# Computer Networks - Lecture 01: Introduction

## Course Information

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- **Department:** Computer and Systems Engineering Department
- **University:** Faculty of Engineering, Alexandria University
- **Textbook:** Computer Networking: A Top-Down Approach, 8th ed., Kurose & Ross

## Course Outline

- **Grading:**
  - Attendance & Participation: 5-7%
  - Assignments & Quizzes: 40%
  - Midterm: 15%
  - Final: 40%
- **Join with Code:** 142tcab
- **Course Materials & Discussions:** MS Teams
- **Teaching Assistant:** Eng. Mohamed Essam

## Chapter 1: Computer Networks and the Internet

### Outline

- What is the Internet?
- The Network Edge
- The Network Core
- Delay, Loss, and Throughput in Packet-Switched Networks
- Protocol Layers and Their Service Models

### What is the Internet?

- The Internet is a **network of networks**.
- We will use the **public Internet** as the basis for our discussion.

### Nuts-and-Bolts Description

- The Internet interconnects **billions of computing devices** worldwide.
- These devices are called **hosts** or **end systems**.
- Estimated number of devices: 18 billion in 2017, reaching **28.5 billion by 2022**.
- End systems are connected by a network of **communication links** and **packet switches**.
- **Packet switches** forward packets received on incoming links to outgoing links.
- Common types of packet switches: **routers** and **link-layer switches**.
- The path a packet takes is called a **route** or **path**.
- **Internet Service Providers (ISPs)** provide access to the Internet.
- ISPs themselves are **networks** of packet switches and links.
- Devices on the Internet run **protocols**.
- Key protocols: **Transmission Control Protocol (TCP)** and **Internet Protocol (IP)**.
- **Internet standards** are developed by the **Internet Engineering Task Force (IETF)**.
- IETF standards documents are called **Requests for Comments (RFCs)**.
- There are nearly **9000 RFCs**.

- Other organizations also specify standards, such as the **IEEE 802 LAN Standards Committee**.

## Services Description

- The Internet is an **infrastructure** that provides services to **distributed applications**.
- Internet applications run on **end systems**. They do **not** run on packet switches.
- End systems provide a **socket interface**. This defines how applications request data delivery.
- The Internet provides **multiple services** to its applications.

## What is a Protocol?

- Two or more entities need to run the same **protocol** to accomplish a task.
- **Human protocols** involve specific messages and actions based on replies or events.
- This course focuses on **computer network protocols**.
- A **protocol** defines the format and order of messages exchanged between entities, as well as actions taken during transmission and reception.

## The Network Edge

- **End Systems:**
    - Include **desktop computers** (PCs, Macs, Linux boxes), **servers** (Web, email), and **mobile devices** (laptops, smartphones, tablets).
    - Also include **"things"** (non-traditional devices) connected to the Internet.
    - End systems are also known as **hosts** because they host application programs.
    - Hosts are categorized as **clients** and **servers**.
    - Most servers reside in **data centers**. Google has 19 data centers worldwide, containing millions of servers.

## Access Networks

- **Home Access:**
    - **DSL (Digital Subscriber Line):** Uses existing telephone lines. Requires a **DSL modem** and **DSLAM (Digital Subscriber Line Access Multiplexer)** in the telco's central office (CO).
        - Downstream rates: 24 Mbps and 52 Mbps.
        - Upstream rates: 3.5 Mbps and 16 Mbps.
        - Newest standard: 1 Gbps.
    - **Cable Internet:** Utilizes existing cable television infrastructure.
        - Downstream rates: 40 Mbps and 1.2 Gbps.
        - Upstream rates: 30 Mbps and 100 Mbps.
    - **Fiber to the Home (FTTH):** Provides very high speeds in the gigabit per second range.
    - **5G Fixed Wireless:** Offers high-speed access without requiring physical cabling.
- **Enterprise/Home Access:**
    - **Ethernet:** Uses twisted-pair copper wire to connect to an **Ethernet switch**.
        - Users typically have 100 Mbps to tens of Gbps access.
        - Servers may have 1 Gbps to 10 Gbps access.
    - **WiFi (Wireless Fidelity):** Based on IEEE 802.11 technology.

        - Requires a **WiFi access point** and a **home router**.
        - Shared transmission rate: Up to over 100 Mbps.

- **Wide-Area Wireless Access:**
    - **3G, LTE 4G, and 5G:** Uses cellular telephony infrastructure.
        - Requires a **base station**.
        - 4G: Download speeds up to 60 Mbps.
        - 5G: Even higher speeds.

### Physical Media

- Bits travel through a series of transmitter-receiver pairs using a **physical medium**.
- Physical media are classified as **guided** or **unguided**:
    - **Guided Media:** Electromagnetic waves or optical pulses travel through a solid medium, such as fiber-optic cables, twisted-pair copper wire, or coaxial cables.
    - **Unguided Media:** Waves propagate through the atmosphere or outer space, such as in wireless LANs or satellite channels.

