

# Enhanced Position Location Reporting System (EPLRS)

## Models User's Guide

7.0

Contract DASW01 03 D 0008

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**Disclaimer:** As of October 2007, NETWARS was redesignated by the Program Manager Office as the Joint Communications Simulation System (JCSS). JCSS was selected as the new industry name to better reflect the inherent joint communication capabilities of the software. Users should be aware that no software updates were conducted as part of the software name change.

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# 1 Overview

This document describes key features, attributes, usage, and statistics of the EPLRS device models shipped as part of the NETWARS models. As part of NETWARS 2007 model development, there are two devices models which, in combination, provide the EPLRS functionality. These devices are:

- EPLRS ENM (EPLRS Network Manager)
- EPLRS RS (Radio System)

EPLRS systems provide various forms of multi-hop radio communication between multiple EPLRS Radio Systems (RS) and the devices connected to each RS. The available options include, but are not limited to, One-to-One vs. Many-to-Many vs. Few-to-Many types of communications, Simplex vs. Duplex communications, and Short-Range vs. Long-Range communications.

## 1.1 Intended Use

This document is intended for NETWARS users who have a reasonable level of knowledge about the EPLRS systems and their use in a tactical network. This document is written to help engineers learn about configuration of EPLRS devices in NETWARS, and the types of interfaces, attributes, and statistics available in Discrete Event Simulations.

## 1.2 Feature Summary

The following table shows a summary of the most important data communication features of EPLRS and the presence or lack of support for them in the proposed EPLRS model in NETWARS.

*Table 1: EPLRS Features*

Feature	Support	Comments
<b>Time and Frequency Resources</b>		
Logical Time Slots	Supported	
Time Slot Index	Supported	
Frequency Channels	Supported	5, 6, 8 Channel Settings
Spread Spectrum/ Frequency Hopping	Supported	Modeling the effective processing gain
<b>Nodes and Interfaces</b>		
ENM Node	Supported	ENM Node is modeled as a Configuration Node and not a real radio device
RS Node	Supported	
<b>Network Features</b>		
Division ID	Supported	Only one ENM per division. Up to 6

		divisions.
CSMA Needlines	Supported	
MSG Needlines	Not supported	
HDR Duplex Needlines	Supported	
LDR Duplex Needlines	Not Supported	
DAP Needlines	Not Supported	
Waveforms	Supported	All 16 waveform modes supported
UTO definition	Not Supported	Common properties in the simulation environment can be applied to group of "selected nodes"
Security features	Not supported	No Key Distribution, Authentication, ...
<b>RS Node</b>		
RSID	Supported	
PVC interfaces	Supported	Arbitrary number of CSMA and HDR Duplex interfaces
Ethernet Interface	Supported	
ADDSI Interface	Not Supported	
MIL-STD-1553 Interface	Not Supported	
Serial Interface	Not Supported	
<b>ENM Node</b>		
ENM functionality	Supported	Only ENM configuration feature is modeled and functions such as monitoring and key distribution are not modeled
ENM Radio Node	Not Supported	The ENM is modeled as a standalone central configuration node. The ENM communication is not modeled explicitly.
<b>Extra Features</b>		
IP Multicast	Not Supported	
PVC Interface Auto Addressing	Supported	This optional capability does not exist on real devices and its availability in simulation environments greatly simplifies the configuration of the RS nodes
Static Routing	Supported	External IP addresses up to 2 hops away from the ETHERNET interface of the RS are reachable
Dynamic Routing	Supported	Normally, EPLRS radios use static routes configured on each radio to reach other nodes and destinations. However, the NETWARS model provides the optional capability of activating RIP or OSPF routing protocols on the PVC interfaces and remove the need for static route definitions

## 1.3 Theory of Operation

In this section a brief introduction to EPLRS is provided to introduce the terminology used throughout this document. The features supported by the NETWARS EPLRS model are a subset of the following general EPLRS features. An EPLRS network is a collection of a number of RS nodes that are configured and managed by one or more ENM nodes. The EPLRS System uses virtual circuits, called *needlines*, to set up communications between EPLRS RSs. A needline is a common set of time and frequency resources shared among two or more RSs to exchange data. The needlines can be either *many- to-many* or *one- to-one* and every RS can support many needlines at the same time. This allows RS units to simultaneously send and receive different information from different RSs. Figure 1 shows a conceptual illustration of how EPLRS needlines provide communication between multiple units in the battlefield. In the following, first the time and frequency resources in EPLRS are explained followed by explanation of different needline types and their properties.

### 1.3.1 EPLRS Resources

The EPLRS network is organized into a Time Division Multiple Access (TDMA) structure. Each RS in a network of RSs is assigned small slices of time (called timeslots) in which the RS can transmit while other RSs can receive. To accomplish this, each RS has a clock that is synchronized with the RS network. The time division entities that are fundamental to EPLRS are the timeslot, frame, and epoch. Timeslot is the smallest time unit in EPLRS during which one unit of information is transferred between two RSs.

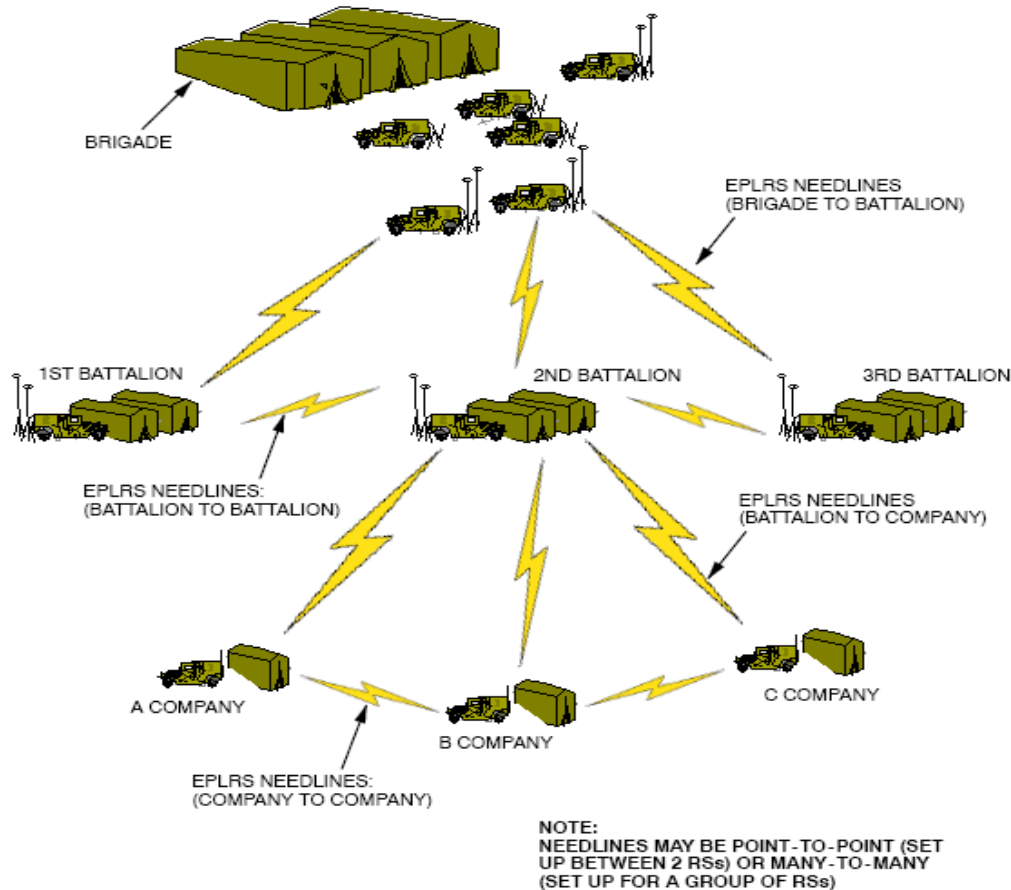


Figure 1. Conceptual structure of needlines in a battlefield

EPLRS allows two choices of 2 msec and 4 msec for the timeslot length in an EPLRS network. The timeslot mode is universal throughout an EPLRS network and remains fixed once it is chosen. A Frame is a group of 128 consecutive timeslots. The largest time division in EPLRS is called an epoch which consists of 256 consecutive frames. Figure 2 displays the time resource structure in EPLRS. The encoded data transmission accounts for some of the time within a timeslot, and the balance of the remaining time is required for setup, RF propagation delay and processing. Figure 3 shows a detailed view of how the 128 timeslots (numbered 0 - 127) are arranged in the frame. The timeslots are numbered such that the data assigned to timeslot 0 is broadcast first, then timeslot 1, then timeslot 2, etc. Timeslots within a frame can be viewed as blocks of timeslots in horizontal or vertical groups. Referring to Figure 3, the sixteen vertical groups of timeslots in a frame are labeled with a Timeslot Index (TSI) number of 0-15 and the eight horizontal group timeslots are labeled with a Logical Timeslot (LTS) number of 0 through 7. The ENM allocates time resources for users on an LTS-by-LTS basis, instead of individual timeslots, to allow the planner to work with manageable blocks of time.



EPLRS uses multiple frequency channels to allow simultaneous transmissions between multiple communicating pairs.

