Fundamentals of Computer Networks
ECE 478/578

Lecture #1
Instructor: Loukas Lazos
Dept of Electrical and Computer Engineering
University of Arizona

What is this Course All About

Fundamental principles of Computer Networks

First course – Broad coverage of topics (important topics in depth)

Topics categorized to:

- network architectures - technologies
- protocols
- applications

We will not discuss specific implementations: e.g., how to configure the latest cisco routers

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Why Learn about Networking?

Indispensable part of modern society

- Commercial – e-commerce, banking, inventorying, telecommunications, archiving, health
- Social – critical infrastructure, homeland security, policing
- Human interaction/communication – email, chat, videoconferencing, social networking, entertainment

Appears in every facet of engineering

- Modern trend – Network every (electronic) device (computers, phones, sensors, planes, cars, TVs, appliances, heart monitors, …)

Prolific field to pursue graduate studies

- Many problems remain unsolved
- Research funding is still strong

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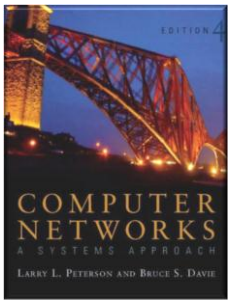
Course Logistics

Textbook

"Computer Networks: A Systems Approach"
L. Peterson, and B. Davie, 4th edition.

Additional References

"Data Networks"
D. Bertsekas, and R. Gallager, 2nd edition
"Computer Networks"
S. Tanenbaum and D. Wetheral,
5th edition,



Course Website

www.ece.arizona.edu/~ece578
Lectures, Homework, Useful links,
Supplementary material, Announcements

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Where to find me

My Office:
ECE bldg: Room 357

Office Hours
10:00 – 11:00 AM TTh
and by appointment

My Email: llazos@ece.arizona.edu

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Class Expectations

Class participation – Your input is needed for good discussion

Keep up with reading material

Complete assignments and projects on time

Submit clean, organized, and concise reports (the back of a flyer is not ok!)

Identify potential project partners early (in one week, if possible)

Brush up prior knowledge (Probability theory, C Programming)

Follow academic integrity code

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Lecture Etiquette

Be on time (if you are late enter the class quiet)

Your ringer is not that great! (cell phones off or muted)

You can do without facebook/youtube/twitter for 1:15 - If you have to, don't disturb your neighbors

Interrupt for questions – there is no dumb question

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Key to Success

Attendance

- Pay attention to lectures and keep extra notes
- Ask questions

Effort

- Do homework on your own. It's ok to ask others, but make your own effort
- Read extra material on your own. Wealth of information available (library books, online articles, research papers)

Consistency

- Keep up with the class pace

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Grading Scheme

Assignment	Points
Homework	30
Midterm	20
Project	20
Final Exam	30
Total	**100**

Homework: Analytical Problems and C implementations

Midterm: March 10th (tentative)

Final Exam: May 12th

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Course Objectives

Develop a fundamental understanding of the network design principles and performance metrics

Become familiar with the mechanisms and protocols for reliable data communication via a computer network

Be able to evaluate the performance of various network technologies and protocols

Think as an engineer: What technologies should be employed to build a network with particular specifications?

Develop interest in performing research in the area of Computer Networks

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Topics to be covered

Network architectures, performance metrics, layering

Medium access control

Internetworking, routing

End-to-end protocols, flow control

Congestion control and resource allocation

Applications

Network security

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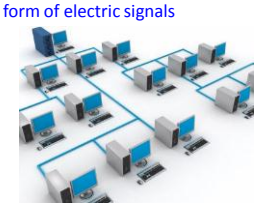
Definition of a Network

A system that carries a commodity between 2 or more entities

Examples: Transportation network, electric grid, postal, water, telephone

Computer network: A system that carries information between 2 or more entities, in the form of electric signals



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Transportation vs. Computer Networks

Transportation Network	Computer Network
Vehicles/People	Packets/Payload
Street address	IP address
Intersection	Bridge/router
Street, highway, path	Link/broadband/path
Traffic jam	Network congestion
Stop and go traffic light	Flow control
Taking alternative path	Alternative route
Collision	Collision of packets
HOV lane	Stream Priority
Following a route to school	Routing algorithm
…	…

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Most commonly known Networks

The Internet*	
Ethernet (LAN)	
WiFi	
3G/4G	
An internet**	

* The global network adopting the IP technology
**Internet: A network of networks

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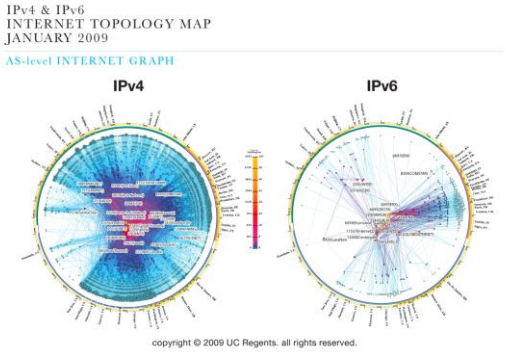
How does the Internet Look Like?



