Wired-Host, start sending 20 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain51
Traffic file: 2-tcp-from-node-0-node-5-simultaneous
Routing protocol: AODVUU

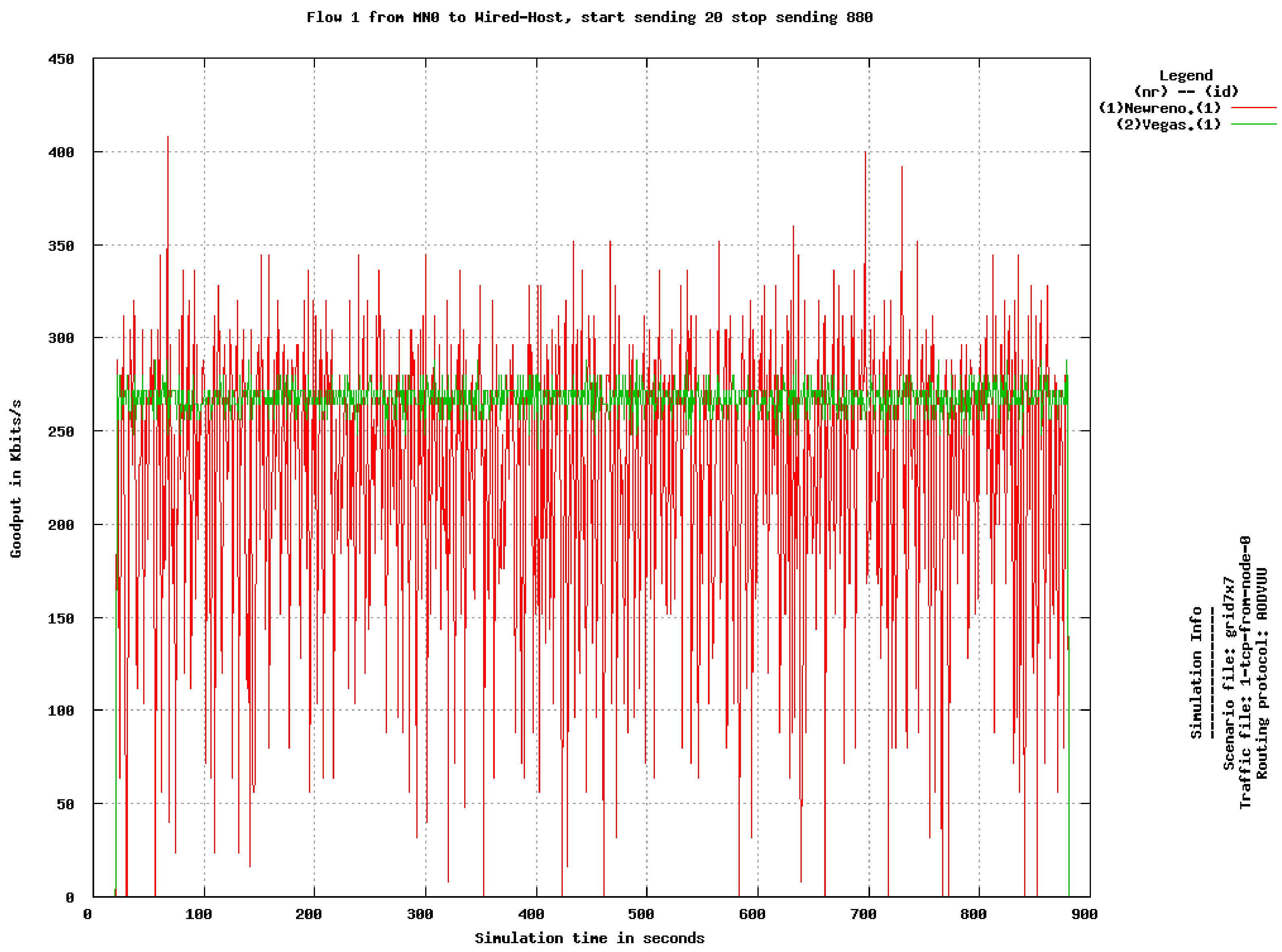


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN5 to Wired-Host, start sending 20 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: chain51
Traffic file: 2-tcp-from-node-0-node-5-simultaneous
Routing protocol: DSDV

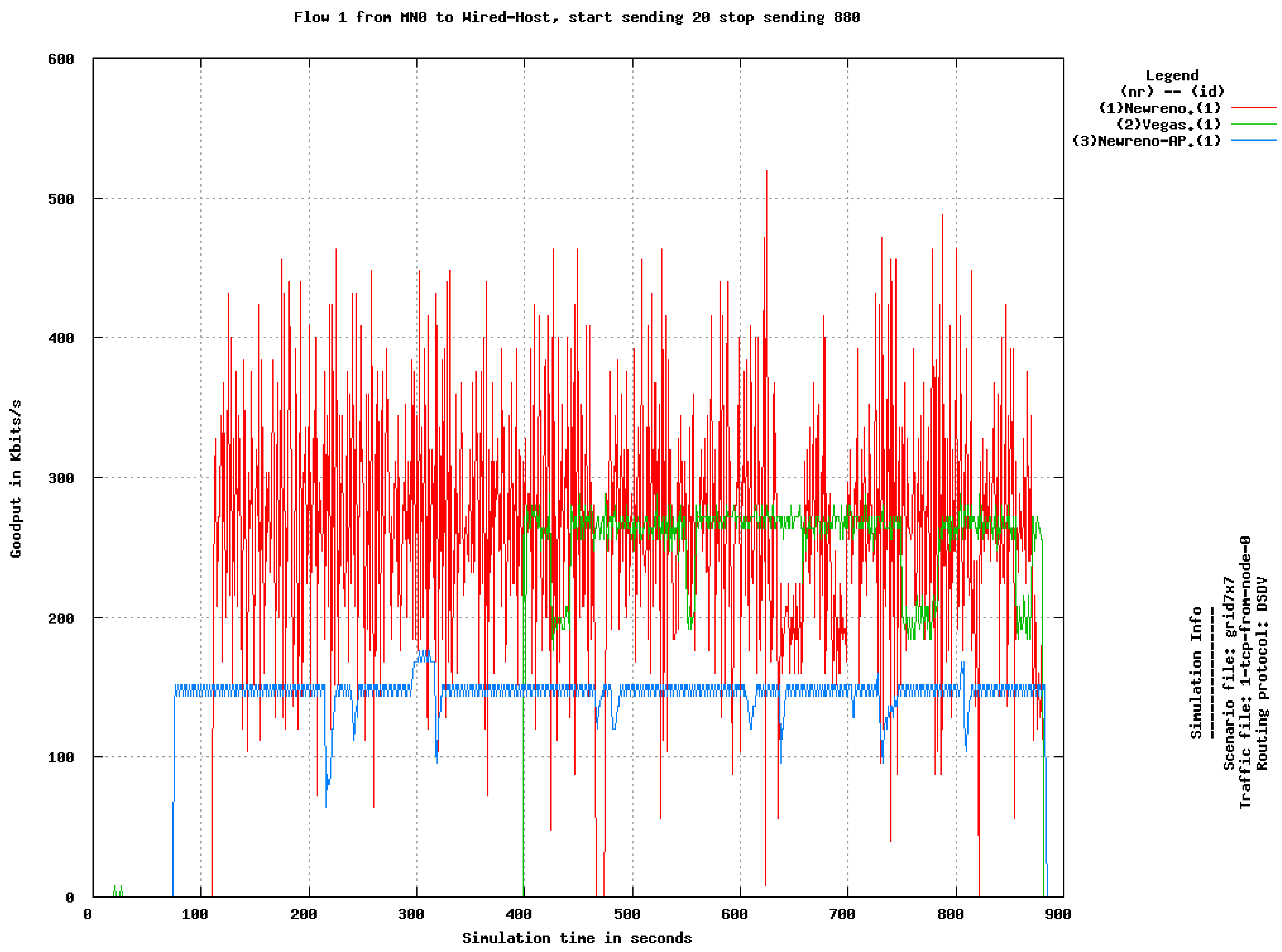

Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN0 to MN4, start sending 220.0 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
50
100
150
200
250
300
350
400
450
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: grid7x7
Traffic file: 1-tcp-from-node-0-1-tcp-between-node-4-node-0
Routing protocol: AODVUU



