

P802.17 D1.1 RPR OPNET Model User Guide

Revision Nov7

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0 Overview

0.1 Installation

The required files to run simulations are included in a single zipped file. This file must be unzipped in the user's models directory. This procedure will create several directories. The paths must be added to the OPNET environment variable **mod_dir** (Edit|Preferences, or edit manually the file \op_admin\env_db8.0).

For example (the name of the directories might be slightly different):

```
<home>\P802_17_D11_Nov5\Scenarios  
<home>\P802_17_D11_Nov5\AggressiveNode  
<home>\P802_17_D11_Nov5\ConservativeNode  
<home>\P802_17_D11_Nov5\Varia
```

<home> is the path to the OPNET user models home directory (e.g. "c:\op_model"). The models are provided in binary format for Windows environment and OPNET version 8.0.C. A model compatible with OPNET version 8.1 is also available by contacting the authors. An example project, P802_17_D11, is provided that includes several scenarios.

The attribute "check_newer_process_model_files" in the OPNET environment must be set to FALSE. Otherwise, OPNET will try to recompile the models and fail to run simulations.

0.2 Features supported with this release

- Support all P802.17 D1.1 message formats
- Support both RPR-Aggressive and RPR-Conservative Models
- Support up to 16 nodes
- Support fairness with single choking point
- Support node auto discovery
- Support multiple priority traffic streams
- Support OC-192 data rate links (9,953,280,000 bps)
- Support CBR traffic generation
- Support VBR traffic generation with exponential inter-packet arrival times and exponential packet sizes

0.3 Contact

Please direct all your questions about this document and its associated OPNET models to Mr. Yan F. Robichaud at yan@sce.carleton.ca.

1 General Introduction

The P802.17 D1.1 RPR OPNET model Revision Nov5 includes several scenarios which can be used as templates to build a variety of others scenarios. It is recommended to duplicate a scenario and modify it, by copying and deleting components, to suit the user's requirements.

The palette in Figure 1 also can be used to add component to a new scenario. The description of these components follows.

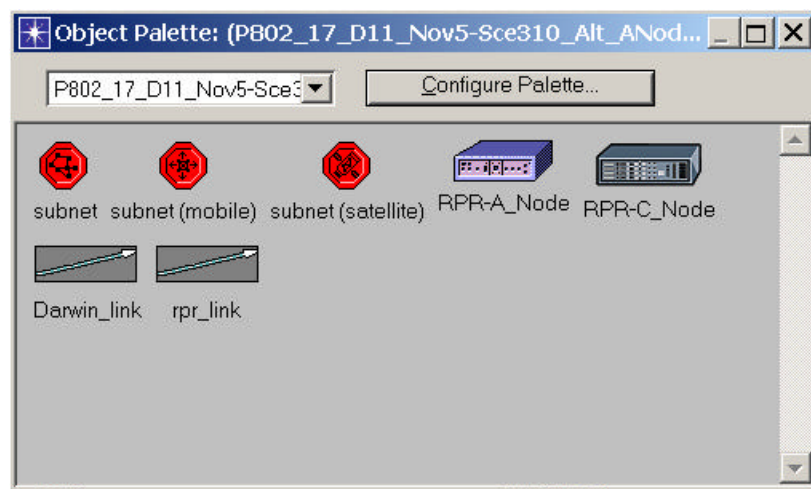


Figure 1. RPR P802.17 D1.1 Object Palette

1.1 RPR-C_Node

The RPR-Conservative Node (or RPR-C Node) realizes two main features as described below.

1.1.1 Topology discovery

Topology discovery is the process used to determine the ring connectivity. The process is initiated by the start of simulation. Each node sends out a message in both the East and West direction, querying the neighboring nodes. Downstream nodes receive this message, append their MAC address to the payload and transmit the message to the next node. When the message comes back to the source, it uses this information to build the node table. This table is then used to determine the shortest path to any given node.

1.1.2 RPR-C Fairness algorithm

The Control Access Protocol (CAP) is an algorithm that manages ring congestion with Fairness. The CAP Fairness mechanism uses explicit congestion notification in conjunction with ingress and egress queues to manage congestion on the ring and reduce the amount of buffering. The CAP protocol works with the queue schedulers to support multiple classes on the ring and weighted bandwidth allocation. When "congestion" is detected, per class fairness messages are sent back to the congestion contribution station. The message contains a "fair rate" for the upstream ring access scheduler to inform it of available bandwidth across the congested link. The Fairness scheduler controls the admission of packets on to the ring. RPR-C Node uses Buffer Insertion Ring technology (BIR). The bandwidth on the ring is shared by all stations and is observant of congestion on the ring when resources are over-subscribed. On the ring there are no

queues, the Insertion buffer is used to prevent packet truncation in case of contention. Delay deviation is low for high priority packets from ingress to egress as the transit delay is bounded on the ring. To ensure high utilization, unused high priority bandwidth can be utilized by the low priority traffic.

1.1.3 RPR-Conservative Priority Queue Model

The RPR-C Priority Queue is a traffic generator internal to the RPR-C Node that generates different classes of Ethernet traffic and acts as a traffic sink. The role of the Priority Queue is to buffer packets (sourced by the internal generators) until there is sufficient bandwidth on the ring provided by the RPR-C Node.

There are three different classes of traffic: EF - Explicit Forward, AF - Assured Forward, and BE - Best Effort. Each Priority Queue has 1 EF, 1 AF1, 1 AF2 and 4 BE traffic generators, which can generate traffic destined to any node in the network. Note that the RPR-C node cannot be connected to an external source in Revision Nov5.

1.2 RPR-A_Node

The RPR-Aggressive Node (RPR-A) works similarly as the RPR-Conservative (RPR-C) Node. The fairness algorithm is different, however they interwork together.

As in the RPR-C node, the RPR-A node includes a traffic generator, which acts also as a sink. Note that the RPR-A node cannot be connected to an external source in Revision Nov5.

1.3 P802_17_link

The P802_17_link is the link type connecting the RPR-C and RPR-A Nodes in an RPR Ring. This link supports the transmission of P802.17 D1.1 Packet Formats only. The link capacity is the OC-192 rate (9,953,280,000 bps).

Delay in the P802_17_link is modeled by distance and can be changed according to the real distance that the user wants to model. The default delay is 70 microseconds (roughly 15 km).

1.4 rpr_link

In Revision Nov5, the case of a scenario with only RPR-A nodes, the rpr_link must be used. If there is at least one RPR-C node on the ring, the P802_17_link must be used for all the links.

1.5 Available Statistics

1.5.1 RPR-Conservative Node

AF Throughput (bits/sec)

BE Throughput (bits/sec)

EF Throughput (bits/sec)

The RPR-C Node Model allows for collection of the Throughput of the different classes of traffic in each direction. Leaky_bucket1 collects Throughput information in the westbound direction. Leaky_bucket2 collects Throughput information in the eastbound direction.

