CSMC 417

Computer Networks

Prof. Ashok K Agrawala

General

- Instructor - Ashok K. Agrawala
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  - 4149 AVW
- TA – Andrew Pachulski
  - Office Hours –
- Class Meets – Tu Th 12:30 – 1:45 CSIC 3117

Prerequisite

- Required Background
  - must have 351 and 330 (412 or 430 would be helpful)

- Expectations
  - Understand the basics of Computer Architecture
  - Experience in implementing non-trivial systems-type projects

  - Should know
    - Processor
    - Memory
    - Kernel vs. user process
  - Familiar with basic probability

Expectations – After the course

- Understand the fundamentals of networking protocols, including protocol layering, basic medium access including wireless protocols, routing, addressing, congestion control
- Understand the principles behind the Internet protocols and some application layer protocols such as http, ftp, and DNS, and a few peer-to-peer systems/protocols such as Gnutella and Chord.
- Understand some of the limitations of the current Internet and its service model
- Understand the causes behind network congestion, and explain the basic methods for alleviating congestion
- Design, implement, and test substantial parts of network protocols

Announcements

- Required Work
  - will require about the same amount of effort as 412
    - 412 a (slightly) harder project to debug
    - 417 project is (by design) more ambiguous
- Required Texts
  - *Computer Networks* **5th Edition**, Tanenbaum and Wetherall, Prentice Hall 2011. ISBN 0-13-212695-8
  - *TCP/IP Sockets in C: A Practical Guide for Programmers* **2nd Edition** by Jeff Donahoo and KenCalvert, Morgan Kaufmann, 2009. ISBN 978-0123745408

Other Material

- Recommended Texts
  - *Computer Networking, 5e: A Top Down Approach Featuring the Internet* by Jim Kurose and Keith Ross, Addison-Wesley, (ISBN: 0-13-607967). The on-line version of this book is at http://www.awlonline.com/kurose-ross.
  - *Computer Networks: A Systems Approach* by Larry Peterson and Bruce Davie, MorganKaufman, 4rd Edition, 2007. ISBN 978-0123705488
  - *An Engineering Approach to Computer Networking*, by S. Keshav. Addison-Wesley,1997. ISBN 0-201-63442-2
  - *Computer Networking with Internet Protocols* by William Stallings, Prentice-Hall, 2004. ISBN 10: 0131410989
  - *TCP/IP Illustrated* volume 1 by W. Richard Stevens. Addison-Wesley. ISBN: 0-201- 63346-9.
- RFCs

Grading

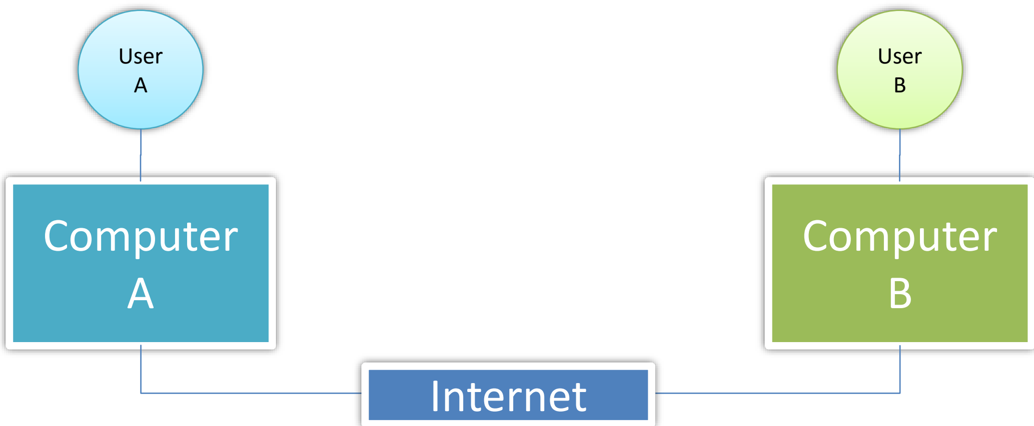
- Final 25%
- In-Term Exam(s) 25%
- Programming Assignments 35%
- Class Participation 15%
  - Learning Reports
  - Pop Quizzes
  - …

Learning Reports

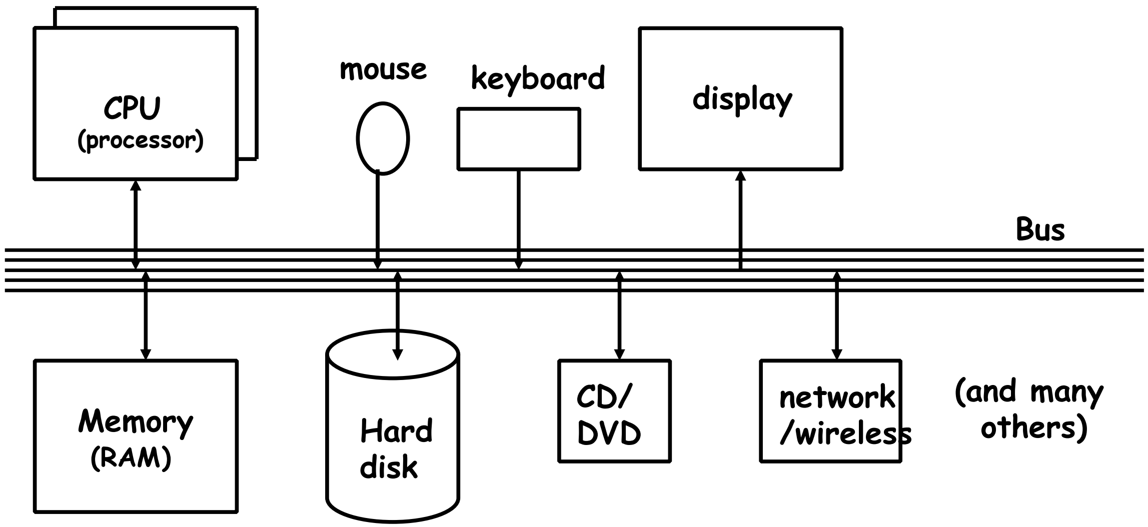
- Usually once a week
  - At the end of the class
  - When I ask you to
- One page
  - Your name and date
  - What you learned this week/this class as asked
  - What concept you found difficult
  - Any comments for me.

What is this course all about?

- Computer Networking
  - ???



Block Diagram of Typical Laptop/desktop



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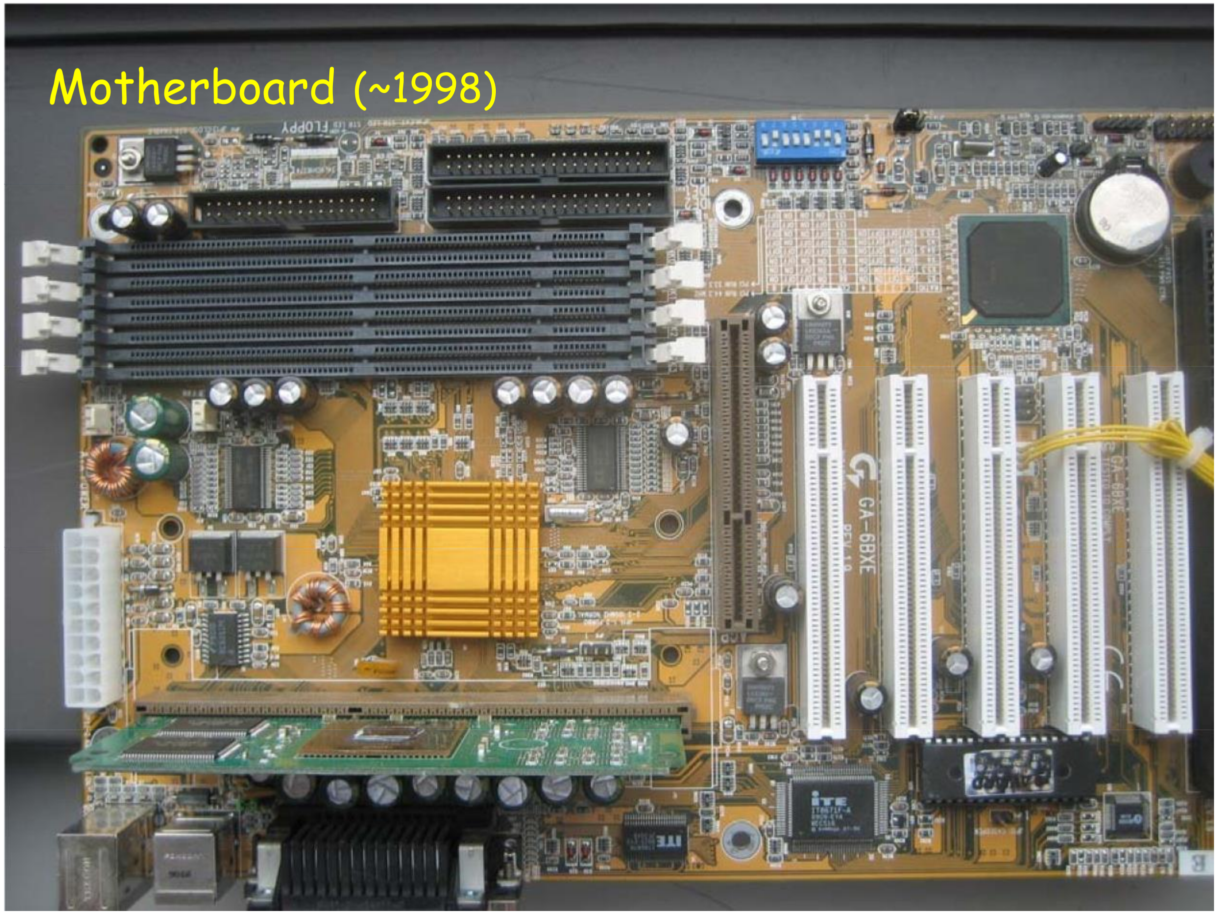

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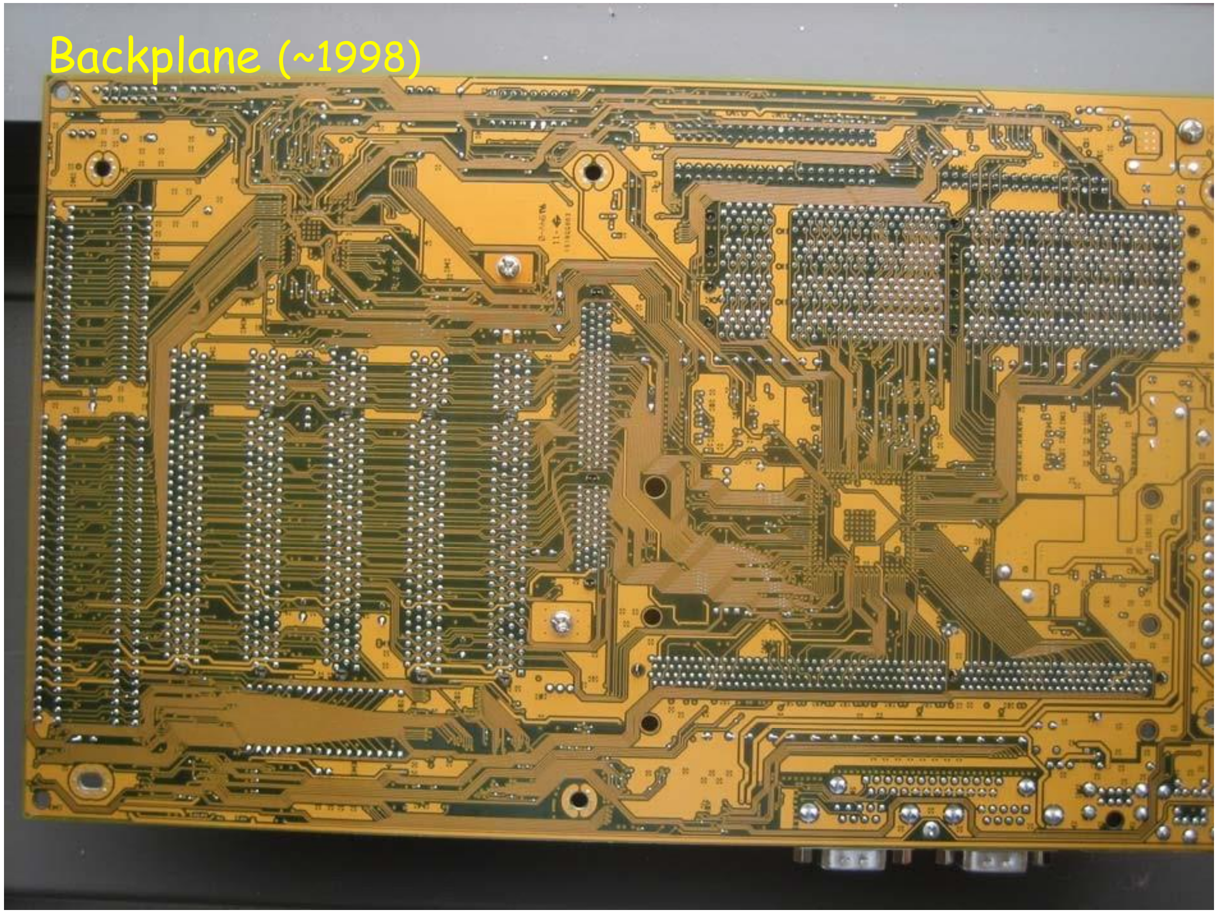