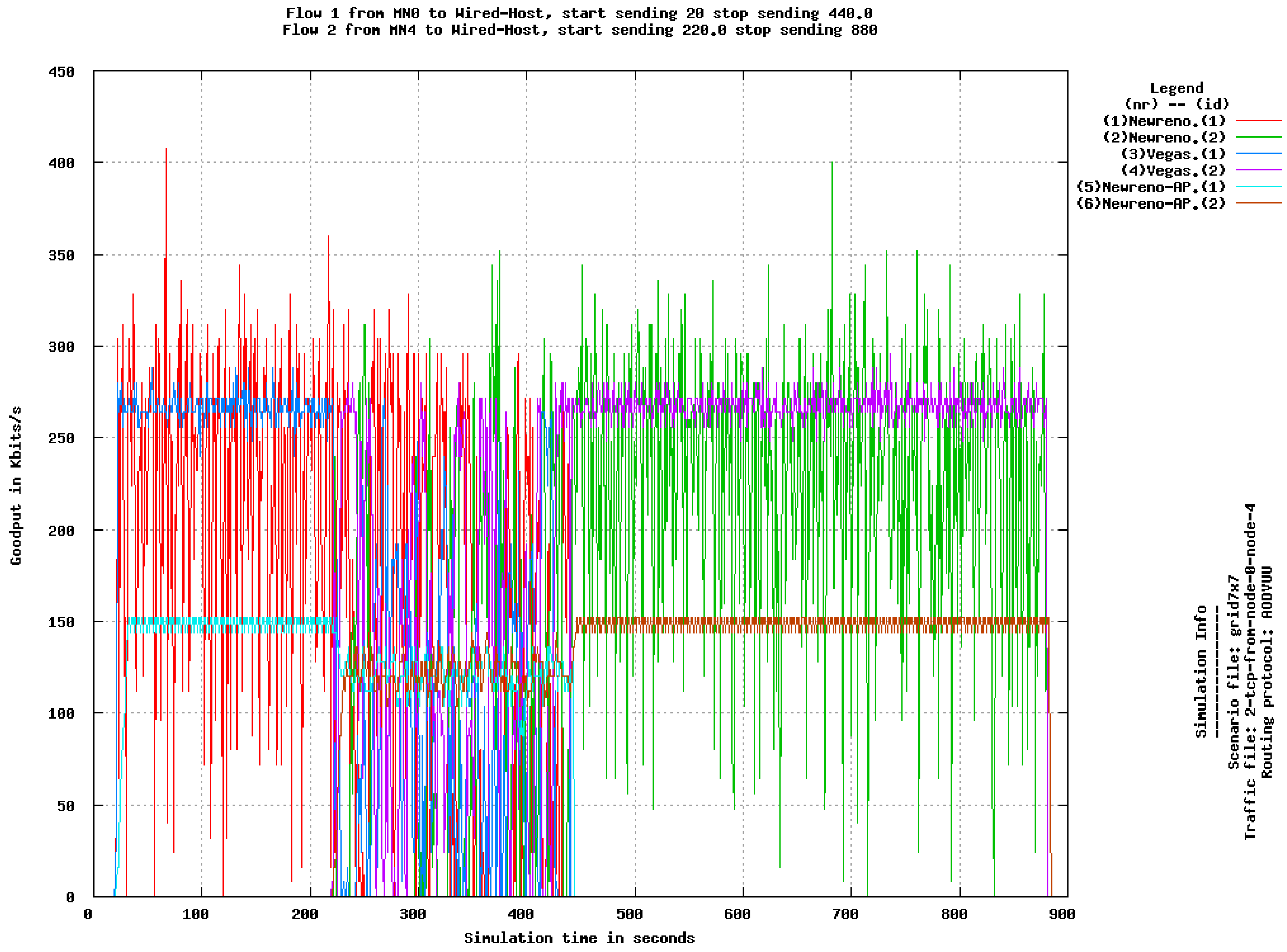
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN0 to MN4, start sending 220.0 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
50
100
150
200
250
300
350
400
450
500
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
Simulation Info
Scenario file: grid7x7
Traffic file: 1-tcp-from-node-0-1-tcp-between-node-4-node-0
Routing protocol: DSDV



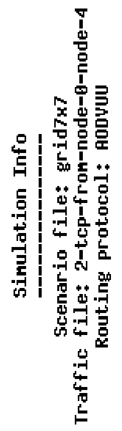
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Goodput in Kbits/s
0
50
100
150
200
250
300
350
400
450
0
100
200
300
400
500
600
700
800
900
Simulation time in seconds
Legend
(nr) -- (id)
(1)Newreno,(1)
(2)Vegas,(1)
Simulation Info
---------------
Scenario file: grid7x7
Traffic file: 1-tcp-from-node-0
Routing protocol: AODVUU



