Lecture 4:
Introduction to
Computer Network Design

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Based on Slides by:
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Computer Networks

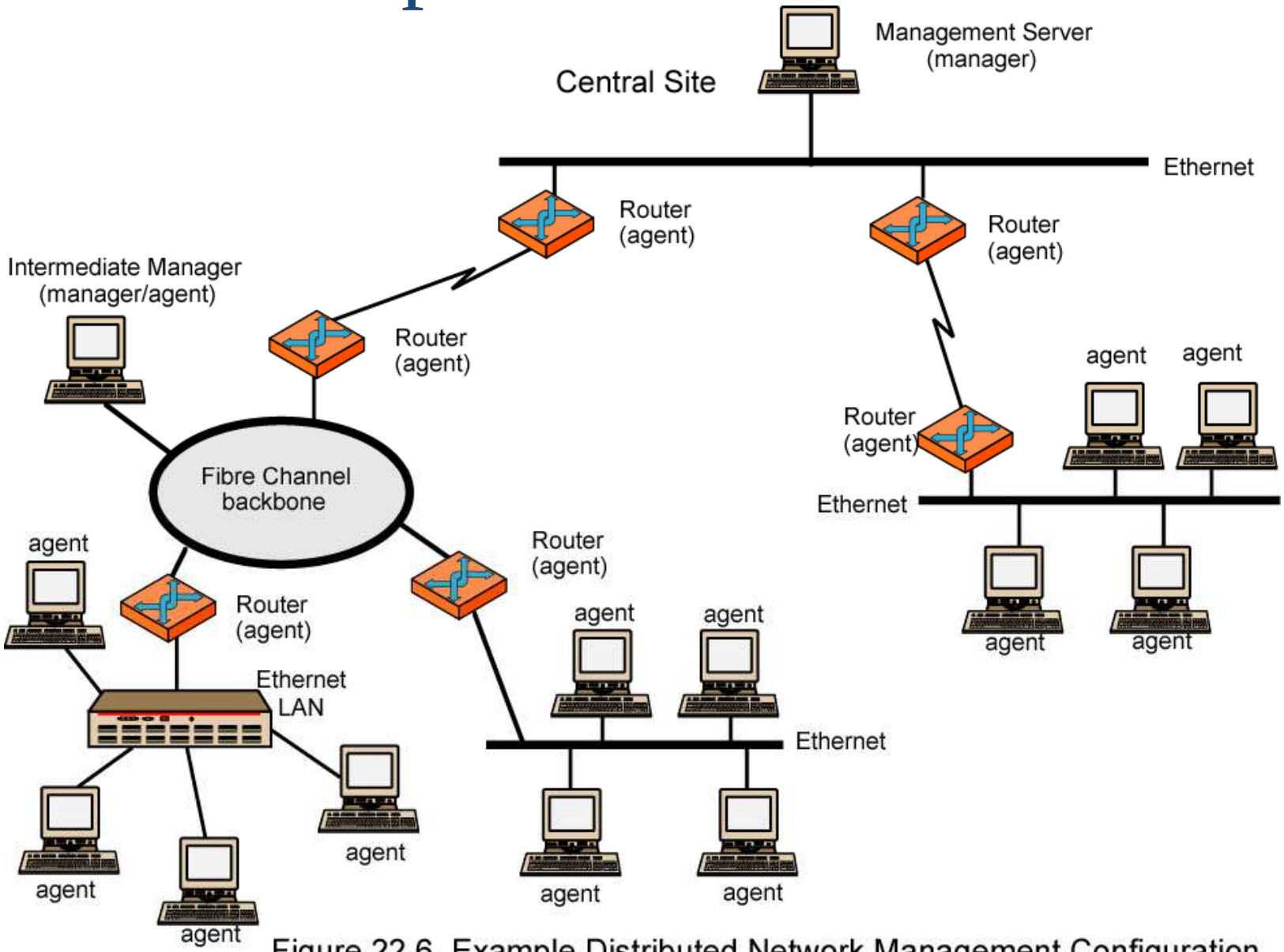


Figure 22.6 Example Distributed Network Management Configuration

Background

- Network design has generally been considered an art consisting of a set of rules acquired through experience.
  - For example the 80/20 rule where 80% of a network's traffic is local and 20% is remote.
  - "Bridge when you can, route when you must". Based on an antiquated view that bridging was easier and cheaper.
- Network technologies and requirements have increased tremendously. There are many options available now.

Factors that affect Network Design

- Capacity planning (a major factor in the design of the network).
  - Generally the solution to a problem will be “throw bandwidth to the problem”. Sometimes and especially recently it offers some relief but it is does not solve all problems.
- Delay performance
  - Has become very important in real-time services and needs to be optimized.
- Network Reliability, Maintainability, and Availability (RMA).
  - A factor that is really important for customer satisfaction.

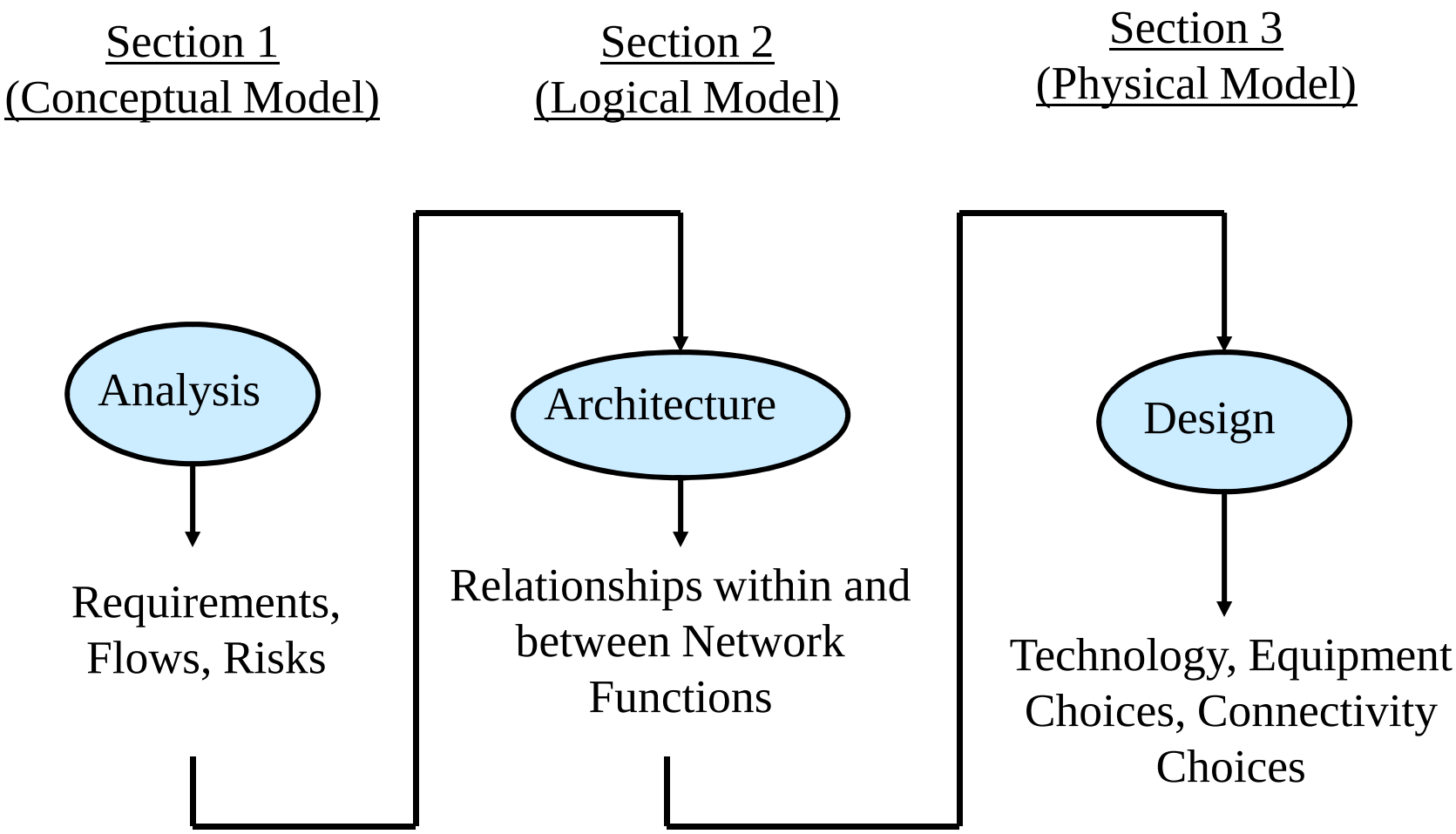
The Technical View

- A “Network” really can be thought of as of three things and they all need to be considered when working on a network design project
  - Connections
  - Communications
  - Services
- Connections: provided by Hardware that ties things together
  - Wire/Fiber Transport Mechanisms
  - Routers
  - Switches/Hubs
  - Computers

The Technical View (…)

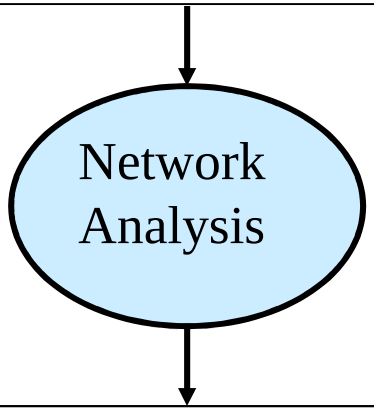
- Communications: provided by Software
  - A common language for 2 systems to communicate with each other.
  - Interoperability Protocols
    - TCP/IP (Internet/Windows NT), IPX / SPX (Novell Netware 4), AppleTalk, etc.
- Services: the Heart of Networking - specially important today: the Internet in particular is moving quickly from a connection emphasis to a service oriented network.
- Cooperation between 2 or more systems to perform some function – Applications driven
  - telnet, ftp, http, SNMP, UDP, etc.