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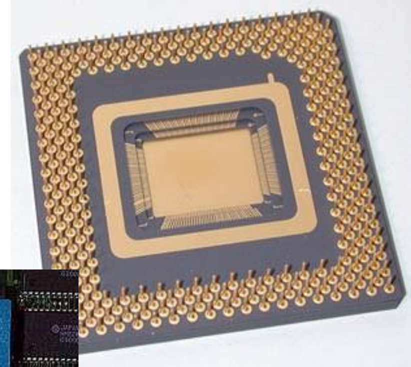
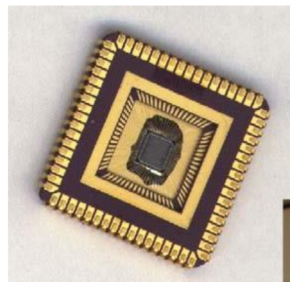
Some CPU chips

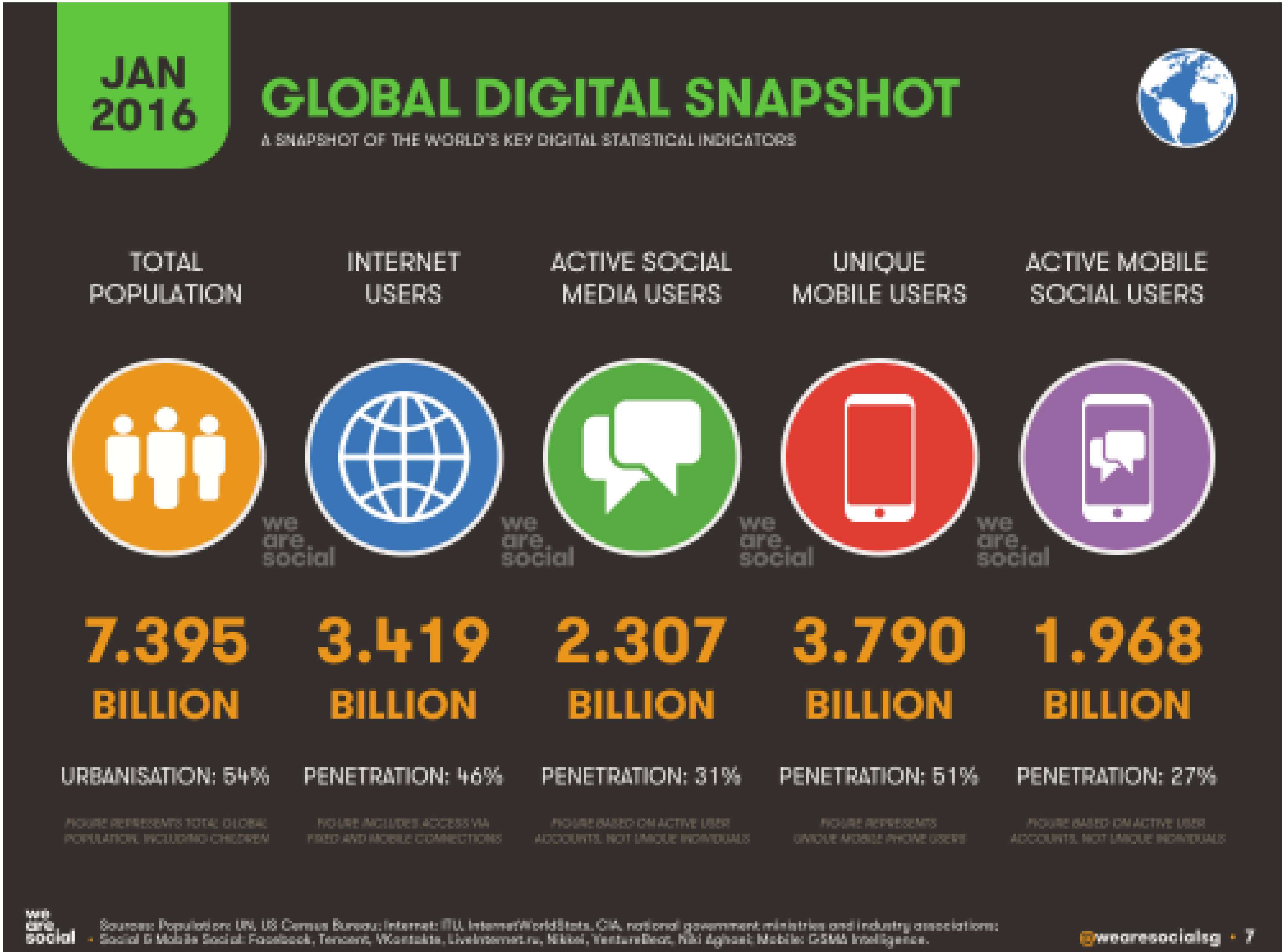




2.5' laptop disk

https://www.cs.princeton.edu/courses/archive/fall11/cos109/02inside.pdf





JAN 2016
GLOBAL DIGITAL SNAPSHOT
A SNAPSHOT OF THE WORLD'S KEY DIGITAL STATISTICAL INDICATORS
TOTAL POPULATION
INTERNET USERS
ACTIVE SOCIAL MEDIA USERS
UNIQUE MOBILE USERS
ACTIVE MOBILE SOCIAL USERS
7.395 BILLION
3.419 BILLION
2.307 BILLION
3.790 BILLION
1.968 BILLION
URBANISATION: 54%
PENETRATION: 46%
PENETRATION: 31%
PENETRATION: 51%
PENETRATION: 27%
Sources: Population: UN, US Census Bureau; Internet: ITU, InternetWorldStats, CIA, national government ministries and industry associations; Social & Mobile Social: Facebook, Tencent, VKontakte, LiveInternet.ru, Nikkei, VentureBeat, Niki Aghaei; Mobile: GSMA Intelligence.
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JAN 2016
UNITED STATES OF AMERICA
A SNAPSHOT OF THE COUNTRY'S KEY DIGITAL STATISTICAL INDICATORS
TOTAL POPULATION
ACTIVE INTERNET USERS
ACTIVE SOCIAL MEDIA USERS
MOBILE CONNECTIONS
ACTIVE MOBILE SOCIAL USERS
322.9 MILLION
282.1 MILLION
192.0 MILLION
342.4 MILLION
169.0 MILLION
URBANISATION: 82%
PENETRATION: 87%
PENETRATION: 59%
vs POPULATION: 106%
PENETRATION: 52%
we are social
Sources: UN, US Census Bureau; ITU; Facebook; GSMA Intelligence.
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JAN 2016

DIGITAL DEVICE OWNERSHIP

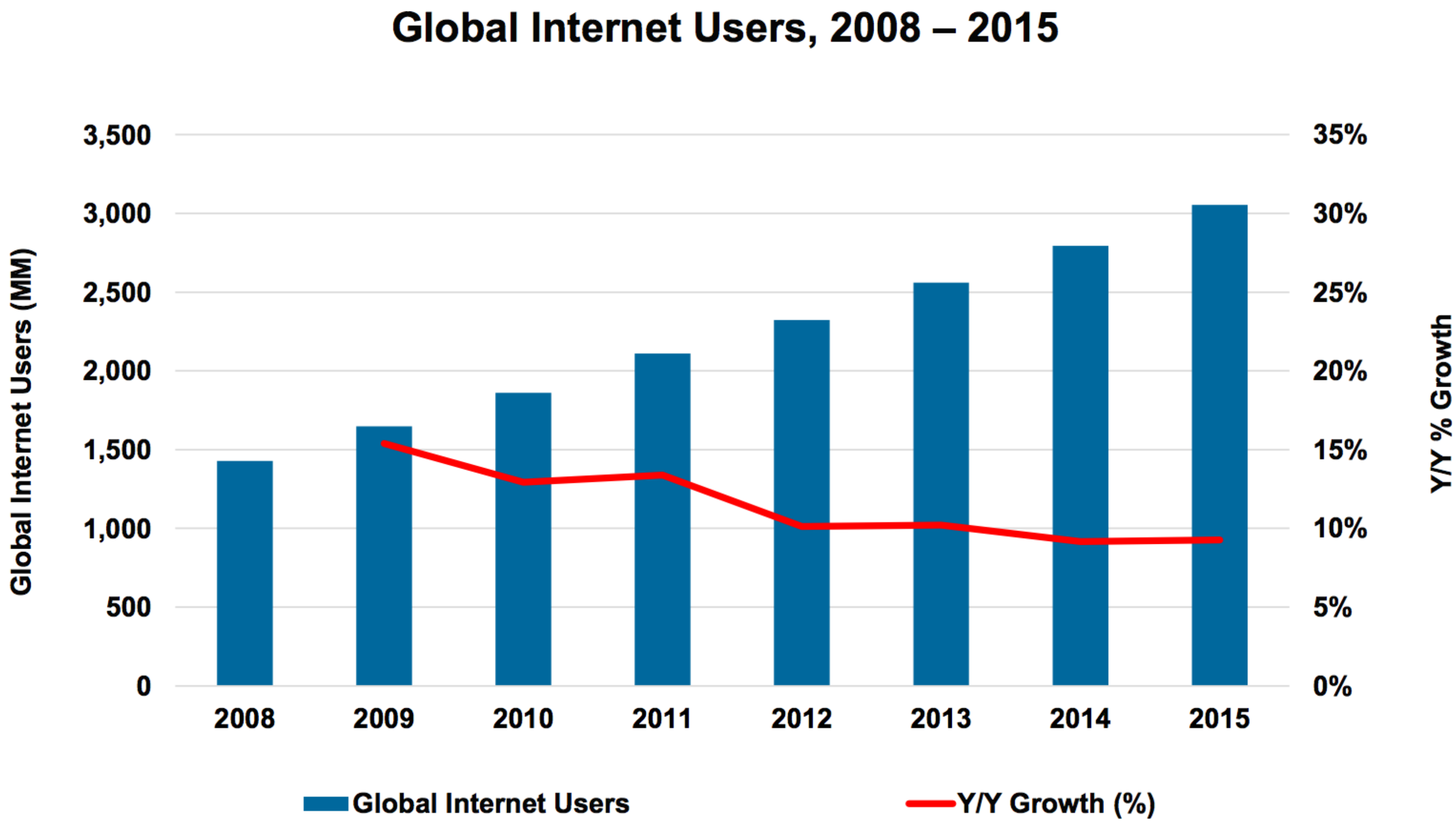
PERCENTAGE OF THE ADULT POPULATION* THAT OWNS EACH KIND OF DEVICE

MOBILE PHONE (ALL TYPES)	SMART PHONE	LAPTOP OR DESKTOP COMPUTER	TABLET DEVICE
86%	51%	50%	7%

TV STREAMING DEVICE	HANDHELD GAMING CONSOLE	E-READER DEVICE	WEARABLE TECH DEVICE
2%	[N/A]	[N/A]	[N/A]

Source: Google Consumer Barometer 2015. Figures based on responses to a questionnaire. *Please see notes at the end of the report for definitions.

Global Internet Users = 3B @ 42% Penetration...
+9% vs. +9% Y/Y...+7% (Excluding India)



Source: United Nations / International Telecommunications Union, US Census Bureau. Internet user data is as of mid-year. Internet user data for: China from CNNIC, Iran from Islamic Republic News Agency, citing data released by the National Internet Development Center, India from IAMAI, Indonesia from APJII / eMarketer.

