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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 (in the case of cable/DSL modems), 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 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 authors have developed the Data 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.

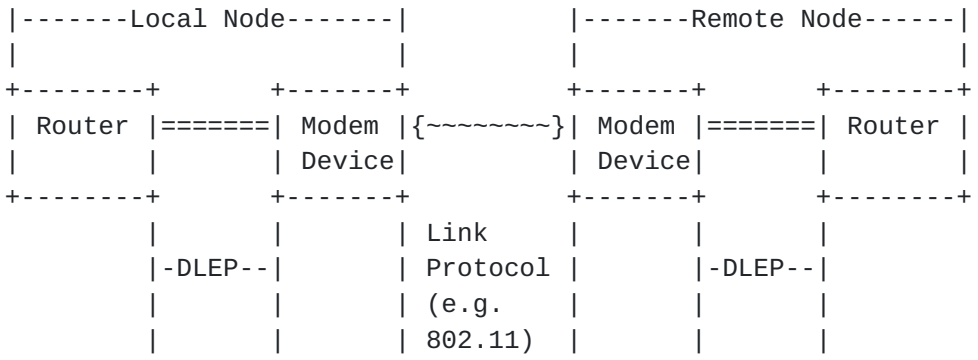



Figure 1: DLEP Network

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. 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 utilize 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.

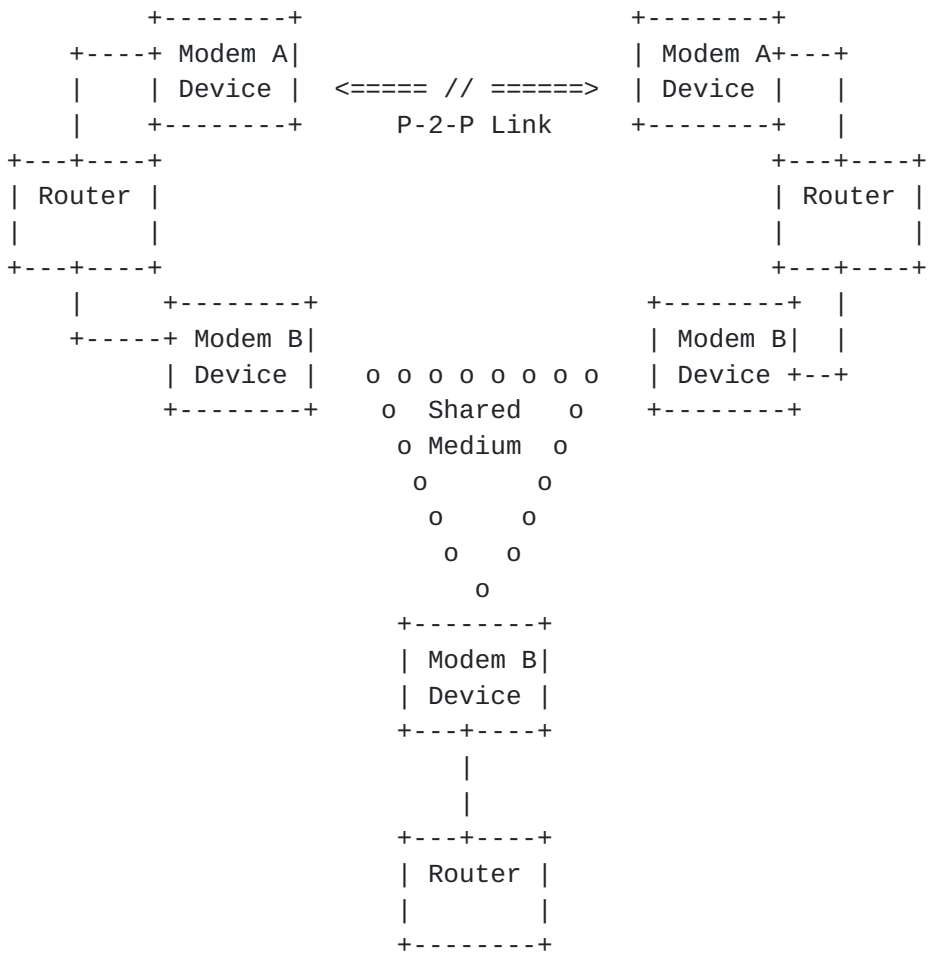



Figure 2: DLEP Network with Multiple Modem Devices

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 signals are further defined as mandatory or optional. Signals will additionally have mandatory and optional data items. Implementations MUST support all mandatory signals and their mandatory data items to be considered compliant. Implementations MAY also support some, or all, of the optional signals and data items.

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), a separate DLEP session MUST exist for each modem. If a modem device supports multiple connections to a router (via multiple logical or physical interfaces), or supports connections to multiple routers, a separate DLEP session MUST exist for each 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.

Any DLEP signal that is 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 data item that is NOT understood by a receiver MUST be ignored.

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 neighbor. The modem, once it is aware of the existence of this logical neighbor, reports link characteristics just as it would for any other destination in the network. The specific algorithms a modem would use to report metrics on multicast (or logical) destinations is outside the scope of this specification, and is left to specific implementations to decide.

### 1.1 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 utilize a discovery technique to locate each other, thus avoiding a-priori configuration. The router is responsible for initialing the discovery process, using the Peer Discovery signal.

DLEP utilizes a session-oriented paradigm. A router and modem form a session by completing the discovery 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 participating modems, and their physical links, act as a transparent IEEE 802.1D bridge. Specifically, the assumption is that the destination MAC address for data traffic (frames destined for the far-end node, as opposed to the DLEP control traffic itself) in any frame emitted by the router should be the MAC address of a device in the remote node. DLEP also assumes that MAC addresses are unique within the context of the router-modem session.

DLEP utilizes 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.

This document refers to a remote node as a "Destination". 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). Destinations MAY refer either to physical devices in the network, or to logical destinations, as in a derived multicast MAC address associated with a group. As "destinations" are discovered, DLEP routers and modems build an information base on destinations accessible via the modem. Changes in link characteristics MAY then be reported as being "modem-wide" (effecting ALL destinations accessed via the modem) or MAY be neighbor (destination) specific.

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 (e.g., MAC address, and OPTIONALLY, Layer 3 addresses), link characteristics (metrics), and OPTIONALLY, flow control information (credits).

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 [TLS]).

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. Mandatory Versus Optional Items

As mentioned above, DLEP defines a core set of signals and data items as mandatory. Support for those signals and data items MUST exist in an implementation to guarantee interoperability and therefore make an implementation DLEP compliant. However, a mandatory signal or data item is not necessarily required - as an example, consider the data item entitled "DLEP Optional Signals Supported", defined in section 10.22 of this document. The data item allows a DLEP implementation to list all optional behavior it supports, and is sent as a part of the Peer Initialization signal. Receiving implementations MUST be capable of parsing and understanding the optional signals that are offered. However, if the sending implementation has chosen NOT to implement ANY optional functionality, this data item would NOT be included in the Peer Initialization. Although parsing and understanding the data item is a mandatory function of a compliant DLEP, the data item itself MAY, or MAY NOT, appear in the flow. Absence of the mandatory data item would not be considered a protocol error, but as support for the core DLEP signals ONLY. Therefore, care should be taken to

differentiate the notion of a mandatory data item versus one that MUST appear in a given message.

## 4. Credits

DLEP includes an OPTIONAL 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", or MRW, and the "Router Receive Window", or RRW.

If the OPTIONAL credit-windowing scheme 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.

DLEP expresses all credit data in number of octets. The total number of credits on a window, and the increment to add to a grant, are always expressed as a 64-bit unsigned quantity.

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

## 5. 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, metrics have to be used within a context - for example, metrics to a unicast address in the network. 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). 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 neighbor only.

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

## 6. Extensions to DLEP

While this draft represents the best efforts of the co-authors, and 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 utilized. There are three possible avenues for DLEP extensions: protocol extensions, vendor extensions, and experimental extensions.

### 6.1 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.

### 6.2 Vendor Extensions

Vendor extensions to DLEP are accommodated via the "DLEP Vendor Extension" TLV, documented in Section 10.22 of this document. If a perceived extension exceeds the scope of what can be contained in the DLEP Vendor Extension TLV, the proposed extension should be addressed as either an update to this document, or as a stand-alone specification.

### 6.3 Experimental Extensions

This document requests numbering space in both the Signal and Data

Item registries for experimental items. The intent is to allow for experimentation with new signals and/or 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. Experimental DLEP signals SHOULD be treated as optional signals - e.g., they SHOULD be announced in the "DLEP Optional Signals TLV" in Peer Initialization and/or Peer Initialization ACK. Likewise, experimental data item TLVs SHOULD be announced in the "DLEP Optioinal Data Items" TLV (also in Peer Initialization/Peer Initialization ACK).

## 7. Normal Session Flow

Normal session flow for a DLEP router has two sub-cases, depending on whether the implementation supports the discovery process. Since modems MUST support the discovery process, there is only one description necessary for modem implementations. The normal flow by DLEP partner type is:

### 7.1 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 to the DLEP link-local multicast address and port (TBD). The implementation then waits on receipt of a Peer Offer signal, which MUST contain the unicast address and port for TCP-based communication with a DLEP modem. The Peer Offer signal MAY contain multiple address/port combinations. If more than one address/port combination is in the Peer Offer, the DLEP router implementation SHOULD consider the list to be in priority sequence, with the "most desired" address/port combination listed first. However, router implementations MAY use their own heuristics to determine the best address/port combination. 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.

### 7.2 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 modem implementation MUST issue a Peer Initialization signal to

the DLEP router. The Peer Initialization signal MUST contain TLVs for ALL supported metrics from this modem (e.g. all mandatory metrics plus all optional metrics supported by the implementation), along with the default values of those metrics. After sending the Peer Initialization, the modem implementation MUST wait for receipt of a Peer Initialization ACK signal from the router. Receipt of the Peer Initialization ACK indicates that the router 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, can flow on the DLEP session between modem and router. The "in session" state is maintained until one of the following conditions occur:

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

### 7.3 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 on the UDP socket, it responds by issuing a Peer Offer signal to the sender of the Peer Discovery. The Peer Offer signal MUST contain the unicast address and port of the TCP listen socket, described above. A DLEP modem implementation MAY respond with ALL address/port combinations that have an active TCP listen posted. If multiple address/port combinations are listed, the receiver of the Peer Offer MAY connect on any available address/port pair. 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 send a Peer Initialization signal. The Peer Initialization MUST contain metric TLVs for ALL mandatory metrics, and MUST contain metric TLVs for ANY optional metrics supported by the modem. If a new 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 signal.