High Level View of Network Design



Overview of Network Analysis

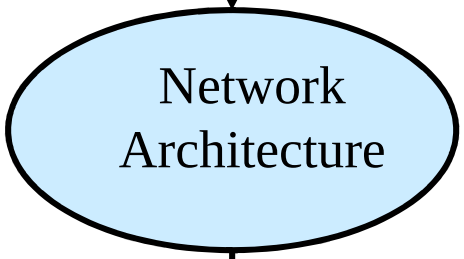
- State of existing network
- Problems with existing network
- Network goals
- Requirements from users, applications, devices



- Description for requirements for the network
- Descriptions of traffic flows
- Mappings of applications and devices to network

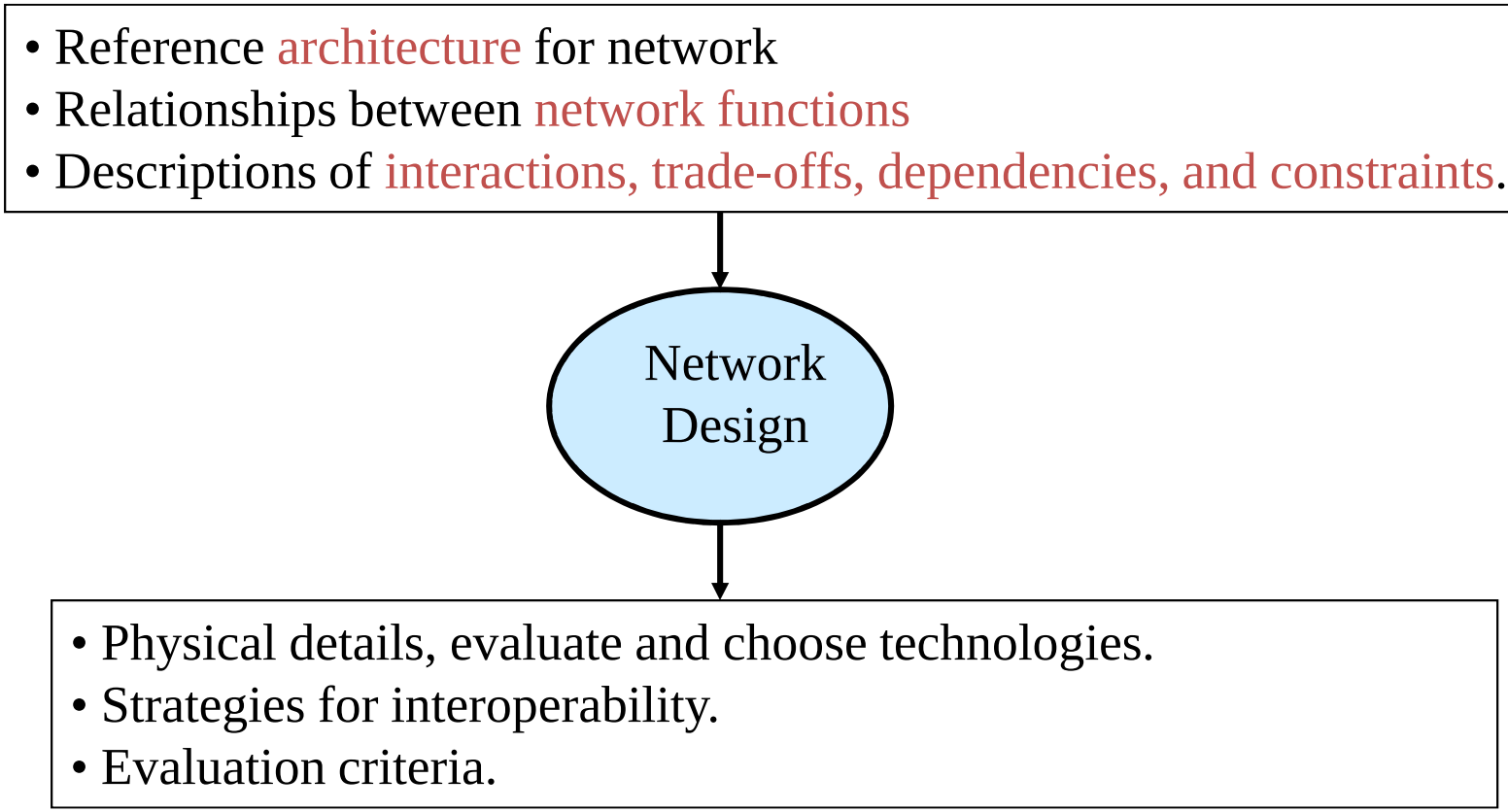
Overview of Network Architecture

- Description for requirements for network
- Descriptions of traffic flows
- Mappings of applications and devices to network

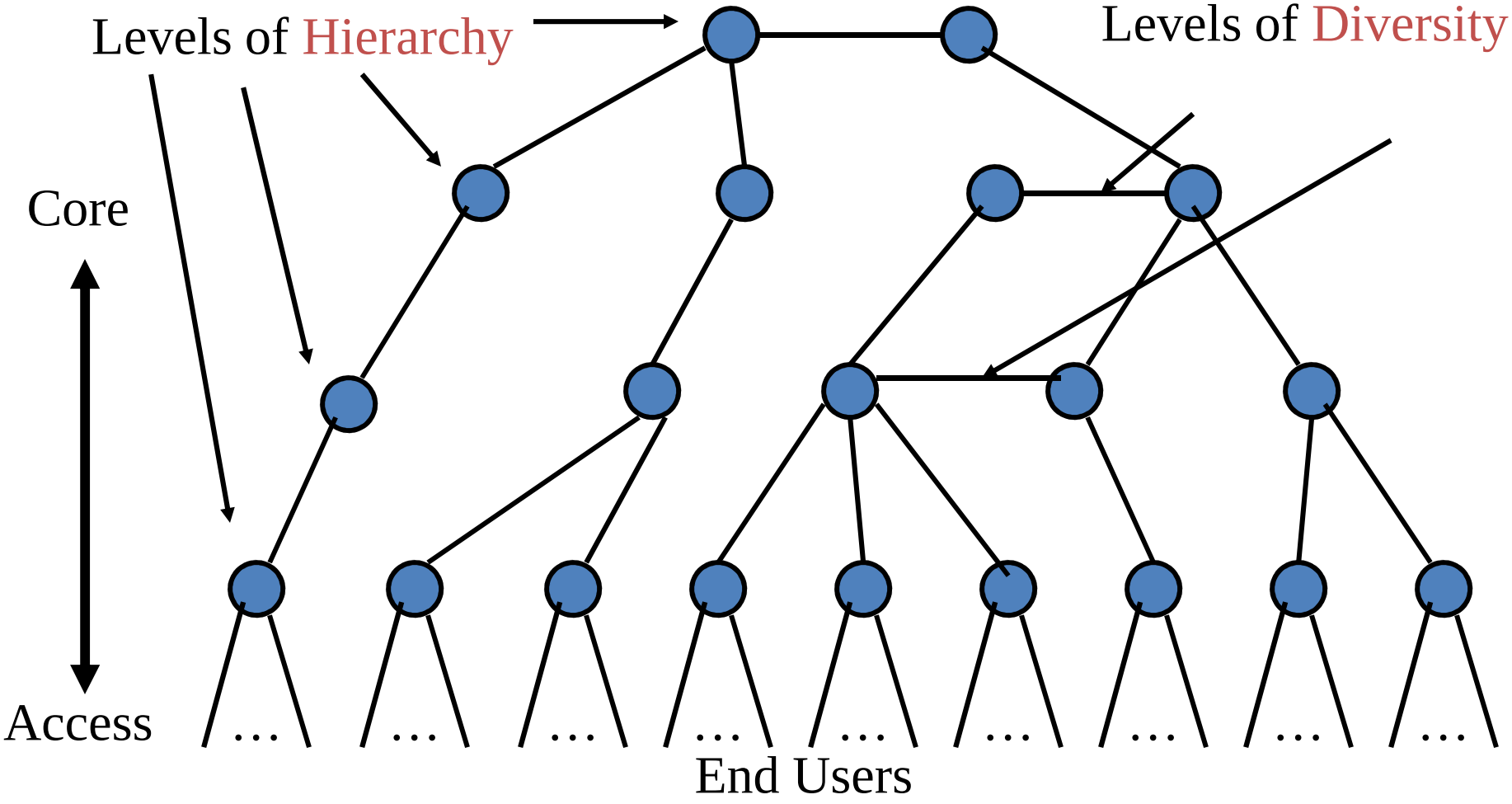


- Reference architecture for network (end to end structure).
- Relationships between functions (routing, management, performance, security).
- Descriptions of interactions, trade-offs, dependencies, and constraints.