Internet Statistics 2016

- *There are **3.26 billion internet users** as at December 2015; that's over 40% of the world population.*
- ***Asia, as a continent, has the most internet users.** It accounts for 48.4% of global internet users.*
- *China, as a country, has the most internet users; with an estimated 640 million internet users, **the number of internet users in China is twice the number of the entire U.S population**.*
- ***China has the highest percentage of internet users (21.97%)**, followed by the U.S. (9.58%) and India (8.33%).*
- ***Bermuda has the highest internet penetration at 97.75%**; a whopping 63,987 of Bermuda's 65,461 population uses the internet.*
- *In contrast, while a whopping 86.75% of the U.S. population uses the internet, the U.S. is only ranked #25 in terms of internet penetration. The U.K. ranks #15 in terms of internet penetration with an estimated 89.90% of U.K. citizens using the internet.*
- *Digital interactions influenced retail sales to the tune of $2.2 trillion in 2015.*
- *By 2017, there will be more internet traffic than all prior internet years combined*
- *Wi-Fi and mobile-connected devices will generate 68% of all internet traffic by 2017.*
- *In 2015, 64% of all in-store sales, or sales to the tune of $2.2 trillion, were influenced by the internet.*
- *Facebook now has 1.55 billion active users.*
- *2.9 billion Google searches are made every day.*
- *2.7 million blog posts are published every day.*

Domain Name Statistics 2016

- ***There are currently 123.78 million registered .com domain names****, making the .com TLD the top domain name extension. This is followed by the .tk TLD with 27.7 million registered domain names.*
- *The .com TLD accounts for 50% of all registered TLDs.*
- *As of November 2015, there are a total of 1096 TLDs.*
- *The most expensive domain name ever sold is Insurance.com, for $35.6 million in 2010.*

Web Hosting and Website 2016

•***There are currently 966 million websites in the world today*.**

Web Hosting and Website 2016

- ***The highest number of websites connected to internet was 1 billion****; this happened in September 2014, but the number eventually declined and is expected to be achievable again by mid 2016.*
- ***The world's first website was published on August 6, 1991 by British physicists Tim Berners-Lee****.*
- ***Only 44% of web traffic is from humans; a massive 56% of web traffic is from bots****,* ***impersonators, hacking tools, scrapers and spammers.***
- *39% of web servers are hosted on Apache.*
- *Google is the #1 most popular website in the world, followed by Facebook and YouTube.*
- *The average e-commerce site takes 7.12 seconds to load in Internet Explorer 9, an average of 7.15 seconds to load in Firefox 7 and an average of 7.5 seconds to load in Google Chrome.*
- *Google uses site speed as a ranking factor.*
- *The most popular CMS is WordPress, powering 25.4% of all websites in the world and responsible for over 76.5 million blogs.*
- *An estimated 37,000 websites are hacked every day.*

JAN 2016

SOCIAL MEDIA USE

TOTAL ACTIVE ACCOUNTS ON THE TOP SOCIAL NETWORK IN EACH COUNTRY, COMPARED TO POPULATION

Sources: Facebook; Tencent; VKontakte, LiveInternet.ru, Nikkei, VentureBeat, Niki Aghaei; UN, US Census Bureau for population data.

E-commerce and Conversion Statistics 2016

- *40% of global internet users, or more than 1 billion people, have bought products or goods online.*
- *The U.S. e-commerce economy is worth $349 billion while China's e-commerce economy is worth $562.66 billion.*
- *A single second delay in your website loading time can result in a 7% loss in conversion, and 40% of web users will abandon a website if it takes longer than 3 seconds to load.*
- *Slow loading websites cost the U.S. e-commerce market more than $500 billion annually.*
- *Online retail sales in the U.K. reached an estimated £52.25 billion in 2015, with the average shopper spending £1,174.*
- *Worldwide B2C e-commerce sales reached $1.7 trillion in 2015, and it is estimated to reach $2.35 trillion by 2018.*
- *8 out of 10 consumers will shop online if offered free shipping.*

E-commerce and Conversion Statistics 2016

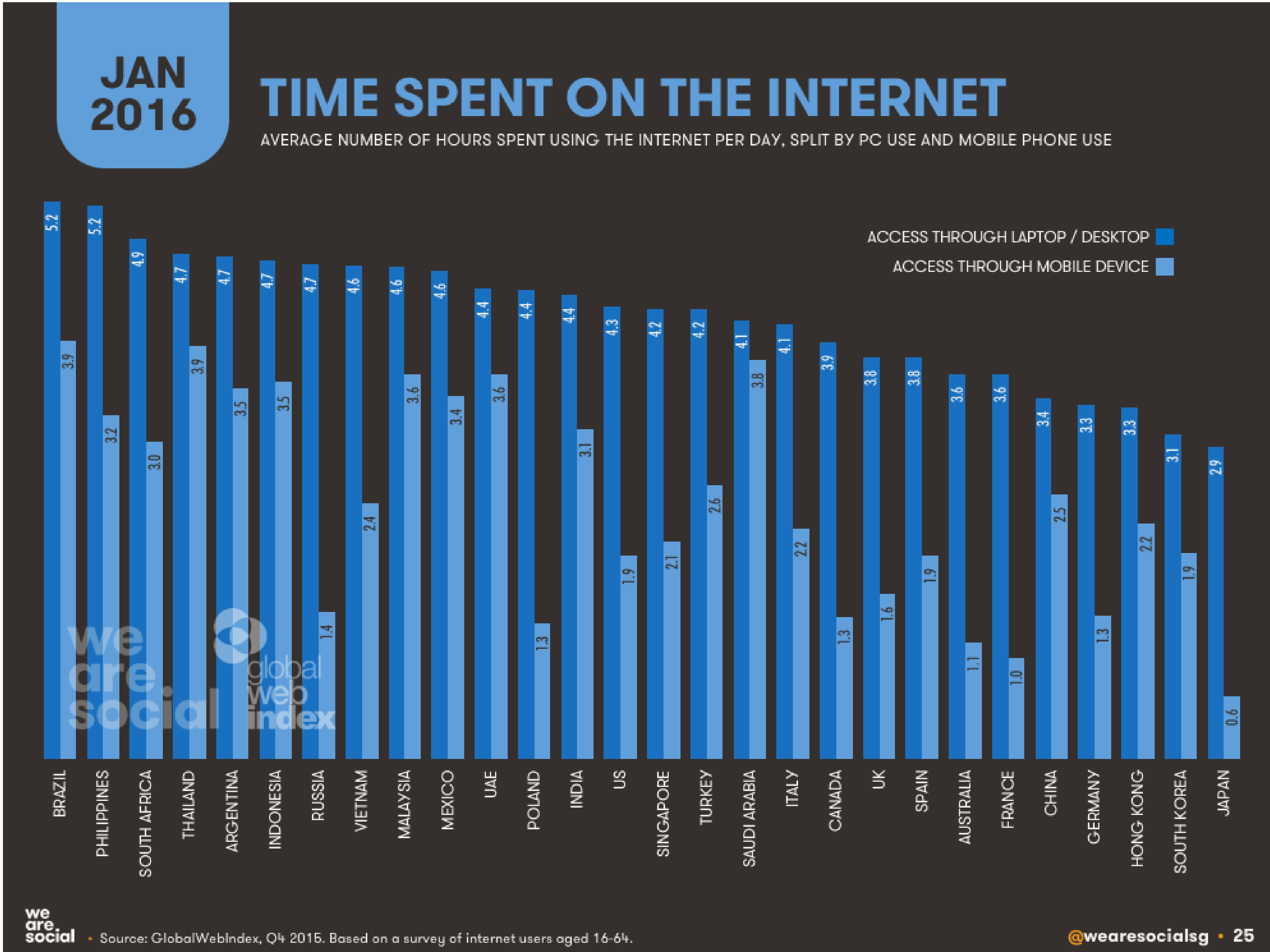
- *Personalized recommendations can increase conversion rates by up to 5.5 times.*
- *51% of U.S. online shoppers cite slow site loading times as the top reason they abandon a purchase.*
- *34% of British consumers cite a store's reputable brand name for being their reason for shopping with a brand, while 38% cite social media interaction as their reason for visiting a retailer's website.*
- *40% of shoppers consult 3 or more channels, often in the process of shopping, before making a purchase; that's a massive increase from 10% in 2002, and it goes to show the increasing importance of having an online presence in as many places as possible.*
- *While mobile internet usage is high, desktop and tablet internet usage still leads for conversions; an estimated 8.52% of desktop users add to cart and an estimated 2.78% convert to sales. This is much higher than Smartphone conversion rates with an estimated 4.70% add to cart rate and an estimated 0.80% sales conversion rate. The number is much higher when you consider conversion rates from tablets and other mobile devices, but desktop still leads when it comes to actual sales.*
- *An increase in site speed from 8 to 2 seconds can boost your conversion rate by 74% (this is based on data monitoring real user activity from 33 major retailers).*

E-commerce and Conversion Statistics 2016

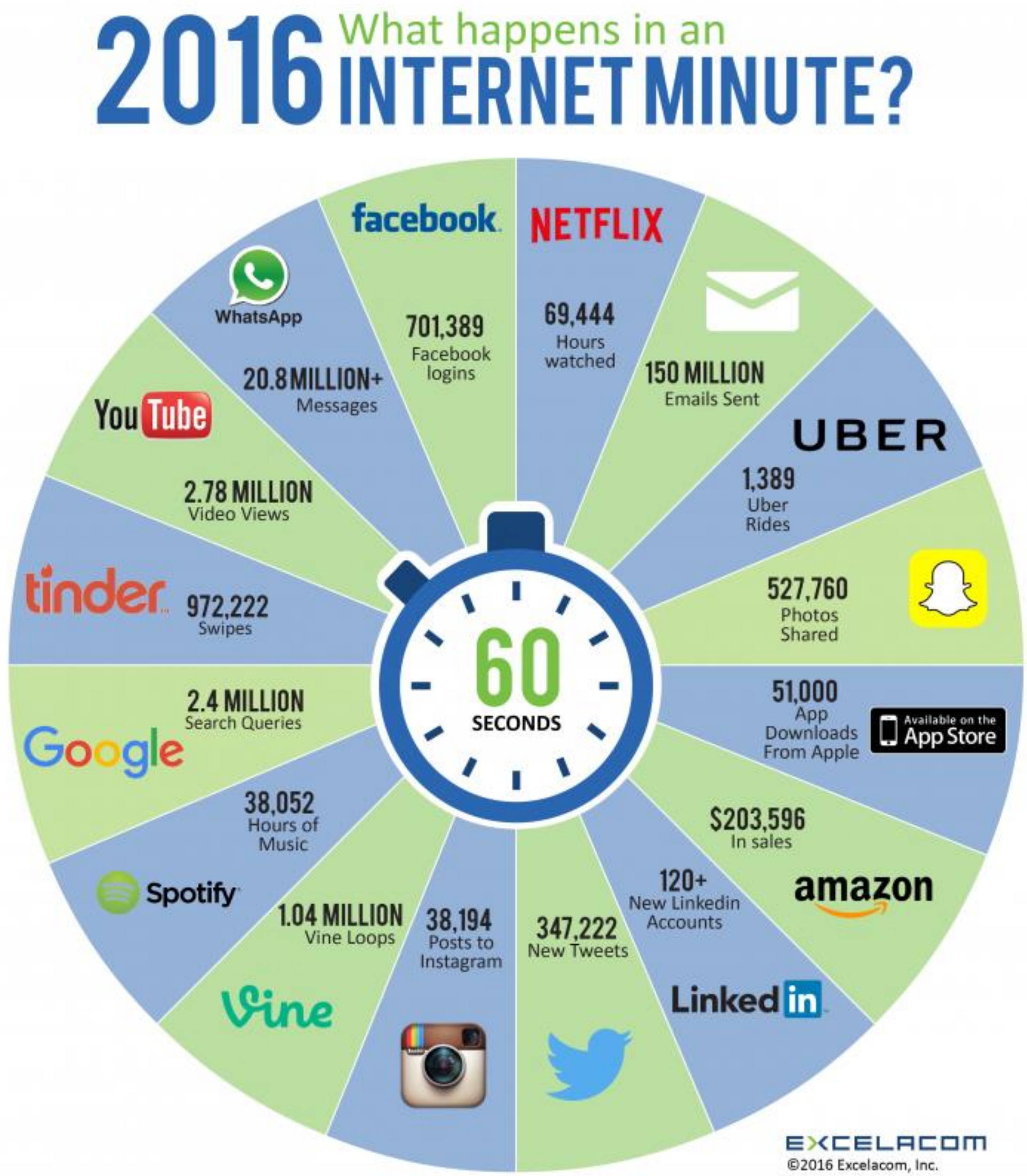
- *Increasingly shrinking attention span keeps influencing e-commerce; in 2010, a page that took 6 seconds to load suffered a 40% loss in conversion. Today, a page that takes 6 seconds to load will experience a 50% loss in conversion.*
- *The abandonment rate for mobile shopping cart is higher (at 97%) than that of desktop shopping carts (at 70 – 75%).*
- *E-commerce sales from social media grew by 202% in 2014, and is expected to further increase.*
- *The average human attention span has declined from 12 seconds in the year 2000 to 8 seconds now. This is much shorter than the attention span of a goldfish (at 9 seconds). This was revealed by a recent study by Microsoft Corp. that surveyed 2,000 people and monitored brain activity of 112 others using electroencephalograms (EEGs).*

Mobile Internet 2016

- ***There are more mobile internet users than desktop internet users****; 52.7% of global internet users access the internet via mobile, and 75.1% of U.S. internet users access the internet via mobile.*
- *Mobile media time in the U.S. has exceeded desktop, with mobile media time estimated to be 51% while desktop media time is estimated to be 42%.*
- *While there are more mobile users than desktop users, mobile advertising spend is still slightly lower than desktop advertising spend; mobile advertising spend currently represents 49% of digital advertising spend, compared to desktop at 51%.*
- *Mobile advertising spend is projected to account for 60.4% of all digital advertising spend by 2016 and 72.2% of all digital advertising spend by 2019.*
- *In 2015, mobile influenced retail sales to the tune of over $1 trillion.*
- *Search engines are the starting point for mobile research, with an estimated 48% of mobile internet users starting their search on search engines.*
- *Consequently, the #1 search engine, Google started to significantly use mobile compatibility as a factor when ranking websites.*
- *B2C mobile commerce sales in the U.S. is valued at an estimated $83.93 billion.*
- *4 out of 5 consumers use a Smartphone to shop.*
- *70% of mobile searches result in an online action within an hour of the search being conducted.*
- *50% of mobile users will abandon of web page if it takes more than 10 seconds to load, and 60% won't return to the site.*



