Logical Link Control Protocol

Technical Specification

NFC Forum™

LLCP 1.0

NFCForum-TS-LLCP_1.0

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RESTRICTIONS ON USE

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1 Overview

This document describes the functions, features and protocol of the Logical Link Control (LLC) layer of the NFC Forum Protocol Suite. The LLC layer constitutes the upper half of the OSI data link layer (cf. figure 1) which is complemented by the lower half, the Medium Access and Control (MAC) layer. MAC layers are supported by the LLCP specification through a set of mappings. Each mapping specifies the binding requirements for LLCP to one externally defined MAC protocol.

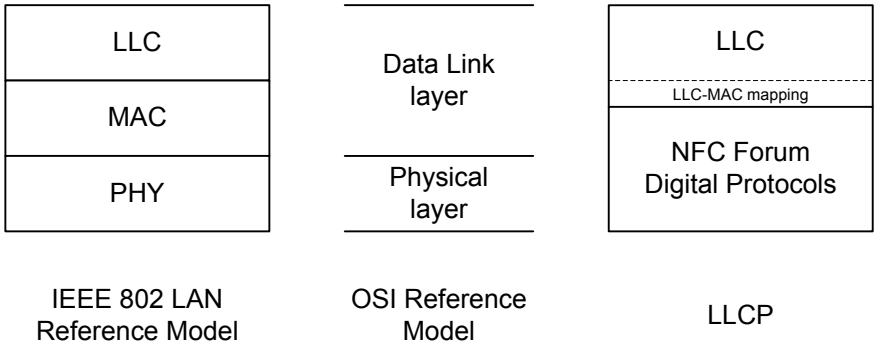

Figure 1: Relationship to OSI Reference Model

1.1 Features and Scope

The Logical Link Control Protocol (LLCP) specification provides the procedural means for the transfer of upper layer information units between two NFC Forum Devices. The set of procedures represents a uniform link abstraction to the user of the data link service.

The main features provided by the LLCP are:

- Link Activation, Supervision and Deactivation

  The LLCP specifies how two NFC Forum Devices within communication range recognize compatible LLCP implementations, establish an LLCP Link, supervise the connection to the remote peer device, and deactivate the link if requested.

- Asynchronous Balanced Communication

  Typical NFC MACs operate in Normal Response Mode where only a master, called the Initiator, is allowed to send data to and request data from the slave, called the Target. The LLCP enables Asynchronous Balanced Mode (ABM) between service endpoints in the two peer devices by use of a symmetry mechanism. Using ABM, service endpoints may initialize, supervise, recover from errors and send information at any time.

- Protocol Multiplexing

  The LLCP is able to accommodate several instances of higher level protocols at the same time.

- Connectionless Transport

  With minimum protocol overhead, connectionless transport provides a service user an unacknowledged data transmission facility that does not require preparative steps to actually send service data units. This transport mode can be used if upper protocol layers implement their own flow control and so need not rely on the link layer flow control mechanism. It can also be used by applications that operate in a command/response model wherein a command is always followed by a response returned before the next command is sent.

- Connection-oriented Transport

  This transport mode provides a data transmission service with sequenced and guaranteed delivery of service data units. Traffic is controlled by a numbering scheme known as the sliding window protocol. Connection-oriented transport requires the preliminary setup of a data link connection and the assignment of resources for as long as the connection persists.

The following features are not defined or are not within the scope of this LLCP specification:

- Isochronous Data Transfer

  The LLCP is not designed to transfer constant-rate data such as speech or video. No timing guarantees are given with respect to the transmission or reception of service data units and no time synchronization between sender and receiver is provided.

- Multicast / Broadcast

  The LLCP does not support multicast or broadcast destination addressing. Data units are always destined for a single service access point.

- Secure Data Transfer

  The LLCP does not provide secure data transfer between any two service access points. Secure communication may be provided by the lower or upper layer protocols.

- Service User Interface

  The LLCP does not specify the interface between the LLC layer and the upper protocol layer. Implementers may choose any appropriate means of device software integration. An interoperable interface may be defined by other NFC Forum specifications.

- Implementation Architecture

  The LLCP does not impose any internal functional partitioning nor does it mandate any internal interface definitions or component clustering.

1.2 Applicable Documents or References

1.2.1 Normative Authorities

[DIGIPROT] NFC Forum. n.d. *NFC Digital Protocol Specification.* Working Draft. Forthcoming. Wakefield, Mass.: NFC Forum

[ISO18092] International Organization for Standardization. 2004. *Near Field Communication – Interface and Protocol.* ISO/IEC 18092:2004. First Edition. Geneva: ISO

[RFC2119] S. Bradner. 1997. *Key words for use in RFCs to Indicate Requirement Levels.* Internet Engineering Task Force RFC 2119. IETF

1.2.2 Normative References

[NFCREG] NFC Forum. n.d. *NFC Forum Assigned Values*. Forthcoming. Wakefield, Mass.: NFC Forum

1.2.3 Informative References

[BLACK] Black, Uyless. 1993. *Data Link Protocols.* Englewood Cliffs, N.J.: PTR Prentice-Hall

1.3 Administration

The NFC Forum Logical Link Control Protocol Specification is an open specification supported by the Near Field Communication Forum, Inc., located at:

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The NFC Forum Devices Technical Working Group maintains this specification. Comments, errors, and other feedback can be submitted at http://www.nfc-forum.org/apps/org/workgroup/chairs/download.php/6070.

1.4 Special Word Usage

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 [RFC2119].

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1.6 Intellectual Property

The Logical Link Control Protocol Specification conforms to the Intellectual Property guidelines specified in the NFC Forum's Intellectual Property Right Policy, as approved on November 9, 2004 and outlined in the NFC Forum Rules of Procedures, as approved on December 17, 2004, and revised on August 4, 2009.

1.7 Glossary

Connectionless Transport

An unacknowledged data transmission service with minimal protocol complexity.

Connection-oriented Transport

A data transmission service with sequenced and guaranteed delivery of service data units.

Data Link Connection

A unique combination of source and destination service access point address used for numbered information transfer.

ISO/IEC 18092

Near field communication protocol according to ISO/IEC 18092. See [DIGIPROT] and [ISO18092].

Link MIU

The maximum number of octets in the information field of any possible LLC protocol data unit.

Local LLC

The LLC component running on the local device.

Logical Data Link

A combination of source and destination service access point address used for unnumbered information transfer.

LLCP Link

The reliable communication channel between the local and the remote LLC that provides the transport for all data link connections and logical data links.

Maximum Information Unit (MIU)

The maximum length of the information field in a single LLC protocol data unit.

Protocol Data Unit (PDU)

The sequence of contiguous octets delivered as a unit to the adjacent lower layer or received as a unit from the adjacent lower layer.

Remote LLC

The LLC component running on the remote device.

Service

The capabilities and features provided to the adjacent upper layer.

Service Data Unit (SDU)

The sequence of contiguous octets received as a unit from the adjacent upper layer or delivered as a unit to the adjacent upper layer.

Service Discovery Protocol (SDP)

An application protocol to discover service access point users bound at the remote LLC.

Service User

The user of a service provided by the adjacent lower layer.

Type-Length-Value (TLV)

A coding method for parameters where the Type field specifies the parameter type, the Length field specifies the length of the parameter value and the Value field contains the actual parameter value octets

1.8 Acronyms and Abbreviations

ABM	Asynchronous Balanced Mode
AGF	Aggregated Frame
ATR_RES	Attribute Response
ATR_REQ	Attribute Request
CC	Connection Complete
CONNECT	Connect
DEP_RES	Data Exchange Protocol Response
DEP_REQ	Data Exchange Protocol Request
DID	Device Identifier

DISC	Disconnect
DM	Disconnected Mode
DSAP	Destination Service Access Point
FRMR	Frame Reject
I	Information
LLC	Logical Link Control
LLCP	Logical Link Control Protocol
MAC	Media Access Control
MIU	Maximum Information Unit
MIUX	Maximum Information Unit Extension
N(R)	Receive Sequence Number
N(S)	Send Sequence Number
NAD	Node Address
PAX	Parameter Exchange
PDU	Protocol Data Unit
PTYPE	Protocol Data Unit Type
RNR	Receive Not Ready
RR	Receive Ready
RW	Receive Window
RWT	Response Waiting Time
SAP	Service Access Point
SDP	Service Discovery Protocol
SDU	Service Data Unit
SSAP	Source Service Access Point
SYMM	Symmetry
TLV	Type-Length-Value
UI	Unnumbered Information
V(R)	Receive State Variable
V(RA)	Receive Acknowledgement State Variable
V(S)	Send State Variable
V(SA)	Send Acknowledgement State Variable
WTX	Waiting Time Extension

2 Definitions

2.1 Bit Significance in Diagrams and Tables

Unless otherwise specified, this document assumes the left-most bit in field definitions is the most significant bit and the right-most bit is least significant bit.

2.2 LLC Protocol Version

This specification describes Version 1.0 of the LLC Protocol.

3 Architecture

3.1 Components

LLCP can be split into the following logical components:

- The *MAC Mapping* integrates an existing RF protocol - such as ISO18092 - into the LLCP architecture.
- The *Link Management* component is responsible for serializing all connection-oriented and connectionless LLC PDU exchanges and for aggregation and disaggregation of small PDUs. This component also guarantees asynchronous balanced mode communication and provides link status supervision by performing the symmetry procedure.
- The *Connection-oriented Transport* component is responsible for maintaining all connection-oriented data exchanges including connection set-up and termination.
- The *Connectionless Transport* component is responsible for handling unacknowledged data exchanges.

