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S. Ratliff
VT iDirect
B. Berry

S. Jury
Cisco Systems
D. Satterwhite
Broadcom
R. Taylor
Airbus Defence & Space

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Dynamic Link Exchange Protocol (DLEP)
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Abstract

When routing devices rely on modems to effect communications over wireless links, they need timely and accurate knowledge of the characteristics of the link (speed, state, etc.) in order to make forwarding decisions. In mobile or other environments where these characteristics change frequently, manual configurations or the inference of state through routing or transport protocols does not allow the router to make the best decisions. A bidirectional, event-driven communication channel between the router and the modem is necessary.

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1. Introduction

There exist today a collection of modem devices that control links of variable datarate and quality. Examples of these types of links include line-of-sight (LOS) terrestrial radios, satellite terminals, and cable/DSL modems. Fluctuations in speed and quality of these links can occur due to configuration, or on a moment-to-moment basis, due to physical phenomena like multipath interference, obstructions, rain fade, etc. It is also quite possible that link quality and datarate varies with respect to individual destinations on a link, and with the type of traffic being sent. As an example, consider the case of an 802.11g access point, serving 2 associated laptop computers. In this environment, the answer to the question "What is the datarate on the 802.11g link?" is "It depends on which associated laptop we're talking about, and on what kind of traffic is being sent." While the first laptop, being physically close to the access point, may have a datarate of 54Mbps for unicast traffic, the other laptop, being relatively far away, or obstructed by some object, can simultaneously have a datarate of only 32Mbps for unicast. However, for multicast traffic sent from the access point, all traffic is sent at the base transmission rate (which is configurable, but depending on the model of the access point, is usually 24Mbps or less).

In addition to utilizing variable datarate links, mobile networks are challenged by the notion that link connectivity will come and go over time, without an effect on a router's interface state (Up or Down). Effectively utilizing a relatively short-lived connection is problematic in IP routed networks, as routing protocols tend to rely

on interface state and independent timers at OSI Layer 3 to maintain network convergence (e.g., HELLO messages and/or recognition of DEAD routing adjacencies). These dynamic connections can be better utilized with an event-driven paradigm, where acquisition of a new neighbor (or loss of an existing one) is signaled, as opposed to a paradigm driven by timers and/or interface state.

Another complicating factor for mobile networks are the different methods of physically connecting the modem devices to the router. Modems can be deployed as an interface card in a router's chassis, or as a standalone device connected to the router via Ethernet or serial link. In the case of Ethernet or serial attachment, with existing protocols and techniques, routing software cannot be aware of convergence events occurring on the radio link (e.g., acquisition or loss of a potential routing neighbor), nor can the router be aware of the actual capacity of the link. This lack of awareness, along with the variability in datarate, leads to a situation where finding the (current) best route through the network to a given destination is difficult to establish and properly maintain. This is especially true of demand-based access schemes such as Demand Assigned Multiple Access (DAMA) implementations used on some satellite systems. With a DAMA-based system, additional datarate may be available, but will not be used unless the network devices emit traffic at a rate higher than the currently established rate. Increasing the traffic rate does not guarantee additional datarate will be allocated; rather, it may result in data loss and additional retransmissions on the link.

Addressing the challenges listed above, the co-authors have developed the Dynamic Link Exchange Protocol, or DLEP. The DLEP protocol runs between a router and its attached modem devices, allowing the modem to communicate link characteristics as they change, and convergence events (acquisition and loss of potential routing destinations). The following diagrams are used to illustrate the scope of DLEP packets.

```
|-------Local Node-------|          |-------Remote Node------|
|                        |          |                        |
+--------+       +-------+          +-------+       +--------+
| Router |=======| Modem |{~~~~~~~~}| Modem |=======| Router |
|        |       | Device|          | Device|       |        |
+--------+       +-------+          +-------+       +--------+
         |       |       | Link     |       |       |
         |-DLEP--|       | Protocol |       |-DLEP--|
         |       |       | (e.g.    |       |       |
         |       |       | 802.11)  |       |       |
```

Figure 1: DLEP Network

In Figure 1, when the local modem detects the presence of a remote node, it (the local modem) sends a signal to its router via the DLEP protocol. The signal consists of an indication of what change has occurred on the link (e.g., presence of a remote node detected), along with a collection of DLEP-defined Data Items that further describe the change. Upon receipt of the signal, the local router may take whatever action it deems appropriate, such as initiating discovery protocols, and/or issuing HELLO messages to converge the network. On a continuing, as-needed basis, the modem devices use DLEP to report any characteristics of the link (datarate, latency, etc.) that have changed. DLEP is independent of the link type and topology supported by the modem. Note that the DLEP protocol is specified to run only on the local link between router and modem. Some over the air signaling may be necessary between the local and remote modem in order to provide some parameters in DLEP signals between the local modem and local router, but DLEP does not specify how such over the air signaling is carried out. Over the air signaling is purely a matter for the modem implementer.

Figure 2 shows how DLEP can support a configuration where routers are connected with different link types. In this example, Modem A implements a point-to-point link, and Modem B is connected via a shared medium. In both cases, the DLEP protocol is used to report the characteristics of the link (datarate, latency, etc.) to routers. The modem is also able to use the DLEP session to notify the router when the remote node is lost, shortening the time required to re-converge the network.

```
                 +--------+                     +--------+
            +----+ Modem A|                     | Modem A+---+
            |    | Device |  <===== // ======>  | Device |   |
            |    +--------+      P-2-P Link     +--------+   |
        +---+----+                                       +---+----+
        | Router |                                       | Router |
        |        |                                       |        |
        +---+----+                                       +---+----+
            |     +--------+                     +--------+  |
            +-----+ Modem B|                     | Modem B|  |
                  | Device |   o o o o o o o o   | Device +--+
                  +--------+    o  Shared   o    +--------+
                                 o Medium  o
                                  o       o
                                   o     o
                                    o   o
                                      o
                                 +--------+
                                 | Modem B|
                                 | Device |
                                 +---+----+
                                     |
                                     |
                                 +---+----+
                                 | Router |
                                 |        |
                                 +--------+
```

Figure 2: DLEP Network with Multiple Modem Devices

1.1. Protocol Overview

As mentioned earlier, DLEP defines a set of signals used by modems and their attached routers. The signals are used to communicate events that occur on the physical link(s) managed by the modem: for example, a remote node entering or leaving the network, or that the link has changed. Associated with these signals are a set of data items - information that describes the remote node (e.g., address information), and/or the characteristics of the link to the remote node.

The protocol is defined as a collection of type-length-value (TLV) based formats, specifying the signals that are exchanged between a router and a modem, and the data items associated with the signal. This document specifies transport of DLEP signals and data items via the TCP transport, with a UDP-based discovery mechanism. Other transports for the protocol are possible, but are outside the scope of this document.

DLEP uses a session-oriented paradigm between the modem device and its associated router. If multiple modem devices are attached to a router (as in Figure 2), or the modem supports multiple connections (via multiple logical or physical interfaces), then separate DLEP sessions exist for each modem or connection. This router/modem session provides a carrier for information exchange concerning 'destinations' that are available via the modem device. A 'destination' can be either physical (as in the case of a specific far-end router), or a logical destination (as in a Multicast group). As such, all of the destination-level exchanges in DLEP can be envisioned as building an information base concerning the remote nodes, and the link characteristics to those nodes.

Multicast traffic destined for the variable-quality network (the network accessed via the DLEP modem) is handled in IP networks by deriving a Layer 2 MAC address based on the Layer 3 address. Leveraging on this scheme, multicast traffic is supported in DLEP simply by treating the derived MAC address as any other 'destination' (albeit a logical one) in the network. To support these logical destinations, one of the DLEP participants (typically, the router) informs the other as to the existence of the logical destination. The modem, once it is aware of the existence of this logical destination, reports link characteristics just as it would for any other destination in the network. The specific algorithms a modem would use to derive metrics on multicast (or logical) destinations is outside the scope of this specification, and is left to specific implementations to decide.

1.2. Requirements

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14, RFC 2119 [RFC2119].

2. Assumptions

Routers and modems that exist as part of the same node (e.g., that are locally connected) can use a discovery technique to locate each other, thus avoiding a priori configuration. The router is responsible for initializing the discovery process, using the Peer Discovery signal (Section 7.1).

DLEP uses a session-oriented paradigm. A router and modem form a session by completing the discovery and initialization process. This router-modem session persists unless or until it either (1) times out, based on the timeout values supplied, or (2) is explicitly torn down by one of the participants. Note that while use of timers in

DLEP is optional, it is strongly recommended that implementations choose to run with timers enabled.

DLEP assumes that the MAC address for delivering data traffic is the MAC specified in the Destination Up signal (Section 7.9). No manipulation or substitution is performed; the MAC address supplied in Destination Up is used as the OSI Layer 2 Destination MAC address. DLEP also assumes that MAC addresses MUST be unique within the context of a router-modem session. Additionally, DLEP can support MAC addresses in either EUI-48 or EUI-64 format, with the restriction that ALL MAC addresses for a given DLEP session MUST be in the same format, and MUST be consistent with the MAC address format of the connected modem (e.g., if the modem is connected to the router with an EUI-48 MAC, all destination addresses via that modem MUST be expressed in EUI-48 format).

DLEP uses UDP multicast for single-hop discovery, and TCP for transport of the control signals. Therefore, DLEP assumes that the modem and router have topologically consistent IP addresses assigned. It is recommended that DLEP implementations utilize IPv6 link-local addresses to reduce the administrative burden of address assignment.

Destinations can be identified by either the router or the modem, and represent a specific destination (e.g., an address) that exists on the link(s) managed by the modem. A destination MUST contain a MAC address, it MAY optionally include a Layer 3 address (or addresses). Note that since a destination is a MAC address, the MAC could reference a logical destination, as in a derived multicast MAC address, as well as a physical device. As destinations are discovered, DLEP routers and modems build an information base on destinations accessible via the modem.

The DLEP signals concerning destinations thus become the way for routers and modems to maintain, and notify each other about, an information base representing the physical and logical (e.g., multicast) destinations accessible via the modem device. The information base would contain addressing information (i.e. MAC address, and OPTIONALLY, Layer 3 addresses), link characteristics (metrics), and OPTIONALLY, flow control information (credits).

DLEP assumes that any signal not understood by a receiver MUST result in an error indication being sent to the originator, and also MUST result in termination of the session between the DLEP peers. Any DLEP data item not understood by a receiver MUST also result in termination of the session.

DLEP assumes that security on the session (e.g., authentication of session partners, encryption of traffic, or both) is dealt with by

the underlying transport mechanism (e.g., by using a transport such as TLS [RFC5246]).