Link Utilization (%)

The RPR-C Node Model allows for the collection of the link utilization leaving the node. It can collect information in both directions (East/West). Scheduler 1 collects information in the westbound direction and Scheduler 2 collects information in the eastbound direction.

MAC ingress/egress - Dropped Traffic Throughput

The RPR-C Node Model allows the statistical collection of the traffic destined for that specific node.

1.5.2 RPR-Conservative Priority Queue

MAC end to end delay from node X (seconds)

The Priority Queue Model can collect the MAC end to end delay from any Priority Queue in the network to the destination Priority Queue.

1.5.3 RPR-Aggressive Node

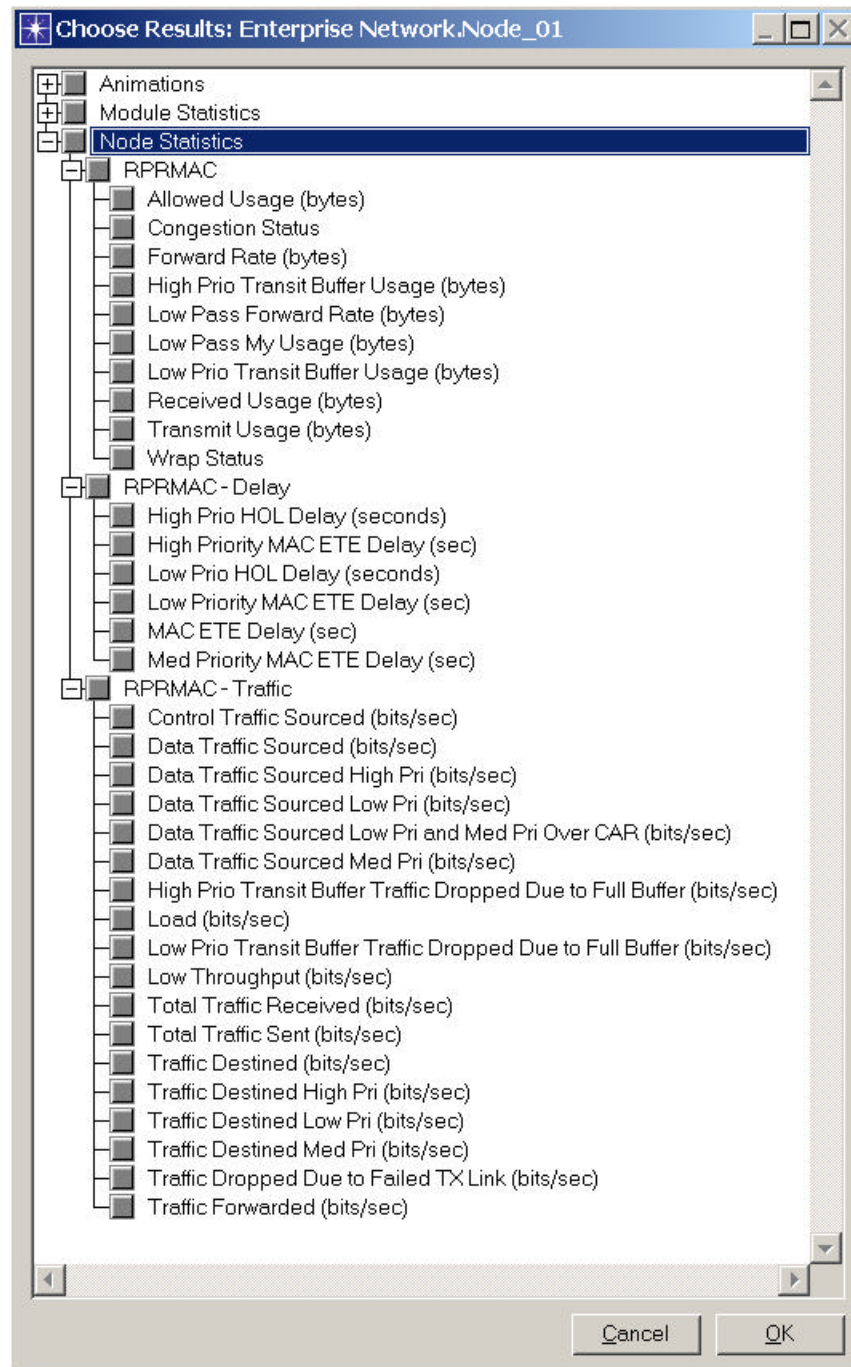


Figure 2. RPR-Aggressive Available Statistics

(The description of the RPR-A statistics will be added in a future revision of this document)

2 P802.17 D1.1 RPR Example Project

An example project titled *Sce310_Alt_ANode_CHub_Load150_Low100_Hi50* is a scenario of the interworking of RPR-C and RPR-A nodes. This scenario highlights an equal bandwidth requirement hub case, wherein all the nodes in the RPR ring send traffic to one destination node in the network (Node_00).

The following will describe the problem illustrated in this scenario, as well as illustrate the attribute settings to achieve this scenario. The results will also be discussed.

2.1 Purpose

To observe the behavior of the RPR-C and RPR-A algorithms working together to 150% traffic load on the link between node 1 and node 0. All nodes will send equal traffic to node 0.