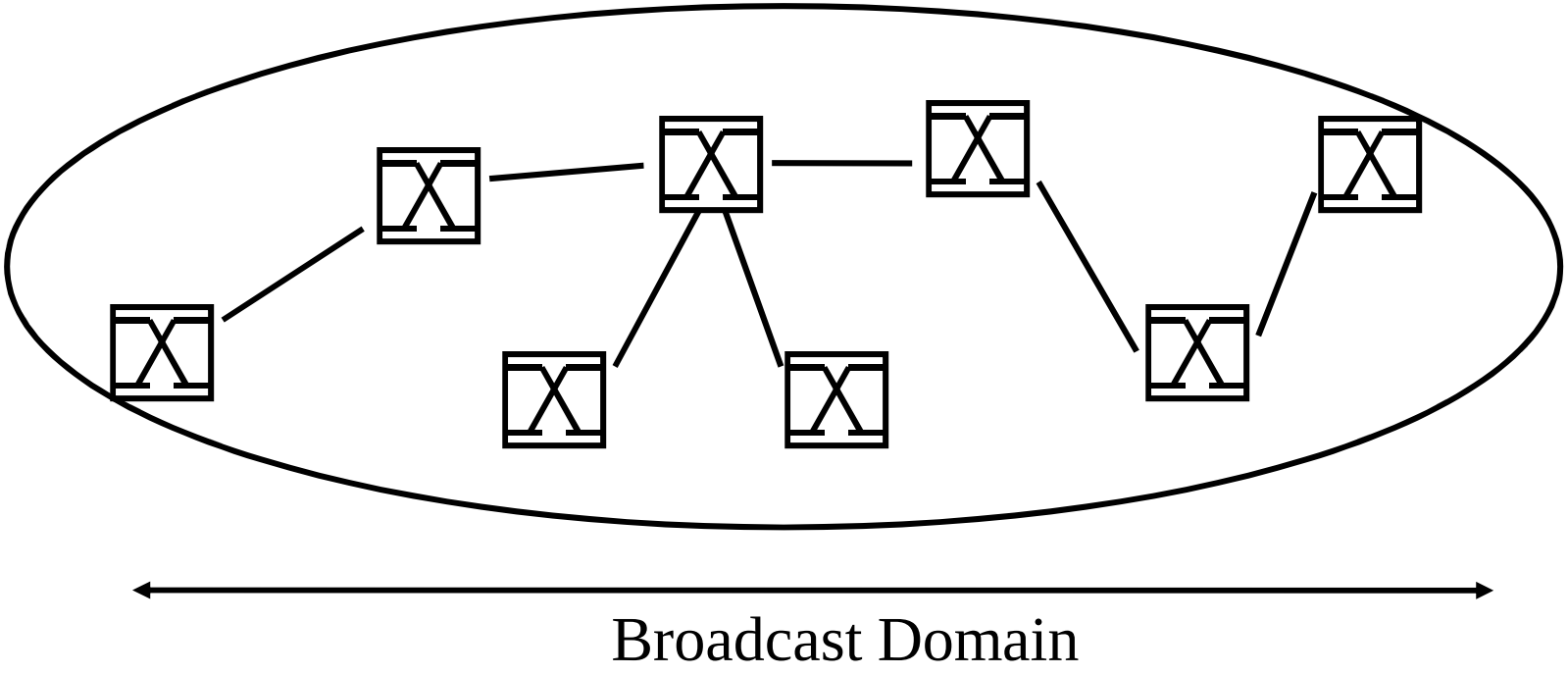
Overview of Network Design



Hierarchy

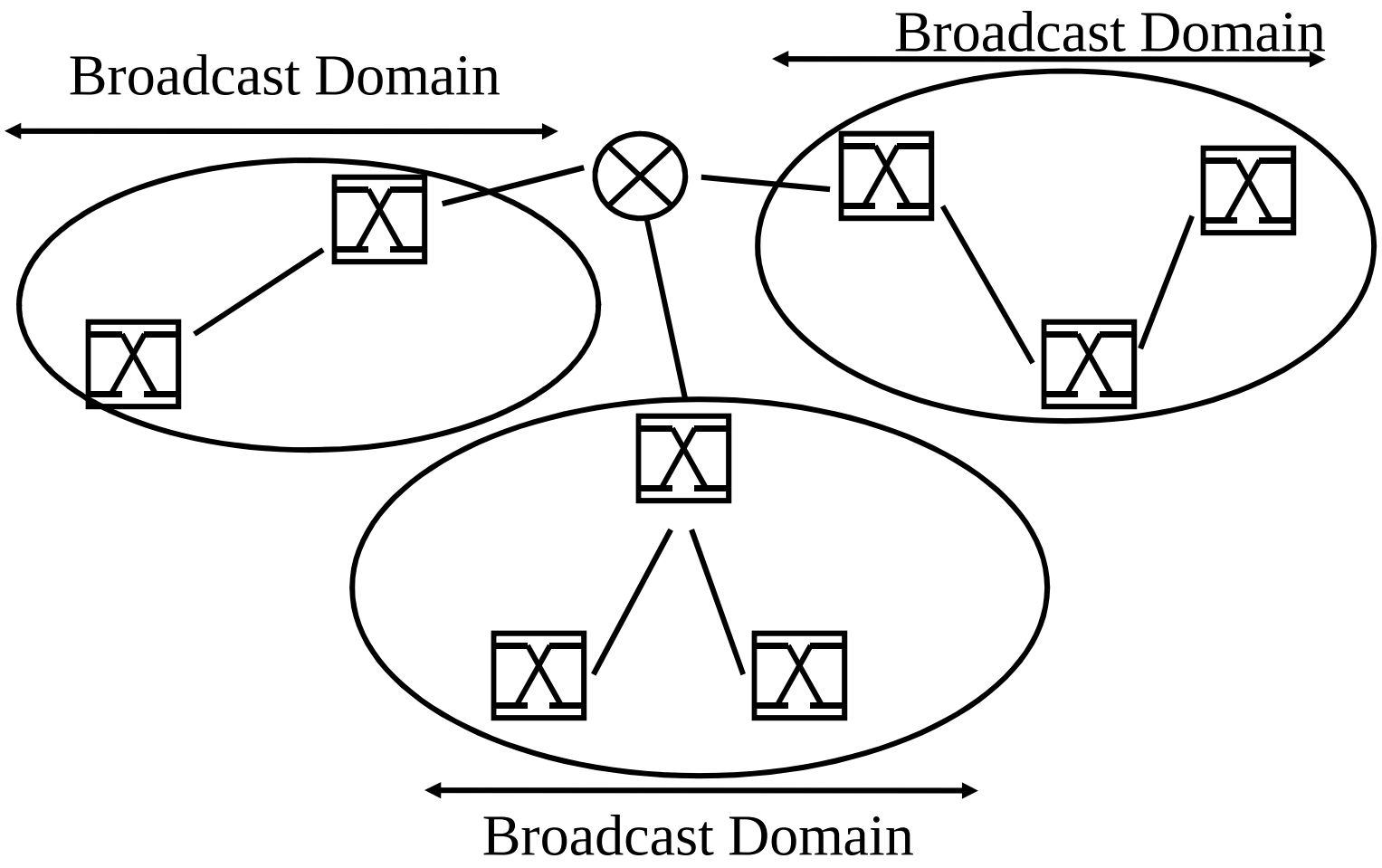

Levels of Hierarchy
Levels of Diversity
Core
Access
End Users

Network - 1 Level



Flat Bridged or Switched Network: what is the problem with this?