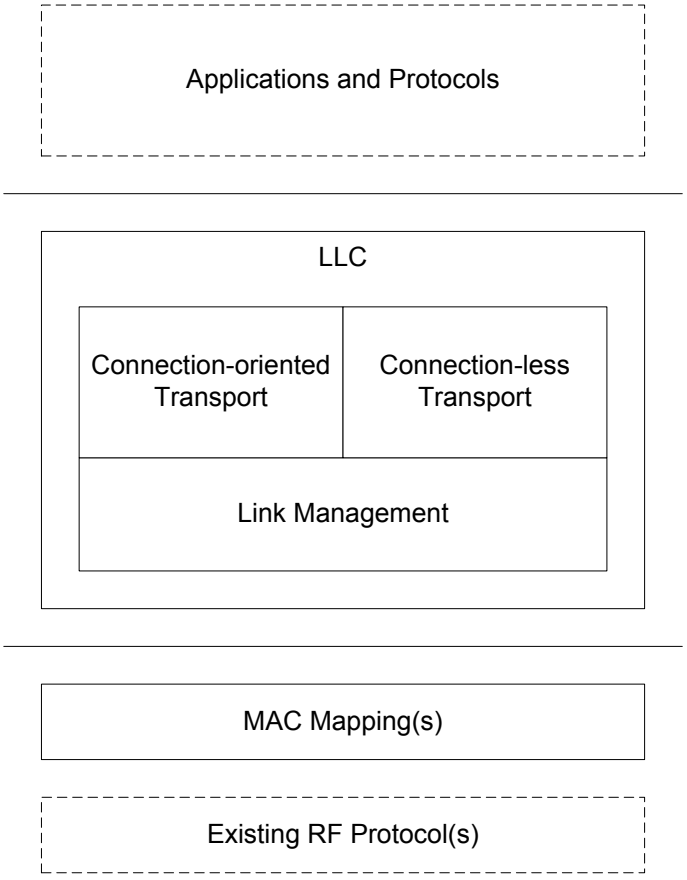


Figure 2: Logical Components

3.2 LLCP Data Transport Services

This section describes the different forms of data transport services that are provided to LLC service users. NFC Forum devices are classified according to their *link service class*—the combination of link transport services they offer to remote devices.

3.2.1 Link Service Class

This version of the LLCP specification defines two forms of data transport service: Connectionless transport and Connection-oriented Transport. Devices offering only the Connectionless transport service are classified as *link service class 1*. Devices offering only the Connection-oriented transport service are classified as *link service class 2*. Devices offering both Connectionless and Connection-oriented transport services are classified as *link service class 3*.

3.2.2 Connectionless Transport

Connectionless transport provides an unacknowledged data transmission service with minimum protocol complexity. This transport service is useful when higher layers provide any essential recovery and sequencing services so that replication of these services in the data link layer becomes needless. It may also prove useful in applications where guaranteed delivery of service data units is not essential. Due to the inherent data transfer reliability of the MAC layer, LLCP connectionless transport data units are guaranteed to arrive at the destination LLC but may not be delivered to the destination service access point.

Connectionless transport does not require any prior connection establishment or terminating procedure, thus allows spontaneous exchange of service data units without a time consuming preamble.

The source and destination of each connectionless service data unit are uniquely determined by the SSAP and DSAP field, respectively, in the data link PDU. Each combination of DSAP and SSAP forms a “logical data link” and this terminology is used in this specification to reference connectionless transport service.

3.2.3 Connection-oriented Transport

Connection-oriented transport provides a data transmission service with sequenced and guaranteed delivery of service data units. These types of data exchanges are described in this specification as “data link connections.”

Prior to the exchange of information-bearing PDUs, a data link connection is established between two service endpoints. The normal cycle of communication then consists of the transfer of PDUs containing information from one LLC to the other, acknowledged by PDUs in the opposite direction. An LLC acknowledges a PDU after it has been dispatched to the service user.

Information flow between the two peer LLCs is controlled by numbering the PDUs and managing a sliding window of sent, but unacknowledged, PDUs. A data link connection persists with its associated resources until explicit closure by either one of the two communicating LLCs or as a consequence of an unexpected link disruption.

Each data link connection is uniquely identified by the pair of DSAP and SSAP included in the header of each LLC PDU. When opening a connection, the DSAP identifies the remote service endpoint for the intended data exchange and the SSAP identifies the local service endpoint. Once the connection is established, each LLC sends PDUs for that data link connection by alternately exchanging the DSAP and SSAP values such that each sent PDU identifies the source LLC's SAP in the SSAP field and the destination LLC's SAP in the DSAP field. During the lifetime of a data link connection, both LLCs maintain state information and manage receive buffers independently of any other data link connection.

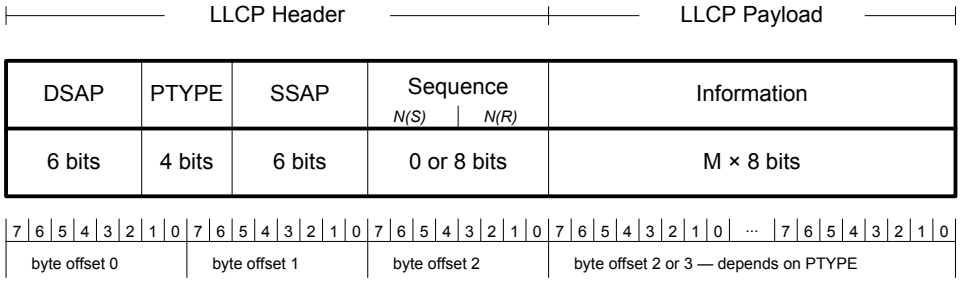
The number of receive buffers at both endpoints of a data link connection is implementation specific, but the PDU numbering scheme in this version of the LLCP specification does not support more than 15 unacknowledged numbered information units. Lower numbers can be announced during connection setup.

4 LLC Elements

This section defines in detail the LLC PDU structure, the method for representing data link layer service access point addresses, the available LLC PDU types and how they are indicated, and the use of the control and information fields for specific PDUs.

4.1 LLC PDU Format

All LLC PDUs SHALL conform to the format shown in figure 3:



DSAP = Destination service access point address field

PTYPE = Payload data unit (PDU) type field

SSAP = Source service access point address field

Sequence = Sequence field (8 bits for formats that include sequence numbers, and 0 bits for formats that do not)

Information = Information field (M is an integer value between and including 0 and the maximum information unit MIU defined in this specification; × denotes multiplication)

Figure 3: Format of the LLC PDU

4.2 Elements of the LLC PDU

4.2.1 Address Fields

Each LLC PDU SHALL contain two address fields – the Destination Service Access Point (DSAP) address field and the Source Service Access Point (SSAP) address field, in the bit positions shown in figure 3. The DSAP address field SHALL identify the service access point for which the LLC information field is intended. The SSAP address field SHALL identify the service access point from which the LLC information field originated.

4.2.1.1 Address Usage

Any address SHALL be usable as both an SSAP and a DSAP address. Table 1 lists the different values that can be taken by the DSAP and SSAP fields and a brief description for the services that are identified by these values.

Table 1: DSAP, SSAP Values

DSAP/SSAP	Description
00h – 0Fh	Identifies the Well-Known Service Access Points
10h – 1Fh	Identifies Services in the local service environment and are advertised by local SDP
20h – 3Fh	Identifies Services in the local service environment and are NOT advertised by local SDP

The "0" address, i.e. 00h, in the DSAP or SSAP address field SHALL designate the LLC Link Management component, and SHALL NOT be used to identify any specific service access point.

The "1" address, i.e. 01h, SHALL designate the well-known service access point for the Service Discovery Protocol (SDP).

Address values between 2 and 15 (02h – 0Fh) inclusively, SHALL be reserved for well-known service access points defined in the NFC Forum Assigned Values Registry [NFCREG].

Address values between 16 and 31 (10h – 1Fh) inclusively, SHALL be assigned by the local LLC to services registered by the local service environment. These registrations SHALL be made available by the local Service Discovery Protocol (SDP) instance for discovery and use by a remote LLC.

Address values between 32 and 63 (20h – 3Fh) inclusively, SHALL be assigned by the local LLC as the result of an upper layer service request, and SHALL NOT be available for discovery using the Service Discovery Protocol (SDP).

4.2.2 PDU Type

Each LLC PDU SHALL contain a 4-bit protocol data unit type field— the PTYPE field—in the bit positions shown in figure 3. The PTYPE field SHALL identify the syntax and semantic of the remaining fields of the LLC PDU, and SHALL take one of the values specified in Table 2. Values marked as reserved in Table 2 SHALL NOT be generated by the sender and SHALL be ignored by the receiver.

In Table 2, the PTYPE values for each PDU Type are defined as are the link service classes for which each PDU Type is applicable.

The PTYPE value 1111b SHALL be reserved for future extensions of the LLCP header format and SHALL then be used in conjunction with the DSAP and SSAP fields set to "0". The extension header format can be recognized by the leading two octets "03h C0h", in that order. Implementations conforming to this version SHALL treat this value as a reserved PTYPE.

Table 2: PDU Type Values

PDU Type	PTYPE	Link Service Class
SYMM	0000	1, 2, 3
PAX	0001	1, 2, 3
AGF	0010	1, 2, 3
UI	0011	1, 3

PDU Type	PTYPE	Link Service Class
CONNECT	0100	2, 3
DISC	0101	1, 2, 3
CC	0110	2, 3
DM	0111	1, 2, 3
FRMR	1000	2, 3
reserved	1001	
reserved	1010	
reserved	1011	
I	1100	2, 3
RR	1101	2, 3
RNR	1110	2, 3
reserved	1111	

4.2.3 Sequence Field

The sequence field SHALL be present in PDUs containing sequence numbers, in the bit positions shown in figure 3. It SHALL NOT be present in other PDUs. The sequence field is always divided into a 4 bit sub-field containing send sequence number N(S) encoded in the most significant bits, and a 4-bit sub-field containing receive sequence number N(R) encoded in the least significant bits. Section 4.3 specifies, for each PDU, whether the sequence field is present and how the sub-fields are utilized.

In this version of the LLCP specification, PDUs containing sequence numbers are the I, RR, and RNR PDU.

4.2.4 Information Field

The information field SHALL consist of an integral number of up to MIU octets. The information field MAY be empty. Section 4.3 specifies, for each PDU, whether the information field is present and what it contains.

4.3 PDU Descriptions

This subsection defines the structure of all valid LLC PDUs.

4.3.1 Symmetry (SYMM)

The SYMM PDU is an unnumbered PDU sent by an LLC whenever no other PDUs are available for sending, to ensure symmetry.

The format of the SYMM PDU SHALL be as shown in figure 4.

