

Lecture 17: Network Stack

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1 Network Requirements

A computer network must:

- Provide general, cost-effectiveness, fair, robust and high-performance, connectivity among a large set of computers.
- Accommodate changes in the underlying technologies and in the demands of application programs. (e.g. developments in the ability to produce fibre-optic cable)

To cope with complexity, the principle of **abstraction** is usually applied in the sciences. In network design, abstraction is reflected in the concept of a **network architecture**.

2 The Principle of Abstraction

Identify a **model** capturing some important system aspect. Then encapsulate this model in an object such that it is **accessible** to other system components via its interface and its implementation details are hidden.

3 End-to-End Communication

Providing cost-effective connectivity among hosts is a necessary but too weak requirement to networks. What is needed is a means for application processes running on different hosts to communicate over the network.

Services for setting up, maintaining and using end-to-end connections are common for many application programs (implemented as part of the OS). Services should support commonly used communication patterns such as:

- **Request-reply:** (For reliable exchange of messages between a client and a server e.g. a download).
- **Message Stream:** Potentially unreliable ordered sequence of messages (e.g. video on demand).

4 Network API

Interface that the OS (running on some node) provides to its networking subsystem. It is a piece of software that provides abstract routines for invoking common services of the network in a particular OS. Its implementation maps

the offered abstract routines to the **services** provided by the network. For example, take UNIX sockets.

5 Network Architecture: Layering

Several steps of abstraction leads to **layering**. The services provided at the high-level (the more abstract) layers are implemented in terms of the services of the lower-level (the less abstract and more concrete) layers. There might be **multiple abstractions at a given layer** which is the case when considering different types of channels.

5.1 Advantages & Disadvantages of Layering

Advantages:

- Obtaining manageable tasks by splitting a complex problem into multiple, simpler sub-problems.
- Achieving a modular design such that adding or altering a service affects only one layer, thus reusing the functionality of all other layers.

Disadvantages:

- Implementing a layered design might induce overheads and, thereby, reduce efficiency.

However the advantages by far outweigh this disadvantage which can usually be dealt with.

- **Note:** In network design, the objects making up the layers are the *protocols*.

6 Protocols: The Networking Software

The role of protocols in a layered architecture:

- Each layer n of some host may carry a conversation with layer n on some other host.
- The layer n protocol defines the rules used in this conversation.

Several layers of protocols build a **protocol stack**.

7 Services and Protocols

Service Interface on the other objects on the same host that want to use its communication services (such as send and receive primitives).

Protocol Interface to the counterparts (peers) on other machines, which defines a set of rules governing the messages that the protocol exchanges with its peers to implement the services.

8 Protocol Graphs

Protocol graphs visualise the dependencies between protocols at different layers (see slides for example).

9 OSI Reference Model (OSI Architecture)

The 7-layer **Open Systems Interconnection (OSI)** architecture is standardised by the International Standards Organisation (ISO). There are two sets of layers; one for end-hosts and another for switch nodes. The end host stack contains the following:

- Application
- Presentation
- Session
- Transport
- Network
- Data Link
- Physical

While the switch node stack only contains:

- Network
- Data Link
- Physical

10 Basic Purpose of ISO Layer

Physical Layer Handles transmission of raw bits over a physical link.

Data Link Layer Collects a stream of bits into a **frame** i.e. frames, not raw bits, are delivered to hosts. (It is usually implemented in network adaptors and in device drivers running on the node's OS.

Network Layer Deals with routing in packet-switched networks and employs the term **packet** rather than frame.

Transport Layer Implements process-to-process channels and employs the term **message** rather than packet or frame.

Session Layer Ties together different transport streams e.g. audio and video for video conferencing.

Presentation Layer Coordinates the format of data exchanged between peers e.g. the length of integer representations.

Application Layer Includes application protocols e.g. HTTP.

11 Internet Architecture (TCP/IP Architecture)

The Internet architecture only considers 4 layers of the OSI model; specifically, it leaves out the presentation and session layer and says that these should be dealt with in the application layer. The data link and physical layer are also replaced with a **host-to-network** layer which is what made it so popular since it expects so little of these layers.

12 Overview of the Internet Protocols

The Internet Protocol (IP) supports the interconnection of multiple network technologies into a single, logical network. There are two main transport protocols (end-to-end protocols):

- The **Transmission Control Protocol TCP** provides a reliably byte-stream channel.
- The **User Datagram Protocol (UDP)** provides an unreliable message delivery channel.

The Internet comes with many application protocols such as:

- File Transfer Protocol (FTP)
- HyperText Transfer Protocol (HTTP)
- Directory Name Service (DNS)
- Real-time Transfer Protocol (RTP)

13 OSI vs. Internet Architecture

The Internet protocols were invented before the OSI model, and the Internet architecture was just a result of an existing implementation. The Internet protocols became the de-facto standard since they were shipped with the popular Berkeley distribution of UNIX, which also helped their further development. The conceptual OSI reference model, however, is a great use for conceptually discussing and teaching about computer networks.

14 Network Standardisation

- International Telecommunication Union (ITU): Telecom sector includes data communications systems.
- International Standards Organisation (ISO): Member of the ITU.
- Institute of Electrical and Electronics Engineers (IEEE): Standards are occasionally adapted by ISO.
- Internet Society:
 - Internet Engineering Task Force (IETF)
 - Internet Research Task Force (IRTF)

Generally protocols are submitted to different organisations depending on their level in the stack. They are submitted by engineers (often funded by their employer) who try to create vendor-independent and non-ambiguous rules.