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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.

Status of this Memo

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1. **Introduction**

There exist today a collection of modem devices that control links of
variable bandwidth and quality. Examples of these types of links
include line-of-sight (LOS) 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 bandwidth varies with respect to individual
neighbors 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 bandwidth 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 bandwidth of 54Mbps for unicast
traffic, the other laptop, being relatively far away, or obstructed
by some object, can simultaneously have a bandwidth 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 bandwidth links, mobile networks
are challenged by the notion that link connectivity will come and go
over time. Effectively utilizing a relatively short-lived connection
is problematic in IP routed networks, as routing protocols tend to
rely on independent timers at OSI Layer 3 to maintain network
convergence (e.g. HELLO messages and/or recognition of DEAD routing
adjacencies). These short-lived 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 timer-
driven paradigm.

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, USB, or
even a 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 bandwidth, leads to a
situation where quality of service (QoS) profiles are extremely
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 bandwidth 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 bandwidth 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 neighbors). 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) |       |        |
```
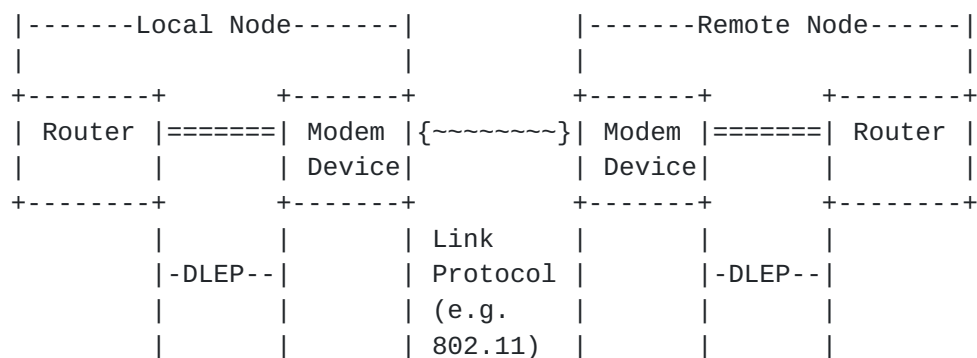
                    Figure 1: DLEP Network

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. 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 (bandwidth, latency, etc) that
have changed. DLEP is independent of the link type and topology
supported by the modem.

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 (bandwidth, 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  | Device +--+
              +--------+   o  Shared   o  +--------+
                          o Medium  o
                           o       o
                            o     o
                             o   o
                              o
                        +--------+
                        | Modem B|
                        | Device |
                        +---+----+
                            |
                            |
                        +---+----+
                        | Router |
                        |        |
                        +--------+
```
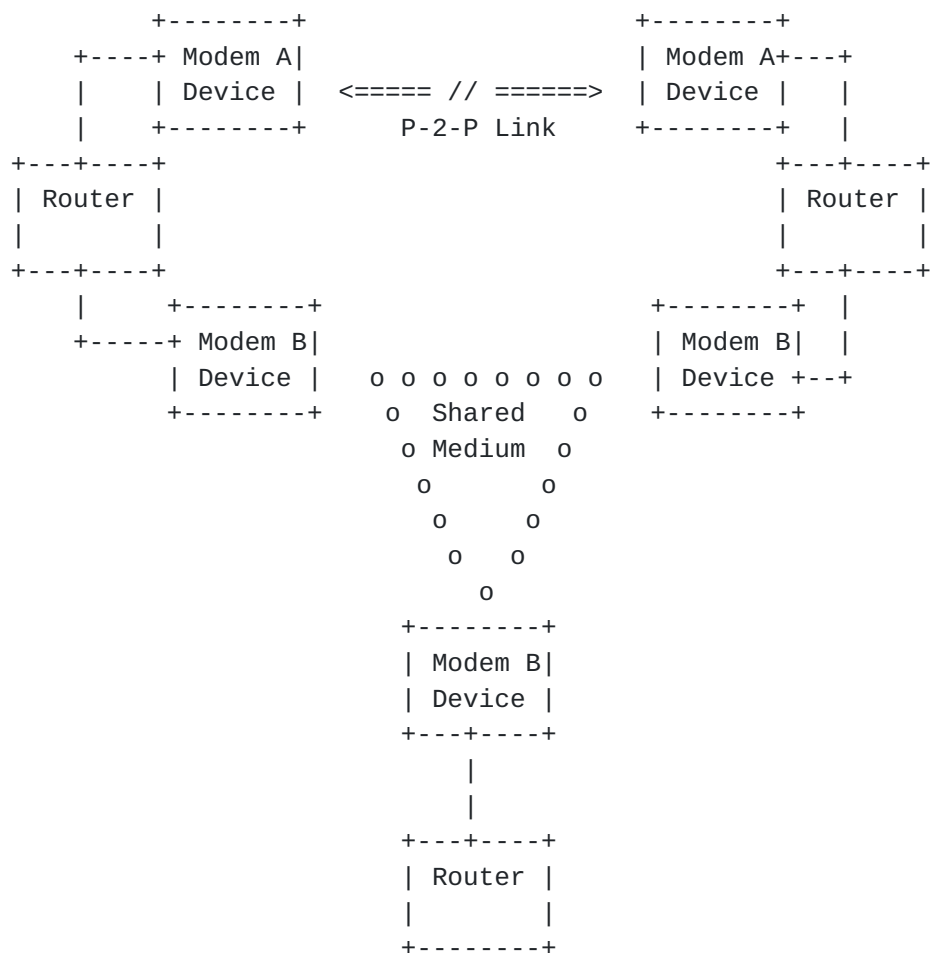
            Figure 2: DLEP Network with Multiple Modem Devices

   DLEP defines a set of logical 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 messages, 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 UDP transport. 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 neighbors (remote nodes) that are accessible via the modem device. As such, all of the neighbor-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 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 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 modem is responsible for initialing the discovery process, using the Peer Discovery message.