This document specifies an implementation of the DLEP signals and data items running over the TCP transport. It is assumed that DLEP running over other transport mechanisms would be documented separately.

3. Core Features and Optional Extensions

DLEP has a core set of signals and data items that MUST be processed without error by an implementation in order to guarantee interoperability and therefore make the implementation DLEP compliant. This document defines the core set of signals and data items, listing them as 'mandatory'. It should be noted that some core signals and data items might not be used during the lifetime of a single DLEP session, but a compliant implementation MUST support them.

While this document represents the best efforts of the working group to be functionally complete, it is recognized that extensions to DLEP will in all likelihood be necessary as more link types are used. To support future extension of DLEP, this document describes an extension negotiation capability to be used during session initialization via the Extensions Supported data item, documented in Section 8.7 of this document.

All extensions are considered OPTIONAL. Only the DLEP functionality listed as 'mandatory' is required by implementation in order to be DLEP compliant.

This specification defines one extension, Credit windowing, exposed via the Extensions Supported mechanism that implementations MAY choose to implement, or to omit.

3.1. Negotiation of Optional Extensions

Optional extensions supported by an implementation MUST be declared to potential DLEP peers using the Extensions Supported data item (Section 8.7) during the session initialization sequence. Once both peers have exchanged initialization signals, an implementation MUST NOT emit any signal or data item associated with an optional extension that was not specified in the received initialization signal from its peer.

3.2. Protocol Extensions

If/when protocol extensions are required, they should be standardized either as an update to this document, or as an additional stand-alone specification. The requests for IANA-controlled registries in this document contain sufficient reserved space, both in terms of DLEP signals and DLEP data items, to accommodate future extensions to the protocol and the data transferred.

3.3. Experimental Signals and Data Items

This document requests numbering space in both the DLEP signal and data item registries for experimental items. The intent is to allow for experimentation with either (1) new signals, (2) new data items, or (3) both new signals and new data items, while still retaining the documented DLEP behavior. If a given experiment proves successful, it SHOULD be documented as an update to this document, or as a stand-alone specification.

Use of the experimental signals, data items, or behaviors MUST be announced by inclusion of an Experimental Definition data item (Section 8.8) with a value agreed upon (a priori) between the participating peers. The exact mechanism for a priori communication of the experimental definition formats is beyond the scope of this document.

Multiple Experimental Definition data items MAY appear in the Peer Initialization/Peer Initialization ACK sequence. However, use of multiple experiments in a single peer session could lead to interoperability issues or unexpected results (e.g., redefinition of experimental signals and/or data items), and is therefore discouraged. It is left to implementations to determine the correct processing path (e.g., a decision on whether to terminate the peer session, or to establish a precedence of the conflicting definitions) if such conflicts arise.

4. Metrics

DLEP includes the ability for the router and modem to communicate metrics that reflect the characteristics (e.g., datarate, latency) of the variable-quality link in use. DLEP does NOT specify how a given metric value is to be calculated, rather, the protocol assumes that metrics have been calculated with a 'best effort', incorporating all pertinent data that is available to the modem device.

As mentioned in the introduction section of this document, DLEP allows for metrics to be sent within two contexts - metrics for a specific destination within the network (e.g., a specific router),

and 'modem-wide' (those that apply to all destinations accessed via the modem). Most metrics can be further subdivided into transmit and receive metrics. Metrics supplied on DLEP Peer signals are, by definition, modem-wide; metrics supplied on Destination signals are, by definition, used for the specific logical destination only.

DLEP modem implementations MUST announce all supported metric items, and provide default values for those metrics, in the Peer Initialization ACK signal (Section 7.4). In order to introduce a new metric type, DLEP modem implementations MUST terminate the session with the router (via the Peer Terminate signal (Section 7.7)), and re-establish the session.

It is left to implementations to choose sensible default values based on their specific characteristics. Modems having static (non-changing) link metric characteristics MAY report metrics only once for a given destination (or once on a modem-wide basis, if all connections via the modem are of this static nature).

The approach of allowing for different contexts for metric data increases both the flexibility and the complexity of using metric data. This document details the mechanism whereby the data is transmitted, however, the specific algorithms (precedence, etc.) for utilizing the dual-context metrics is out of scope and not addressed by this document.

4.1. Mandatory Metrics

As mentioned above, DLEP modem implementations MUST announce all supported metric items during session initialization. However, an implementation MUST include the following list of metrics:

- o Maximum Data Rate (Receive) (Section 8.14)
- o Maximum Data Rate (Transmit) (Section 8.15)
- o Current Data Rate (Receive) (Section 8.16)
- o Current Data Rate (Transmit) (Section 8.17)
- o Latency (Section 8.18)

5. DLEP Session Flow

For routers supporting DLEP, support of Discovery is optional. Discovery is initiated in the DLEP modem by sending the Peer Discovery Signal (Section 7.1) to a well-known multicast address. However, support for receipt and processing of the signal is optional

in the router (see Appendix A and B for flow diagrams of the discovery signal). Due to the optional (on the router) support for discovery, normal session flow is described for both the 'Discovery case', and the 'Configured case'. Again, for modem implementations of DLEP, support of Discovery is mandatory; therefore, that is the only case to be described.

5.1. DLEP Router session flow - Discovery case

If the DLEP router implementation is utilizing the optional discovery mechanism, then the implementation will initialize a UDP socket, binding it to an arbitrary port. This UDP socket is used to send the Peer Discovery signal (Section 7.1) to the DLEP link-local multicast address and port (TBD). The implementation then waits on receipt of a Peer Offer signal (Section 7.2), which MAY contain the unicast address and port for TCP-based communication with a DLEP modem, via the IPv4 Connection Point data item (Section 8.3) or the IPv6 Connection Point data item (Section 8.4). The Peer Offer signal MAY contain multiple IP Connection Point data items. If more than one IP Connection Point data items is in the Peer Offer, router implementations MAY use their own heuristics to determine the best address/port combination. If no IP Connection Point data items are included in the Peer Offer signal, the receiver MUST use the origin address of the signal as the IP address, and the DLEP well-known port number (Section 11.7) to establish the TCP connection. At this point, the router implementation MAY either destroy the UDP socket, or continue to issue Peer Discovery signals to the link-local address/port combination. In either case, the TCP session initialization occurs as in the configured case.

5.2. DLEP Router session flow - Configured case

When a DLEP router implementation has the address and port information for a TCP connection to a modem (obtained either via configuration or via the discovery process described above), the router will initialize and bind a TCP socket. This socket is used to connect to the DLEP modem software. After a successful TCP connect, the router implementation MUST issue a Peer Initialization signal (Section 7.3) to the DLEP modem. After sending the Peer Initialization, the router implementation MUST wait for receipt of a Peer Initialization ACK signal (Section 7.4) from the modem. Receipt of the Peer Initialization ACK signal containing a Status data item (Section 8.2) with value 'Success', indicates that the modem has received and processed the Peer Initialization, and the session MUST transition to the 'in session' state. At this point, signals regarding destinations in the network, and/or Peer Update signals (Section 7.5), can flow on the DLEP session between modem and router, and Heartbeat signals can begin to flow, if Heartbeats are used. The

'in session' state is maintained until one of the following conditions occur:

- o The session is explicitly terminated (using Peer Termination), or
- o The session times out, based on supplied timeout values.

5.3. DLEP Modem session flow

DLEP modem implementations MUST support the discovery mechanism. Therefore, the normal flow is as follows:

The implementation will initialize a UDP socket, binding that socket to the DLEP link-local multicast address (TBD) and the DLEP well-known port number (also TBD). The implementation will then initialize a TCP socket, on a unicast address and port. This socket is used to listen for incoming TCP connection requests.

When the modem implementation receives a Peer Discovery signal (Section 7.1) on the UDP socket, it responds by issuing a Peer Offer signal (Section 7.2) to the sender of the Peer Discovery signal. The Peer Offer signal MAY contain the unicast address and port of the listening TCP socket, as described above. A DLEP modem implementation MAY respond with ALL address/port combinations that have an active TCP listen posted. Anything other than Peer Discovery signals received on the UDP socket MUST be silently dropped.

When the DLEP modem implementation accepts a connection via TCP, it MUST wait for receipt of a Peer Initialization signal (Section 7.3), sent by the router. Upon receipt and successful parsing of a Peer Initialization signal, the modem MUST respond with a Peer Initialization ACK signal (Section 7.4). The Peer Initialization ACK signal MUST contain metric data items for ALL supported metrics. If an additional metric is to be introduced, the DLEP session between router and modem MUST be terminated and restarted, and the new metric described in a Peer Initialization ACK signal. Once the Peer Initialization signal (Section 7.3) and Peer Initialization ACK signal (Section 7.4) have been exchanged, the session is transitioned to the 'in session' state. As in the router case, when the 'in session' state is reached, signals regarding destinations in the network, and/or Peer Update signals (Section 7.5), can flow on the DLEP session between modem and router, and Heartbeat signals can begin to flow, if Heartbeats are used. The 'in session' state persists until the session is explicitly terminated (using Peer Termination), or it times out (based on timeout values).

5.4. Common Session Flow

In order to maintain the session between router and modem, periodic Heartbeat signals (Section 7.14) MAY be exchanged. These signals are intended to keep the session alive, and to verify bidirectional connectivity between the two participants. If heartbeat signals are exchanged, they do not begin until the DLEP peer session has entered the 'in session' state. Each DLEP peer is responsible for the creation of heartbeat signals. Receipt of any DLEP signal SHOULD reset the heartbeat interval timer (i.e., valid DLEP signals take the place of, and obviate the need for, Heartbeat signals).

DLEP also provides a Peer Update signal (Section 7.5), intended to communicate some change in status (e.g., a change of layer 3 address parameters, or a modem-wide link change).

In addition to the local (Peer level) signals above, the participants will transmit DLEP signals concerning destinations in the network. These signals trigger creation/maintenance/deletion of destinations in the information base of the recipient. For example, a modem will inform its attached router of the presence of a new destination via the Destination Up signal (Section 7.9). Receipt of a Destination Up causes the router to allocate the necessary resources, creating an entry in the information base with the specifics (i.e. MAC Address, Latency, Data Rate, etc.) of the destination. The loss of a destination is communicated via the Destination Down signal (Section 7.11), and changes in status to the destination (e.g., varying link quality, or addressing changes) are communicated via the Destination Update signal (Section 7.13). The information on a given destination will persist in the router's information base until (1) a Destination Down signal is received, indicating that the modem has lost contact with the remote node, or (2) the router/modem session terminates, indicating that the router has lost contact with its own local modem.