JAN 2016
TIME SPENT ON THE INTERNET
AVERAGE NUMBER OF HOURS SPENT USING THE INTERNET PER DAY, SPLIT BY PC USE AND MOBILE PHONE USE
ACCESS THROUGH LAPTOP / DESKTOP
ACCESS THROUGH MOBILE DEVICE
BRAZIL 5.2 3.9
PHILIPPINES 5.2 3.2
SOUTH AFRICA 4.9 3.0
THAILAND 4.7 3.9
ARGENTINA 4.7 3.5
INDONESIA 4.7 3.5
RUSSIA 4.7 1.4
VIETNAM 4.6 2.4
MALAYSIA 4.6 3.6
MEXICO 4.6 3.4
UAE 4.4 3.6
POLAND 4.4 1.3
INDIA 4.4 3.1
US 4.3 1.9
SINGAPORE 4.2 2.1
TURKEY 4.2 2.6
SAUDI ARABIA 4.1 3.8
ITALY 4.1 2.2
CANADA 3.9 1.3
UK 3.8 1.6
SPAIN 3.8 1.9
AUSTRALIA 3.6 1.1
FRANCE 3.6 1.0
CHINA 3.4 2.5
GERMANY 3.3 1.3
HONG KONG 3.3 2.2
SOUTH KOREA 3.1 1.9
JAPAN 2.9 0.6
we are social
global web index
Source: GlobalWebIndex, Q4 2015. Based on a survey of internet users aged 16-64.
@wearesocialsg • 25


2016 What happens in an INTERNET MINUTE?
facebook
701,389 Facebook logins
NETFLIX
69,444 Hours watched
150 MILLION Emails Sent
UBER
1,389 Uber Rides
527,760 Photos Shared
51,000 App Downloads From Apple
Available on the App Store
$203,596 In sales
amazon
120+ New Linkedin Accounts
LinkedIn
347,222 New Tweets
38,194 Posts to Instagram
1.04 MILLION Vine Loops
Vine
38,052 Hours of Music
Spotify
2.4 MILLION Search Queries
Google
tinder
972,222 Swipes
YouTube
2.78 MILLION Video Views
WhatsApp
20.8 MILLION+ Messages
60 SECONDS
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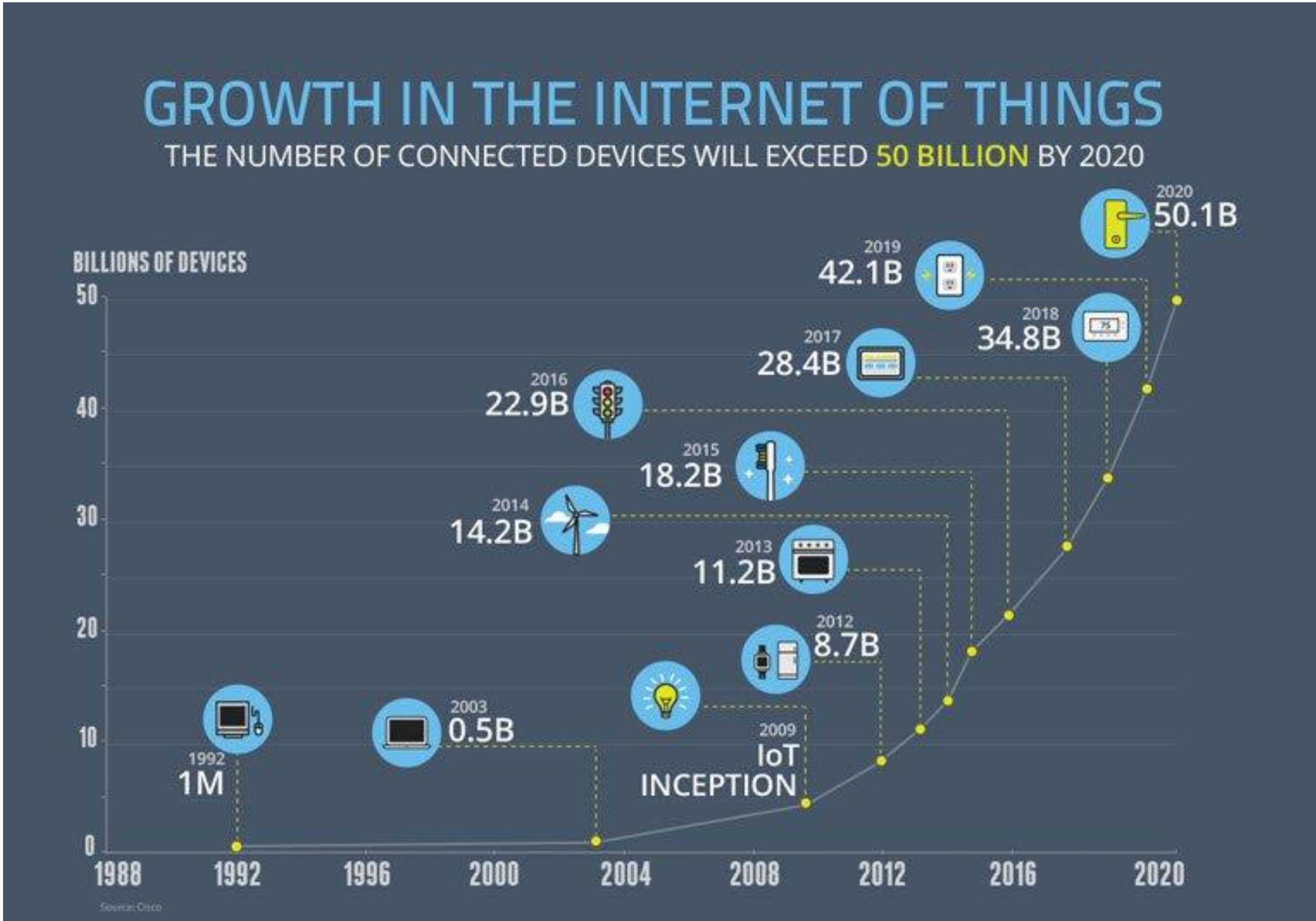

GROWTH IN THE INTERNET OF THINGS
THE NUMBER OF CONNECTED DEVICES WILL EXCEED 50 BILLION BY 2020
BILLIONS OF DEVICES
50
40
30
20
10
0
1988
1992
1996
2000
2004
2008
2012
2016
2020
1992
1M
2003
0.5B
2009
IoT
INCEPTION
2012
8.7B
2013
11.2B
2014
14.2B
2015
18.2B
2016
22.9B
2017
28.4B
2018
34.8B
2019
42.1B
2020
50.1B

Social Issues

- Network neutrality – no network restrictions
- Content ownership, e.g., DMCA takedowns
- Anonymity and censorship
- Privacy, e.g., Web tracking and profiling
- Theft, e.g., botnets and phishing

Network Types

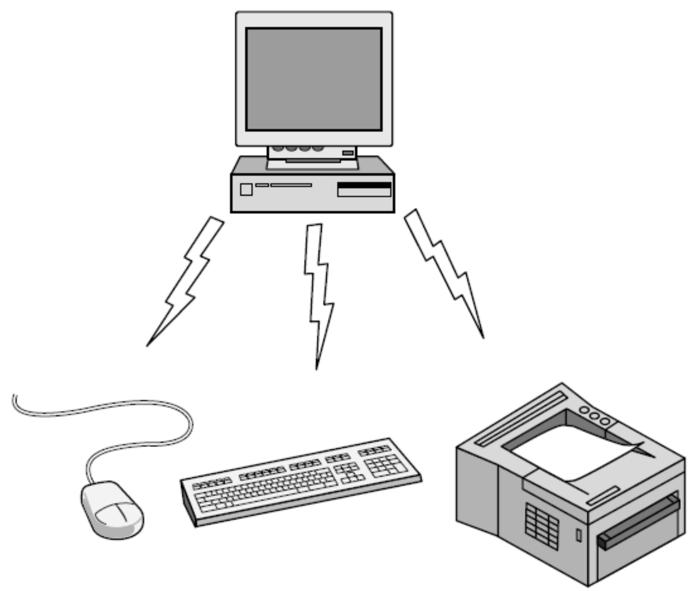
Networks can be classified by their scale:

Scale	Type
Vicinity	PAN (Personal Area Network) »
Building	LAN (Local Area Network) »
City	MAN (Metropolitan Area Network) »
Country	WAN (Wide Area Network) »
Planet	The Internet (network of all networks)

Personal Area Network

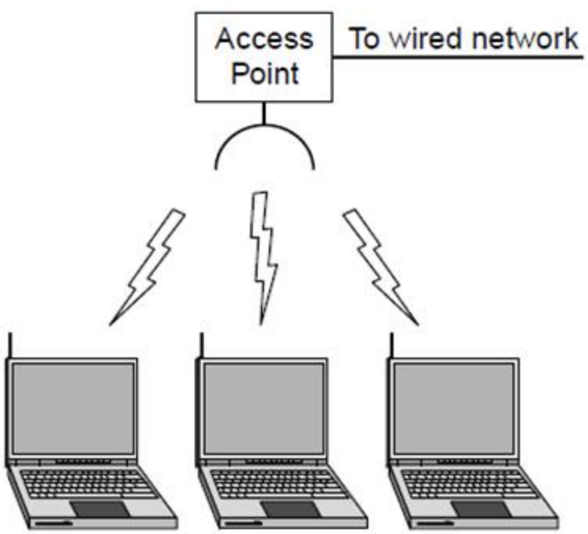
Connect devices over the range of a person

Example of a Bluetooth (wireless) PAN:

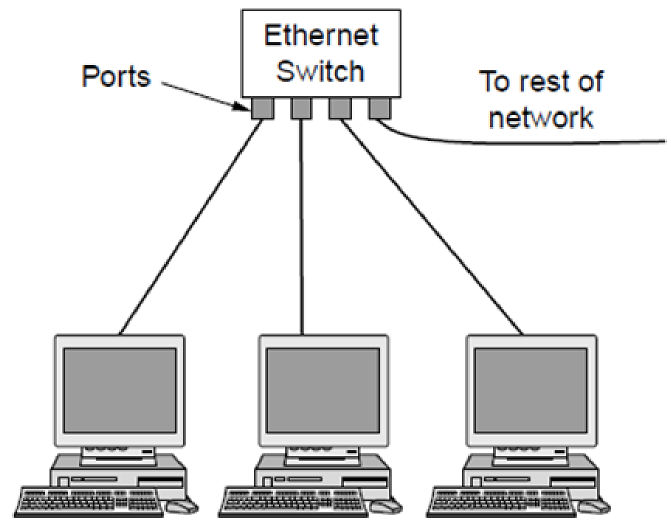


Local Area Networks

- Connect devices in a home or office building
- Called <u>enterprise network</u> in a company