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 use of timers in DLEP is OPTIONAL; that
is, implementations can choose to run with no timers (or effectively,
timers set to an infinite value).

DLEP assumes that participating modems, and their physical links, act
as a transparent bridge. Specifically, the assumption is that the
destination MAC address for data traffic 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.

This document refers to a remote node as a "Neighbor". Neighbors 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. Examples of a destination include a MAC
address, a unicast Layer 3 address, or a multicast Layer 3 address.
As "neighbors" 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 neighbors accessed via the modem) or MAY be neighbor
(destination) specific.

The DLEP signals concerning neighbors 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 DTLS [DTLS]).

Sequence Numbers for DLEP messages start at 0 and are incremented by
one for each original and retransmitted message. The unsigned 16-bit
Sequence Number rolls over at 65535 to 0. Sequence Numbers are unique
within the context of a DLEP session. Sequence numbers are used in
DLEP to correlate a response to a request.

This document specifies an implementation of the DLEP signals and
data items running over the UDP transport, utilizing a well-known UDP
Port number. It is assumed that DLEP running over other transport
mechanisms would be documented separately.

[3](#). 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 credits are used, they 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.

[4](#). Metrics

DLEP includes the ability for the router and modem to communicate metrics that reflect the characteristics (e.g. bandwidth, latency) of the variable-quality link in use. 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 neighbor (those for a given destination within the network), and "modem-wide" (those that apply to all destinations accessed via the modem). Metrics supplied on DLEP Peer signals are, by definition, modem-wide; metrics supplied on Neighbor signals are, by definition, used for the specific neighbor only.

Metrics are further subdivided into transmit and receive metrics.

It is left to implementations to choose sensible default values based on their specific characteristics. Additionally, this mechanism (either at a modem-wide or specific neighbor context) MAY be used to report non-changing, or static, metrics. Modems having static 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.

5. 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. To allow for future innovation, the draft
allocates numbering space for experimental implementations of both
signals and data items.

DLEP implementations MUST be capable of parsing and acting on the
mandatory signals and data items as documented in this specification.
DLEP signals/data items that are optional, or are in the experimental
numbering range SHOULD be silently dropped by an implementation if
they are not understood.

The intent of the optional signals and data items, as well as the
experimental numbering space, is to allow for further development of
DLEP protocol features and function. Having experimental space
reserved for both signals and data items gives maximum flexibility
for extending the protocol as conditions warrant. For example,
experimental data items could be used by implementations to send
additional metrics. A combination of experimental signals, and
associated data items, could be used to implement new flow control
schemes. If subsequent research and development define new features
and function, then it should be standardized either as an update to
this document, or as an additional stand-alone specification.

6. Normal Session Flow

At the start of a run, DLEP implementations (both router and modem)
initialize the communications path. In a UDP implementation, this
includes opening a socket and binding to the well-known port address
(TBD). Once the communications path is established, modem
implementations are free to issue a "Peer Discovery" message. The
Peer Discovery MAY be sent either to the multicast address allocated
for DLEP (TBD), or to a unicast address, obtained via a-priori
configuration.

Routers receiving a Peer Discovery message respond with a "Peer
Offer" signal to indicate readiness to participate in the DLEP

session. The receiver of a Peer Offer message responds with a "Peer Offer ACK" message, completing discovery. While the Peer Discovery message MAY be sent to the DLEP multicast address (TBD), the Peer Offer, and all subsequent traffic, is sent to the unicast address that originated the Peer Discovery. Once the Peer Offer signal is acknowledged, both participants (router and modem) transition to the "in session" state, creating a logical, stateful session between the modem and the router. Subsequent DLEP signals are then processed within the context of this router/modem session. In the UDP-based implementation, traffic between DLEP modems and routers is correlated using the UDP 4-tuple (Source Address, Source Port, Destination Address, Destination Port). DLEP partners use these signals to build their respective information bases regarding destinations that are accessible via the modem, and link characteristics associated with those destinations.

The "in session" state created by the discovery signals 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.

In order to maintain the session between router and modem, OPTIONAL periodic "Heartbeat" messages MAY be exchanged. These messages are intended to keep the session alive, and to verify bidirectional connectivity between the two participants. DLEP also provides for an OPTIONAL Peer Update message, 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 messages above, the participants will transmit DLEP messages concerning destinations in the network. These messages trigger creation/maintenance/deletion of "neighbors" 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 "Neighbor Up" signal. Receipt of a Neighbor 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 "Neighbor Down" signal, and changes in status to the destination (e.g. varying link quality, or addressing changes) are communicated via the "Neighbor Update" signal. The information on a given neighbor will persist in the router's information base until (1) a "Neighbor 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 Neighbor Update message, or on a modem-wide basis
via the Peer Update message. In cases where metrics are provided on
the router/modem session, the receiver MUST propagate the metrics to
all neighbors 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 message) and a
specific neighbor context (via Neighbor 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 amount of
bandwidth, or latency, from the modem. This signal is referred to as
the Link Characteristics Message, and gives the router the ability to
deal with requisite increases (or decreases) of allocated
bandwidth/latency in demand-based schemes in a more deterministic
manner.

7. 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            None

        Peer Offer                None

        Peer Offer ACK            Status

        Peer Termination          None

        Peer Termination ACK      Status

        Neighbor Up               MAC Address
                                  Maximum Data Rate
                                  Current Data Rate

        Neighbor Update           MAC Address
                                  Maximum Data Rate
                                  Current Data Rate

        Neighbor 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 and data items SHOULD parse, and silently drop, all
unsupported signals and/or data items.