Metrics can be expressed within the context of a specific destination via the Destination Update signal, or on a modem-wide basis via the Peer Update signal. In cases where metrics are provided at peer level, the receiver MUST propagate the metrics to all destinations in its information base that are accessed via the originator. A DLEP participant MAY send metrics both in a router/modem session context (via the Peer Update signal) and a specific destination context (via Destination Update) at any time. The heuristics for applying received metrics is left to implementations.

In addition to receiving metrics about the link, DLEP provides a signal allowing a router to request a different datarate, or latency, from the modem. This signal is referred to as the Link

Characteristics Request signal (Section 7.15), and gives the router the ability to deal with requisite increases (or decreases) of allocated datarate/latency in demand-based schemes in a more deterministic manner.

6. DLEP Signal Processing

Communication between DLEP peers consists of a bidirectional stream of signals (messages), each signal consisting of a signal header and an unordered list of data items. Signal headers consist of Type and Length information, while data items are encoded as TLV (Type-Length-Value) structures. In this document, the data items following the signal header are described as being 'contained in' the signal.

All integer values structures MUST be in network byte-order.

There is no restriction on the order of data items following a signal, and the multiplicity of duplicate data items is defined by the definition of the signal declared by the type in the signal header.

If an unrecognized, or unexpected signal is received, or a received signal contains unrecognized, invalid, or disallowed duplicate data items, the receiving peer MUST terminate the session by issuing a Peer Termination signal (Section 7.7) with a Status data item (Section 8.2) containing the most relevant status code, and then close the TCP connection.

