DATA LINK LAYER

The data link layer provides error-free transfer of data frames from one node to another over the physical layer, allowing layers above it to assume virtually error-free transmission over the link. To do this, the data link layer provides:

- Link establishment and termination: establishes and terminates the logical link between two nodes.
- Frame traffic control: tells the transmitting node to "back-off" when no frame buffers are available.
- Frame sequencing: transmits/receives frames sequentially.
- Frame acknowledgment: provides/expects frame acknowledgments. Detects and recovers from errors that occur in the physical layer by retransmitting non-acknowledged frames and handling duplicate frame receipt.
- Frame delimiting: creates and recognizes frame boundaries.
- Frame error checking: checks received frames for integrity.
- Media access management: determines when the node "has the right" to use the physical medium.

The **Data Link Layer** is Layer 2 of the seven-layer OSI model of computer networking. It corresponds to, or is part of the link layer of the TCP/IP reference model.

The Data Link Layer is the protocol layer which transfers data between adjacent network nodes in a wide area network or between nodes on the same local area network segment. The Data Link Layer provides the functional and procedural means to transfer data between network entities and might provide the means to detect and possibly correct errors that may occur in the Physical Layer. Examples of data link protocols are Ethernet for local area networks (multi-node), the Point-to-Point Protocol (PPP), HDLC and ADCCP for point-to-point (dual-node) connections.

The Data Link Layer is concerned with local delivery of frames between devices on the same LAN. Data Link frames, as these protocol data units are called, do not cross the boundaries of a local network. Inter-network routing and global addressing are higher layer functions, allowing Data Link protocols to focus on local delivery, addressing, and media arbitration. In this way, the Data Link layer is analogous to a neighborhood traffic cop; it endeavors to arbitrate between parties contending for access to a medium.

When devices attempt to use a medium simultaneously, frame collisions occur. Data Link protocols specify how devices detect and recover from such collisions, and may provide mechanisms to reduce or prevent them.

Delivery of frames by layer 2 devices is affected through the use of unambiguous hardware addresses. A frame's header contains source and destination addresses that indicate which device originated the frame and which device is expected to receive and process it. In contrast to the hierarchical and routable addresses of the network layer, layer 2 addresses are flat, meaning that no part of the address can be used to identify the logical or physical group to which the address belongs.

The data link thus provides data transfer across the physical link. That transfer can be reliable or unreliable; many data link protocols do not have acknowledgments of successful frame reception and acceptance, and some data link protocols might not even have any form of checksum to check for transmission errors. In those cases, higher-level protocols must provide flow control, error checking, and acknowledgments and retransmission.

In some networks, such as IEEE 802 local area networks, the Data Link Layer is described in more detail with Media Access Control (MAC) and Logical Link Control (LLC) sublayers; this means that the IEEE 802.2 LLC protocol can be used with all of the IEEE 802 MAC layers, such as Ethernet, token ring, IEEE 802.11, etc., as well as with some non-802 MAC layers such as FDDI. Other Data Link Layer protocols, such as HDLC, are specified to include both sublayers, although some other protocols, such as Cisco HDLC, use HDLC's low-level framing as a MAC layer in combination with a different LLC layer. In the ITU-T G.hn standard, which provides a way to create a high-speed (up to 1 Gigabit/s) Local area network using existing home wiring (power lines, phone lines and coaxial cables), the Data Link Layer is divided into three sub-layers (Application Protocol Convergence, Logical Link Control and Medium Access Control).

Within the semantics of the OSI network architecture, the Data Link Layer protocols respond to service requests from the Network Layer and they perform their function by issuing service requests to the Physical Layer.

Sublayers of the Data Link Layer

Logical Link Control sublayer

The uppermost sublayer is *Logical Link Control* (LLC). This sublayer multiplexes protocols running atop the Data Link Layer, and optionally provides flow control, acknowledgment, and error notification. The LLC provides addressing and control of the data link. It specifies which mechanisms are to be used for addressing stations over the transmission medium and for controlling the data exchanged between the originator and recipient machines.

Media Access Control sublayer

The sublayer below it is *Media Access Control* (MAC). Sometimes this refers to the sublayer that determines who is allowed to access the media at any one time (usually CSMA/CD). Other times it refers to a frame structure with MAC addresses inside.