8. Generic DLEP Packet Definition

The Generic DLEP Packet consists of a sequence of TLVs. The first TLV
represents the signal being communicated (e.g., a "Neighbor 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:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Signal TLV Type | Length        | DLEP data items...          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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

     Length   - The length 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.

9. DLEP Data Items

As mentioned earlier, DLEP protocol messages are transported as a
collection of TLVs. The first TLV present in a DLEP message MUST be
one of the Signal TLVs, documented in section [INSERT REFERENCE
HERE]. 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       TLV
        Value     Description
        =====================================
        TBD       DLEP Version
        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       Transmit Latency
        TBD       Receive Resources
        TBD       Transmit Resources
        TBD       Expected Forwarding Time (EFT)
        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
```

DLEP data item TLVs 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   TLV Type    | Length        | Value...                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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.

9.1 DLEP Version

The DLEP Version TLV is an OPTIONAL TLV in both the Peer Discovery
and Peer Offer messages. The Version TLV is used to indicate the
version of the protocol running in the originator. A participant 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:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|TLV Type =TBD  |Length=4       |         Major Version         |
```

```
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         Minor Version         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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 '1', and the Minor Version to '3' (e.g. Version 1.3).

9.2 Peer Type

The Peer Type TLV is an OPTIONAL TLV in both the Peer Discovery and
Peer Offer messages. 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:

```
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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|TLV Type =TBD  |Length= peer   |Peer Type String               |
|               |type string len|Max Len = 80                   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

TLV Type   - TBD

Length   - Length of peer type string (80 octets maximum).

Peer Type String - Non-Null terminated string, maximum length of 80
                   octets. For example, a satellite modem might set
                   this variable to 'Satellite terminal'.

9.3 MAC Address

The MAC address TLV MUST appear in all neighbor-oriented signals
(e.g. Neighbor Up, Neighbor Up ACK, Neighbor Down, Neighbor Down ACK,
Neighbor 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).

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|TLV Type =TBD  |Length = 6     |          MAC Address          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         MAC Address                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

   TLV Type   - TBD

   Length   - 6

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

9.4 IPv4 Address

   The IPv4 Address TLV is an OPTIONAL TLV. If supported, it MAY appear
   in Neighbor Up, Neighbor Update, and Peer Update messages. When
   included in Neighbor messages, the IPv4 Address TLV contains the IPv4
   address of the neighbor, as well as a subnet mask value. In the Peer
   Update message, it contains the IPv4 address of the originator of the
   message. 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:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|TLV Type =TBD  |Length = 6     |  Add/Drop     | IPv4 Address  |
|               |               |  Indicator    |               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           IPv4 Address                        |  Subnet Mask  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

   TLV Type   - TBD

   Length   - 6

   Add/Drop   - Value indicating whether this is a new or existing
                  IPv4 address

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

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

9.5 IPv6 Address

   The IPv6 Address TLV is an OPTIONAL TLV. If supported, it MAY be used
   in the Neighbor Up, Neighbor Update, Peer Discovery, and Peer Update
   Messages. When included in Neighbor messages, this data item contains
   the IPv6 address of the neighbor. 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:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|TLV Type =TBD  |Length = 18    |   Add/Drop    | IPv6 Address  |
|               |               |   Indicator   |               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         IPv6 Address                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         IPv6 Address                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         IPv6 Address                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|              IPv6 Address                      | Subnet Mask   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

   TLV Type   - TBD

   Length   - 18

   Add/Drop   - Value indicating whether this is a new or existing
                  address (0x01), or a withdrawal of an address (0x02).
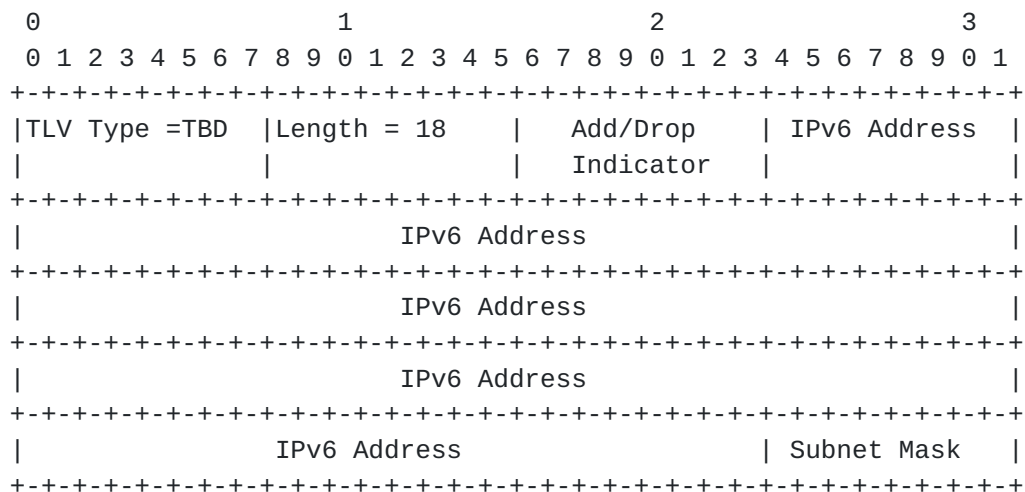
   IPv6 Address - IPv6 Address of the neighbor or peer.

   Subnet Mask - A subnet mask value (0-128) to be applied to the Ipv6
                  address.