6.1. DLEP Signal Header

The DLEP signal header contains the following fields:

```
 0                   1                   2
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Signal Type   | Length                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 3: DLEP Signal Header

Signal Type: One of the DLEP Signal Type values defined in this document.

Length: The length, expressed as a 16-bit unsigned integer, of all of the DLEP data items associated with this signal. This length does not include the length of the header itself

The DLEP Signal Header is immediately followed by one or more DLEP data items, encoded in TLVs, as defined in this document.

6.2. DLEP Generic Data Item

All DLEP data items contain the following fields:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Data Item Type| Length        | Value...                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 4: DLEP Generic Data Item

Data Item Type: An 8-bit unsigned integer field specifying the data item being sent.

Length: The length, expressed as an 8-bit unsigned integer, of the value field of the data item.

Value: A field of length <Length> which contains data specific to a particular data item.

7. DLEP Signals

As mentioned above, all DLEP signals begin with the DLEP signal header structure. Therefore, in the following descriptions of specific signals, this header structure is assumed, and will not be replicated.

Following is the set of MANDATORY signals that must be recognized by a DLEP compliant implementation. As mentioned before, not all signals may be used during a session, but an implementation MUST correctly process these signals when received.

The mandatory DLEP signals are:

Signal	Description	Mnemonic	Section
TBD	Peer Discovery	DLEP_PEER_DISCOVERY	Section 7.1
TBD	Peer Offer	DLEP_PEER_OFFER	Section 7.2
TBD	Peer Initialization	DLEP_PEER_INIT	Section 7.3
TBD	Peer Initialization ACK	DLEP_PEER_INIT_ACK	Section 7.4
TBD	Peer Update	DLEP_PEER_UPDATE	Section 7.5
TBD	Peer Update ACK	DLEP_PEER_UPDATE_ACK	Section 7.6
TBD	Peer Termination	DLEP_PEER_TERM	Section 7.7
TBD	Peer Termination ACK	DLEP_PEER_TERM_ACK	Section 7.8
TBD	Destination Up	DLEP_DEST_UP	Section 7.9
TBD	Destination Up ACK	DLEP_DEST_UP_ACK	Section 7.10
TBD	Destination Down	DLEP_DEST_DOWN	Section 7.11
TBD	Destination Down ACK	DLEP_DEST_DOWN_ACK	Section 7.12
TBD	Destination Update	DLEP_DEST_UPDATE	Section 7.13
TBD	Heartbeat	DLEP_PEER_HEARTBEAT	Section 7.14
TBD	Link Characteristics Request	DLEP_LINK_CHAR_REQ	Section 7.15
TBD	Link Characteristics ACK	DLEP_LINK_CHAR_ACK	Section 7.16

Table 1: DLEP Signal Values

7.1. Peer Discovery Signal

A Peer Discovery signal SHOULD be sent by a router to discover DLEP modems in the network. The Peer Offer signal (Section 7.2) is required to complete the discovery process. Implementations MAY implement their own retry heuristics in cases where it is determined the Peer Discovery signal has timed out.

To construct a Peer Discovery signal, the Signal Type value in the signal header is set to DLEP_PEER_DISCOVERY in Table 1.

The Peer Discovery signal MUST contain the following data item:

o DLEP Version (Section 8.1)

The Peer Discovery signal MAY contain the following data item:

o Peer Type (Section 8.5)

7.2. Peer Offer Signal

A Peer Offer signal MUST be sent by a DLEP modem in response to a valid Peer Discovery signal (Section 7.1).

The Peer Offer signal MUST be sent to the unicast address of the originator of the Peer Discovery signal.

To construct a Peer Offer signal, the Signal Type value in the signal header is set to DLEP_PEER_OFFER in Table 1.

The Peer Offer signal MUST contain the following data item:

o DLEP Version (Section 8.1)

The Peer Offer signal MAY contain the following data item:

o Peer Type (Section 8.5)

The Peer Offer signal MAY contain one or more of any of the following data items, with different values:

o IPv4 Connection Point (Section 8.3)

o IPv6 Connection Point (Section 8.4)

The IP Connection Point data items indicate the unicast address the receiver of Peer Offer MUST use when connecting the DLEP TCP session. If multiple IP Connection Point data items are present in the Peer Offer signal, implementations MAY use their own heuristics to select the address to connect to. If no IP Connection Point data items are included in the Peer Offer signal, the receiver MUST use the origin address of the signal as the IP address, and the DLEP well-known port number (Section 11.7) to establish the TCP connection.

7.3. Peer Initialization Signal

A Peer Initialization signal MUST be sent by a router as the first signal of the DLEP TCP session. It is sent by the router after a TCP connect to an address/port combination that was obtained either via receipt of a Peer Offer, or from a priori configuration.

If any optional extensions are supported by the implementation, they MUST be enumerated in the Extensions Supported data item. If an Extensions Supported data item does NOT exist in a Peer

Initialization signal, the receiver of the signal MUST conclude that there is NO support for extensions in the sender.

If any experimental signals or data items are used by the implementation, they MUST be enumerated in one or more Experimental Definition data items. If there are no Experimental Definition data items in a Peer Initialization signal, the receiver of the signal MUST conclude that NO experimental definitions are in use by the sender.

Implementations supporting the Heartbeat Interval (Section 8.6) should understand that heartbeats are NOT fully established until receipt of Peer Initialization ACK Signal (Section 7.4), and should therefore implement their own timeout and retry heurestics for this signal.

To construct a Peer Initialization signal, the Signal Type value in the signal header is set to DLEP_PEER_INIT in Table 1.

The Peer Initialization signal MUST contain one of each of the following data items:

- o DLEP Version (Section 8.1)

- o Heartbeat Interval (Section 8.6)

The Peer Initialization signal MAY contain one of each of the following data items:

- o Peer Type (Section 8.5)

- o Extensions Supported (Section 8.7)

The Peer Initialization signal MAY contain one or more of any of the following data items, with different values:

- o Experimental Definition (Section 8.8)

A Peer Initialization signal MUST be acknowledged by the receiver issuing a Peer Initialization ACK signal (Section 7.4).

7.4. Peer Initialization ACK Signal

A Peer Initialization ACK signal MUST be sent in response to a received Peer Initialization signal (Section 7.3). The Peer Initialization ACK signal completes the DLEP session establishment; the sender of the signal should transition to an 'in-session' state when the signal is sent, and the receiver should transition to the

'in-session' state upon receipt (and successful parsing) of an acceptable Peer Initialization ACK signal.

All supported metric data items MUST be included in the Peer Initialization ACK signal, with default values to be used on a 'modem-wide' basis. This can be viewed as the modem 'declaring' all supported metrics at DLEP session initialization. Receipt of any DLEP signal containing a metric data item NOT included in the Peer Initialization ACK signal MUST be treated as an error, resulting in the termination of the DLEP session between router and modem.

If any optional extensions are supported by the modem, they MUST be enumerated in the Extensions Supported data item. If an Extensions Supported data item does NOT exist in a Peer Initialization ACK signal, the receiver of the signal MUST conclude that there is NO support for extensions in the sender.

If any experimental signals or data items are used by the implementation, they MUST be enumerated in one or more Experimental Definition data items. If there are no Experimental Definition data items in a Peer Initialization ACK signal, the receiver of the signal MUST conclude that NO experimental definitions are in use by the sender.

After the Peer Initialization/Peer Initialization ACK signals have been successfully exchanged, implementations MUST only use extensions and experimental definitions that are supported by BOTH peers.

To construct a Peer Initialization ACK signal, the Signal Type value in the signal header is set to DLEP_PEER_INIT_ACK in Table 1.

The Peer Initialization ACK signal MUST contain one of each of the following data items:

o DLEP Version (Section 8.1)

o Heartbeat Interval (Section 8.6)

o Maximum Data Rate (Receive) (Section 8.14)

o Maximum Data Rate (Transmit) (Section 8.15)

o Current Data Rate (Receive) (Section 8.16)

o Current Data Rate (Transmit) (Section 8.17)

o Latency (Section 8.18)

The Peer Initialization ACK signal MUST contain one of each of the following data items, if the data item will be used during the lifetime of the session:

- Resources (Receive) (Section 8.19)
- Resources (Transmit) (Section 8.20)
- Relative Link Quality (Receive) (Section 8.21)
- Relative Link Quality (Transmit) (Section 8.22)

The Peer Initialization ACK signal MAY contain one of each of the following data items:

- Status (Section 8.2)
- Peer Type (Section 8.5)
- Extensions Supported (Section 8.7)

The Peer Initialization ACK signal MAY contain one or more of any of the following data items, with different values:

- Experimental Definition (Section 8.8)

7.5. Peer Update Signal

A Peer Update signal MAY be sent by a DLEP peer to indicate local Layer 3 address changes, or metric changes on a modem-wide basis. For example, addition of an IPv4 address to the router MAY prompt a Peer Update signal to its attached DLEP modems. Also, for example, a modem that changes its Maximum Data Rate (Receive) for all destinations MAY reflect that change via a Peer Update signal to its attached router(s).

Concerning Layer 3 addresses, if the modem is capable of understanding and forwarding this information (via proprietary mechanisms), the address update would prompt any remote DLEP modems (DLEP-enabled modems in a remote node) to issue a Destination Update signal (Section 7.13) to their local routers with the new (or deleted) addresses. Modems that do not track Layer 3 addresses SHOULD silently parse and ignore the Peer Update signal. Modems that track Layer 3 addresses MUST acknowledge the Peer Update with a Peer Update ACK signal (Section 7.6).

If metrics are supplied with the Peer Update signal (e.g., Maximum Data Rate), these metrics are considered to be modem-wide, and

therefore MUST be applied to all destinations in the information base associated with the router/modem session.

Supporting implementations are free to employ heuristics to retransmit Peer Update signals. The sending of Peer Update signals for Layer 3 address changes SHOULD cease when either participant (router or modem) determines that the other implementation does NOT support Layer 3 address tracking.

To construct a Peer Update signal, the Signal Type value in the signal header is set to DLEP_PEER_UPDATE in Table 1.

The Peer Update signal MAY contain one of each of the following data items:

- Maximum Data Rate (Receive) (Section 8.14)
- Maximum Data Rate (Transmit) (Section 8.15)
- Current Data Rate (Receive) (Section 8.16)
- Current Data Rate (Transmit) (Section 8.17)
- Latency (Section 8.18)
- Resources (Receive) (Section 8.19)
- Resources (Transmit) (Section 8.20)
- Relative Link Quality (Receive) (Section 8.21)
- Relative Link Quality (Transmit) (Section 8.22)

The Peer Update signal MAY contain one or more of the following data items, with different values:

- IPv4 Address (Section 8.10)
- IPv6 Address (Section 8.11)

A Peer Update signal MUST be acknowledged by the receiver issuing a Peer Update ACK signal (Section 7.6).

7.6. Peer Update ACK Signal

A Peer Update ACK signal MUST be sent by implementations to indicate whether a Peer Update signal (Section 7.5) was successfully received.

To construct a Peer Update ACK signal, the Signal Type value in the signal header is set to DLEP_PEER_UPDATE_ACK in Table 1.

The Peer Update ACK signal MAY contain one of each of the following data items:

- o Status (Section 8.2)

A receiver of a Peer Update ACK signal without a Status data item MUST behave as if a Status data item with code 'Success' had been received.

7.7. Peer Termination Signal

A Peer Termination signal MUST be sent by a DLEP participant when the router/modem session needs to be terminated. Implementations receiving a Peer Termination signal MUST send a Peer Termination ACK signal (Section 7.8) to confirm the termination process.

The receiver of a Peer Termination signal MUST release all resources allocated for the router/modem session, and MUST eliminate all destinations in the information base accessible via the router/modem pair represented by the session. Router and modem state machines are returned to the 'discovery' state. No Destination Down signals (Section 7.11) are sent.

The sender of a Peer Termination signal is free to define its heuristics in event of a timeout. It may resend the Peer Termination or free resources and return to the 'discovery' state.

To construct a Peer Termination signal, the Signal Type value in the signal header is set to DLEP_PEER_TERM in Table 1.

The Peer Termination signal MAY contain one of each of the following data items:

- o Status (Section 8.2)

A receiver of a Peer Termination signal without a Status data item MUST behave as if a Status data item with status code 'Success', implying graceful termination, had been received.

A Peer Termination signal MUST be acknowledged by the receiver issuing a Peer Termination ACK signal (Section 7.8).

7.8. Peer Termination ACK Signal

A Peer Termination ACK signal MUST be sent by a DLEP peer in response to a received Peer Termination signal (Section 7.7). Receipt of a Peer Termination ACK signal completes the teardown of the router/ modem session.

To construct a Peer Termination ACK signal, the Signal Type value in the signal header is set to DLEP_PEER_TERM_ACK in Table 1.

The Peer Termination ACK signal MAY contain one of each of the following data items:

o Status (Section 8.2)

A receiver of a Peer Termination ACK signal without a Status data item MUST behave as if a Status data item with status code 'Success', implying graceful termination, had been received.

7.9. Destination Up Signal

A Destination Up signal can be sent either by the modem, to indicate that a new remote node has been detected, or by the router, to indicate the presence of a new logical destination (e.g., a Multicast group) in the network.

A Destination Up signal MUST be acknowledged by the receiver issuing a Destination Up ACK signal (Section 7.10). The sender of the Destination Up signal is free to define its retry heuristics in event of a timeout. When a Destination Up signal is received and successfully processed, the receiver should add knowledge of the new destination to its information base, indicating that the destination is accessible via the modem/router pair.

To construct a Destination Up signal, the Signal Type value in the signal header is set to DLEP_DEST_UP in Table 1.

The Destination Up signal MUST contain one of each of the following data items:

o MAC Address (Section 8.9)

The Destination Up signal MAY contain one of each of the following data items:

o Maximum Data Rate (Receive) (Section 8.14)

o Maximum Data Rate (Transmit) (Section 8.15)

- Current Data Rate (Receive) (Section 8.16)
- Current Data Rate (Transmit) (Section 8.17)
- Latency (Section 8.18)
- Resources (Receive) (Section 8.19)
- Resources (Transmit) (Section 8.20)
- Relative Link Quality (Receive) (Section 8.21)
- Relative Link Quality (Transmit) (Section 8.22)

The Destination Up signal MAY contain one or more of the following data items, with different values:

- IPv4 Address (Section 8.10)
- IPv6 Address (Section 8.11)
- IPv4 Attached Subnet (Section 8.12)
- IPv6 Attached Subnet (Section 8.13)

If the sender has IPv4 and/or IPv6 address information for a destination it SHOULD include the relevant data items in the Destination Up signal, reducing the need for the receiver to probe for any address.

