Performance of Communication Systems

CS461: Computer Networks and Communications

HiLCoE - School of Computer Science and Technology

Lecture 3

Performance of Communication Systems

- Data communications is about sharing information
- What types of information? What type of applications?
- How much information is shared by different applications?
- What is an effective communication system?
- How can we measure/compare performance of communication systems?
- What are the performance requirements of applications?

Contents

Info and Apps

Metrics

Delay

Requirements

Information and Applications

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Delay in Detail

Application Performance Requirements

How big is a ...

Info and Apps

Metrics

Delay

Requirements

- Web page?
- Email?
- Photo?
- Song?
- Audio CD?
- TV show?
- Movie?

Classify Types of Information

Information may be in analog or (more commonly) digital form

- Audio: voice calls, radio, music
- Video: video conference, video streams
- Data:
  - Early: signalling, fax, SMS, ...
  - Internet: messaging (email, instant), web browsing, remote login, database, business-specific apps, monitoring and control systems, ...

Effective Data Communications

Delivery: the data must be delivered to the correct destination

Accuracy: the data received must be accurate representation of the data sent

Timeliness: the data should be delivered within a reasonable time

Types of Internet Applications

Traditional Internet-Based Applications

- File transfer, email, web browsing, remote login, database
- Accuracy is most important

Multimedia or Real-time Applications

- Audio/video streaming, voice/video calls, gaming, collaborations
- Timeliness is most important

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Information and Applications

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Application Performance Requirements

Performance Metrics

- Metrics: Ways to measure the performance of communication systems
- How do we use metrics?
  - Measure the actual performance of real systems
  - Calculate/estimate to predict performance of planned systems
- Represented using different statistics:
  - Instantaneous
  - Average (mean) over some time
  - Maximum (peak), minimum, standard deviation, variance, ...
- Following slides show some common metrics
  - Others: bandwidth (Hz), SNR and SINR (dB), reliability, availability/uptime, energy consumption (W, J), ...

Data Rate

Definition

Rate at which data is delivered from one point to another

Other/Related Names

Bit rate, capacity, signalling rate, bandwidth

Units

bits per second

Examples

- My computer LAN card can send 100Mb every second; all bits arrive at destination: Data rate = 100Mb/s

Delay

Definition

Time it takes to get data from one point to another

Other/Related Names

Latency; Response time, Round Trip Time

Units

seconds

Examples

- I send an email at 10:00am; it arrives at destination at 10:03am: Delay = 3 minutes
- At time 1.4s I click on a webpage link; at time 2.6s the webpage is fully displated on my browser: Response Time = 1.2s

Error Rate

Definition

Fraction of data sent that doesn't get delivered to destination

Other Names

Bit Error Rate (BER), Packet Error Rate (PER), Loss rate

Units

none (fraction, percentage)

Examples

- I send a copy of an email to 100 students; 5 students do not receive the email: Error rate = 0.05 = 5%
- For every 1,000 bits sent across a link, on average 23 bits arrive in error: BER = 0.023 = 2.3%

Overhead

Definition
Amount of additional data needed in order to deliver useful data

Other Names
-

Units
bits

Examples

- For every 8 bits of data, a 2-bit parity check is added: Overhead = 2b
- A packet contains 1000B of data and a 50B header: Overhead = 50B

Throughput

Definition
Rate at which useful data is delivered to destination

Other Names
Goodput, Bandwidth

Units
bits per second

Example

- Downloading a 12MB file from website takes 26 seconds: Throughput = 6Mb/s
- WiFi link has data rate of 54Mb/s. For every 500 Bytes of data sent, there is additional 200 Bytes of overhead plus 20us spent not sending. Throughput = 32.3Mb/s

Efficiency

Definition

Fraction of time spent using a resource for intended purpose

Other Names

Utilization

Units

none (fraction, percentage)

Example

- I pay 10000 Birr per month for 10Mb/s home Internet. On average, each month I download at 2Mb/s: Efficiency $= 0.2 = 20\%$
- WiFi link has data rate of 54Mb/s, but throughput of 20Mb/s: Efficiency $= 0.37 = 37\%$
- For every 1000B of data sent, there is an overhead of 200B: Efficiency $= 0.83 = 83\%$

