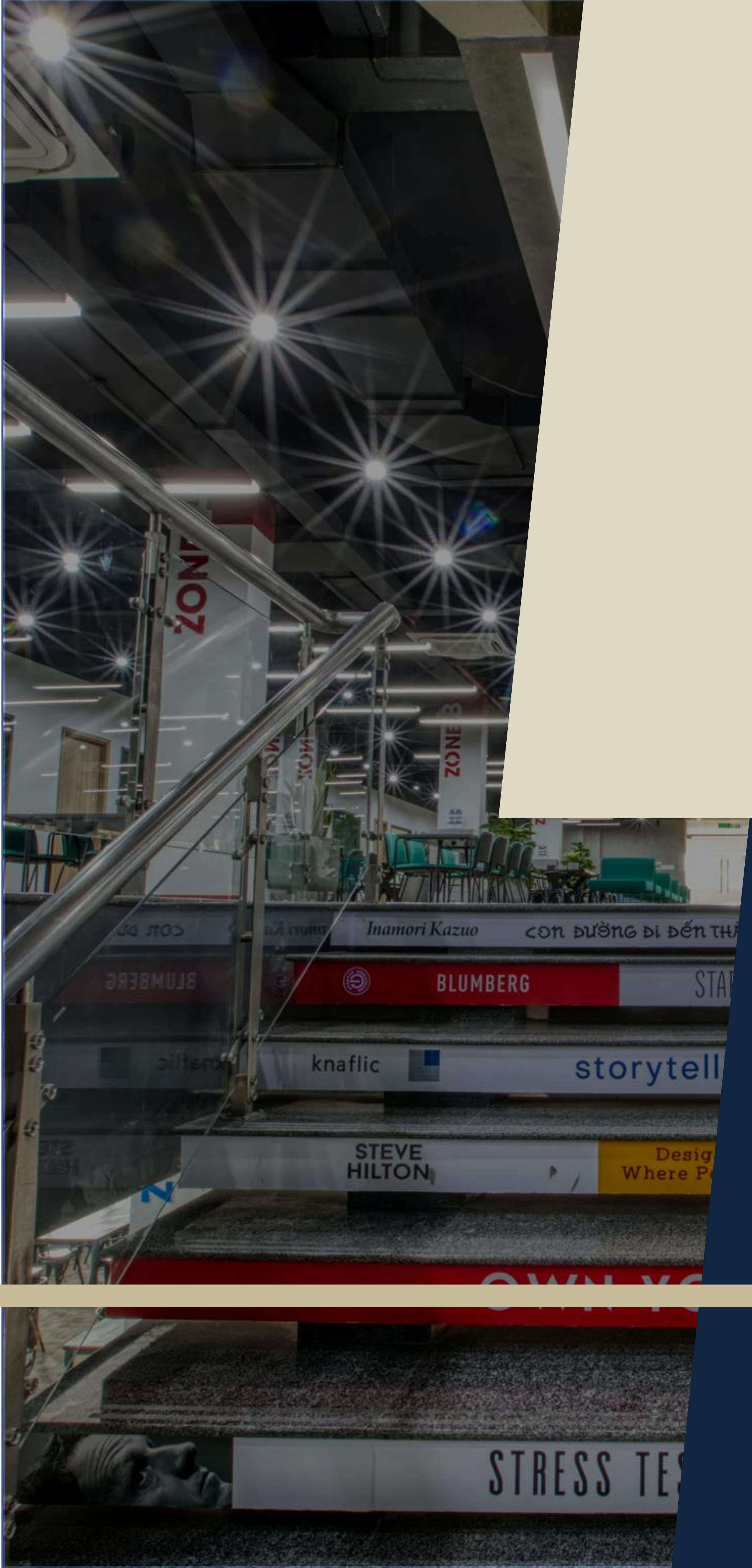

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Chapter 1. A Review of Core Concepts for Complex Networks

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- Key Drivers of Modern Change
- An overview of the Internet.
- The OSI and client-server model
- TCP, UDP, and IP protocol suites.