7.10. Destination Up ACK Signal

A DLEP participant MUST send a Destination Up ACK signal to indicate whether a Destination Up signal (Section 7.9) was successfully processed.

To construct a Destination Up ACK signal, the Signal Type value in the signal header is set to DLEP_DEST_UP_ACK in Table 1.

The Destination Up ACK signal MUST contain one of each of the following data items:

- MAC Address (Section 8.9)

The Destination Up ACK signal MAY contain one of each of the following data items:

- Status (Section 8.2)

A receiver of a Destination Up ACK signal without a Status data item MUST behave as if a Status data item with status code 'Success' had been received. Implementations are free to define retry heurestics when receiving a Destination Up ACK signal indicating an error.

7.11. Destination Down Signal

A DLEP peer MUST send a Destination Down signal to report when a destination (a remote node or a multicast group) is no longer reachable. A Destination Down ACK signal (Section 7.12) MUST be sent by the recipient of a Destination Down signal to confirm that the relevant data has been removed from the information base. The sender of the Destination Down signal is free to define its retry heuristics in event of a timeout.

To construct a Destination Down signal, the Signal Type value in the signal header is set to DLEP_DEST_DOWN in Table 1.

The Destination Down signal MUST contain one of each of the following data items:

o MAC Address (Section 8.9)

7.12. Destination Down ACK Signal

A DLEP participant MUST send a Destination Down ACK signal to indicate whether a received Destination Down signal (Section 7.11) was successfully processed. If successfully processed, the sender of the ACK MUST have removed all entries in the information base that pertain to the referenced destination.

To construct a Destination Down ACK signal, the Signal Type value in the signal header is set to DLEP_DEST_DOWN_ACK in Table 1.

The Destination Down ACK signal MUST contain one of each of the following data items:

o MAC Address (Section 8.9)

The Destination Down ACK signal MAY contain one of each of the following data items:

o Status (Section 8.2)

A receiver of a Destination Down ACK signal without a Status data item MUST behave as if a Status data item with status code 'Success' had been received. Implementations are free to define retry

heurestics when receiving a Destination Down ACK signal indicating an error.

7.13. Destination Update Signal

A DLEP participant SHOULD send the Destination Update signal when it detects some change in the information base for a given destination (remote node or multicast group). Some examples of changes that would prompt a Destination Update signal are:

o Change in link metrics (e.g., Data Rates)

o Layer 3 addressing change

To construct a Destination Update signal, the Signal Type value in the signal header is set to DLEP_DEST_UPDATE in Table 1.

The Destination Update signal MUST contain one of each of the following data items:

o MAC Address (Section 8.9)

The Destination Update signal MAY contain one of each of the following data items:

o Maximum Data Rate (Receive) (Section 8.14)

o Maximum Data Rate (Transmit) (Section 8.15)

o Current Data Rate (Receive) (Section 8.16)

o Current Data Rate (Transmit) (Section 8.17)

o Latency (Section 8.18)

o Resources (Receive) (Section 8.19)

o Resources (Transmit) (Section 8.20)

o Relative Link Quality (Receive) (Section 8.21)

o Relative Link Quality (Transmit) (Section 8.22)

The Destination Update signal MAY contain one or more of the following data items, with different values:

o IPv4 Address (Section 8.10)

- IPv6 Address (Section 8.11)
- IPv4 Attached Subnet (Section 8.12)
- IPv6 Attached Subnet (Section 8.13)

7.14. Heartbeat Signal

A Heartbeat signal SHOULD be sent by a DLEP participant every N seconds, where N is defined in the Heartbeat Interval data item of the Peer Initialization signal (Section 7.3) or Peer Initialization ACK signal (Section 7.4). Note that implementations setting the Heartbeat Interval to 0 effectively set the interval to an infinite value, therefore, in those cases, this signal SHOULD NOT be sent.

The signal is used by participants to detect when a DLEP session partner (either the modem or the router) is no longer communicating. Participants SHOULD allow two (2) heartbeat intervals to expire with no traffic on the router/modem session before initiating DLEP session termination procedures.

To construct a Heartbeat signal, the Signal Type value in the signal header is set to DLEP_PEER_HEARTBEAT in Table 1.

There are no valid data items for the Heartbeat signal.

7.15. Link Characteristics Request Signal

The Link Characteristics Request signal MAY be sent by the router to request that the modem initiate changes for specific characteristics of the link. The request can reference either a real destination (e.g., a remote node), or a logical destination (e.g., a multicast group) within the network.

The Link Characteristics Request signal MAY contain either a Current Data Rate (CDRR or CDRT) data item to request a different datarate than what is currently allocated, a Latency data item to request that traffic delay on the link not exceed the specified value, or both. A Link Characteristics ACK signal (Section 7.16) is required to complete the request. Issuing a Link Characteristics Request with ONLY the MAC Address data item is a mechanism a peer MAY use to request metrics (via the Link Characteristics ACK) from its partner.

The sender of a Link Characteristics Request signal MAY attach a timer to the request using the Link Characteristics ACK Timer data item. If a Link Characteristics ACK signal is received after the timer expires, the sender MUST NOT assume that the request succeeded.

Implementations are free to define their retry heuristics in event of a timeout.

To construct a Link Characteristics Request signal, the Signal Type value in the signal header is set to DLEP_LINK_CHAR_REQ in Table 1.

The Link Characteristics Request signal MUST contain one of each of the following data items:

- MAC Address (Section 8.9)

The Link Characteristics Request signal MAY contain one of each of the following data items:

- Link Characteristics ACK Timer (Section 8.23)

- Current Data Rate (Receive) (Section 8.16)

- Current Data Rate (Transmit) (Section 8.17)

- Latency (Section 8.18)

7.16. Link Characteristics ACK Signal

A DLEP participant MUST send a Link Characteristics ACK signal to indicate whether a received Link Characteristics Request signal (Section 7.15) was successfully processed. The Link Characteristics ACK signal SHOULD contain a complete set of metric data items, and MUST contain a full set (i.e. those declared in the Peer Initialization ACK signal (Section 7.4)), if metrics were requested by only including a MAC address data item. It MUST contain the same metric types as the request. The values in the metric data items in the Link Characteristics ACK signal MUST reflect the link characteristics after the request has been processed.

If an implementation is not able to alter the characteristics of the link in the manner requested, then a Status data item with status code 'Request Denied' MUST be added to the signal.

To construct a Link Characteristics Request ACK signal, the Signal Type value in the signal header is set to DLEP_LINK_CHAR_ACK in Table 1.

The Link Characteristics ACK signal MUST contain one of each of the following data items:

- MAC Address (Section 8.9)

The Link Characteristics ACK signal SHOULD contain one of each of the following data items:

- Maximum Data Rate (Receive) (Section 8.14)
- Maximum Data Rate (Transmit) (Section 8.15)
- Current Data Rate (Receive) (Section 8.16)
- Current Data Rate (Transmit) (Section 8.17)
- Latency (Section 8.18)

The Link Characteristics ACK signal MAY contain one of each of the following data items:

- Resources (Receive) (Section 8.19)
- Resources (Transmit) (Section 8.20)
- Relative Link Quality (Receive) (Section 8.21)
- Relative Link Quality (Transmit) (Section 8.22)
- Status (Section 8.2)

A receiver of a Link Characteristics ACK signal without a Status data item MUST behave as if a Status data item with status code 'Success' had been received.

8. DLEP Data Items

Following is the list of MANDATORY data items that must be recognized by a DLEP compliant implementation. As mentioned before, not all data items need be used during a session, but an implementation MUST correctly process these data items when correctly associated with a signal.

The DLEP data items are:

Data Item	Description	Section
TBD	DLEP Version	Section 8.1
TBD	Status	Section 8.2
TBD	IPv4 Connection Point	Section 8.3
TBD	IPv6 Connection Point	Section 8.4
TBD	Peer Type	Section 8.5
TBD	Heartbeat Interval	Section 8.6
TBD	Extensions Supported	Section 8.7
TBD	Experimental Definition	Section 8.8
TBD	MAC Address	Section 8.9
TBD	IPv4 Address	Section 8.10
TBD	IPv6 Address	Section 8.11
TBD	IPv4 Attached Subnet	Section 8.12
TBD	IPv6 Attached Subnet	Section 8.13
TBD	Maximum Data Rate (Receive) MDRR)	Section 8.14
TBD	Maximum Data Rate (Transmit) (MDRT)	Section 8.15
TBD	Current Data Rate (Receive) (CDRR)	Section 8.16
TBD	Current Data Rate (Transmit) (CDRT)	Section 8.17
TBD	Latency	Section 8.18
TBD	Resources (Receive) (RESR)	Section 8.19
TBD	Resources (Transmit) (REST)	Section 8.20
TBD	Relative Link Quality (Receive) (RLQR)	Section 8.21
TBD	Relative Link Quality (Transmit) (RLQT)	Section 8.22
TBD	Link Characteristics ACK Timer	Section 8.23

Table 2: DLEP Data Item Values

8.1. DLEP Version

The DLEP Version data item MUST appear in the Peer Discovery (Section 7.1), Peer Offer (Section 7.2), Peer Initialization (Section 7.3) and Peer Initialization ACK (Section 7.4) signals. The Version data item is used to indicate the version of the protocol running in the originator. A DLEP implementation SHOULD use this information to decide if the potential session partner is running at a supported level.

The DLEP Version data item contains the following fields:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Data Item Type|    Length     |         Major Version         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|       Minor Version           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Data Item Type: TBD

Length: 4

Major Version: The major version of the DLEP protocol, expressed as an 16-bit unsigned integer.

Minor Version: The minor version of the DLEP protocol, expressed as an 16-bit unsigned integer.

Support of this draft is indicated by setting the Major Version to '1', and the Minor Version to '0' (i.e. Version 1.0).

8.2. Status

The Status data item MAY appear in the Peer Initialization ACK (Section 7.4), Peer Termination (Section 7.7), Peer Termination ACK (Section 7.8), Peer Update ACK (Section 7.6), Destination Up ACK (Section 7.10), Destination Down ACK (Section 7.12) and Link Characteristics ACK (Section 7.16) signals as part of an acknowledgement from either the modem or the router, to indicate the success or failure of the previously received signal.

The status data item includes an optional Text field that can be used to provide a textual description of the status. The use of the Text field is entirely up to the receiving implementation, i.e., it could be output to a log file or discarded. If no Text field is supplied with the Status data item, the Length field MUST be set to 1.

The Status data item contains the following fields:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Data Item Type|    Length     |     Code      | Text...
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Data Item Type: TBD

Length: 1 + Length of text

Status Code: One of the codes defined below.

Text: UTF-8 encoded string, describing an problem, used for implementation defined purposes. Since this field is used for a description of the problem, implementations SHOULD limit characters in this field to printable characters. Implementations receiving this data item SHOULD check for printable characters in the field.

An implementation MUST NOT assume the Text field is NUL-terminated.

Status Code	Value	Reason
Success	0	The signal was processed successfully.
Unknown Signal	TBD	The signal was not recognized by the implementation.
Invalid Data	TBD	One or more data items in the signal are invalid, unexpected or duplicated.
Unexpected Signal	TBD	The signal was not expected while the machine was in this state, e.g., a Peer Initialization signal after session establishment.
Request Denied	TBD	The receiver has not completed the request.
Timed Out	TBD	The request could not be completed in the time allowed.
Invalid Destination	TBD	The destination provided in the signal does not match a previously announced destination. For example, in the Link Characteristic Request ACK signal (Section 7.16).

8.3. IPv4 Connection Point

The IPv4 Connection Point data item MAY appear in the Peer Offer signal (Section 7.2). The IPv4 Connection Point data item indicates the IPv4 address and, optionally, the TCP port number on the DLEP modem available for connections. If provided, the receiver MUST use this information to perform the TCP connect to the DLEP server.

The IPv4 Connection Point data item contains the following fields:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Data Item Type|    Length     |          IPv4 Address         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|          IPv4 Address         |   TCP Port Number (optional)  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Data Item Type: TBD

Length: 4 (or 6 if TCP Port included)

IPv4 Address: The IPv4 address listening on the DLEP modem.

TCP Port Number: TCP Port number on the DLEP modem.

If the Length field is 6, the port number specified MUST be used to establish the TCP session. If the TCP Port Number is omitted, i.e. the Length field is 4, the receiver MUST use the DLEP well-known port number (Section 11.7) to establish the TCP connection.

8.4. IPv6 Connection Point

The IPv6 Connection Point data item MAY appear in the Peer Offer signal (Section 7.2). The IPv6 Connection Point data item indicates the IPv6 address and, optionally, the TCP port number on the DLEP modem available for connections. If provided, the receiver MUST use this information to perform the TCP connect to the DLEP server.

The IPv6 Connection Point data item contains the following fields:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Data Item Type|    Length     |          IPv6 Address         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         IPv6 Address                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         IPv6 Address                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         IPv6 Address                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|          IPv6 Address         |   TCP Port Number (optional)  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Data Item Type: TBD

Length: 16 (or 18 if TCP Port included)

IPv6 Address: The IPv6 address listening on the DLEP modem.

TCP Port Number: TCP Port number on the DLEP modem.

If the Length field is 18, the port number specified MUST be used to establish the TCP session. If the TCP Port Number is omitted, i.e. the Length field is 16, the receiver MUST use the DLEP well-known port number (Section 11.7) to establish the TCP connection.

8.5. Peer Type

The Peer Type data item MAY appear in the Peer Discovery (Section 7.1), Peer Offer (Section 7.2), Peer Initialization (Section 7.3) and Peer Initialization ACK (Section 7.4) signals. The Peer Type data item is used by the router and modem to give additional information as to its type. The peer type is a string and is envisioned to be used for informational purposes (e.g., as output in a display command).

The Peer Type data item contains the following fields:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Data Item Type|    Length     | Peer Type                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Data Item Type: TBD