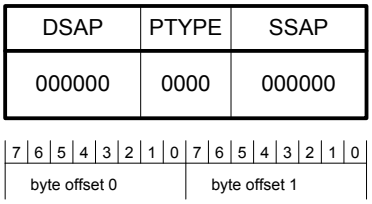


Figure 4: Format of the SYMM PDU

The sequence field SHALL NOT be present in a SYMM PDU.

An information field SHALL NOT be present in a SYMM PDU.

4.3.2 Parameter Exchange (PAX)

The PAX PDU SHALL be used to exchange parameters concerning the LLCP Link configuration.

The format of the PAX PDU SHALL be as shown in figure 5 (where *n* is the length of the PDU).

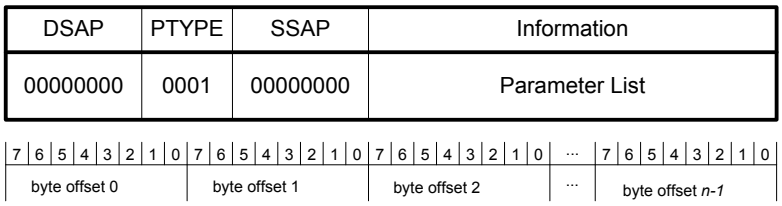


Figure 5: Format of the PAX PDU

The sequence field SHALL NOT be present in a PAX PDU.

PAX SHALL NOT use any DSAP or SSAP value other than 0.

The information field of the PAX PDU SHALL be encoded as a contiguous sequence of LLC parameter TLV elements, with the generic encoding format defined in section 4.4. The LLC parameters that are allowed in the information field of a PAX PDU are defined in section 4.5. The receiver of a PAX PDU SHALL ignore any TLV elements that are not defined in section 4.5.

4.3.3 Aggregated Frame (AGF)

The AGF is an unnumbered PDU. The AGF PDU MAY be used by the LLC Link Management component to aggregate and transfer multiple LLC PDUs to the remote LLC Link Management component in a single transmission.

Upon reception of an AGF PDU, the LLC Link Management component SHALL dispatch the aggregated LLC PDUs according to each PDU's destination and source service access point address. Each PDU SHALL be dispatched as if transmitted separately and in the order it appears in the AGF PDU.

The format of the AGF PDU SHALL be as shown in figure 6 (where *n* is the length of the PDU).

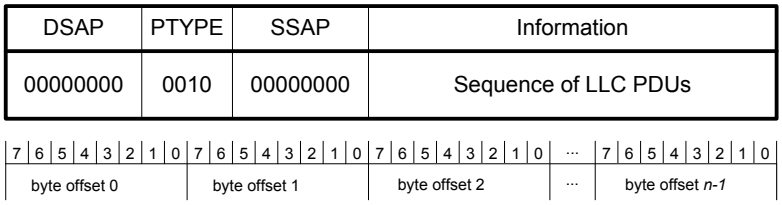


Figure 6: Format of the AGF PDU

The sequence field SHALL NOT be present in an AGF PDU.

The information field of the AGF PDU SHALL be encoded as a contiguous sequence of LLC PDUs. Each PDU SHALL be encapsulated by preceding it with a 16-bit length field, encoded most significant byte first, as shown in figure 7. The length field SHALL specify the number of octets in the following LLC PDU.

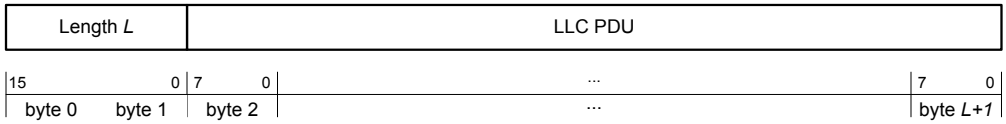


Figure 7: Encapsulated LLC PDU format

The AGF PDU SHALL contain at least two encapsulated PDUs. SYMM and AGF PDUs SHALL NOT be aggregated. No other restrictions exist on the type of PDU, or the use of service access point addresses, or the values of sequence numbers.

The maximum number of octets in the information field of the AGF PDU SHALL be determined by the Link MIU established with the LLC link activation procedure described in section 5.2.

4.3.4 Unnumbered Information (UI)

The UI PDU is used to transfer service data units to the peer LLC without prior establishment of a data link connection.

The format of the UI PDU SHALL be as shown in figure 8.

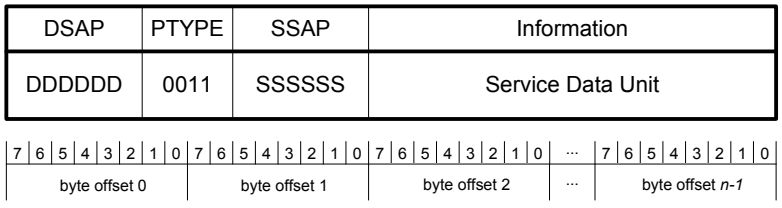


Figure 8: Format of the UI PDU

The sequence field SHALL NOT be present in a UI PDU.

The information field of a UI PDU SHALL contain a single service data unit. The maximum number of octets in the information field SHALL be determined by the Link MIU established with the LLC link activation procedure described in section 5.2.

The information field of a UI PDU MAY be empty.

4.3.5 Connect (CONNECT)

The CONNECT PDU is an unnumbered PDU which is used to request a data link connection between a source and a destination service access point.

The CONNECT PDU SHALL have the format shown in figure 9.

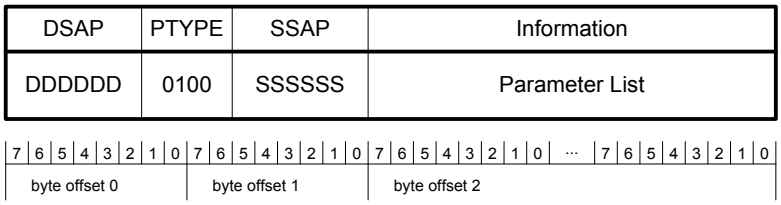


Figure 9: Format of the CONNECT PDU

The sequence field SHALL NOT be present in a CONNECT PDU.

The information field of the CONNECT PDU MAY contain connection specific parameters. These parameters SHALL be encoded as a contiguous sequence of TLV elements and each TLV element SHALL be encoded as defined in section 4.4. The LLC parameters that are allowed in the information field of a CONNECT PDU are defined in section 4.5. The receiver of a CONNECT PDU SHALL ignore any TLV elements that are not defined in section 4.5.

4.3.6 Disconnect (DISC)

The DISC PDU is an unnumbered PDU which is used to terminate a data link connection or is used to deactivate the LLCP Link.

The DISC PDU SHALL have the format shown in figure 10.

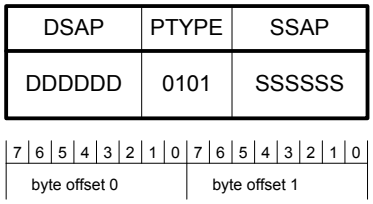


Figure 10: Format of the DISC PDU

The sequence field SHALL NOT be present in a DISC PDU.

An information field SHALL NOT be present in a DISC PDU.

4.3.7 Connection Complete (CC)

The CC PDU is an unnumbered PDU which is used by an LLC to acknowledge the receipt and acceptance of the CONNECT.

The CC PDU SHALL have the format shown in figure 11.

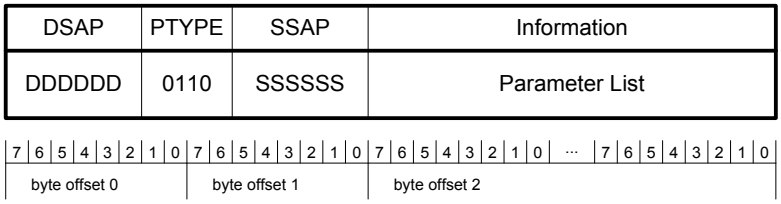


Figure 11: Format of the CC PDU

The sequence field SHALL NOT be present in a CC PDU.

The information field of the CC PDU MAY contain connection specific parameters. These parameters SHALL be encoded as a contiguous sequence of TLV elements and each TLV element SHALL be encoded as defined in section 4.4. The parameters that are allowed in the information field of a CC PDU are defined in section 4.5. The receiver of a CC PDU SHALL ignore any TLV elements that are not defined in section 4.5.

4.3.8 Disconnected Mode (DM)

The DM PDU is an unnumbered PDU which is used to report status indicating that the LLC is logically disconnected from the data link connection identified by the DSAP and SSAP address pair.

The DM PDU SHALL have the format shown in figure 12.

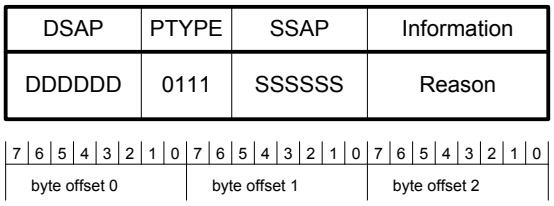


Figure 12: Format of the DM PDU

The sequence field SHALL NOT be present in a DM PDU.

The information field of the DM PDU SHALL contain a single octet, the reason field, that gives further information about the cause of the DM response. The reason field SHALL be one of the values in table 3. In table 3, the term *target service access point* refers to the value in the SSAP field of the DM PDU (which is the same as the destination access point specified in the PDU which caused return of the DM PDU).

Table 3: Disconnected Mode Reasons

00h	SHALL indicate that the LLC has received a DISC PDU and is now logically disconnected from the data link connection.
01h	SHALL indicate that the LLC has received a connection-oriented PDU but the target service access point has no active connection.

02h	SHALL indicate that the remote LLC has received a CONNECT PDU and there is no service bound to the specified target service access point.
03h	SHALL indicate that the remote LLC has processed a CONNECT PDU and the request to connect was rejected by the service layer.
10h	SHALL indicate that the LLC will permanently not accept any CONNECT PDUs with the same target service access point address.
11h	SHALL indicate that the LLC will permanently not accept any CONNECT PDUs with any target service access point address.
20h	SHALL indicate that the LLC will temporarily not accept any CONNECT PDUs with the specified target service access point address.
21h	SHALL indicate that the LLC will temporarily not accept any CONNECT PDUs with any target service access point address.
Any other value	SHALL NOT be used by an LLC sending a DM PDU, and SHALL be interpreted as 00h by an LLC receiving a DM PDU.