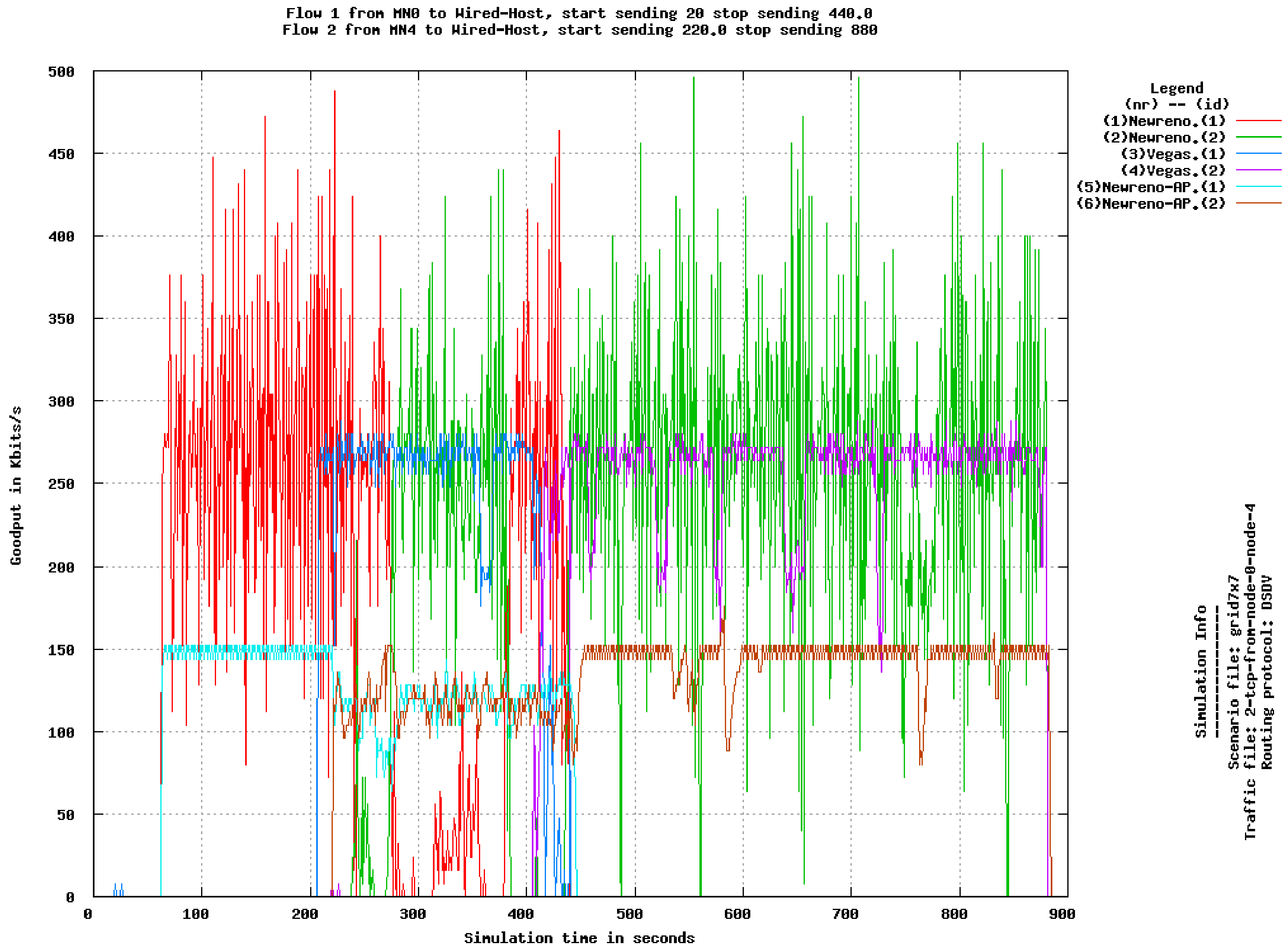
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
Scenario file: grid7x7
Traffic file: 1-tcp-from-node-0
Routing protocol: DSDV



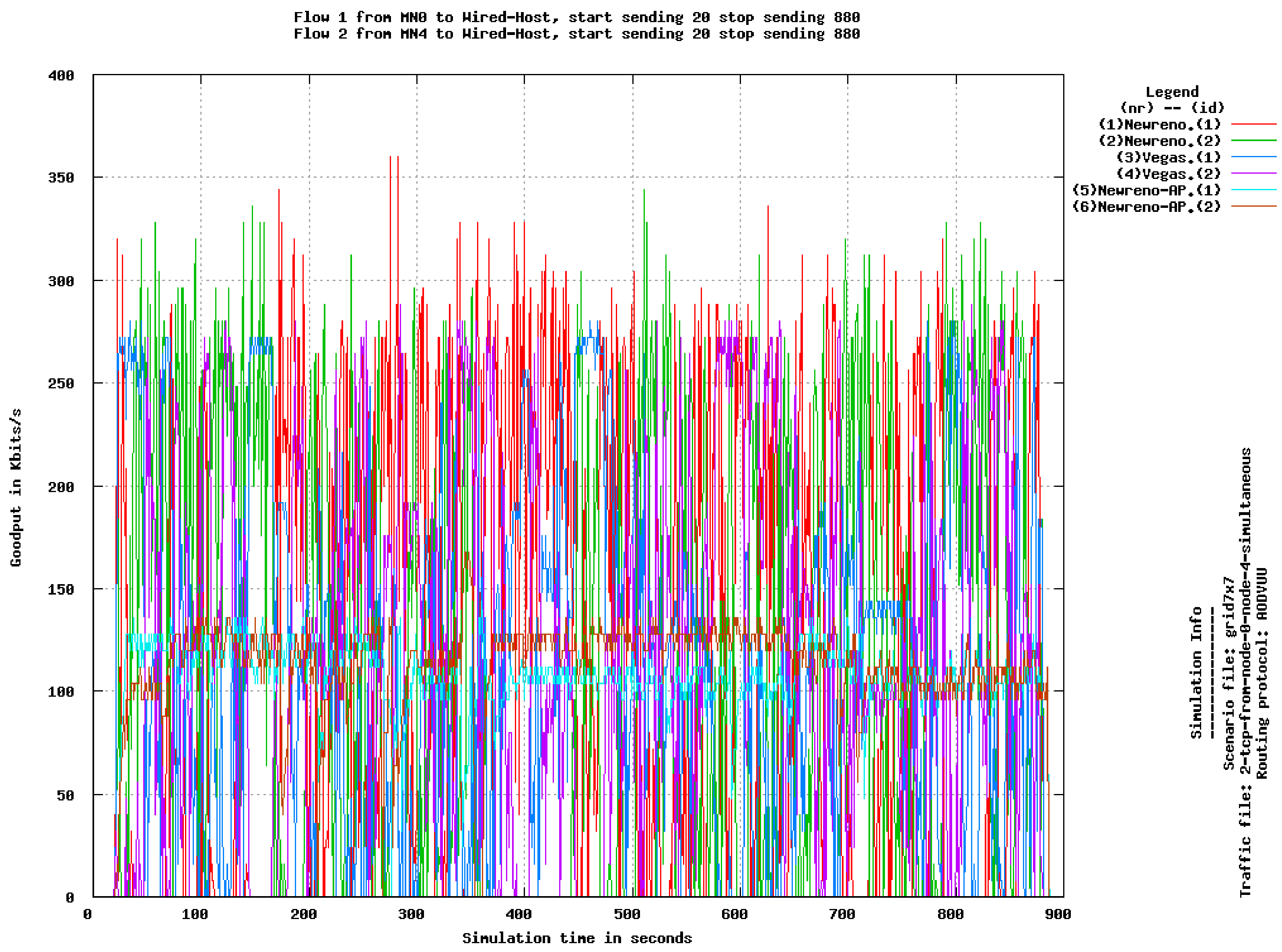
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN4 to Wired-Host, start sending 220.0 stop sending 880
Goodput in Kbits/s
450
400
350
300
250
200
150
100
50
0
0
100
200
300
400
500
600
700
800
900
Simulation time in seconds
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)