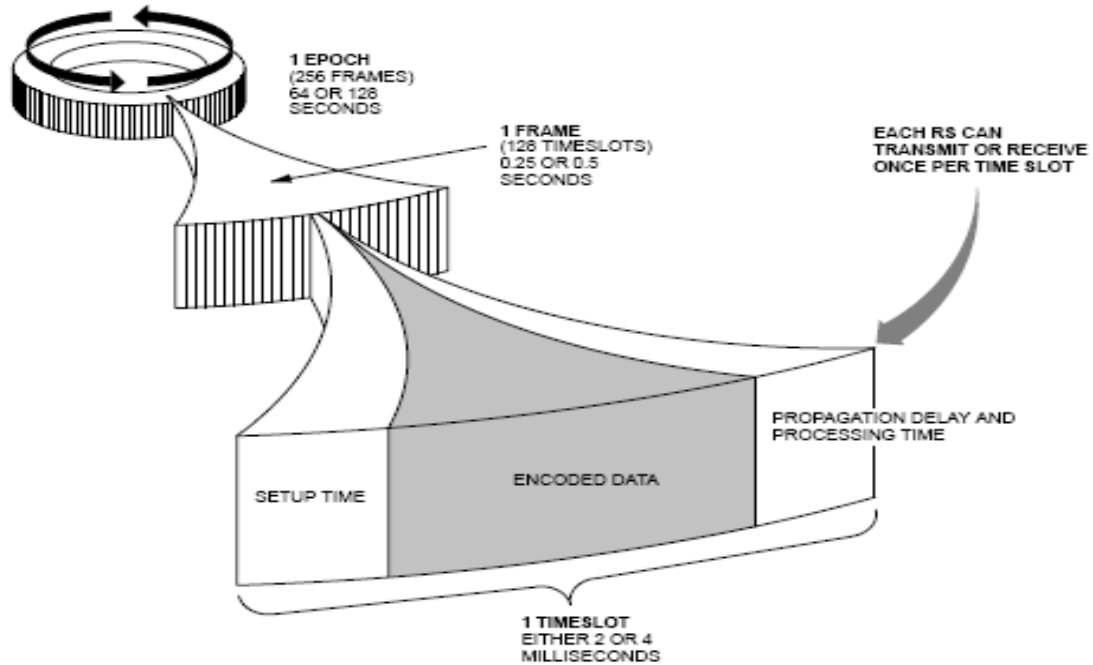


Figure 2. EPLRS Time Resource Architecture

LT#0	0	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120
LT#1	1	9	17	25	33	41	49	57	65	73	81	89	97	105	113	121
LT#2	2	10	18	26	34	42	50	58	66	74	82	90	98	106	114	122
LT#3	3	11	19	27	35	43	51	59	67	75	83	91	99	107	115	123
LT#4	4	12	20	28	36	44	52	60	68	76	84	92	100	108	116	124
LT#5	5	13	21	29	37	45	53	61	69	77	85	93	101	109	117	125
LT#6	6	14	22	30	38	46	54	62	70	78	86	94	102	110	118	126
LT#7	7	15	23	31	39	47	55	63	71	79	87	95	103	111	119	127
	TS#0	TS#1	TS#2	TS#3	TS#4	TS#5	TS#6	TS#7	TS#8	TS#9	TS#10	TS#11	TS#12	TS#13	TS#14	TS#15
	←----- 1 Frame -----→															

Figure 3. Timeslot Allocation in EPLRS Frame

This frequency division multiplexing over different frequencies (called channels in EPLRS) also increases network capacity and minimizes mutual interference. The maximum number of usable channels (called the channel set) is 5, 6 or 8. Figure 4 graphically depicts the three different channel sets. Once a channel set of five, six or eight is chosen, the planner can further modify the channel set by selecting or deselecting individual frequencies within the set to be used.

With both Time and Frequency resources available as explained above, the planner of an EPLRS network can allocate different sets of Logical Timeslots (LTS) and channels to

different needlines based on the bandwidth requirements of each needline. Figure 5 shows an example of such resource allocation in a tactical network.

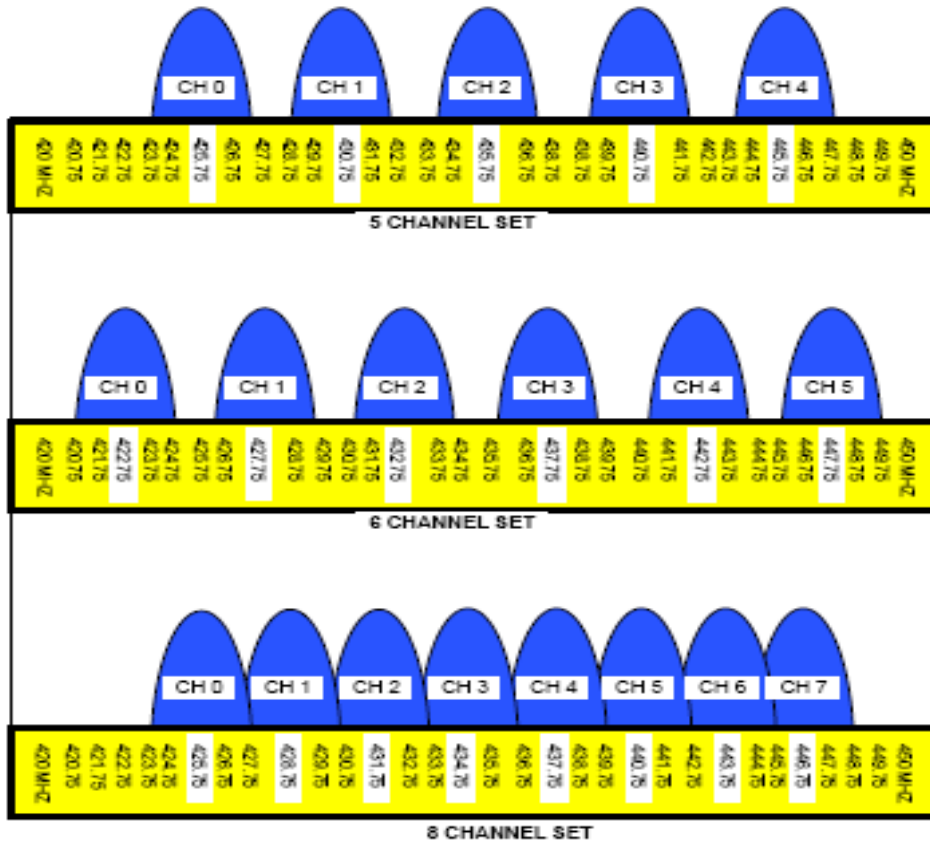


Figure 4. EPLRS Channel Options

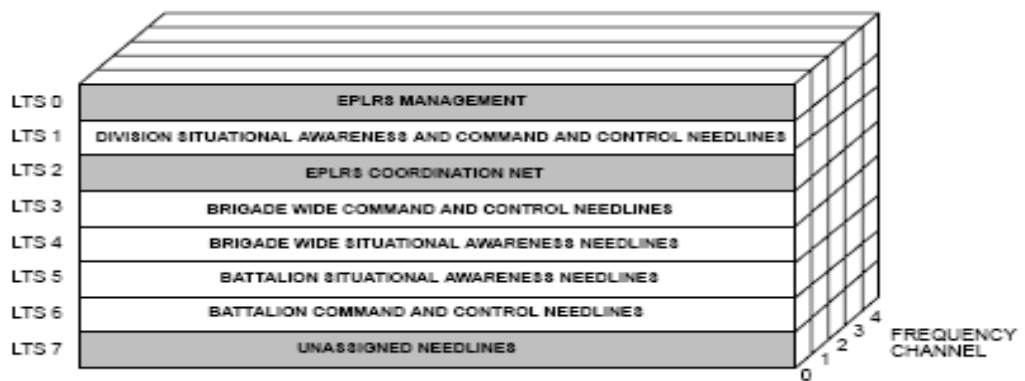


Figure 5. Example of an EPLRS Time and Frequency Resource Allocation Using Only Channel Zero of a Five Channel System

### 1.3.2 Waveforms

EPLRS provides various types of waveforms to support different operation properties of each of the needlines operating in an EPLRS network. Each waveform has a specific combination of payload size per slot, allowed propagation delay, modulation, spreading and error correction coding. Different waveforms, therefore, allow for different combinations of rate, range and error resiliency to be assigned to each needline based on its specific requirements. Figure 6 shows the main properties of EPLRS waveforms.

Waveform Group	Waveform Mode	Data Rate (kbps)	User Data Bits per Transmission	User Data Bytes per Transmission	General Anti-Jam Performance	90% Burst Throughput (dBm)	RS-to-RS Propagation Range (No Relays) (nautical miles)	RS-to-RS Propagation Range (No Relays) (Km)
Tactical Internet (2ms)	0	38	80	10	Better	-100	85	157
	1	38	80	10	Best	-102	64	118
	2	77	160	20	Better	-100	59	109
	3	115	240	30	Good	-98	59	109
	4	311	648	81	OK	-94	51	94
(SADL)	10	38	80	10	Good	-99	139	257
Expanded Data* (4ms)	5	65	272	34	Best	-102	87	161
	6	127	528	66	Better	-100	90	166
	7	184	768	96	Good	-98	81	150
	8	238	992	124	Good	-98	81	150
	9	486	2024	253	OK	-94	54	100
Expanded Range (4ms) (SADL)	11	44	184	23	Best	-101	341	631
	12	84	352	44	Better	-100	340	629
	13	119	496	62	Good	-99	337	624
	14	215	896	112	OK	-94	328	607

\* Future Capability

Figure 6. EPLRS Waveform Modes

### 1.3.3 EPLRS Needlines

EPLRS provides various types of communication services through different needline types available for the network planner. Needlines are virtual circuits between two or more EPLRS communication units. The needlines can be Many- to-Many, Few- to-Many

or One- to-One to support different host communication requirements. A single RS can support up to 32 needlines at the same time but the maximum number is usually 28 due to the coordination network being used on LTS 2. Supporting many needlines at once allows host computers connected to RSs to simultaneously send and receive different information to other host computers on the EPLRS network. Each needline is defined by its needline type and the waveform mode, timeslots, and channels assigned to that needline. The choice of time and frequency resources has a direct impact on the communication capacity of a needline while the choice of waveforms provides a tradeoff between rate, range and error resiliency for the needline. EPLRS provides 4 major needline types as discussed below. Only CSMA and HDR Duplex needline types are supported by the current EPLRS model.

### 1.3.3.1 CSMA Needlines

CSMA needlines provide many hosts the capability to send data to each other, with user data rates (for the whole needline) from about 150 bps to 971,520 bps. A CSMA needline allows a large number of endpoints to broadcast data to other members of the needline on demand. Source transmit opportunities are not reserved for particular endpoints as they are in all other types of EPLRS needlines. This feature allows hundreds of endpoints to source data on a single CSMA needline at different times and each source potentially use all of the available bandwidth if it is not used by the other nodes.

CSMA needlines can operate in 1 hop, 2 hops, 4 hops, and 6 hops modes where the number of hops in each mode shows how far (in terms of hops) the source and destination can be located from each other. CSMA uses what is called as the blocking relaying for multihop communication. For example, In a 4 hops CSMA needline, the source remain silent for 3 consecutive available timeslots after each transmission and then sends the next data segment on the fourth available timeslot. In other words, the source doesn't start the next transmission until the previous transmission has reached the maximum number of hops defined by the needline. The selection of relay nodes in a CSMA needline is performed in a global fashion and specific nodes will be assigned as "Relay" nodes by a proprietary "Relay Assignment" algorithm. All transmission by RS nodes on the needline will be relayed only by the relay nodes and if the relay nodes are selected properly, all other nodes on the needline will receive any transmission by any RS on that needline. CSMA needlines are defined for one-way communications and the transmissions are not acknowledged.