4.3.9 Frame Reject (FRMR)

The FRMR PDU is an unnumbered PDU which is used to report the receipt of a malformed or inappropriate PDU on a data link connection. The specific reasons for sending the FRMR PDU are described in section 5.6.4.5.

The FRMR PDU SHALL have the format shown in figure 13.

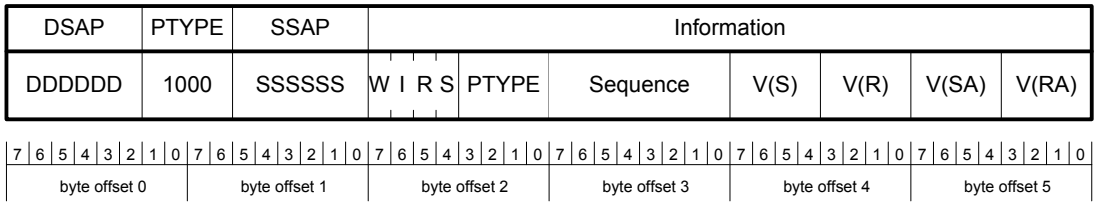


Figure 13: Format of the FRMR PDU

The sequence field SHALL NOT be present in a FRMR PDU.

An information field SHALL be returned with the FRMR PDU to provide the reason for the PDU rejection, and SHALL contain the fields shown in figure 13 with the following meaning:

Table 4: Frame Reject Information Fields

W Flag	Well-formedness Error—set to "1" SHALL indicate that the rejected PDU was invalid or not well formed. Please refer to clause 5.5.4.5 for further information.
I Flag	Information Field Error—set to "1" SHALL indicate that the rejected PDU contained an incorrect or unexpected information field. Please refer to clause 5.5.4.5 for further information.
R Flag	Receive Sequence Error—set to "1" SHALL indicate that the rejected PDU contained an invalid N(R) in the sequence field.

S Flag	Send Sequence Error—set to “1” SHALL indicate that the rejected PDU contained an invalid N(S) in the sequence field.
PTYPE field	SHALL indicate the type of the rejected PDU, i.e. it SHALL have the same value as the PTYPE field of the rejected PDU.
Sequence field	SHALL have the same value as the sequence field of the rejected PDU if the format of the rejected PDU is defined to contain sequence numbers. If the rejected PDU does not contain sequence numbers, i.e. the sequence field of the rejected PDU has a length of 0 bits; it SHALL be set to all bits zero.
V(S) field	SHALL contain the current value of the send state variable for this data link connection at the rejecting LLC.
V(R) field	SHALL contain the current value of the receive state variable value for this data link connection at the rejecting LLC.
V(SA) field	SHALL contain the current value of the acknowledgement send state variable for this data link connection at the rejecting LLC.
V(RA) field	SHALL contain the current value of the receive acknowledgement state variable value for this data link connection at the rejecting LLC.

4.3.10 Information (I)

The I PDU is a numbered PDU which is used to transfer service data units across a data link connection. The format of the I PDU SHALL be as shown in figure 14, where *n* is the length of the I PDU.

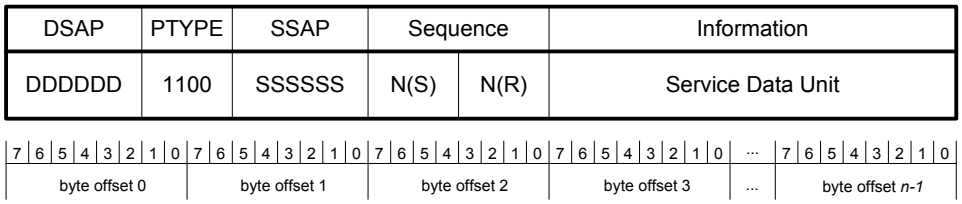


Figure 14: Format of the I PDU

The I PDU sequence field SHALL contain two sequence numbers: The send sequence number N(S) and the receive sequence number N(R). The send sequence number N(S) SHALL indicate the sequence number associated with this I PDU. The receive sequence number N(R) value SHALL indicate that I PDUs numbered up through N(R) - 1 have been received correctly by the sender of this I PDU and successfully passed to the senders SAP identified in the SSAP field. These I PDUs SHALL be considered as acknowledged.

The information field of an I PDU SHALL contain a single service data unit. The maximum number of octets in the information field SHALL be determined by the MIU for the data link connection as described in section 5.6.2.1.

The information field of an I PDU MAY be empty.

4.3.11 Receive Ready (RR)

The RR PDU is a numbered PDU which is used by an LLC to acknowledge one or more received I PDUs and indicate that the LLC is able to receive subsequent I PDUs.

The RR PDU SHALL have the format shown in figure 15.

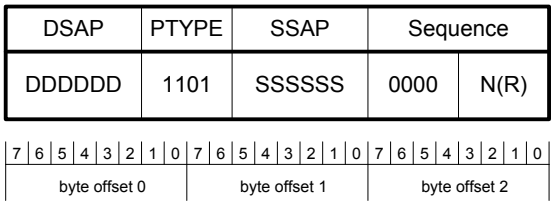


Figure 15: Format of the RR PDU

The RR PDU sequence field SHALL contain the receive sequence number N(R). The receive sequence number N(R) SHALL indicate that I PDUs numbered up through N(R) - 1 have been received correctly by the sender of this I PDU and successfully passed to the senders SAP identified in the SSAP field. These I PDUs SHALL be considered as acknowledged. The higher nibble of the sequence field SHALL be set to zero by the sender and SHALL be ignored by the receiver.

An information field SHALL NOT be present in an RR PDU.

4.3.12 Receive Not Ready (RNR)

The RNR PDU is a numbered PDU which is used by an LLC to indicate a temporary inability to process subsequent I PDUs.

The RNR PDU SHALL have the format shown in figure 16.

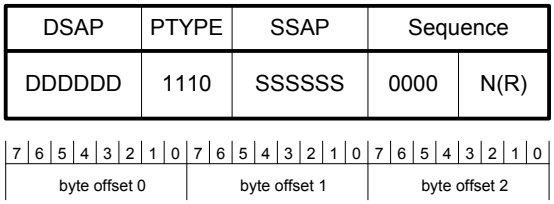


Figure 16: Format of the RNR PDU

The RR PDU sequence field SHALL contain the receive sequence number N(R). The receive sequence number N(R) SHALL indicate that I PDUs numbered up through N(R) - 1 have been received correctly by the sender of this I PDU and successfully passed to the senders SAP identified in the SSAP field. These I PDUs SHALL be considered as acknowledged. The higher nibble of the sequence field SHALL be set to zero by the sender and SHALL be ignored by the receiver.

An information field SHALL NOT be present in an RNR PDU.

4.4 LLC Parameter Format

All LLC Parameters SHALL conform to the format shown in figure 17.

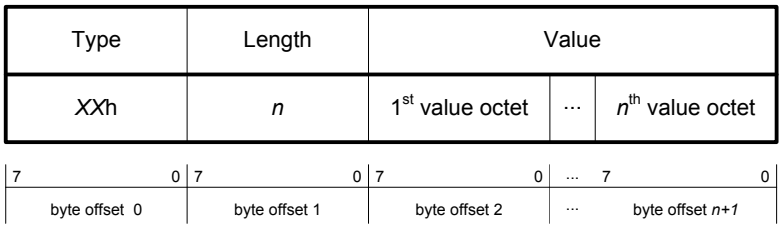


Figure 17: LLC Parameter Format

4.5 Parameter Descriptions

This subsection defines the syntax and semantic of all LLC parameters that may appear in the information field of LLC PDUs or in MAC specific link activation frames.

A parameter exchanged using LLC PDUs SHALL appear in the information field of only the LLC PDUs listed in table 5.

Any parameter that can be exchanged in the information field of a PAX PDU MAY also be included in a MAC link activation message as defined by the specific MAC mapping.

Any parameters included in MAC link activation frames SHALL NOT be repeated in the PAX PDU used in the LLC link activation procedure (cf. section 5.2).

A specific MAC mapping MAY provide an alternative format for encoding LLC parameters in link activation frames.

A specific MAC mapping MAY prohibit the use of PAX PDU exchange during LLC link activation if it provides for the exchange of all LLC parameters allowed in a PAX PDU (shown in table 5) as part of the MAC link activation.

Table 5: Use of LLC Parameters

Parameter	Included	In PDU Type
Version Number, VERSION	MUST	PAX
Maximum Information Unit Extension, MIUX	MAY	PAX, CONNECT, CC
Well-Known Service List, WKS	SHOULD	PAX
Link Timeout, LTO	MAY	PAX
Receive Window Size, RW	MAY	CONNECT, CC
Service Name, SN	MAY	CONNECT
Option, OPT	MAY	PAX

In the event that a TLV is received which does not comply to the normative requirements of this section it SHALL be ignored.

4.5.1 Version Number, VERSION

The version number (VERSION) parameter is a configuration parameter that MUST be transmitted during the link activation. It SHALL denote the major and minor release levels of the LLCP specification implemented by the sending LLC.

The VERSION parameter SHALL be encoded as an 8-bit structure consisting of two 4-bit unsigned integer values representing the major and minor release levels of this specification. The most-significant 4 bits SHALL denote the major release level. The least-significant 4 bits SHALL denote the minor release level of this specification.

When the VERSION parameter is encoded as a TLV, the TLV Type field SHALL be 01h and the TLV Length field SHALL be 01h.

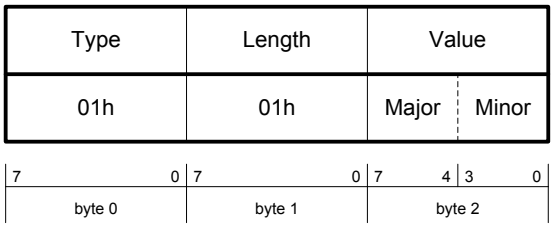


Figure 18: Format of the VERSION parameter TLV

4.5.2 Maximum Information Unit Extension, MIUX

The maximum information unit (MIU) is the maximum number of octets in the information field of an LLC PDU that the local LLC is able to receive. The default MIU is 128.