### 7.4 Common Session Flow

In order to maintain the session between router and modem, periodic "Heartbeat" signals MAY be exchanged. These signals are intended to keep the session alive, and to verify bidirectional connectivity between the two participants. DLEP also provides an OPTIONAL Peer Update signal, 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. Receipt of a Destination Up causes the router to allocate the necessary resources, creating an entry in the information base with the specifics (e.g., MAC Address, Latency, Data Rate, etc) of the neighbor. The loss of a destination is communicated via the "Destination Down" signal, and changes in status to the destination (e.g. varying link quality, or addressing changes) are communicated via the "Destination Update" signal. The information on a given neighbor will persist in the router's information base until (1) a "Destination Down" 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.

Again, metrics can be expressed within the context of a specific neighbor via the Destination Update signal, or on a modem-wide basis via the Peer Update signal. In cases where metrics are provided on the router/modem session, 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 neighbor 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 an OPTIONAL signal allowing a router to request a different datarate, or latency, from the modem. This signal is referred to as the Link Characteristics Signal, 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.

## 8. Mandatory Signals and Data Items

The following DLEP signals are considered core to the specification; implementations MUST support these signals, and the associated data

items, in order to be considered compliant:

| Signal | Data Items |
|---|---|
| Peer Discovery (Router Only) | None |
| Peer Offer (Modem Only) | IPv4 Address<br>IPv6 address<br>DLEP Port |
| Peer Initialization | Maximum Data Rate (Receive)<br>Maximum Data Rate (Transmit)<br>Current Data Rate (Receive)<br>Current Data Rate (Transmit)<br>Latency<br>Relative Link Quality (Receive)<br>Relative Link Quality (Transmit)<br>DLEP Optional Signal Support<br>DLEP Optional Data Item Support |
| Peer Initialization ACK | Status |
| Peer Termination | Status |
| Peer Termination ACK | Status |
| Destination Up | MAC Address<br>Maximum Data Rate (Receive)<br>Maximum Data Rate (Transmit)<br>Current Data Rate (Receive)<br>Current Data Rate (Transmit)<br>Latency<br>Relative Link Quality (Receive)<br>Relative Link Quality (Transmit) |
| Destination Update | MAC Address<br>Maximum Data Rate (Receive)<br>Maximum Data Rate (Transmit)<br>Current Data Rate (Receive)<br>Current Data Rate (Transmit)<br>Latency<br>Relative Link Quality (Receive)<br>Relative Link Quality (Transmit) |
| Destination Down | MAC Address |

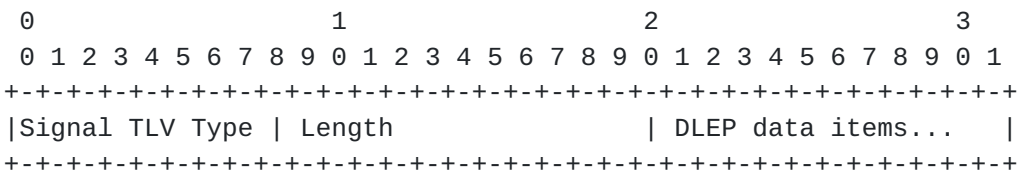
All other DLEP signals and data items are OPTIONAL. Implementations MAY choose to provide them. Implementations that do not support

optional signals MUST report an error condition and terminate the router/modem session upon receipt of any such signal received. OPTIONAL data items received that are not supported MUST be silently dropped.

## 9. Generic DLEP Signal Definition

The Generic DLEP Signal consists of a sequence of TLVs. The first TLV represents the signal being communicated (e.g., a "Destination Up", or a "Peer Offer"). Subsequent TLVs contain the data items pertinent to the signal (e.g., Maximum Data Rate, or Latency, etc).

The Generic DLEP Packet Definition contains the following fields:




Signal - One of the DLEP Signal TLV type values defined in this document.

Length - The length, expressed as a 16-bit quantity, of all of the DLEP data items associated with this signal.

DLEP data items - One or more data items, encoded in TLVs, as defined in this document.

## 10. DLEP Data Items

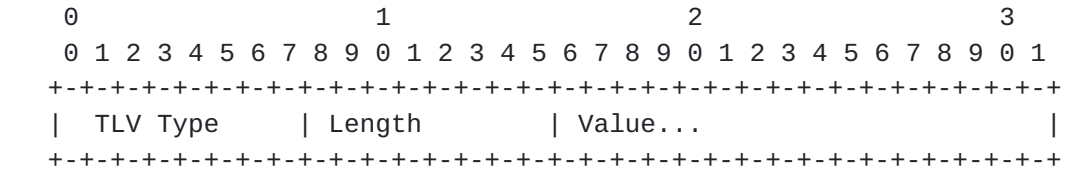
As mentioned earlier, DLEP protocol signals are transported as a collection of TLVs. The first TLV present in a DLEP signal MUST be one of the Signal TLVs, documented in section 10. The signals are followed by one or more data items, indicating the specific changes that need to be instantiated in the receiver's information base.

Valid DLEP Data Items are:

| TLV Value | TLV Description |
|---|---|
| TBD | DLEP Port |
| TBD | Peer Type |
| TBD | IPv4 Address |

| | |
|---|---|
| TBD | IPv6 Address |
| TBD | Maximum Data Rate (Receive) (MDRR) |
| TBD | Maximum Data Rate (Transmit) (MDRT) |
| TBD | Current Data Rate (Receive) (CDRR) |
| TBD | Current Data Rate (Transmit) (CDRT) |
| TBD | Latency |
| TBD | Receive Resources |
| TBD | Transmit Resources |
| TBD | Relative Link Quality (Receive) (RLQR) |
| TBD | Relative Link Quality (Transmit) (RLQT) |
| TBD | Status |
| TBD | Heartbeat Interval/Threshold |
| TBD | Neighbor down ACK timer |
| TBD | Link Characteristics ACK timer |
| TBD | Credit Window Status |
| TBD | Credit Grant |
| TBD | Credit Request |
| TBD | DLEP Optional Signals Supported |
| TBD | DLEP Optional Data Items Supported |
| TBD | DLEP Vendor Extension |

DLEP data item TLVs contain the following fields:




TLV Type - An 8-bit unsigned integer field specifying the data item being sent.

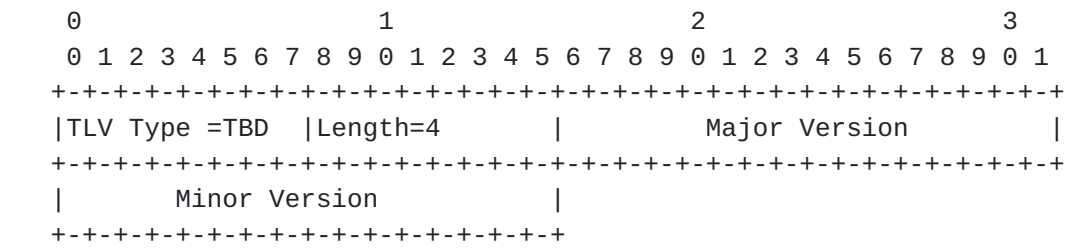
Length - An 8-bit length of the value field of the data item

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

## 10.1 DLEP Version

The DLEP Version TLV is a mandatory TLV in the Peer Discovery, Peer Initialization, and Peer Initialization ACK signals. The Version TLV is used to indicate the version of the protocol running in the originator. A DLEP implementation MAY use this information to decide if the potential session partner is running at a supported level.

The DLEP Version TLV contains the following fields:




TLV Type - TBD

Length - Length is 4

Major Version - Major version of the modem or router protocol.

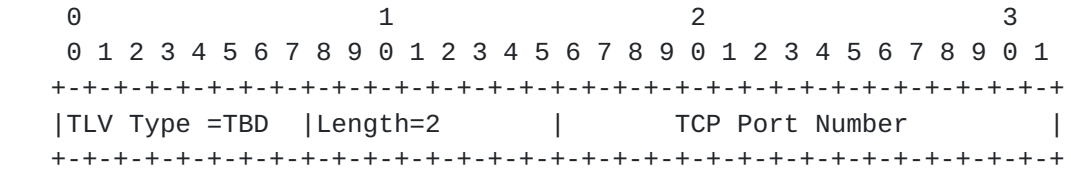
Minor Version - Minor version of the modem or router protocol.

Support of this draft is indicated by setting the Major Version to '0', and the Minor Version to '7' (e.g. Version 0.7).

## 10.2 DLEP Port

The DLEP Port TLV is a mandatory TLV in the Peer Offer signal. The DLEP Port TLV is used to indicate the TCP Port number on the DLEP server available for connections. The receiver MUST use this information to perform the TCP connect to the DLEP server.

The DLEP Port TLV contains the following fields:




TLV Type - TBD

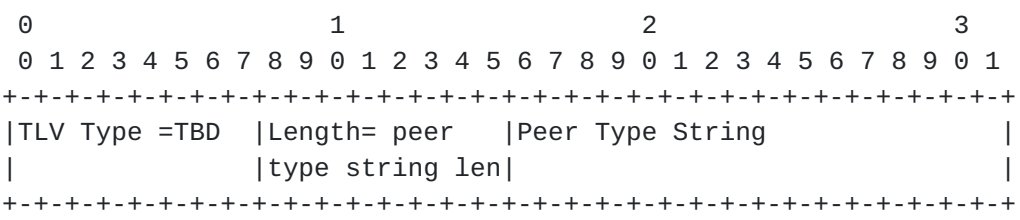
Length - Length is 2

TCP Port Number - TCP Port number on the DLEP server.

## 10.3 Peer Type

The Peer Type TLV is an OPTIONAL TLV in both the Peer Discovery and Peer Offer signals. The Peer Type TLV 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 TLV contains the following fields:



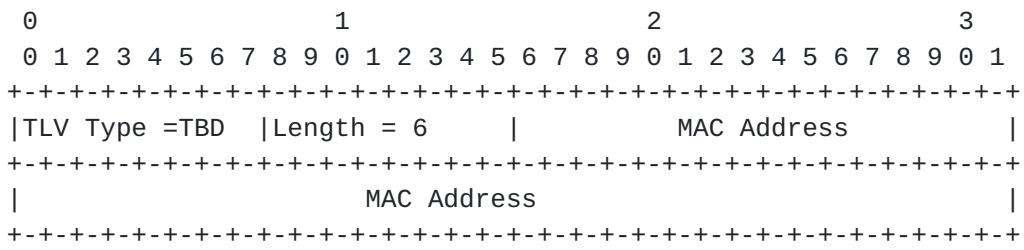

TLV Type - TBD

Length - Length of peer type string.

Peer Type String - Non-Null terminated string, using UTF-8 encoding. For example, a satellite modem might set this variable to 'Satellite terminal'.