How does the Internet Look Like?

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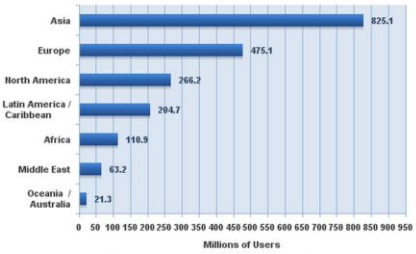
How Many Users?



Source: Internet World Stats - www.internetworldstats.com/stats.htm
Estimated Internet users are 1,966,514,816 on June 31, 2010
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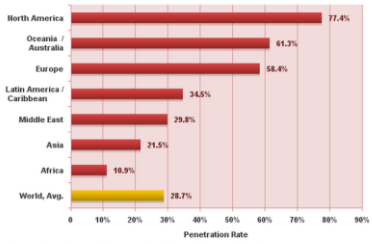
How many more Users?



Source: Internet World Stats - www.internetworldststs.com/stats.htm
Penetration Rates are based on a world population of 6,845,609,960
and 1,966,514,816 estimated Internet users on June 30, 2010.
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How much Traffic?

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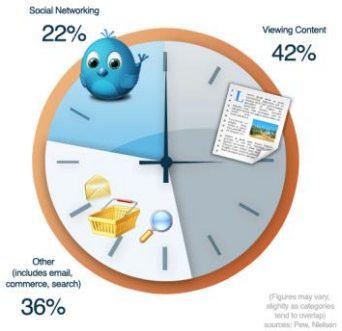
How is Time Spent?



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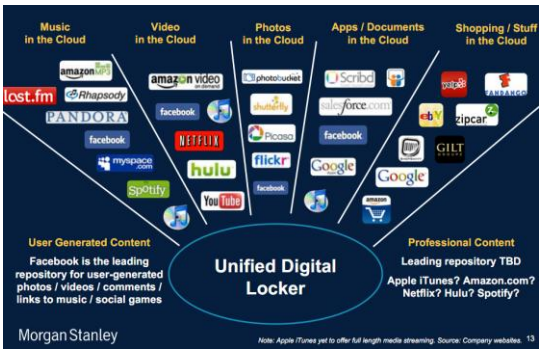
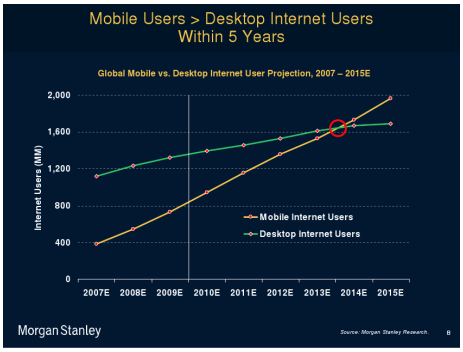
What Do Users Expect?



How do they get it?



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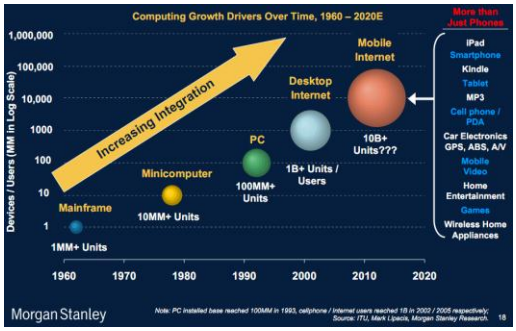
Where are we headed?



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Biggest Internet Challenge

Scale

How to manage such a large system,
growing rapidly and uncontrollably,
consisting of heterogeneous devices,
managed by multiple entities
having limited resources

Let's take things one at a time

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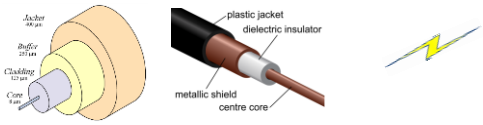
Network Elements

Nodes: Special purpose devices

PC server switch bridge router

Links: Connections between nodes



Optical fiber Coaxial cable wireless

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Network Design

The task of **connecting nodes via links**, so that nodes can exchange information, reliably, timely, efficiently, safely, privately, "greenly", and with low cost.

Need to define the network architecture, protocols, applications, interfaces, policies, usages.

Let's start with the architecture

- Directly connected networks
- Circuit-switched networks
- Packet-switched Networks

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What Drives Network Design?

