- OSI Reference Model -

Network Reference Models

A **computer network** connects two or more devices together to share information and services. Multiple networks connected together form an **internetwork.**

Internetworking present challenges - interoperating between products from different manufacturers requires consistent standards. **Network reference models** were developed to address these challenges. A network reference model serves as a blueprint, detailing how communication between network devices should occur.

The two most recognized network reference models are:

- The **Open Systems Interconnection (OSI)** model
- The **Department of Defense (DoD)** model

Without the framework that network models provide, all network hardware and software would have been proprietary. Organizations would have been locked into a single vendor's equipment, and global networks like the Internet would have been impractical, if not impossible.

Network models are organized into **layers,** with each layer representing a specific networking function. These functions are controlled by **protocols**, which are *rules* that govern end-to-end communication between devices.

Protocols on one layer will interact with protocols on the layer above and below it, forming a protocol **suite** or **stack.** The **TCP/IP suite** is the most prevalent protocol suite, and is the foundation of the Internet.

A network model is not a physical entity – there is no OSI *device*. Manufacturers do not always strictly adhere to a reference model's blueprint, and thus not every protocol fits perfectly within a single layer. Some protocols can function across multiple layers.

OSI Reference Model

The **Open Systems Interconnection (OSI) model** was developed by the **International Organization for Standardization (ISO),** and formalized in 1984. It provided the first framework governing how information should be sent across a network.

The OSI model consists of seven layers, each corresponding to a specific network function:

7	Application
6	Presentation
5	Session
4	Transport
3	Network
2	Data-link
1	Physical

Note that the *bottom* layer is Layer 1. Various mnemonics make it easier to remember the order of the OSI model's layers:

7	Application	**A**ll	**A**way
6	Presentation	**P**eople	**P**izza
5	Session	**S**eem	**S**ausage
4	Transport	**T**o	**T**hrow
3	Network	**N**eed	**N**ot
2	Data-link	**D**ata	**D**o
1	Physical	**P**rocessing	**P**lease

ISO further developed an entire protocol suite based on the OSI model; however, the **OSI protocol suite** was never widely implemented.

The OSI model itself is now somewhat deprecated – modern protocol suites, such as the TCP/IP suite, are difficult to fit cleanly within the OSI model's seven layers. This is especially true of the **upper three layers**.

The **bottom** (or ***lower***) **four layers** are more clearly defined, and terminology from those layers is still prevalently used. Many protocols and devices are described by which lower layer they operate at.

OSI Model - The Upper Layers

The top three layers of the OSI model are often referred to as the **upper layers**:

- Layer-7 - **Application** layer
- Layer-6 - **Presentation** layer
- Layer-5 - **Session** layer

Protocols that operate at these layers manage application-level functions**,** and are generally implemented in *software*.

The function of the upper layers of the OSI model can be difficult to visualize. Upper layer protocols do not always fit perfectly within a layer, and often function across multiple layers.

OSI Model - The Application Layer

The **Application layer (Layer-7)** provides the interface between the user application and the network. A web browser and an email client are examples of user applications.

The user application itself *does not* reside at the Application layer - the *protocol* does. The user interacts with the application, which in turn interacts with the application protocol.

Examples of Application layer protocols include:

- **FTP**, via an FTP client
- **HTTP**, via a web browser
- **POP3** and **SMTP**, via an email client
- **Telnet**

The Application layer provides a variety of functions:

- Identifies communication partners
- Determines resource availability
- Synchronizes communication

The Application layer interacts with the Presentation layer below it. As it is the top-most layer, it does not interact with any layers above it.

(Reference: http://docwiki.cisco.com/wiki/Internetworking_Basics)

OSI Model - The Presentation Layer

The **Presentation layer (Layer-6)** controls the *formatting* and *syntax* of user data for the application layer. This ensures that data from the *sending* application can be understood by the *receiving* application.

Standards have been developed for the formatting of data types, such as text, images, audio, and video. Examples of Presentation layer formats include:

- **Text** - RTF, ASCII, EBCDIC
- **Images** - GIF, JPG, TIF
- **Audio** - MIDI, MP3, WAV
- **Movies** - MPEG, AVI, MOV

If two devices do not support the same format or syntax, the Presentation layer can provide **conversion** or **translation** services to facilitate communication.

Additionally, the Presentation layer can perform **encryption** and **compression** of data, as required. However, these functions can also be performed at lower layers as well. For example, the Network layer can perform encryption, using IPSec.