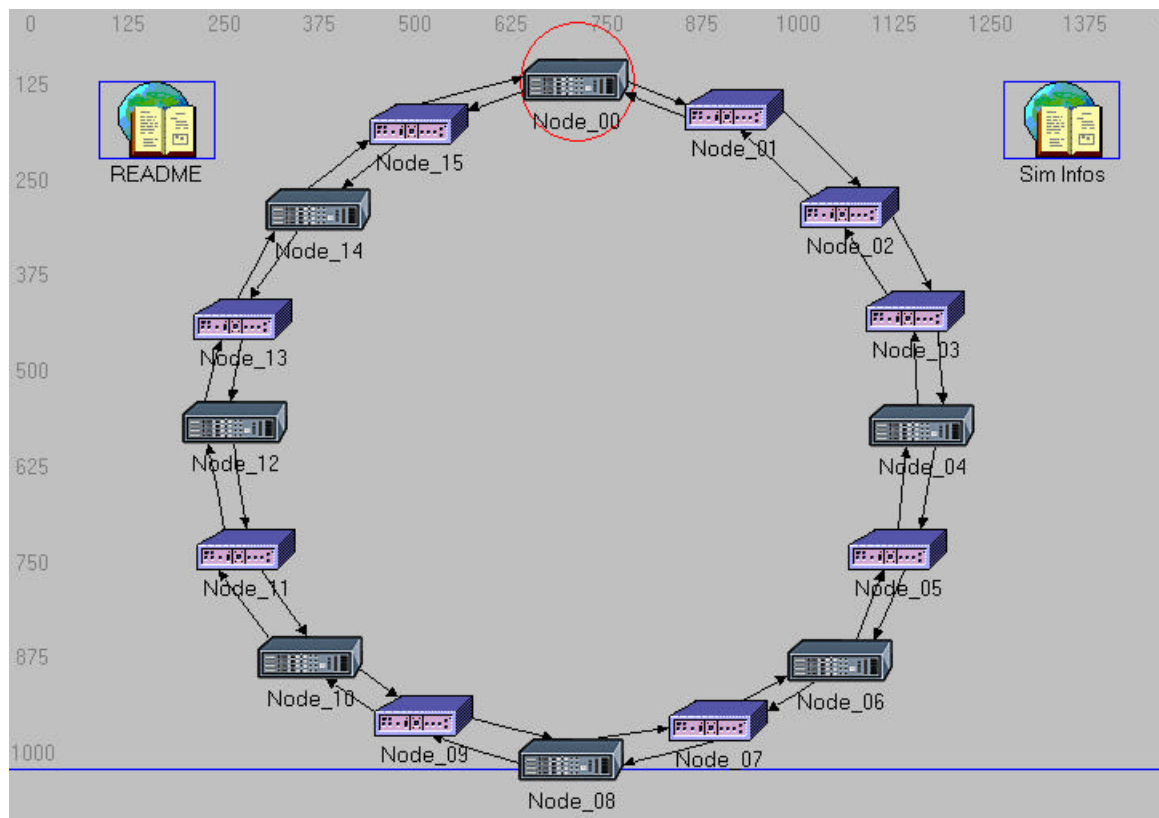


Figure 3. RPR-Conservative fairness weights scenario

2.2 Method

The network topology, illustrated in Figure 3, shows the scenario. Each node will deliver traffic to Node 0. All nodes will send traffic in the westward transmit direction (inner ring, counterclockwise), thus congesting the link between Node 1 and Node 0 with a traffic utilization of 150%. The link type between each node is a P802_17_link.

2.3 RPR-Conservative Node Attributes Description and Values

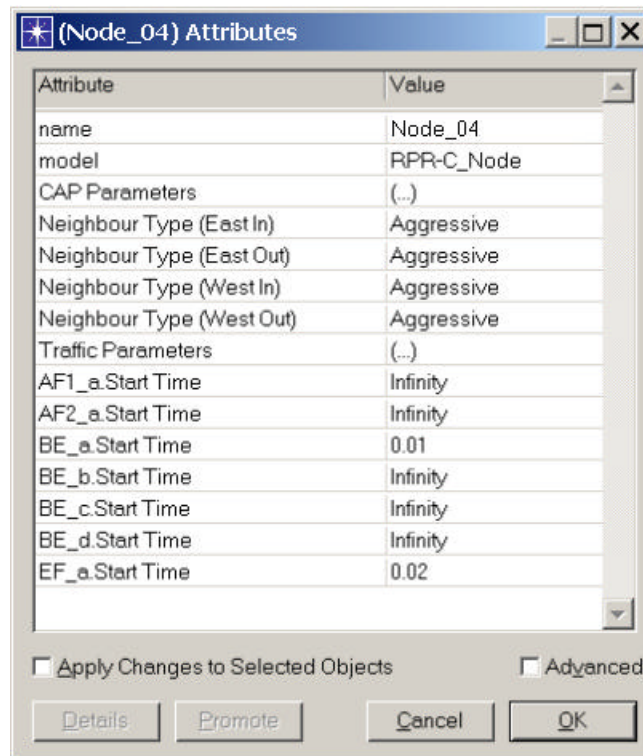


Figure 4. RPR-Conservative Node Model Attributes and Settings

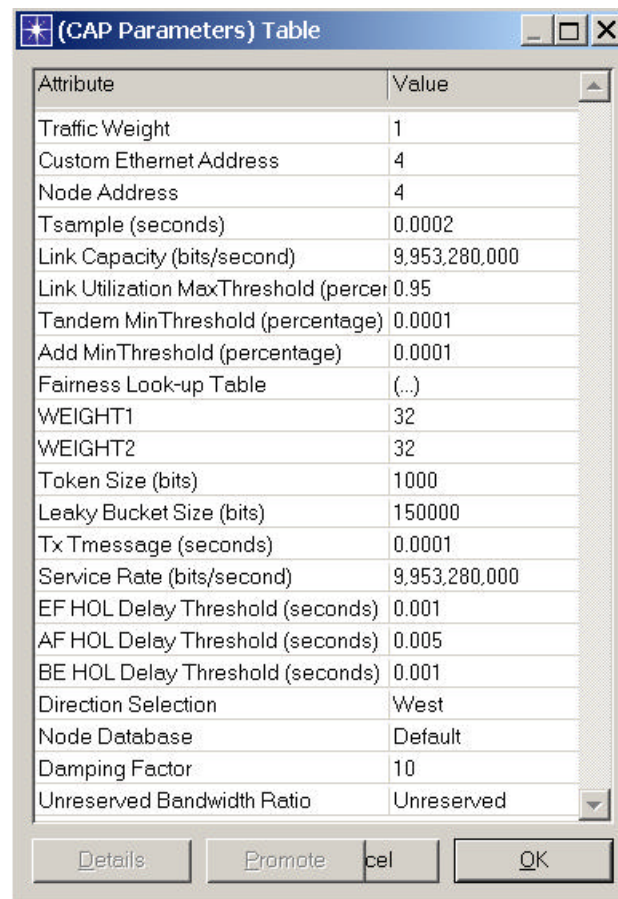
Start Time

The start time of each of the traffic generators (EF, AF, BE, a, b, c, d) in seconds from the beginning of the simulation time. Infinity means that the generator is never started. The BE traffic is set to start at 0.01 seconds. (It must be greater than or equal to 0.01 sec, to give time for the topology discovery mechanism to setup the routing tables).

Neighbour Type

These values inform the node which type of nodes are connected to itself. If a RPR-C node is connected, use the value Conservative. If a RPR-A node is connected, use Aggressive. This must be done for each port of the RPR-C node. The west/east information can be found in the links attributes.

2.3.1 CAP Parameters



Attribute	Value
Traffic Weight	1
Custom Ethernet Address	4
Node Address	4
Tsample (seconds)	0.0002
Link Capacity (bits/second)	9,953,280,000
Link Utilization MaxThreshold (percentage)	0.95
Tandem MinThreshold (percentage)	0.0001
Add MinThreshold (percentage)	0.0001
Fairness Look-up Table	(...)
WEIGHT1	32
WEIGHT2	32
Token Size (bits)	1000
Leaky Bucket Size (bits)	150000
Tx Tmessage (seconds)	0.0001
Service Rate (bits/second)	9,953,280,000
EF HOL Delay Threshold (seconds)	0.001
AF HOL Delay Threshold (seconds)	0.005
BE HOL Delay Threshold (seconds)	0.001
Direction Selection	West
Node Database	Default
Damping Factor	10
Unreserved Bandwidth Ratio	Unreserved

Figure 5. RPR-Conservative CAP Parameters

Traffic Weight

This is used for weighted Bandwidth Fairness. This weight is related to all nodes on the ring. The calculation is made by dividing the Traffic Weight with the sum of all the Traffic Weights in the entire network. The default mode of operation is 1 for all nodes, which is fair, each node will receive the same amount of bandwidth. (This is the only supported option available in Revision Nov5).