## 10.4 MAC Address

The MAC address TLV MUST appear in all destination-oriented signals (e.g. Destination Up, Destination Up ACK, Destination Down, Destination Down ACK, Destination Update, Link Characteristics Request, and Link Characteristics ACK). The MAC Address TLV contains the address of the destination on the remote node. The MAC address MAY be either a physical or a virtual destination. Examples of a virtual destination would be a multicast MAC address, or the broadcast MAC (0xFFFFFFFFFFFF).




TLV Type - TBD

Length - 6

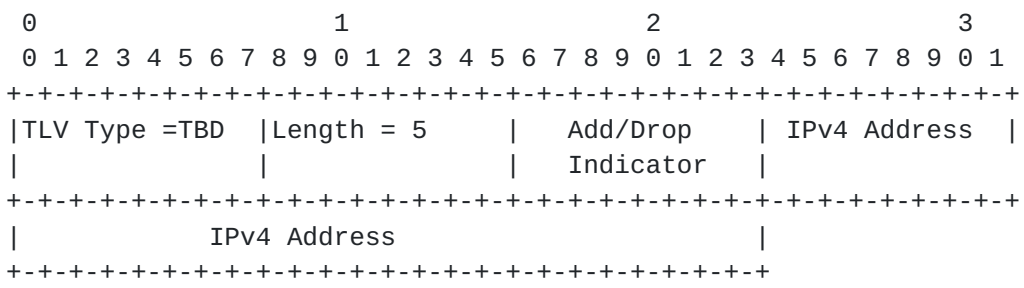
MAC Address - MAC Address of the destination (either physical or virtual).

## 10.5 IPv4 Address

The IPv4 Address TLV is an optional TLV. If supported, it MAY appear in Destination Up, Destination Update, Peer Initialization, and Peer

Update signals. When included in Destination signals, the IPv4 Address TLV contains the IPv4 address of the destination, as well as a subnet mask value. In the Peer Update signal, it contains the IPv4 address of the originator of the signal. In either case, the TLV 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 TLV contains the following fields:




TLV Type - TBD

Length - 6

Add/Drop - Value indicating whether this is a new or existing address (0x01), or a withdrawal of an address (0x02).

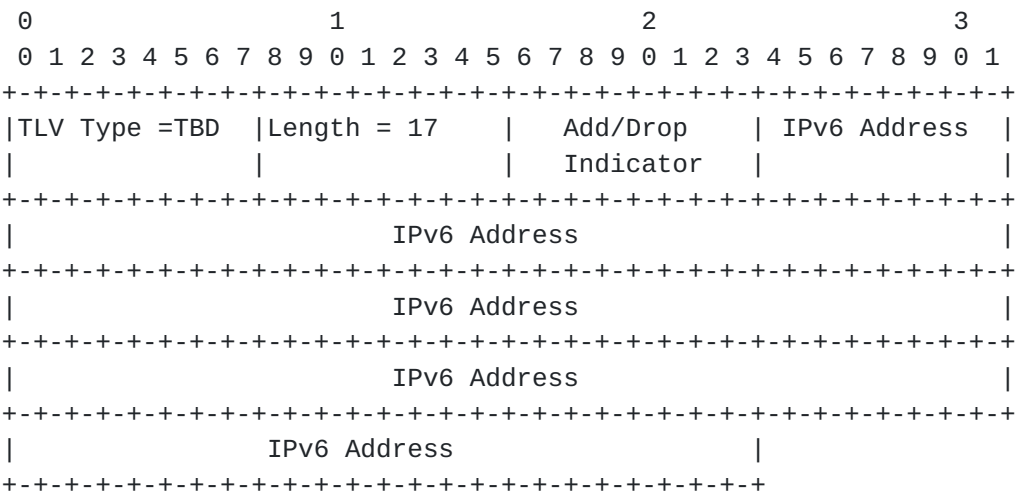
IPv4 Address - The IPv4 address of the destination or peer.

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

## 10.6 IPv6 Address

The IPv6 Address TLV is an optional TLV. If supported, it MAY be used in the Destination Up, Destination Update, Peer Initialization, and Peer Update Signals. When included in Destination signals, this data item contains the IPv6 address of the destination. In the Peer Discovery and Peer Update, it contains the IPv6 address of the originating 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, as well as a subnet mask.

The IPv6 Address TLV contains the following fields:




TLV Type - TBD

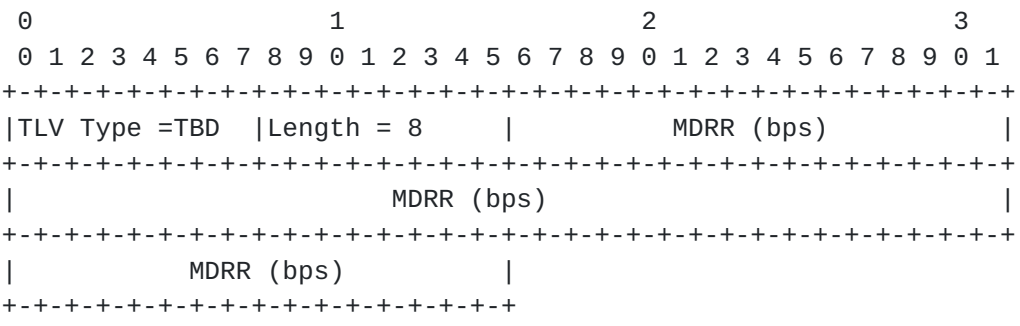
Length - 17

Add/Drop - Value indicating whether this is a new or existing address (0x01), or a withdrawal of an address (0x02).

IPv6 Address - IPv6 Address of the destination or peer.

## 10.7 Maximum Data Rate (Receive)

The Maximum Data Rate Receive (MDRR) TLV is a mandatory data item, used in Destination Up, Destination Update, Peer Initialization, Peer Update, and Link Characteristics ACK Signals to indicate the maximum theoretical data rate, in bits per second, that can be achieved while receiving data on the link. When metrics are reported via the signals listed above, the maximum data rate receive MUST be reported.




TLV Type - TBD

Length - 8

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

### 10.8 Maximum Data Rate (Transmit)

The Maximum Data Rate Transmit (MDRT) TLV is a mandatory data item, used in Destination Up, Destination Update, Peer Initialization, Peer Update, and Link Characteristics ACK Signals to indicate the maximum theoretical data rate, in bits per second, that can be achieved while transmitting data on the link. When metrics are reported via the signals listed above, the maximum data rate transmit MUST be reported.


TLV Type - TBD

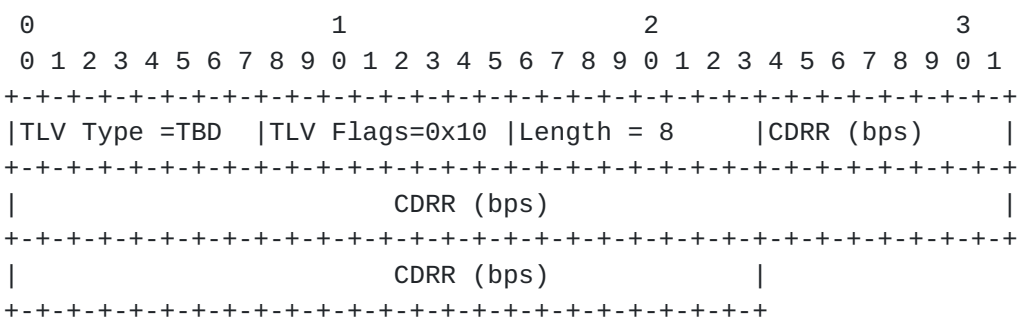
Length - 8

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

### 10.9 Current Data Rate (Receive)

The Current Data Rate Receive (CDRR) TLV is a mandatory data item, used in Destination Up, Destination Update, Peer Initialization, Peer Update, Link Characteristics Request, and Link Characteristics ACK signals to indicate the rate at which the link is currently operating for receiving traffic. In the case of the Link Characteristics Request, CDRR represents the desired receive data rate for the link. When metrics are reported via the signals above (e.g. Destination Update), the current data rate receive MUST be reported.

The Current Data Rate Receive TLV contains the following fields:




TLV Type - TBD

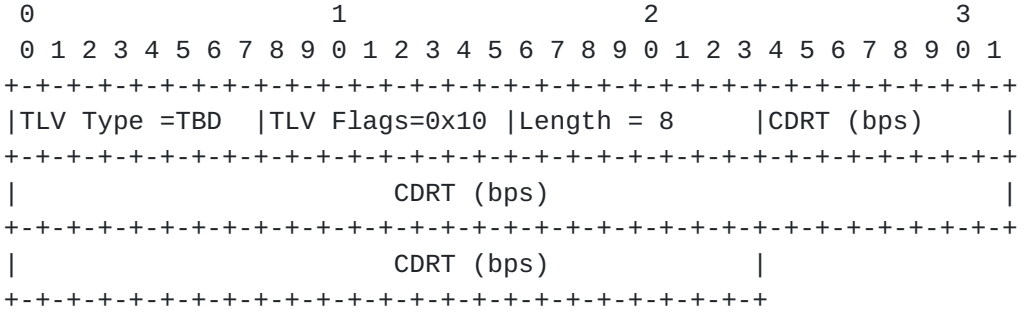
Length - 8

Current Data Rate Receive - A 64-bit unsigned number, representing the current data rate, in bits per second, that is currently be achieved while receiving traffic on the link. When used in the Link Characteristics Request, CDRR represents the desired receive rate, in bits per second, on the link. If there is no distinction between current and maximum receive data rates, current data rate receive SHOULD be set equal to the maximum data rate receive.

## 10.10 Current Data Rate (Transmit)

The Current Data Rate Receive (CDRT) TLV is a mandatory data item, used in Destination Up, Destination Update, Peer Initialization, Peer Update, Link Characteristics Request, and Link Characteristics ACK signals to indicate the rate at which the link is currently operating for transmitting traffic. In the case of the Link Characteristics Request, CDRT represents the desired transmit data rate for the link. When metrics are reported via the signals above (e.g. Destination Update), the current data rate transmit MUST be reported.

The Current Data Rate Transmit TLV contains the following fields:



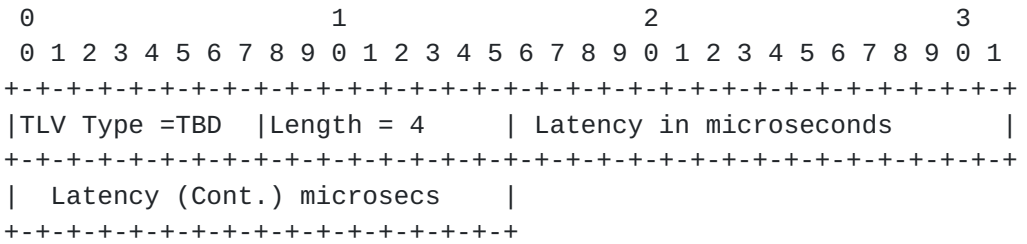

TLV Type - TBD

Length - 8

Current Data Rate Transmit - A 64-bit unsigned number, representing the current data rate, in bits per second, that is currently be achieved while transmitting traffic on the link. When used in the Link Characteristics Request, CDRT represents the desired transmit rate, in bits per second, 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.