There are generally two forms of media access control: distributed and centralized. Both of these may be compared to communication between people. In a network made up of people speaking, i.e. a conversation, we look for clues from our fellow talkers to see if any of them appear to be about to speak. If two people speak at the same time, they will back off and begin a long and elaborate game of saying "no, you first".

The Media Access Control sublayer also determines where one frame of data ends and the next one starts -- frame synchronization. There are four means of frame synchronization: time based, character counting, byte stuffing and bit stuffing.

- The *time based* approach simply puts a specified amount of time between frames. The major drawback of this is that new gaps can be introduced or old gaps can be lost due to external influences.
- *Character counting* simply notes the count of remaining characters in the frame's header. This method, however, is easily disturbed if this field gets faulty in some way, thus making it hard to keep up synchronization.
- *Byte stuffing* precedes the frame with a special byte sequence such as DLE STX and succeeds it with DLE ETX. Appearances of DLE (byte value 0x10) has to be escaped with another DLE. The start and stop marks are detected at the receiver and removed as well as the inserted DLE characters.
- Similarly, *bit stuffing* replaces these start and end marks with flag consisting of a special bit pattern (e.g. a 0, six 1 bits and a 0). Occurrences of this bit pattern in the data to be transmitted is avoided by inserting a bit. To use the example where the flag is 01111110, a 0 is inserted after 5 consecutive 1's in the data stream. The flags and the inserted 0's are removed at the receiving end. This makes for arbitrary long frames and easy synchronization for the recipient. Note that this stuffed bit is added even if the following data bit is 0, which could not be mistaken for a sync sequence, so that the receiver can unambiguously distinguish stuffed bits from normal bits.

List of Data Link Layer services

- Encapsulation of network layer data packets into frames
- Frame synchronization

- Logical link control (LLC) sublayer:
  - Error control (automatic repeat request,ARQ), in addition to ARQ provided by some Transport layer protocols, to forward error correction (FEC) techniques provided on the Physical Layer, and to error-detection and packet canceling provided at all layers, including the network layer. Data link layer error control (i.e. retransmission of erroneous packets) is provided in wireless networks and V.42 telephone network modems, but not in LAN protocols such as Ethernet, since bit errors are so uncommon in short wires. In that case, only error detection and canceling of erroneous packets are provided.
  - Flow control, in addition to the one provided on the Transport layer. Data link layer error control is not used in LAN protocols such as Ethernet, but in modems and wireless networks.

- Media access control (MAC) sublayer:
  - Multiple access protocols for channel-access control, for example CSMA/CD protocols for collision detection and retransmission in Ethernet bus networks and hub networks, or the CSMA/CA protocol for collision avoidance in wireless networks.
  - Physical addressing (MAC addressing)
  - LAN switching (packet switching) including MAC filtering and spanning tree protocol
  - Data packet queueing or scheduling
  - Store-and-forward switching or cut-through switching
  - Quality of Service (QoS) control
  - Virtual LANs (VLAN)

Protocol examples

- Address Resolution Protocol (ARP)
- ARCnet
- ATM
- Cisco Discovery Protocol (CDP)
- Controller Area Network (CAN)
- Econet
- Ethernet
- Ethernet Automatic Protection Switching (EAPS)
- Fiber Distributed Data Interface (FDDI)
- Frame Relay
- High-Level Data Link Control (HDLC)
- IEEE 802.2 (provides LLC functions to IEEE 802 MAC layers)
- IEEE 802.11 wireless LAN
- LattisNet
- Link Access Procedures, D channel (LAPD)
- LocalTalk
- Multiprotocol Label Switching (MPLS)

- Point-to-Point Protocol (PPP)
- Serial Line Internet Protocol (SLIP) (obsolete)
- Spanning tree protocol
- StarLan
- Token ring
- Unidirectional Link Detection (UDLD)
- and most forms of serial communication.

Interfaces

The Data Link Layer is often implemented in software as a "network card driver". The operating system will have a defined software interface between the data link and the network transport stack above. This interface is not a layer itself, but rather a definition for interfacing between layers.