Custom Ethernet Address

The MAC address of the entity, which is directly connected to this RPR-C Node through the Queuing Node. This allows the user to manually specify the Ethernet Address of the node directly connected to the RPR Node. (In Revision Nov5, the Internal Priority Queue and the RPR-C Node should have the exact same Custom Ethernet Address. Do not connect an external generator, since this configuration has not been fully tested yet.)

Node Address

The Custom MAC address of the local RPR-C Node. This Node Address must be an integer from 0 to 15 (in future revisions, up to 256 nodes will be supported). This Node Address of the RPR-C Node is the same as the Priority Queue's Local Node Address (set internally).

Tsample

The sample timer is used for rate estimation for tandem and add rate estimations. The default value is 200 microseconds, which is a specific value for a 10Gbps link.

Link Capacity

The maximum data rate that the link can transmit, in bits per second. The value is set to 9,953,280,000 bps.

Link Utilization Max Threshold

This is the maximum utilization that may occur before congestion is declared. Once the utilization exceeds this threshold, the fairness algorithm will be triggered.

Tandem MinThreshold and Add MinThreshold

The minimum utilization of traffic on a link that the fairness algorithm will use in its equation.

Fairness look-up table

This is where the advertised rate is chosen from.

Weight

The integer value used for tandem and add rate estimations.

Token size

The size of the token in bits.

Leaky bucket size

This is the maximum number of bits the leaky bucket can hold.

Tx Tmessage

This a message timer used to resend messages to upstream nodes for robustness.

Service Rate

The maximum rate that the RPR-C node can process packets.

HOL delay threshold

This is the threshold of Head of Line delay to trigger the fairness algorithm.

Direction selection

This is to decide which direction a packet should choose when it arrives at the MAC ingress of the RPR-C node.

2.3.2 Traffic Parameters

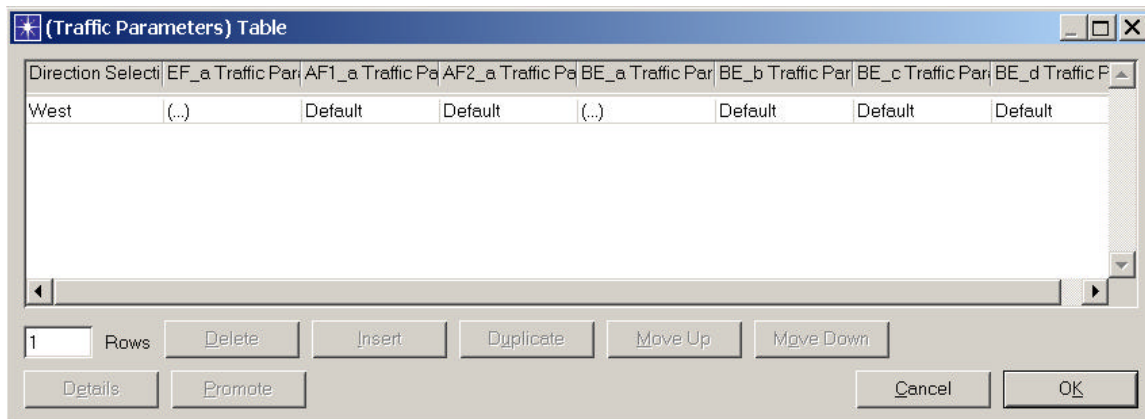


Figure 6. RPR-Conservative Priority Queue Attributes, Traffic Parameters

Direction Selection

If specified, the packets will explicitly be sent either eastbound or westbound (Figure 6).