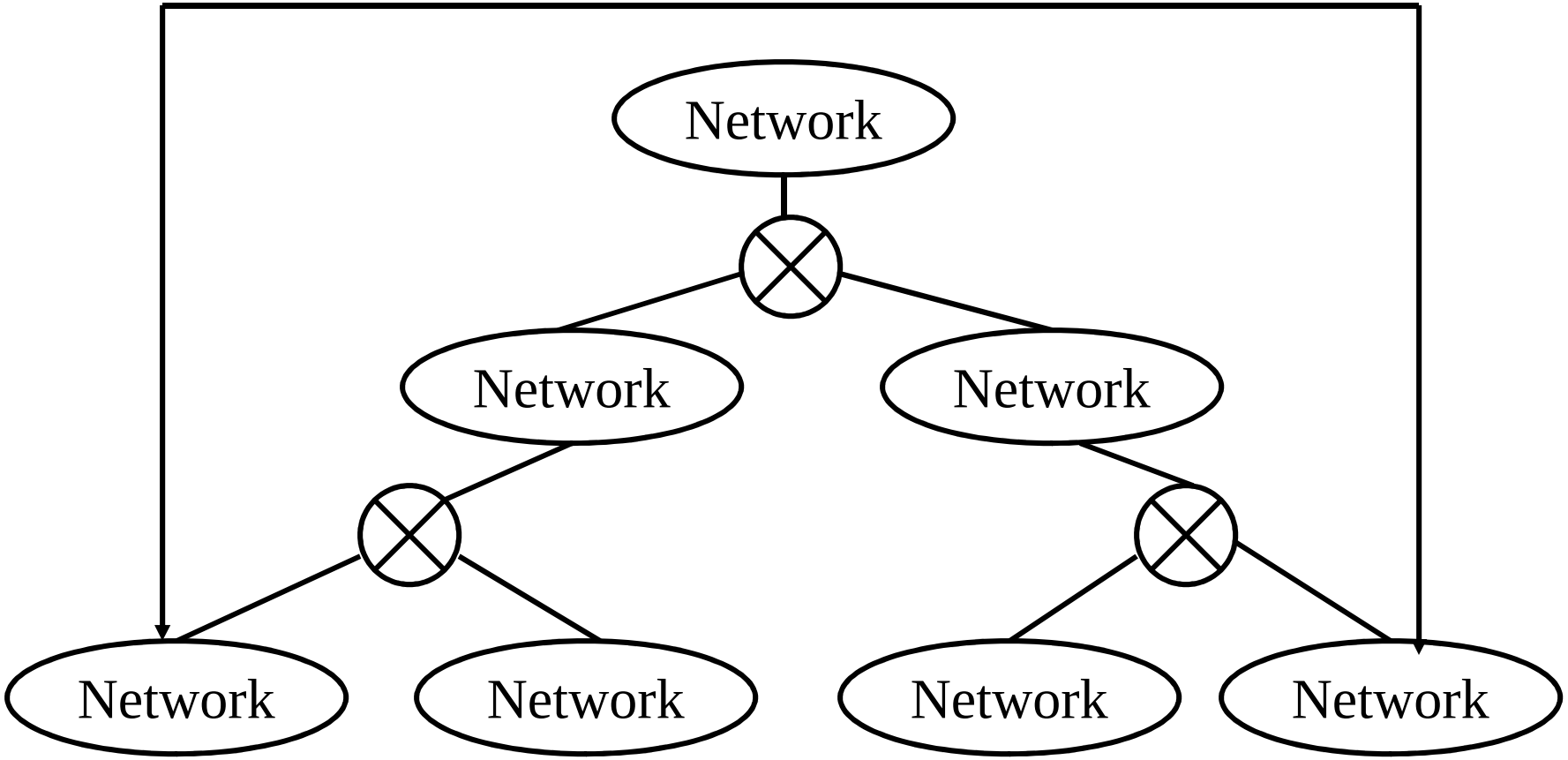
Network - 2 Levels



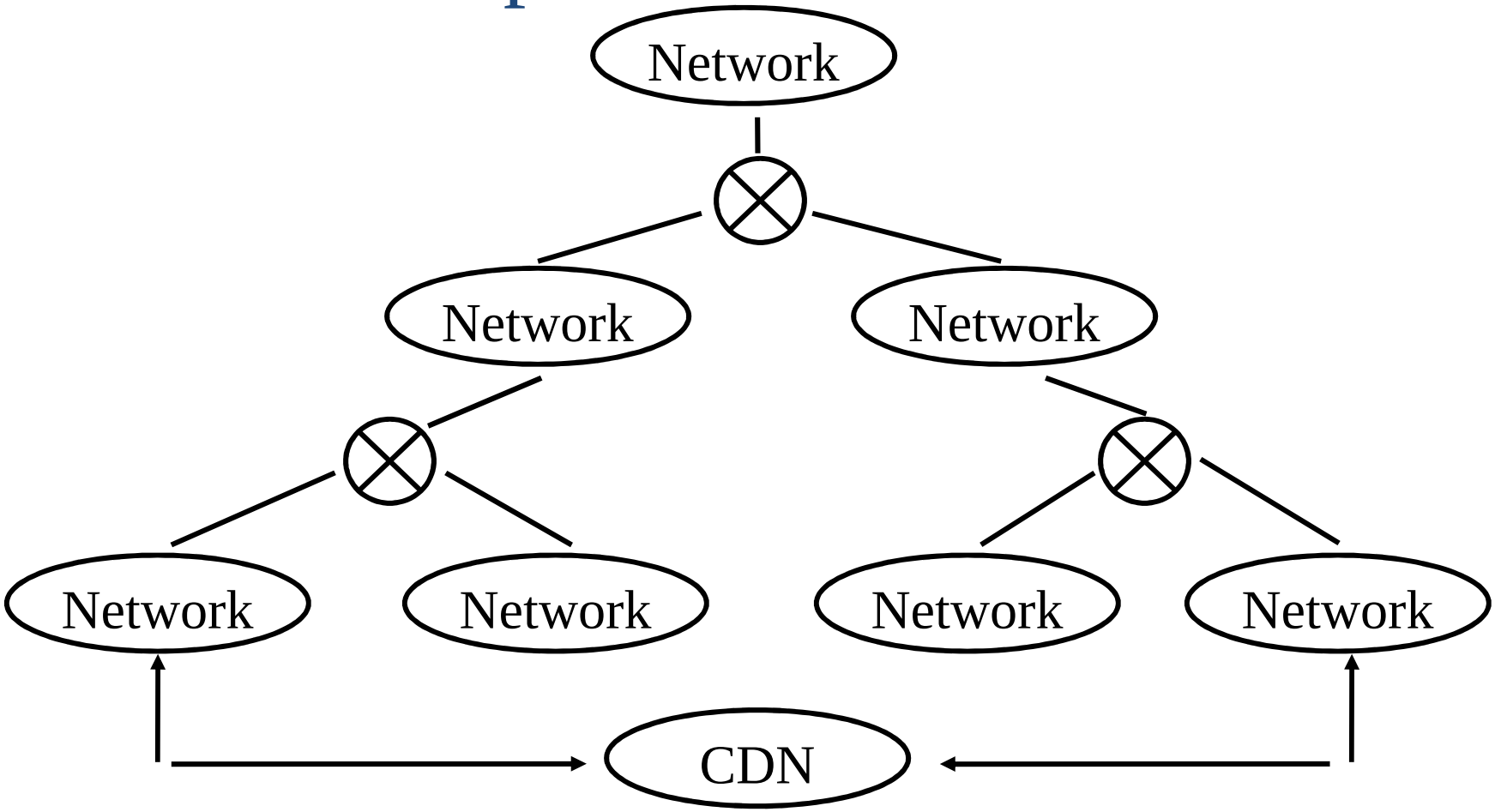
What is the hierarchy degree?