## 10.11 Latency

The Latency TLV is a mandatory data item. It is used in Peer Initialization, Destination Up, Destination Update, Peer Initialization, Peer Update, Link Characteristics Request, and Link Characteristics ACK signals to indicate the amount of latency on the link, or in the case of the Link Characteristics Request, to indicate the maximum latency required on the link.




TLV Type - TBD

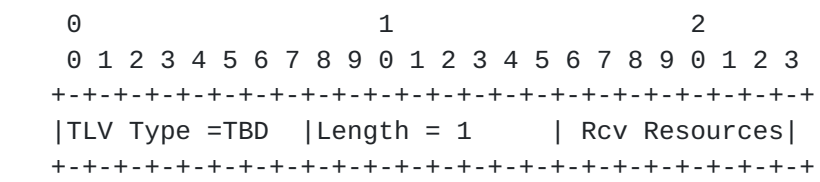
Length - 4

Latency - A 32-bit unsigned value, representing the transmission delay that a packet encounters as it is transmitted over the link. In Destination Up, Destination Update, and Link Characteristics ACK, this value is reported as delay, in microseconds. The calculation of latency is implementation dependent. For example, the latency may be a running average calculated from the internal queuing. If a device cannot calculate latency, this TLV SHOUD NOT be issued. In the Link Characteristics Request Signal, this value represents the maximum delay, in microseconds, expected on the link.

## 10.12 Resources (Receive)

The Receive Resources TLV is an optional data item. If supported, it is used in Destination Up, Destination Update, Peer Initialization, Peer Update, and Link Characteristics ACK signals to indicate a percentage (0-100) amount of resources (e.g. battery power), committed to receiving data, remaining on the originating peer.

The Resources TLV contains the following fields:




TLV Type - TBD

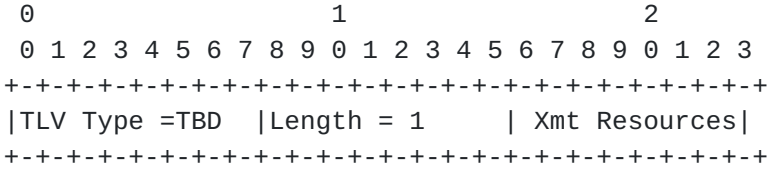
Length - 1

Receive Resources - A percentage, 0-100, representing the amount of remaining resources, such as battery power, allocated to receiving data. If a device cannot calculate receive resources, this TLV SHOULD NOT be issued.

## 10.13 Resources (Transmit)

The Transmit Resources TLV is an optional data item. If supported, it is used in Destination Up, Destination Update, Peer Initialization, Peer Update, and Link Characteristics ACK signals to indicate a percentage (0-100) amount of resources (e.g. battery power), committed to transmitting data, remaining on the originating peer.

The Resources TLV contains the following fields:




TLV Type - TBD

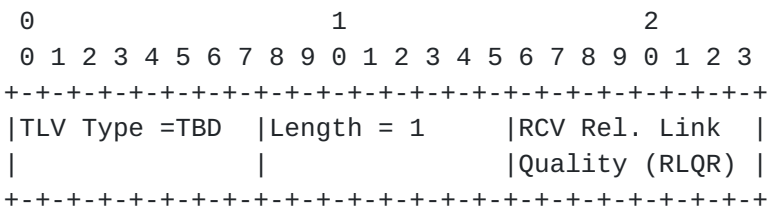
Length - 1

Transmit Resources - A percentage, 0-100, representing the amount of remaining resources, such as battery power, allocated to transmitting data. If the transmit resources cannot be calculated, then the TLV SHOULD NOT be issued.

## 10.14 Relative Link Quality (Receive)

The Relative Link Quality Receive (RLQR) TLV is an optional data item. If supported, it is used in Peer Initialization, Destination Up, Destination Update, Peer Initialization, Peer Update, and Link Characteristics ACK signals to indicate the quality of the link for receiving data as calculated by the originating peer.

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




TLV Type - TBD

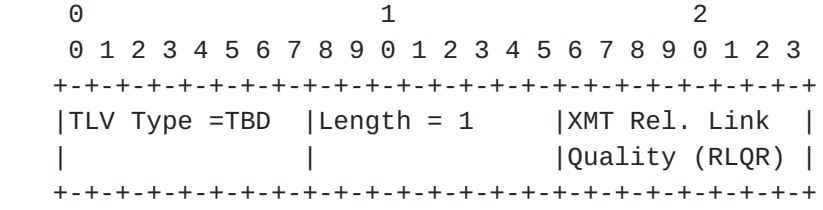
Length - 1

Relative Link Quality (Receive) - A non-dimensional number, 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 TLV SHOULD NOT be issued.

### 10.15 Relative Link Quality (Transmit)

The Transmit Link Quality Receive (RLQT) TLV is an optional data item. It is used in Peer Initialization, Destination Up, Destination Update, Peer Initialization, Peer Update, and Link Characteristics ACK signals to indicate the quality of the link for transmitting data as calculated by the originating peer.

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




TLV Type - TBD

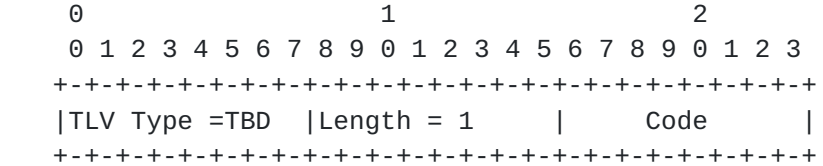
Length - 1

Relative Link Quality (Transmit) - A non-dimensional number, 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 TLV SHOULD NOT be issued.

### 10.16 Status

The Status TLV is sent as part of an acknowledgement signal, from either the modem or the router, to indicate the success or failure of a given request.

The Status TLV contains the following fields:




TLV Type - TBD

Length - 1

Termination Code - 0 = Success, Non-zero = Failure. Specific values

of a non-zero termination code depend on the operation requested (e.g. Destination Up, Destination Down, etc).

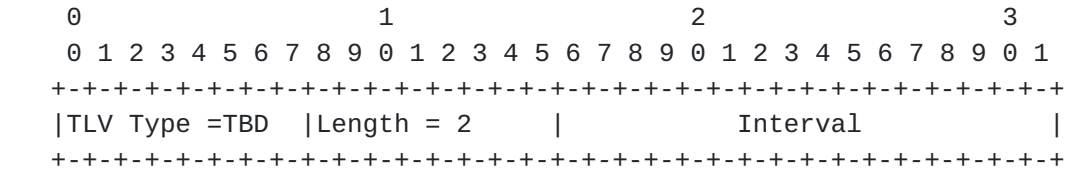
### 10.17 Heartbeat Interval

The Heartbeat Interval TLV is a mandatory TLV. It MUST be sent during Peer Initialization to indicate the desired Heartbeat timeout window. The receiver MUST either accept the timeout interval supplied by the sender, or reject the Peer Initialization, and close the socket. Implementations MUST implement heuristics such that DLEP signals sent/received reset the timer interval.

The Interval is used to specify a period (in seconds) for Heartbeat Signals (See Section 11.15). By specifying an Interval value of 0, implementations MAY indicates the desire to disable Heartbeat signals entirely (e.g., the Interval is set to an infinite value), however, it is strongly recommended that implementations use non 0 timer values.

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

The Heartbeat Interval TLV contains the following fields:




TLV Type - TBD

Length - 2

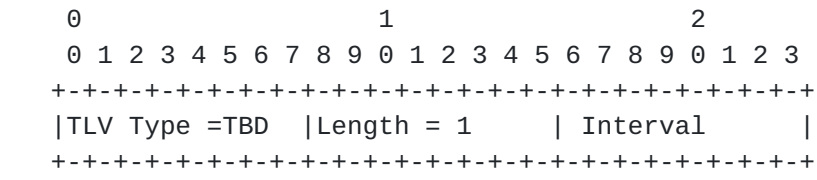
Interval - 0 = Do NOT use heartbeats on this peer-to-peer session. Non-zero = Interval, in seconds, for heartbeat signals.

### 10.18 Link Characteristics ACK Timer

The Link Characteristics ACK Timer TLV is an optional TLV. If supported, it MAY be sent during Peer Initialization to indicate the desired number of seconds to wait for a response to a Link Characteristics Request. If this TLV is omitted, implementations supporting the Link Characteristics Request SHOULD choose a default

value.

The Link Characteristics ACK Timer TLV contains the following fields:




TLV Type - TBD

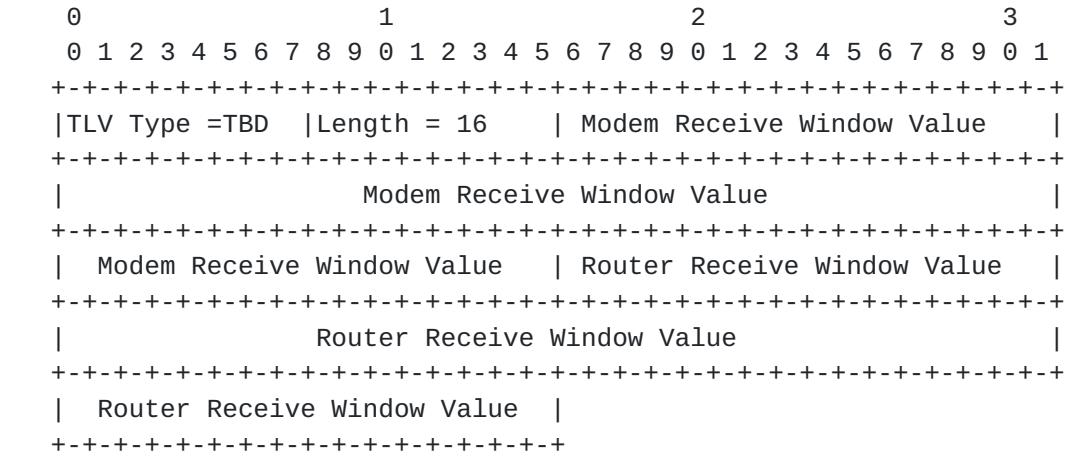
Length - 1

Interval - 0 = Do NOT use timeouts for Link Characteristics requests on this router/modem session. Non-zero = Interval, in seconds, to wait before considering a Link Characteristics Request has been lost.