### 1.3.3.2 MSG Needlines (Not Supported)

The MSG needline provides hosts with a few- to-many communication capability. Messages are transmitted by a select group of Source RSs (RSs that are allowed to transmit data from their hosts to other RSs on the needline) and are carried on the MSG needline, either directly or through relays, to other RSs on the needline. Although there can be many RSs designated as sources on an MSG needline, only 16 source RS can be simultaneously active at any one time. Hosts connected to these source RSs on the MSG needline have the capability to send data, with guaranteed bandwidth without conflict, to many hosts, with user data rates from about 37.5 bps to 485,760 bps. In an MSG

needline, specific timeslots can be assigned to some sources so that they have dedicated resources whether or not it is actually used, while some other sources can demand and release timeslots based on the need. The main difference between the MSG and CSMA needlines is the availability of timeslot reservation is MSG needlines. MSG needlines can operate in either 2 hops or 6 hops mode. MSG uses pipeline relaying in Multihop communications meaning that the source only waits for one timeslot after each transmission (to allow the first hop make its transmission) and then sends the next segment. It obviously results in lesser waste of bandwidth compared to the blocking pipeline method used in the CSMA needlines. MSG needlines are defined for one-way communications and the transmissions are not acknowledged.

### **1.3.3.3 LDR Duplex Needlines (Not Supported)**

LDR duplex needlines provide one-to-one communication path between two RSs. Each transmission is acknowledged by the destination which ensures that the packets are received by the other end. These needlines provide high reliability balanced data transfer between two RSs with data rates from about 20 bps to 16192 bps, each way. LDR duplex needlines are automatically established via the coordination net. The coordination net uses relay path finding between the two LDR Duplex endpoints, and new relay paths are re-negotiated throughout the deployment period as required. The time and frequency resources for all LDR needlines are reserved before the deployment as a pool of resources. Individual LDR Duplex needlines will then be assigned some of the pool resources on an as-needed and availability basis.

### **1.3.3.4 HDR Duplex Needlines**

HDR Duplex needline provides the most reliable one-to-one communication path between two RSs (and their connected hosts) compared to all other needline types. HDR duplex needlines provide hosts with an acknowledged communications that ensures host data is received by the other host. In HDR duplex needlines the resources are reserved a priori and in both directions thus the bandwidth is always available for use by each of the two RSs. The data transfer rate between two hosts can range from about 600 bps to 242,880 bps, each way. This type of needline is similar to LDR duplex needlines, except the user data rate can be much higher. HDR duplex needlines can use the coordination net to set up and maintain needlines. HDR duplex can also be pre-planned by directing specific RSs to act as relays for the needline. The path between the two ends of the needline is in general determined by a “Path Finding” process which involves transmission of control packets from one end to discover a path to the destination using nodes with relay functionality and reverse transmission of the packet to the source to form a bidirectional path. This process will also involve assignment of timeslots and possibly frequency channels to each node on the path. These needlines use pipeline relaying similar to MSG needlines. HDR duplex needlines are pre-planned and the resources will be assigned specifically to each needline.

### **1.3.3.5 DAP Needlines (Not Supported)**

Dynamically Assigned PVCs (DAP) are the needlines that are established during the operation on an on-demand basis and are torn down when not needed. Resources for DAP needlines are allocated before the deployment as a pool of resources and when needed, some of those resources will be used to establish specific DAP needlines. DAP needlines are end-to-end duplex needlines and are established either as HDR or as LDR needlines.

### **1.3.4 EPLRS Network Management (ENM)**

EPLRS ENM is an application that facilitates the deployment of an EPLRS network by providing a detailed graphical user interface to make the planning process more structured and organized. All properties of all RSs and definitions of resources allocated to RSs, and to the needlines, are defined through use of the ENM node. The ENM also monitors the network topology regularly and makes updates to the network configuration if necessary. Communication between the ENM node and RSs is done using the LTS2 and the coordination net of EPLRS. In the absence of explicit modeling of the coordination net communications, the attribute structure of ENM, as the carrier of almost all properties of the network, needs to be carefully designed.

### **1.3.5 EPLRS Radio Set (RS)**

EPLRS RSs are the communication devices that make use of all the resources and needlines explained in the previous sections and serve as the nodes which form the EPLRS network. In addition to their radio interface, RS nodes can also contain some or all of the four types of wired interfaces namely, ADDSI, Ethernet, RS-232 and MIL-STD-1553B to allow connection of other computers (hosts) to them to use EPLRS communication services.

From the view point of IP hosts, an RS functions as an IP router with a number of wired interfaces as explained above and one radio interface per each needline that the RS is a member of. Each needline is defined as a separate IP interface called the PVC interfaces and an IP address is assigned to it. For each needline, the associated needline-specific protocols define the PHY and MAC layers for the associated IP interface. Each RS by default has an Ethernet IP interface and a DAP IP interface. Therefore, as an example, an RS which takes part in 4 needlines will have one Ethernet interface, one DAP interface and 4 PVC interfaces all defined as IP interfaces. Although all needline-related interfaces (including DAP) use the same physical interface, their transmissions are separated in time and frequency based on the initial definition of the needlines and the resources assigned to them. The routes on each interface are defined as static routes and no dynamic IP routing protocol is used by the EPLRS RS on its needline IP interfaces.

## 1.4 Feature Description

### 1.4.1 EPLRS ENM

In the current EPLRS model in NETWARS, only one ENM node per division is used. A division is defined by the RS nodes that operate under that division and a standard set of system operational parameters such as Active Channels, Time Slot Length, Default Radio Power and more importantly, the needlines defined for that division and their parameters and RS members. All of the above configuration information is defined by the attributes of the ENM node that is associated with the division. The ENM node is represented by the EPLRS\_ENM node model in NETWARS.

#### 1.4.1.1 System Parameters

Figure 7 shows the attributes of the EPLRS\_ENM node model. We use the term System Parameters for all attributes except the Needline Definitions attribute to emphasize the division-wide nature of those parameters. System parameters define the fundamental operation mode for the division and determine which frequency channels can be used by the division or what is the basic time slot length mode (2ms or 4ms) that will be used in the division. For quick configuration purposes, a default set of values is assigned to those attributes that can be used if it matches the requirements of the real-world network.

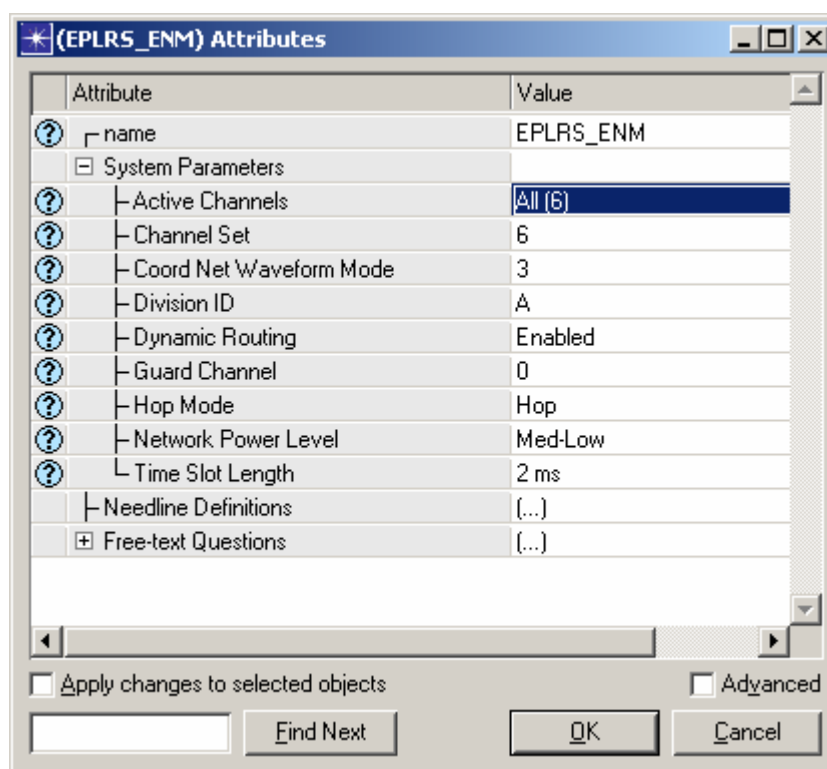


Figure 7: Attributes of the EPLRS\_ENM Node Model

The *Channel Set* and *Active Channels* attributes together define which channels will be used by the needlines of that division. *Division ID* is the identifier of the division and The *Hop Mode* attribute defines whether the frequency hopping is ON or OFF throughout the division. *Time Slot Length* takes one of 2ms and 4ms values and defines the basic slot length of the division. *Network Power Level* defines the power level used by each radio if the *Radio Power Level* is set to “Network Default”. *Dynamic Routing* is an attribute that does not exist in real EPLRS systems and is designed to facilitate quick deployment of EPLRS scenarios in NETWARS. Section 1.4.2.2 explains in more details how this attribute works. *Coord Net Waveform Mode* is an attribute that is not used in simulations and serves as a placeholder for the same attribute in real systems.

### 1.4.1.2 Needline Definitions

While *System Parameters* attributes define the basic operational parameters of an EPLRS division, no data can be transmitted unless at least one needline is defined for that division and some RS nodes have been listed as members of that needline. Figure 8 shows the structure of the *Needline Definitions* attribute. Each needline is identified by its unique name. The *Type* attribute defines what type of needline (CSMA or HDR Duplex) is defined under that name. *Relay Coverage* shows the maximum number of hops a message can travel from source to destination under that needline. The *LTS(s)* attribute defines which of the 8 logical time slots (LTS) is used by the needline for data transmission. However, not all of the slots within those LTSs will necessarily be used by the needline and that feature is defined by the combination of *Circuit Size* and *Sub LTS* attributes.

Name	Type	Relay Coverage	LTS(s)	Circuit Size	Sub LTS	Channel	Waveform	LCN	HDR Members	CSMA Members
CSMA_DF	CSMA	2 Hops (1 Relay)	LTS 2	1 LTS	Full	0	0	DF (Hex)	N/A	All Radios
CSMA_1	CSMA	4 Hops (3 Relay)	LTS 0,4	1 LTS	Full	0	4	5	N/A	All Radios

Figure 8: Needline Definitions attributes

The *Circuit Size* defines the fraction of the LTS (Full, 1/2 LTS or, 1/4 LTS) that is used by the needline and *Sub LTS* shows which fraction (0, 1, 2 or, 3 in case of 1/4 LTS and 0 or 1 in case of 1/2 LTS cases) of a full LTS is used by that needline. For example in Figure 9, four needlines use LTS 0 but each of them only uses a separate 1/4 share of that LTS defines by the *Sub LTS* attribute.