OSI Model - The Session Layer

The **Session layer (Layer-5)** is responsible for establishing, maintaining, and ultimately terminating *sessions* between devices. If a session is *broken,* this layer can attempt to recover the session.

Sessions communication falls under one of three categories:

- **Full-Duplex** – simultaneous two-way communication
- **Half-Duplex** – two-way communication, but not simultaneous
- **Simplex –** one-way communication

Many modern protocol suites, such as TCP/IP, do not implement Session layer protocols. Connection management is often controlled by lower layers, such as the Transport layer.

The lack of true Session layer protocols can present challenges for high-availability and failover. Reliance on lower-layer protocols for session management offers less flexibility than a strict adherence to the OSI model.

OSI Model - The Lower Layers

The bottom four layers of the OSI model are often referred to as the **lower layers**:

- Layer-4 – **Transport** layer
- Layer-3 – **Network** layer
- Layer-2 – **Data-Link** layer
- Layer-1 – **Physical** layer

Protocols that operate at these layers control the end-to-end transport of data between devices, and are implemented in both software and hardware.

OSI Model - The Transport Layer

The **Transport layer (Layer-4)** does *not* actually send data, despite its name. Instead, this layer is responsible for the *reliable* transfer of data, by ensuring that data arrives at its destination error-free and in order.

Transport layer communication falls under two categories:

- **Connection-oriented** – requires that a connection with specific agreed-upon parameters be established before data is sent.
- **Connectionless** – requires no connection before data is sent.

Connection-oriented protocols provide several important services:

- **Segmentation and sequencing –** data is *segmented* into smaller pieces for transport. Each segment is assigned a *sequence number*, so that the receiving device can reassemble the data on arrival.
- **Connection establishment –** connections are established, maintained, and ultimately terminated between devices.
- **Acknowledgments –** receipt of data is confirmed through the use of *acknowledgments*. Otherwise, data is retransmitted, guaranteeing delivery.
- **Flow control** (or **windowing) –** data transfer rate is negotiated to prevent congestion.

The TCP/IP protocol suite incorporates two Transport layer protocols:

- **Transmission Control Protocol (TCP) –** connection-oriented
- **User Datagram Protocol (UDP) -** connectionless

(Reference: http://www.tcpipguide.com/free/t_TransportLayerLayer4-2.htm)

OSI Model - The Network Layer

The **Network layer (Layer-3)** controls *internetwork* communication, and has two key responsibilities:

- **Logical addressing** – provides a unique address that identifies both the *host*, and the *network* that host exists on.
- **Routing** – determines the *best path* to a particular destination network, and then *routes* data accordingly.

Two of the most common Network layer protocols are:

- **Internet Protocol (IP)**
- Novell's **Internetwork Packet Exchange (IPX)**.

IPX is almost entirely deprecated. IP version 4 (IPv4) and IP version 6 (IPv6) are covered in nauseating detail in other guides.

OSI Model - The Data-Link Layer

While the Network layer is concerned with transporting data *between* networks, the **Data-Link layer (Layer-2)** is responsible for transporting data *within* a network.

The Data-Link layer consists of two sublayers:

- **Logical Link Control (LLC)** sublayer
- **Media Access Control (MAC)** sublayer

The LLC sublayer serves as the intermediary between the physical link and all higher layer protocols. It ensures that protocols like IP can function regardless of what type of physical technology is being used.

Additionally, the LLC sublayer can perform flow-control and error-checking, though such functions are often provided by Transport layer protocols, such as TCP.

The MAC sublayer controls access to the physical medium, serving as mediator if multiple devices are competing for the same physical link. Data-link layer technologies have various methods of accomplishing this - **Ethernet** uses *Carrier Sense Multiple Access* with *Collision Detection (CSMA/CD)*, and **Token Ring** utilizes a *token*.

Ethernet is covered in great detail in another guide.

OSI Model - The Data-Link Layer (continued)

The Data-link layer *packages* the higher-layer data into **frames,** so that the data can be put onto the physical wire. This packaging process is referred to as **framing** or **encapsulation.**

The encapsulation type will vary depending on the underlying technology. Common Data-link layer technologies include following:

- Ethernet – the most common LAN data-link technology
- Token Ring – almost entirely deprecated
- FDDI (Fiber Distributed Data Interface)
- 802.11 Wireless
- Frame-Relay
- ATM (Asynchronous Transfer Mode)

The data-link frame contains the source and destination **hardware** (or **physical**) address. Hardware addresses uniquely identify a host within a network, and are often hardcoded onto physical network interfaces. However, hardware addresses contain no mechanism for differentiating one *network* from another, and can only identify a host *within* a network.