### The Network Core

- The network core consists of **packet switches** (primarily **routers**).
- Routers are connected to the network edge through **access networks**.

### Packet Switching

- End systems exchange **messages**.
- Messages are divided into **packets**.
- Packets travel through **communication links** and **packet switches**.
- Most packet switches use **store-and-forward transmission**. They receive the entire packet before forwarding it.
- **Output buffers/queues** store packets waiting to be sent on a specific link.
- Packets experience **store-and-forward delay** and **queuing delay**. Queuing delay depends on the level of **congestion**.
- **Packet loss** can occur if the buffer space is full, resulting in a dropped packet.

### Forwarding Tables and Routing Protocols

- Routers use **forwarding tables** to determine the appropriate outgoing link for a packet.
- **IP addresses** are used to identify hosts and have a hierarchical structure.
- The destination's **IP address** is included in the packet header.
- **Routing protocols** are used to automatically set up forwarding tables.

### Circuit Switching

- **Traditional telephone networks** are circuit-switched networks.
- **Circuit-switched networks** reserve resources (buffers, transmission rate) along a path for the duration of a communication session.
- A dedicated **end-to-end connection** is established between hosts.
- The sender can transmit data at a **guaranteed constant rate**.
- The Internet uses a **best-effort** approach to deliver packets, without guarantees.

## Multiplexing in Circuit-Switched Networks

- **Frequency-division multiplexing (FDM)** and **time-division multiplexing (TDM)** are used to share a link between multiple connections.
- **FDM:** Each connection gets a dedicated frequency band.
- **TDM:** Time is divided into frames, and each frame is further divided into slots. Each connection gets a dedicated slot within each frame.

## Packet Switching vs. Circuit Switching

- **Packet switching:**
  - **Advantages:** Better sharing of transmission capacity, simpler and more efficient implementation, and lower cost.
  - **Disadvantage:** Not suitable for real-time services.
- **Circuit switching:**
  - **Advantages:** Guaranteed constant rate.
  - **Disadvantages:** Pre-allocates resources, wasting unused time, and is more complex.

## A Network of Networks

- The Internet has evolved into a **complex network of networks**.
- This evolution is driven by **economics** and **national policy**.
- **Network Structures:**
  - **Structure 1:** Single global transit ISP connecting all access ISPs (expensive).
  - **Structure 2:** Two-tier hierarchy, with multiple global transit ISPs competing for access ISPs.
  - **Structure 3:** Multi-tier hierarchy, with regional ISPs connecting access ISPs within a region.
  - **Structure 4:** Adds **Points of Presence (PoPs)**, **multi-homing**, and **peering** to the hierarchy.
  - **Structure 5:** Builds on Structure 4 and includes **content-provider networks**.

## Delay, Loss, and Throughput

- **Delay:**
  - **Processing delay:** Microseconds or less.
  - **Queuing delay:** Microseconds to milliseconds, depending on the number of packets waiting.
  - **Transmission delay:** L/R (packet length divided by transmission rate).
  - **Propagation delay:** d/s (distance divided by propagation speed).
  - **Nodal delay:** The sum of all delay components at a node.
- **Loss:**
  - Packets can be dropped if the buffer is full.
  - **Packet loss** is dependent on **traffic intensity** and the **nature of the arriving traffic**.
- **Throughput:**
  - The amount of data transferred per second.

- **Bottleneck links** limit throughput.
- In the core of the Internet, throughput is limited by **access networks**.

## Protocol Layers

- Network protocols are organized into **layers**.
- Layers provide services by performing certain actions and utilizing services from lower layers.
- **Layers:**
    - **Application Layer:** Where network applications and their protocols reside.
    - **Transport Layer:** Transports application messages between endpoints.
        - **UDP:** Connectionless service.
        - **TCP:** Connection-oriented service with guaranteed delivery, flow control, and congestion control.
    - **Network Layer:** Moves network packets (datagrams) between hosts.
        - Contains **routing protocols**.
    - **Link Layer:** Delivers datagrams to the next node along the route.
        - Uses different link-layer protocols for different links.
    - **Physical Layer:** Moves individual bits within a frame between nodes.
        - Dependent on the transmission medium.

## Encapsulation

- Layers encapsulate information from higher layers.
- **Application Layer:** Messages are encapsulated into **transport-layer segments**.
- **Transport Layer:** Segments are encapsulated into **network-layer datagrams**.
- **Network Layer:** Datagrams are encapsulated into **link-layer frames**.
- This layered architecture is used by hosts, routers, and link-layer switches, with each having its own specific layers.

## Summary

- This lecture covered the fundamentals of computer networks, including the Internet's structure, how data is transmitted, and the different types of delays and throughput.
- The lecture also introduced the concept of protocol layering and how it helps organize network protocols.
- The key takeaways are:
    - The Internet is a network of networks.
    - Packet switching is more efficient than circuit switching but not suitable for real-time services.
    - Network performance is affected by delays, loss, and throughput.
    - Protocol layers provide a structured approach to designing and implementing network protocols.