Name	Type	Relay Coverage	LTS(s)	Circuit Size	Sub LTS	Channel	Waveform	LCN	HDR Members	CSMA Members
CSMA_1	CSMA	2 Hops (1 Relay)	LTS 0	1/4 LTS	First 1/4	0	0	DF (Hex)	N/A	All Radios
CSMA_2	CSMA	2 Hops (1 Relay)	LTS 0	1/4 LTS	Second 1/4	0	4	5	N/A	All Radios
CSMA_3	CSMA	2 Hops (1 Relay)	LTS 0	1/4 LTS	Third 1/4	0	9	6	N/A	All Radios
CSMA_4	CSMA	2 Hops (1 Relay)	LTS 0	1/4 LTS	Fourth 1/4	0	9	7	N/A	All Radios

Figure 9 : Example needline configuration

The *Channel* attribute shows which channel, from the active channels defines in the system parameters, is used by the needline. *Waveform* is the index of the waveform used by the needline and *LCN* is the identifying number of the needline that is used by the model to map IP addresses to needlines. The “Auto Assigned” option for that attribute can be used to speed up the deployment of the network model. Once the time and frequency resources of a needline are defined, the user must specify which RS nodes will be part of that needline and can send or receive information over the needline. The “All Radios” option automatically makes all RS nodes under that division be members of the needline. Otherwise, the hierarchical names of all members (excluding the “top.” part of the name) should be added one by one under the *CSMA Members* or the *HDR Members* compound attribute depending on the type of the needline. Unlike the CSMA needline where all members have the same role and their names are added under one list, in a HDR Duplex needline the two endpoints of the needline need to be explicitly specified under the *Endpoint A* and *Endpoint B* sub-attributes of the *HDR Members* attribute. Also, any other RS that can potentially serve as a relay node between the two endpoints needs to be added under the *Relays* sub-attribute of the same attribute.

The CSMA\_DF needline shown in Figure 8 is a CSMA needlines that always exist by default under the *Needline Definitions* attribute. This needline is used by all RS nodes to exchange control messages with each other and thus should not be deleted.

### 1.4.1.3 Relay path-finding and other functions

It was explained before that in a CSMA needline each node can be the source, destination or just a relay node for a message transmission as long as it is a member of that needline. A message transmitted by a source RS will be broadcasted by any node that receives it (flooding) until it traverses the maximum number of hops defined for that needline. In the HDR Duplex needlines, on the other hand, a specific path between the two endpoints of the needline is established and only the relay nodes in that path forward each message only to the next hop in that direction of the path. This method offers a much more efficient use of the channel compared to the flooding method used in CSMA. However, reliance of the network on a specific path makes the transmission more susceptible to mobility and other effects that can result in disconnects along the path. To avoid such situations, all nodes under a HDR Duplex needline periodically exchange control messages to discover their neighbor RS nodes and monitor connectivity to them. When a

relay RS detects loss of connectivity with its next hop relay, it will notify the ENM node so that it can find an alternative path from the source to the destination. The topology of the network is maintained internally as a connectivity graph by the ENM node so that it can always find the shortest path between the endpoints of HDR Duplex needlines.

### 1.4.2 EPLRS RS

The EPLRS RS node is the single radio node models which is used in EPLRS networks in NETWARS. This node model is an IP-capable node and has two main interfaces namely, Ethernet and EPLRS radio interfaces. The Ethernet interface is a regular Ethernet interface under the IP layer that is used to connect the EPLRS radio node to external networks. Operation of each RS node is defined by the needlines it belongs to. Each RS node can be a member of arbitrary number of needlines and can receive and send traffic over each needline separately. Figure 10 shows the attributes of the RS node and highlights the 4 attributes under the EPLRS category.

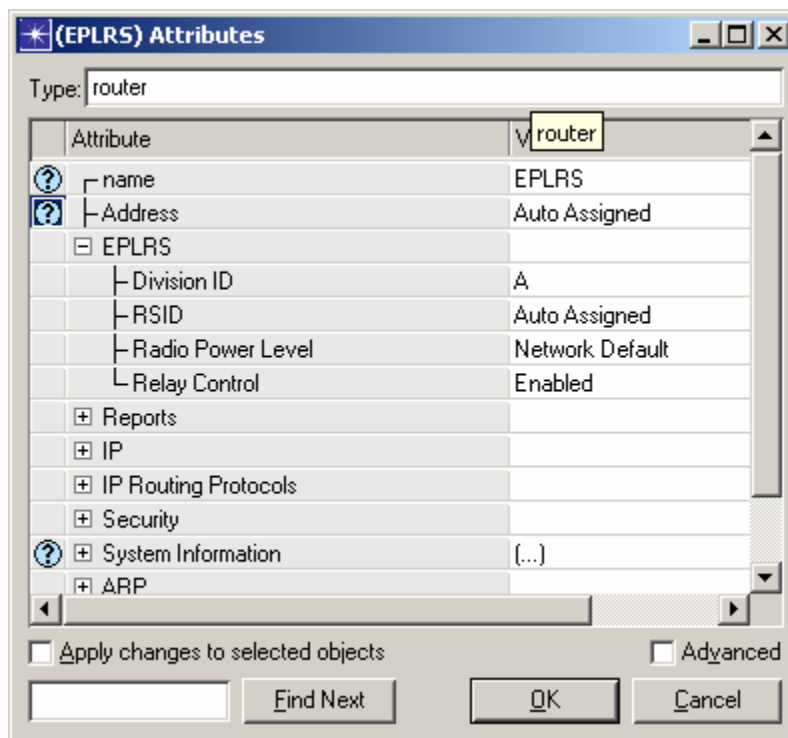


Figure 10: Attribute structure of the EPLRS RS node model

The *Division ID* attribute specifies the division and therefore the ENM node which carries the system parameters for the RS node. Each RS is identified by its unique *RSID* which is a positive integer number. The “Auto Assigned” option can be safely used to automatically assign valid addresses to RS nodes. The *Radio Power Level* defines the transmit power of the radio interface. Finally, the *Relay Control* Boolean attribute determines whether this node can perform relay functionality for any of the needlines it belongs to. The RS attribute structure does not show any relation to specific needlines

that RS belongs to except only the division ID of the ENM node where all the needlines for that division are defined. The effect of needlines on a RS node is in fact reflected on the IP interfaces of the RS node and is done automatically by the model once the needlines and their members are completely defined. In the next section, we will explain the IP interface structure of the RS node.

### 1.4.2.1 IP Interfaces

**Note:** The IP interface structure of the EPLRS\_RS node model is automatically set by the system and the user does not need to make any changes to that.

The EPLRS\_RS node model has 2 IP interfaces named ETHERNET and EPLRS. The EPLRS interface has as many subinterfaces as there are needlines which have that RS node as their member. The subinterfaces are created every time the needlines are defined or edited and the “OK” button of the attribute window of the ENM node is pressed. This means that **all RS nodes must be present in the scenario before configuring the needlines on the ENM node.**

Each needline subinterface is (automatically) configured with a primary and a secondary address. The secondary address of each subinterface is used to mimic the addressing scheme used in real EPLRS radios where addresses of the form 127.10.x.1 are assigned to different PVC (needline) interfaces. The primary address of each subinterface is used by the “Dynamic Routing” utility which will be explained in the following. The addressing scheme used for the primary addresses assumes that all subinterfaces on different radios in a division, which correspond to the same needline, belong to the same subnet and there are no other interfaces in that subnet. In other words, we have one subnet per needline. Both primary and secondary addresses for the interfaces are created as part of the automatic creation and configuration process of the interfaces and the user doesn’t need to be concerned about them.

### 1.4.2.2 IP Routing

IP routing in real EPLRS systems is done through configuration of static routes on RSs. In that scheme, for each destination IP address, the IP address of the PVC interface which should be used to carry the packet to its destination RS node will be specified as the next-hop address. In the current EPLRS model, exactly the same scheme can be used by specifying the secondary IP address of the proper needline subinterface as the next-hop address when configuring the static route for each destination IP address. Static routes are configured using the standard methodology provided by the IP module in NETWARS.

Although static routing closely represents the way EPLRS routing is configured in real-world, it may become a time consuming task in simulations with large number of radio nodes to configure static routes on all RS nodes. The Dynamic Routing utility provided in the EPLRS model is developed to overcome this problem. When the *Dynamic Routing* attribute of the ENM node is set to “Enabled”, it activates the RIP routing protocol on all needline subinterfaces on all RS nodes under that division. This allows the RS nodes to exchange routing information and build their dynamic routing tables without need for

static route definitions. Obviously, this utility should be used with care since it can potentially introduce different routes in the network from what an engineer would configure using static routes.

### 1.4.2.3 Waveforms

The EPLRS model in NETWARS supports 15 different waveforms defined for EPLRS systems by properly setting the payload size to what specified by each waveform. Moreover, the 90% point of the packet error rate curve for each waveform matches the 90% throughput threshold defined for that waveform in the documents. Assignment of waveforms to needlines is done in the *Needline Definitions* attribute of the ENM node. All RS nodes which are members of a needline will use the characteristics (payload size, error curve) of that waveform WHEN sending data over that needline.

## 1.5 Limitations/Assumptions

Due to the proprietary nature of the protocols and some parameters used in real EPLRS, some features and values have been developed in a generic way based on the partial information available for them. These approximations include but are not limited to:

- Relay Path-finding in HDR Duplex needlines
- Overhead size and modulation types in Waveforms
- ARP process
- Control Messages between Radios

## 1.6 Model List

The standard NETWARS model library contains two node models representing EPLRS devices. Those models can be located under the “Node Models” directory of the “NETWARS Radio Systems” palette as shown in figure 11. The new EPLRS model includes the models provided below. Other node models with the name “EPLRS” belong to older models of the EPLRS radio and are not compatible with the new model and its extended capabilities.

