# Top-Down Network Design

## Chapter Two

### Analyzing Technical Goals and Tradeoffs

# Technical Goals

- Scalability
- Availability
- Performance
- Security
- Manageability
- Usability
- Adaptability
- Affordability

# Scalability

- Scalability refers to the ability to grow
- Some technologies are more scalable
  – Flat network designs, for example, don't scale well
- Try to learn
  – Number of sites to be added
  – What will be needed at each of these sites
  – How many users will be added
  – How many more servers will be added

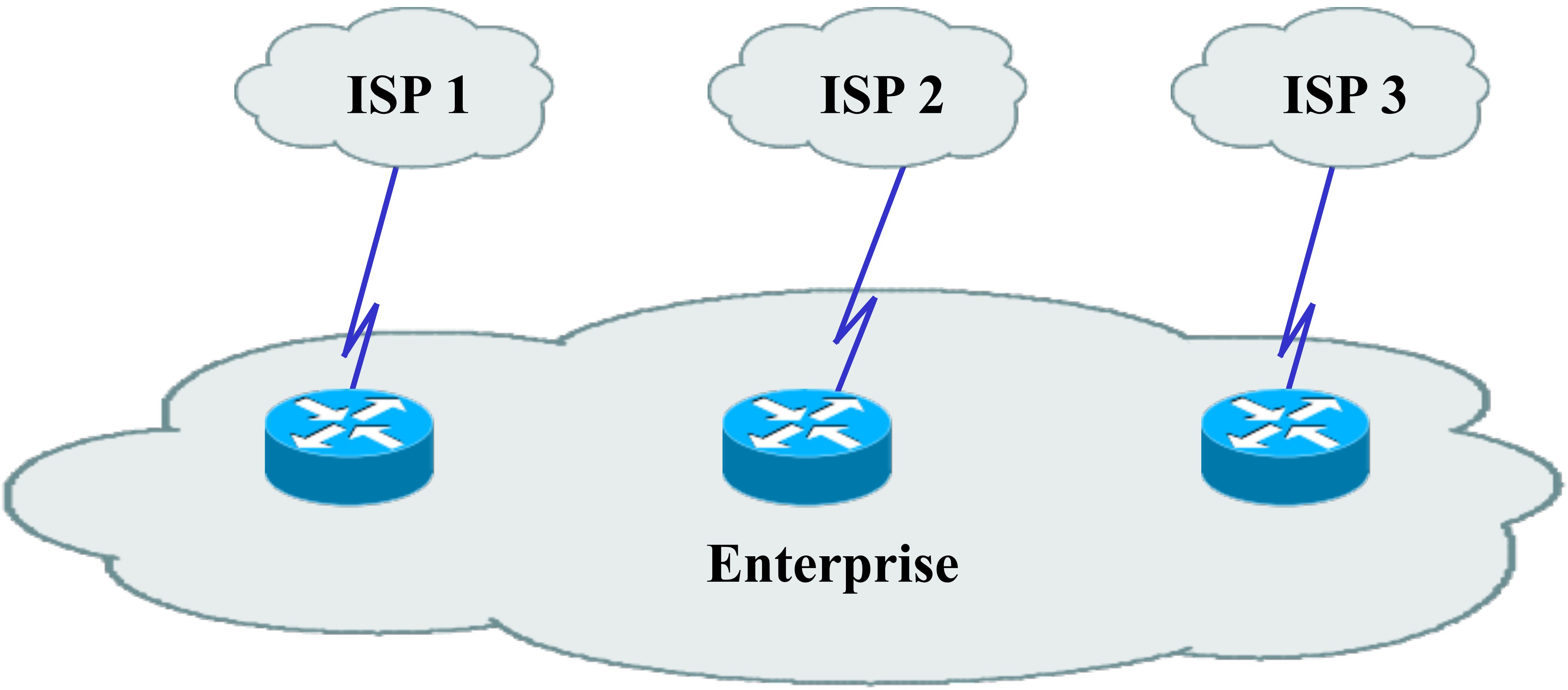
# Availability

- Availability can be expressed as a percent uptime per year, month, week, day, or hour, compared to the total time in that period
  - For example:
    - 24/7 operation
    - Network is up for 165 hours in the 168-hour week
    - Availability is 98.21%
- Different applications may require different levels
- Some enterprises may want 99.999% or "Five Nines" availability