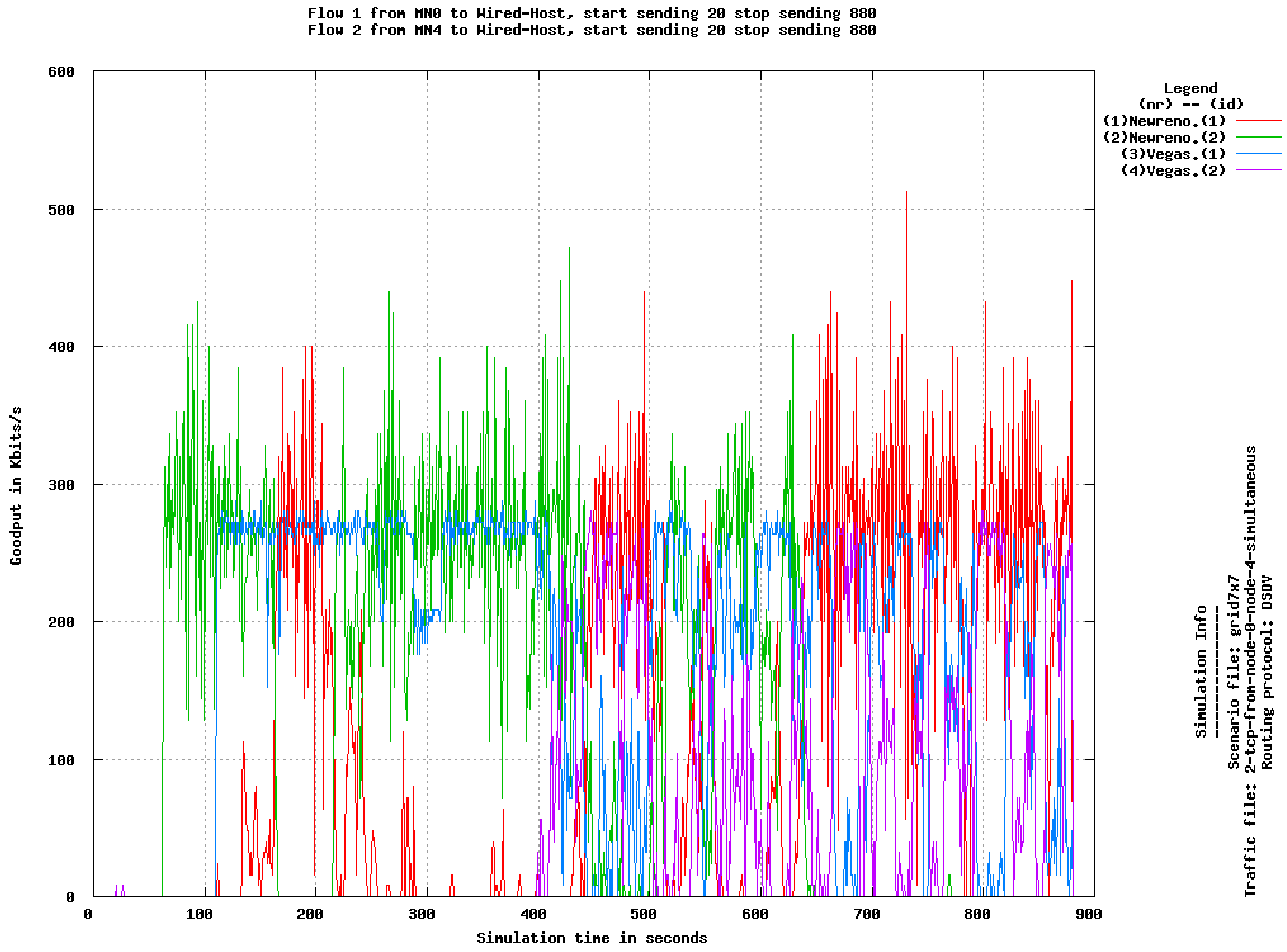


Simulation Info
---------------
Scenario file: grid7x7
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: AODVUU