## 10.19 Credit Window Status

The Credit Window Status TLV is an optional TLV. If credits are supported by the DLEP participants (both the router and the modem), the Credit Window Status TLV MUST be sent by the participant receiving a Credit Grant Request for a given destination.

The Credit Window Status TLV contains the following fields:




TLV Type - TBD

Length - 16

Modem Receive Window Value - A 64-bit unsigned number, indicating the current (or initial) number of

credits available on the Modem Receive Window.

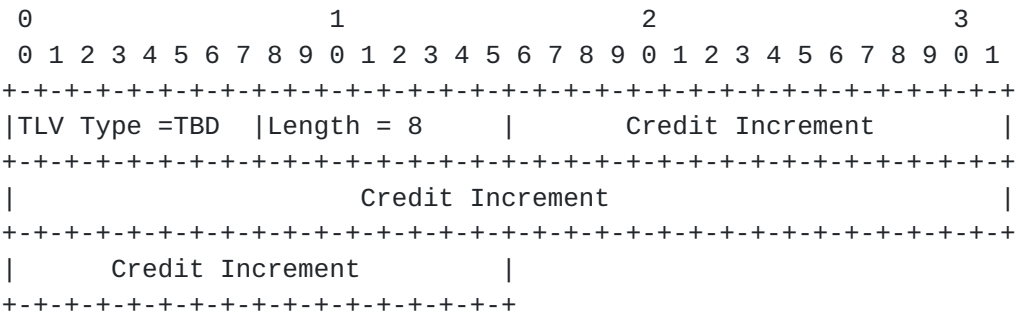
Router Receive Window Value - A 64-bit unsigned number, indicating the current (or initial) number of credits available on the Router Receive Window.

## 10.20 Credit Grant Request

The Credit Grant Request TLV is an optional TLV. If credits are supported, the Credit Grant Request TLV is sent from a DLEP participant to grant an increment to credits on a window. The Credit Grant TLV is sent as a data item in either the Destination Up or Destination Update signals. The value in a Credit Grant TLV represents an increment to be added to any existing credits available on the window. Upon successful receipt and processing of a Credit Grant TLV, the receiver MUST respond with a signal containing a Credit Window Status TLV to report the updated aggregate values for synchronization purposes.

In the Destination Up signal, when credits are desired, the originating peer MUST set the initial credit value of the window it controls (e.g. 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 Request TLV supports credits, the receiver MUST either reject the use of credits, via a Destination Up ACK response with the correct Status TLV, or set the initial value from the data contained in the Credit Window Status TLV. 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 TLV, initializing its receive window.

The Credit Grant TLV contains the following fields:




TLV Type - TBD

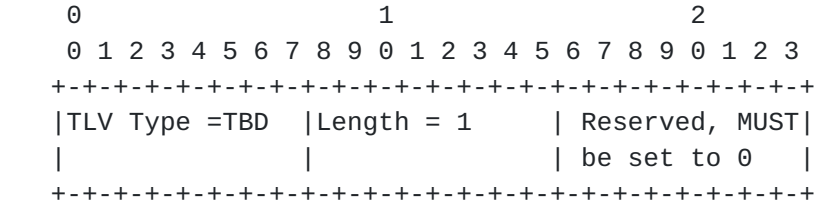
Length - 8

Reserved - A 64-bit unsigned number 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.

## 10.21 Credit Request

The Credit Request TLV is an optional TLV. If credits are supported, the Credit Request TLV MAY be sent from either DLEP participant, via a Destination Update signal, 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 for this session did NOT contain a Credit Window Status TLV, indicating that credits are to be used on the session, then the Credit Request TLV MUST be rejected by the receiver via a Destination Update ACK signal.

The Credit Request TLV contains the following fields:




TLV Type - TBD

Length - 1

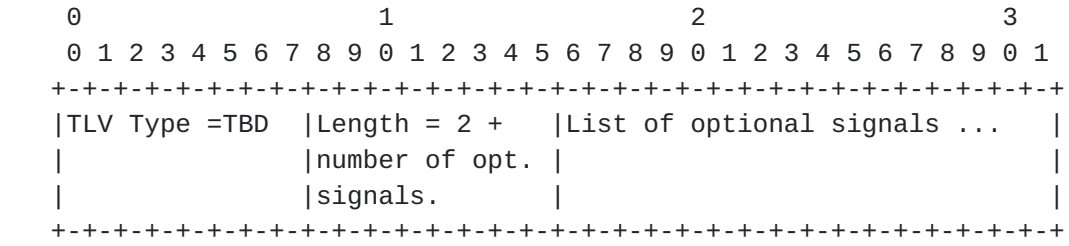
Reserved - This field is currently unused and MUST be set to 0.

## 10.22 DLEP Optional Signals Supported

The DLEP Optional Signals Supported TLV is a mandatory data item. If optional signals (e.g., the Link Characteristics Request Signal) are supported, they MUST be enumerated with this data item inserted into the Peer Initialization and Peer Initialization ACK signals. Failure to indicate optional signals indicates to a receiving peer that the sending implementation ONLY supports the core (mandatory) items

listed in this specification. Optional signals that are NOT enumerated in this data item when issuing Peer Initialization or Peer Initialization ACK MUST NOT be used during the DLEP session.

The DLEP Optional Signals Supported TLV contains the following fields:



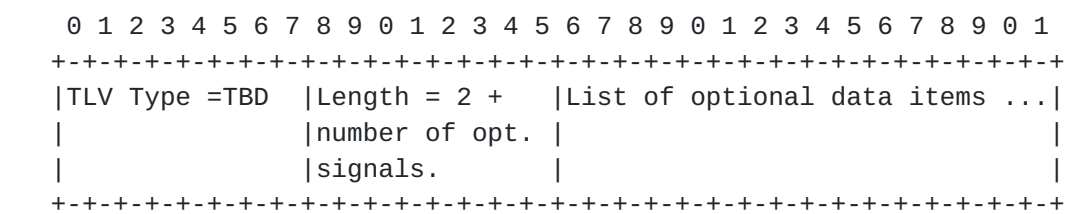

TLV Type - TBD

Length - 2 + the number of optional signals supported
List - An enumeration of the optional signal TLV Types supported by the implementation.

## 10.23 DLEP Optional Data Items Supported

The DLEP Optional Data Items Supported TLV is a mandatory data item. If optional data items (e.g., Resources) are supported, they MUST be enumerated with this data item inserted into the Peer Initialization and Peer Initialization ACK signals. Failure to indicate optional data items indicates to a receiving peer that the sending implementation ONLY supports the core (mandatory) data items listed in this specification. Optional data items that are NOT listed in this data item MUST NOT be used during the DLEP session.

The DLEP Optional Data Items Supported TLV contains the following fields:



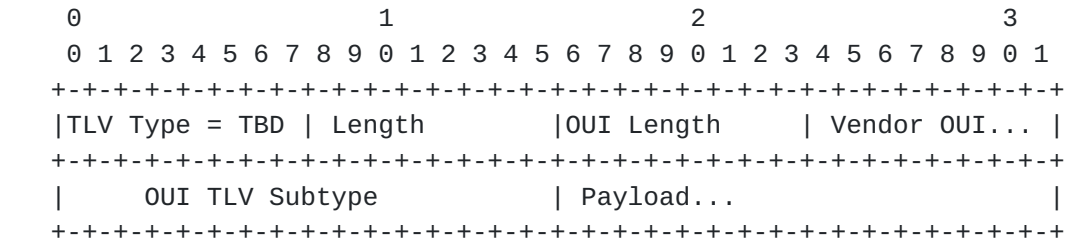

TLV Type - TBD

Length - 2 + the number of optional data items supported
List - An enumeration of the optional data item TLV Types supported by the implementation.

### 10.24 DLEP Vendor Extension

The DLEP Vendor Extension data item is an optional data item, and allows for vendor-defined information to be passed between DLEP participants. The precise data carried in the payload portion of the data item is vendor-specific, however, the payload MUST adhere to a Type-Length-Value format. This optional data item is ONLY valid on Peer Initialization ACK, and if present, SHOULD contain device-specific information geared to optimizing data transmission/reception over the modem's link.

The DLEP Vendor Extension Data Item TLV contains the following fields:




TLV Type - TBD

Length - 3 + length of OUI (in octets) + payload length

Vendor OUI - The vendor OUI, as specified in [IEEE]

OUI TLV Subtype - A 16-bit quantity, intended to indicate the specific device.

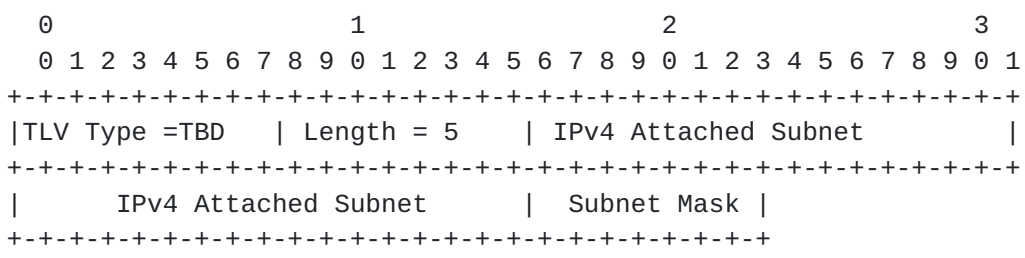
Payload - Vendor-specific payload, formatted as Type, Length, Value construct(s).

### 10.25 IPv4 Attached Subnet

The DLEP IPv4 Attached Subnet is an optional data item, and allows a device to declare that it has an IPv4 subnet (e.g., a stub network) attached. If supported, the DLEP IPv4 Attached Subnet TLV is allowed ONLY in the DLEP "Destination Up" signal, and MUST NOT appear more than once. All other occurrences of the DLEP IPv4 Attached Subnet TLV MUST be treated as an error. Once an IPv4 Subnet has been declared by a device, the declaration can NOT be withdrawn without terminating the destination (via the "Destination Down" signal) and re-issuing the "Destination Up" signal.