9.6 Maximum Data Rate (Receive)

The Maximum Data Rate Receive (MDRR) TLV is used in Neighbor Up,
Neighbor Update, Peer Discovery, Peer Update, and Link
Characteristics ACK Messages 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 messages listed above,
the maximum data rate receive MUST be reported. A value of 0 for the
MDRR indicates that the Maximum Data Rate Receive is currently
'unknown'.

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|TLV Type =TBD  |Length = 8     |           MDRR (bps)          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          MDRR (bps)                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|          MDRR (bps)           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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. An MDRR value of 0 MAY be
                     used to indicate an 'unknown' data rate.

9.7 Maximum Data Rate (Transmit)

The Maximum Data Rate Transmit (MDRT) TLV is used in Neighbor Up,
Neighbor Update, Peer Discovery, Peer Update, and Link
Characteristics ACK Messages 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 messages listed
above, the maximum data rate transmit MUST be reported. A value of 0
for the MDRT MAY be used to indicate that the Maximum Data Rate
Transmit is currently unknown, or cannot be calculated.

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|TLV Type =TBD  |Length = 8     |           MDRT (bps)          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          MDRT (bps)                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

```
|              MDRT (bps)          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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. An MDRT value of 0
                      indicates an 'unknown' data rate.

9.8 Current Data Rate (Receive)

The Current Data Rate Receive (CDRR) TLV is used in Neighbor Up,
Neighbor Update, Peer Discovery, Peer Update, Link Characteristics
Request, and Link Characteristics ACK messages 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 messages above (e.g. Neighbor Update), the current data rate
receive MUST be reported.

The Current Data Rate Receive TLV 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|TLV Type =TBD  |TLV Flags=0x10 |Length = 8     |CDRR (bps)     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         CDRR (bps)                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         CDRR (bps)           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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. A CDRR value of 0 MAY be used
                              to indicate the CDRT is unknown, or cannot be
                              calculated.

9.9 Current Data Rate (Transmit)

   The Current Data Rate Receive (CDRT) TLV is used in Neighbor Up,
   Neighbor Update, Peer Discovery, Peer Update, Link Characteristics
   Request, and Link Characteristics ACK messages 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 messages above (e.g. Neighbor Update), the current data rate
   transmit MUST be reported.

   The Current Data Rate Transmit TLV 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|TLV Type =TBD  |TLV Flags=0x10 |Length = 8     |CDRT (bps)     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          CDRT (bps)                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          CDRT (bps)           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

   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. A CDRT value of 0
                        MAY be used to indicate the CDRT is 'unknown',
                        or cannot be calculated.

9.10 Expected Forwarding Time

   The Expected Forwarding Time (EFT) TLV is is an OPTIONAL data item.
   If supported, it MAY be used in Neighbor Up, Neighbor Update, Peer
   Discovery, and Peer Update messages to indicate the typical latency
   between the arrival of a given packet at the transmitting device and
   the reception of the packet at the other end of the link. EFT
   combines transmission time, idle time, waiting time, freezing time,
   and queuing time to the degree that those values are meaningful to a
   given transmission medium.

   The Expected Forwarding Time TLV 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|TLV Type =TBD  |Length = 4     |           EFT (ms)            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            EFT (ms)           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

   TLV Type   - TBD

   Length   - 4

   EFT   - A 32-bit unsigned number, representing the expected
                  forwarding time, in milliseconds, on the link.

9.11 Latency

   The Latency TLV is an OPTIONAL data item. If supported, it is used in
   Neighbor Up, Neighbor Update, Peer Discovery, Peer Update, Link
   Characteristics Request, and Link Characteristics ACK messages 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.

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|TLV Type =TBD  |Length = 2     |          Latency (ms)         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

   TLV Type   - TBD

   Length   - 2

     Latency   -   A 16-bit unsigned value, representing the transmission
                      delay that a packet encounters as it is transmitted
                      over the link. In Neighbor Up, Neighbor Update, and
                      Link Characteristics ACK, this value is reported as
                      delay, in milliseconds. 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 Message, this value represents the maximum
                      delay, in milliseconds, expected on the link.

9.12 **Resources (Receive)**

   The Receive Resources TLV is an OPTIONAL data item. If supported, it
   is used in Neighbor Up, Neighbor Update, Peer Discovery, Peer Update,
   and Link Characteristics ACK messages 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:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|TLV Type =TBD  |Length = 1     | Rcv Resources|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

   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. A value of '0' MAY be
                   used to indicate the receive resources are unknown or
                   cannot be calculated.

9.13 **Resources (Transmit)**

   The Transmit Resources TLV is an OPTIONAL data item. If supported, it
   is used in Neighbor Up, Neighbor Update, Peer Discovery, Peer Update,
   and Link Characteristics ACK messages 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:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|TLV Type =TBD  |Length = 1     | Xmt Resources|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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. A value of '0' MAY be
             used to indicate the transmit resources are unknown or
             cannot be calculated.

9.14 Relative Link Quality (Receive)

The Relative Link Quality Receive (RLQR) TLV is an OPTIONAL data
item. If supported, it is used in Neighbor Up, Neighbor Update, Peer
Discovery, Peer Update, and Link Characteristics ACK messages 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:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|TLV Type =TBD  |Length = 1     |RCV Rel. Link  |
|               |               |Quality (RLQR) |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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.