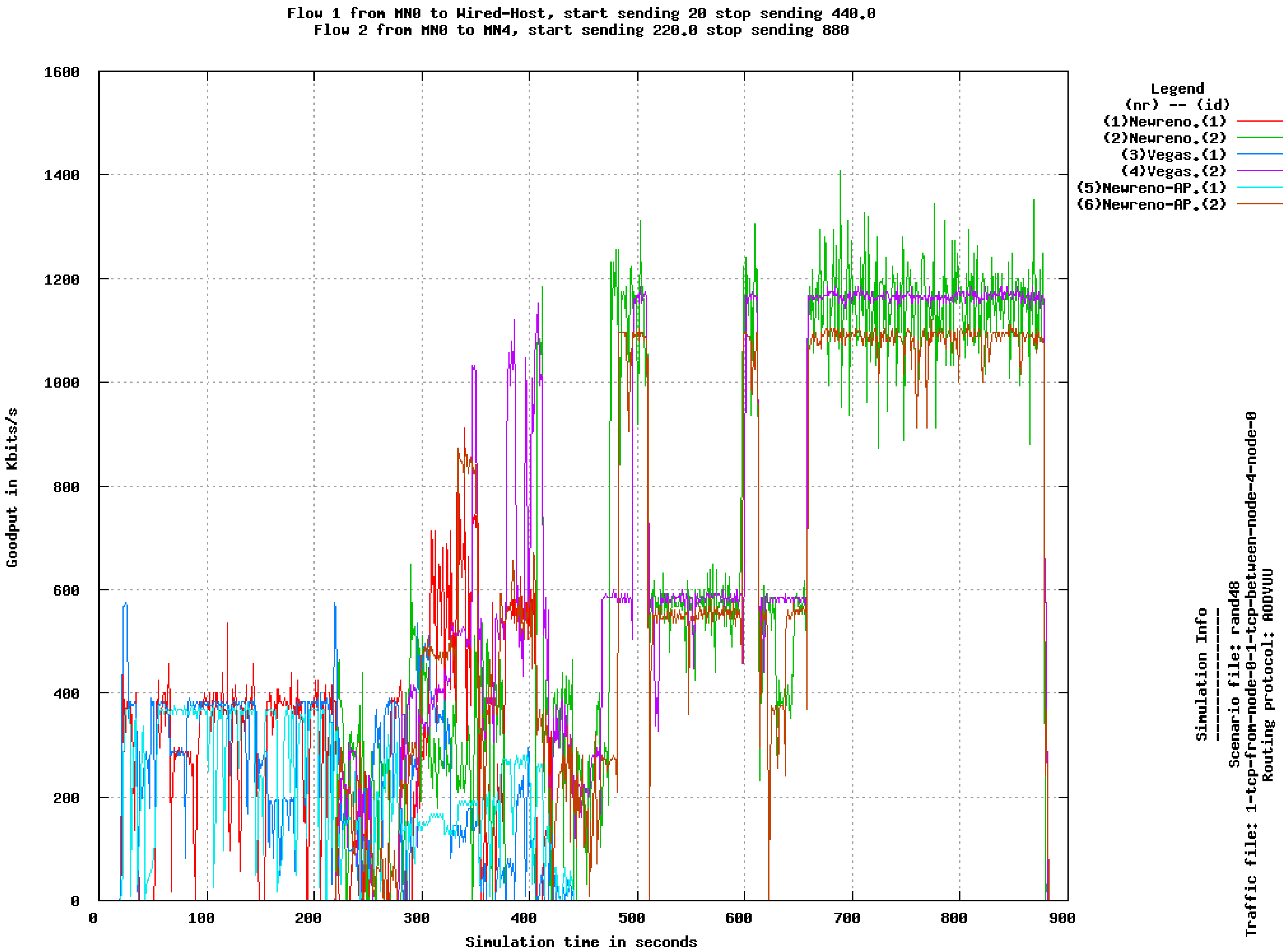


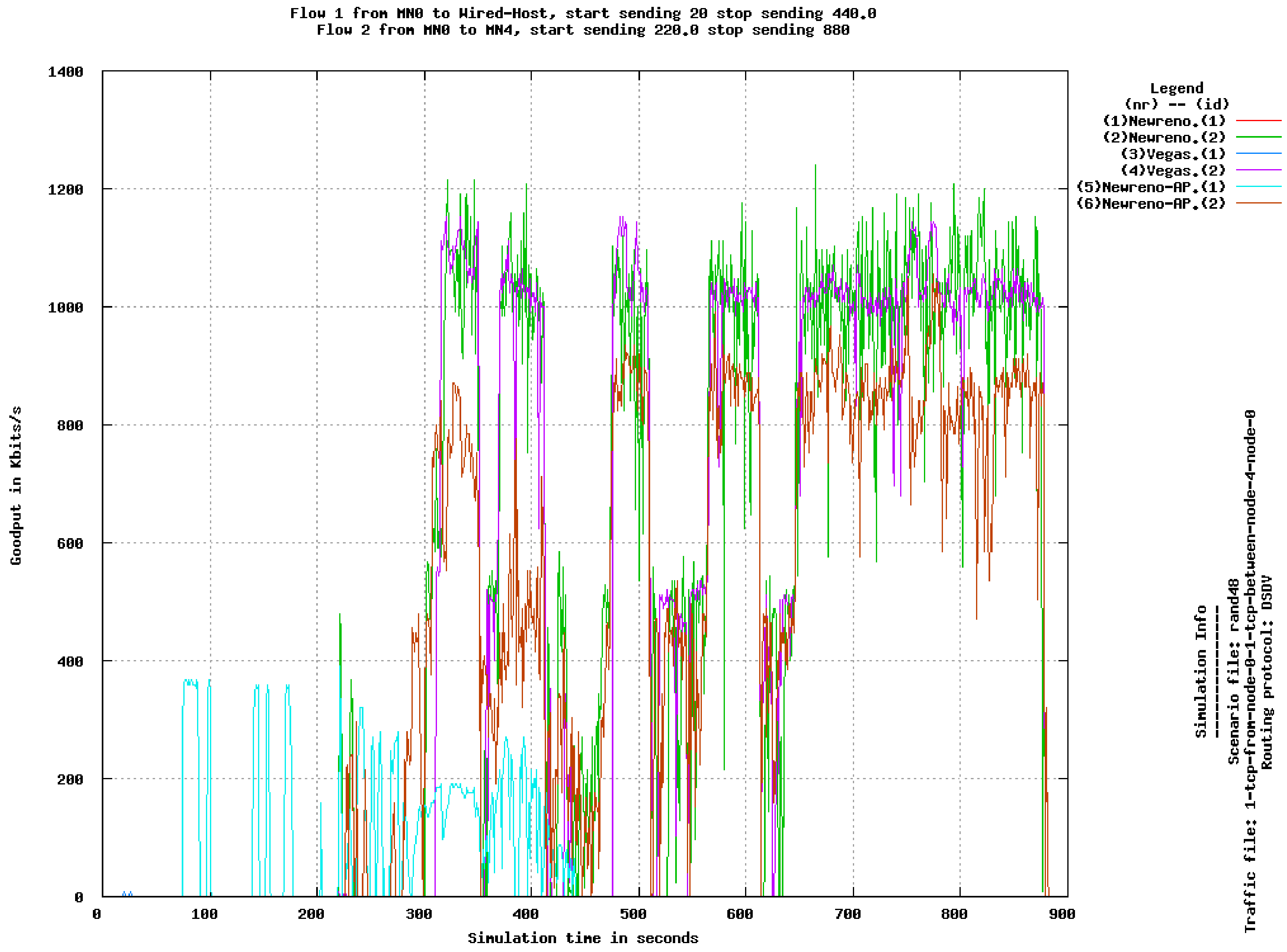
Simulation Info
-------------
Scenario file: grid7x7
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: DSDV


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN4 to Wired-Host, start sending 20 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
50
100
150
200
250
300
350
400
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: grid7x7
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: AODVUU

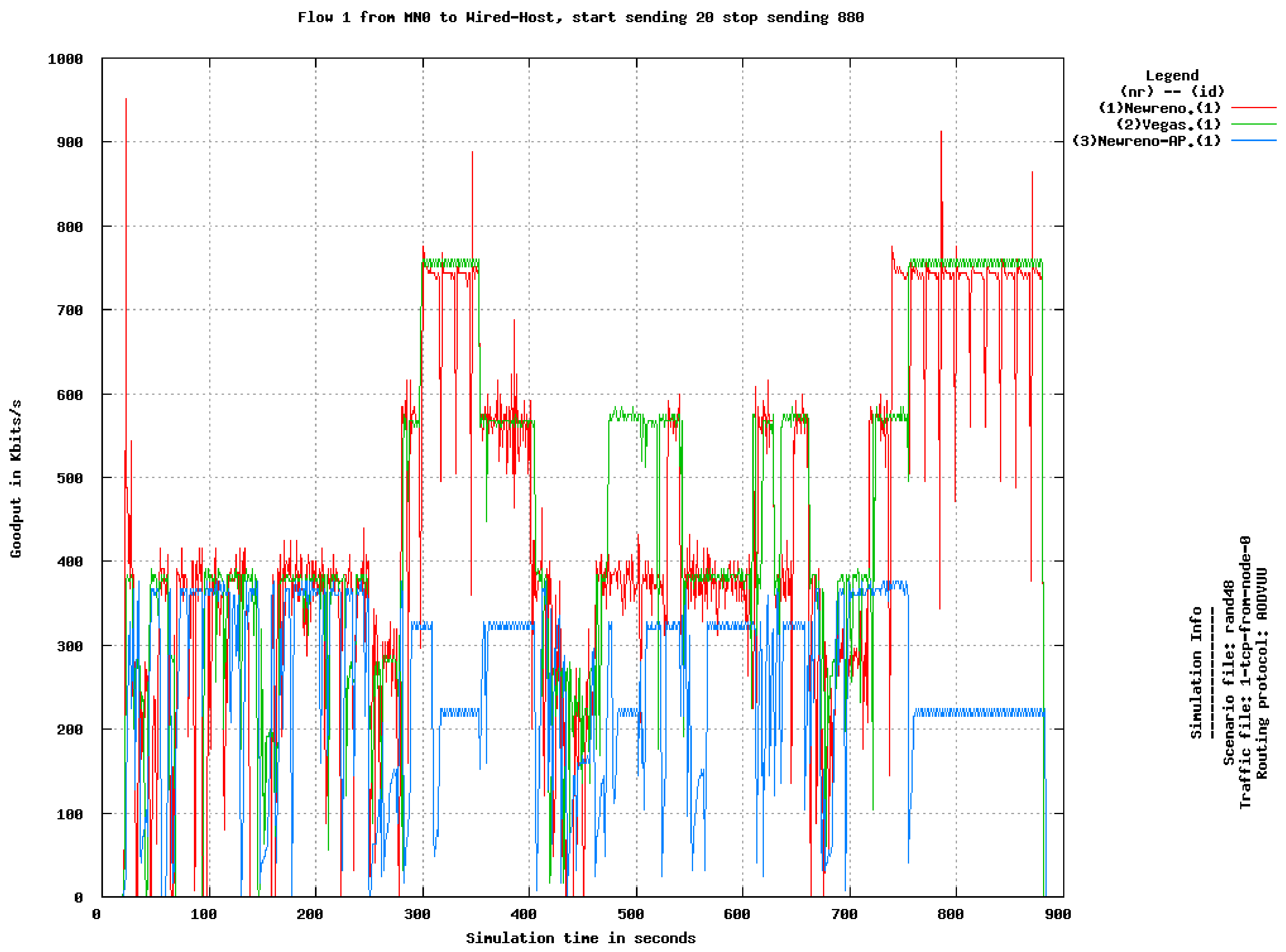


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN4 to Wired-Host, start sending 20 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
Simulation Info
Scenario file: grid7x7
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: DSDV