The maximum information unit extension (MIUX) parameter MAY be used by an LLC to announce the ability to receive LLC PDUs with information fields larger than the default.

The MIUX parameter MAY be transmitted during link activation to announce the local LLC's larger Link MIU.

The MIUX parameter MAY be transmitted in the information field of a CONNECT or CC PDU to announce the local LLC's larger MIU for that data link connection endpoint.

The MIUX parameter specifies the number of octets by which an information field MAY exceed the default maximum size. It SHALL be encoded as an 11-bit unsigned integer value according to the following formula:

$$MIUX = MIU - 128$$

When the MIUX parameter is encoded as a TLV, the TLV Type field SHALL be 02h and the TLV Length field SHALL be 02h. The MIUX parameter SHALL be encoded into the least-significant 11 bits of the TLV Value field. The unused bits in the TLV Value field SHALL be set to zero by the sender and SHALL be ignored by the receiver.

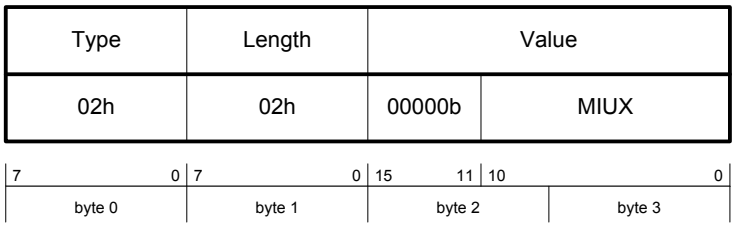


Figure 19: Format of the MIUX parameter TLV

The receiver of an MIUX parameter SHALL calculate the MIU value as follows:

$$MIU = 128 + MIUX$$

If no MIUX parameter is transmitted, the default MIU value of 128 SHALL be used.

4.5.3 Well-Known Service List, WKS

The well-known service (WKS) parameter is a configuration parameter that SHALL denote the binding of service listeners to well-known service access point addresses and therefore the willingness of the sender of the WKS parameter to accept PDUs on those SAPs.

The WKS parameter SHALL be encoded as a 16-bit field. The most-significant bit of the 16-bit field value SHALL signify SAP address 0Fh and the least-significant bit SHALL signify SAP address 00h. The other bits SHALL signify SAP addresses corresponding to their respective bit positions. A bit set to “1” SHALL indicate that a service listener is bound to the corresponding well-known service access point. A bit set to “0” SHALL indicate that no service listener is bound to the corresponding well-known service access point. As the LLC Link Management Service is bound to SAP 00h, the least significant bit, representing SAP 00h, SHALL always be set to “1” by the sender and SHALL be ignored by the receiver.

When the WKS parameter is encoded as a TLV, the TLV Type field SHALL be 03h, the TLV Length field SHALL be 02h, and the WKS parameter value SHALL be encoded into the TLV Value field with the most-significant byte first.

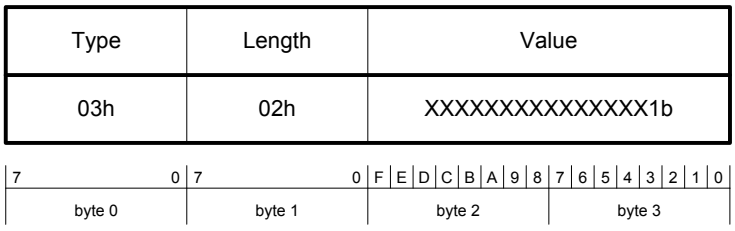


Figure 20: Format of the WKS parameter TLV

4.5.4 Link Timeout, LTO

The link timeout (LTO) parameter is a configuration parameter that specifies the local link timeout interval guarantee.

The LTO parameter SHALL specify the maximum time interval between the last received bit of an LLC PDU transmission from the remote to the local LLC and the first bit of the subsequent

LLC PDU transmission from the local to the remote LLC. It is an implementation concern to take into account any internally required processing time and propagation delays.

The LTO parameter value SHALL be an 8-bit unsigned integer that specifies the link timeout value in multiples of 10 milliseconds.

When the LTO parameter is encoded as a TLV, the TLV Type field SHALL be 04h and the TLV Length field SHALL be 01h.

If no LTO parameter is transmitted or if the LTO parameter value is zero, the default link timeout value of 100 milliseconds SHALL be used.

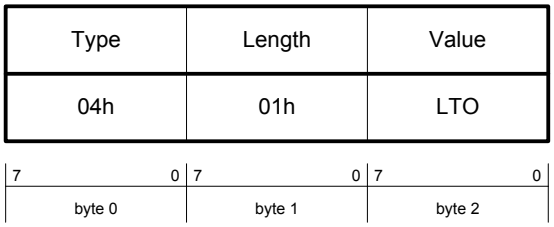


Figure 21: Format of the LTO parameter TLV

4.5.5 Receive Window Size, RW

The receive window size (RW) is a data link connection parameter that MAY be transmitted with a CONNECT or a CC PDU and applies to the sender of the CONNECT or CC PDU.

The RW parameter SHALL be encoded as a 4-bit unsigned integer value indicating the receive window size. The receive window size SHALL be in the inclusive range of values between 0 and 15.

Note: A receive window size of zero indicates that the local LLC will not accept I PDUs on that data link connection. A receive window size of one indicates that the local LLC will acknowledge every I PDU before accepting additional I PDUs.

To encode the RW parameter as a TLV, the TLV Type field SHALL be 05h and the TLV Length field SHALL be 01h. The RW parameter SHALL be encoded into the least-significant 4 bits of the TLV Value field. The unused bits in the TLV Value field SHALL be set to zero by the sender and SHALL be ignored by the receiver.

If not transmitted, the default value of RW SHALL be 1.

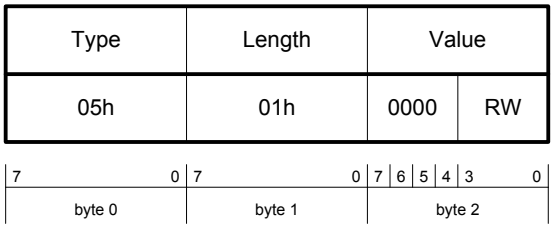


Figure 22: Format of the RW parameter TLV

4.5.6 Service Name, SN

The service name (SN) parameter MAY be transmitted with a CONNECT PDU to the well-known destination service access point address 01h and SHALL then indicate that the sending LLC intends to establish a data link connection with the named service registered in the remote service environment.

To encode the service name parameter as a TLV, the TLV Type field SHALL be set to 06h and the TLV Length field SHALL be set to the number of octets within the TLV Value field.

If the service name parameter is transmitted with a CONNECT PDU to a destination service access point other than 01h, it SHALL be ignored.

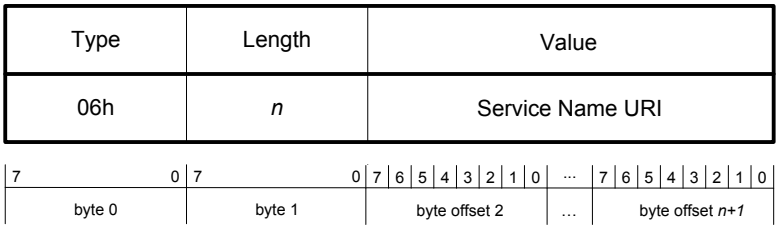


Figure 23: Format of the Service Name parameter TLV

The format of the value field SHALL be a URI reference and SHALL represent either an NFC Forum well-known service or an external service name.

NFC Forum well-known service names SHALL take the form:

"urn:nfc:sn:<servicename>"

External service names MAY be formatted as uniform resource names (URN) with the reserved prefix “urn:nfc:xsn:” if the following requirements are met:

The service name SHALL be prefixed with the fully qualified domain name of the service owner followed by a colon (“:”) and followed by a service name of the service owner's choosing:

urn:nfc:xsn:<domain>:<servicename>

Examples:

“urn:nfc:xsn:somedomain.com:atestservice”

“urn:nfc:xsn:somedomain.com:md5:01234567890123456789012345678901”

4.5.7 Option, OPT

The Option (OPT) parameter is a configuration parameter that MAY be transmitted during the LLCP Link activation.

The Option parameter communicates the link service class and the set of options supported by the sending LLC.

To encode the Option parameter as a TLV, the TLV Type field SHALL be 07h and the TLV Length field SHALL be 01h.

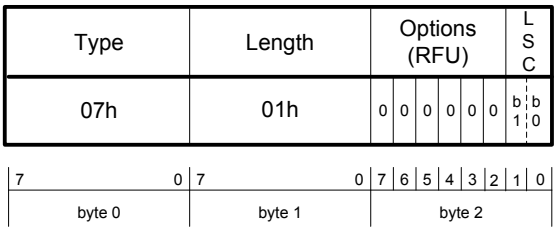


Figure 24: Format of the Option parameter TLV

The Value field contains a single 8-bit byte representing a set of flags which indicate the link service class of the sending LLC and the support of optional features implemented by the sending LLC.

Link Service Class

Within the link service class subfield (LSC), the two bits, "*b0*" and "*b1*", indicate support for the connectionless and connection-oriented link transports, respectively:

- Bit *LSC b0* indicates support in the sending LLC for Connectionless transport mode, as described in section 3.2.2 of this specification. The sending LLC SHALL set bit *LSC b0* to 1 when Connectionless transport is supported. The sending LLC SHALL set bit *LSC b0* to 0 to when Connectionless transport is not supported.
- Bit *LSC b1* indicates support in the sending LLC for Connection-oriented transport mode, as described in section 3.2.3 of this specification. The sending LLC SHALL set bit *LSC b1* to 1 when Connection-oriented transport is supported. The sending LLC SHALL set bit *LSC b1* to 0 when Connection-oriented transport is not supported.

The LSC bits form a 2-bit unsigned value that represents the link service class of the sending device as shown in Table 6.

When the Option parameter is not received during the LLCP Link activation, or if the link service class is specified as 0 (unknown), the link service class supported by the remote LLC remains unknown to the local LLC. In this case the local LLC MAY behave as though link service class 3 was specified, thus allowing the local LLC to attempt communication with the remote LLC using either transport service.