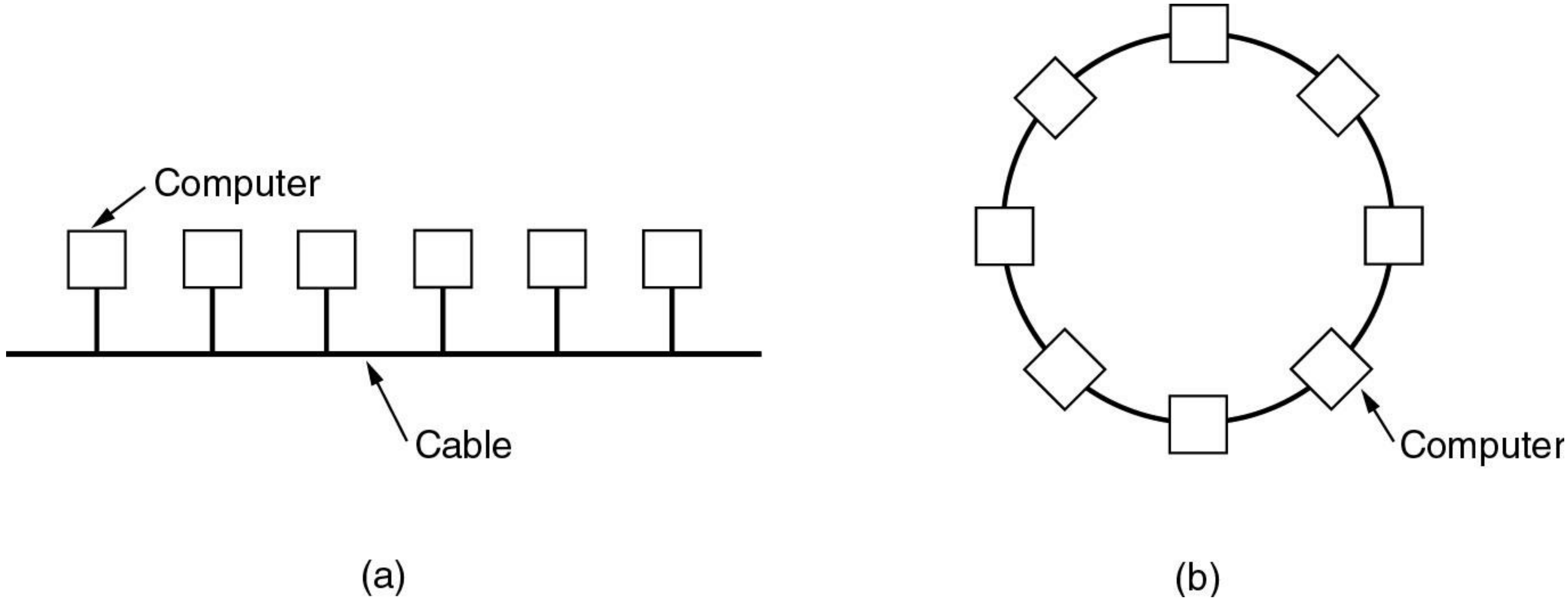


Wireless LAN
with 802.11



Wired LAN with
switched Ethernet

Local Area Networks

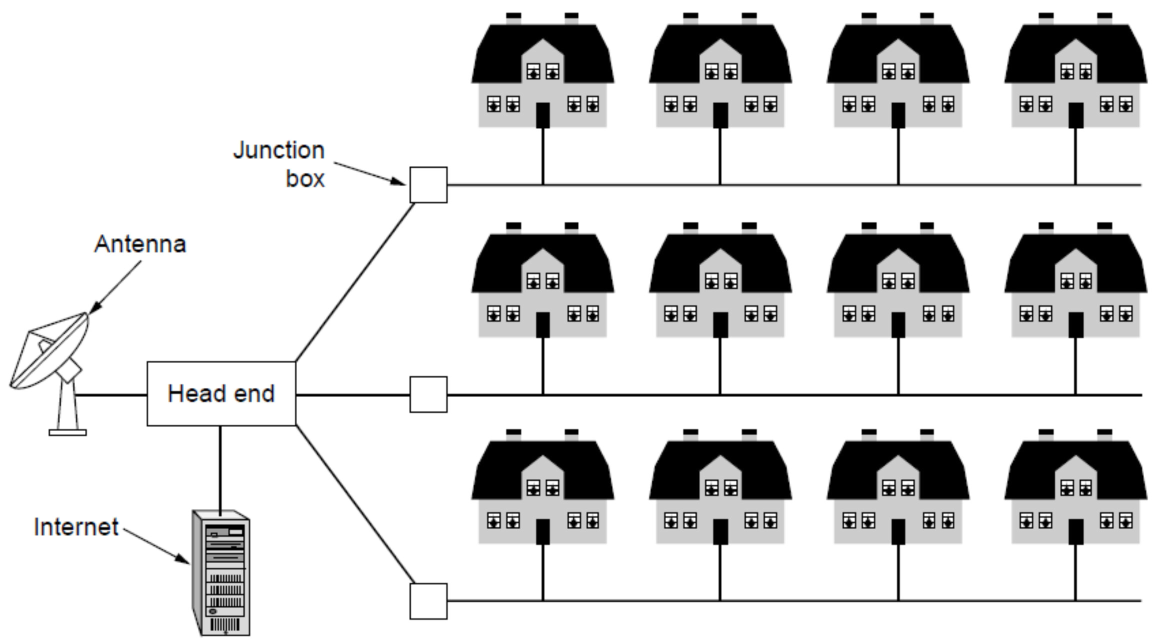


- Two broadcast networks
- (a) Bus
- (b) Ring

Metropolitan Area Networks

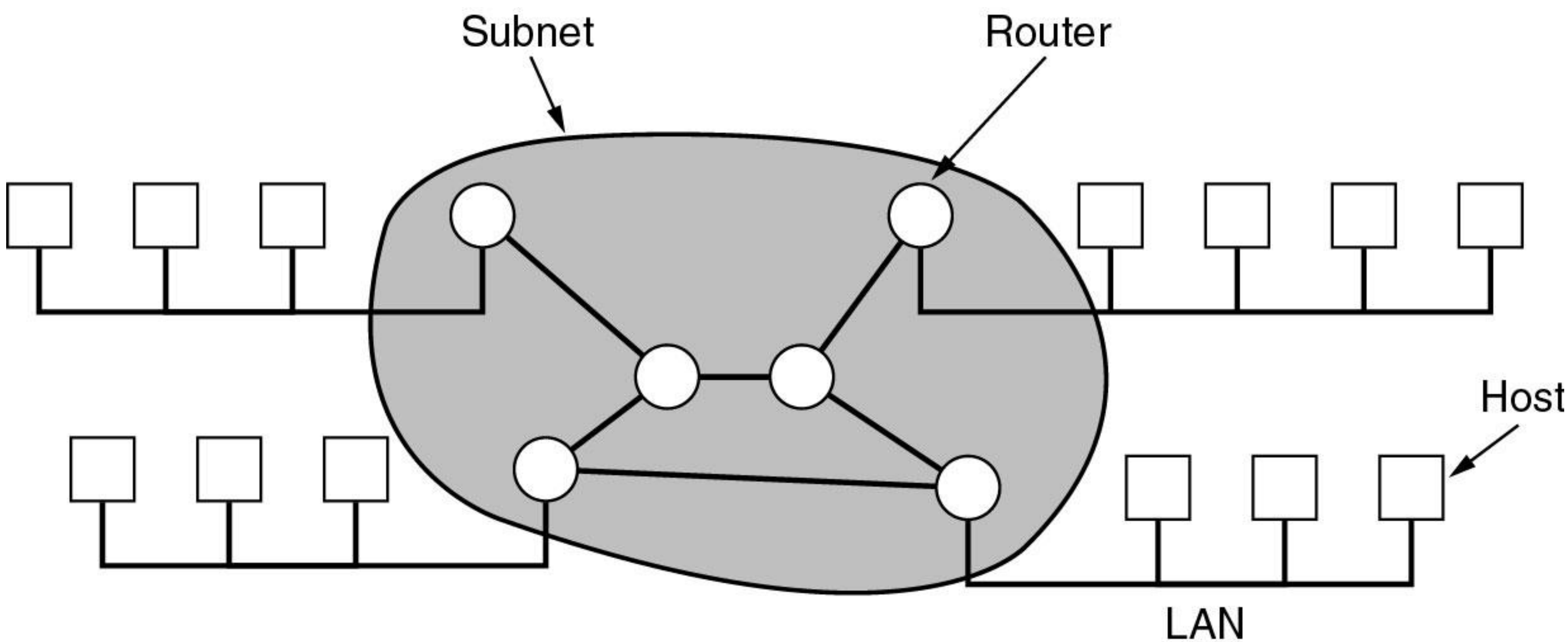
Connect devices over a metropolitan area

Example MAN based on cable TV:



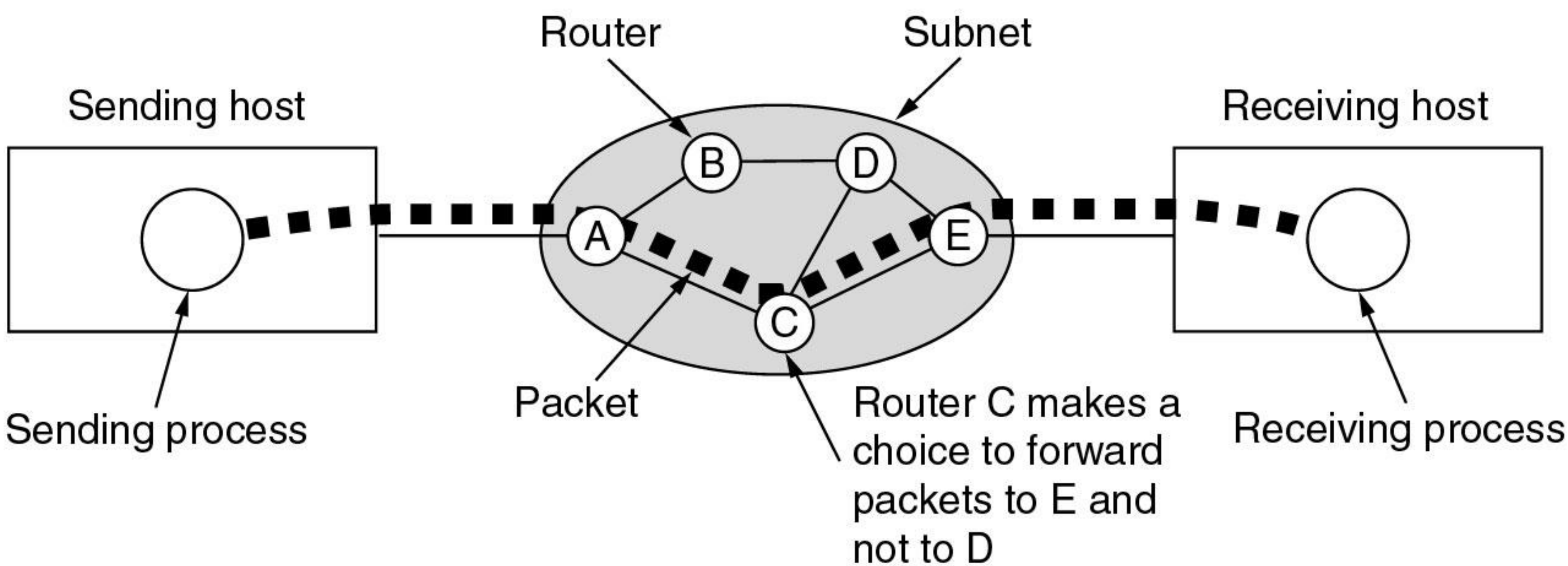
Wide Area Networks

- Relation between hosts on LANs and the subnet.



Wide Area Networks (2)

- A stream of packets from sender to receiver.



Broadcast Networks

- Types of transmission technology
- Broadcast links
- Point-to-point links

Broadcast Networks (2)

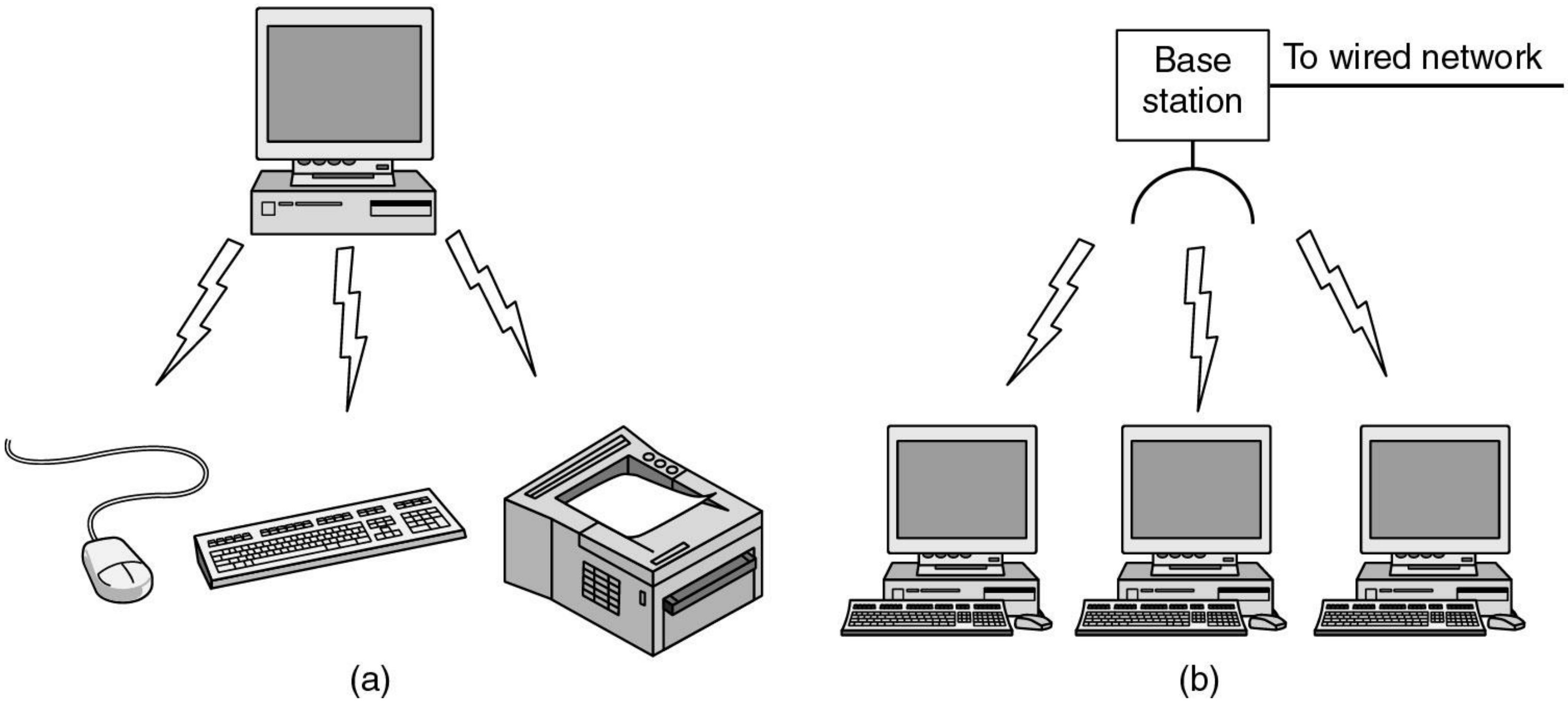
- Classification of interconnected processors by scale.