The DLEP IPv4 Attached Subnet data item TLV contains the following

fields:




TLV Type - TBD

Length - 5

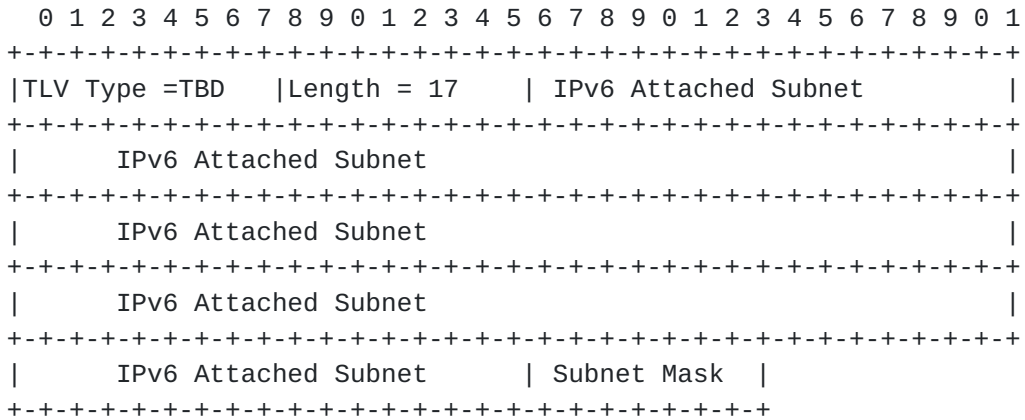
IPv4 Subnet - The IPv4 subnet reachable at the destination.

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

## 10.26 IPv6 Attached Subnet

The DLEP IPv6 Attached Subnet is an optional data item, and allows a device to declare that it has an IPv6 subnet (e.g., a stub network) attached. If supported, the DLEP IPv6 Attached Subnet TLV is allowed ONLY in the DLEP "Destination Up" signal, and MUST NOT appear more than once. All other occurrences of the DLEP IPv6 Attached Subnet TLV MUST be treated as an error. As in the case of the IPv4 attached subnet, once an IPv6 attached subnet has been declared, it can NOT be withdrawn without terminating the destination (via "Destination Down") and re-issuing the "Destination Up" signal.

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



TLV Type - TBD

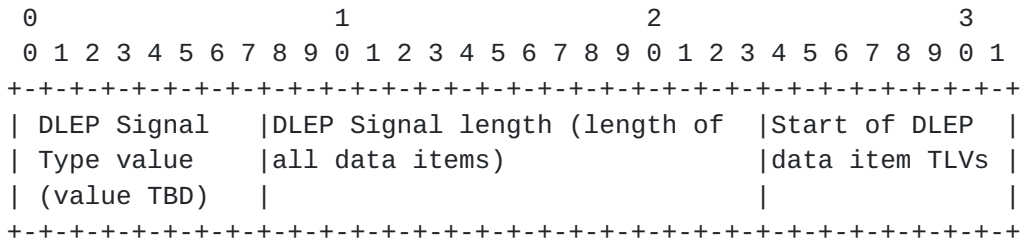
Length - 17

IPv4 Subnet - The IPv6 subnet reachable at the destination.

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

## 11. DLEP Protocol Signals

DLEP signals are encoded as a string of Type-Length-Value (TLV) constructs. The first TLV in a DLEP signal MUST be a valid DLEP signal, as defined in section 11.1 of this document. Following the signal TLV is 0 or more TLVs, representing the data items that are appropriate for the signal. The layout of a DLEP signal is thus:




All DLEP signals begin with this structure. Therefore, in the following descriptions of specific signals, this header structure is assumed, and will not be replicated.

### 11.1 Signal TLV Values

As mentioned above, all DLEP signals begin with the Type value. Valid DLEP signals are:

| TLV Value | TLV Description |
|---|---|
| TBD | Peer Discovery |
| TBD | Peer Offer |
| TBD | Peer Initialization |
| TBD | Peer Update |
| TBD | Peer Update ACK |
| TBD | Peer Termination |
| TBD | Peer Termination ACK |
| TBD | Destination Up |
| TBD | Destination Up ACK |
| TBD | Destination Down |

| | |
|---|---|
| TBD | Destination Down ACK |
| TBD | Destination Update |
| TBD | Heartbeat |
| TBD | Link Characteristics Request |
| TBD | Link Characteristics ACK |

### 11.2 Peer Discovery Signal

The Peer Discovery Signal is sent by a router to discover DLEP routers in the network. The Peer Offer signal 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 initial TLV Type value is set to DLEP_PEER_DISCOVERY (value TBD). The signal TLV MUST be followed by the mandatory Data Item TLVs.

Mandatory Data Item TLVs:

- DLEP Version
- Heartbeat Interval

There are NO optional data items for the Peer Discovery signal.

### 11.3 Peer Offer Signal

The Peer Offer Signal is sent by a DLEP modem in response to a Peer Discovery Signal. Upon receipt, and processing, of a Peer Offer signal, the router responds by issuing a TCP connect to the address/port combination specified in the received Peer Offer.

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

To construct a Peer Offer signal, the initial TLV type value is set to DLEP_PEER_OFFER (value TBD). The signal TLV is then followed by all mandatory Data Item TLVs, then by any optional Data Item TLVs the implementation supports:

Mandatory Data Item TLVs:

- DLEP Version
- Heartbeat Interval
- At least one (1) IPv4 or IPv6 Address TLV
- DLEP Port

Optional Data Item TLVs:

- Peer Type
- Status

### 11.4 Peer Initialization Signal

The Peer Initialization signal is sent by a router to start 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 signals or data items are supported by the implementation, they MUST be enumerated in the DLEP Optional Signals Supported and DLEP Optional Data Items Supported items.

Mandatory Data Item TLVs:
- DLEP Version
- Heartbeat Interval
- Optional Signals Supported
- Optional Data Items Supported

Optional Data Item TLVs:
- Peer Type

If the Optional Signals Supported (or the Optional Data Items Supported) TLV is absent in Peer Initialization, the receiver of the signal MUST conclude that there is NO optional support in the sender.

### 11.5 Peer Initialization ACK Signal

The Peer Initialization ACK signal is a mandatory signal, sent in response to a received Peer Initialization signal. The Peer Initialization ACK signal completes the TCP-level 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 Peer Initialization ACK.

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 Peer Initialization ACK MUST be treated as an error, resulting in termination of the DLEP session between router and modem. If optional signals and/or data items are supported by the modem, they MUST be enumerated in the DLEP Optional Signals supported and DLEP Optional data items supported TLVs.

The Peer Initialization ACK signal MAY contain the DLEP Vendor Extension data item, as documented in section 10.22

After the Peer Initialization/Peer Initialization ACK signals have been successfully exchanged, implementations SHOULD only utilize

options that are supported in BOTH peers (e.g. router and modem). Any attempt by a DLEP session peer to send an optional signal to a peer without support MUST result in an error which terminates the session. Any optional data item sent to a peer without support will be ignored and silently dropped.

To construct a Peer Initialization ACK signal, the initial TLV type value is set to DLEP_PEER_INIT_ACK (value TBD). The signal TLV is then followed by the required data items:

Mandatory Data Item TLVs:

- DLEP Version
- Heartbeat Interval
- Maximum Data Rate Receive
- Maximum Data Rate Transmit
- Current Data Rate Receive
- Current Data Rate Transmit
- DLEP Optional Signals Supported
- DLEP Optional Data Items Supported
- Status

Optional Data Item TLVs:

- Peer Type
- DLEP Vendor Extension
- Latency
- Relative Link Quality Receive
- Relative Link Quality Transmit
- Resources (Receive)
- Resources (Transmit)

### 11.6 Peer Update Signal

The Peer Update signal is an optional signal, sent by a DLEP peer to indicate local Layer 3 address changes, or for 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, a modem that changes its Maximum Data Rate 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 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. Routers receiving a Peer Update with metric changes MUST

apply the new metric to all destinations (remote nodes) accessible via the modem. 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 a either participant (router or modem) determines that the other implementation does NOT support Layer 3 address tracking.

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.

To construct a Peer Update signal, the initial TLV type value is set to DLEP_PEER_UPDATE (value TBD). The Signal TLV is followed by any OPTIONAL Data Item TLVs.

Optional Data Item TLVs:

- IPv4 Address
- IPv6 Address
- Maximum Data Rate (Receive)
- Maximum Data Rate (Transmit)
- Current Data Rate (Receive)
- Current Data Rate (Transmit)
- Latency
- Resources (Receive)
- Resources (Transmit)
- Relative Link Quality (Receive)
- Relative Link Quality (Transmit)

### 11.7 Peer Update ACK Signal

The Peer Update ACK signal is an optional signal, and is sent by implementations supporting Layer 3 address tracking and/or modem-wide metrics to indicate whether a Peer Update Signal was successfully processed. If the Peer Update ACK is issued, it MUST contain a Status data item, indicating the success or failure of processing the received Peer Update.

To construct a Peer Update ACK signal, the initial TLV type value is set to DLEP_PEER_UPDATE_ACK (value TBD). The Status data item TLV is placed in the packet next, completing the Peer Update ACK.

Mandatory Data Item TLVs:

- Status

Note that there are NO optional data item TLVs specified for this signal.

### 11.8 Peer Termination Signal

The Peer Termination Signal is 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 to confirm the termination process. The sender of a Peer Termination signal is free to define its heuristics in event of a timeout. 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 are sent.

To construct a Peer Termination signal, the initial TLV type value is set to DLEP_PEER_TERMINATION (value TBD). The signal TLV is followed by any OPTIONAL Data Item TLVs the implementation supports:

Optional Data Item TLVs:

- Status

### 11.9 Peer Termination ACK Signal

The Peer Termination Signal ACK is sent by a DLEP peer in response to a received Peer Termination order. Receipt of a Peer Termination ACK signal completes the teardown of the router/modem session.

To construct a Peer Termination ACK signal, the initial TLV type value is set to DLEP_PEER_TERMINATION_ACK (value TBD). The Identification data item TLV is placed in the packet next, followed by any OPTIONAL TLVs the implementation supports:

Optional Data Item TLVs:

- Status

### 11.10 Destination Up Signal

A DLEP participant sends the Destination Up signal to report that a new destination has been detected. A Destination Up ACK Signal is required to confirm a received Destination Up. 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) exists in the network.

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 parsed, 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 initial TLV type value is set to DLEP_DESTINATION_UP (value TBD). The MAC Address data item TLV is placed in the packet next, followed by any supported optional Data Item TLVs into the packet:

Optional Data Item TLVs:

- IPv4 Address
- IPv6 Address
- Maximum Data Rate (Receive)
- Maximum Data Rate (Transmit)
- Current Data Rate (Receive)
- Current Data Rate (Transmit)
- Latency
- Resources (Receive)
- Resources (Transmit)
- Relative Link Factor (Receive)
- Relative Link Factor (Transmit)
- Credit Window Status
- IPv4 Attached Subnet
- IPv6 Attached Subnet

### 11.11 Destination Up ACK Signal

A DLEP participant sends the Destination Up ACK Signal to indicate whether a Destination Up Signal was successfully processed.