# Availability
# Downtime in Minutes

| | Per Hour | Per Day | Per Week | Per Year |
|---|---|---|---|---|
| 99.999% | .0006 | .01 | .10 | 5 |
| 99.98% | .012 | .29 | 2 | 105 |
| 99.95% | .03 | .72 | 5 | 263 |
| 99.90% | .06 | 1.44 | 10 | 526 |
| 99.70% | .18 | 4.32 | 30 | 1577 |

# 99.999% Availability May Require Triple Redundancy




- Can the customer afford this?

# Availability

- Availability can also be expressed as a mean time between failure (MTBF) and mean time to repair (MTTR)
- Availability = MTBF/(MTBF + MTTR)
  - For example:
    - The network should not fail more than once every 4,000 hours (166 days) and it should be fixed within one hour
    - 4,000/4,001 = 99.98% availability

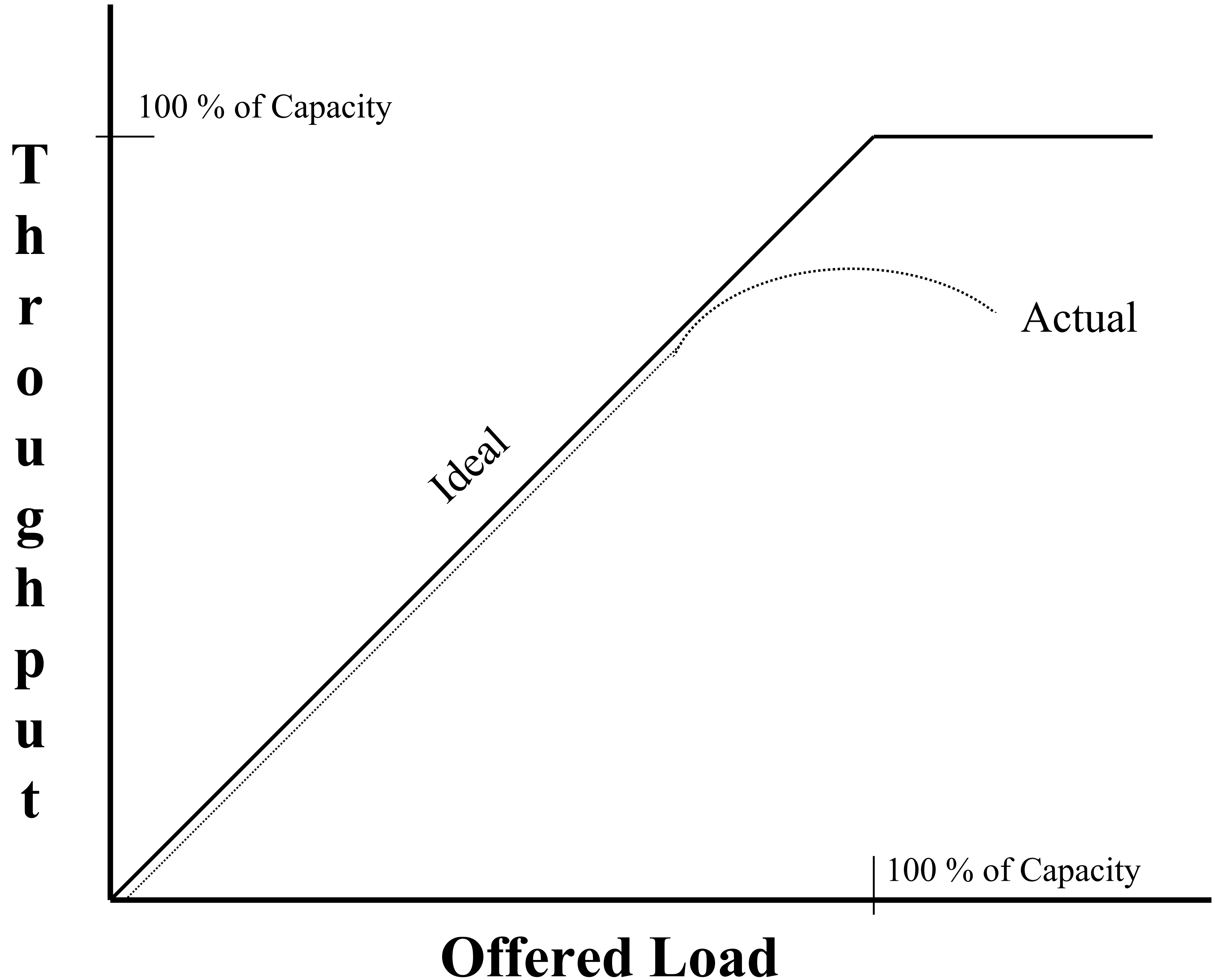
# Network Performance

- Common performance factors include
  - Bandwidth
  - Throughput
  - Bandwidth utilization
  - Offered load
  - Accuracy
  - Efficiency
  - Delay (latency) and delay variation
  - Response time

# Bandwidth Vs. Throughput

- Bandwidth and throughput are not the same thing
- Bandwidth is the data carrying capacity of a circuit
  - Usually specified in bits per second
- Throughput is the quantity of error free data transmitted per unit of time