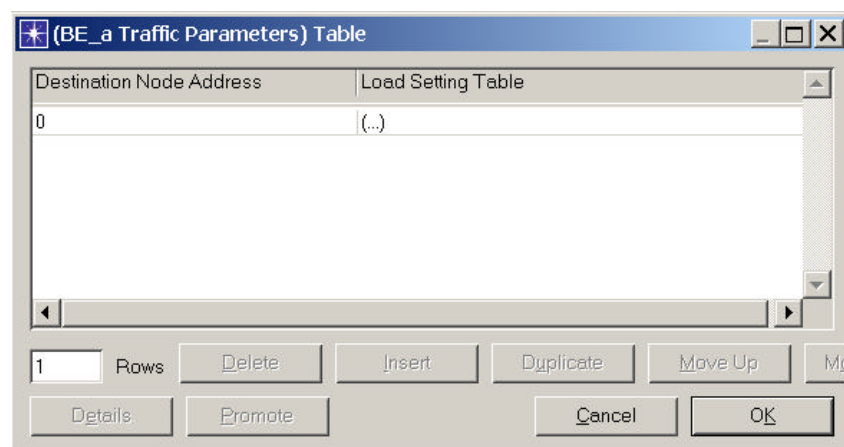


Figure 7. RPR-Conservative Priority Queue Attributes, BE_a Traffic Parameters

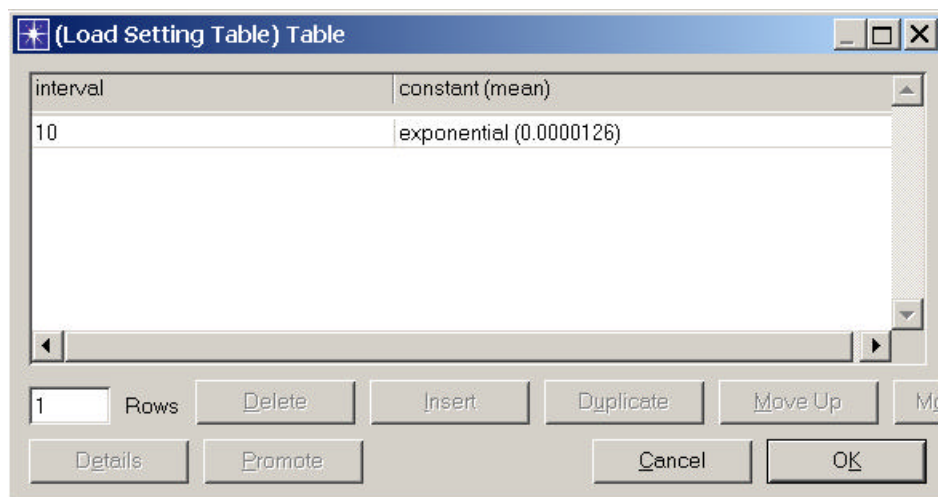


Figure 8. RPR-Conservative Priority Queue Attributes, FE_a Traffic Parameters

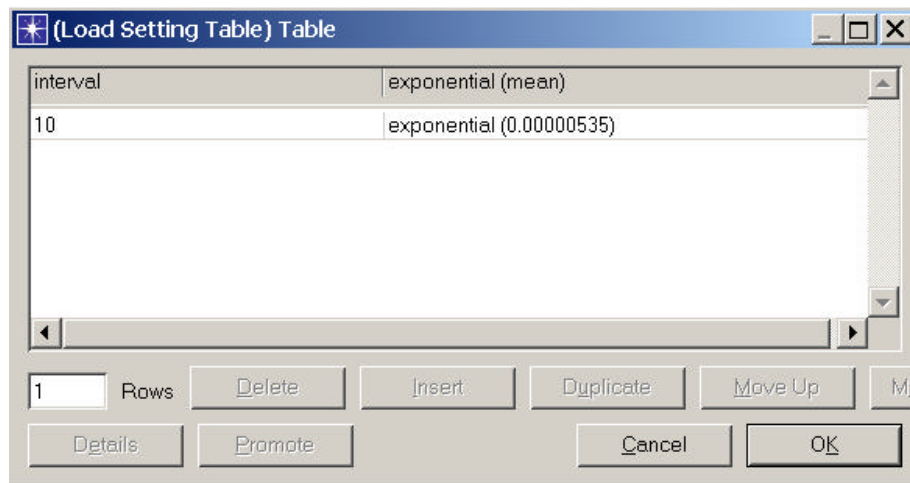


Figure 9. RPR-Conservative Priority Queue Attributes, BE_a Settings

- Destination Node Address (Figure 7): This is the Local Node Address of the destination RPR Node.
- Settings Table, EF Traffic (Figure 8)
 - Interval: The traffic generation period in seconds.
 - Exponential (Mean): The packet interarrival time of EF Class Packet. The value of Mean is in seconds and the packets will be distributed with a exponential interarrival time. (It is also possible to use constant interarrival time).
- Settings Table, AF, BE Traffic (Figure 9).
 - Interval: The traffic generation period in seconds.
 - Exponential (Mean): The packet interarrival time of AF or BE Class Packets. The value of Mean is in seconds and the packets will be distributed with an exponential interarrival time.

Figure 9 illustrates the “Load Setting Table”. The “Interval” is set to 10, meaning that this node will generate traffic for 10 seconds (which largely exceeds the required simulation time). “Exponential (mean)” is the interarrival time of the packets with an Exponential distribution of times. The Mean is in seconds. To generate a specific utilization by this node, the interarrival time must be calculated properly. We want each node in this scenario, to generate 150% (100% of BE traffic and 50% of EF traffic), thus the Mean will be calculated as follows:

$$\text{Mean} = (n \times p \times 8\text{bits}) / (u \times l)$$

n = the Number of Nodes on the Ring

p = Average Payload Size plus Header (460.4 bytes)

u = Utilization of last link (2 for 200%)

l = Line Rate (9,953,280,000 bps)

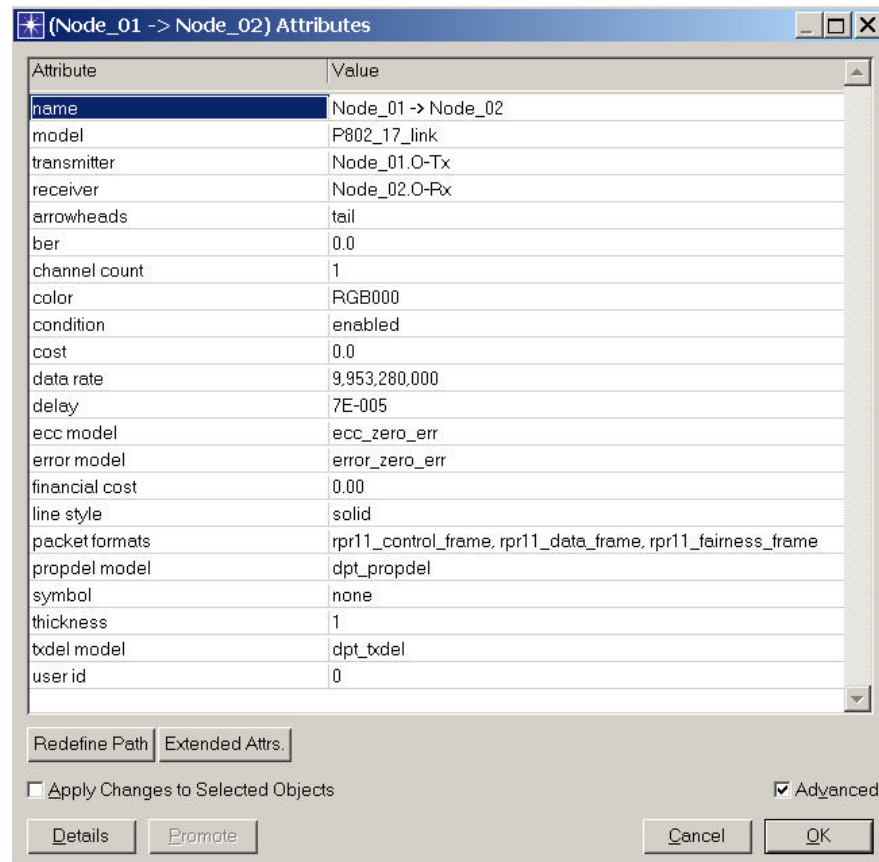


Figure 10. P802_17_link Attributes and Settings

Each link is set to 9,953,280,000 bps and has a fixed delay time to mimic a distance of 15km between each RPR-C Node. The settings for the link are illustrated in Figure 10. The two attributes highlighted in red are the two that pertain to RPR-C Node.

Specific statistics are needed to be collected to observe the RPR-C algorithm at work. Statistics to be collected are the throughput and the link utilization.

Node 1: Collect

- Leaky Bucket1.BE Throughput (bits per second)
- Scheduler1.Link Utilization (%)

Nodes 15 to 2: Collect

- Leaky Bucket1.BE Throughput (bits per second)

The Simulation should be run for 0.5 seconds and should take roughly 1.5 hours on a PIII Class computer.

2.4 RPR-Aggressive Node Attributes Description

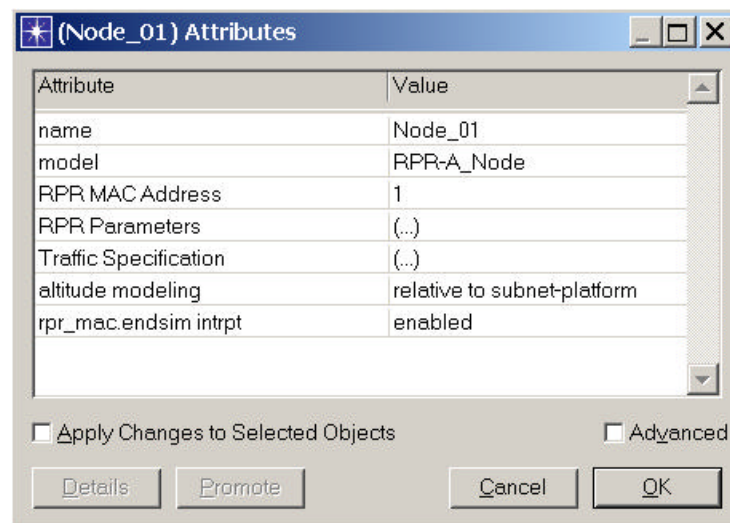


Figure 11. RPR-Aggressive Node Model Attributes and Settings

RPR Mac Address

The Custom MAC address of the local RPR-A Node (Figure 11). This Node Address must be an integer from 0 to 15 (in future versions, up to 256 nodes will be supported).