To construct a Destination Up ACK signal, the initial TLV type value is set to DLEP_DESTINATION_UP_ACK (value TBD). The MAC Address data item TLV is placed in the packet next, containing the MAC address of the DLEP destination. The implementation would then place any supported optional Data Item TLVs into the packet:

Optional Data Item TLVs:

- Credit Window Status

### 11.12 Destination Down Signal

A DLEP peer sends the Destination Down signal to report when a destination (a remote node or a multicast group) is no longer reachable. The Destination Down signal MUST contain the MAC Address data item TLV. Other TLVs as listed are OPTIONAL, and MAY be present if an implementation supports them. A Destination Down ACK Signal

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 initial TLV type value is set to DLEP_DESTINATION_DOWN (value TBD). The signal TLV is followed by the mandatory MAC Address data item TLV.

Note that there are NO OPTIONAL data item TLVs for this signal.

### 11.13 Destination Down ACK Signal

A DLEP participant sends the Destination Down ACK Signal to indicate whether a received Destination Down Signal 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. As with the Destination Down signal, there are NO OPTIONAL Data Item TLVs defined for the Destination Down ACK signal.

To construct a Destination Down signal, the initial TLV type value is set to DLEP_DESTINATION_DOWN_ACK (value TBD). The mandatory data item TLVs follow:

- MAC Address Data item
- Status data item

### 11.14 Destination Update Signal

A DLEP participant sends 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:

- Change in link metrics (e.g., Data Rates)
- Layer 3 addressing change (for implementations that support it)

To construct a Destination Update signal, the initial TLV type value is set to DLEP_DESTINATION_UPDATE (value TBD). Following the signal TLV are the mandatory Data Item TLVs:

MAC Address data item TLV

After placing the mandatory data item TLV into the packet, the implementation would place any supported OPTIONAL data item TLVs. Possible OPTIONAL data item TLVs are:

- IPv4 Address
- IPv6 Address
- Maximum Data Rate (Receive)
- Maximum Data Rate (Transmit)
- Current Data Rate (Receive)
- Current Data Rate (Transmit)
- Latency
- Resources (Receive)
- Resources (Transmit)
- Relative Link Quality (Receive)
- Relative Link Quality (Transmit)
- Credit Window Status
- Credit Grant
- Credit Request

### 11.15 Heartbeat Signal

A Heartbeat Signal is sent by a DLEP participant every N seconds, where N is defined in the "Heartbeat Interval" field of the Peer Initialization signal. Note that implementations setting the Heartbeat Interval to 0 effectively set the interval to an infinite value, therefore, in those cases, this signal would 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 initial TLV type value is set to DLEP_PEER_HEARTBEAT (value TBD). The signal TLV is followed by the mandatory Heartbeat Interval/Threshold data item.

Note that there are NO OPTIONAL data item TLVs for this signal.

### 11.16 Link Characteristics Request Signal

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

The Link Characteristics Request signal contains either a Current Data Rate (CDRR or CDRT) TLV to request a different datarate than what is currently allocated, a Latency TLV to request that traffic delay on the link not exceed the specified value, or both. A Link

Characteristics ACK Signal is required to complete the request. Implementations are free to define their retry heuristics in event of a timeout. Issuing a Link Characteristics Request with ONLY the MAC Address TLV is a mechanism a peer MAY use to request metrics (via the Link Characteristics ACK) from its partner.

To construct a Link Characteristics Request signal, the initial TLV type value is set to DLEP_Destination_LINK_CHAR_REQ (value TBD). Following the signal TLV is the mandatory Data Item TLV:

MAC Address data item TLV

After placing the mandatory data item TLV into the packet, the implementation would place any supported OPTIONAL data item TLVs. Possible optional data item TLVs are:

Current Data Rate - If present, this value represents the NEW (or unchanged, if the request is denied) Current Data Rate in bits per second (bps).

Latency - If present, this value represents the maximum desired latency (e.g., it is a not-to-exceed value) in microseconds on the link.

### 11.17 Link Characteristics ACK Signal

The LInk Characteristics ACK signal is an optional signal, and is sent by modems supporting it to the router letting the router know the success or failure of a requested change in link characteristics. The Link Characteristics ACK signal SHOULD contain a complete set of metric data item TLVs. It MUST contain the same TLV types as the request. The values in the metric data item TLVs in the Link Characteristics ACK signal MUST reflect the link characteristics after the request has been processed.

To construct a Link Characteristics Request ACK signal, the initial TLV type value is set to DLEP_Destination_LINK_CHAR_ACK (value TBD). Following the signal TLV is the mandatory Data Item TLV:

MAC Address data item TLV

After placing the mandatory data item TLV into the packet, the implementation would place any supported OPTIONAL data item TLVs. Possible OPTIONAL data item TLVs are:

Current Data Rate - If present, this value represents the requested data rate in bits per second (bps).

| | | |
|---|---|---|
| Latency | - | If present, this value represents the NEW maximum latency (or unchanged, if the request is denied), expressed in microseconds, on the link. |

## 12. 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 DTLS or some other mechanism), and is therefore outside the scope of this document.

## 13. IANA Considerations

This section specifies requests to IANA.

### 13.1 Registrations

This specification defines:

o A new repository for DLEP signals, with fifteen values currently assigned.

o Reservation of numbering space for Experimental DLEP signals.

o A new repository for DLEP Data Items, with twenty-one values currently assigned.

o Reservation of numbering space in the Data Items repository for experimental data items.

o A request for allocation of a well-known port for DLEP communication.

o A request for allocation of a multicast address for DLEP discovery.

### 13.2 Expert Review: Evaluation Guidelines

No additional guidelines for expert review are anticipated.

### 13.3 Signal TLV Type Registration

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

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.

### 13.4 DLEP Data Item Registrations

A new repository for DLEP Data Items must be created. Valid Data Items are:

- DLEP Version
- Peer Type
- MAC Address
- IPv4 Address
- IPv6 Address
- Maximum Data Rate (Receive)
- Maximum Data Rate (Transmit)
- Current Data Rate (Receive)
- Current Data Rate (Transmit)
- Latency
- Resources (Receive)
- Resources (Transmit)
- Relative Link Quality (Receive)
- Relative Link Quality (Transmit)
- Status
- Heartbeat Interval/Threshold
- Link Characteristics ACK Timer
- Credit Window Status
- Credit Grant
- Credit Request

- DLEP Optional Signals Supported
- DLEP Optional Data Items Supported
- DLEP Vendor Extension

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

### 13.5 DLEP Well-known Port

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

### 13.6 DLEP Multicast Address

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

## 14. Appendix A.

### 14.1 Peer Level Signal Flows

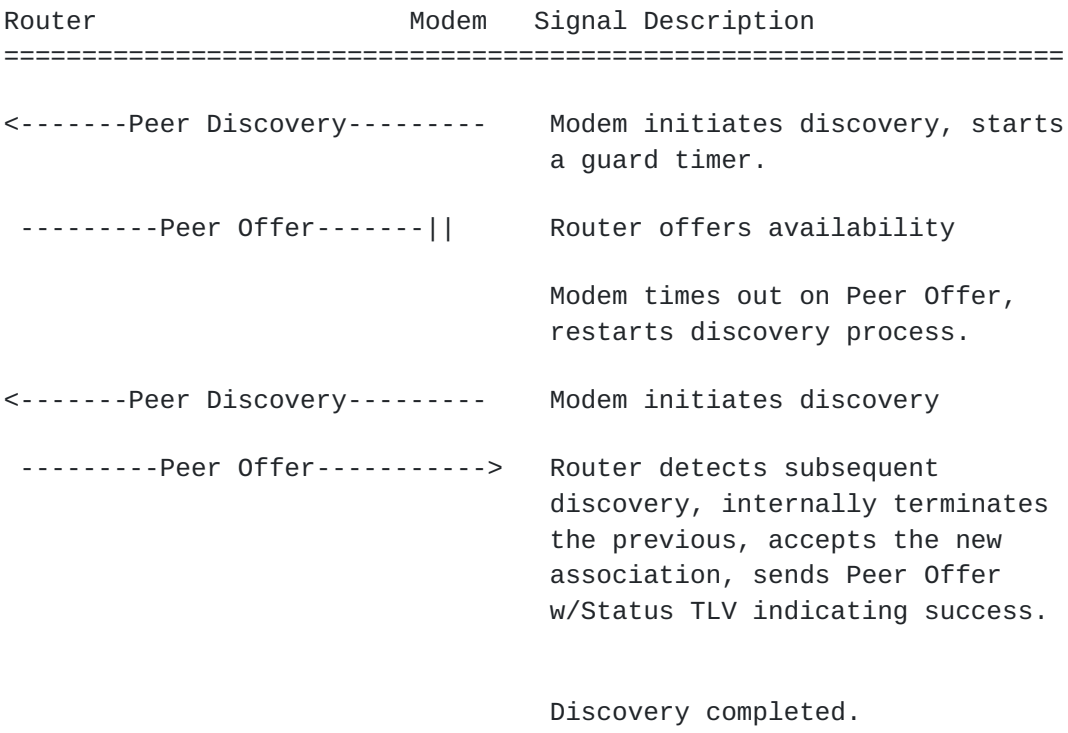
#### 14.1.1 Router Device Restarts Discovery

| Router | Modem | Signal Description |
|---|---|---|
| --------Peer Discovery--------> | | Router initiates discovery |
| <--------Peer Offer------------ w/ Non-zero Status TLV | | Modem detects a problem, sends Peer Offer w/Status TLV indicating the error.<br><br>Router accepts failure, restarts discovery process. |
| --------Peer Discovery--------> | | Router initiates discovery |
| <--------Peer Offer------------ | | Modem accepts, sends Peer Offer w/Zero Status TLV indicating success.<br><br>Discovery completed. |