  - Measured in bps, Bps, or packets per second (pps)

# Bandwidth, Throughput, Load



# Other Factors that Affect Throughput

- The size of packets
- Inter-frame gaps between packets
- Packets-per-second ratings of devices that forward packets
- Client speed (CPU, memory, and HD access speeds)
- Server speed (CPU, memory, and HD access speeds)
- Network design
- Protocols
- Distance
- Errors
- Time of day, etc., etc., etc.

# Throughput Vs. Goodput

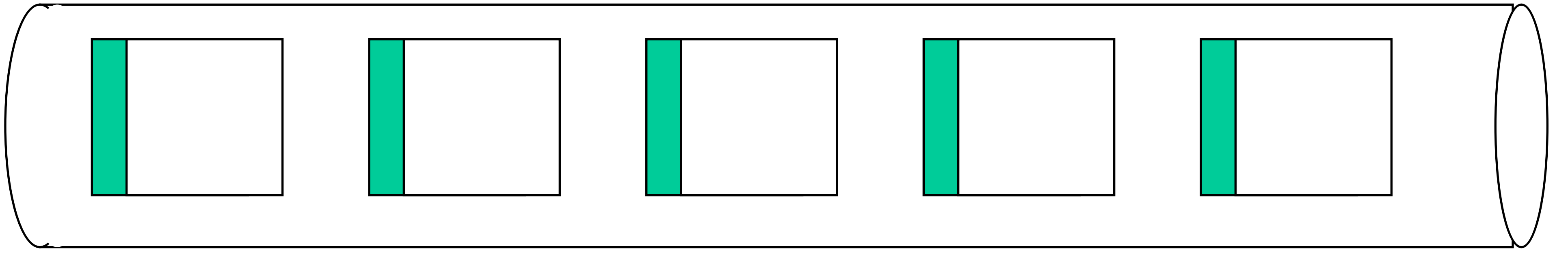
- You need to decide what you mean by throughput
- Are you referring to bytes per second, regardless of whether the bytes are user data bytes or packet header bytes
  - Or are you concerned with application-layer throughput of user bytes, sometimes called "goodput"
    - In that case, you have to consider that bandwidth is being "wasted" by the headers in every packet

# Performance (continued)

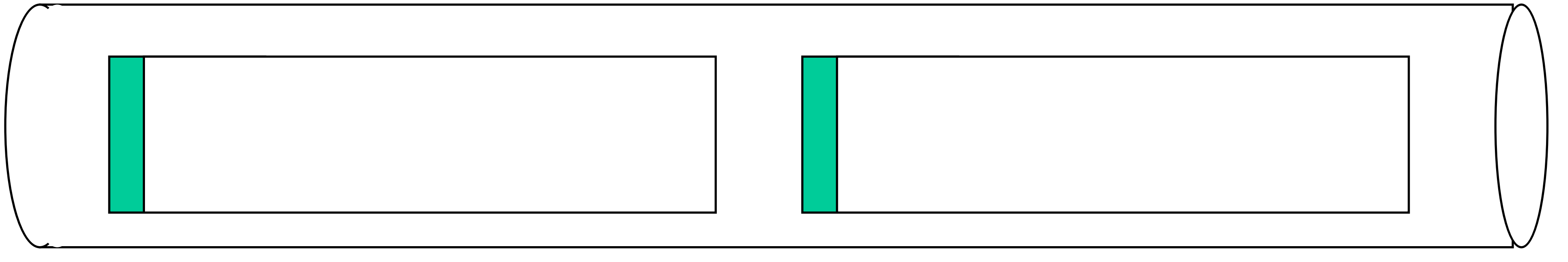
- Efficiency
  - How much overhead is required to deliver an amount of data?
  - How large can packets be?
    - Larger better for efficiency (and goodput)
    - But too large means too much data is lost if a packet is damaged
    - How many packets can be sent in one bunch without an acknowledgment?