The Need for Diversity

Flows are forced through hierarchy



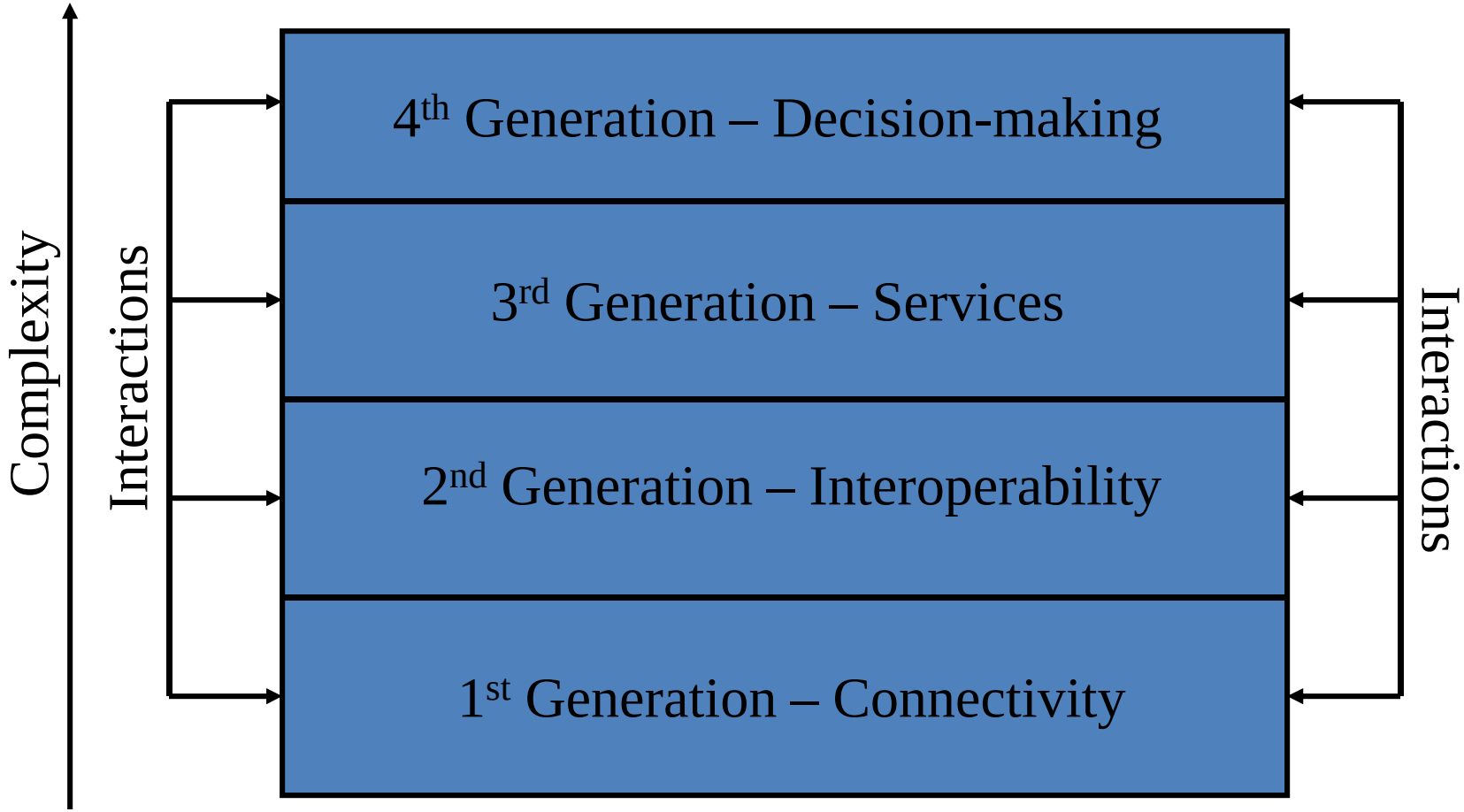
Flows Improvement with a CDN



Content Delivery Network provides direct connectivity

Diversity (aka, Interconnectivity, aka Redundancy): interconnecting the network at different levels to achieve desired performance.

Network & System Complexity



Where are we today?

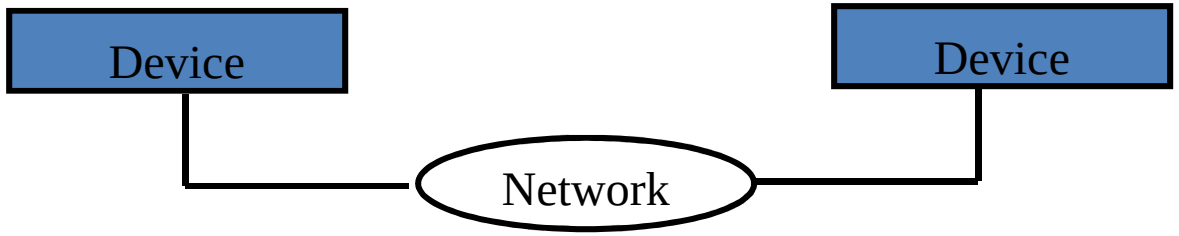
Architecture & Design Defensibility

- Very important and often overlooked part of network analysis and design.
  - During analysis you are gathering data and making decisions.
  - Details about how one got to those decisions is generally lost.
  - It is important to keep an audit trail.
    - A set of documents, data, and decisions for the architecture and design.
  - This audit would answer questions like:
    - Why did you choose this technology?
    - Why does it cost this amount?
- Time spent at this phase can save large amount of time and resources later.
- What type of information? (Time stamp it)
  - Requirements (What type of Network Requirements would you expect?)
  - Problem definitions (There is no end to these).
  - Goals, Decisions
  - Data (What type of data?)

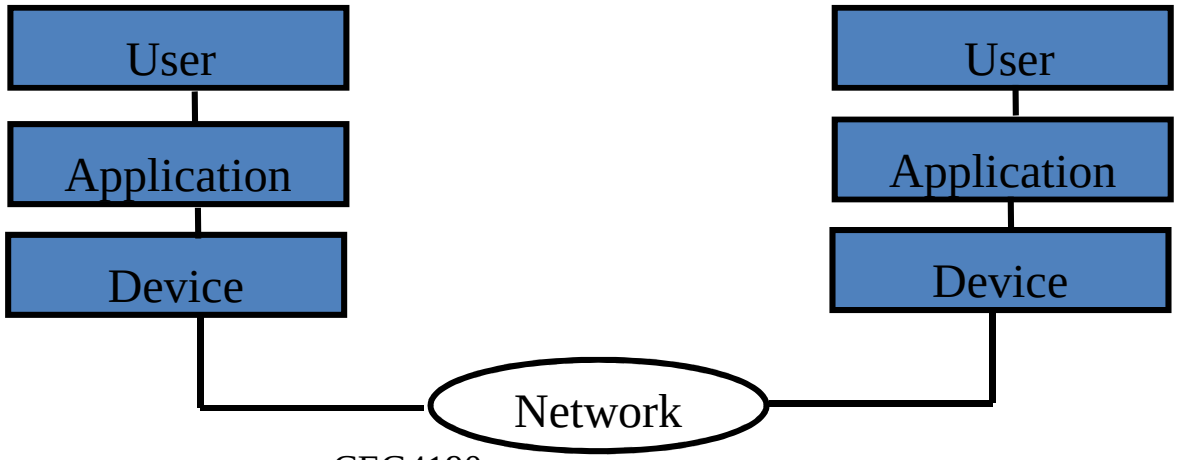
A Systems Methodology

- The idea is to view the network and a subset of its environment (what it impacts or interacts with) as a system.
  - This primarily implies looking at the services associated with the network (3rd generation networks).
  - Interactions and dependencies between the network its users, applications, and devices arises from this analysis.