The most common hardware address is the Ethernet **MAC address.**

OSI Model - The Physical Layer

The **Physical layer (Layer-1)** controls the signaling and transferring of raw bits onto the physical medium. The Physical layer is closely related to the Data-link layer, as many technologies (such as Ethernet) contain both data-link and physical functions.

The Physical layer provides specifications for a variety of hardware:

- Cabling
- Connectors and transceivers
- Network interface cards (NICs)
- Wireless radios
- Hubs

Physical-layer devices and topologies are covered extensively in other guides.

Encapsulation and Layered Communication

As data is passed from the user application down the virtual layers of the OSI model, each layer adds a **header** (and sometimes a **trailer**) containing protocol information specific to that layer. These headers are called **Protocol Data Units (PDUs)**, and the process of adding these headers is called **encapsulation**. Note that in the TCP/IP protocol suite only the lower layers perform encapsulation, generally.

For example, a Transport layer protocol such as TCP will add a header containing flow control, port numbers, and sequencing. The Network layer header contains logical addressing information, and the Data-link header contains physical addressing and other hardware specific information.

The PDU of each layer is identified with a different term:

Layer	*PDU Name*
Application	**-**
Presentation	**-**
Session	**-**
Transport	**Segments**
Network	**Packets**
Data-Link	**Frames**
Physical	**Bits**

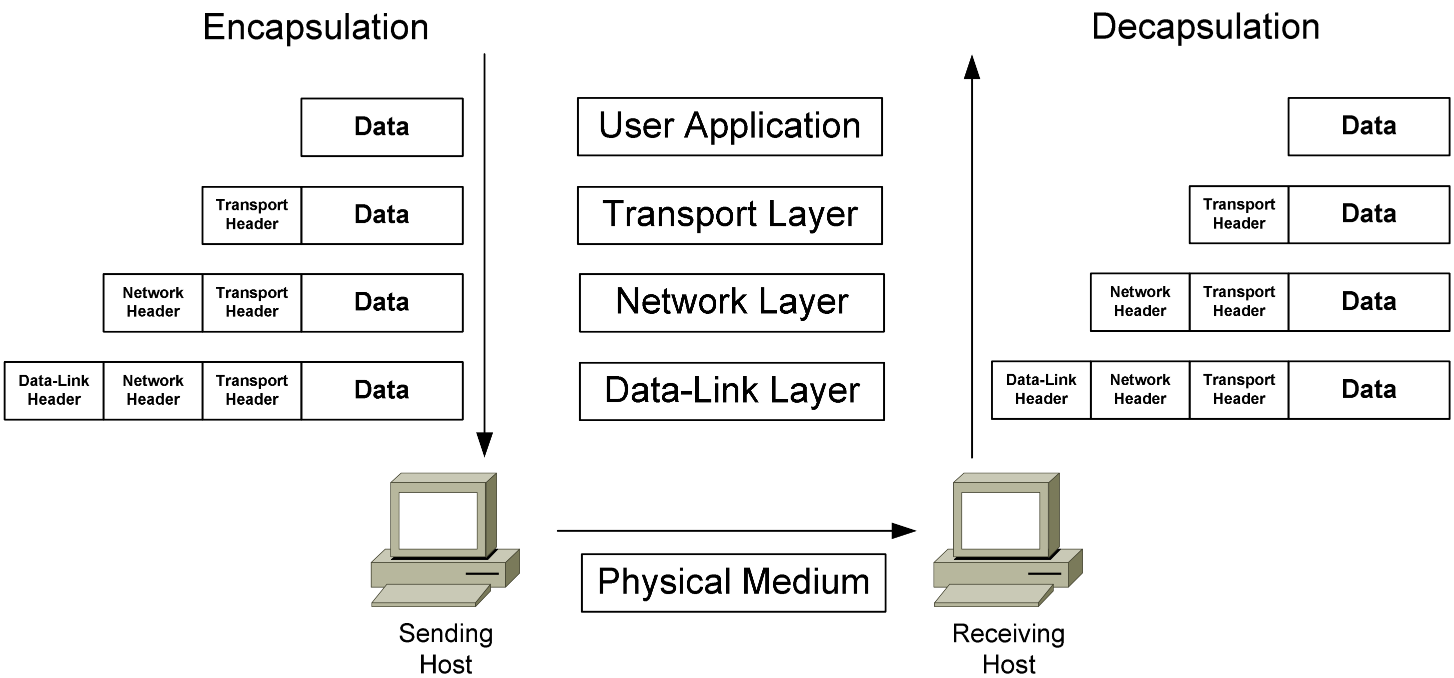
Each layer **communicates with the corresponding layer** on the receiving device. For example, on the sending device, source and destination hardware addressing is placed in a Data-link header. On the receiving device, that Data-link header is processed and stripped away (**decapsulated)** before being sent up to the Network and other upper layers.