Length: Length of peer type string.

Peer Type: UTF-8 encoded string. For example, a satellite modem might set this variable to "Satellite terminal". Since this data item is intended to provide additional information for display commands, sending implementations SHOULD limit the data to printable characters, and receiving implmentations SHOULD check the data for printable characters.

An implementation MUST NOT assume the Peer Type field is NUL-terminated.

8.6. Heartbeat Interval

The Heartbeat Interval data item MUST appear in both the Peer Initialization (Section 7.3) and Peer Initialization ACK (Section 7.4) signals to indicate the Heartbeat timeout window to be used by the sender.

The Interval is used to specify a period (in seconds) for Heartbeat signals (Section 7.14). By specifying an Interval value of 0, implementations MAY indicates the desire to disable Heartbeat signals entirely (i.e., the Interval is set to an infinite value). However, it is strongly recommended that implementations use non 0 timer values. Implementations MUST implement heuristics such that DLEP signals sent/received reset the timer interval.

A DLEP session will be considered inactive, and MUST be torn down, via the Peer Termination procedure, by an implementation detecting that two (2) Heartbeat intervals have transpired without receipt of any DLEP signals.

The Heartbeat Interval data item contains the following fields:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Data Item Type|    Length     |           Interval            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Data Item Type: TBD

Length: 2

Interval: 0 = Do NOT use heartbeats on this DLEP session. Non-zero = Interval, in seconds, for heartbeat signals.

8.7. Extensions Supported

The Extensions Supported data item MAY be used in both the Peer Initialization and Peer Initialization ACK signals. The Extensions Supported data item is used by the router and modem to negotiate additional optional functionality they are willing to support. The Extensions List is a concatenation of the types of each supported extension, found in the IANA DLEP Extensions repository.

The Extensions Supported data item contains the following fields:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Data Item Type|    Length     | Extensions List               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Data Item Type: TBD

Length: Number of Extensions supported.

Extension List: A list of extensions supported, identified by their 1-octet value as listed in the extensions registry.

8.8. Experimental Definition

The Experimental Definition data item MAY be used in both the Peer Initialization and Peer Initialization ACK signals. The Experimental Definition data item is used by the router and modem to indicate the formats to be used for experimental signals and data items for the given peer session. The formats are identified by using a string that matches the 'name' given to the experiment.

The Experimental Definition item contains the following fields:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Data Item Type|    Length     | Experiment Name               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Data Item Type: TBD

Length: Length of the name string for the Experiment.

Experiment Name: UTF-8 encoded string, containing the name of the experiment being implemented.

An implementation receiving this data item MUST compare the received string to a list of experiments that it supports.

An implementation MUST NOT assume the Experiment Name field is NUL-terminated.

8.9. MAC Address

The MAC address data item MUST appear in all destination-oriented signals (i.e., Destination Up (Section 7.9), Destination Up ACK (Section 7.10), Destination Down (Section 7.11), Destination Down ACK (Section 7.12), Destination Update (Section 7.13), Link Characteristics Request (Section 7.15), and Link Characteristics ACK (Section 7.16)). The MAC Address data item contains the address of the destination on the remote node. The MAC address MAY be either a physical or a virtual destination, and MAY be expressed in EUI-48 or EUI-64 format. Examples of a virtual destination would be a multicast MAC address, or the broadcast MAC (FF:FF:FF:FF:FF:FF).

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Data Item Type|    Length     |          MAC Address          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      MAC Address                              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      MAC Address              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Data Item Type: TBD

Length: 6 for EUI-48 format, or 8 for EUI-64 format

MAC Address: MAC Address of the destination.

8.10. IPv4 Address

The IPv4 Address data item MAY appear in the Peer Update (Section 7.5), Destination Up (Section 7.9) and Destination Update (Section 7.13) signals. When included in Destination signals, this data item contains the IPv4 address of the destination. When included in the Peer Update signal, this data item contains the IPv4 address of the peer. In either case, the data item also contains an indication of whether this is a new or existing address, or is a deletion of a previously known address.

The IPv4 Address data item contains the following fields:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Data Item Type|    Length     |   Add/Drop    | IPv4 Address  |
|               |               |   Indicator   |               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            IPv4 Address                       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Data Item Type: TBD

Length: 5

Add/Drop: Value indicating whether this is a new or existing address (1), or a withdrawal of an address (0).

IPv4 Address: The IPv4 address of the destination or peer.

8.11. IPv6 Address

The IPv6 Address data item MAY appear in the Peer Update (Section 7.5), Destination Up (Section 7.9) and Destination Update (Section 7.13) signals. When included in Destination signals, this data item contains the IPv6 address of the destination. When included in the Peer Update signal, this data item contains the IPv6 address of the peer. In either case, the data item also contains an indication of whether this is a new or existing address, or is a deletion of a previously known address.

The IPv6 Address data item contains the following fields:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Data Item Type|    Length     |   Add/Drop    | IPv6 Address  |
|               |               |   Indicator   |               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        IPv6 Address                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        IPv6 Address                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        IPv6 Address                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                IPv6 Address                   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Data Item Type: TBD

Length: 17

Add/Drop: Value indicating whether this is a new or existing address (1), or a withdrawal of an address (0).

IPv6 Address: IPv6 Address of the destination or peer.

8.12. IPv4 Attached Subnet

The DLEP IPv4 Attached Subnet allows a device to declare that it has an IPv4 subnet (e.g., a stub network) attached, and MAY appear in the Destination Up (Section 7.9) and Destination Update (Section 7.13) signals. Once an IPv4 Subnet has been declared on a device, the declaration can NOT be withdrawn without terminating the destination (via the Destination Down signal (Section 7.11)) and re-issuing the Destination Up signal.

The DLEP IPv4 Attached Subnet data item contains the following fields:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Data Item Type |    Length     | IPv4 Attached Subnet          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      IPv4 Attached Subnet     | Subnet Mask   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Data Item Type: TBD

Length: 5

IPv4 Subnet: The IPv4 subnet reachable at the destination.

Subnet Mask: A subnet mask (0-32) to be applied to the IPv4 subnet.

8.13. IPv6 Attached Subnet

The DLEP IPv6 Attached Subnet allows a device to declare that it has an IPv6 subnet (e.g., a stub network) attached, and MAY appear in the Destination Up (Section 7.9) and Destination Update (Section 7.13) signals. As in the case of the IPv4 attached Subnet data item above, once an IPv6 attached subnet has been declared, it can NOT be withdrawn without terminating the destination (via the Destination Down signal (Section 7.11)) and re-issuing the Destination Up signal.

The DLEP IPv6 Attached Subnet data item contains the following fields:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Data Item Type|    Length     | IPv6 Attached Subnet          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      IPv6 Attached Subnet                                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      IPv6 Attached Subnet                                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      IPv6 Attached Subnet                                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      IPv6 Attached Subnet     | Subnet Mask   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Data Item Type: TBD

Length: 17

IPv4 Subnet: The IPv6 subnet reachable at the destination.

Subnet Mask: A subnet mask (0-128) to be applied to the IPv6 subnet.

8.14. Maximum Data Rate (Receive)

The Maximum Data Rate (Receive) (MDRR) data item MUST appear in the Peer Initialization ACK signal (Section 7.4), and MAY appear in the Peer Update (Section 7.5), Destination Up (Section 7.9), Destination Update (Section 7.13) and Link Characteristics ACK (Section 7.16) signals to indicate the maximum theoretical data rate, in bits per second, that can be achieved while receiving data on the link.

The Maximum Data Rate (Receive) data item contains the following fields:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Data Item Type|    Length     |          MDRR (bps)           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        MDRR (bps)                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           MDRR (bps)          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Data Item Type: TBD

Length: 8

Maximum Data Rate (Receive): A 64-bit unsigned integer, representing the maximum theoretical data rate, in bits per second (bps), that can be achieved while receiving on the link.

8.15. Maximum Data Rate (Transmit)

The Maximum Data Rate (Transmit) (MDRT) data item MUST appear in the Peer Initialization ACK signal (Section 7.4), and MAY appear in the Peer Update (Section 7.5), Destination Up (Section 7.9), Destination Update (Section 7.13) and Link Characteristics ACK (Section 7.16) signals to indicate the maximum theoretical data rate, in bits per second, that can be achieved while transmitting data on the link.

The Maximum Data Rate (Transmit) data item contains the following fields:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Data Item Type|    Length     |          MDRT (bps)           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        MDRT (bps)                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           MDRT (bps)          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Data Item Type: TBD

Length: 8

Maximum Data Rate (Transmit): A 64-bit unsigned integer, representing the maximum theoretical data rate, in bits per second (bps), that can be achieved while transmitting on the link.

8.16. Current Data Rate (Receive)

The Current Data Rate (Receive) (CDRR) data item MUST appear in the Peer Initialization ACK signal (Section 7.4), and MAY appear in the Peer Update (Section 7.5), Destination Up (Section 7.9), Destination Update (Section 7.13) and Link Characteristics ACK (Section 7.16) signals to indicate the rate at which the link is currently operating for receiving traffic.

When used in the Link Characteristics Request signal (Section 7.15), CDRR represents the desired receive rate, in bits per second, on the link.

The Current Data Rate (Receive) data item contains the following fields:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Data Item Type|    Length     | CDRR (bps)                    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        CDRR (bps)                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|        CDRR (bps)             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Data Item Type: TBD

Length: 8

Current Data Rate (Receive): A 64-bit unsigned integer, representing the current data rate, in bits per second, that can currently be achieved while receiving traffic on the link.

If there is no distinction between current and maximum receive data rates, current data rate receive MUST be set equal to the maximum data rate receive.

8.17. Current Data Rate (Transmit)

The Current Data Rate Transmit (CDRT) data item MUST appear in the Peer Initialization ACK signal (Section 7.4), and MAY appear in the Peer Update (Section 7.5), Destination Up (Section 7.9), Destination Update (Section 7.13), and Link Characteristics ACK (Section 7.16) signals to indicate the rate at which the link is currently operating for transmitting traffic.

When used in the Link Characteristics Request signal (Section 7.15), CDRT represents the desired transmit rate, in bits per second, on the link.

The Current Data Rate (Transmit) data item contains the following fields:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Data Item Type|    Length     | CDRT (bps)                    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        CDRT (bps)                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|        CDRT (bps)             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Data Item Type: TBD

Length: 8

Current Data Rate (Transmit): A 64-bit unsigned integer, representing the current data rate, in bits per second, that can currently be achieved while transmitting traffic on the link.

If there is no distinction between current and maximum transmit data rates, current data rate transmit MUST be set equal to the maximum data rate transmit.

8.18. Latency

The Latency data item MUST appear in the Peer Initialization ACK signal (Section 7.4), and MAY appear in the Peer Update (Section 7.5), Destination Up (Section 7.9), Destination Update (Section 7.13), and Link Characteristics ACK (Section 7.16) signals to indicate the amount of latency, in microseconds, on the link.

When used in the Link Characteristics Request signal (Section 7.15), Latency represents the maximum latency desired on the link.

The Latency value is reported as delay. The calculation of latency is implementation dependent. For example, the latency may be a running average calculated from the internal queuing.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Data Item Type|    Length     | Latency                       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Latency (cont.)                       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Latency (cont.)              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Data Item Type: TBD

Length: 8

Latency: A 64-bit unsigned integer, representing the transmission delay, in microseconds, that a packet encounters as it is transmitted over the link.

8.19. Resources (Receive)

The Resources (Receive) (RESR) data item MAY appear in the Peer Initialization ACK signal (Section 7.4), Peer Update (Section 7.5), Destination Up (Section 7.9), Destination Update (Section 7.13) and Link Characteristics ACK (Section 7.16) signals to indicate the amount of resources for reception (with 0 meaning 'no resources available', and 100 meaning 'all resources available') at the destination. The list of resources that might be considered is beyond the scope of this document, and is left to implementations to decide.

The Resources (Receive) data item contains the following fields:

```
 0                   1                   2
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Data Item Type|    Length     |     RESR      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Data Item Type: TBD

Length: 1

Resources (Receive): An 8-bit integer percentage, 0-100, representing the amount of resources allocated to receiving data.

If a device cannot calculate RESR, this data item SHOULD NOT be issued.

8.20. Resources (Transmit)

The Resources (Transmit) (REST) data item MAY appear in the Peer Initialization ACK signal (Section 7.4), Peer Update (Section 7.5), Destination Up (Section 7.9), Destination Update (Section 7.13) and Link Characteristics ACK (Section 7.16) signals to indicate the amount of resources for transmission (with 0 meaning 'no resources available', and 100 meaning 'all resources available') at the destination. The list of resources that might be considered is beyond the scope of this document, and is left to implementations to decide.

The Resources (Transmit) data item contains the following fields:

```
 0                   1                   2
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Data Item Type|    Length     |     REST      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Data Item Type: TBD

Length: 1

Resources (Transmit): An 8-bit integer percentage, 0-100, representing the amount of resources allocated to transmitting data.

If a device cannot calculate REST, this data item SHOULD NOT be issued.

8.21. Relative Link Quality (Receive)

The Relative Link Quality (Receive) (RLQR) data item MAY appear in the Peer Initialization ACK signal (Section 7.4), Peer Update (Section 7.5), Destination Up (Section 7.9), Destination Update (Section 7.13) and Link Characteristics ACK (Section 7.16) signals to indicate the quality of the link for receiving data.

The Relative Link Quality (Receive) data item contains the following fields:

```
 0                   1                   2
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Data Item Type|    Length     |     RLQR      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Data Item Type: TBD

Length: 1

Relative Link Quality (Receive): A non-dimensional 8-bit integer, 1-100, representing relative link quality. A value of 100 represents a link of the highest quality.

If a device cannot calculate the RLQR, this data item SHOULD NOT be issued.

8.22. Relative Link Quality (Transmit)

The Relative Link Quality (Transmit) (RLQT) data item MAY appear in the Peer Initialization ACK signal (Section 7.4), Peer Update (Section 7.5), Destination Up (Section 7.9), Destination Update (Section 7.13) and Link Characteristics ACK (Section 7.16) signals to indicate the quality of the link for transmitting data.

The Relative Link Quality (Transmit) data item contains the following fields:

```
 0                   1                   2
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Data Item Type|    Length     |     RLQT      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Data Item Type: TBD

Length: 1

Relative Link Quality (Transmit): A non-dimensional 8-bit integer, 1-100, representing relative link quality. A value of 100 represents a link of the highest quality.

If a device cannot calculate the RLQT, this data item SHOULD NOT be issued.

8.23. Link Characteristics ACK Timer

The Link Characteristics ACK Timer data item MAY appear in the Link Characteristics Request signal (Section 7.15) to indicate the desired number of seconds to the sender will wait for a response to the request. If this data item is omitted, implementations supporting the Link Characteristics Request SHOULD choose a default value.

The Link Characteristics ACK Timer data item contains the following fields:

```
 0                   1                   2
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Data Item Type|    Length     | Interval      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Data Item Type: TBD

Length: 1

Interval: 0 = Do NOT use timeouts for this Link Characteristics request. Non-zero = Interval, in seconds, to wait before considering this Link Characteristics Request has been lost.

9. Credit-Windowing

DLEP includes an OPTIONAL Protocol Extension for a credit-windowing scheme analogous to the one documented in [RFC5578]. In this scheme, traffic between the router and modem is treated as two unidirectional windows. This document identifies these windows as the 'Modem Receive Window' (MRW), and the 'Router Receive Window' (RRW).

If the OPTIONAL credit-windowing extension is used, credits MUST be granted by the receiver on a given window - that is, on the 'Modem Receive Window' (MRW), the modem is responsible for granting credits to the router, allowing it (the router) to send data to the modem. Likewise, the router is responsible for granting credits on the RRW, which allows the modem to send data to the router.

Credits are managed on a destination-specific basis; that is, separate credit counts are maintained for each destination requiring the service. Credits do not apply to the DLEP session that exists between routers and modems.

If a peer is able to support the OPTIONAL credit-windowing extension then it MUST include a Extensions Supported data item (Section 8.7) including the value DLEP_EXT_CREDITS (value TBD) in the appropriate Peer Initialization or Peer Initialization ACK signal.

9.1. Credit-Windowing Signals

The credit-windowing extension introduces no additional DLEP signals. However, if a peer has advertised during session initialization that it supports the credit-windowing extension then the following DLEP signals MAY contain additional credit-windowing data items:

9.1.1. Destination Up Signal

The Destination Up signal MAY contain one of each of the following data items:

- Credit Grant (Section 9.2.1)

If the Destination Up signal does not contain the Credit Grant data item, credits MUST NOT be used for that destination.

9.1.2. Destination Up ACK Signal

If the corresponding Destination Up signal contained the Credit Grant data item, the Destination Up ACK signal MUST contain one of each of the following data items:

- Credit Window Status (Section 9.2.2)

9.1.3. Destination Update Signal

If the corresponding Destination Up signal contained the Credit Grant data item, the Destination Update signal MUST contain one of each of the following data items:

- Credit Window Status (Section 9.2.2)

If the corresponding Destination Up signal contained the Credit Grant data item, the Destination Update signal MAY contain one of each of the following data items:

- Credit Grant (Section 9.2.1)

o Credit Request (Section 9.2.3)

9.2. Credit-Windowing Data Items

The credit-windowing extension introduces 3 additional data items. If a peer has advertised during session initialization that it supports the credit-windowing extension then it MUST correctly process the following data items without error.

Data Item	Description	Section
TBD	Credit Grant	Section 9.2.1
TBD	Credit Window Status	Section 9.2.2
TBD	Credit Request	Section 9.2.3

9.2.1. Credit Grant

The Credit Grant data item is sent from a DLEP participant to grant an increment to credits on a window. The Credit Grant data item MAY appear in the Destination Up (Section 7.9) and Destination Update (Section 7.13) signals. The value in a Credit Grant data item represents an increment to be added to any existing credits available on the window. Upon successful receipt and processing of a Credit Grant data item, the receiver MUST respond with a signal containing a Credit Window Status data item to report the updated aggregate values for synchronization purposes, and if initializing a new credit window, granting initial credits.

In the Destination Up signal, when credits are desired, the originating peer MUST set the initial credit value of the window it controls (i.e., the Modem Receive Window, or Router Receive Window) to an initial, non-zero value. If the receiver of a Destination Up signal with a Credit Grant data item supports credits, the receiver MUST either reject the use of credits for this destination, via a Destination Up ACK response containing a Status data item (Section 8.2) with a status code of 'Request Denied', or set the initial value from the data contained in the Credit Window Status data item. If the initialization completes successfully, the receiver MUST respond to the Destination Up signal with a Destination Up ACK signal that contains a Credit Window Status data item, initializing its receive window.

The Credit Grant data item contains the following fields:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Data Item Type|    Length     |       Credit Increment        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      Credit Increment                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      Credit Increment         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Data Item Type: TBD

Length: 8

Reserved: A 64-bit unsigned integer representing the additional credits to be assigned to the credit window.

Since credits can only be granted by the receiver on a window, the applicable credit window (either the MRW or the RRW) is derived from the sender of the grant. The Credit Increment MUST NOT cause the window to overflow; if this condition occurs, implementations MUST set the credit window to the maximum value contained in a 64-bit quantity.

9.2.2. Credit Window Status

If the credit-window extension is supported by the DLEP participants (both the router and the modem), the Credit Window Status data item MUST be sent by the participant receiving a Credit Grant for a given destination.

The Credit Window Status data item contains the following fields:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Data Item Type|    Length     | Modem Receive Window Value    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                   Modem Receive Window Value                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Modem Receive Window Value   | Router Receive Window Value   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                Router Receive Window Value                    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Router Receive Window Value  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Data Item Type: TBD

Length: 16

Modem Receive Window Value: A 64-bit unsigned integer, indicating the current number of credits available on the Modem Receive Window, for the destination referred to by the signal.

Router Receive Window Value: A 64-bit unsigned integer, indicating the current number of credits available on the Router Receive Window, for the destination referred to by the signal.

9.2.3. Credit Request

The Credit Request data item MAY be sent from either DLEP participant, via the Destination Update signal (Section 7.13), to indicate the desire for the partner to grant additional credits in order for data transfer to proceed on the session. If the corresponding Destination Up signal (Section 7.9) for this session did NOT contain a Credit Window Status data item, indicating that credits are to be used on the session, then the Credit Request data item MUST be silently dropped by the receiver.

The Credit Request data item contains the following fields:

```
 0                   1                   2
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Data Item Type|    Length     | Reserved, MUST|
|               |               | be set to 0   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Data Item Type: TBD

Length: 1

Reserved: This field is currently unused and MUST be set to 0.

10. Security Considerations

The protocol does not contain any mechanisms for security (e.g., authentication or encryption). The protocol assumes that any security would be implemented in the underlying transport (for example, by use of TLS or some other mechanism), and is therefore outside the scope of this document.

11. IANA Considerations

This section specifies requests to IANA.

11.1. Registrations

This specification defines:

- A new repository for DLEP signals, with sixteen values currently assigned.
- Reservation of numbering space for Experimental DLEP signals.
- A new repository for DLEP data items, with twenty-six values currently assigned.
- Reservation of numbering space in the data items repository for experimental data items.
- A new repository for DLEP status codes, with seven currently assigned.
- A new repository for DLEP extensions, with one value currently assigned.
- A request for allocation of a well-known port for DLEP TCP and UDP communication.
- A request for allocation of a multicast IP address for DLEP discovery.

11.2. Expert Review: Evaluation Guidelines

No additional guidelines for expert review are anticipated.

11.3. Signal Type Registration

A new repository must be created with the values of the DLEP signals.

All signal values are in the range [0..255].

Valid signals are:

- Peer Discovery
- Peer Offer
- Peer Initialization

- Peer Initialization ACK
- Peer Update
- Peer Update ACK
- Peer Termination
- Peer Termination ACK
- Destination Up
- Destination Up ACK
- Destination Down
- Destination Down ACK
- Destination Update
- Heartbeat
- Link Characteristics Request
- Link Characteristics ACK

It is also requested that the repository contain space for experimental signal types.

11.4. DLEP Data Item Registrations

A new repository for DLEP data items must be created.

All data item values are in the range [0..255].

Valid data items are:

- DLEP Version
- Status
- IPv4 Connection Point
- IPv6 Connection Point
- Peer Type
- Heartbeat Interval

o Extensions Supported

o Experimental Definition

o MAC Address

o IPv4 Address

o IPv6 Address

o IPv4 Attached Subnet

o IPv6 Attached Subnet

o Maximum Data Rate (Receive)

o Maximum Data Rate (Transmit)

o Current Data Rate (Receive)

o Current Data Rate (Transmit)

o Latency

o Resources (Receive)

o Resources (Transmit)

o Relative Link Quality (Receive)

o Relative Link Quality (Transmit)

o Link Characteristics ACK Timer

o Credit Window Status

o Credit Grant

o Credit Request

It is also requested that the registry allocation contain space for experimental data items.

11.5. DLEP Status Code Registrations

A new repository for DLEP status codes must be created.

All status codes are in the range [0..255].

Valid status codes are:

- o Success (value 0)
- o Unknown Signal
- o Invalid Data
- o Unexpected Signal
- o Request Denied
- o Timed Out
- o Invalid Destination

11.6. DLEP Extensions Registrations

A new repository for DLEP extensions must be created.

All extension values are in the range [0..255].

Valid extensions are:

- o DLEP_EXT_CREDITS - Credit windowing

11.7. DLEP Well-known Port

It is requested that IANA allocate a well-known port number for DLEP communication.

11.8. DLEP Multicast Address

It is requested that IANA allocate a multicast address for DLEP discovery signals.

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13. References

13.1. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

13.2. Informative References

[RFC5246] Dierks, T. and E. Rescorla, "The Transport Layer Security (TLS) Protocol Version 1.2", RFC 5246, August 2008.

[RFC5578] Berry, B., Ratliff, S., Paradise, E., Kaiser, T., and M. Adams, "PPP over Ethernet (PPPoE) Extensions for Credit Flow and Link Metrics", RFC 5578, February 2010.

Appendix A. Peer Level Signal Flows

A.1. Discovery