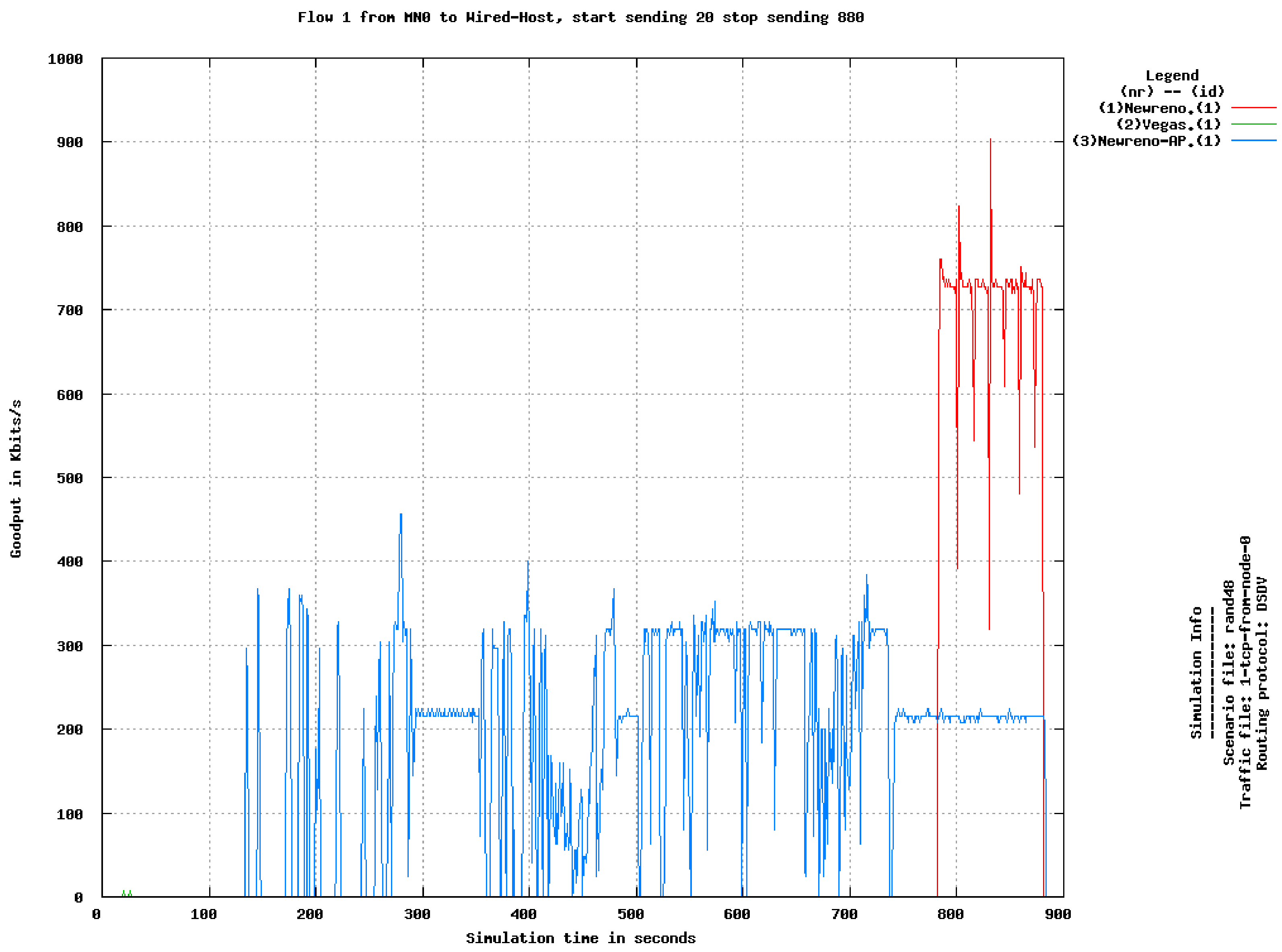

Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN0 to MN4, start sending 220.0 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
200
400
600
800
1000
1200
1400
1600
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: rand48
Traffic file: 1-tcp-from-node-0-1-tcp-between-node-4-node-0
Routing protocol: AODVUU



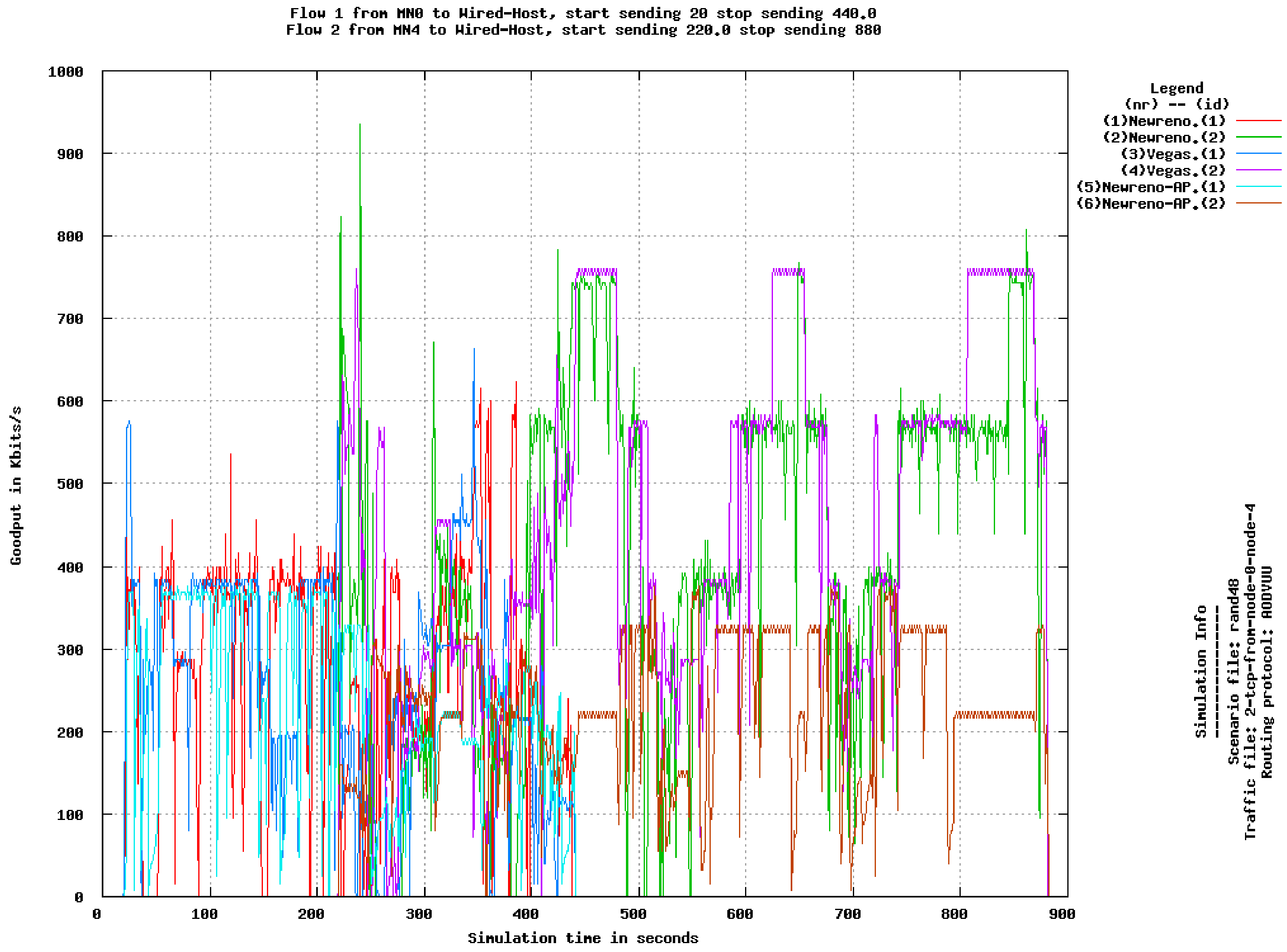
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN0 to MN4, start sending 220.0 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
1000
1200
1400
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: rand48
Traffic file: 1-tcp-from-node-0-1-tcp-between-node-4-node-0
Routing protocol: DSDV