Interprocessor distance	Processors located in same	Example
1 m	Square meter	Personal area network
10 m	Room	Local area network
100 m	Building	Local area network
1 km	Campus	Local area network
10 km	City	Metropolitan area network
100 km	Country	Wide area network
1000 km	Continent	Wide area network
10,000 km	Planet	The Internet

Wireless Networks

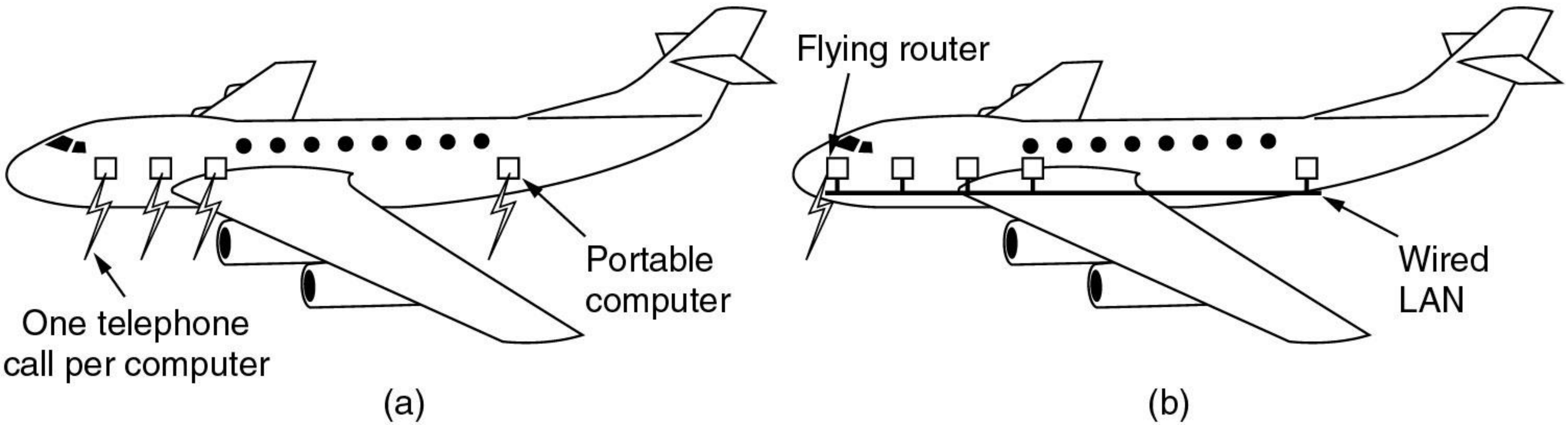
- Categories of wireless networks:
- System interconnection
- Wireless LANs
- Wireless WANs

Wireless Networks (2)



- (a) Bluetooth configuration
- (b) Wireless LAN

Wireless Networks (3)



- (a) Individual mobile computers
- (b) A flying LAN

Home Network Categories

- Computers (desktop PC, PDA, shared peripherals
- Entertainment (TV, DVD, VCR, camera, stereo, MP3)
- Telecomm (telephone, cell phone, intercom, fax)
- Appliances (microwave, fridge, clock, furnace, airco)
- Telemetry (utility meter, burglar alarm, babycam).

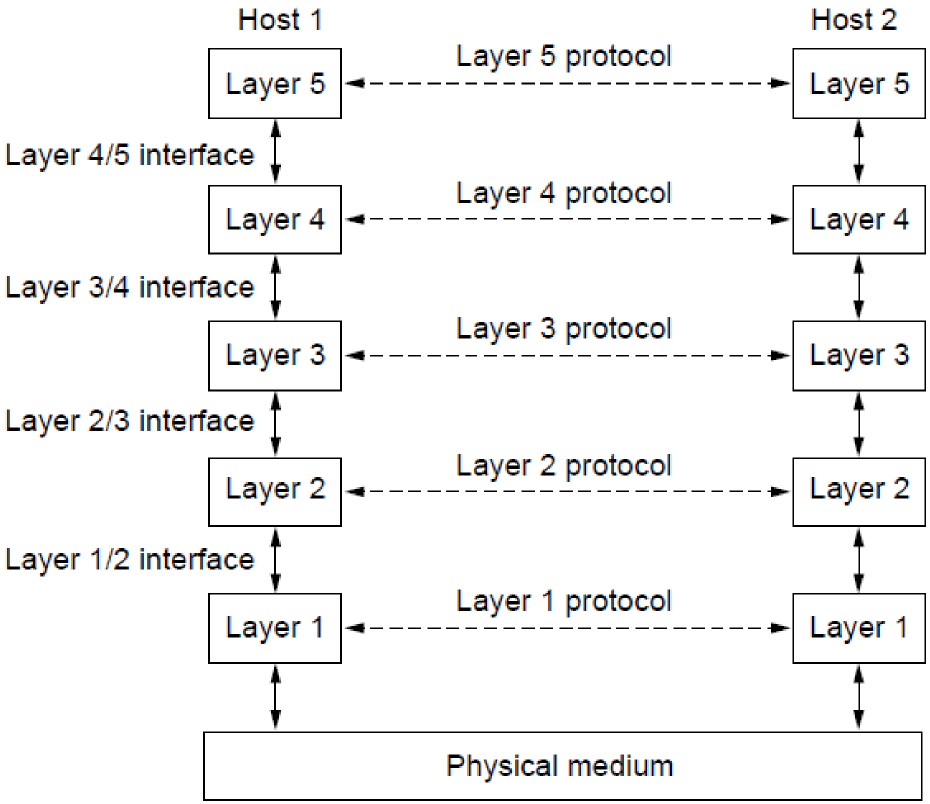
Network Software

- Protocol layers »
- Design issues for the layers »
- Connection-oriented vs. connectionless service »
- Service primitives »
- Relationship of services to protocols »

Protocol Layers (1)

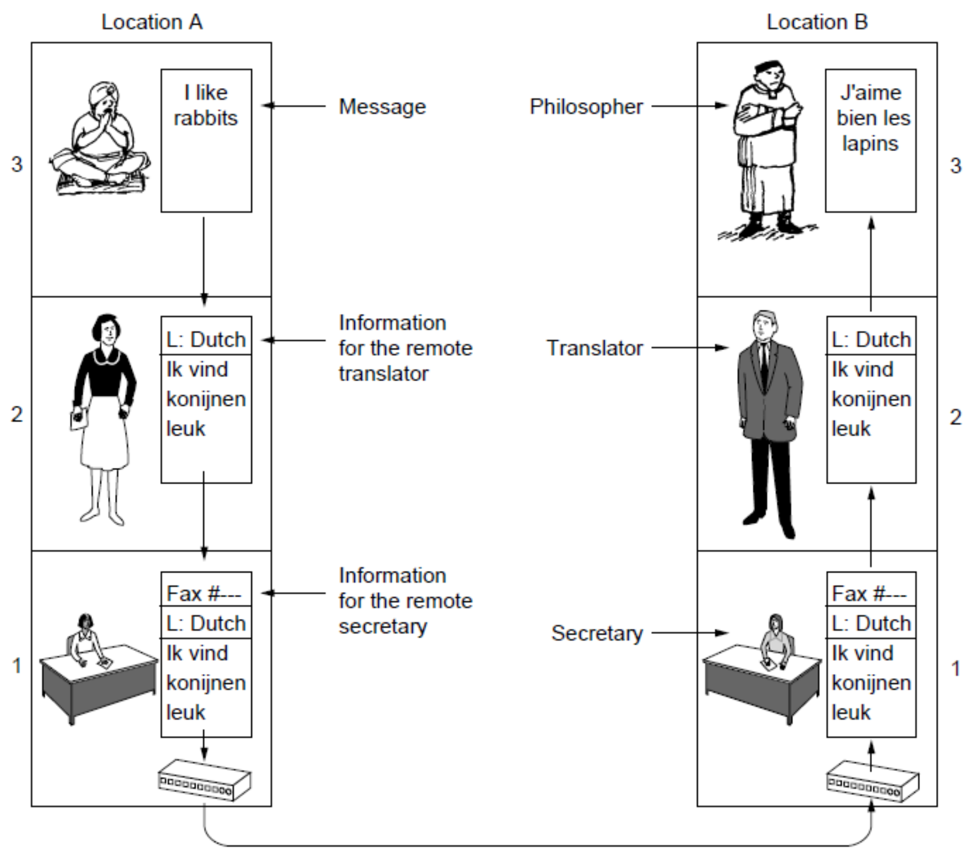
Protocol layering is the main structuring method used to divide up network functionality.

- Each protocol instance talks virtually to its <u>peer</u>
- Each layer communicates only by using the one below
- Lower layer <u>services</u> are accessed by an <u>interface</u>
- At bottom, messages are carried by the medium



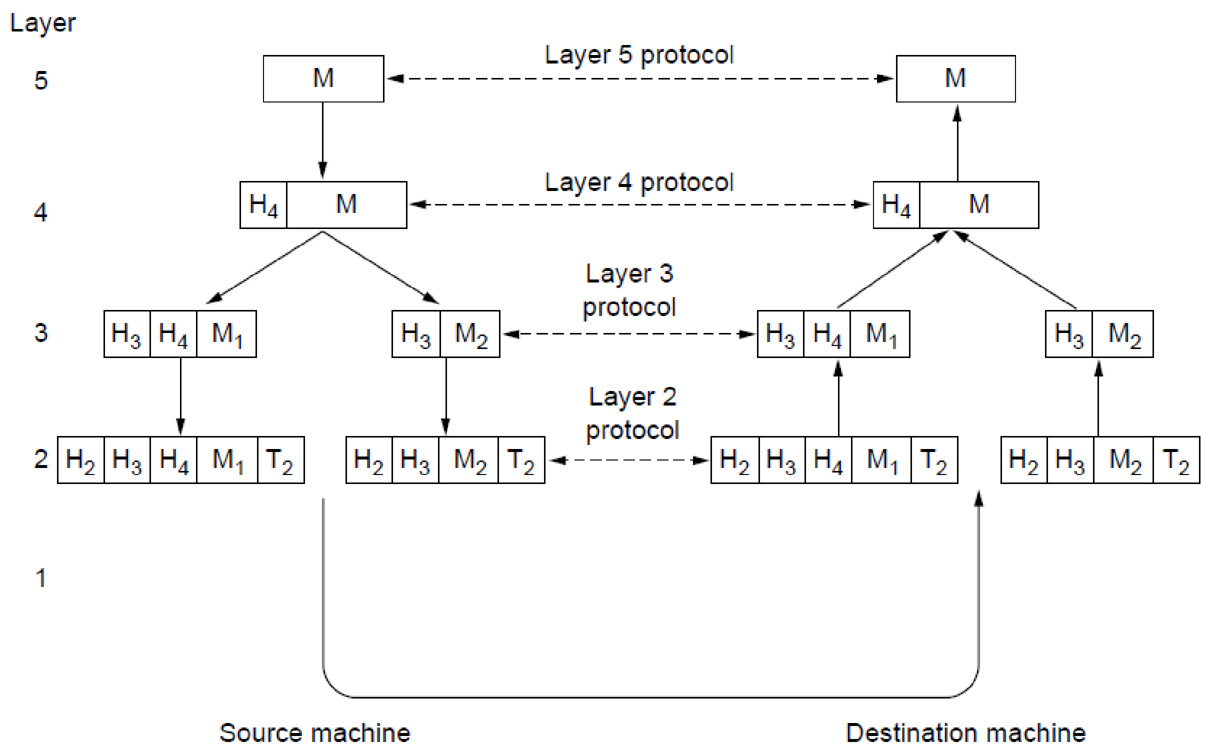
Protocol Layers (2)

- Example: the philosopher-translator-secretary architect
- Each pro … different purpose



Protocol Layers (3)

- Each lower layer adds its own <u>header</u> (with control inforr … oves it on re…



- Layer…

Design Issues for the Layers

Each layer solves a particular problem but must include mechanisms to address a set of recurring design issues

Issue	**Example mechanisms at different layers**
Reliability despite failures	Codes for error detection/correction (§3.2, 3.3) Routing around failures (§5.2)
Network growth and evolution	Addressing (§5.6) and naming (§7.1) Protocol layering (§1.3)
Allocation of resources like bandwidth	Multiple access (§4.2) Congestion control (§5.3, 6.3)
Security against various threats	Confidentiality of messages (§8.2, 8.6) Authentication of communicating parties (§8.7)

Connection-Oriented vs. Connectionless

- Service provided by a layer may be kinds of either:
  - Connection-oriented, must be set up for ongoing use (and torn down after use), e.g., phone call
  - Connectionless, messages are handled separately, e.g., postal delivery

