# Advanced Computer Network

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**Abstract**

*This course covers a set of advanced topics in computer networks. The focus is on principles, architectures, and protocols used in modern networked systems, such as the Internet itself, wireless and mobile networks, high-performance networks and data center networks.The goals of the courses are to build on essential networking course material in providing an understanding of the tradeoffs and existing technology in building large, complex networked systems, and provide concrete experience of the challenges through a series of lab exercises.*

*The focus of the course is on principles, architectures, and protocols used in modern networked systems. Topics include:*

- *Wireless networks and mobility issues at the network and transport layer (Mobile IP and micro mobility protocols, TCP in wireless environments).*
- *Data center and high-performance networking.*
- *Network virtualization.*

## Introduction

A computer network or data network is a digital telecommunications network which allows nodes to share resources. In computer networks, computing devices exchange data with each other using connections (data links) between nodes. These data links have been established over cable media such as wires or optic cables, or wireless media such as Wi-Fi.

Network computer devices that originate, route and terminate the data are called network nodes.[1] Nodes can include hosts such as personal computers, phones, servers as well as networking hardware. Two such devices can be said to be networked together when one device can exchange information with the other device, whether or not they have a direct connection to each other. In most cases, application-specific communications protocols are layered (i.e., carried as payload) over other more general communications protocols. This formidable collection of information technology requires skilled network management to keep it all running reliably.

## Interconnection Network

Interconnection networks are composed of switching elements. Topology is the pattern to connect the individual switches to another element, like processors, memories and other switches. A system allows the exchange of data between processors in the parallel system.

- Direct connection networks − Direct networks have point-to-point connections between neighboring nodes. These networks are static, which means that the point-to-point links are fixed. Some examples of direct networks are rings, meshes, and cubes.
- Indirect connection networks − Indirect networks have no fixed neighbors. The communication topology can be changed dynamically based on the application demands. Indirect networks can be subdivided into three parts: bus networks, multistage networks, and crossbar switches.
- Bus networks − A bus network is composed of some bit lines onto which some resources are attached. When busses use the same physical lines for data and addresses, the data and the address lines are time multiplexed. When there are multiple bus-masters attached to the bus, an arbiter is required.
- Multistage networks − A multistage network consists of multiple stages of switches. It is composed of 'axb' switches which are connected using a particular interstate connection pattern (ISC). Small 2x2 switch elements are a common choice for many multistage networks. The number of stages determines the delay of the network. By choosing different interstate connection patterns, various types of multistage network can be created.
- Crossbar switches − A crossbar switch contains a matrix of simple switch elements that can switch on and off to create or break a connection. Turning on a switch element in the matrix, a connection between a processor and a memory can be made. Crossbar switches are non-blocking, that is all communication permutations can be performed without blocking.

**Evaluating Design Trade-Offs in Network Topology**

If the major concern is the routing distance, then the dimension has to be maximized, and a hypercube made. In store-and-forward routing, assuming that the degree of the switch and the number of links were not a significant cost factor, and the numbers of links or the switch degree are the main costs, the dimension has to be minimized and a mesh built.

The worst case traffic pattern for each network, it is preferred to have high dimensional networks where all the paths are short. In patterns where each node is communicating with only one or two nearby neighbors, it is preferred to have low dimensional networks, since only a few of the dimensions are used.

**Routing**

The routing algorithm of a network determines which of the possible paths from source to destination is used as routes and how the route followed by each particular packet is determined. Dimension order routing limits the set of legal paths so that there is accurately one route from each source to each destination. The one obtained by first traveling the correct distance in the high-order dimension, then the next dimension and so on.

**Routing Mechanisms**

Arithmetic, source-based port select, and table look-up are three mechanisms that high-speed switches use to determine the output channel from information in the packet header. All of these mechanisms are simpler than the kind of general routing computations implemented in traditional LAN and WAN routers. In parallel computer networks, the switch needs to make the routing decision for all its inputs in every cycle, so the mechanism needs to be simple and fast.

**Deterministic Routing**

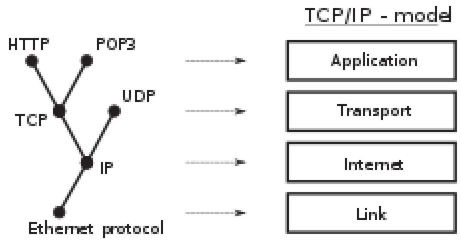
A routing algorithm is deterministic if the route taken by a message is determined exclusively by its source and destination, and not by other traffic in the network. If a routing algorithm only selects shortest paths toward the destination, it is minimal. Otherwise, it is non-minimal.