                        A value of '0' indicated the RLQR is
                        'unknown', or cannot be calculated.

9.15 Relative Link Quality (Transmit)

The Transmit Link Quality Receive (RLQT) TLV is an OPTIONAL data
item. If supported, it is used in Neighbor Up, Neighbor Update, Peer
Discovery, Peer Update, and Link Characteristics ACK messages 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:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|TLV Type =TBD  |Length = 1     |XMT Rel. Link  |
|               |               |Quality (RLQR) |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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.
                          A value of '0' indicated the RLQT is
                          'unknown', or cannot be calculated.

9.16 Status

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

The Status TLV 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|TLV Type =TBD  |Length = 1     |     Code      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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. Neighbor Up,
                          Neighbor Down, etc).

9.17 **Heartbeat Interval/Threshold**

   The Heartbeat Interval/Threshold TLV is an OPTIONAL TLV. If
   supported, it MAY be sent during Peer Discovery to indicate the
   desired Heartbeat timeout window. If the modem includes the Heartbeat
   Interval TLV in Peer Discovery, the router MUST either accept the
   timeout interval supplied by the modem, or reject the Peer Discovery.
   Peer Discovery messages that do not include the Heartbeat Interval
   TLV in Peer Discovery indicates a desire to establish the
   router/modem session without an activity timeout (e.g. an infinite
   timeout value). If an activity timeout is supported, implementations
   MAY choose to implement heuristics such that signals sent/received
   reset the timer window.

   The Interval is used to specify a period (in seconds) for Heartbeat
   Messages (See Section 23). The Threshold value is used to indicate
   the desired number of windows, each of time (Heartbeat Interval)
   seconds, to wait before either participant declares the router/modem
   session lost. In this case, the overall amount of time before a
   router/modem is declared lost is expressed as (Interval * Threshold).
   Specifying an Interval value of 0 indicates the desire to disable
   Heartbeat messages entirely (e.g., the Interval is set to an infinite
   value). Setting the Threshold value to 0 is undefined, and TLVs with
   a Threshold value of 0 MUST be rejected by the recipient.

   The Heartbeat Interval/Threshold TLV 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|TLV Type =TBD  |Length = 1     | Interval      |  Threshold    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

   TLV Type   - TBD

   Length   - 1

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

   Threshold   - Number of windows, of Heartbeat Interval seconds,
                       to wait before declaring a peer-to-peer session to

be lost.

9.18 Link Characteristics ACK Timer

The Link Characteristics ACK Timer TLV is an OPTIONAL TLV. If
supported, it MAY be sent during Peer Discovery to indicate the
desired number of seconds to wait for a response to a Link
Characteristics Request. If a router receives this TLV from a modem
during Peer Discovery, the router MUST either accept the timeout
value, or reject the Peer Discovery. 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:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|TLV Type =TBD  |Length = 1     | Interval      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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.

9.19 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 neighbor.

The Credit Window Status TLV 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|TLV Type =TBD  |Length = 16    | Modem Receive Window Value    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Modem Receive Window Value                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Modem Receive Window Value   | Router Receive Window Value   |
```

```
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                   Router Receive Window Value                  |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |  Router Receive Window Value  |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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.

9.20 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 Neighbor Up or
Neighbor Update messages. 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 message containing a Credit Window
Status TLV to report the updated aggregate values for synchronization
purposes.

In the Neighbor Up message, 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 Neighbor Up message
with a Credit Grant Request TLV supports credits, the receiver MUST
either reject the use of credits, via a Neighbor 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 Neighbor Up
message with a Neighbor Up ACK message that contains a Credit Window
Status TLV, initializing its receive window.

The Credit Grant TLV 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|TLV Type =TBD  |Length = 8     |         Credit Increment      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        Credit Increment                       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      Credit Increment         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

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.

9.21 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 Neighbor 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 Neighbor Up message 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 Neighbor Update ACK message.

The Credit Request TLV 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|TLV Type =TBD  |Length = 0     | Reserved, MUST|
|               |               | be set to 0   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

TLV Type   - TBD

Length   - 0

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

10. DLEP Protocol Messages

DLEP messages are encoded as a string of Type-Length-Value (TLV)
constructs. The first TLV in a DLEP message MUST be a valid DLEP
signal, as defined in section 11.1 of this document. The second TLV
MUST be the Identification data item, defined in section 10.1
Following those two TLVs are 0 or more TLVs, representing the data
items that are appropriate for the signal. The layout of a DLEP
message is thus:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| DLEP Signal   |DLEP Message   |Identification |Identification |
| Type value    |length (9 +    |TLV Type       |TLV length     |
| (value TBD)   |optional TLVs) |(TBD)          |(8)            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Router ID                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Modem ID                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Start of optional DLEP       |
| TLVs...                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
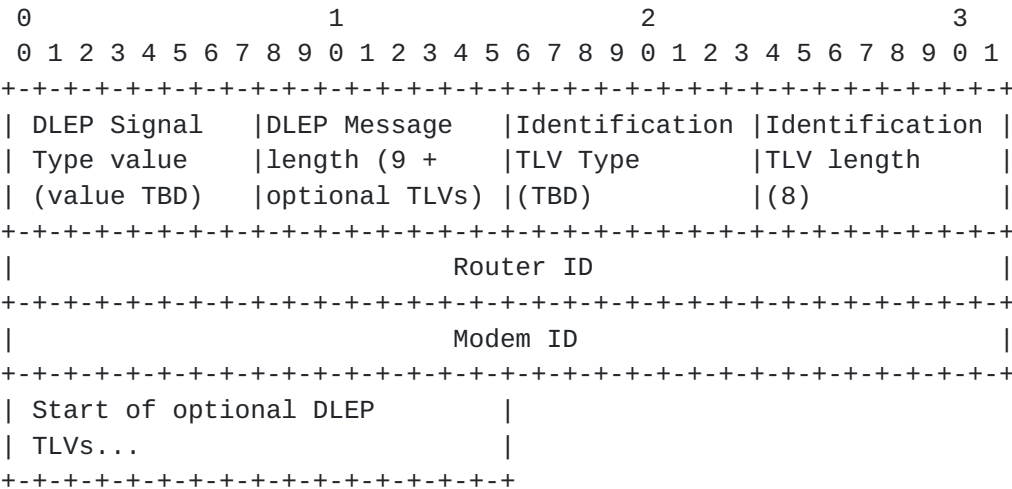
All DLEP messages (signals) begin with this structure. Therefore, in
the following descriptions of specific messages, this header
structure is assumed, and will not be replicated.

10.1 Signal TLV Values

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

