Goals of This Class

- Understand principles and practice of networking
- How are modern networks designed? Operated? Managed?
- Performance and design trade-offs in network protocols and applications
- How do network applications work? How to write applications that use the network?
  - Hands-on approach to understand network internals
- How will different aspects of networking evolve in the future?

Goal of Networking

- Enable communication between network applications on different end-points: computers, cell phones...
- Application? Web, Peer to Peer, Streaming video, IM
- Communication? Transfer bits or information across a “network”
- Network must understand application needs/demands
  - What data rate?
  - Traffic pattern? (bursty or constant bit rate)
  - Traffic target? (multipoint or single destination, mobile or fixed)
  - App sensitivity? (to delay, “jitter”, loss)
  - Difficulty: Network may not know these in the first place!
- How does the application “use” the network?
  - Peer to peer: how to find nearest host
  - Web: how to modulate sending rate? Coexist with other users/apps?
Defining a “Network”

- Network = nodes + links
  - Will build on this soon

- Intentionally vague. There are several different networks:
  - The Internet
  - Wisc CS network
  - Telephone network
  - Home wireless networks

- Our focus on Internet
  - Also explore important common issues and challenges

Challenges for Networking

- Accommodate different geographic scopes
  - The Internet vs. home network

- Enable scale
  - CS network vs. the Internet

- Seamlessly integrate different application types
  - Email vs. video conferencing

- Independent administration and Trust
  - Corporate network – owned by one entity
  - Internet owned and managed by 17,000 network providers
  - Independent, conflicting interests

Network Building Block: Links

- "Physical"-layer questions
  - Wired or wireless
  - Voltage (Electrical) or wavelength (optical)

- "Link"-layer issues: How to send data?
  - Medium access – can either side talk at once?
  - Data format?
Basic Building Block: Links

- But what if we want more hosts?

![Diagram](wires_for_everybody)

- Wires for everybody?
- How many wires?

- How many additional wires per host?
- Scalability?

Key Idea: Multiplexing

- Multiplex: share network resources
  - Resources need “provisioning”
  - Grow at slower rate than number of nodes

- How to share? Switched network
  - Party "A" gets resources sometimes
  - Party "B" gets them sometimes

- Interior nodes act as “Switches”

Circuit Switching

- Source first establishes a circuit to destination
  - Switches along the way stores info about connection
    - Possibly allocate resources
    - Different src-dst's get different paths

- Source sends the data over the circuit
  - No address required since path is established beforehand

- The connection is explicitly set up and torn down

- Switches use TDM (digital) or FDM (analog) to transmit data from various circuits
Switching in the Telephone Network

Circuit Switching Discussion

• Positives
  - Fast and simple data transfer, once the circuit has been established
  - Predictable performance since the circuit provides isolation from other users
    - E.g. guaranteed max bandwidth

• Negatives
  - How about bursty traffic
    - Circuit will be idle for significant periods of time
    - Also, can't send more than max rate
  - Circuit set-up/tear down is expensive
  - Also, reconfiguration is slow
    - Fast becoming a non-issue

Packet Switching

• Source sends information as self-contained packets
  - Packets have an address,
  - Source may have to break up single message in multiple packets
• Packets travel independently to the destination host
  - Switches use the address in the packet to determine how to forward the packets
    - “Store and forward”
• Analogy: a letter in surface mail
Benefits of Statistical Multiplexing

TDM: Flow gets chance in fixed time-slots
SM: Flow gets chance on demand; no need to wait for slot

Packets vs. Circuits

- Efficient
  - Can send from any input that is ready
  - No notion of wastage of resources that could be used otherwise
- Contention (i.e. no isolation)
  - Congestion
  - Delay
- Accommodates bursty traffic
  - But need packet buffers
- Address look-up and forwarding
  - Need optimization
- Packet switching pre-dominant
  - Circuit switching used on large time-scales, low granularities

Internetwork

- A collection of interconnected networks
- Networks: Different depts, labs, etc.
- Router: node that connects different networks
- Host: network endpoints (computer, PDA, light switch, ...)
- Together, an independently administered entity
  - Enterprise, ISP, etc.
Internetwork Challenges

- Many differences between networks
  - Address formats
  - Performance - bandwidth/latency
  - Packet size
  - Loss rate/pattern/handling
  - Routing
- How to translate and inter-operate?
  - Routers are key to many of these issues

“The Internet”

- Internet vs. internet
- The Internet: the interconnected set of networks of the Internet Service Providers (ISPs) and end-networks, providing data communications services.
  - Network of internetworks, and more
  - About 17,000 different ISP networks make up the Internet
  - Many other “end” networks
  - 100,000,000s of hosts

Internet Design Issues

- Extra Slides...
  - We will cover these topics in greater detail in future lectures
Some Key "Internet" Design Issues

Need:
1. naming,
2. addressing and
3. routing
4. ...

Key Issues: Naming/Addressing

What's the address for www.wisc.edu?
It is 144.92.104.243

Translates human readable names to logical endpoints

Key Issues: Routing

Routers send packet towards destination
Key Issues: Network Service Model

- **What is the service model?**
  - Defines what to expect from the network
  - *Best-effort*: packets can get lost, no guaranteed delivery
- **What if you want more?**
  - Performance guarantees (QoS)
  - Reliability
    - Corruption
    - Lost packets
  - In-order delivery for file chunks
  - Etc...

What if the Data gets Corrupted?

Problem: Data Corruption

Solution: Add a checksum

What if the Data gets Lost?

Problem: Lost Data

Solution: Timeout and Retransmit
What if Data is Out of Order?

Problem: Out of Order

Solution: Add Sequence Numbers

Meeting Application Demands

• Sometimes network can do it
  - E.g., Quality of Service
    - Benefits of circuit switching in packet-switched net
    - Hard in the Internet, easy in restricted contexts
    - Lecture 20

• OR hosts can do it
  - E.g., end-to-end Transport protocols
    - TCP performs end-to-end retransmission of lost packets
e to give the illusion of a reliable underlying network.
    - Lectures 16-19

To Summarize...

Networks implement many functions
• Links
• Sharing/Multiplexing
• Routing
• Addressing/naming
• Reliability
• Flow control
• Fragmentation
• Etc....