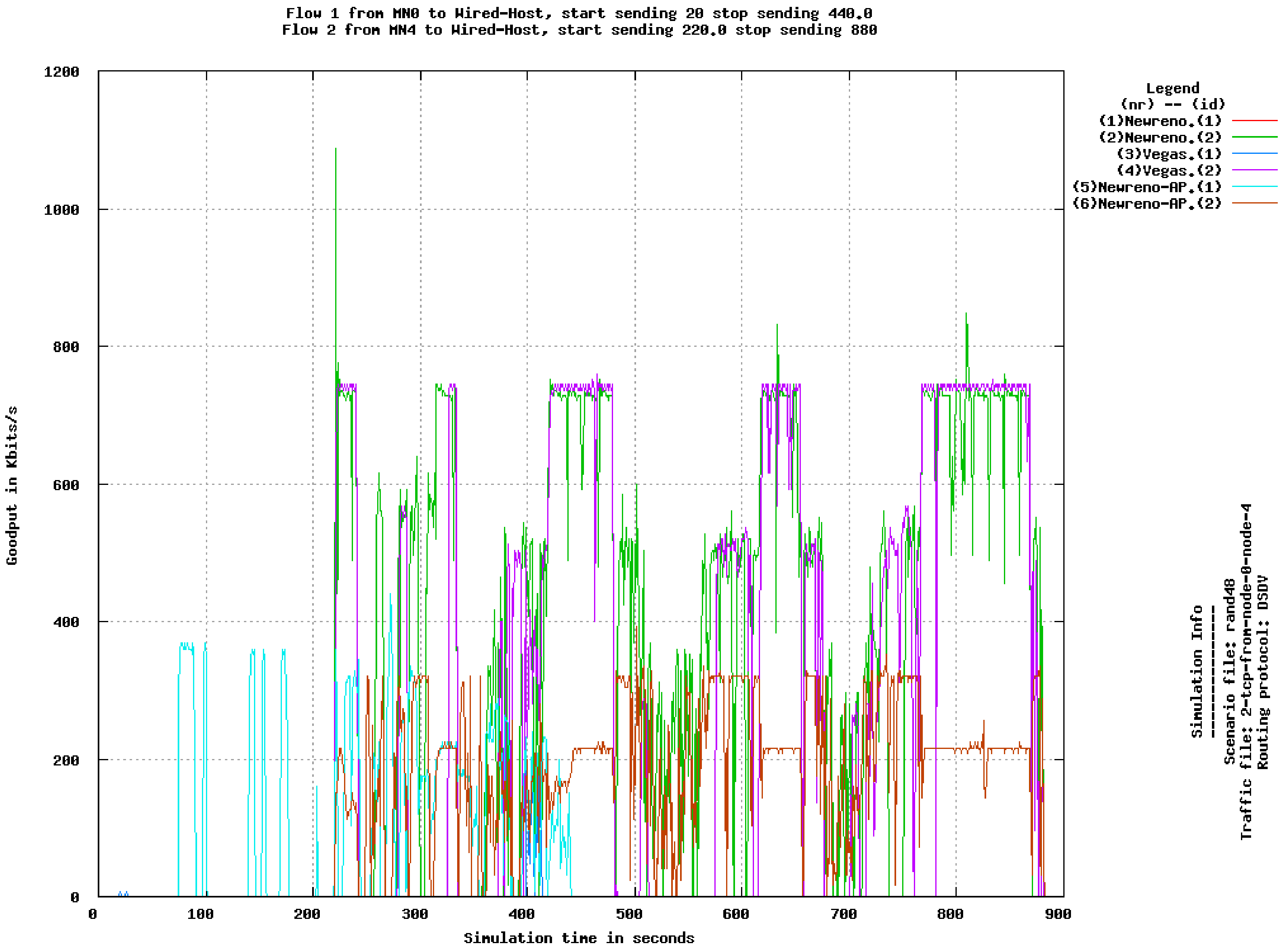
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
1000
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
Scenario file: rand48
Traffic file: 1-tcp-from-node-0
Routing protocol: AODVUU