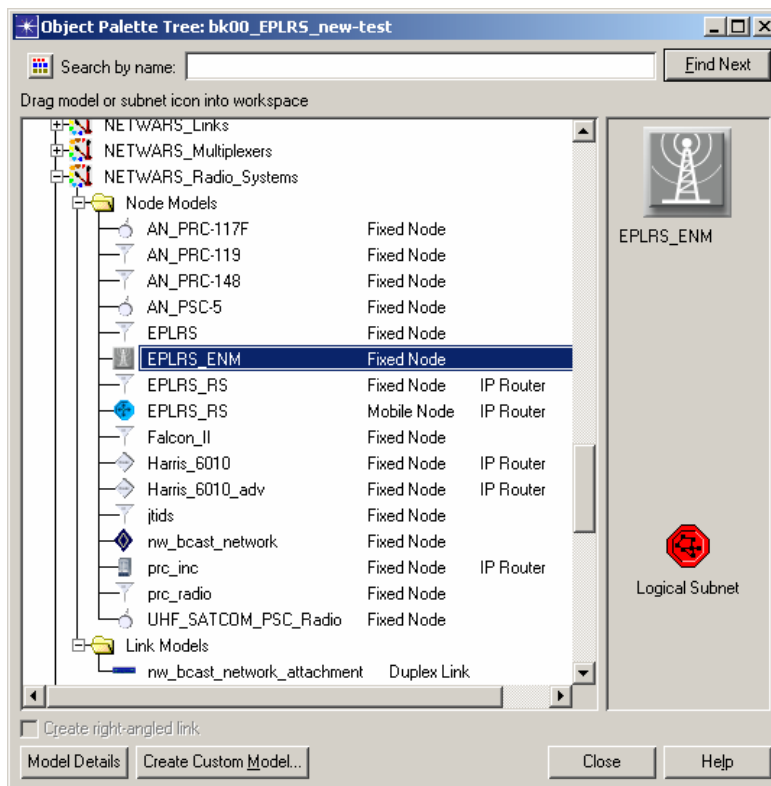


Figure 11: Location of EPLRS nodes in the palette

Table 2: EPLRS Node Models

Model Name	Function	Comments
EPLRS_ENM	Operational parameters for each Division	One ENM node per Division
EPLRS_RS	Single Radio node (RS)	1 Ethernet + 1 EPLRS interface

**Note:** The node model named EPLRS which exists under the same palette belongs to an older version of EPLRS developed in NETWARS and is not compatible with the new node models and the EPLRS networks defined by them.

## 1.7 Reference Documents

1. “Operator’s Manual for NET Control Station”, Part of Enhanced Position Location Reporting System (EPLRS), TB 11-5825-298-10-1.
2. “Planner’s Manual for EPLRS Networks”, Part of Enhanced Position Location Reporting System (EPLRS), TB 11-5825-298-10-3.

## 1.8 Additional Information

For any additional information not discussed in this document, please consult the NETWARS Model Development Guide (MDG) or other NETWARS documentation. Information provided in the Model Development Guide includes interfacing with NETWARS models, using NETWARS traffic types, expected packet formats and interrupts, and suggested model development processes, etc. This documentation is provided in a standard NETWARS installation and can be found in the <**NETWARS Installation Directory**>\<**Documents**> directory (where <**NETWARS Installation Directory**> is the directory where NETWARS is installed).

Also, for any questions dealing with OPNET specific functionality, consult the standard OPNET documentation. This documentation can be accessed inside NETWARS by using the **Help > Documentation > ITGuru Documentation** menu.

## 2 Configuration

The following steps need to be followed in the specified order for correct configuration of an EPLRS network:

- Deploying the ENM node and **all** required RS nodes in the scenario from the palette
- Configuring the ENM *System Parameters* attribute group
- Configuring the ENM *Needline Definitions* compound attribute

If a node needs to be added later to the scenario, the *Needline Definitions* attribute of the ENM node should be opened and “OK”ed even if no changes to the needlines is needed.

Also, if a change is being made to the ENM *System Parameters* attributes such as the *Channel Set*, *Active Channels* or the *Time Slot Length*, all needline definitions must be revisited and their attributes set again. This is because the previous channels may not be available any more or for example a change in the time slot length may cause the previous waveforms not to be available any more.

If an RS node is deleted from the network, the needline definitions need to be revisited only if that node has been specifically mentioned under either the *HDR Members* or *CSMA Members* of one or more needlines.

### 2.1 EPLRS\_ENM Attributes

The attributes of the ENM node are the most important part of the configuration of an EPLRS network. Each ENM node manages the operation of one division and there can be up to six EPLRS divisions in one scenario. As mentioned before, the active attributes of the ENM node properly configure the RS nodes based on their membership to different needlines defined in that ENM. This requires the RS nodes to be present in the network before the ENM attributes are set. Therefore, creating all RS nodes for each division is regarded as a prerequisite for the ENM configuration.

The first step to configure the ENM is to specify the division it represents and the time and frequency resources used by that division. This part is performed by configuring the *System Parameters* attributes of the ENM node (Figure 7). The 6-Channel option for the *Channel Set* provides the largest number of non-overlapping channels and the *Active Channels* is better to be set to “All (6)” unless not all channels are expected to be used by that division (for example when having two divisions i.e., two ENM nodes, and each of them using 3 channels).

The *Needline Definitions* attribute is the place where all needlines are defined and it is also defined which nodes are members of each needline or, equivalently, which needlines each node supports. Figures 8, 9, and 10 show different examples of needlines defined for a system. It is reminded again that the CSMA\_DF needline which exists by default under the *Needline Definitions* attribute, is used for control messaging and should not be removed (though its resources may be reduced if the number of nodes under that division is very low).

## 2.2 EPLRS\_RS Attributes

In principle, the only attribute that needs to be manually assigned on each RS node is the *Division ID* to specify the ENM node the RS needs to refer to for getting all system and needline information. Other attributes may be set if desired. Otherwise, the default values assigned to them should allow them to work in a typical configuration. These additional attributes are:

1. *RSID*: This is the unique integer number that identifies each RS node. If set to “Auto Assigned”, the system will pick a valid unique number for that.
2. *Radio Power Level*: This value is usually set to “Network Default” so that all nodes use the same power level as set on the division-wide “Network Power Level” attribute of the ENM node. However, if individual nodes are desired to have different power levels, it can be set on this attribute.
3. *Relay Control*: By default, all RS nodes can relay the received messages over the CSMA needlines they belong to, to other nodes around them. However, this can be overridden if not all nodes are required to serve as relays by setting the “Relay Control” attribute of those nodes to “Disabled”. In that case the node will not perform any relay functionality and simply drops the packets that are not destined for that node.



## 3 Usage

### 3.1 Discrete Event Simulation Statistics

The Discrete Event Simulation (DES) allows you to simulate the performance of a network in detail by actually sending packets and data across a created NETWARS scenario. The statistics gathered during this simulation allow you to gain specific details about how a network and particular devices are performing. This information provides you with a widespread picture of the simulated network and allows you to perform a wide variety of studies. The listed statistics below are the specific statistics available when using the NETWARS EPLRS models. Many other DES statistics are available based on the type of technologies deployed inside the scenario. However, as this document is based purely on the EPLRS device, the other available statistics are outside the scope of this document. Refer to the NETWARS and OPNET IT Guru standard documentation for more details on other statistics. EPLRS statistics are grouped under “EPLRS” group (under “Node Statistics”).

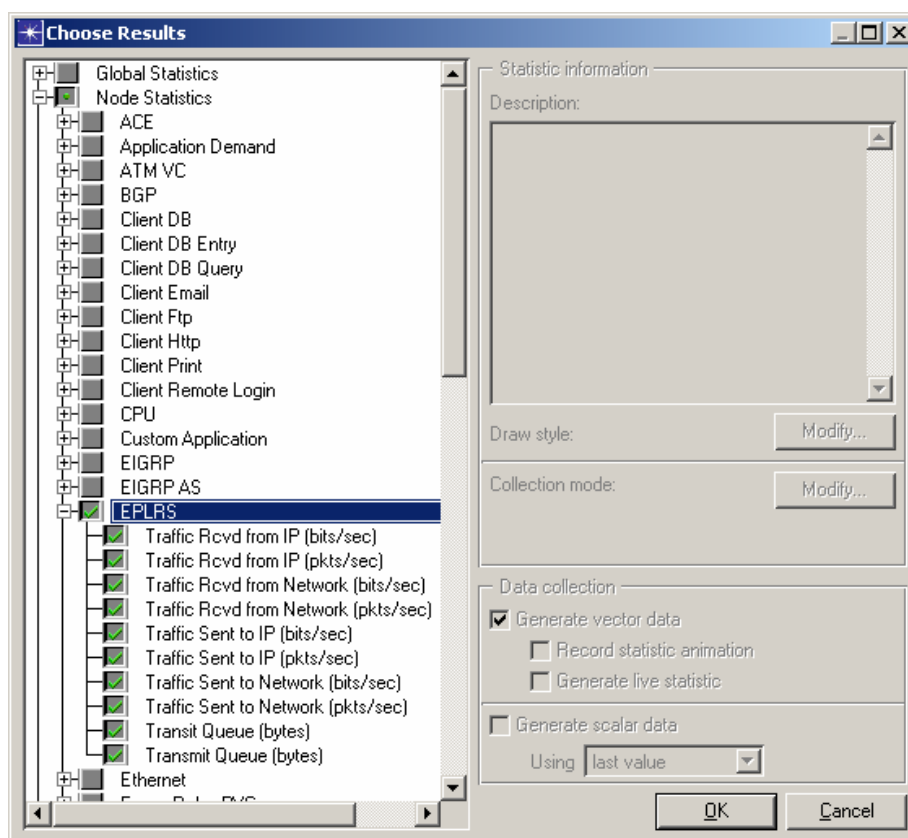


Figure 12: EPLRS related node statistics

To choose these statistics, right-click on a node or right-click in the workspace, and select “Choose Individual DES Statistics”. Figure 12 shows the list of the available statistics for the EPLRS nodes. The statistics include the volume of traffic which is sent to and

received from both the higher layer (IP) and lower layer (PHY, Network) by the EPLRS MAC process. The queue statistics shows the length of the transit and transmit queues. The transmit queue holds the packets received from the IP layer until they are sent to the network. The transit queue holds the packets received from the network and need to be forwarded to other RS nodes.

<b>Statistic</b>	<b>Description</b>
Traffic Rcvd from IP (bits/sec)	Rate of the traffic received by the EPLRS module from the IP layer in bits per second
Traffic Rcvd from IP (pkts/sec)	Rate of the traffic received by the EPLRS module from the IP layer in packets per second
Traffic Rcvd from Network (bits/sec)	Rate of the traffic received by the EPLRS module from the EPLRS network in bits per second
Traffic Rcvd from Network (pkts/sec)	Rate of the traffic received by the EPLRS module from the EPLRS network in packets per second
Traffic Sent to IP (bits/sec)	Rate of the traffic sent by the EPLRS module to the IP layer in bits per second
Traffic Sent to IP (pkts/sec)	Rate of the traffic sent by the EPLRS module to the IP layer in packets per second
Traffic Sent to Network (bits/sec)	Rate of the traffic sent by the EPLRS module to the EPLRS network in bits per second (both IP layer and relay traffic)
Traffic Sent to Network (pkts/sec)	Rate of the traffic sent by the EPLRS module to the EPLRS network in packets per second (both IP layer and relay traffic)
Transmit Queue (bytes)	Length of the buffer that is used to hold the received IP packets (from IP layer) until they are sent over the EPLRS network.
Transit Queue (bytes)	Length of the buffer that is used to hold the received EPLRS packets (from other EPLRS nodes) until they are sent again over the EPLRS network.