Network devices are commonly identified by the OSI layer they *operate* at; or, more specifically, what *header* or *PDU* the device processes.

For example, **switches** are generally identified as Layer-2 devices, as switches process information stored in the **Data-Link** header of a frame, such as Ethernet MAC addresses. Similarly, **routers** are identified as Layer-3 devices, as routers process *logical* addressing information in the **Network** header of a packet, such as IP addresses.

Encapsulation Illustrated

The following illustrates how basic encapsulation occurs with the TCP/IP stack, which typically performs encapsulation only at the lower layers:



During **encapsulation** on the sending host**:**

- Data from the user application is handed off to the Transport layer.
- The Transport layer adds a header containing protocol-specific information, and then hands the *segment* to the Network layer.
- The Network layer adds a header containing source and destination logical addressing, and then hands the *packet* to the Data-Link layer.
- The Data-Link layer adds a header containing source and destination physical addressing and other hardware-specific information.
- The Data-Link *frame* is then handed off to the Physical layer to be transmitted on the network medium as *bits*.

During **decapsulation** on the receiving host, the reverse occurs:

- The frame is received from the physical medium.
- The Data-Link layer processes its header, strips it off, and then hands it off to the Network layer.
- The Network layer processes its header, strips it off, and then hands it off to the Transport layer.
- The Transport layer processes its header, strips it off, and then hands the data to the user application.

OSI Reference Model Example

A web browser serves as a good practical illustration of the OSI model and the TCP/IP protocol suite:

- The web browser serves as the user interface for accessing a website. The browser itself does not function at the **Application layer.** Instead, the web browser invokes the *Hyper Text Transfer Protocol (HTTP)* to interface with the remote web server, which is why *http://* precedes every web address.

- The Internet can provide data in a wide variety of *formats,* a function of the **Presentation layer**. Common formats on the Internet include *HTML, XML, PHP, GIF,* and *JPEG*. Any *encryption* or *compression* mechanisms used on a website are also considered a Presentation layer function.

- The **Session layer** is responsible for establishing, maintaining, and terminating the session between devices, and determining whether the communication is *half-duplex* or *full-duplex*. However, the TCP/IP stack generally does not include session-layer protocols, and is reliant on lower-layer protocols to perform these functions.

- HTTP utilizes the *TCP* **Transport layer** protocol to ensure the reliable delivery of data. TCP establishes and maintains a connection from the client to the web server, and packages the higher-layer data into *segments.* A sequence number is assigned to each segment so that data can be reassembled upon arrival.

- The best path to *route* the data between the client and the web server is determined by *IP*, a **Network layer** protocol. IP is also responsible for the assigned logical addresses on the client and server, and for encapsulating segments into *packets.*

- Data cannot be sent directly to a logical address. As packets travel from network to network, IP addresses are translated to *hardware* addresses, which are a function of the **Data-Link layer**. The packets are encapsulated into *frames* to be placed onto the physical medium.

- The data is finally transferred onto the network medium at the **Physical layer**, in the form of raw bits. Signaling and encoding mechanisms are defined at this layer, as is the hardware that forms the physical connection between the client and the web server.

<u>IP and the DoD Model</u>

The **Internet Protocol (IP)** was originally developed by the Department of Defense (DoD), and was a cornerstone for a group of protocols that became known as the **TCP/IP protocol suite**.

The DoD developed their own networking model, which became known as the **DoD** or **TCP/IP Model**. It consists of four layers:

	OSI Model		***DoD Model***
7	Application	4	Application
6	Presentation		
5	Session		
4	Transport	3	Host-to-Host
3	Network	2	Internet
2	Data-link	1	Network Access
1	Physical		

The consolidated DoD model is generally regarded as more practical than the OSI model. Upper layer protocols often provide services that span the top three layers. A converged Data-link and Physical layer is also sensible, as many technologies provide specifications for both layers, such as Ethernet.

The following chart illustrates where common protocols fit into the DoD model:

Layer	***Example Protocols***
Application	FTP, HTTP, SMTP
Host-to-Host	TCP, UDP
Internet	IP
Network Access	Ethernet

Despite the practicality of the DoD model, the OSI model is still the basis for most network terminology.

So, Please Do Not Throw Sausage Pizza Away. ☺