Table 6: Link Service Classes

Link Service Class	*LSC b1*	*LSC b0*	*Definition*
unknown	0	0	Link service class is unknown at time of link activation
Class 1	0	1	Connectionless link service only
Class 2	1	0	Connection-oriented link service only
Class 3	1	1	Both connectionless and connection-oriented link service

Other Options

All other bits are reserved for future use (RFU). An LLC MUST set the RFU bits to 0 when sending the Option parameter. An LLC receiving an Option parameter MUST ignore the values of the RFU bits.

5 LLC Procedures

5.1 MIU Requirements

The requirements of this section SHALL NOT apply to I PDUs.

The MIU value used for all LLC PDUs with information fields SHALL be the Link MIU determined according to section 5.2.3.

An LLC SHALL NOT send any LLC PDU with an information field that is larger than the Link MIU determined for the remote LLC.

An LLC MAY discard any received LLC PDU with an information field that is larger than the local LLCs Link MIU value.

5.2 Link Activation Procedure

The LLC link activation procedure SHALL be started when the local MAC component notifies the local LLC component that a peer device capable of executing LLCP enters communication range and the MAC link activation procedure has been successfully completed.

If the specific MAC mapping specifies the exchange of LLC parameters during the MAC link activation procedure, the parameters that have been received with the MAC link activation procedure SHALL be available to the local LLC.

If the specific MAC mapping does not prohibit the use of PAX PDU in LLC link activation, following successful completion of the MAC link activation, the PAX PDUs are exchanged according to section 5.2.1.

If the specific MAC mapping prohibits the use of PAX PDU in LLC link activation, the local LLC SHALL perform the version number agreement procedure defined in section 5.2.2:

- If version number agreement has been achieved, the local LLC SHALL perform the Link MIU agreement procedure defined in section 5.2.3 and SHALL then enter normal operation.
- If version number agreement cannot be achieved, the LLC SHALL abandon the link activation and SHOULD notify the MAC component that link activation failed.

5.2.1 Exchange of PAX PDU

The MAC link activation event will indicate whether the local LLC is operating in the Initiator or Target role.

Operating in the Initiator role:

The local LLC SHALL send a PAX PDU to the remote LLC that includes all required LLC parameters not exchanged during the MAC link activation. The local LLC SHALL then await receipt of a PAX PDU from the remote LLC. Upon receipt of the PAX PDU, the local LLC SHALL perform the version number agreement procedure defined in section 5.2.2.

- If version number agreement has been achieved, the local LLC SHALL perform the Link MIU agreement procedure defined in section 5.2.3 and SHALL then enter normal operation.
- If version number agreement cannot be achieved, the LLC SHALL abandon the link activation and SHOULD notify the MAC component that link activation failed.

Operating in the Target role:

The local LLC SHALL await receipt of a PAX PDU from the remote LLC. Upon receipt of the PAX PDU, the local LLC SHALL perform the version number agreement procedure defined in section 5.2.2.

- If the version number agreement has been achieved, the local LLC SHALL perform the Link MIU agreement procedure defined in section 5.2.3. The local LLC SHALL then return a PAX PDU to the remote LLC that includes all required LLC parameters that were not exchanged during the MAC link activation. The local LLC SHALL then enter normal operation.
- If version number agreement cannot be achieved, the LLC SHALL abandon the link activation and SHOULD notify the MAC component that link activation failed.

5.2.2 LLCP Version Number Agreement Procedure

The local LLC SHALL perform version number agreement to determine if the version of LLCP being used by the local LLC is compatible with the version of LLCP being used by the remote LLC.

The version of LLCP SHALL be described using a two-part version number comprised of a *major release value* and a *minor release value*. Version numbers SHALL be exchanged during LLC link activation using the VERSION parameter defined in section 4.5.1.

To determine version agreement, the local LLC SHALL compare the version information sent to the remote LLC with the version information it received from the remote LLC.

- In the case where the major release values are identical and the minor release values are identical then version agreement SHALL be achieved.
- In the case where the major release values are identical but the minor release values are not identical then version agreement SHALL be achieved. The agreed minor release value SHALL then be the lower of the two exchanged minor release values.
- In the case where the major release values are not identical then the LLC with the higher major release number SHALL decide if version agreement is possible. If version agreement is possible, the agreed LLCP version SHALL be the lower of the two version values exchanged (e.g. LLCs with versions 2.3 and 1.7 agree on version 1.7).

If version agreement is achieved, the local LLC SHALL behave according to the requirements of the agreed LLCP version.

5.2.3 Link MIU Determination Procedure

The local and remote LLCs each establish and maintain distinct Link MIU values.

The Link MIU prior to entering normal operation SHALL be the default MIU of 128 octets.

If the local LLC receives an MIUX parameter during link activation, the remote Link MIU SHALL be determined as specified in section 4.5.2.

If the local LLC does not receive an MIUX parameter during link activation, the remote Link MIU SHALL be determined to be the default MIU of 128 octets.

An LLC MAY send an MIUX parameter during link activation if it can accept LLC PDUs with information fields larger than the default MIU.

If an LLC does not send an MIUX parameter during link activation, the local Link MIU SHALL be the default value of 128 octets.

5.3 Normal Operation Phase

In the normal operation phase, the LLC MAY send or receive information using connectionless and connection-oriented transport mode procedures as defined in sections 5.5 and 5.6, MAY aggregate or disaggregate PDUs using the aggregation procedure defined in section 5.7, SHALL execute the symmetry procedure defined in section 5.8, and SHALL be able to perform the deactivation procedure defined in section 5.4 on request of a device management function.

When entering the normal operation phase in the Initiator role, the LLC SHALL initialize the symmetry procedure by assuming previous reception of an LLC PDU from the remote LLC. When entering the normal operation phase in the Target role, the LLC SHALL initialize the symmetry procedure by assuming previous transmission of an LLC PDU to the remote LLC.

5.4 Link Deactivation Procedure

The LLC link deactivation procedure SHALL be used to terminate normal operation between the local and the remote LLC. Either LLC MAY initiate link deactivation. The local LLC MUST execute link deactivation upon request from the remote LLC (cf. section 5.4.1) or as the result of a link timeout (cf. section 5.8).

When executing the link deactivation procedure, the local LLC SHOULD pass disconnect indications to the service layer and SHALL then execute the MAC link deactivation.

5.4.1 Intentional Link Deactivation

The LLC deactivation procedure MAY be initiated by sending a DISC PDU, with the DSAP and SSAP fields set to address “00h”, thus designating the LLC Link Management component.

After sending the DISC PDU, the LLC that initiated the link deactivation SHALL deactivate the local link.

When receiving a DISC PDU with the DSAP and SSAP fields set to address “00h”, the receiving LLC SHALL deactivate the local link.

5.5 Connectionless Transport Mode Procedures

Connectionless transport mode does not require any prior connection establishment, and consequently does not require disconnection. Once a service access point has been enabled in the LLC, information may be sent to, or received from, the remote LLC SAP.

5.5.1 Logical Data Link Parameters

5.5.1.1 Maximum Information Unit Size for UI PDUs

The information field of a UI PDU sent by the local LLC SHALL NOT be greater than the remote LLC’s Link MIU.

5.5.2 Information Transfer

Information transfer SHALL be accomplished by sending UI PDUs and the local LLC SHALL be able to send or receive UI PDUs at any time. Sending or receiving UI PDUs SHALL NOT affect any state variable associated with any data link connection.

Reception of UI PDUs SHALL NOT be acknowledged by the receiving LLC.

The MIU values used in connectionless mode SHALL be the Link MIU determined according to section 5.2.3.

Local conditions at the receiving LLC may result in the discarding of valid UI PDUs. It is the choice of an implementation whether or not to report discarded UI PDUs to the service user.

5.6 Connection-oriented Transport Mode Procedures

5.6.1 Data Link Connection State Variables

For the purpose of this specification, each LLC can be said to have a virtual state for each data link connection. The following normative statements with respect to these state variables set forth the operational requirements of the LLC but do not mandate any particular implementation in either hardware or software.

In the following descriptions, the term *modulo-16* SHALL denote the inclusive range of values between 0 and 15, with the numbers cycling through the entire range. Addition and subtraction on these values SHALL conform to the rules of modulo arithmetic. For example, incrementing a state variable by one, when it's present value is 15, SHALL yield a new value 0.

5.6.1.1 Send State Variable V(S)

The send state variable V(S) SHALL denote the sequence number, modulo-16, of the next in-sequence I PDU to be sent on a specific data link connection. The value of the send state variable V(S) SHALL be incremented by one following each successive I PDU transmission on the associated data link connection. V(S) SHALL exhibit the invariant condition that it is always less than or equal to (V(SA) + RW(R)) modulo-16.

5.6.1.2 Send Acknowledgement State Variable V(SA)

The send acknowledgement state variable V(SA) SHALL denote the most recently received N(R) value for a specific data link connection.

5.6.1.3 Receive State Variable V(R)

The receive state variable V(R) SHALL denote the sequence number, modulo-16, of the next in-sequence I PDU to be received on a specific data link connection. The value of the receive state variable V(R) associated with a specific data link connection SHALL be incremented by one whenever an error-free, in-sequence I PDU is received whose send sequence number N(S) equals the current value of the receive state variable V(R) for the data link connection.

5.6.1.4 Receive Acknowledgement State Variable V(RA)

The receive acknowledgement state variable V(RA) SHALL denote the most recently sent N(R) value for a specific data link connection.

5.6.2 Data Link Connection Parameters

5.6.2.1 Maximum Information Unit Size for I PDUs

The maximum information unit size for I PDUs SHALL denote the maximum number of octets in the information field of any I PDU exchanged on the data link connection. The local and remote LLCs each establish and maintain distinct MIU values for each data link connection endpoint. In this way each data link connection has two MIU values: these are the local MIU and the remote MIU.

The default value of the MIU for I PDUs SHALL be 128 octets.

An LLC MAY announce a larger MIU for a data link connection by transmitting an MIUX parameter within the information field of the CONNECT or CC PDU that it sends to the remote LLC. The announced MIU SHALL NOT exceed the local LLC's Link MIU value.

If an LLC receives an MIUX parameter, it SHALL establish the remote MIU value as defined in section 4.5.2.