### 3.2 Traffic Usage

In general, EPLRS RS nodes do not create any traffic and only forward the traffic in one of the following three situations:

The EPLRS\_RS nodes receives generic IP over Ethernet traffic from an external device through its Ethernet interface and sends it to the IP layer so that it can be sent to the proper needline's IP sub-interface and reach the destination RS through the members of that needline. The traffic inside the EPLRS network (between RS nodes) is in the form of EPLRS packets and is only recognized by the EPLRS interfaces.

The RS node receives an EPLRS packet from its EPLRS interface. After determining which needline this packet corresponds to, it will be either queued and sent out again on the EPLRS network (Relay functionality) or, alternatively, the received packet will be queued as a segment of an IP packet and when the IP packet is fully reconstructed, it will be sent to the IP layer so that it will be forwarded to the Ethernet interface to reach an external device.

Since EPLRS RS nodes do not contain any application layer module, the traffic is typically configured on the devices connected to the RS nodes. The types of traffic that can be used are therefore determined by the type of the external node that is used regardless of the fact that it will be sent to the EPLRS network. The EPLRS Radios are typically used in conjunction with an Ethernet workstation connected to them directly or through a router between them (Figure 20). In that case, all types of traffic provided by NETWARS and OPNET Standard models (IERS, Flows, Discrete Application-Layer Traffic) can be configured on those workstation nodes.

### 3.3 Supported Equipment Strings

The EPLRS RS node provides a single Ethernet interface that can be connected to any other devices with an Ethernet interface. However, the most common cases are when an Ethernet workstation is directly connected to the RS node and when a workstation is connected through an IP router with at least one Ethernet interface (to connect to the EPLRS RS). These configurations are shown in figure 13 and figure 14.

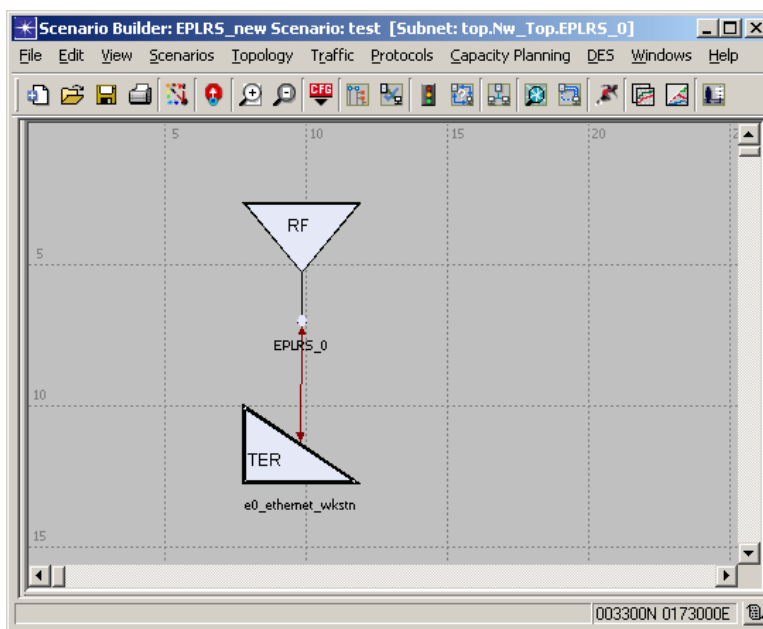


Figure 13: Direct connection of Ethernet workstation to EPLRS RS

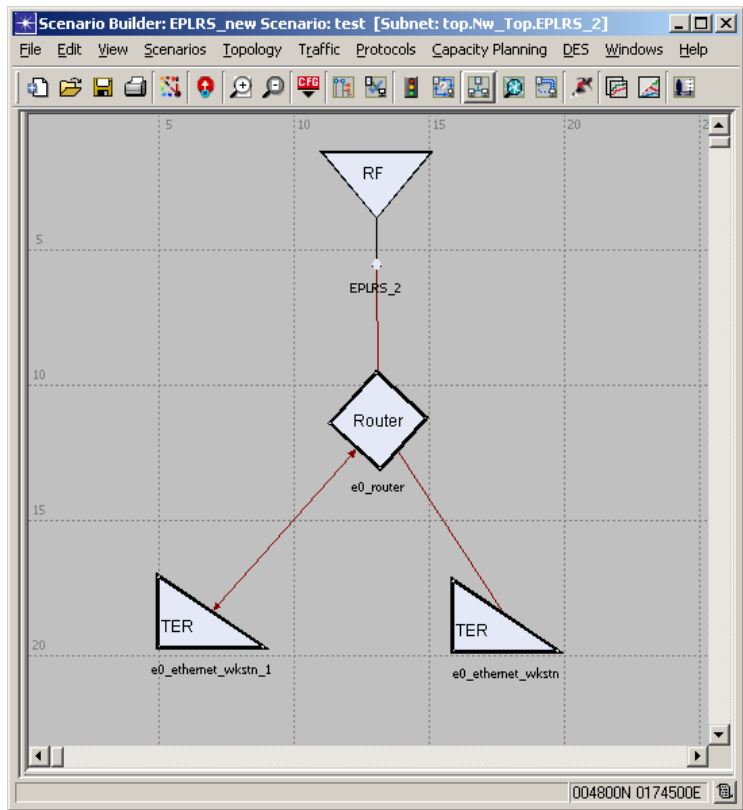
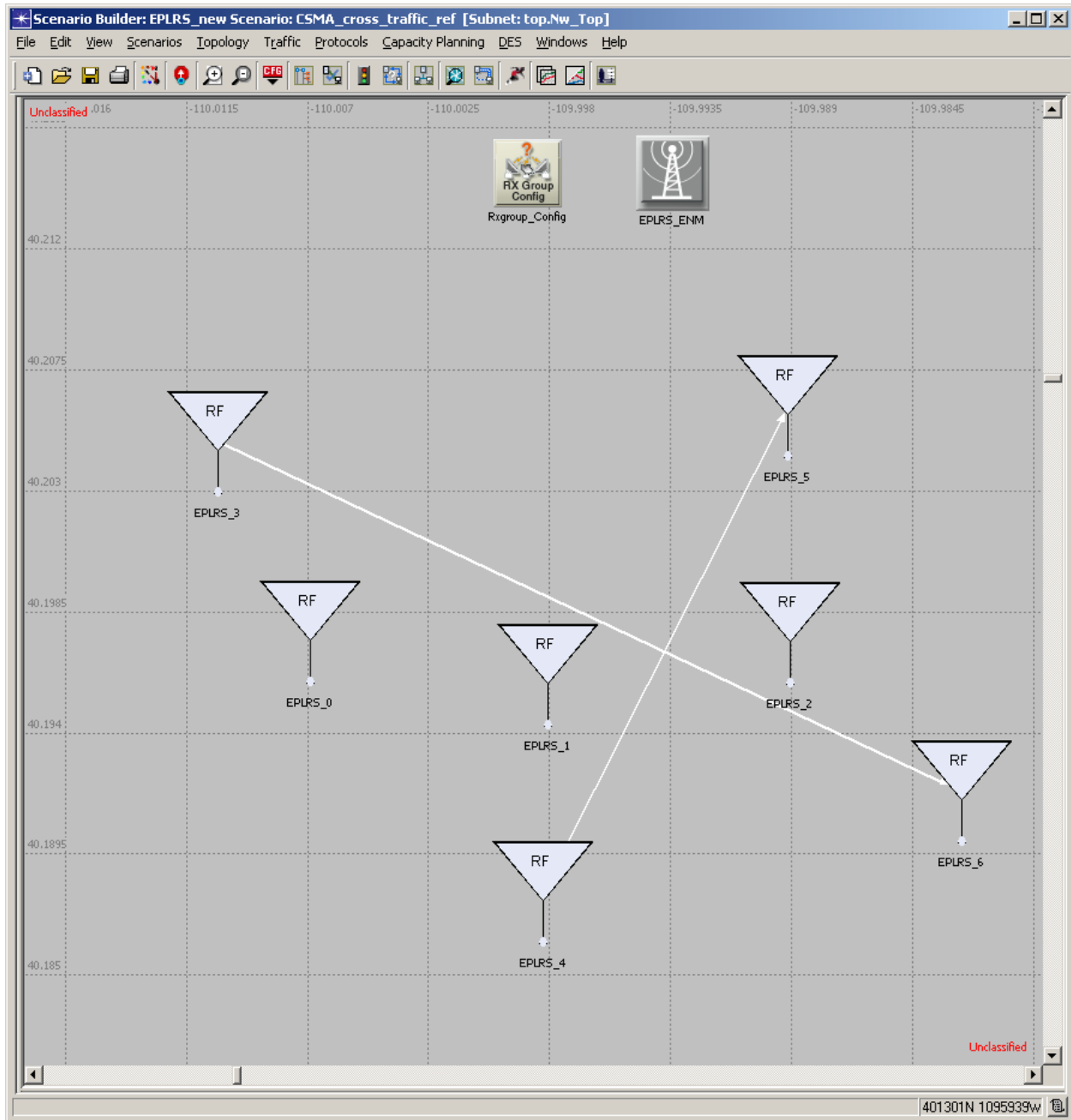


Figure 14: Use of IP router to connect multiple devices to EPLRS RS

Although the EPLRS RS can be potentially connected to the end IP node through arbitrary number of IP hops, it should be noted that the static routing option in EPLRS only supports addresses up to two hops away from the radio. This means that the above configurations work fine with both static and dynamic routing options. But any additional IP nodes between the workstation and the EPLRS RS can only be supported when the dynamic Routing utility is enabled. Finally, if an EPLRS radio is only used as a relay node, it can perform by itself and does not need to be connected to any external devices.

### 3.4 Example Scenarios

In this section, we explain the configuration process for both CSMA and HDR Duplex needline types by reviewing two example scenarios where each uses one of the needline types. Throughout this discussion, we will ignore the default CSMA\_DF needline that is always present since it is not used for data communication.



*Figure 15: EPLRS network with 2 CSMA needlines and selective membership for the data needlines.*

Figure 15 shows a scenario with one EPLRS division that contains 7 RS OPFACs. Each OPFAC in this scenario is a combination of an EPLRS RS node, a router connected to its Ethernet interface and a workstation node connected to the router (Figure 16). This typical configuration allows multiple IP devices to be connected to an EPLRS RS node via the router.