2.4.1 RPR Parameters

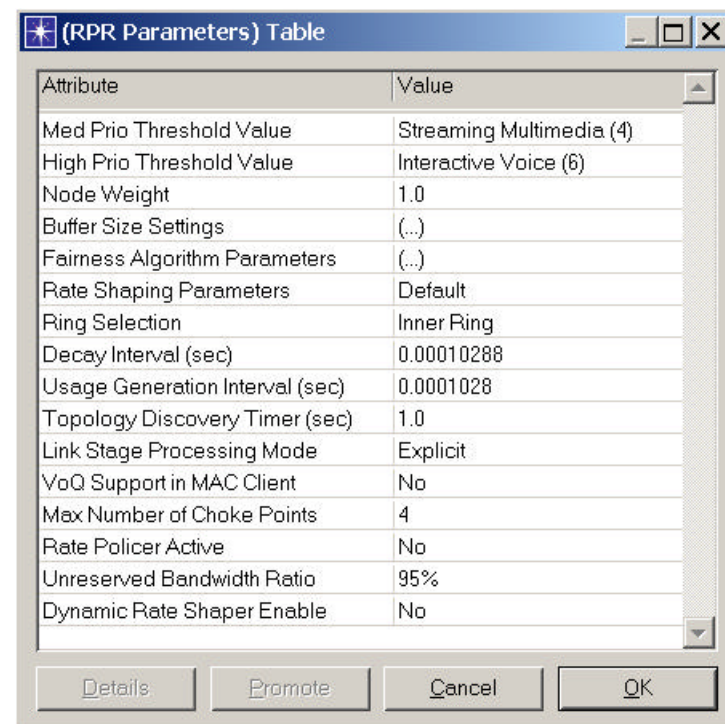


Figure 12. RPR-Aggressive Node RPR Parameters

RPR Parameters (tested values shown in Figure 12). This includes several nested attributes:

- Med Prio Threshold Value
- High Prio Threshold Value
If a packet has a Type-of-Service value less than Med Prio Threshold Value, it will be considered Low Priority. Otherwise, if a packet has a Type-of-Service value less than High Prio Threshold Value, it will be considered Med Priority. Otherwise, it will be considered High Priority.
- Node Weight: same meaning as RPR-C Node.

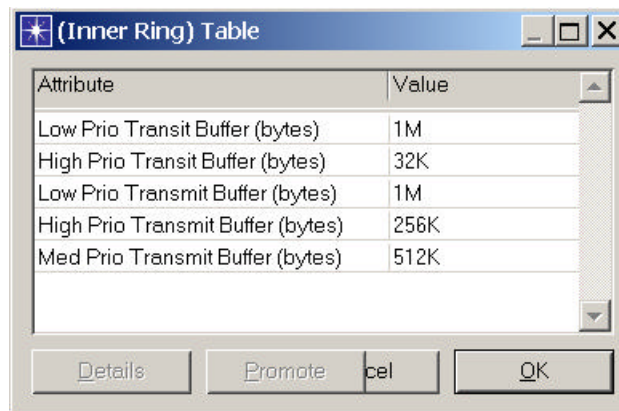


Figure 13. RPR-Aggressive Buffer Size Settings (Inner Ring)

- Buffer Size Settings (Figure 13): RPR MAC Client will use the Transmit Buffer settings to configure the total size available for its queues.

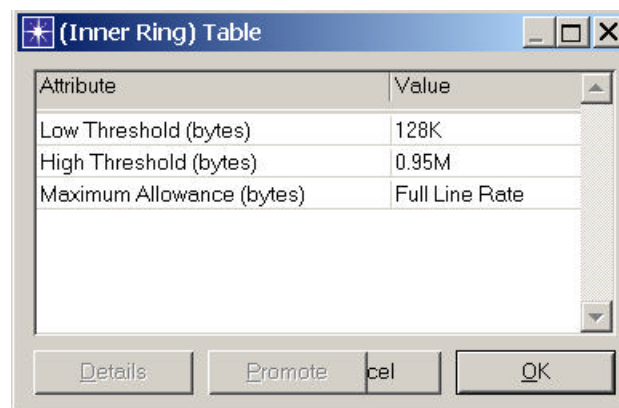


Figure 14. RPR-Aggressive Fairness Algorithm Settings (Inner Ring)

- Fairness Algorithm (Figure 14)
- Ring Selection: If it is set to “Auto Select”, ring selection is based on Topology Table.
- Link Stage Processing Mode: This is provided to run simulations faster. If it is set to “Efficient”, then packets will be delivered via OPNET kernel procedures and link statistics for the RPR links will not be collected. Therefore, if link statistics such as throughput are to be collected, this must be set to “Explicit”.
- VoQ Support in MAC Client: RPR MAC Client will use this attribute to create VoQs. If it is set to “No”, then RPR MAC Client will be a simple client that has one queue for each

priority. (Note: VoQ Client will schedule the individual queues in a packet-based round-robin fashion. If large packet sizes are used, it may lead to unfairness.)

- Max Number of Choke Points: RPR MAC Client will use this attribute for scheduling the VoQs.
- Rate Policer Active: If enabled, rate policing based on most congested node will be performed by the MAC. (NB: This option has not been tested in an interworking scenario).
- Unreserved Bandwidth Ratio: If set to a non-zero value, MAC will treat the ratio of the total link capacity on inner and outer rings as reserved.
- Dynamic Rate Shaper Enable: If enabled, MAC will adjust the allowed rate dynamically. (Note: If VoQ support is selected and dynamic rate shaping is enabled, rate policer will become active.) (NB: This option has not been tested in an interworking scenario)