- Traditional view of a system

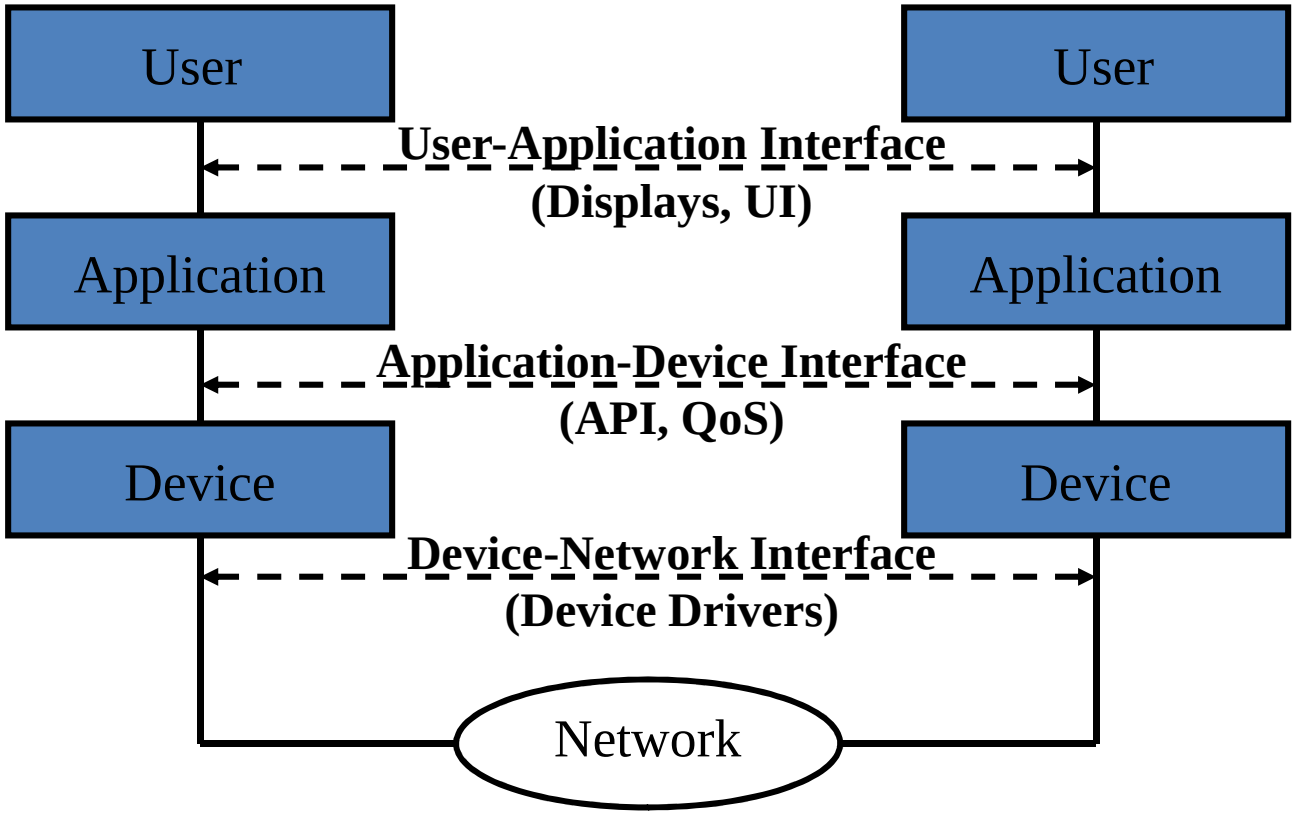


- Better generic components of a system

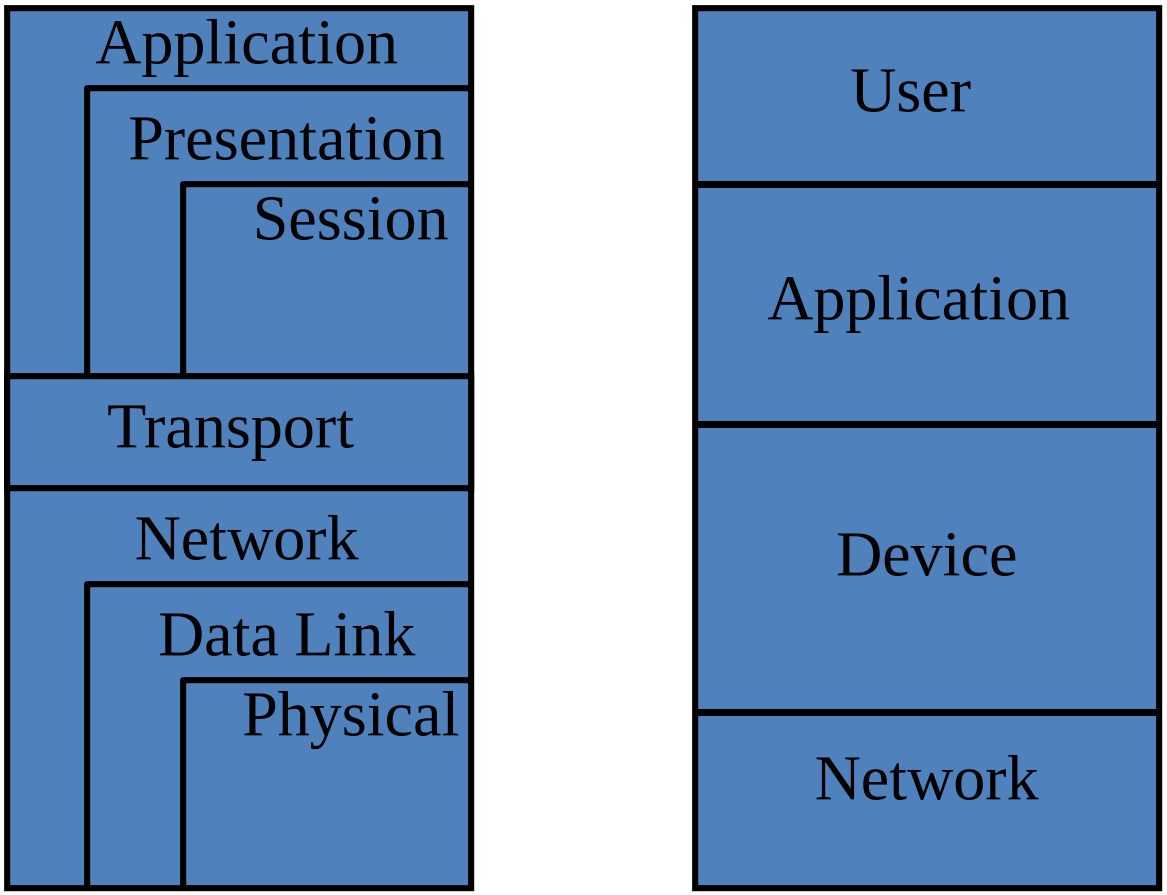


A Systems Methodology (granularity)

- Components help identify interfaces



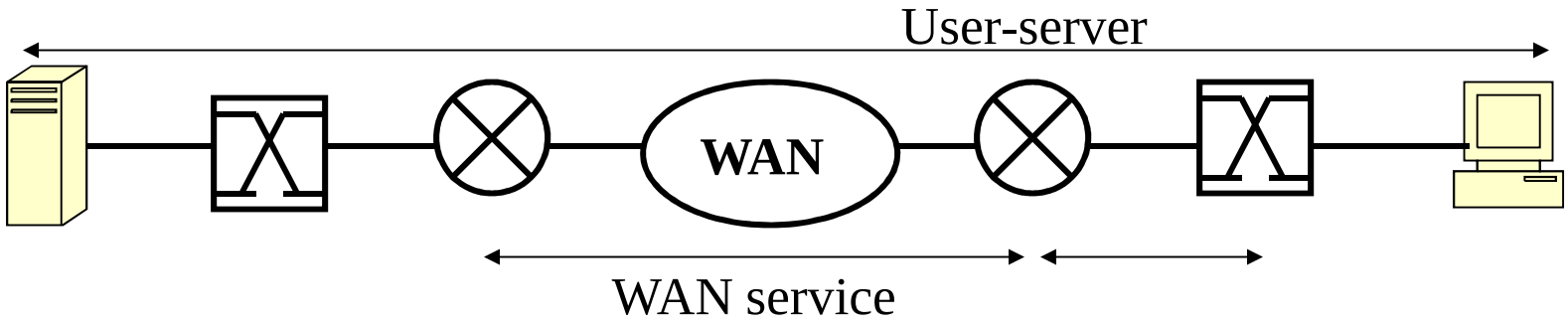
Comparison to OSI



OSI System Levels

Service Characteristics

- Service Characteristics: individual network performance and functional parameters that are used to describe the services.
  - These can be considered as requirements for the network.
  - E.g.:
    - Providing 1.5 Mb/s peak capacity to a user
    - Guaranteeing a maximum RTT of 100 msec
    - Defining a specific security level for a group of users



LAN-WAN

Service Metrics

- Services must also be configurable, measureable, and verifiable within the system to ensure that applications, users and devices are getting the services requested
  - Leads to accounting and billing
- How: using service metrics.
- Service Metrics: measurements of characteristics in the actual network to monitor, verify, and manage services.
- Services must be described and provisioned end-to-end at all network components between well-defined demarcation points.
  - Otherwise some components might not be capable of supporting the services.