An LLC SHALL NOT send an I PDU with an information field larger than the remote MIU established for the data link connection.

If an LLC receives an I PDU with an information field larger than the local MIU established for the data link connection it SHALL respond as defined in section 5.6.4.5.

5.6.2.2 Local Receive Window Size, RW(L)

The local receive window size SHALL denote the maximum number of sequentially numbered I PDUs that the local LLC allows the remote LLC to have unacknowledged. The local receive window size SHALL be in the inclusive range of values between 1 and 15. It MAY be sent by the local LLC with a CONNECT PDU or CC PDU.

5.6.2.3 Remote Receive Window Size, RW(R)

The remote receive window size SHALL denote the maximum number of sequentially numbered I PDUs that the remote LLC allows the local LLC to have unacknowledged. It MAY be received within a CONNECT or CC PDU.

5.6.3 Connection Establishment

Either LLC MAY be able to establish a data link connection.

The LLC instructed to establish a data link connection SHALL send the CONNECT PDU. The CONNECT PDU MAY provide connection specific parameters.

The local LLC SHALL NOT send more than one CONNECT PDU with the same SSAP address value before receipt of a CC or DM PDU with the DSAP value equal to the SSAP value in the pending CONNECT PDU. Note that the CC PDU may contain a SSAP value that is different from the DSAP value in the CONNECT PDU.

If the LLC receives a CC PDU with a DSAP value equal to the SSAP value of a sent but not yet acknowledged CONNECT PDU, it SHALL act as follows:

1. Set the state variables V(S) and V(R) and V(SA) and V(RA) to 0

1. Process connection specific parameters in the information field of the CC PDU

2. Enter the information transfer phase described in section 5.6.4.

If the LLC receives a DM PDU with a DSAP value equal to the SSAP value of a sent but not yet acknowledged CONNECT PDU, it SHALL abandon connection establishment and report the reason to the service layer.

If the local LLC receives a CONNECT PDU and is unable to process the connection request, it SHALL return a DM PDU with the appropriate reason code (cf. table 3 in section 4.3.8) to the remote LLC at the earliest opportunity.

Otherwise, the local LLC SHALL act as follows:

1. Process connection specific parameters (if provided with the CONNECT PDU)
2. Indicate to the service layer that a data link connection is requested from the remote LLC
3. Await notification from the service layer to either accept or reject the connection request
4. If the service layer rejects the connection request, send a DM PDU with the appropriate reason code to the remote LLC
5. If the service layer accepts the connection request, send a CC PDU to the remote LLC.
6. Set the state variables V(S) and V(R) and V(SA) and V(RA) to 0
7. Enter the information transfer phase described in section 5.6.4.

5.6.4 Information Transfer

During the information transfer phase, the LLC SHALL be able to send and receive information according to the procedures described in this section.

5.6.4.1 Sending I PDUs

While the send state variable V(S) is equal to the send acknowledge state variable V(SA) plus the remote receive window size RW(R), the LLC SHALL NOT send an I PDU on that data link connection.

When the LLC sends an I PDU, it SHALL set the N(S) field equal to the current value of the send state variable V(S), and set the N(R) field equal to the current value of the receive state variable V(R) for that data link connection. After sending the I PDU, the LLC SHALL increment the send state variable V(S) by one.

5.6.4.2 Receiving I PDUs

When an I PDU is received with the send sequence number N(S) equal to the receive state variable V(R), the LLC SHALL pass the service data unit, contained in the information field, to the service access point and increment by one its receive state variable, V(R). The LLC SHALL then acknowledge receipt of that I PDU as described in section 5.6.4.3.

5.6.4.3 Sending Acknowledgement

If at least one I PDU is available to send on this data link connection, the received I PDU will be acknowledged when sending the next I PDU.

If no I PDU is available to send on this data link connection, and the data link connection is not presently in the receiver busy condition, the LLC SHALL send an RR PDU.

If no I PDU is available to send on this data link connection, and the data link connection is presently in the receiver busy condition, the LLC SHALL send an RNR PDU.

5.6.4.4 Receiving Acknowledgement

The sequence field of a numbered PDU (i.e. RR, RNR or I) contains the receive sequence number N(R). This N(R) field value indicates that I PDUs numbered up through N(R)-1 have been received correctly and SHALL be considered as acknowledged.

This N(R) value becomes the new value of the send acknowledgement state variable, V(SA), for this data link connection.

5.6.4.5 Reception of erroneous PDUs

If an erroneous PDU is received on a data link connection, the local LLC SHALL send the FRMR PDU. A PDU with one or more of the following conditions SHALL be considered erroneous and the W, I, R and S flags SHALL indicate the error condition as defined in table 7:

Table 7: FRMR Error Conditions

Error Condition	W Flag	I Flag	R Flag	S Flag
A PDU with a PTYPE that is reserved (undefined)	1	0	0	0
A PDU with an information field that is not permitted for this PDU TYPE	1	1	0	0
An I PDU with an information field exceeding the maximum information field length for that data link connection for reception at the rejecting LLC.	0	1	0	0
A numbered PDU with an N(R) field value where repeatedly incrementing this N(R) value, modulo-16, results in a value that would become equal to V(SA) before it would become equal to V(S)	0	0	1	0
A numbered PDU with an N(S) that is greater than or equal to (V(RA) + RW(L)), modulo-16, for that data link connection	0	0	0	1
A numbered PDU with an N(S) that is not an increment by 1 of the last received N(S)	0	0	0	1

If an erroneous PDU exhibits more than one error condition, the flag values SHALL be the logical OR of the flag values associated with the individual error conditions in table 7. An LLC receiving an FRMR PDU on a data link connection can acquire further knowledge about the error conditions causing the FRMR exception by inspecting the additional fields provided with the FRMR PDU.

After sending or receiving a FRMR PDU the local LLC SHALL pass a disconnect indication to the service access point for that data link connection. The data link connection SHALL be closed and resources released. The service layer is responsible for initiating any corrective action by for example instructing the LLC to re-establish the data link connection.

5.6.5 Receiver Busy Condition

While in the information transfer phase a condition could arise at the service access point that prevents acceptance of service data units from the local LLC. An LLC SHALL send an RNR PDU on a data link connection when it is temporarily unable to dispatch service data units to the local SAP. While in the receiver busy condition, the local LLC SHALL continue to accept and buffer I PDUs, process control requests and transmit I PDUs and control requests. When the receiver busy condition clears, the local LLC SHALL send an RR PDU on the data link connection.

When sending the RNR PDU the LLC SHALL set the N(R) field to the current value of the receive state variable V(R).

5.6.5.1 Receiving an RNR PDU

An LLC receiving an RNR PDU on a data link connection SHALL cause that data link connection to enter the remote receiver busy condition. While in this condition the local LLC SHOULD stop sending I PDUs on that data link connection.

5.6.5.2 Receiving an RR PDU

An LLC receiving an RR PDU on a data link connection which is in the remote receiver busy condition SHALL clear the remote receiver busy condition and resume the normal information transfer phase.

5.6.6 Connection Termination

When either LLC wishes to terminate the data link connection, it SHALL send the DISC PDU and enter the disconnecting phase.

While in the disconnecting phase the LLC SHALL NOT send further PDUs on that data link connection and SHALL discard subsequently received PDUs other than DM. Upon receipt of a DM PDU, the LLC SHALL pass a disconnect indication to the service access point for that data link connection. The data link connection SHALL be closed and resources released. The LLC SHALL discard subsequently received information PDUs.

When receiving a DISC PDU, the LLC SHALL return a DM PDU and pass a disconnect indication to the service access point for that data link connection. The data link connection SHALL then be closed.

5.7 Aggregation Procedure

An LLC SHALL be able to receive and disaggregate AGF PDUs. An LLC SHOULD be able to aggregate and send AGF PDUs.

AGF PDUs SHALL exclusively be used by the LLC Link Management component.

The LLC Link Management component SHALL aggregate PDUs in the same order as they would have been transmitted without aggregation.

The LLC Link Management component SHALL dispatch aggregated PDUs in the same order as they appear in the AGF PDU.

Reception of AGF PDUs SHALL NOT be acknowledged by the receiving LLC.

5.8 Symmetry Procedure

The symmetry procedure provides the appearance of asynchronous balanced mode (ABM) communication on top of MAC layers operating in normal response mode (NRM) and enables link loss detection. By performing the symmetry procedure, the peers mutually pass permission to send back and forth. The link timeout (LTO) parameter allows each peer to determine when communication over the LLCP Link has become impossible.

After receipt of an LLC PDU, the receiving LLC SHALL commence sending an LLC PDU to the remote LLC within the time interval determined by the link timeout (LTO) parameter of the local LLC. In case no other PDU can be sent, the LLC SHALL send a SYMM PDU prior to the expiration of the LTO of the local LLC.

After sending an LLC PDU, if reception of a PDU from the remote LLC does not commence within the time interval determined by the remote LLC's link timeout (LTO) parameter, the local LLC SHALL execute the LLC link deactivation procedure (cf. section 5.4).

Compliance to the symmetry procedure SHALL be verified by observing the communication traffic between the peer devices.

6 MAC Mappings

The LLC layer can be mapped on top of different MAC layers, as long as they comply with the requirements set forth in section 6.1. The MAC layers defined with this version of the LLCP specification are given thereafter, starting with section 6.2.

6.1 Requirements

The LLC protocol places the following mandatory requirements on the medium access control (MAC) layer. All MAC layers enabled with this specification MUST support the complete set of requirements either directly or by the mapping procedures defined in this specification. These requirements are:

1. Provide framing of LLC PDUs. Segmentation and reassembly procedures on the MAC layer PDU exchange MUST NOT appear visible on the LLC layer.
2. Accept any defined LLC PDU from the LLC layer in their entirety.
3. Pass any defined LLC PDU to the LLC layer in their entirety and provide the length of the LLC PDU.
4. Transmit any defined LLC PDU without error and in sequence. Transmission errors MUST be detected and corrected before an LLC PDU is passed to the LLC layer.
5. Indicate unrecoverable transmission errors to the LLC layer.