```
     TLV       TLV
     Value     Description
     =====================================
     TBD       Peer Discovery
     TBD       Peer Offer
     TBD       Peer Offer ACK
     TBD       Peer Update
     TBD       Peer Update ACK
```

```
          TBD       Peer Termination
          TBD       Peer Termination ACK
          TBD       Neighbor Up
          TBD       Neighbor Up ACK
          TBD       Neighbor Down
          TBD       Neighbor Down ACK
          TBD       Neighbor Update
          TBD       Heartbeat
          TBD       Link Characteristics Request
          TBD       Link Characteristics ACK
```

11. Peer Discovery Message

The Peer Discovery Message is sent by a modem to begin a new DLEP association. The Peer Offer message is required to complete the discovery process. Implementations MAY implement their own retry heuristics in cases where it is determined the Peer Discovery Message has timed out. A Peer Discovery Message received from a modem that is already in session MUST be processed as if a Peer Termination Message had been received. A router implementation MAY then process the received Peer Discovery Message.

Note that metric data items MAY be supplied with the Peer Discovery, in order to populate default metric values, or to indicate a static, modem-wide environment. If metrics are supplied with the Peer Discovery message, these metrics MUST be used as the initial values for all neighbors (remote nodes) established via the modem.

Given the packet format described in section 11, the initial TLV Type value is set to DLEP_PEER_DISCOVERY (value TBD). OPTIONAL TLVs are then placed into the packet:

```
Optional Data Item TLVs:
        - DLEP Version
        - DLEP Peer Type
        - Heartbeat Interval
        - Heartbeat Threshold
        - Link Characteristics ACK Timer
        - Maximum Data Rate (Receive)
      - Maximum Data Rate (Transmit)
        - Current Data Rate (Receive)
      - Current Data Rate (Transmit)
        - Latency
        - Expected Forwarding Time
        - Resources (Receive)
      - Resources (Transmit)
        - Relative Link Quality (Receive)
      - Relative Link Quality (Transmit)
```

12. Peer Offer Message

The Peer Offer Message is sent by a DLEP router in response to a Peer
Discovery Message. Upon receipt, and processing, of a Peer Offer
message, the modem MUST respond with a Peer Offer ACK message,
completing the discovery phase of DLEP. Both DLEP participants
(router and modem) would then enter an "in session" state. Any
subsequent Discovery messages sent or received on this session MUST
be considered an error, and the session MUST be terminated as if a
Peer Termination Message had been received.

The Peer Offer message MUST be sent to the unicast address of the
originator of Peer Discovery, regardless of whether the discovery was
received on the DLEP multicast address (TBD) or on a unicast
address.

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

Optional Data Item TLVs:

            - DLEP Version
            - Peer Type
            - IPv4 Address
            - IPv6 Address
            - Status
            - Heartbeat Interval
            - Heartbeat Threshold
            - Link Characteristics ACK Timer

13. Peer Offer ACK Message

The Peer Offer ACK message acknowledges receipt of a Peer Offer
message, and completes the router/modem session establishment for
DLEP. The Peer Offer ACK message MUST be sent to unicast address of
the originator of a Peer Offer message. The Peer Offer ACK message
MUST contain an OPTIONAL Status data item, indicating success or
failure of the attempt to establish a router/modem session.

To construct a Peer Offer ACK message, the initial TLV type value is
set to DLEP_PEER_OFFER_ACK (value TBD). Mandatory data item TLV's are
placed into the packet next:

Mandatory Data Item TLVs:
        - Status

Note that there are NO OPTIONAL data item TLVs specified for this

message.

14. Peer Update Message

The Peer Update message is an OPTIONAL message, 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 would prompt a Peer Update message 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 Message 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 "Neighbor Update"
message 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 Message. Modems that track Layer 3 addresses
MUST acknowledge the Peer Update with a Peer Update ACK message.
Routers receiving a Peer Update with metric changes MUST apply the
new metric to all neighbors (remote nodes) accessible via the modem.
Supporting implementations are free to employ heuristics to
retransmit Peer Update messages. The sending of Peer Update Messages
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 message (e.g. Maximum
Data Rate), these metrics are considered to be modem-wide, and
therefore MUST be applied to all neighbors in the information base
associated with the router/modem session.

To construct a Peer Update message, 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
          - Expected Forwarding Time
          - Resources (Receive)
       - Resources (Transmit)

            - Relative Link Quality (Receive)
         - Relative Link Quality (Transmit)

[15]. Peer Update ACK Message

   The Peer Update ACK message is an OPTIONAL message, and is sent by
   implementations supporting Layer 3 address tracking and/or modem-wide
   metrics to indicate whether a Peer Update Message 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 message, 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.

   Optional Data Item TLVs:

          - Status

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

[16]. Peer Termination Message

   The Peer Termination Message is sent by a DLEP participant when the
   router/modem session needs to be terminated. Implementations
   receiving a Peer Termination message MUST send a Peer Termination ACK
   message to confirm the termination process. The sender of a Peer
   Termination message is free to define its heuristics in event of a
   timeout. The receiver of a Peer Termination Message MUST release all
   resources allocated for the router/modem session, and MUST eliminate
   all neighbors 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 Neighbor Down messages are
   sent.

   To construct a Peer Termination message, 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

[17]. Peer Termination ACK Message

   The Peer Termination Message ACK is sent by a DLEP peer in response

   to a received Peer Termination order. Receipt of a Peer Termination
   ACK message completes the teardown of the router/modem session.

   To construct a Peer Termination ACK message, 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

[18]. Neighbor Up Message

   A DLEP participant sends the Neighbor Up message to report that a new
   destination has been detected. A Neighbor Up ACK Message is required
   to confirm a received Neighbor Up. A Neighbor Up message 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 Neighbor Up Message is free to define its retry
   heuristics in event of a timeout. When a Neighbor Up message 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 Neighbor Up message, the initial TLV type value is set
   to DLEP_NEIGHBOR_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
              - Expected Forwarding Time
              - Resources (Receive)
          - Resources (Transmit)
              - Relative Link Factor (Receive)
          - Relative Link Factor (Transmit)
              - Credit Window Status

19. Neighbor Up ACK Message

A DLEP participant sends the Neighbor Up ACK Message to indicate whether a Neighbor Up Message was successfully processed.

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

Optional Data Item TLVs:
          - Credit Window Status

20. Neighbor Down Message

A DLEP peer sends the Neighbor Down message to report when a destination (a remote node or a multicast group) is no longer reachable. The Neighbor Down message MUST contain the MAC Address data item TLV. Other TLVs as listed are OPTIONAL, and MAY be present if an implementation supports them. A Neighbor Down ACK Message MUST be sent by the recipient of a Neighbor Down message to confirm that the relevant data has been removed from the information base. The sender of the Neighbor Down message is free to define its retry heuristics in event of a timeout.

To construct a Neighbor Down message, the initial TLV type value is set to DLEP_NEIGHBOR_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 message.

21. Neighbor Down ACK Message

A DLEP participant sends the Neighbor Down ACK Message to indicate whether a received Neighbor Down Message 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 neighbor. As with the Neighbor Down message, there are NO OPTIONAL Data Item TLVs defined for the Neighbor Down ACK message.

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

   - MAC Address Data item
   - Status data item

22. Neighbor Update Message

A DLEP participant sends the Neighbor Update message when it detects
some change in the information base for a given neighbor (remote node
or multicast group). Some examples of changes that would prompt a
Neighbor Update message are:

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

To construct a Neighbor Update message, the initial TLV type value is
set to DLEP_NEIGHBOR_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

23. Heartbeat Message

A Heartbeat Message is sent by a DLEP participant every N seconds,
where N is defined in the "Heartbeat Interval" field of the discovery
message. Note that implementations omitting the Heartbeat Interval
effectively set the interval to an infinite value, therefore, in
those cases, this message would NOT be sent.

The message is used by participants to detect when a DLEP session
partner (either the modem or the router) is no longer communicating.
Participants SHOULD allow some integral number of heartbeat intervals

   (default 4) to expire with no traffic on the router/modem session
   before initiating DLEP session termination procedures.

   To construct a Heartbeat message, 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 message.

[24]. **Link Characteristics Request Message**

   The Link Characteristics Request Message is an OPTIONAL message, and
   is sent by the router to request that the modem initiate changes for
   specific characteristics of the link. Since the request specifies a
   neighbor, it can reference either a real destination (e.g., a remote
   node), or a logical destination (e.g., a multicast destination)
   within the network.

   The Link Characteristics Request message contains either a Current
   Data Rate (CDRR or CDRT) TLV to request a different amount of
   bandwidth 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 Message 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 message, the initial TLV
   type value is set to DLEP_NEIGHBOR_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 milliseconds on the link.

[25]. **Link Characteristics ACK Message**

The LInk Characteristics ACK message is an OPTIONAL message, 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 message 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 message MUST reflect the link characteristics
after the request has been processed.

To construct a Link Characteristics Request ACK message, the initial
TLV type value is set to DLEP_NEIGHBOR_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 milliseconds, on the
                        link.

26. 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.

27. IANA Considerations

   This section specifies requests to IANA.

27.1 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.

27.2 Expert Review: Evaluation Guidelines

No additional guidelines for expert review are anticipated.

27.3 Signal (Message) TLV Type Registration

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

o   Peer Discovery
o   Peer Offer
o   Peer Offer ACK
o   Peer Update
o   Peer Update ACK
o   Peer Termination
o   Peer Termination ACK
o   Neighbor Up
o   Neighbor Up ACK
o   Neighbor Down
o   Neighbor Down ACK
o   Neighbor Update
o   Heartbeat
o   Link Characteristics Request
o   Link Characteristics ACK

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

27.4 DLEP Data Item Registrations

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

    o   DLEP Version
    o   Peer Type
    o   MAC Address
    o   IPv4 Address
    o   IPv6 Address
    o   Maximum Data Rate (Receive)
    o   Maximum Data Rate (Transmit)
    o   Current Data Rate (Receive)
    o   Current Data Rate (Transmit)
    o   Latency
    o   Expected Forwarding Time
    o   Resources (Receive)
    o   Resources (Transmit)
    o   Relative Link Quality (Receive)
    o   Relative Link Quality (Transmit)
    o   Status
    o   Heartbeat Interval/Threshold
    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.

27.5 DLEP Well-known Port

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

27.6 DLEP Multicast Address

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

30. Appendix A.

30.1 Peer Level Message Flows

30.1.1 Modem Device Restarts Discovery

```
Router                    Modem   Message Description
==================================================================

<-------Peer Discovery---------    Modem initiates discovery
```

```
      ---------Peer Offer----------->   Router detects a problem, sends
        w/ Non-zero Status TLV          Peer Offer w/Status TLV indicating
                                        the error.