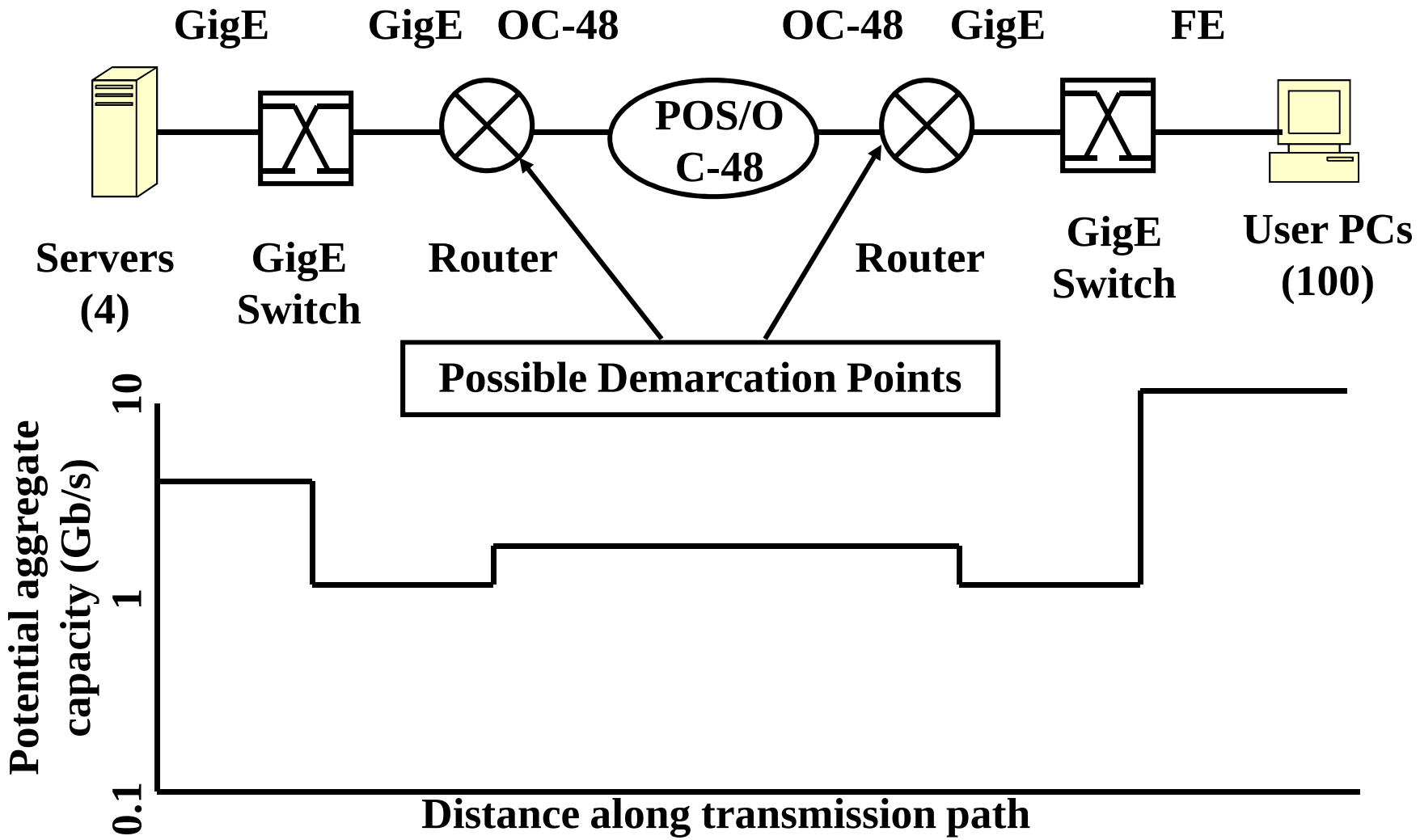
Service Levels

- Service Levels: grouping of a number of service characteristics.
- E.g., combining capacity (1.5 Mb/s) and reliability (99.99% uptime).
- Can be offered by service providers to customers, in packages:
  - Basic (No Priority)
  - Gold (High Capacity)
  - Platinum (High Capacity, Reliability, Low Delay)

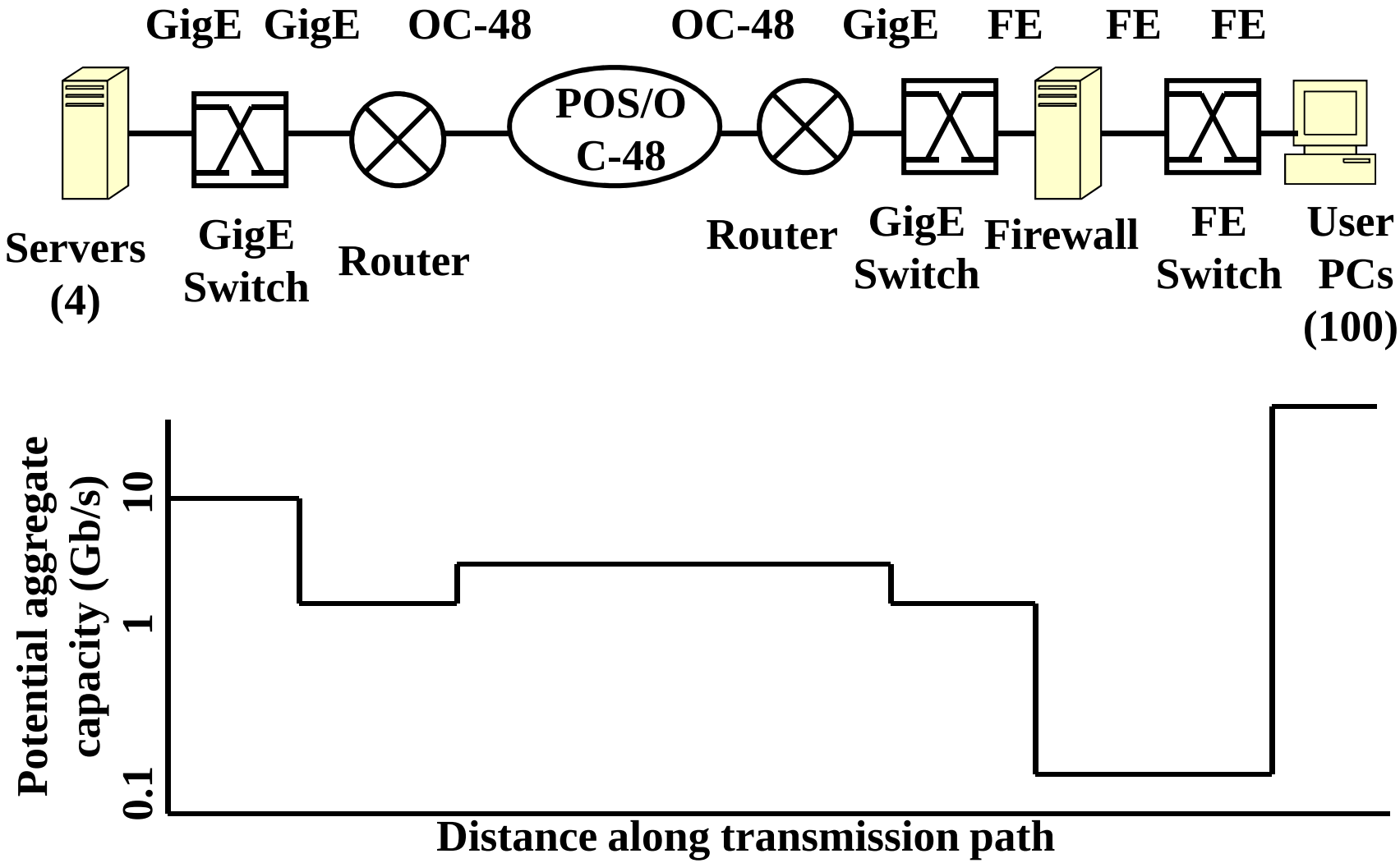
Grouping Characteristics into Services

Item	Examples
Characteristics	Delay (100 ms) Capacity (10 Mb/s) RMA (99.999% Uptime) Security (Encryption)
Service Metrics	End-to-End delay, Round-Trip delay, capacity, throughput, Buffer/Queue Utilization, priority levels.
Service Levels	Basic (No Priority) Gold (High Capacity) Platinum (High Capacity, Reliability, Low Delay)

System Components & Network Services (1)



System Components & Network Services (2)