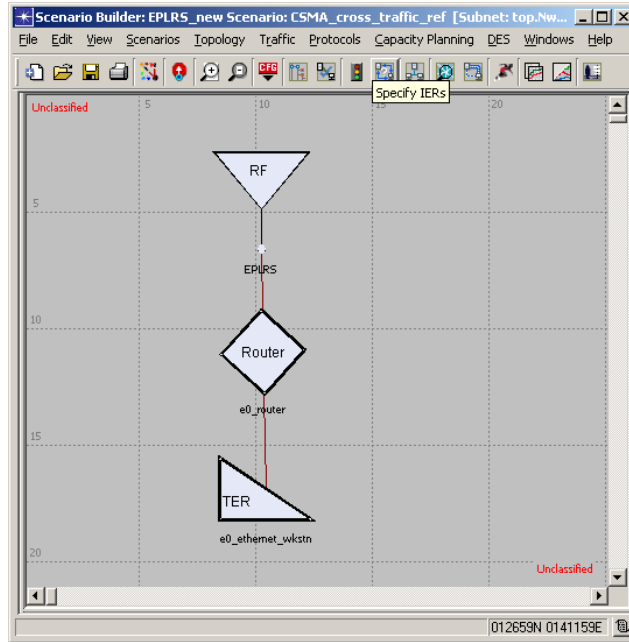


Figure 16: Connection of IP devices to EPLRS RS

In order to highlight the multi-hop behavior of the network, a receiver group configuration node (Rxgroup\_Config) is placed in the network and is configured to limit the communication range of each RS to 1Km with the grid in the scenario representing 500m blocks. This shows that, for example, traffic generated at EPLRS\_3 must pass through EPLRS\_0, EPLRS\_1 and EPLRS\_2 relays to reach its destination at EPLRS\_6. Figure 17 displays the division-wide settings for the division which shows that the 6-channels configuration is used and all 6 channels are active. It also shows that the Dynamic Routing is enabled which means no static routing configurations are needed on the nodes.

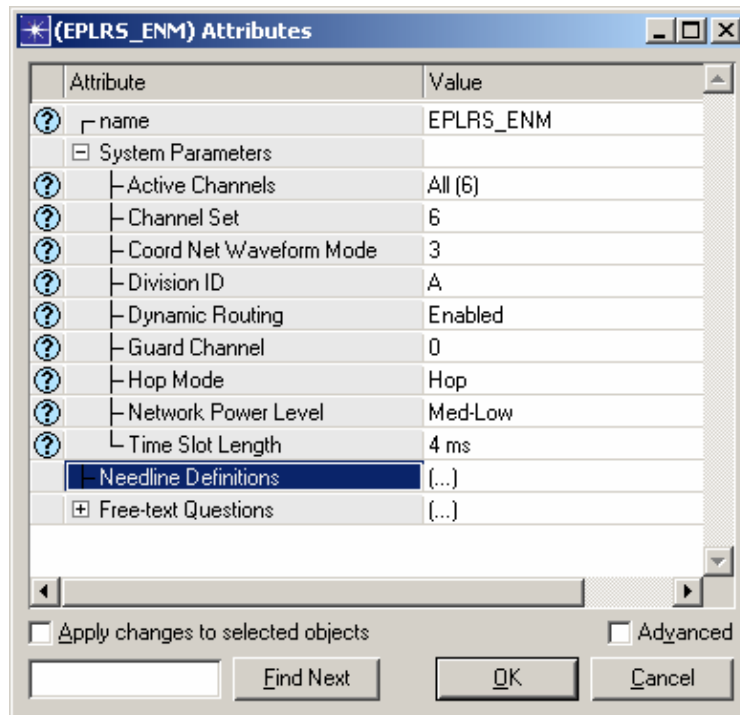


Figure 17: System Parameters of the division

The Default Power Level for the radios is set to “Med-Low” and the system uses the 4ms time slot length option. The Time Slot Length chosen in this part will determine the available waveforms for the needlines.

There are 2 CSMA needlines in this division named CSMA\_1 and CSMA\_2 which are defined under the Needline Definitions attribute of the ENM node as shown in Figure 18.

Name	Type	Relay Coverage	LTS(s)	Circuit Size	Sub LTS	Channel	Waveform	LCN	HDR Members	CSMA Members
CSMA_DF	CSMA	2 Hops (1 Relay)	LTS 2	1 LTS	Full	0	5	DF (Hex)	N/A	All Radios
CSMA_1	CSMA	4 Hops (3 Relay)	LTS 0.4	1 LTS	Full	0	9	5	N/A	(...)
CSMA_2	CSMA	4 Hops (3 Relay)	LTS 1.5	1 LTS	Full	0	9	6	N/A	(...)

Figure 18: Needline definitions for figure 12 network

Both needlines are set to the 4-Hops “Relay Coverage” mode meaning that each packet will only be relayed 3 times after leaving the source RS and can reach the destination RS only if it is within a 4-hops “radius” of the source. The choice of the “Relay Coverage” is a trade of between the communication range and the data capacity of the network. A higher coverage number results into longer usage of bandwidth for each packet due to more relaying transmissions of the same packet. The “LTS(s)”, “Circuit Size” and, “Sub

LTS” attributes for the two needlines show that each needline uses 2 full separate Less. Since all 3 needlines in this ENM use separate LTS resources. There is no need for assigning different frequency channels to them and the “Channel” attribute is set to 0 for all of them meaning that they all use channel 0 for communications. The traffic is set between node EPLRS\_3 and EPLRS\_6 and also between EPLRS\_4 and EPLRS\_5. The two separate needlines in this scenario are in fact introduced to carry these two traffic flows separately so that they use different resources and don’t interfere with each other. In this example scenario, nodes EPLRS\_0, EPLRS\_1 and EPLRS\_2 are assumed to be located in the middle of the network and will be used as relays for both traffic flows. The CSMA\_1 needline carries the traffic between EPLRS\_3 and EPLRS\_6 and therefore it only has these two nodes plus the 3 relay nodes as its members (Figure 19).

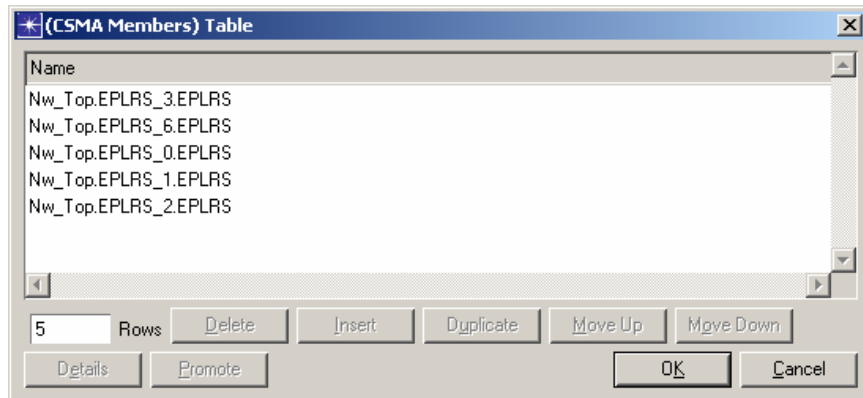


Figure 19: Needline member definitions for figure 12 network

Similarly, the CSMA\_2 needline only has EPLRS\_4 and EPLRS\_5 and the three relay nodes as its members (Figure 20).

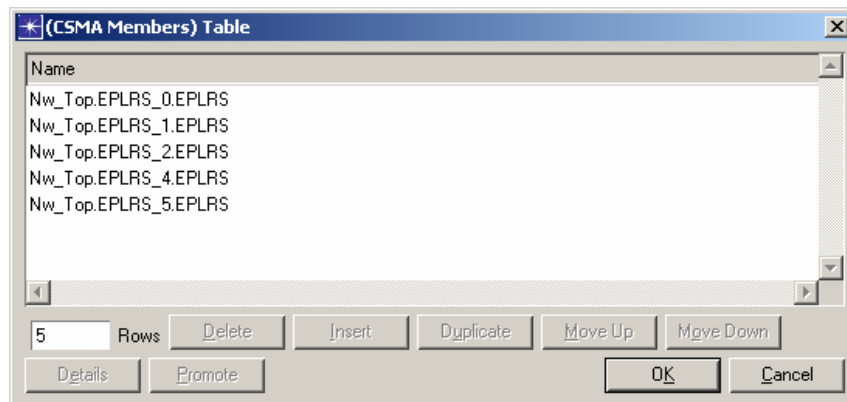
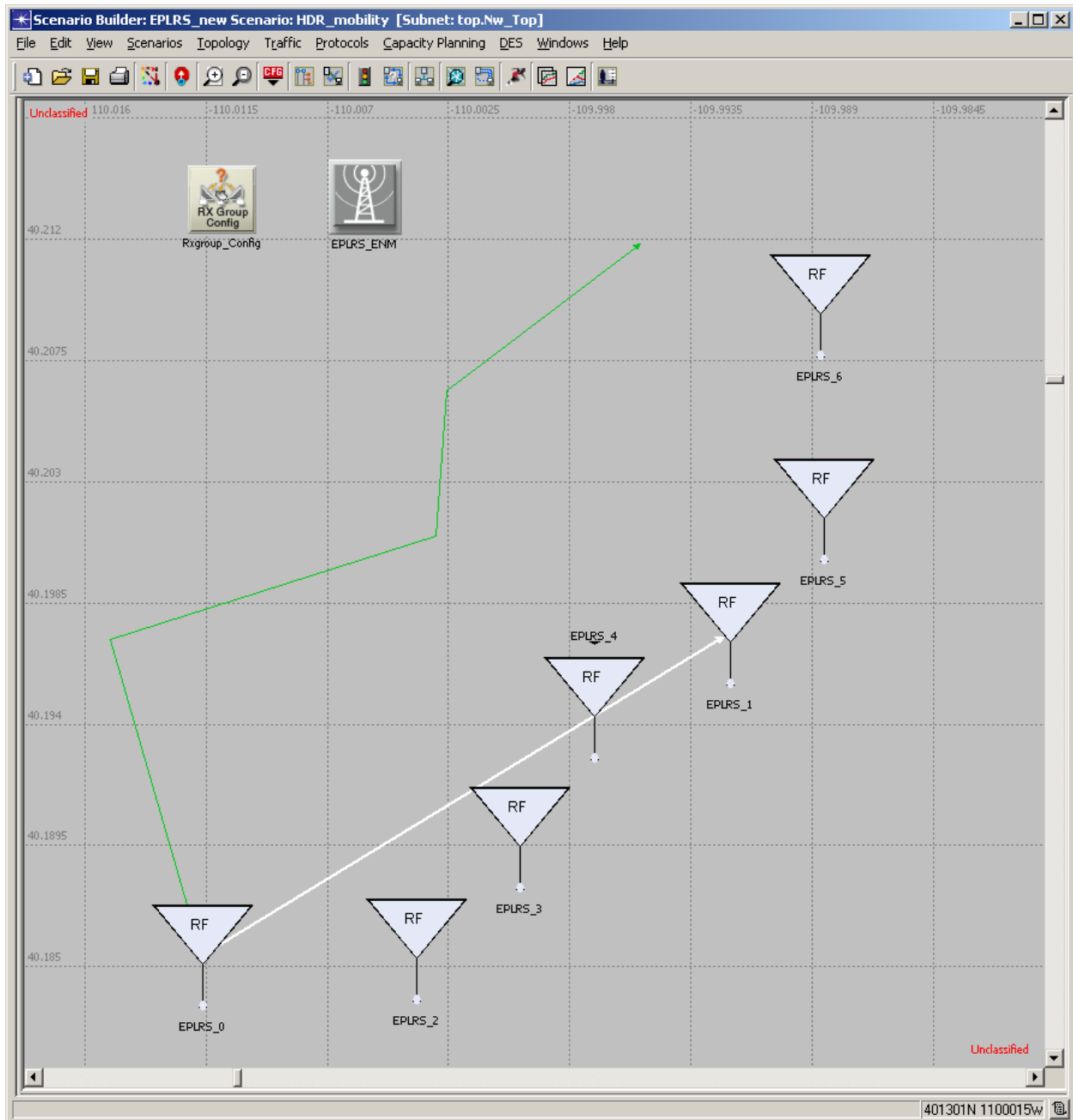