# Efficiency

Small Frames (Less Efficient)



Large Frames (More Efficient)



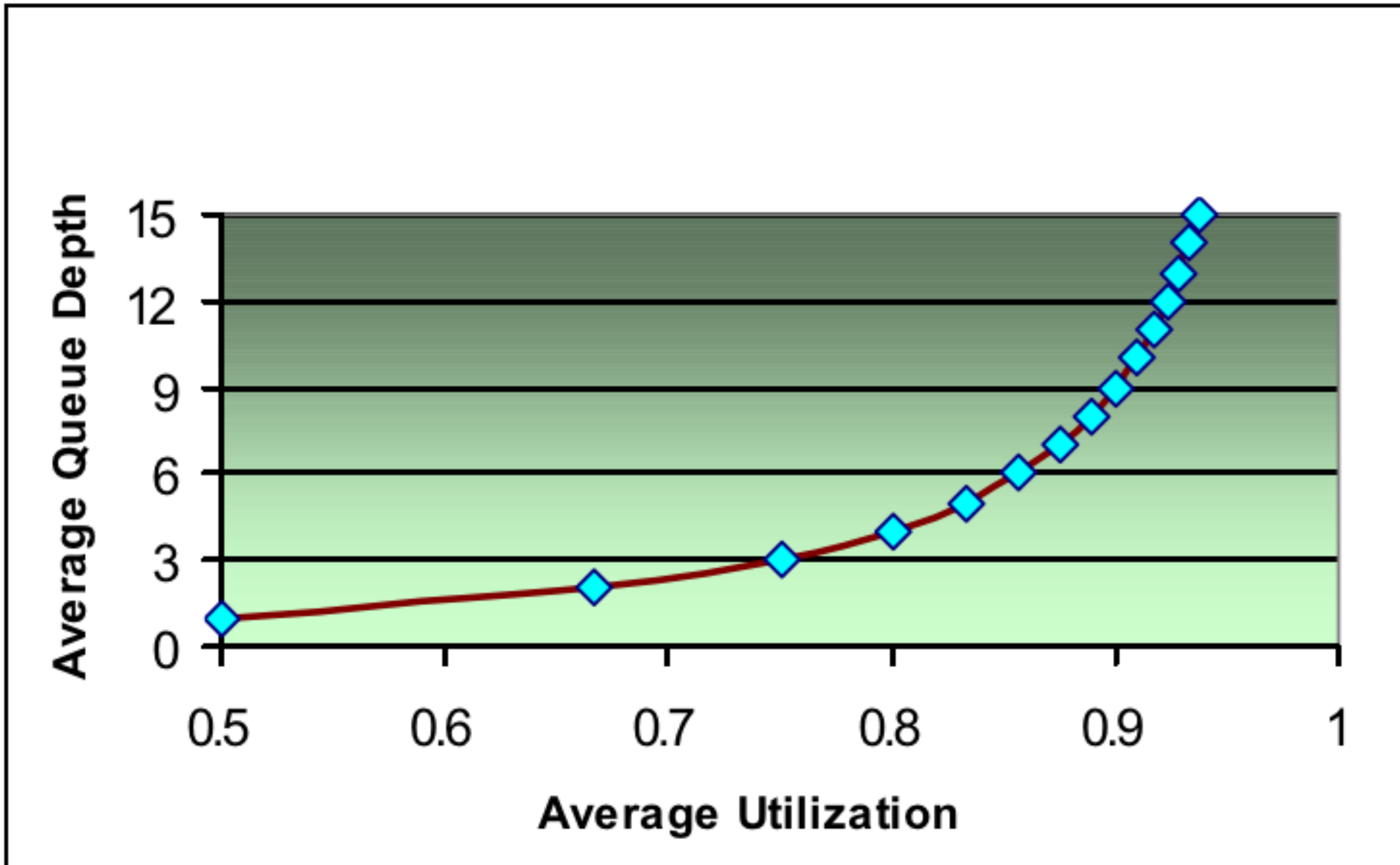
# Delay from the User's Point of View

- Response Time
  - A function of the application and the equipment the application is running on, not just the network
  - Most users expect to see something on the screen in 100 to 200 milliseconds

# Delay from the Engineer's Point of View

- Propagation delay
  - A signal travels in a cable at about 2/3 the speed of light in a vacuum
- Transmission delay (also known as serialization delay)
  - Time to put digital data onto a transmission line
    - For example, it takes about 5 ms to output a 1,024 byte packet on a 1.544 Mbps T1 line
- Packet-switching delay
- Queuing delay

# Queuing Delay and Bandwidth Utilization




- Number of packets in a queue increases exponentially as utilization increases

# Example

- A packet switch has 5 users, each offering packets at a rate of 10 packets per second
- The average length of the packets is 1,024 bits
- The packet switch needs to transmit this data over a 56-Kbps WAN circuit
  - Load = 5 x 10 x 1,024 = 51,200 bps
  - Utilization = 51,200/56,000 = 91.4%
  - Average number of packets in queue = 
    (0.914)/(1-0.914) = 10.63 packets

# Delay Variation

- The amount of time average delay varies
  - Also known as jitter
- Voice, video, and audio are intolerant of delay variation
- So forget everything we said about maximizing packet sizes
  - There are always tradeoffs
  - Efficiency for high-volume applications versus low and non-varying delay for multimedia

# Security

- Focus on requirements first
- Detailed security planning later (Chapter 8)
- Identify network assets
  – Including their value and the expected cost associated with losing them due to a security problem
- Analyze security risks

# Network Assets

- Hardware
- Software
- Applications
- Data
- Intellectual property
- Trade secrets
- Company’s reputation

# Security Risks

- Hacked network devices
  - Data can be intercepted, analyzed, altered, or deleted
  - User passwords can be compromised
  - Device configurations can be changed