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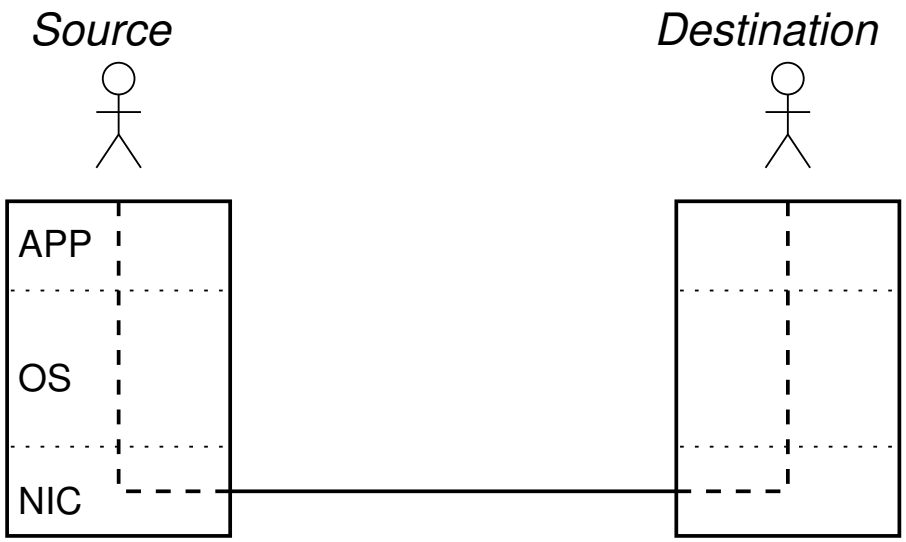
Delay in Detail

Application Performance Requirements

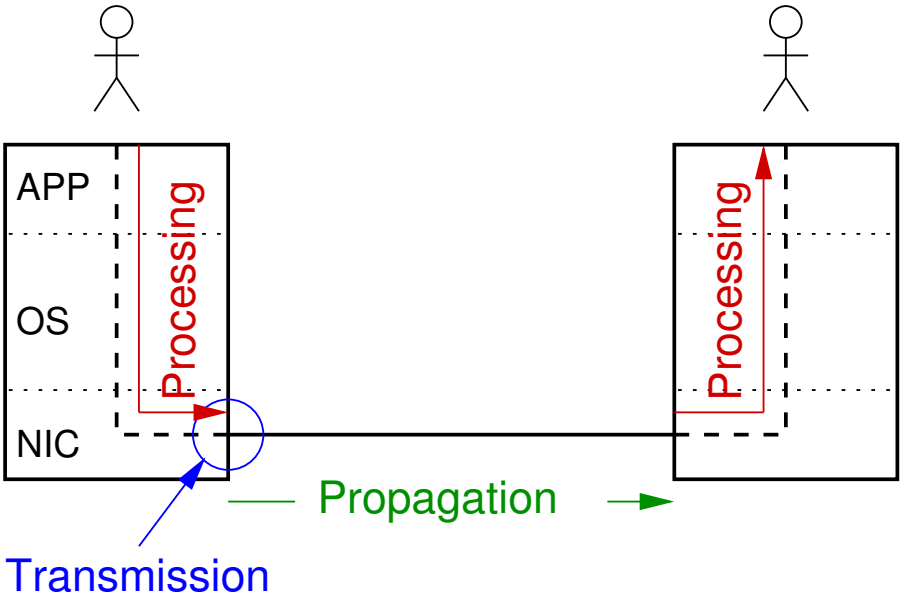
Delay

- Time it takes to get data from one point to another
- Delay is additive
- Four components that contribute to total delay:
  1. Transmission delay: time to transmit data on to link
  2. Propagation delay: time for a signal element (or bit) to propagate across link
  3. Processing delay: time for device to process data
  4. Queuing delay: time data spent waiting in queue (memory) inside device