Figure 20: Needline member definitions for figure 12 network

The next example scenario (Figure 21) shows how the HDR Duplex needlines are configured. In this network, a dedicated duplex communication line between RS nodes in EPLRS\_0 and EPLRS\_1 OPFACs is required. Also, since EPLRS\_0 is a mobile node



which moves on the trajectory shown in the scenario, the traffic should be re-routed if the path breaks. This network uses the same “System Parameters” as used by the previous scenario. However, instead of using a many-to-many CSMA needline, it uses a one-to-one HDR Duplex needline to establish the link. This is done by configuring a needline as shown in figure 22.



*Figure 21: EPLRS network with an HDR Duplex needline and node mobility representing path break-up and re-establishment*

In this case, the needline type is set to HDR Duplex and one full LTS (LTS 0) is dedicated to that. HDR Duplex needlines provide 1-Hop (direct communications), 2-Hop, 4-Hop and, 6-Hop relay coverage options.

Name	Type	Relay Coverage	LTS(s)	Circuit Size	Sub LTS	Channel	Waveform	LCN	HDR Members	CSMA Members
CSMA_DF	CSMA	2 Hops (1 Relay)	LTS 2	1 LTS	Full	0	0	DF (Hex)	N/A	All Radios
HDR_1	HDR Duplex	4 Hops (3 Relay)	LTS 0	1 LTS	Full	(1,4)	4	5	(...)	N/A

Figure 22: Needline definitions for figure 16 network

The last two options (4 and 6 hops) require 2 frequency channels to be assigned to the needline and only those options will be provided for the “Channel” attribute when the 4 or 6-hops mode are chosen. The HDR endpoints and the relays are configured under the “HDR Members” attribute as shown in figure 23.

Endpoint A	Endpoint B	Relays
Nw_Top.EPLRS_0.EPLRS_0	Nw_Top.EPLRS_1.EPLRS_1	All Radios

Figure 23: Needline member definitions for figure 16 network

In this case, all nodes have been assigned as potential relays for this needline so that if the initial path is broken, a new path can be established by using other nodes as relays. The initial path between EPLRS\_0 and EPLRS\_1 is expected to be through EPLRS\_2, EPLRS\_3 and, EPLRS\_4 nodes. However, EPLRS\_0 trajectory suggests that the path will be broken when EPLRS\_0 moves towards Waypoint 1 since it cannot reach any relay node at that point. When EPLRS\_0 moves toward Waypoint 2, it will establish connectivity with EPLRS\_4 at some point and a new path to EPLRS\_1 will be established through EPLRS\_4. Again, the new path will be lost as the source moves towards Waypoint 3 but it should be reestablished when EPLRS\_0 approaches Waypoint 4 and established connectivity with EPLRS\_6. In that case, the path should go through EPLRS\_5 and EPLRS\_5.

A look at the collected statistics for this scenario shows the operation of the network as predicted by the above argument. Figure 24 shows the relayed traffic at nodes EPLRS\_2,

EPLRS\_4 and EPLRS\_6. As we expect, EPLRS\_2 is only on the initial path between the endpoints and after that the traffic doesn't pass through that node. However, EPLRS\_4 is on the path both when the endpoint EPLRS\_0 is at its initial position and also when it is at waypoint 2. EPLRS\_6 is on the path only near the end of the simulation when EPLRS\_0 reaches Waypoint 4 and established a path through EPLRS\_6 and EPLRS\_5.

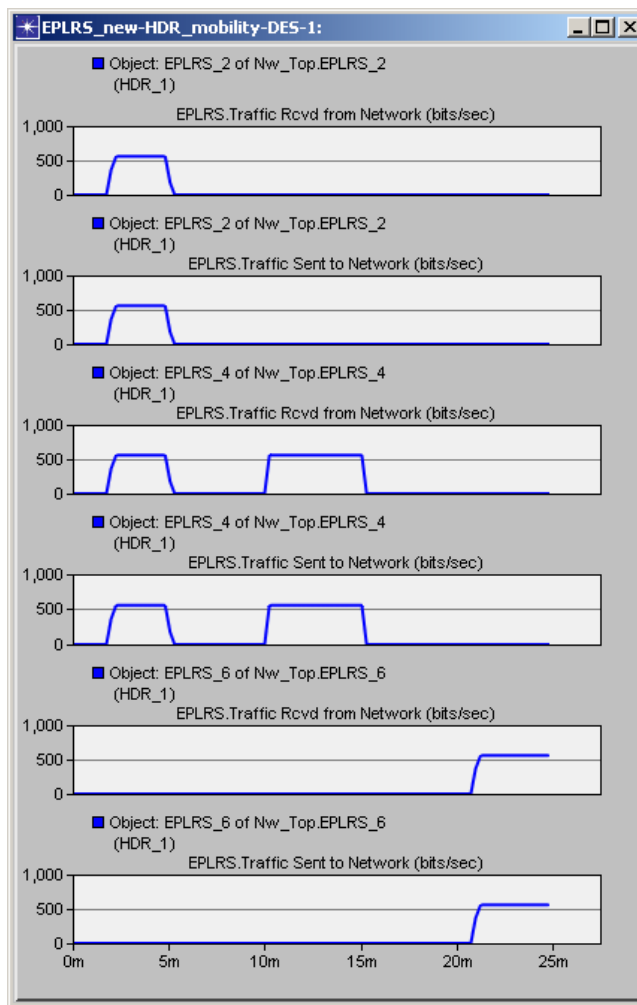


Figure 24: Relayed traffic by the intermediate nodes in the HDR Duplex scenario

### 3.5 Troubleshooting

The relative complexity of EPLRS in terms of its features and options makes it more susceptible to configuration errors made by the users. The EPLRS model in NETWARS provides various forms of checking and debugging tools that make it simple for the user to troubleshoot a misconfigured network. Below, is a suggested troubleshooting checklist for locating possible problems in an EPLRS network:

- **Simulation Aborts:** These types of error result in a simulation abort and typically happen at time 0 when the different attributes of the EPLRS network (ENM and RS

- nodes) are being read and processed by the model. Some of the common causes of this type of errors are as follows:
- Addition of RS nodes after the ENM node has been configured
    - A number of active attribute handlers on the ENM automatically perform necessary configurations on the RS node every time the OK button on the ENM “Needline Definitions” attribute window is pressed. If a node is added to the scenario after the initial ENM configuration, the ENM “Needline Definitions” attribute window needs to be opened and “OK”ed to configure the newly added RS nodes.
  - Duplicate LCN numbers for Needlines
    - If the “LCN” field of a needline definition is set to “Auto Assigned”, it will be given a unique LCN number by the active attribute handlers and that number will be written in the attribute cell. If LCN numbers are assigned manually, user must make sure they are all unique integer numbers.
  - Incorrect node name in the needline members attribute
    - Under both the “CSMA Members” and “HDR Members” attributes, the hierarchical name of the RS nodes must be entered. The hierarchical name starts from the Nw\_Top and goes down the subnet hierarchy until it ends with the name of the RS node. The “top” subnet string is not part of the hierarchical name.
  - Incorrect end-to-end traffic flow: This type of error is not specific to EPLRS and is a typical problem in any communication network. The following are the suggested checkpoints to diagnose the problem:
    - Statistics: the data rate statistics can be effectively used to trace the flow of traffic from the IP layer of the source RS node, to the MAC layers of the relay RS nodes and finally to the IP layer of the destination RS node.
    - ODB traces: for more precise debugging and troubleshooting, a number of traces have been defined which, when activated, provide useful information about the feature they represent. These traces are as follows:
      - *eplrs\_enm*: this trace displays the initial information about the needlines and RS nodes that is prepared by the ENM node.
      - *eplrs\_mac*: this trace displays information about the operation of the EPLRS MAC process. Each RS node has a MAC process which creates as many CSMA or HDR child processes as necessary for that RS node
      - *eplrs\_csma*: this trace displays information about the operation of the CSMA needlines
      - *eplrs\_hdr*: this trace displays information about the operation of the HDR Duplex needlines
      - *eplrs\_pipeline*: this trace displays information about the physical layer operation of the EPLRS performed by the pipeline stages
      - *eplrs\_autoaddr*: this trace shows detail information about the IP addresses assigned to IP interfaces of the RS nodes

- *eplrs\_hello*: the trace shows information about the sending and receiving of the hello messages by the RS nodes. This trace enables the user to detect one-hop connectivity among the RS nodes.
- *eplrs\_graph*: this trace displays the information about the operation performed on the graph of each needline. The ENM node creates a separate graph for each HDR Duplex needline in the network. Every RS node creates a vertex representing that node on the graphs associated with all the needlines that RS belongs to. The RS nodes also use the periodic hello messages to detect and monitor their neighbor RS nodes and add or delete the corresponding edges on the graphs. The graphs are used to find the shortest paths between the endpoints of each HDR Duplex needline and find new paths when the current path is broken.
- IP forwarding tables at the source node: If the traffic does not reach the EPLRS MAC layer from IP, the problem should be sought in the IP layer and IP forwarding tables created by the standard OPNET IP module is the best starting point for finding the cause.