6.2 Definition of the ISO18092 MAC Mapping

The MAC layer defined within this section is based on the ISO/IEC 18092 [DIGIPROT] specification. Elements and procedures required by the LLC layer, and not described in [DIGIPROT], are defined in this section. The terminology used to define the MAC layer is oriented towards the LLC layer service user; it is not intended to define a MAC layer usable for other purposes.

6.2.1 Restrictions on the use of ISO 18092

The following restrictions on the use of the ISO/IEC 18092 specification are made for the ISO/IEC 18092 MAC layer defined with this specification:

1. The DID feature SHALL NOT be used.
2. The NAD feature SHALL NOT be used.
3. Frame waiting time extensions (WTX) SHALL NOT be used.
4. Except as required by the Digital Protocol Specification [DIGIPROT], the Target Presence procedure SHALL NOT be used and the Attention command SHALL NOT be sent.
5. The Length Reduction values LRi and LRt MUST be 11b.
6. For the Target device, the scaled value of RWT MUST be less than or equal to the scaled value of the LLC Link Timeout (LTO).

6.2.2 Restrictions on LLC when using ISO 18092

The following restrictions apply to an LLC operating over an ISO/IEC 18092 MAC layer as defined with this specification:

1. For the Target device, the value of LTO SHOULD be sufficiently larger than RWT to allow one or more MAC error recovery cycles.
2. For the Target device, after receipt of an LLC PDU, the receiving LLC SHALL commence sending an LLC PDU to the remote LLC within the time interval determined by the scaled value of RWT. In case no other PDU can be sent, the LLC SHALL send a SYMM PDU prior to the expiration of RWT.

6.2.3 MAC Link Activation

The ISO/IEC18092 MAC component SHALL use the three octet sequence “46h 66h 6Dh” as the NFC Forum LLCP magic number. This magic number is encoded into the ATR_REQ / ATR_RES General Bytes fields, as described below. The use of the magic number by the Initiator and Target SHALL indicate compatibility with the requirements of this specification.

The link activation phase SHALL be started when a peer device capable of executing the LLCP peer-to-peer protocol enters communication range, and the local device is instructed to perform peer-to-peer communication. The link activation phase is different for the Initiator and the Target device and is described separately for each role.

6.2.3.1 Link Activation procedure for the ISO 18092 Initiator

Following the initialization and anti-collision procedure defined in [DIGIPROT], the Initiator device sends the Attribute Request ATR_REQ command. The format of the ATR_REQ SHALL be as shown in figure 25.

The Initiator SHALL include the NFC Forum LLCP magic number in the first three octets of the ATR_REQ General Bytes field.

All LLC parameters defined in section 4.5 table 5 for use in PAX PDUs that are to be exchanged MUST be included as TLVs beginning at the fourth octet of the ATR_REQ General Bytes field. The PAX PDU exchange described in the LLC link activation procedure (cf. section 5.2) SHALL NOT be used.

The ATR_REQ General Bytes field SHALL NOT contain any additional information.

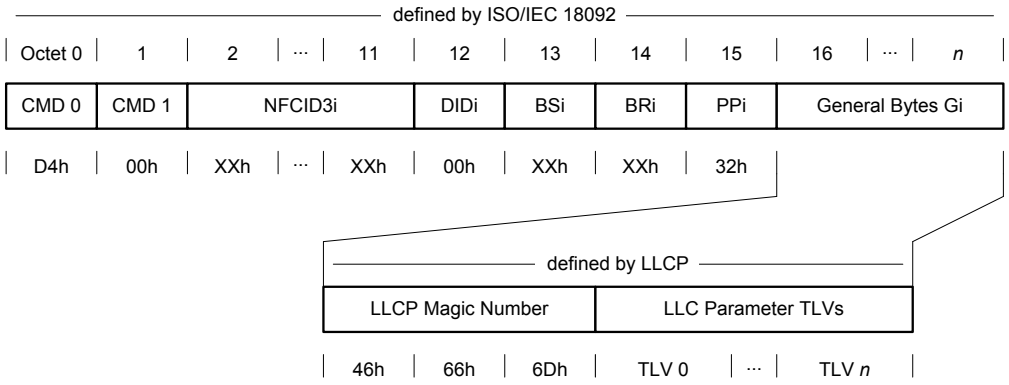


Figure 25: Format of the Attribute Request (ATR_REQ)

Upon receipt of the Attribute Response ATR_RES the Initiator SHALL verify that the first three octets of the General Bytes field are equal to the NFC Forum LLCP magic number defined in section 6.2.2. If the octets are equal to the NFC Forum LLCP magic number, the Initiator SHALL notify the local LLC component about the MAC link activation completion and SHALL then enter normal operation described in chapter 6.2.5.

If the first three octets of the General Bytes field are not equal to the NFC Forum LLCP magic number, the link activation SHALL fail. In this case, any further communication between the Initiator and the Target is out of scope of this specification and left to implementation.

6.2.3.2 Link Activation procedure for the ISO 18092 Target

Following the initialization and anti-collision procedure defined in [DIGIPROT], the Target device waits until the receipt of the Attribute Request ATR_REQ command.

Upon receipt of ATR_REQ the Target SHALL verify that the first three octets of the General Bytes field are equal to the NFC Forum LLCP magic number defined in section 6.2.2. If the octet sequence is equal to the NFC Forum LLCP magic number, the Target responds by sending the Attribute Response ATR_RES, as defined in [DIGIPROT]. The format of the ATR_RES SHALL be as shown in figure 26.

The Target SHALL include the NFC Forum LLCP magic number in the first three octets of the ATR_RES General Bytes field.

All LLC parameters defined in section 4.5 table 5 for use in PAX PDUs that are to be exchanged MUST be included as TLVs beginning at the fourth octet of the ATR_RES General Bytes field. The PAX PDU exchange described in the LLC link activation procedure (cf. section 5.2) SHALL NOT be used.

The ATR_RES General Bytes field SHALL NOT contain any additional information.

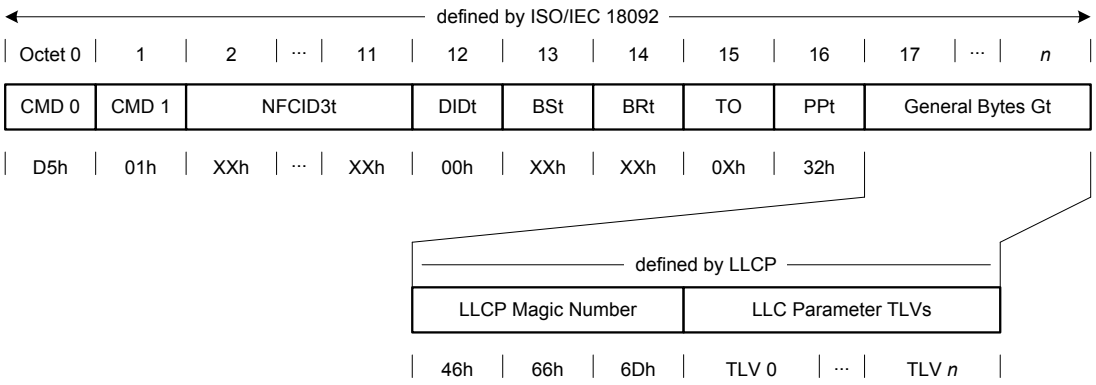


Figure 26: Format of the Attribute Response (ATR_RES)

After sending ATR_RES the Target SHALL notify the local LLC component about the MAC link activation completion and SHALL then enter normal operation described in section 6.2.5.

If the magic number in the received ATR_REQ cannot be verified, the link activation SHALL fail. In this case, any further communication between the Target and the Initiator is out of scope of this specification and left to implementation.

6.2.4 MAC Link Deactivation

An 18092 MAC SHALL perform link deactivation either if requested by the local LLC or if communication with the peer MAC has become impossible and error recovery as described by [DIGIPROT] did not re-establish communication.

The MAC performing the Initiator role SHALL:

- On request of the local LLC, stop sending subsequent ISO/IEC 18092 DEP_REQ commands, send the Deselect Request (DSL_REQ) as specified in [DIGIPROT].
- On the condition of unsuccessful error recovery, send the Deselect Request (DSL_REQ) as specified in [DIGIPROT] and indicate link failure to the local LLC.

The MAC performing the Target role SHALL:

- On request of the local LLC, stop responding to ISO/IEC 18092 DEP_REQ commands until the peer device sends the Deselect Request (DSL_REQ), and confirm link deactivation back to the local LLC.
- On the condition that the local device has received the Deselect Request (DSL_REQ), send the Deselect Response (DSL_RES) as specified in [DIGIPROT] and indicate link deactivation to the local LLC.
- On the condition that the peer device has stopped generating the RF field, indicate link deactivation to the local LLC.

6.2.5 Normal Operation

In normal operation mode, both the Initiator and the Target MAC component SHALL be able to accept LLC PDUs from the local LLC and SHALL be able to pass LLC PDUs to the local LLC.

6.2.5.1 Transmission of LLC PDUs

LLC PDUs SHALL be transmitted using the ISO/IEC 18092 Data Exchange Protocol Request (DEP_REQ) and Response (DEP_RES) protocol frames. Outbound LLC PDUs SHALL be mapped onto consecutive transport data bytes of DEP_REQ or DEP_RES protocol frames. If an LLC PDU does not fit completely into a single DEP_REQ or DEP_RES protocol frame, the chaining procedure of [ISO18092] SHALL be used to transmit the LLC PDU in a number of consecutive segments; when chaining is activated, every segment except the last SHALL use the maximum number of transport data bytes.

6.2.5.2 Reception of LLC PDUs

LLC PDUs SHALL be passed to the local LLC when the last octet has been received without transmission errors. LLC PDUs transmitted in segments MUST be assembled by the receiving MAC. With indication to the local LLC, the total number of octets of the received LLC PDU MUST be made available.

6.2.6 Error Handling

If error recovery as described by [DIGIPROT] does not re-establish communication, the ISO/IEC 18092 MAC SHALL trigger the MAC link deactivation procedure described in section 6.2.4.

A. Revision History

The following table outlines the revision history of Logical Link Control Protocol.

Table 8: Revision History

Document Name	Revision and Release Date	Status	Change Notice	Supersedes
Logical Link Control Protocol	1.0, December 11, 2009	Final		All previous versions