Applications

- WWW, email, chat, videoconferencing, e-commerce, audio/video streaming, VOIP, file sharing

Who deploys the network

- Enterprise, government, end-user

Where is the network deployed

- Home, building, campus, state, country, continent, globe

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How do we Evaluate a Network

Metrics (think again a transportation network)

- How many cars can it service (throughput)?
- How fast can it service them (delay)?
- How reliable can it service them (collisions, losses, outage probabilities, etc)?
- Can it provide any guarantees (QoS)?
- Any other metrics you can think of?

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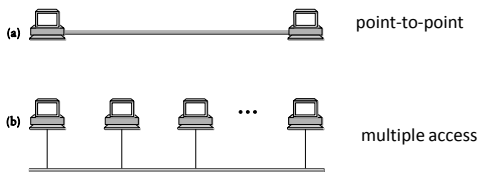
Directly-Connected Networks

Point-to-point links: Each node is directly connected to all others via a link

Multiple access: All nodes share the same physical medium



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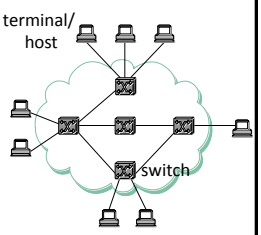
Switched Networks

Circuit-Switched

- A dedicated circuit is established across a set of links
- Example: Telephone network

Packet-Switched

- Data is split into blocks called packets or messages.
- Store-and-forward strategy
- Switches: Store and forward packets



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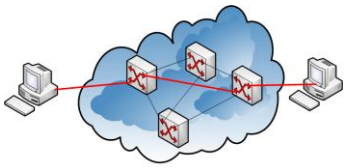
Circuit-Switched Networks

End-to-end permanent connection
- Dedicated path for communication
- No need for a destination address since a path is already established

Once communication is complete, connection is ended and links are released.



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Advantages of Circuit Switching

Guaranteed bandwidth (Quality of Service)
- Predictable bitrate and delay
- Good for delay-sensitive applications

Reliable communication
- Rare packet loss
- Packets are delivered in order

Simple data routing
- Forwarding based on time slot or frequency (multiplexing)
- No need to inspect a packet header for address

Low per-packet overhead
- Forwarding based on time slot or frequency
- No IP (and TCP/UDP) header on each packet

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Disadvantages of Circuit Switching

Wasted bandwidth
- Bursty traffic leads to idle connection during silent period

Blocked connections
- Connection refused when resources are not sufficient
- Unable to offer "okay" service to everybody

Connection set-up delay
- No communication until the connection is set up
- Unable to avoid extra latency for small data transfers

Network state
- Network nodes must store per-connection information
- Unable to avoid per-connection storage and state

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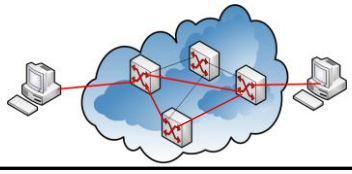
Packet Switched Networks

Data is divided into packets (messages)

- Each packet contains identification info (source/destination address seq. number, etc)

Packets traverse the network individually

- Use the destination address to forward packets
- May use more than one routes, nodes may store packets temporarily



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Advantages of Packet Switching

No wasted bandwidth (not entirely true)

- Links are not reserved during idle period

Multiplexing (see next slides)

- Frequency, time, statistical multiplexing

Service

- More connections of lesser quality
- No blocking of users

Adaptation

- Can adapt to network congestion and failures

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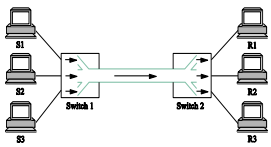
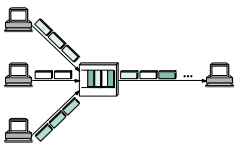
Multiplexing



Three pairs of senders/receivers share the same physical link to communicate



A switch is multiplexing packets from different senders into one packet stream

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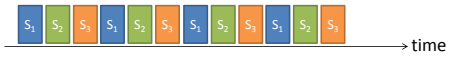
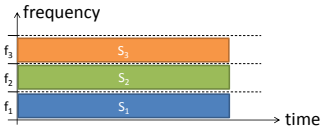
Multiplexing Methods

Time Division Multiplexing



Frequency Division Multiplexing



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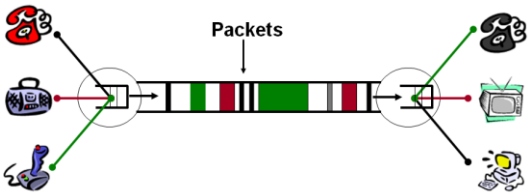
Multiplexing Methods

Statistical multiplexing

Division of the communication medium into a number of channels of variable bandwidth



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Disadvantages of Packet Switching

No guaranteed bandwidth

Harder to build applications requiring QoS

Per packet overhead

Need a header with source/dest. address, etc.

Complex end-to-end control

Packets can be lost, corrupted or delivered out-of-order

Delay and Congestion

No congestion control, can lead to arbitrary delays and packet drops

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