- Reconnaissance attacks
- Denial-of-service attacks

# Manageability

- Fault management
- Configuration management
- Accounting management
- Performance management
- Security management

# Usability

- Usability: the ease of use with which network users can access the network and services
- Networks should make users' jobs easier
- Some design decisions will have a negative affect on usability:
  - Strict security, for example

# Adaptability

- Avoid incorporating any design elements that would make it hard to implement new technologies in the future
- Change can come in the form of new protocols, new business practices, new fiscal goals, new legislation
- A flexible design can adapt to changing traffic patterns and Quality of Service (QoS) requirements

# Affordability

- A network should carry the maximum amount of traffic possible for a given financial cost
- Affordability is especially important in campus network designs
- WANs are expected to cost more, but costs can be reduced with the proper use of technology
  - Quiet routing protocols, for example

# Network Applications Technical Requirements

| Name of Application | Cost of Downtime | Acceptable MTBF | Acceptable MTTR | Throughput Goal | Delay Must be Less Than: | Delay Variation Must be Less Than: |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

# Making Tradeoffs

| | |
|---|---|
| • Scalability | 20 |
| • Availability | 30 |
| • Network performance | 15 |
| • Security | 5 |
| • Manageability | 5 |
| • Usability | 5 |
| • Adaptability | 5 |
| • Affordability | 15 |
| Total (must add up to 100) | 100 |

# Summary

- Continue to use a systematic, top-down approach
- Don’t select products until you understand goals for scalability, availability, performance, security, manageability, usability, adaptability, and affordability
- Tradeoffs are almost always necessary

# Review Questions

- What are some typical technical goals for organizations today?
- How do bandwidth and throughput differ?
- How can one improve network efficiency?
- What tradeoffs may be necessary in order to improve network efficiency?