                                        Modem accepts failure, restarts
                                        discovery process.

     <-------Peer Discovery---------    Modem initiates discovery


      ---------Peer Offer----------->   Router accepts, sends Peer Offer
           w/ Zero Status TLV           w/ Status TLV indicating success.

                                        Discovery completed.
```


30.1.2 **Modem Device Detects Peer Offer Timeout**

```
   Router                    Modem   Message Description
   ================================================================

   <-------Peer Discovery---------    Modem initiates discovery, starts
                                      a guard timer.

                                      Modem guard timer expires. Modem
                                      restarts discovery process.

    <-------Peer Discovery---------   Modem initiates discovery, starts
                                      a guard timer.

     ---------Peer Offer----------->  Router accepts, sends Peer Offer
          w/ Zero Status TLV          w/ Status TLV indicating success.

                                      Discovery completed.
```

[30.1.3](#) **Router Peer Offer Lost**

```
   Router                    Modem   Message Description
   ================================================================

   <-------Peer Discovery---------    Modem initiates discovery, starts
                                      a guard timer.

    ---------Peer Offer-------||      Router offers availability

                                      Modem times out on Peer Offer,
                                      restarts discovery process.

   <-------Peer Discovery---------    Modem initiates discovery

    ---------Peer Offer----------->   Router detects subsequent
                                      discovery, internally terminates
                                      the previous, accepts the new
                                      association, sends Peer Offer
                                      w/Status TLV indicating success.


                                      Discovery completed.
```

[30.1.4](#) **Discovery Success**

```
   Router                    Modem   Message Description
   ================================================================

   <-------Peer Discovery---------    Modem initiates discovery

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

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

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

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

   <============================>    Neighbor Sessions

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

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

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

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

30.1.5 Router Detects a Heartbeat timeout

```
    Router                     Modem    Message Description
    ==================================================================

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

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

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

           ~ ~ ~ ~ ~ ~ ~

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

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

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

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

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

30.1.6 Modem Detects a Heartbeat timeout

```
    Router                     Modem    Message Description
    ==================================================================

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

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

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

           ~ ~ ~ ~ ~ ~ ~

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

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

```
                                  Modem Heartbeat Timer expires,
                                  detects missing heartbeats. Modem
                                  takes down all neighbor sessions

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

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

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

30.1.7 **Peer Terminate (from Modem) Lost**

```
   Router                      Modem   Message 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
```

30.1.8 **Peer Terminate (from Router) Lost**

```
   Router                      Modem   Message Description
   ================================================================

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

                                  Modem HB times out,
                                  terminates association.

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

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

30.2 **Neighbor Specific Message Flows**

30.2.1 **Modem Neighbor Up Lost**

```
   Router                      Modem   Message Description
   ====================================================================

    ||-----Neighbor Up ------------   Modem sends Neighbor Up

                                      Modem timesout on ACK

    <------Neighbor Up ------------   Modem sends Neighbor Up

    ------Neighbor Up ACK--------->   Router accepts the neighbor
                                      session

   <------Neighbor Update---------    Modem Neighbor Metrics
         . . . . . . .
   <------Neighbor Update---------    Modem Neighbor Metrics
```

30.2.2 **Router Detects Duplicate Neighbor Ups**

```
   Router                      Modem   Message Description
   ====================================================================

    <------Neighbor Up ------------   Modem sends Neighbor Up

    ------Neighbor Up ACK-------||    Router accepts the neighbor
                                      session

                                      Modem timesout on ACK

    <------Neighbor Up ------------   Modem resends Neighbor Up

                                      Router detects duplicate Neighbor,
                                      takes down the previous, accepts
                                      the new Neighbor.

    ------Neighbor Up ACK--------->   Router accepts the neighbor
                                      session

   <------Neighbor Update---------    Modem Neighbor Metrics
         . . . . . . .
   <------Neighbor Update---------    Modem Neighbor Metrics
```

30.2.3 Neighbor Up, No Layer 3 Addresses

```
Router                     Modem    Message Description
=====================================================================

 <------Neighbor Up ------------   Modem sends Neighbor Up

 ------Neighbor Up ACK--------->   Router accepts the neighbor
                                   session

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

 <------Neighbor Update---------   Modem Neighbor Metrics
         . . . . . . . .
 <------Neighbor Update---------   Modem Neighbor Metrics
```

30.2.4 Neighbor Up with IPv4, No IPv6

```
Router                     Modem    Message Description
=====================================================================

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

 ------Neighbor Up ACK--------->   Router accepts the neighbor
                                   session

                                   Router drives ND for IPv6 if
                                   defined.

 <------Neighbor Update---------   Modem Neighbor Metrics
         . . . . . . . .
 <------Neighbor Update---------   Modem Neighbor Metrics
```

30.2.5 Neighbor Up with IPv4 and IPv6

```
Router                     Modem    Message Description
=====================================================================

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

 ------Neighbor Up ACK--------->   Router accepts the neighbor
                                   session
```

```
      <------Neighbor Update---------    Modem Neighbor Metrics
              . . . . . . . .
```

30.2.6 Neighbor Session Success

```
   Router                      Modem   Message Description
   ==================================================================


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

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


   <------Neighbor Up -----------       Modem

    ------Neighbor Up ACK-------->      Router

   <------Neighbor Update---------      Modem
          . . . . . . . .
   <------Neighbor Update---------      Modem

                                        Modem initiates the terminate

   <------Neighbor Down ----------      Modem

    ------Neighbor Down ACK------->     Router

                                        or

                                        Router initiates the terminate

    ------Neighbor Down ---------->     Router

   <------Neighbor Down ACK-------      Modem
```

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