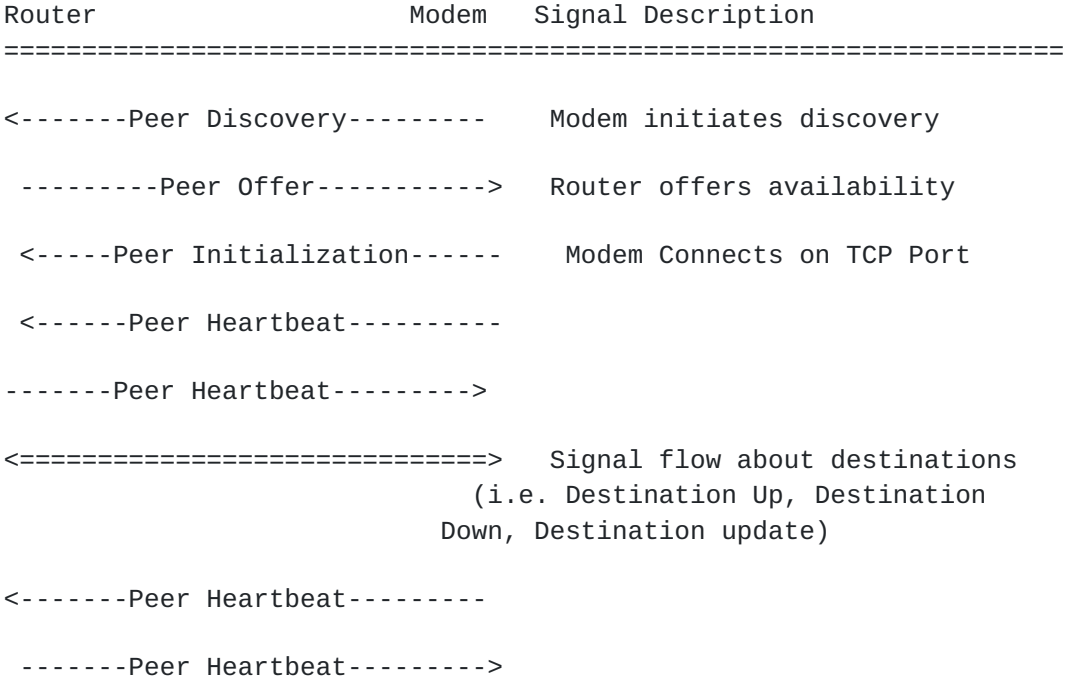
### 14.1.2 Router Device Detects Peer Offer Timeout

| Router | Modem | Signal Description |
|---|---|---|
| --------Peer Discovery--------> | | Router initiates discovery, starts a guard timer. |
| | | Router guard timer expires. Router restarts discovery process. |
| --------Peer Discovery--------> | | Router initiates discovery, starts a guard timer. |
| <--------Peer Offer------------ | | Modem accepts, sends Peer Offer w/Zero Status TLV indicating success. |
| | | Discovery completed. |

### 14.1.3 Router Peer Offer Lost




### 14.1.4 Discovery Success



```
    --------Peer Term Req--------->   Terminate Request

   <--------Peer Term Res---------    Terminate Response
```

### 14.1.5 Router Detects a Heartbeat timeout

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

   <-------Peer Heartbeat---------

    -------Peer Heartbeat--------->

      ||---Peer Heartbeat---------

           ~ ~ ~ ~ ~ ~ ~

    -------Peer Heartbeat--------->

      ||---Peer Heartbeat---------
                                    Router Heartbeat Timer expires,
                                    detects missing heartbeats. Router
                                    takes down all destination sessions
                                    and terminates the Peer
                                    association.

    ------Peer Terminate ---------->   Peer Terminate Request

                                    Modem takes down all destination
                                    sessions, then acknowledges the
                                    Peer Terminate

   <----Peer Terminate ACK---------   Peer Terminate ACK
```

### 14.1.6 Modem Detects a Heartbeat timeout

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

   <-------Peer Heartbeat---------

    -------Peer Heartbeat------||

   <-------Peer Heartbeat---------

           ~ ~ ~ ~ ~ ~ ~

    -------Peer Heartbeat------||
```

```
   <-------Peer Heartbeat---------
                                     Modem Heartbeat Timer expires,
                                     detects missing heartbeats. Modem
                                     takes down all destination sessions

    <-------Peer Terminate--------    Peer Terminate Request

                                     Router takes down all destination
                                     sessions, then acknowledges the
                                     Peer Terminate

    ------Peer Terminate ACK----->    Peer Terminate ACK
```

### 14.1.7 Peer Terminate (from Modem) Lost

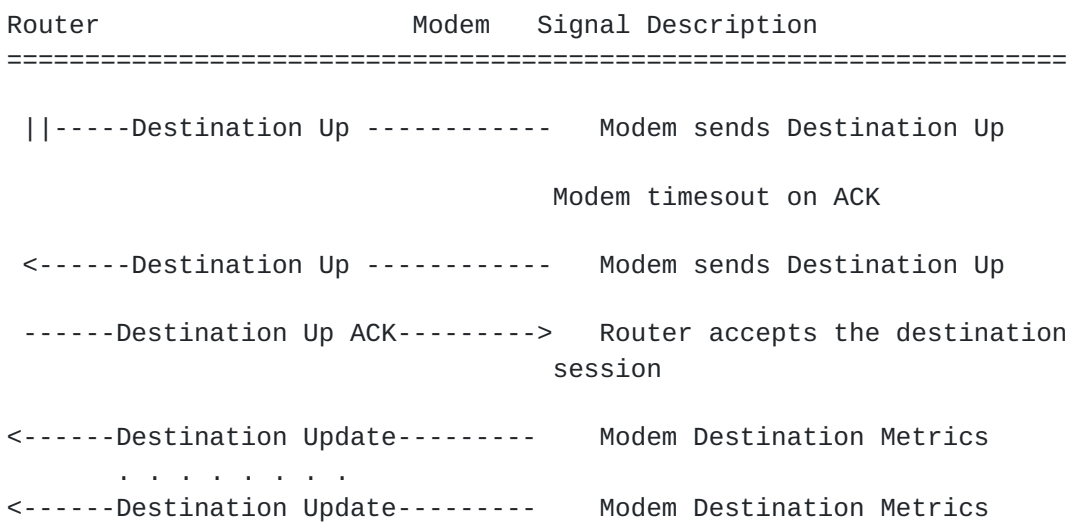
```
   Router                    Modem   Signal Description
   ========================================================================

     ||------Peer Terminate--------   Modem Peer Terminate Request

                                     Router Heartbeat times out,
                                     terminates association.

    --------Peer Terminate------->    Router Peer Terminate

    <-----Peer Terminate ACK------    Modem sends Peer Terminate ACK
```

### 14.1.8 Peer Terminate (from Router) Lost

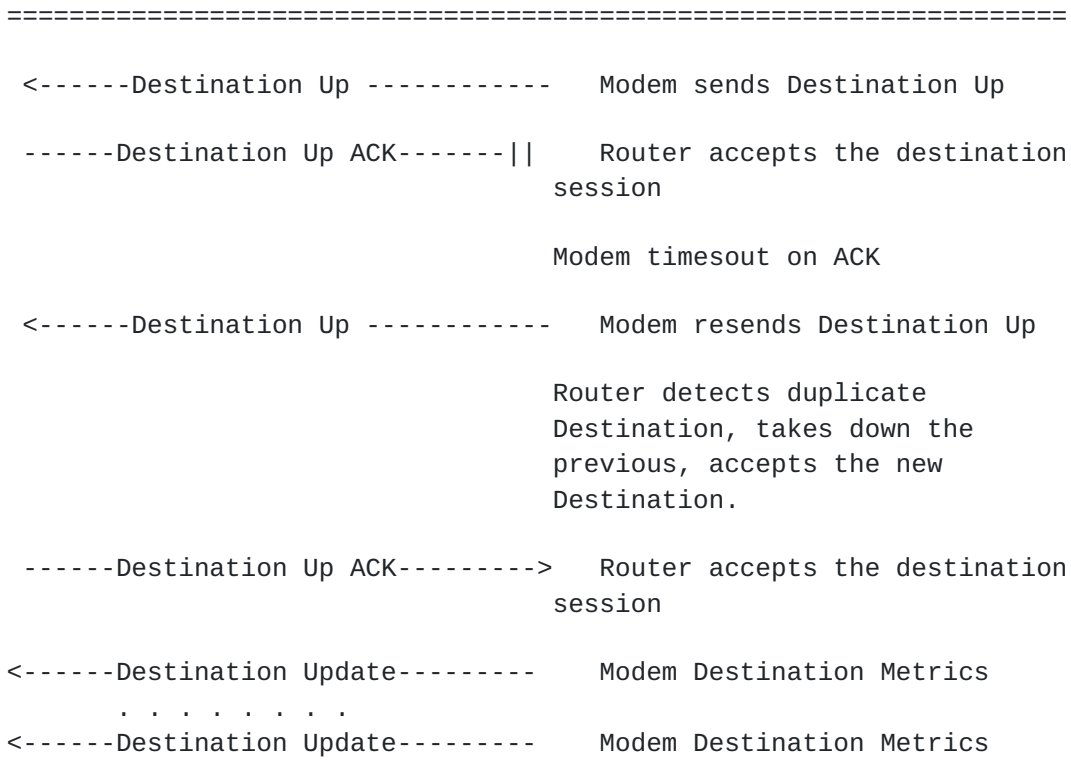
```
   Router                    Modem   Signal Description
   ========================================================================

    -------Peer Terminate-------->    Router Peer Terminate Request

                                     Modem HB times out,
                                     terminates association.

    <------Peer Terminate--------     Modem Peer Terminate

    ------Peer Terminate ACK----->    Peer Terminate ACK
```

## 14.2 Destination Specific Signal Flows

### 14.2.1 Modem Destination Up Lost




### 14.2.2 Router Detects Duplicate Destination Ups



### 14.2.3 Destination Up, No Layer 3 Addresses

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

 <------Destination Up ------------   Modem sends Destination Up

 ------Destination Up ACK--------->   Router accepts the destination
                                      session

                                      Router ARPs for IPv4 if defined.
                                      Router drives ND for IPv6 if
                                      defined.

<------Destination Update---------    Modem Destination Metrics
       . . . . . . . .
<------Destination Update---------    Modem Destination Metrics
```

### 14.2.4 Destination Up with IPv4, No IPv6

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

 <------Destination Up ------------   Modem sends Destination Up with
                                      the IPv4 TLV

 ------Destination Up ACK--------->   Router accepts the destination
                                      session

                                      Router drives ND for IPv6 if
                                      defined.

<------Destination Update---------    Modem Destination Metrics
       . . . . . . . .
<------Destination Update---------    Modem Destination Metrics
```

### 14.2.5 Destination Up with IPv4 and IPv6

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

 <------Destination Up ------------   Modem sends Destination Up with
                                      the IPv4 and IPv6 TLVs

 ------Destination Up ACK--------->   Router accepts the destination
                                      session
```

```
   <------Destination Update---------    Modem Destination Metrics
          . . . . . . . . .
```

### 14.2.6 Destination Session Success

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


    ---------Peer Offer----------->   Router offers availability

    -------Peer Heartbeat--------->


   <------Destination Up -----------      Modem

    ------Destination Up ACK-------->     Router

   <------Destination Update---------     Modem
          . . . . . . . . .
   <------Destination Update---------     Modem

                                       Modem initiates the terminate

   <------Destination Down ----------     Modem

    ------Destination Down ACK------->    Router

                                       or

                                       Router initiates the terminate

    ------Destination Down ---------->    Router

   <------Destination Down ACK-------     Modem
```

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