The Evolving Role of the Network Engineer

The Shift from Traditional CLI Management

Past Role (Turn of the Millennium)	Current Role (Today)
• Primarily possessed **domain-specific knowledge**.	• The lines between roles are significantly blurred.
• Managed networks using the **command-line interface (CLI)**.	• There is an **explicit expectation to write code** or understand programming concepts.
• Might occasionally cross over to systems administration or development tasks.	• Adopting Network DevOps and network programmability is common.

Key Drivers of Modern Change

- The **DevOps movement** has significantly blurred the lines between network engineers, systems engineers, and developers.
- **Software–Defined Networking (SDN)** is another factor contributing to the demand for programming concepts.
- Network engineers are challenged by the **scale and complexity** of the networks they need to manage.

Foundational Networking Knowledge Scope

- **Focus:** A quick, high-level visit to relevant networking topics, without deep dives.
- **Requirement:** Network professionals must be familiar with the basics of the **Open Systems Interconnection (OSI) model**, the **Transmission Control Protocol (TCP)** and **User Datagram Protocol (UDP) operations**, different **IP header fields**, and other fundamental concepts.
- *Note:* Most daily tasks do not require deep-level knowledge (e.g., remembering the exact TCP state machine).

Overview of the Internet

- **Definition:** To a network engineer, the Internet is a global computer network consisting of a **web of internetworks connecting large and small networks** together.
- **Structure:** It is fundamentally a **network of networks** without a centralized owner.
- **Importance:** Without the Internet, services like email, websites, API, streaming media, or cloud computing would not exist.

Local Area Networks (LAN) and ISPs

- A local device setup (computers, smartphones, tablets) communicating forms a **Local Area Network (LAN)**.
- When a LAN needs to communicate externally, it passes information to a larger network managed by an **Internet Service Provider (ISP)**.
- ISPs aggregate small networks into bigger networks they maintain.
- ISPs connect to other ISPs at specialized nodes called **Internet exchange points** to pass traffic to its destination.

Internet Components: Hosts and Servers

- **Hosts** (End Nodes): Communicate with other nodes (e.g., traditional computers, smartphones).
  - IoT Expansion: The broad definition expands to include Internet Protocol (IP) cameras, TV set-top boxes, and various sensors used in agriculture and automobiles.
  - The explosion of hosts demands greater capability for addressing, routing, and management.
- **Servers** ("Super Nodes"): Provide services (viewing a web page, sending email). They generally have higher hardware specifications and offer additional capabilities to their peers.

Internet Components: Network Infrastructure

- Network components are the "roads and highways" connecting servers (cities) and hosts (towns).
- These components operate from Layer 1 to Layer 3 (and sometimes Layer 4).
- **Layer 2 & 3:** Routers and switches that direct traffic.
- **Layer 1:** Physical transports, such as fiber optic cables, coaxial cables, twisted copper pairs, and Dense Wavelength Division Multiplexing (DWDM) equipment.
- Collectively, hosts, servers, storage, and network components make up the Internet..

The Rise of Data Centers

- Because servers demand higher hardware capacity (power, cooling, bandwidth), they are often grouped in a central location for efficient management, known as a **data center**.
- Data centers are generally classified into three broad categories:
    1. **Enterprise data centers**
    2. **Cloud data centers**
    3. **Edge data centers**

Enterprise Data Centers

- **Purpose:** To house internal business tools (emailing, document storage, intranets).
- **Server Requirements:** High-end computers requiring higher power, cooling, and high bandwidth network connections.
- **Location:** Servers are placed in the **Main Distribution Frame (MDF)**.
- **Aggregation:** User traffic is aggregated at closer locations, the **Intermediate Distribution Frame (IDF)**, before being bundled and connected to the MDF.

Enterprise Three-Layer Network Design

- Many enterprise data centers follow a three-layer network design, which is used as a general guide.
- **Access Layer:** Analogous to the physical ports each user connects to.
- **Distribution Layer:** Can be thought of as the IDF, aggregating traffic.
- **Core Layer:** Consists of the connection to the MDF and the enterprise data centers.