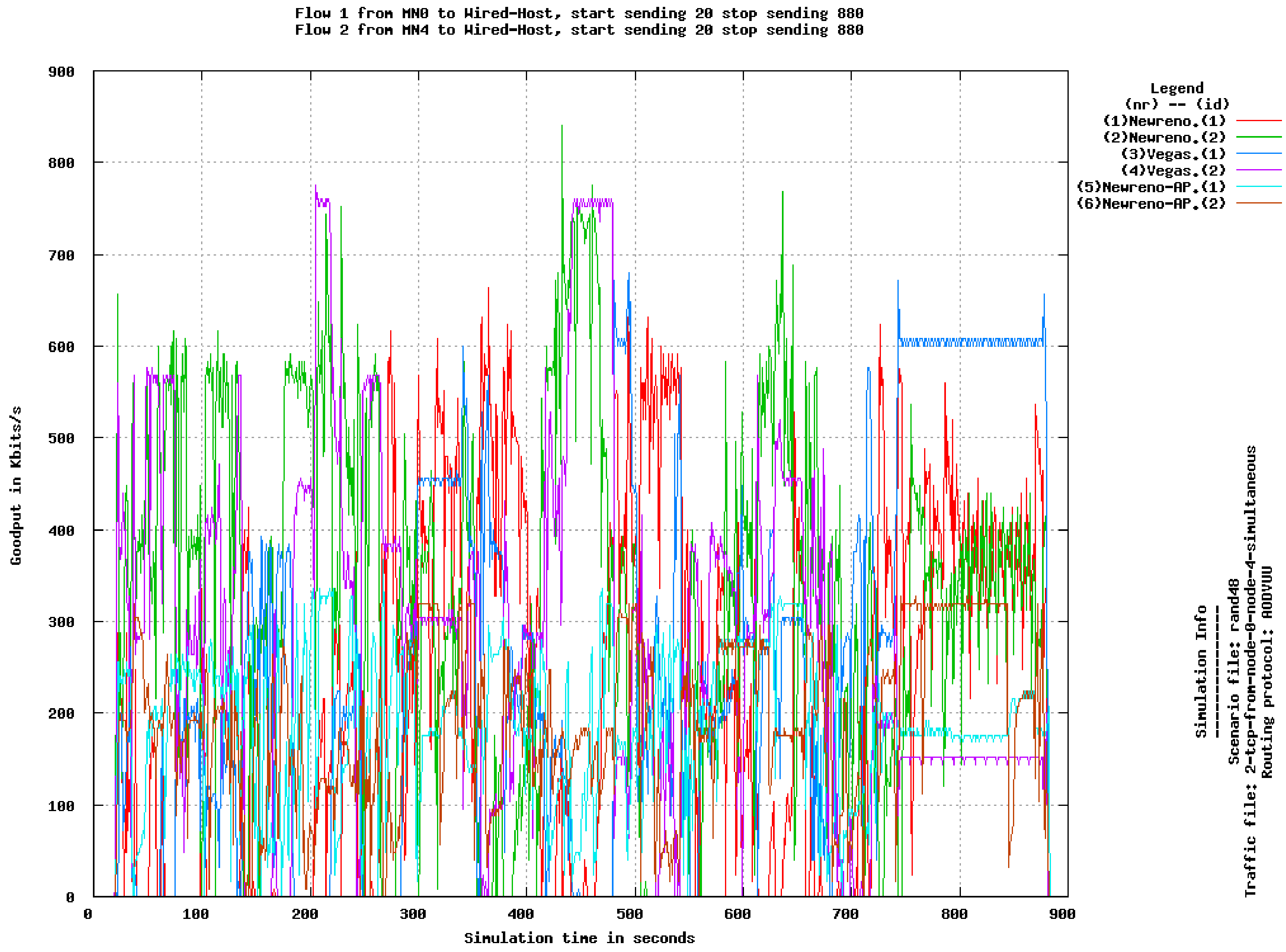
Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
1000
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Vegas.(1)
(3)Newreno-AP.(1)
Simulation Info
Scenario file: rand48
Traffic file: 1-tcp-from-node-0
Routing protocol: DSDV



Simulation Info
-------------
Scenario file: rand48
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: AODVUU



Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 440.0
Flow 2 from MN4 to Wired-Host, start sending 220.0 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: rand48
Traffic file: 2-tcp-from-node-0-node-4
Routing protocol: DSDV



Simulation Info
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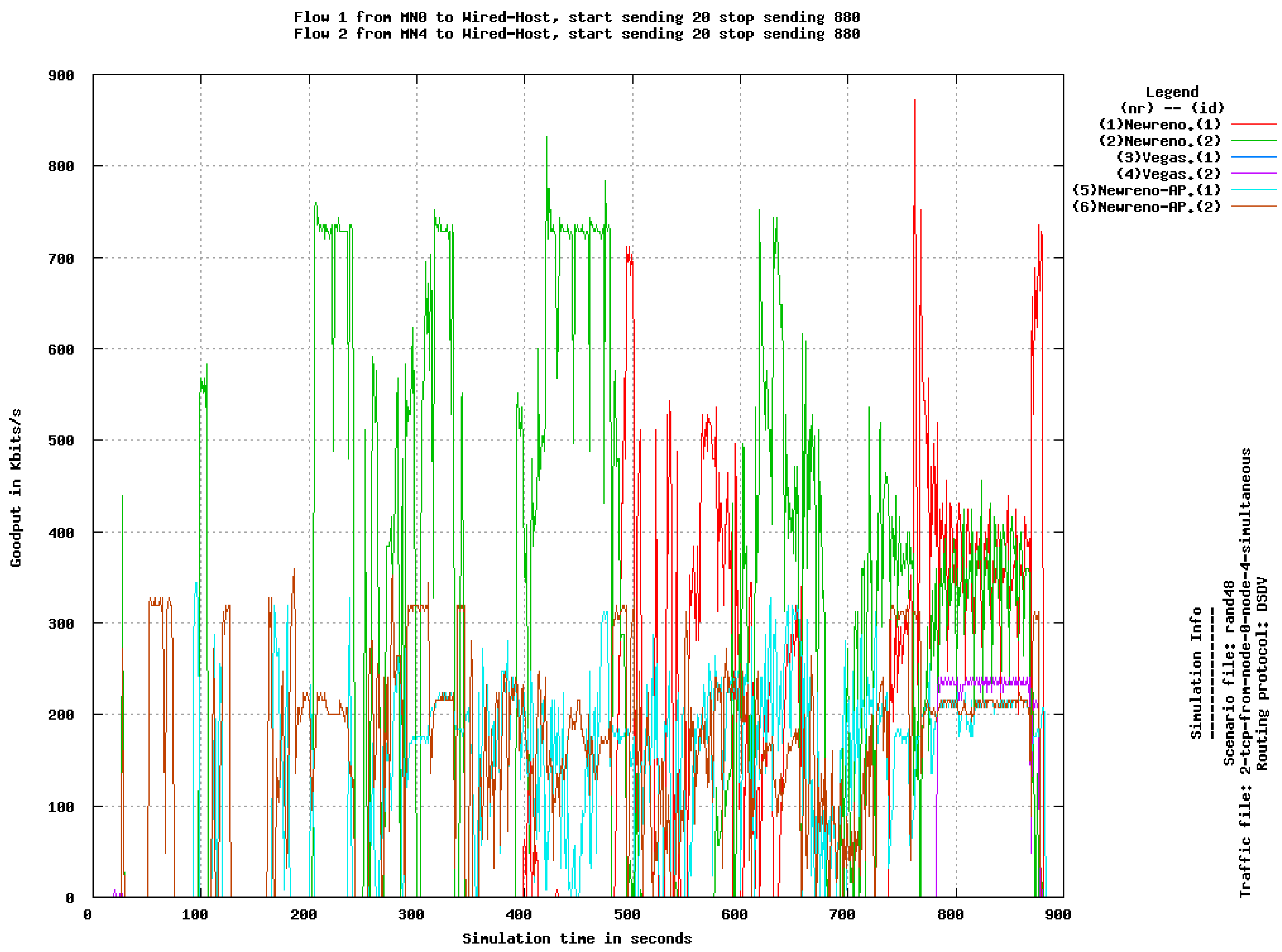
Scenario file: rand48
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: AODVUU


Flow 1 from MN0 to Wired-Host, start sending 20 stop sending 880
Flow 2 from MN4 to Wired-Host, start sending 20 stop sending 880
Goodput in Kbits/s
Simulation time in seconds
0
100
200
300
400
500
600
700
800
900
Legend
(nr) -- (id)
(1)Newreno.(1)
(2)Newreno.(2)
(3)Vegas.(1)
(4)Vegas.(2)
(5)Newreno-AP.(1)
(6)Newreno-AP.(2)
Simulation Info
Scenario file: rand48
Traffic file: 2-tcp-from-node-0-node-4-simultaneous
Routing protocol: DSDV