```
Router                        Modem    Signal Description
========================================================================

|                                      Router initiates discovery, starts
|                                      a timer, send Peer Discovery
|-------Peer Discovery---->||          signal.

         ~ ~ ~ ~ ~ ~ ~                 Router discovery timer expires
                                       without receiving Peer Offer.


|                                      Router sends another Peer
|-------Peer Discovery---------->|     Discovery signal.
                                 |
                                 |     Modem receives Peer Discovery
                                 |     signal.
                                 |
                                 |     Modem sends Peer Offer with
|<--------Peer Offer-------------|     Connection Point information.
:
:                                      Router MAY cancel discovery timer
:                                      and stop sending Peer Discovery
:                                      signals.
```

A.2. Session Initialization

```
Router                       Modem    Signal Description
========================================================================

|                                     Router connects to discovered or
|                                     pre-configured Modem Connection
|---------TCP connect---------->      Point.
|
|                                     Router sends Peer Initialization
|-------Peer Initialization----->|    signal.
                                 |
                                 |    Modem receives Peer Initialization
                                 |    signal.
                                 |
                                 |    Modem sends Peer Initialization
                                 |    ACK, with compatible extensions,
|<----Peer Initialization ACK----|    and Success status data item.
|                                |
|<<============================>>|    Session established. Heartbeats
:                                :    begin.
```

A.3. Session Initialization - Refused

```
Router                       Modem    Signal Description
========================================================================

|                                     Router connects to discovered or
|                                     pre-configured Modem Connection
|---------TCP connect---------->      Point.
|
|                                     Router sends Peer Initialization
|-------Peer Initialization----->|    signal.
                                 |
                                 |    Modem receives Peer Initialization
                                 |    signal, and will not support the
                                 |    advertised version, experiment or
                                 |    extensions.
                                 |
                                 |    Modem sends Peer Initialization
                                 |    ACK, with 'Request Denied' status
|<----Peer Initialization ACK----|    data item.
|                                |
|  <---- TCP shutdown (send)-----|    Modem closes TCP connection.
|
|                                     Router receives negative Peer
|                                     Initialization ACK, closes
|---------TCP close----------->       TCP connection.
|
||------------------------------||    Session not started.
```

A.4. Router Changes IP Addresses

```
Router                        Modem    Signal Description
========================================================================

|                                      Router sends Peer Update signal to
|--------Peer Update------------>|    announce change of IP address
                                 |
                                 |    Modem receives Peer Update signal
                                 |    and updates internal state.
                                 |
|<-------Peer Update ACK---------|    Modem sends Peer Update ACK.
```

A.5. Modem Changes Session-wide Metrics

```
Router                        Modem    Signal Description
========================================================================

                                 |    Modem sends Peer Update signal to
                                 |    announce change of modem-wide
|<--------Peer Update------------|    metrics
|
|                                      Router receives Peer Update signal
|                                      and updates internal state.
|
|-------Peer Update ACK--------->|    Router sends Peer Update ACK.
```

A.6. Router Terminates Session

```
Router                        Modem    Signal Description
========================================================================

|                                      Router sends Peer Termination
|-------Peer Termination-------->|    signal with Status data item.
|                                |
|-------TCP shutdown (send)--->  |    Router stops sending signals.
                                 |
                                 |    Modem receives Peer Termination,
                                 |    stops counting received heartbeats
                                 |    and stops sending heartbeats.
                                 |
                                 |    Modem sends Peer Termination ACK
|<-----Peer Termination ACK------|    with Status 'Success'.
|                                |
|  <----TCP shutdown (send)------|    Modem stops sending signals.
|
||------------------------------||    Session terminated.
```

A.7. Modem Terminates Session

```
Router                       Modem    Signal Description
========================================================================

                                 |    Modem sends Peer Termination
|<------Peer Termination---------|    signal with Status data item.
|                                |
|  <----TCP shutdown (send)------|    Modem stops sending signals.
|
|                                     Router receives Peer Termination,
|                                     stops counting received heartbeats
|                                     and stops sending heartbeats.
|
|                                     Router sends Peer Termination ACK
|------Peer Termination ACK----->|    with Status 'Success'.
|                                |
|-------TCP shutdown (send)--->  |    Router stops sending signals.
                                 |
||------------------------------||    Session terminated.
```

A.8. Session Heartbeats

```
Router                        Modem    Signal Description
========================================================================

|----------Heartbeat------------>|    Router sends heartbeat signal
                                 |
                                 |    Modem resets heartbeats missed
                                 |    counter.

         ~ ~ ~ ~ ~ ~ ~

|----------[Any signal]--------->|    When the Modem receives any signal
                                 |    from the Router.
                                 |
                                 |    Modem resets heartbeats missed
                                 |    counter.

         ~ ~ ~ ~ ~ ~ ~

|<---------Heartbeat-------------|    Modem sends heartbeat signal
|
|                                     Router resets heartbeats missed
|                                     counter.

         ~ ~ ~ ~ ~ ~ ~

|<---------[Any signal]----------|    When the Router receives any
|                                     signal from the Modem.
|
|                                     Modem resets heartbeats missed
|                                     counter.
```

A.9. Router Detects a Heartbeat timeout

```
Router                        Modem    Signal Description
========================================================================

        ||<----------------------|    Router misses a heartbeat


|       ||<----------------------|    Router misses too many heartbeats
|
|
|-------Peer Termination-------->|    Router sends Peer Termination
|                                     signal with 'Timeout' Status
|                                     data item.
:
:                                     Termination proceeds as above.
```

A.10. Modem Detects a Heartbeat timeout

```
Router                        Modem    Signal Description
========================================================================

|---------------------->||             Modem misses a heartbeat


|---------------------->||       |     Modem misses too many heartbeats
                                 |
                                 |
|<-------Peer Termination--------|     Modem sends Peer Termination
                                 |     signal with 'Timeout' Status
                                 |     data item.
                                 :
                                 :     Termination proceeds as above.
```

Appendix B. Destination Specific Signal Flows

B.1. Common Destination Signaling

```
Router                        Modem    Signal Description
========================================================================

                                 |     Modem detects a new logical
                                 |     destination is reachable, and
|<-------Destination Up----------|     sends Destination Up signal.
|
|--------Destination Up ACK----->|     Router sends Destination Up ACK.

           ~ ~ ~ ~ ~ ~ ~
                                 |     Modem detects change in logical
                                 |     destination metrics, and sends
|<-------Destination Update------|     Destination Update signal.

           ~ ~ ~ ~ ~ ~ ~
                                 |     Modem detects change in logical
                                 |     destination metrics, and sends
|<-------Destination Update------|     Destination Update signal.

            ~ ~ ~ ~ ~ ~ ~
                                 |     Modem detects logical destination
                                 |     is no longer reachable, and sends
|<-------Destination Down--------|     Destination Down signal.
|
|                                      Router receives Destination Down,
|                                      updates internal state, and sends
|--------Destination Down ACK--->|     Destination Down ACK signal.
```

B.2. Multicast Destination Signaling

```
Router                        Modem    Signal Description
========================================================================

|                                      Router detects a new multicast
|                                      destination is in use, and sends
|--------Destination Up--------->|     Destination Up signal.
                                 |
                                 |     Modem updates internal state to
                                 |     monitor multicast destination, and
|<-------Destination Up ACK------|     sends Destination Up ACK.

           ~ ~ ~ ~ ~ ~ ~
                                 |     Modem detects change in multicast
                                 |     destination metrics, and sends
|<-------Destination Update------|     Destination Update signal.

           ~ ~ ~ ~ ~ ~ ~
                                 |     Modem detects change in multicast
                                 |     destination metrics, and sends
|<-------Destination Update------|     Destination Update signal.

            ~ ~ ~ ~ ~ ~ ~
|                                      Router detects multicast
|                                      destination is no longer in use,
|--------Destination Down------->|     and sends Destination Down signal.
                                 |
                                 |     Modem receives Destination Down,
                                 |     updates internal state, and sends
|<-------Destination Down ACK----|     Destination Down ACK signal.
```

B.3. Link Characteristics Request

```
Router                       Modem    Signal Description
========================================================================

                                      Destination has already been
           ~ ~ ~ ~ ~ ~ ~              announced by either peer.

|                                     Router requires different
|                                     Characteristics for the
|                                     destination, and sends Link
|--Link Characteristics Request->|    Characteristics Request signal.
                                 |
                                 |    Modem attempts to adjust link
                                 |    status to meet the received
                                 |    request, and sends a Link
                                 |    Characteristics Request ACK
|<---Link Char. Request ACK------|    signal with the new values.
```

Authors' Addresses

Stan Ratliff
VT iDirect
13861 Sunrise Valley Drive, Suite 300
Herndon, VA 20171
USA

Email: sratliff@idirect.net

Bo Berry

Shawn Jury
Cisco Systems
170 West Tasman Drive
San Jose, CA 95134
USA

Email: sjury@cisco.com

Darryl Satterwhite
Broadcom

Email: dsatterw@broadcom.com

Rick Taylor
Airbus Defence & Space
Quadrant House
Celtic Springs
Coedkernew
Newport NP10 8FZ
UK

Email: rick.taylor@airbus.com