2.4.2 Traffic Specification

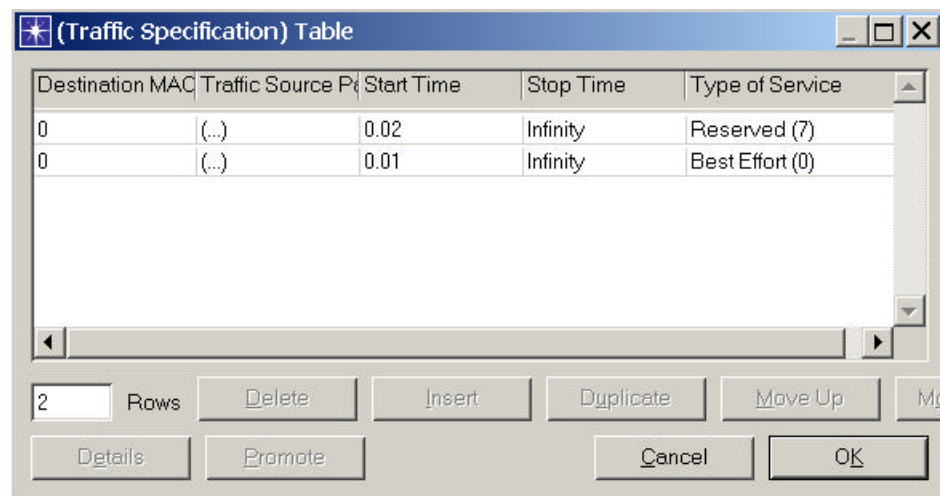


Figure 15. RPR-Aggressive Traffic Specification Settings

- Destination MAC Address: "MAC address" of the destination node to which traffic is sent by this node (Figure 15). Multi destination addresses can be specified. A set of traffic generators and their parameters has to be configured for each destination.

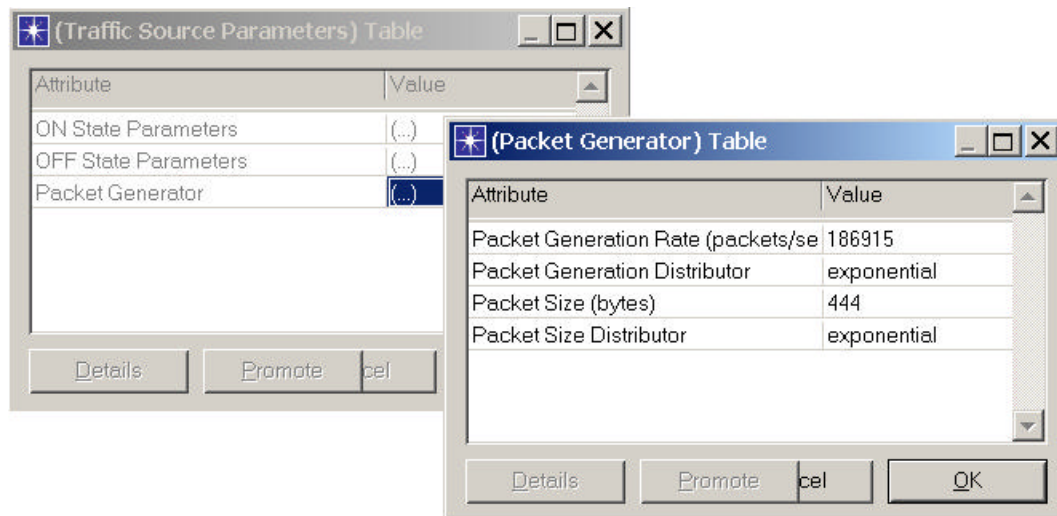


Figure 16. RPR-Aggressive Best Effort Packet Generator Settings (100% load)

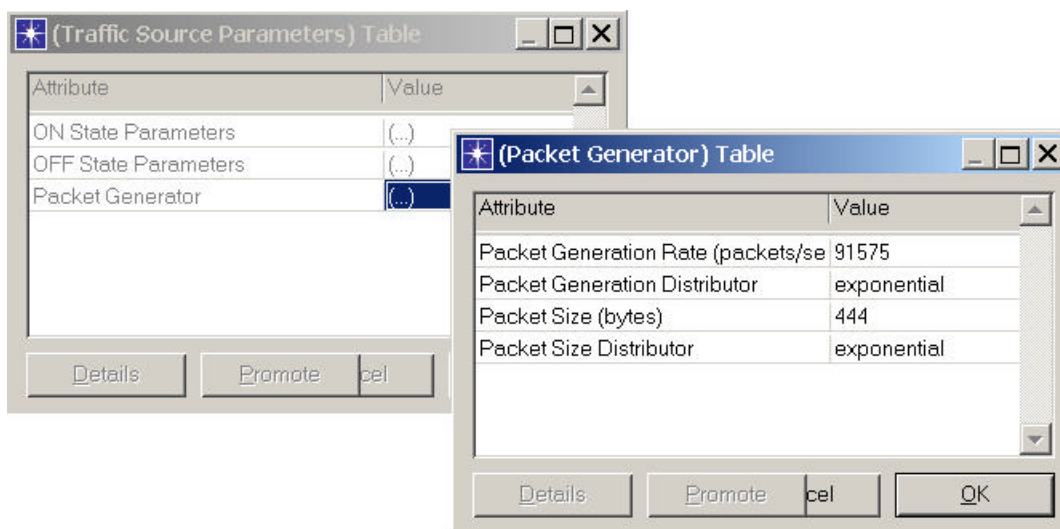


Figure 17. RPR-Aggressive Reserved Traffic Packet Generator Settings (50% load)

- **Traffic Generation Parameters:** This node contains an ON/OFF processor to generate traffic. This attribute controls the rate, size, start/stop times for traffic generation (Figure 16, Figure 17).

2.4.3 RPR-A MAC provides the following simulation attribute

- **RPR Topology Discovery Stop time:** This attribute is provided to run simulations faster. No topology discovery packets will be generated after this time.

2.5 Simulation Results

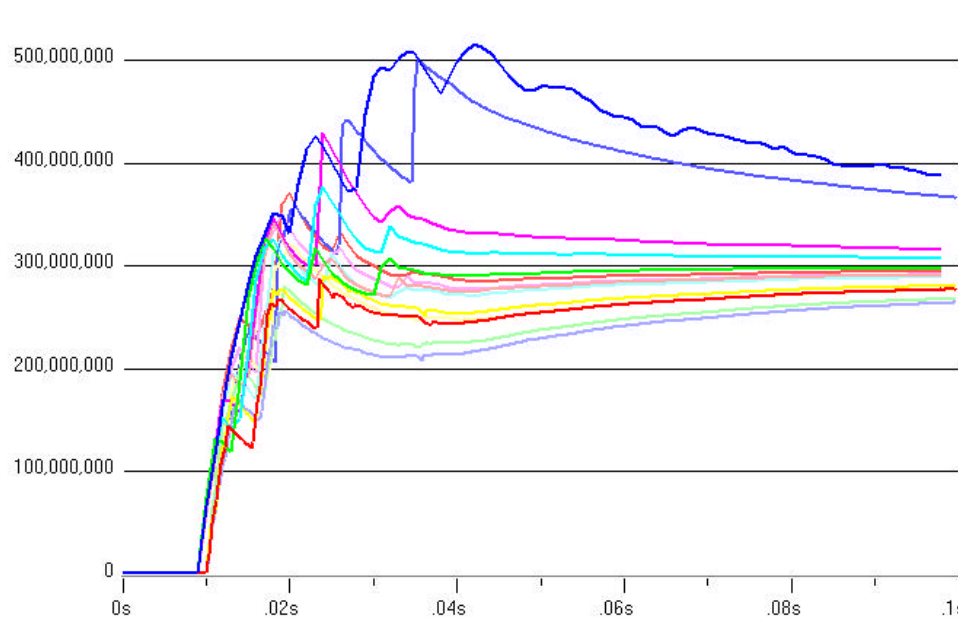


Figure 18. Graph of the time average of BE Throughput for Nodes 1 to 15

Figure 18 illustrates the time averages of the BE Throughput for Nodes 1 to 15. All the nodes have been setup with an equal weight, thereby they will receive an equal share of the bandwidth under congestion. The traffic generators are set to transmit approx. 663 Mbps, but the time average fair share calculated converge to approx 300 Mbps as shown in the figure.