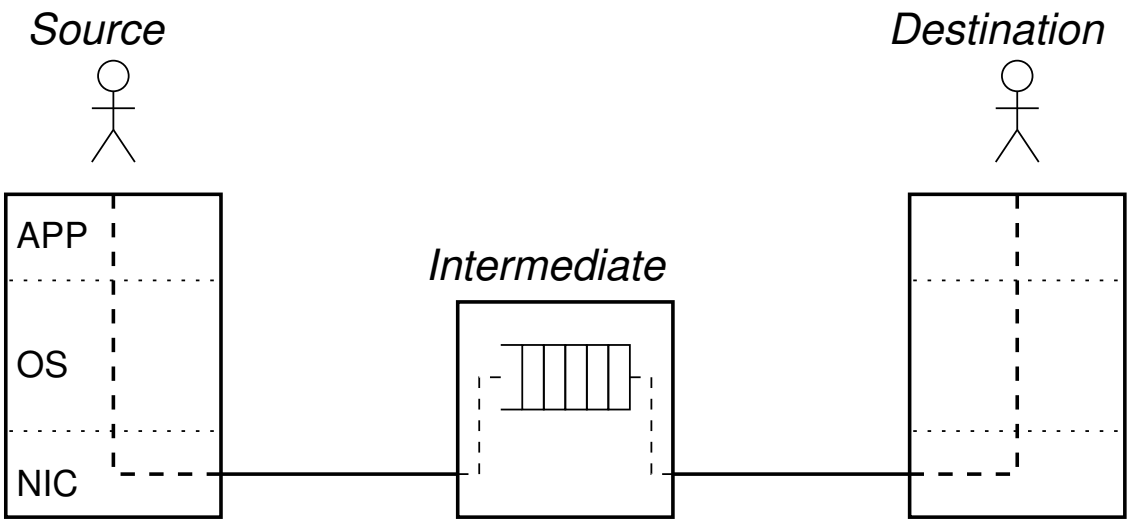
Delay Components in a Link



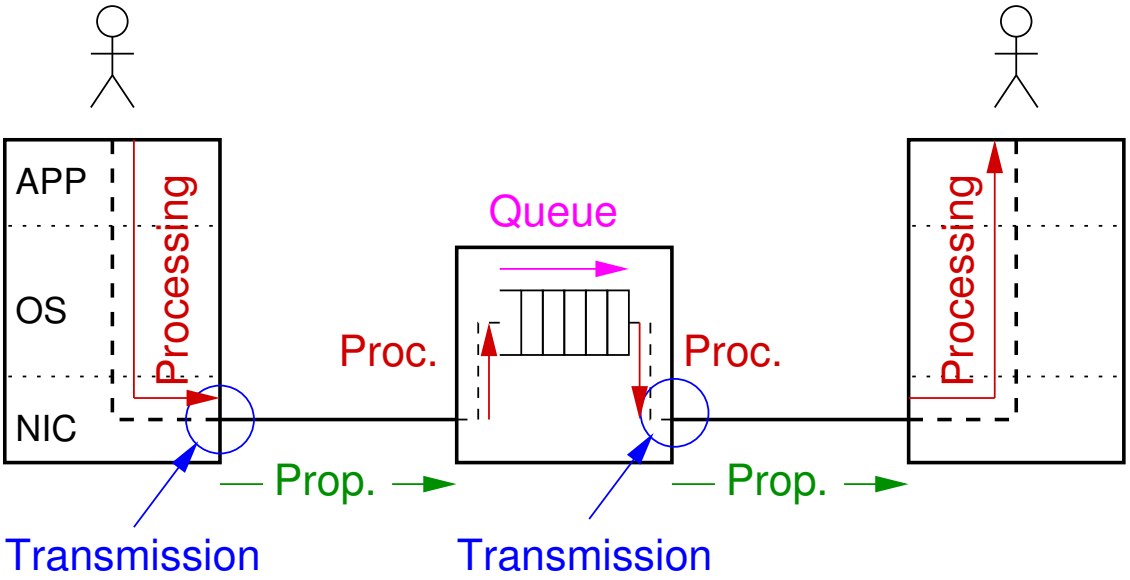
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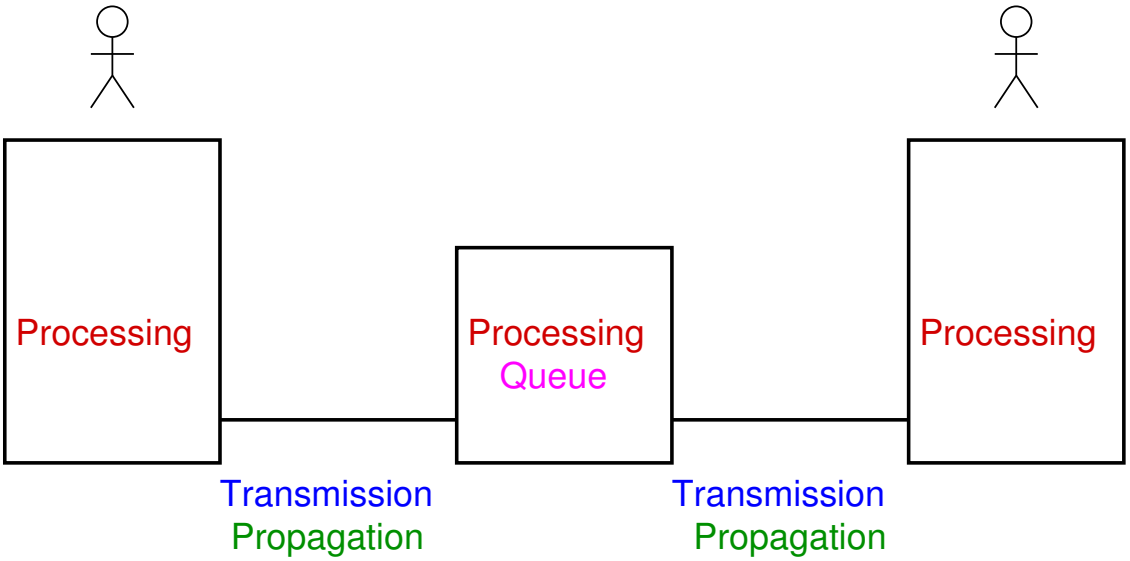
Delay Components in a Network



Delay Components in a Network



Simplified View of Delay Components



- Processing and queuing delay are for devices
  - Queuing delay normally only in intermediate devices
- Transmission and propagation delay are for links

Determining Delay

Transmission Delay

- Number of bits to send, b [bits]
- Link data rate, r [bits per second]
- Transmission delay, $trans = \frac{b}{r}$

Propagation Delay

- Link distance, d [metres]
- Speed of signal propagation, s [metres per second]
- Propagation delay, $prop = \frac{d}{s}$
  - Unless otherwise stated, $s = c = 3 \times 10^8$ m/s

Determining Delay

Processing Delay

- Depends on amount of data to process, software implementation, computer hardware, and other activities of computer
- Often very small compared to transmission and propagation delay
- Unless otherwise stated, assume $proc = 0$ s

Queuing Delay

- Depends on amount of data arriving from other users and leaving device, and queuing scheme (e.g. FIFO, priority)
- Can be significant in large networks, e.g. the Internet
- Unless otherwise stated, assume $queue = 0$ s

Delay Examples

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What performance is necessary for a happy user?

Web Browsing

- Response time: over 100ms is noticeable by most users
- Estimated 100ms response time reduced Amazon's sales by 1% in 2009
- Response time: over several seconds may result in user abandoning website

Voice Calls

- Delay:
  - 0 to 150ms: acceptable by most users
  - 150 to 400ms: acceptable if users/operators are aware of quality reduction
  - Above 400ms: unacceptable for most cases
- Packet error rate: less than 1% to avoid audible errors
- Throughput: 10kb/s to 100kb/s

What performance is necessary for a happy user?

Video Streaming

- Throughput for Low Quality/Resolution: 0.5–1.0 Mb/s
- Throughput for Standard Definition (720p): ∼5 Mb/s
- Throughput for High Definition (1080p): ∼11 Mb/s
- Delay: several seconds

Others