Cloud Data Centers (Hyper-Scale)

- **Scale:** With the rise of IaaS (Infrastructure as a Service), these are often referred to as **hyper-scale data centers** (e.g., Amazon AWS, Google Cloud).
- **Extreme Demands:** Demand a much higher capacity of power, cooling, and network capacity than any enterprise data center.
- **Location Strategy:** Typically built close to power plants for cheap rates and sometimes leverage environmental cooling (e.g., Facebook's Lulea data center).

Cloud Networking and Automation Necessity

- **Network Pressure:** Interconnecting vast server fleets leads to an **explosive growth of network equipment**.
- **Topology:** A typical cloud network design is a **multi-staged Clos network**.
- **Automation:** Managing this sheer number of devices via CLI is inefficient and error-prone. **Network automation** is necessary for speed, flexibility, and reliability to keep services available.

Edge Data Centers (Latency Solution)

- **The Problem:** Significant latency is introduced when routing requests all the way back to a large, central data center due to physical transport time (traversing undersea cables, satellite links, etc.).
- **The Solution: Edge data centers** reduce latency by placing resources as close to the end-user as possible—at the network edge.
- **Use Cases:** Common for servicing media content (music, video streaming) where low latency is critical for customer satisfaction.

Concepts of the Intelligent Edge

- Edge nodes benefit greatly from network automation in terms of increased reliability, flexibility, security, and visibility.
- **Advanced Applications:**
  - **Self-Driving Cars:** Must make split-second decisions based on local sensors.
  - **Software-Defined Wide-Area-Networks (SD-WANs):** Routers route packets locally without the need to consult a central "brain."

The OSI Model

- The model componentizes telecommunication functions into **seven independent layers**.
- Each layer sits independently on top of another one with defined structures (e.g., IP sits on top of data link layers like Ethernet).
- **Purpose:** It normalizes diverse technologies into a set of common languages, reducing the scope for parties working on individual layers.
- It was developed and published jointly by the International Organization for Standardization (ISO) and the ITU-T.

The TCP/IP Protocol Suite Model

- The model used by the original designers of the Internet.
- It divides end-to-end data communication into abstraction layers, similar to the OSI model.
- **Key Differences:** It combines several layers: OSI Layers 5, 6, and 7 are combined into the **Application layer**, while OSI Layers 1 and 2 are combined into the **Link layer**.

The Client-Server Model

- **Roles:** Servers, which have higher hardware specifications, provide resources and services. Servers typically sit idle, waiting for clients to initiate requests. Clients initiate requests for resources.
- **Networking Importance:** The need to transfer bits and bytes from the client to the server greatly highlights the importance of network engineering.
- **Protocol Shift:** The need for inter-network communication caused proprietary protocols (like IPX/SPX) to give way to standardized protocols (TCP, UDP, IP).

TCP: The Reliable Transport Protocol

- **Reliability:** Responsible for delivering data segments between two nodes in a **reliable and error-checked manner** (a connection-oriented protocol).
- **Connection:** Delivery is guaranteed by first establishing a connection using a **three-way handshake** (SYN, SYN-ACK, ACK).
- **Operation:** Managed by a complex state machine (e.g., LISTEN, ESTABLISHED, TIME-WAIT) that tracks the communication session.

UDP and IP: Speed and Addressing

UDP (User Datagram Protocol)	IP (Internet Protocol)
Layer: Layer 4.	**Layer:** Layer 3 (The layer network engineers "live at").
Function: Delivers data segments quickly. It is **connectionless and unreliable** (no guaranteed delivery).	**Function:** Addressing and routing between end nodes.
Header: Lightweight 64-bit header, ideal for speed.	**Addressing:** Address space is divided into two parts: the network portion and the host portion.
Use Cases: Ideal for low-latency applications like DNS lookup, multimedia video streaming, and Skype calls.	**Notation:** IPv4 uses dotted notation (e.g., 192.168.0.1) and a subnet mask (e.g., /24).

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