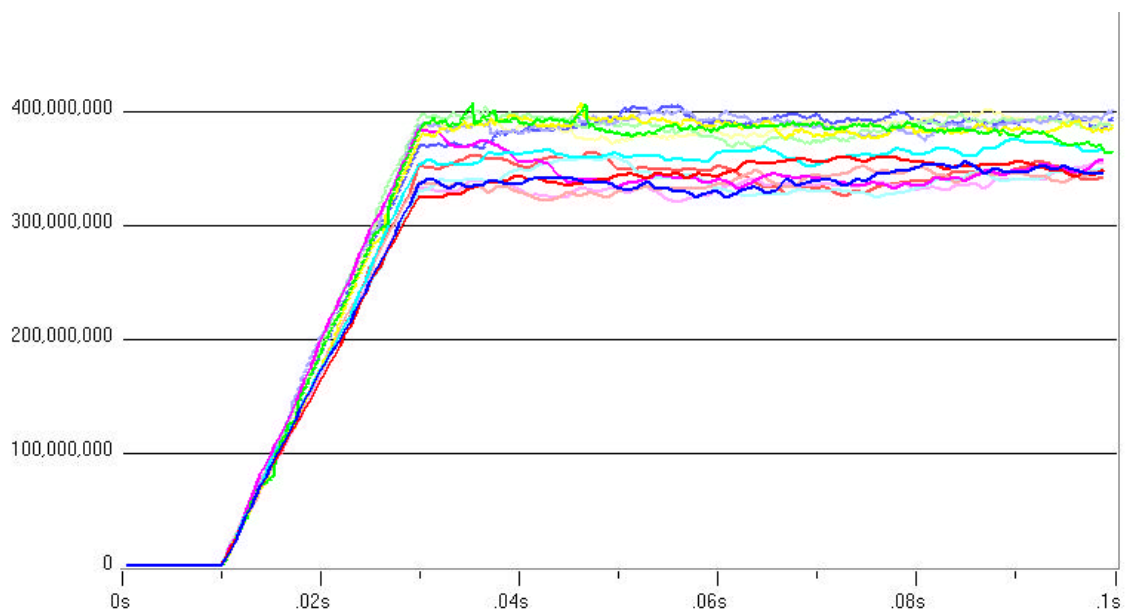


Figure 19. Graph of the moving average of FE Throughput for Nodes 1 to 15

Figure 19 shows the high priority traffic generated by all nodes. The parameters set create approx. 325 Mbps without including the RPR header, which is shown in the figure.

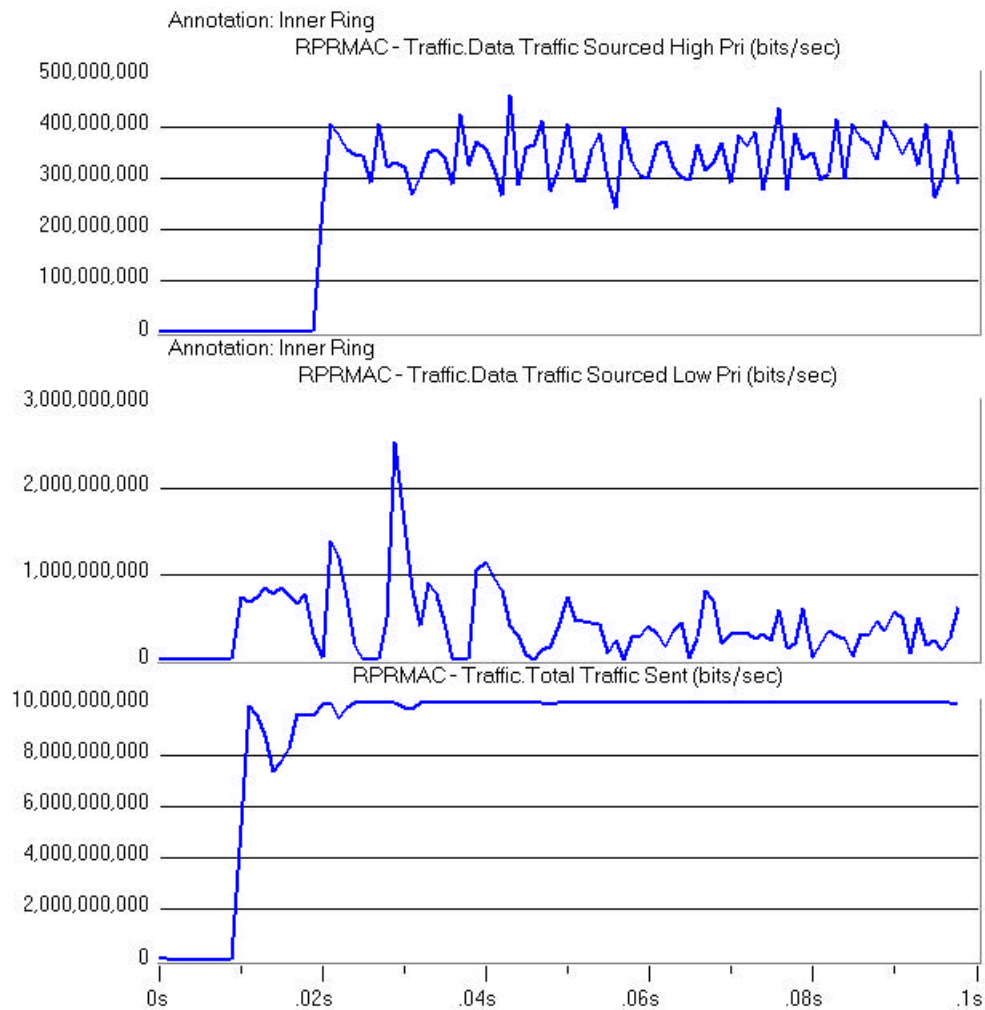


Figure 20. Graph of High and Low Priority data transmitted from Node 1 and utilization of the last link between Nodes 1 and 0.

In Figure 20 we find that the utilization is 100% after a initial transient period. We see that even if the low and high priority traffic data rate fluctuates, the utilization is quite stable at 100%.

