EE5722/EE4272:
Computer Networks

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Introduction of EE5722-EE4272

Course Syllabus
Course Schedule
Grading Policies for HWs & Quizzes
Pre-Course Survey

Introduction of Computer Networks

Communication vs. Computer/Data Networks
- Applications of Computer Networks
- Requirements & Issues for Network Design
- Network Layering Architectures & Protocols
- Network Performance Measurements

Communication Networks vs. Computer/Data Networks

What are the differences between…
- Applications
- Underline technologies
Applications of Computer Networks

- Surfing the Web
  - Request/Reply of Client/Server
- Streaming Audio & Video
  - Video-on-demand: (One directional)
  - Video Conference: (Interactive)
- Various applications ->Different requirements
  - Different Technologies

High-level Major Requirements & Issues - Network Designers' Perspectives

- General Design Goals: cost-effective design i.e., network resources are efficiently utilized and fairly allocated to different users

- Major Requirements
  - Connectivity
  - Cost-Effective Resource Sharing
  - Reliability

Building Blocks & Connectivity

- Nodes: PC, special-purpose hardware...
  - Host: edge node for end user
  - Switch: node to forward packets
  - Router/Gateway: node connects two/more different networks
- Links: coaxial cable, optical fiber, wireless links

- Direct connectivity
  - point-to-point
  - multiple access
  - Ref. Chapter 2

Indirect Connectivity

- Switched networks
  - switch

- Internetworks
  - router
  - gateway
**Switch vs. Router**

- **Switch:**
  - A network node that forwards packets from inputs to outputs based on header information in each packet.
  - It differs from a router mainly in that it typically does not interconnect networks of different types.

- **Router:**
  - A network node connected to two or more networks that forwards packets from one network to another.
  - It makes use of an internet protocol and assumes that all of the attached devices on the networks use the same communications architecture and protocols.

**Issues Related to Connectivity**

- **Switching Strategies**
  - Circuit switching (telephone network): dedicated circuit; send/receive a bit stream
  - Packet switching (Internet): store-and-forward; shared channel; send/receive messages (packets)
  - Ref. Chapter 3

- **Addressing and Routing**
  - Address: byte-string that identifies a node; usually unique
    - Types of addresses
      - Unicast: node-specific
      - Broadcast: all nodes on the network
      - Multicast: some subset of nodes on the network
  - Routing: process of forwarding messages towards the destination node based on its address
  - Ref. Chapter 4

**High-level Major Requirements**

- Network Designers' Perspectives
  - Connectivity
  - Cost-Effective Resource Sharing
  - Reliability

**Cost-Effective Resource Sharing**

- Must share (multiplex) network resources (nodes & links) among multiple users

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**Examples:**

(a) L1 L2 L3

(b) DMUX MUX Trunk group

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**Figure:**

- Diagram showing network topology with nodes and links.
Conventional Multiplexing Strategies

- Synchronous Time-Division Multiplexing (STDM)
- Frequency-Division Multiplexing (FDM)

With STDM, each channel gets all of the bandwidth periodically during brief intervals of time.

With FDM, each channel continuously gets a fraction of the bandwidth.

Limitations?

Statistical Multiplexing

- On-demand (not predetermined) time-division
- Schedule link on a per-packet basis (fairness): FIFO, Round-robin… Scheduling problem (Ref. Chapter 6)
- Packets from different sources interleaved on link
  - What about if only one source has data?
  - Why buffer is needed?
    - Buffer packets that are contending for the link: QoS
    - Buffer (queue) overflow is called congestion

High-level Major Requirements

- Network Designers’ Perspectives

- Connectivity
- Cost-Effective Resource Sharing
- Reliability

What Goes Wrong in the Network?

- Reliability Issue

- Bit-level errors (light, power, microwave interference -> error detection/correction): single or burst error
  - depend on transmission med.: coaxial cable, optical fiber? (1/10^5~7: 1/10^{12}~14)
  - Ref. Chapter 2
- Packet-level errors (congestion control):
  - Ref. Chapter 4
- Link & node failures (network survivability)
Network Architecture

**Networks are complex!**
- many "pieces":
  - hosts
  - routers
  - links of various media
  - applications
  - protocols
  - hardware, software
- **Substantial requirements**
- Evolve to accommodate changes
  - Underline technologies
  - Demands by applications

**Question:**
Is there any hope of organizing structure of network?
Or at least our discussion of networks?

Layering Network Architecture: Blueprint

- Use abstractions (unified model) to hide complexity
- Abstractions naturally lead to layering
- Can have alternative abstractions at each layer

**Advantages of Layering**
- Manageable
- Modular design
- Change implementations of services

Layering of airline functionality

(Source: Computer Network – A Top-down Approach Featuring the Internet)

Layers: each layer implements a service
- via its own peer-to-peer internal-layer actions
- relying on services provided by layer below
Internet Protocol Architecture/Stack

- **Application**: supporting network applications
  - FTP, SMTP, HTTP
- **Transport**: host-host data transfer
  - TCP, UDP
- **Network**: routing of datagrams from source to destination
  - IP, routing protocols
- **Link**: data transfer between neighboring network elements
  - PPP, Ethernet
- **Physical**: bits “on the wire”
  - Defined by Internet Engineering Task Force (IETF)

OSI (open systems interconnection) Architecture

Protocols
- building blocks of a network architecture layer
- Each protocol object has two different interfaces
  - **service interface**: operations **locally**
  - **peer-to-peer interface**: messages exchanged w/ **peer**
What’s a protocol?

A human communication protocol and a computer network protocol.

**Human protocols:**
- “What’s the time?”
- “I have a question”
- Introductions

**Network protocols:**
- Machines rather than humans
- All communication activity in the Internet governed by protocols

Specific messages sent, specific actions taken when messages received, or other events.

Performance Metrics:

- **Bandwidth (throughput):**
  - Nyquist Bandwidth & Shannon Capacity Formula
  - Data transmitted per time unit (bps)
  - Link (point-to-point) vs. end-to-end

- **Latency (delay):**
  - Time to send message from point A to point B
  - One-way vs. round-trip time (RTT)
  - Components
    - Latency = Propagation + Transmit + Queue
    - Propagation = Distance / c (one-way or RTT)
    - Transmit = Size / Bandwidth

- **Throughput (end-to-end):**
  - TransferTime = TransferSize / TransferTime
  - Effective end-to-end throughput achievable
**Delay x Bandwidth Product**

- Amount of data “in flight” or “in the pipe” (utilization)
- Example: 100ms x 45Mbps = 560KB

**Application Performance Needs**
- **bandwidth** requirements (upper bound): burst w/ peak rate
- **jitter**: variation in latency (inter-packet gap)

Queueing delay varies w/ time