	Service	Example
Connection-oriented	Reliable message stream	Sequence of pages
	Reliable byte stream	Movie download
	Unreliable connection	Voice over IP
Connection-less	Unreliable datagram	Electronic junk mail
	Acknowledged datagram	Text messaging
	Request-reply	Database query

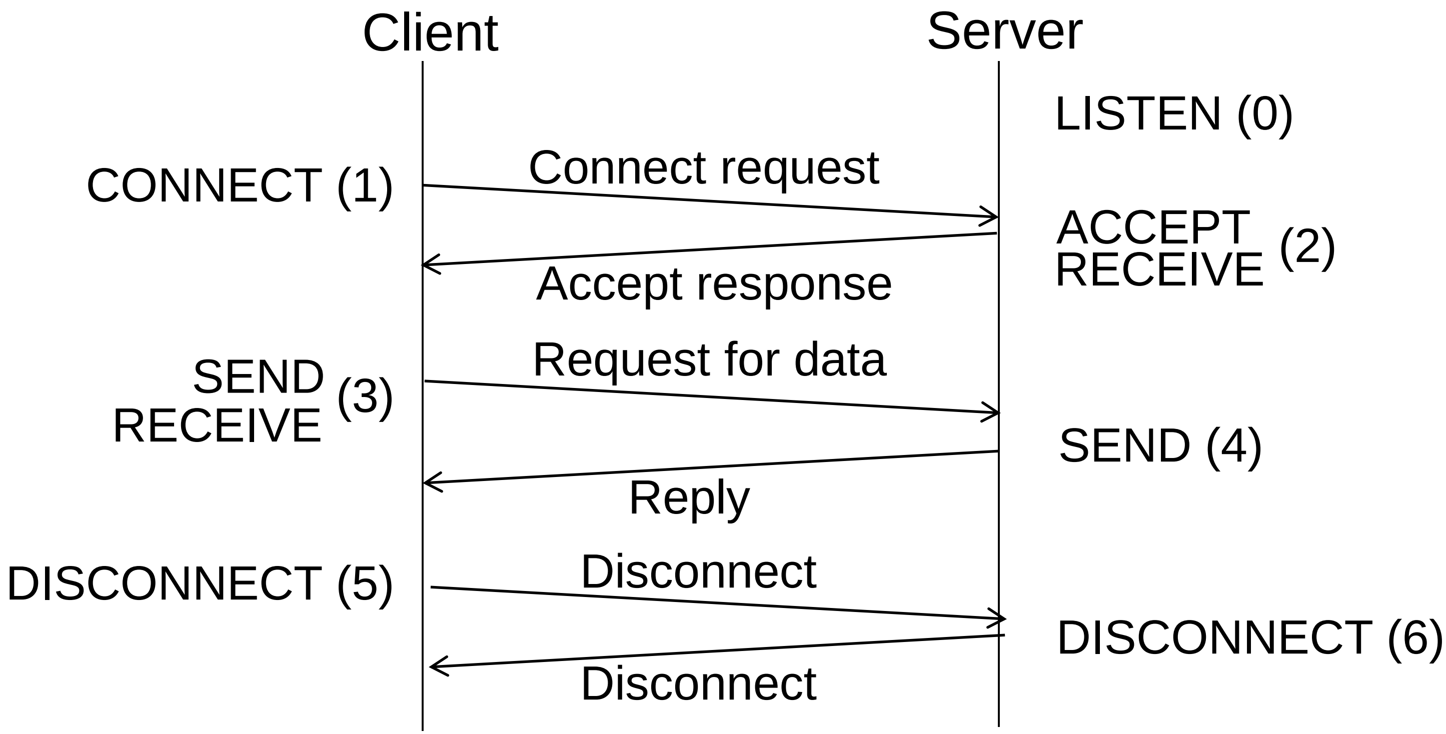
Service Primitives (1)

- A service is provided to the layer above as primitives
- Hypothetical example of service primitives that may provide a reliably byte stream (connection-oriented) service:

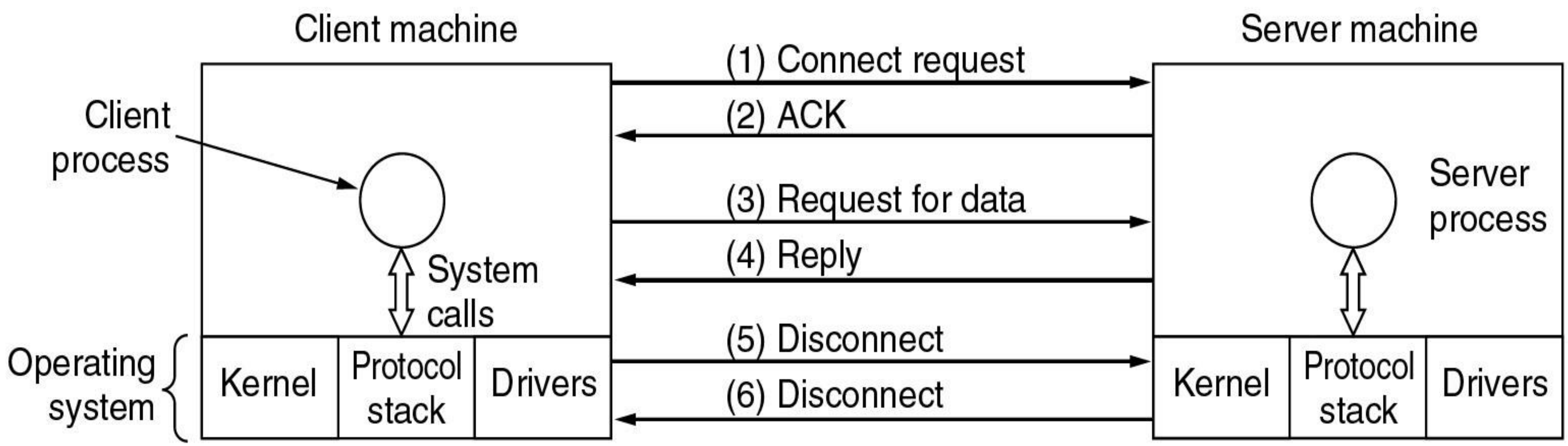
Primitive	Meaning
LISTEN	Block waiting for an incoming connection
CONNECT	Establish a connection with a waiting peer
ACCEPT	Accept an incoming connection from a peer
RECEIVE	Block waiting for an incoming message
SEND	Send a message to the peer
DISCONNECT	Terminate a connection

Service Primitives (2)

- Hypothetical example of how these primitives may be used for a client-server interaction



Service Primitives (2)

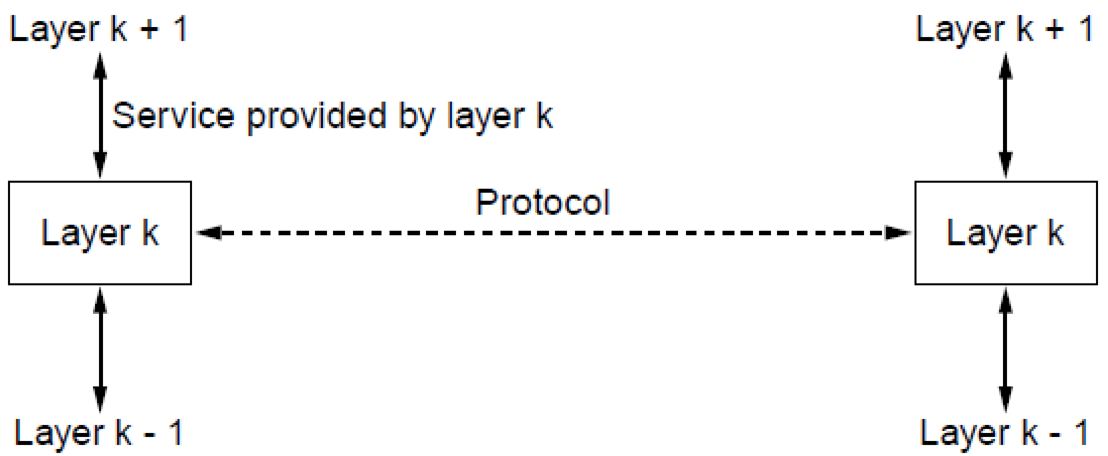


- Packets sent in a simple client-server interaction on a connection-oriented network.

Relationship of Services to Protocols

Recap:

- A layer provides a service to the one above [vertical]
- A layer talks to its peer using a protocol [horizontal]



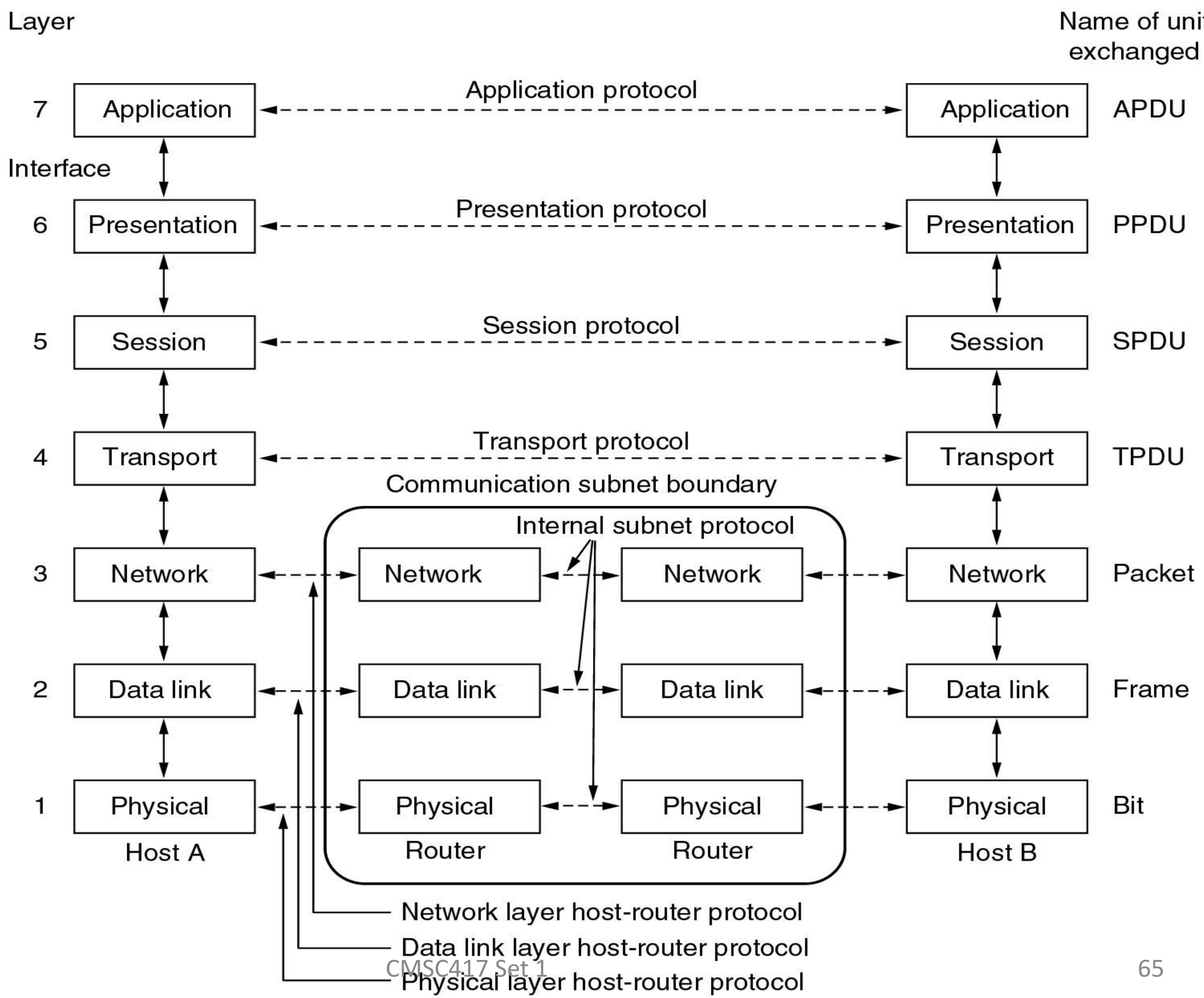
Reference Models

Reference models describe the layers in a network architecture

- OSI reference model »
- TCP/IP reference model »
- Model used for this text »
- Critique of OSI and TCP/IP »

Reference Models

The OSI reference model.