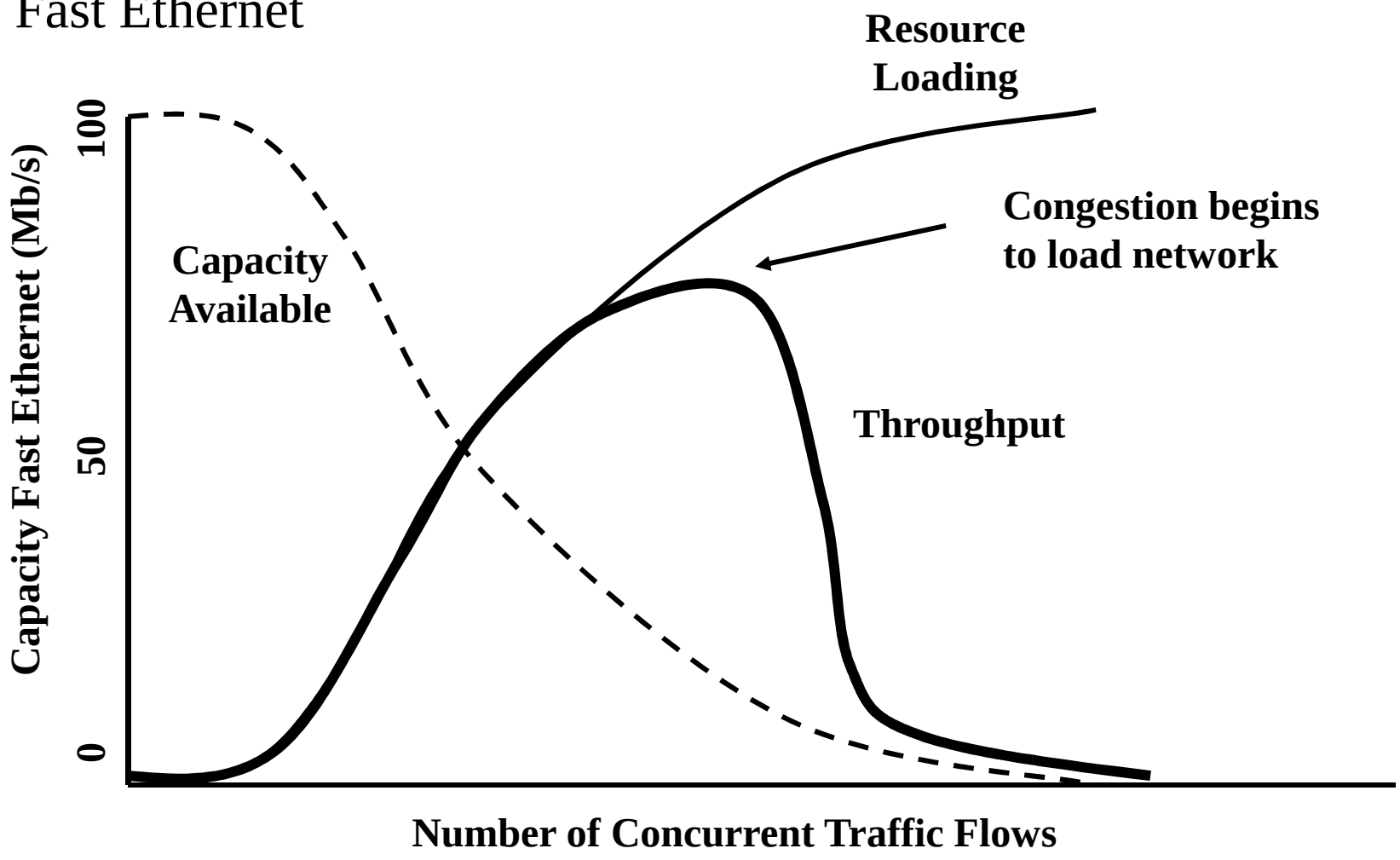


Types of Network Service

- Best-effort service
  - No control how the network will satisfy the service request. Unpredictable and unreliable service with variable performance.
- Guaranteed service
  - Opposite of best-effort service. Predictable and reliable. Implies a contract between the user and the service provider.
- Predictable service
  - Some degree of predictability without accountability. Service requirements must be configurable, measurable, and verifiable. Control of the system is required.

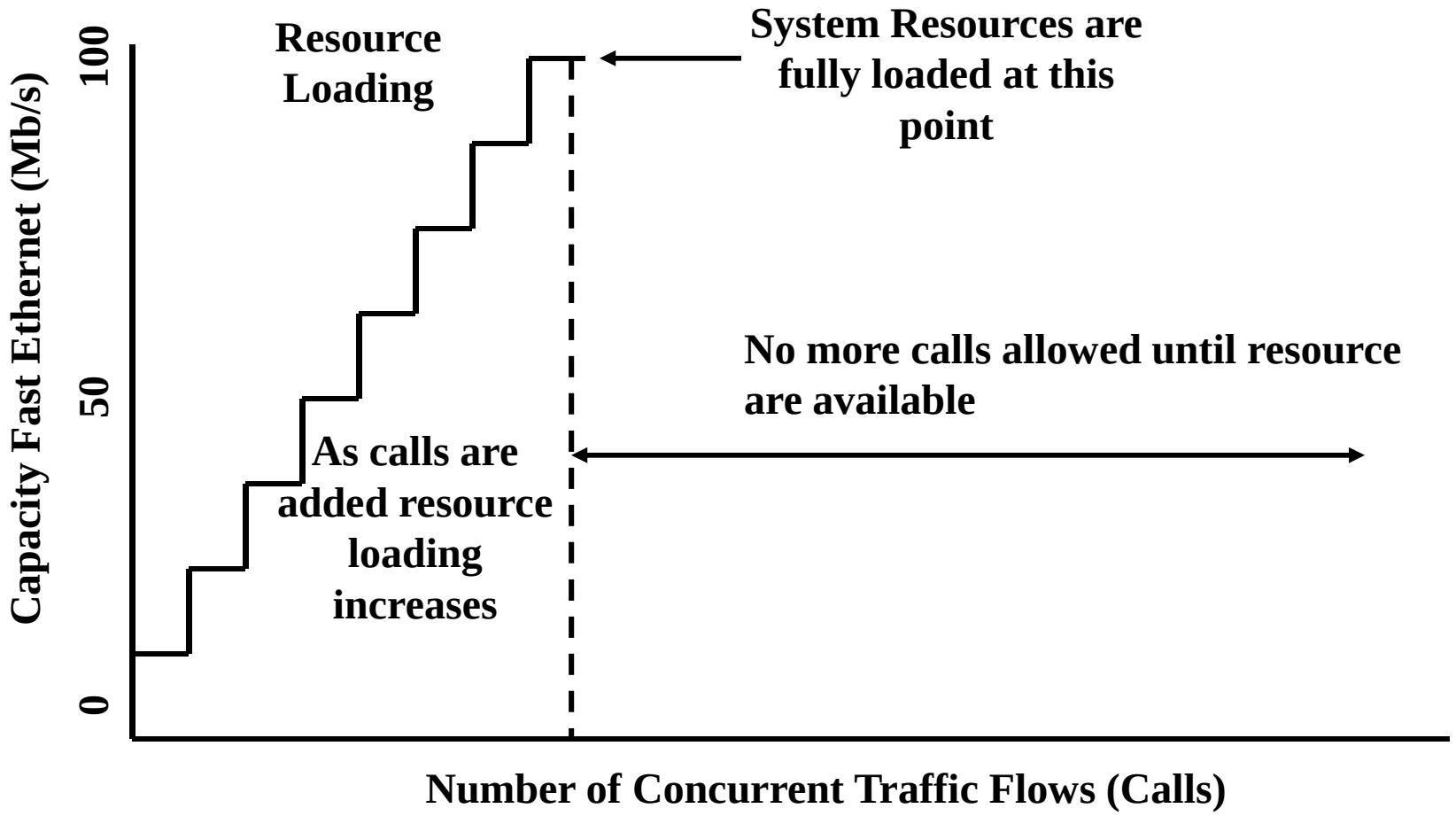
Best Effort Performance

- Fast Ethernet



Guaranteed Performance

- Telephony network, with Call Admission Control (CAC)



Best Effort vs. Guaranteed

- Best Effort: allows maximum number of traffic flows, but performance degradation likely.
- Guaranteed: performance will be met, but fewer traffic flows can be accepted.
- Many applications need a hybrid of the two (Predictable Effort).
  - E.g., VoIP requires characteristics of CAC while operating on top of best-effort Internet.

Performance Characteristics

- Capacity – is a measure of the system's ability to transfer information (voice, data, video, etc).
- Delay – is a measure of the time difference in the transmission of information across the system.
- RMA – refers to Reliability, Maintainability, and Availability

Capacity

- Bandwidth: theoretical capacity of one or more network devices or communication links in the system.
  - Raw capacity does not take into account overhead from higher-layer protocols or performance loss due to device inefficiencies.
- Throughput: is the realizable capacity of the system or its network devices.
- E.g., theoretical SONET OC-3c link capacity (bandwidth) is 155.52 Mb/s
  - This does not include data-link, network, or transport-layer protocol overhead.
  - Performing at line rate when T=155.52 Mb/s
- In reality, when tested with TCP, SONET OC-3c link capacity (throughput) is 80 to 128 Mb/s
  - Where does the majority of this overhead coming from?

Delay

- Sources:
  - Propagation, transmission, queuing, and processing
- There are several ways to measure delay
  - Direction (end-to-end, round-trip)
  - Latency – time it takes to process information and reply. E.g., response time of a network device.
  - Jitter or delay variation – change in delay over time. Real-time and near real-time require strict delay variation.
    - Jitter is NOT delay

RMA

- Reliability: a statistical indicator of the frequency of failure of the network.
  - Represents un-scheduled outages of services.
  - Predictable behavior – delivery of information must occur within well-known time boundaries.
- Maintainability: a statistical measure of the time to restore the system to fully operational status after it has experienced a fault.
  - It is generally expressed as a mean-time-to-repair (MTTR).
- Availability: relationship between the frequency of mission-critical failures and the time to restore the service.
  - Defined as the mean time between failures divided by the sum of mean time to repair and mean time between failures:

$$A = (MTBF) / (MTBF + MTTR)$$

Thank You!