**Deadlock Freedom**

Deadlock can occur in various situations. When two nodes attempt to send data to each other, and each begins sending before either receives, a 'head-on' deadlock may occur. Another case of deadlock occurs when there are multiple messages competing for resources within the network.

The basic technique for proving a network is deadlock free is to clear the dependencies that can occur between channels as a result of messages moving through the networks and to show that there are no cycles in the overall channel dependency graph; hence there are no traffic patterns that can lead to a deadlock. The common way of doing this is to number the channel resources such that all routes follow a particular increasing or decreasing sequences so that no dependency cycles arise.

**Communication Protocols**




The TCP/IP model or Internet layering scheme and its relation to common protocols often layered on top of it.

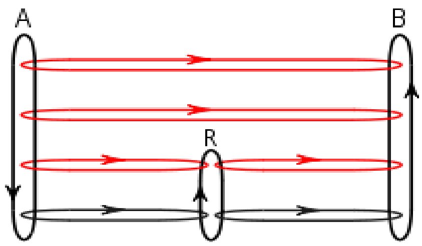



**Figure 4 Message flows (A-B) in the presence of a router (R), red flows are effective communication paths, black paths are across the actual network links**

A communication protocol is a set of rules for exchanging information over a network. In a protocol stack (also see the OSI model), each protocol leverages the services of the protocol layer below it, until the lowest layer controls the hardware which sends information across the media. The use of protocol layering is today ubiquitous across the field of computer networking. An important example of a protocol stack is HTTP (the World Wide Web protocol) running over TCP over IP (the Internet protocols) over IEEE 802.11 (the Wi-Fi protocol). This stack is used between the wireless router and the home user's personal computer when the user is surfing the web. Communication protocols have various characteristics. They may be connection-oriented or connectionless, they may use circuit mode or packet switching, and they may use hierarchical addressing or flat addressing.

There are many communication protocols, a few of which are described below.

**IEEE 802**

IEEE 802 is a family of IEEE standards dealing with local area networks and metropolitan area networks. The complete IEEE 802 protocol suite provides a diverse set of networking capabilities. The protocols have a flat addressing scheme. They operate mostly at levels 1 and 2 of the OSI model.

For example, MACbridging (IEEE 802.1D) deals with the routing of Ethernet packets using a Spanning Tree Protocol. IEEE 802.1Q describes VLANs, and IEEE 802.1X defines a port-based Network Access Control protocol, which forms the basis for the authentication mechanisms used in VLANs (but it is also found in WLANs) – it is what the home user sees when the user has to enter a "wireless access key."

**Ethernet**

Ethernet, sometimes simply called LAN, is a family of protocols used in wired LANs, described by a set of standards together called IEEE 802.3 published by the Institute of Electrical and Electronics Engineers.

**LAN**

Wireless LAN, also widely known as WLAN or Wi-Fi, is probably the most well-known member of the IEEE 802 protocol family for home users today. It is standardized by IEEE 802.11 and shares many properties with wired Ethernet.

**Internet Protocol Suite**

The Internet Protocol Suite, also called TCP/IP, is the foundation of all modern networking. It offers connection-less as well as connection-oriented services over an inherently unreliable network traversed by data-gram transmission at the Internet protocol (IP) level. At its core, the protocol suite defines the addressing, identification, and routing specifications for Internet Protocol Version 4 (IPv4) and for IPv6, the next generation of the protocol with a much enlarged addressing capability.

**SONET/SDH**

Synchronous optical networking (SONET) and Synchronous Digital Hierarchy (SDH) are standardized multiplexing protocols that transfer multiple digital bit streams over optical fiber using lasers. They were originally designed to transport circuit mode communications from a variety of different sources, primarily to support real-time, uncompressed, circuit-switched voice encoded in PCM (Pulse-Code Modulation) format. However, due to its protocol neutrality and transport-oriented features, SONET/SDH also was the obvious choice for transporting Asynchronous Transfer Mode (ATM) frames.

**Conclusion**

The evolution of information technology reached a turning point with the development of the Internet. Once a government project, the Internet was created for military purposes. Through the course of its development, researchers began finding other uses for the network and use of the technology spread worldwide. Access to the Internet today by individuals, businesses, and institutions alike has created a global market for Internet service and has spurned an increase in productivity in the technological communication field. Our research compares Internet development, access, and use in the United States and Russia. Our surveys prove our prediction that access to the

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