OSI Reference Model

- A principled, international standard, seven layer model to connect different systems

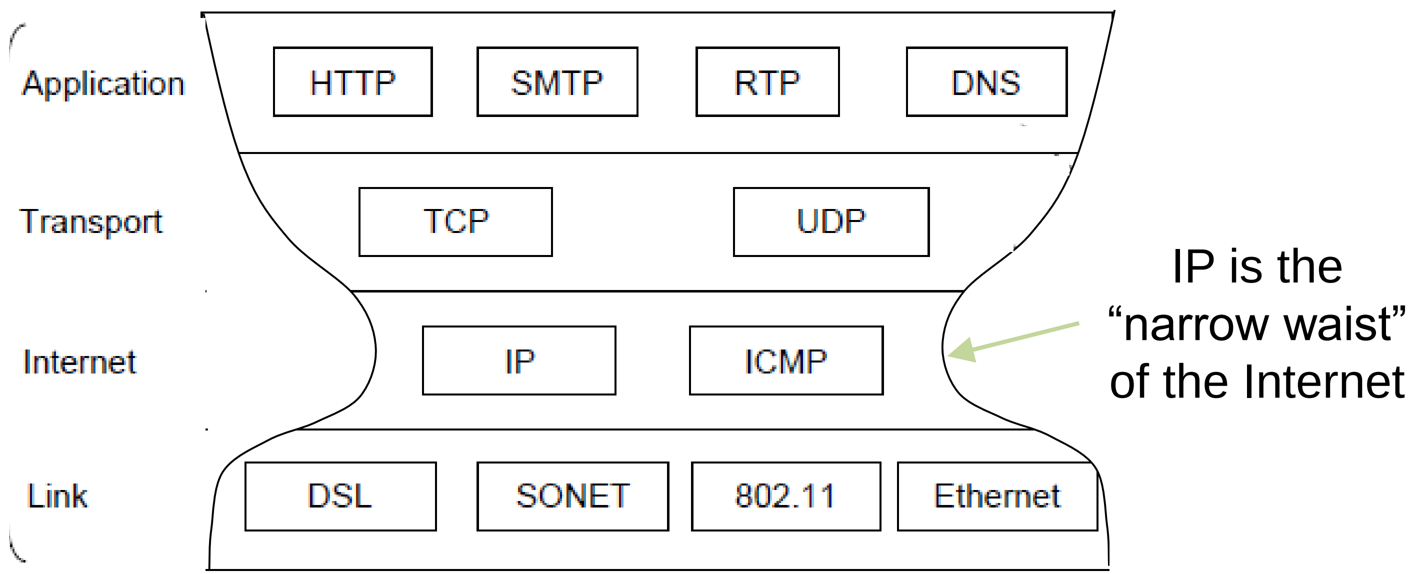
7	Application	– Provides functions needed by users
6	Presentation	– Converts different representations
5	Session	– Manages task dialogs
4	Transport	– Provides end-to-end delivery
3	Network	– Sends packets over multiple links
2	Data link	– Sends frames of information
1	Physical	– Sends bits as signals

The TCP/IP Reference Model Layers

- Link layer
- Internet layer
- Transport layer
- Application layer

TCP/IP Reference Model

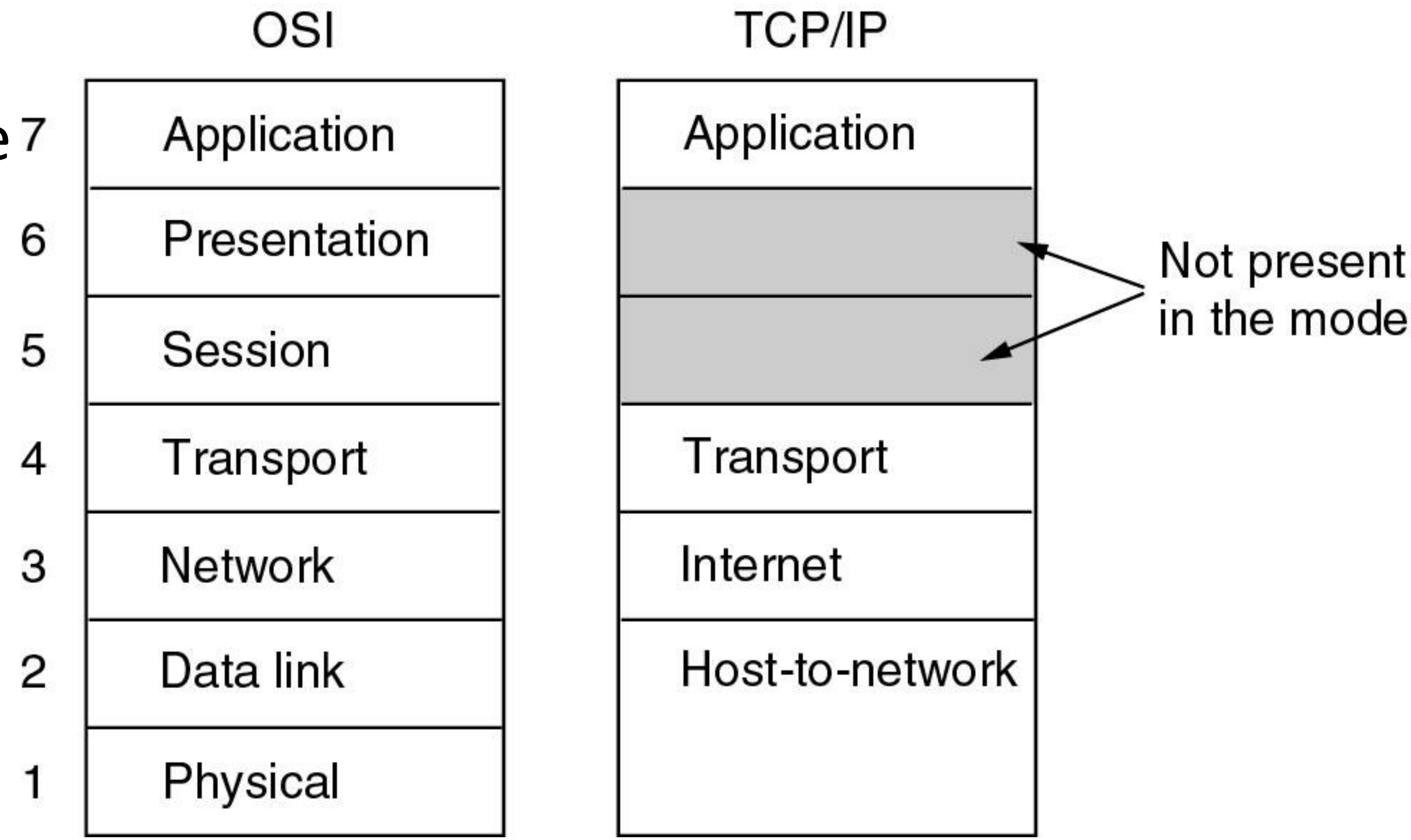
- A four layer model derived from experimentation; omits some OSI layers and uses the IP as the network



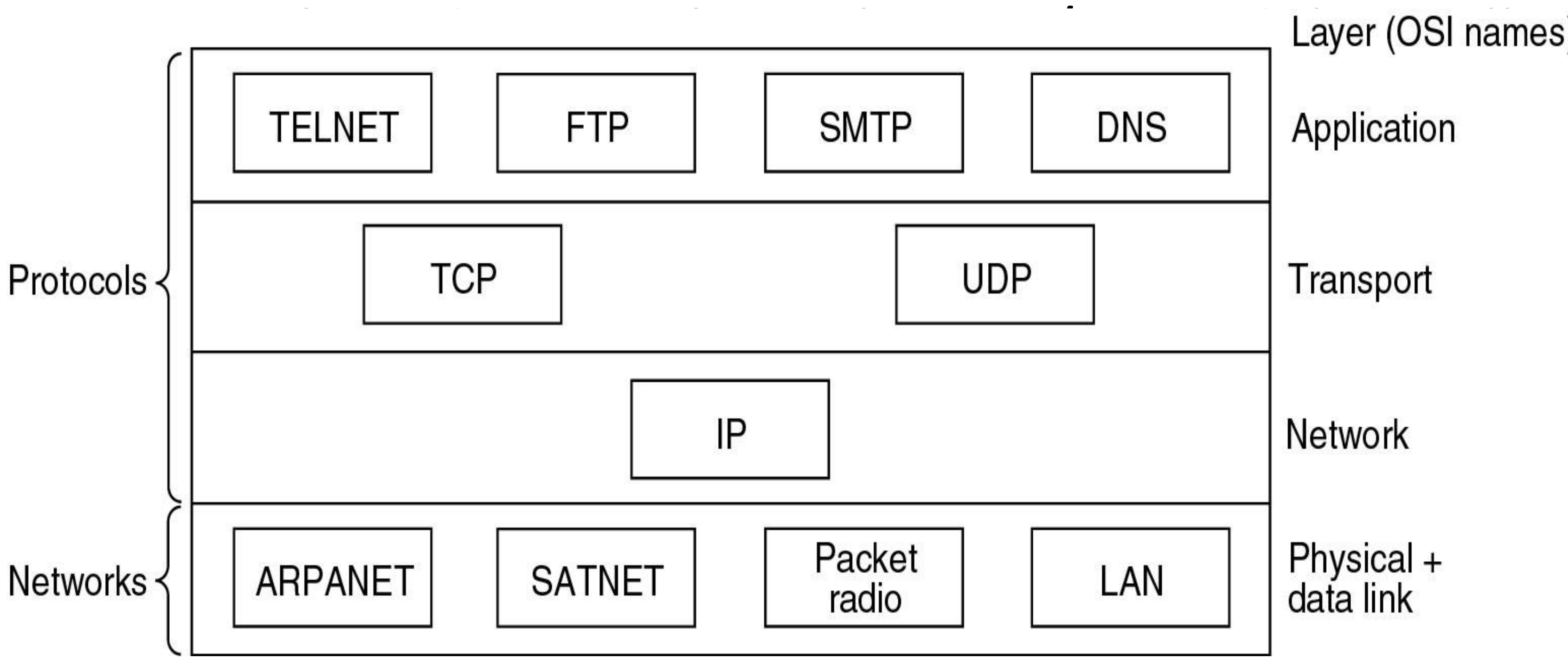
Protocols are shown in their respective layers

Reference Models (2)

- The



Reference Models (3)



Model Used in this Course

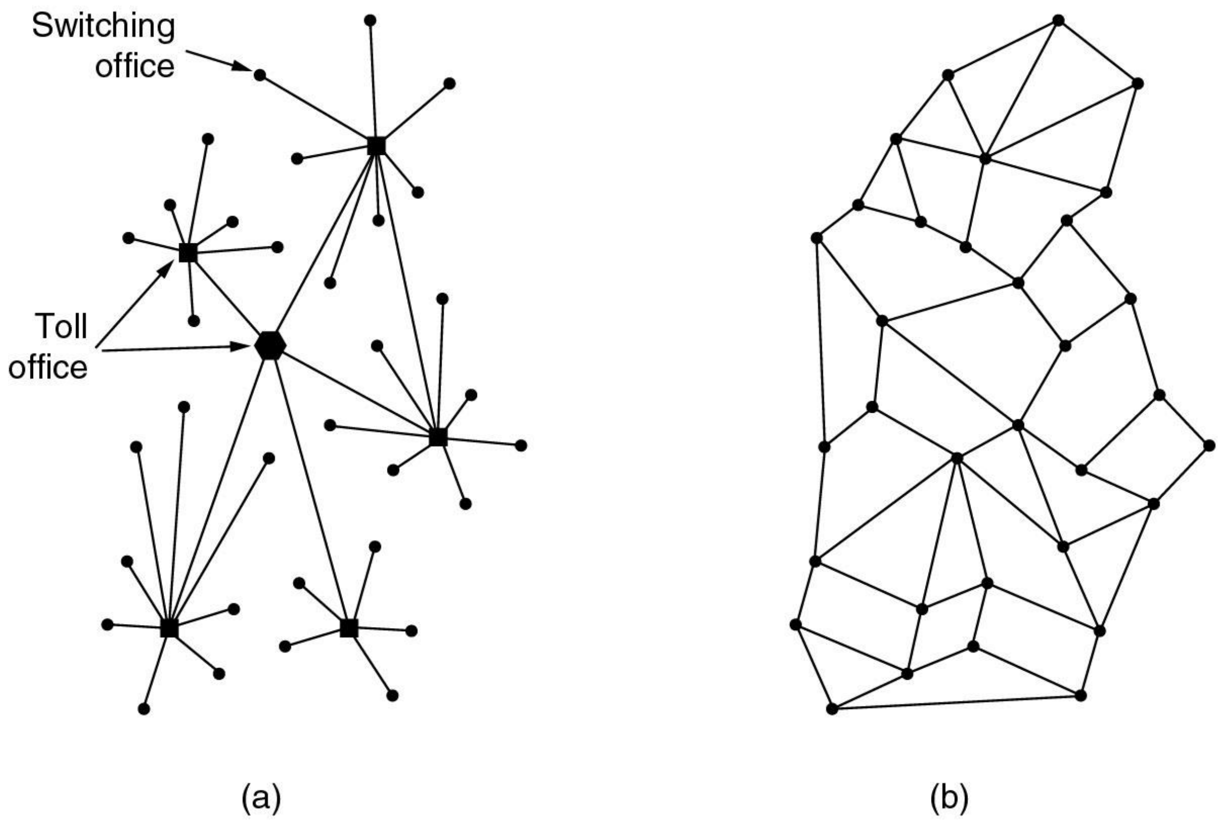
It is based on the TCP/IP model but we call out the physical layer and look beyond Internet protocols.

5	Application
4	Transport
3	Network
2	Link
1	Physical

Example Networks

- The Internet »
- 3G mobile phone networks »
- Wireless LANs »
- RFID and sensor networks »

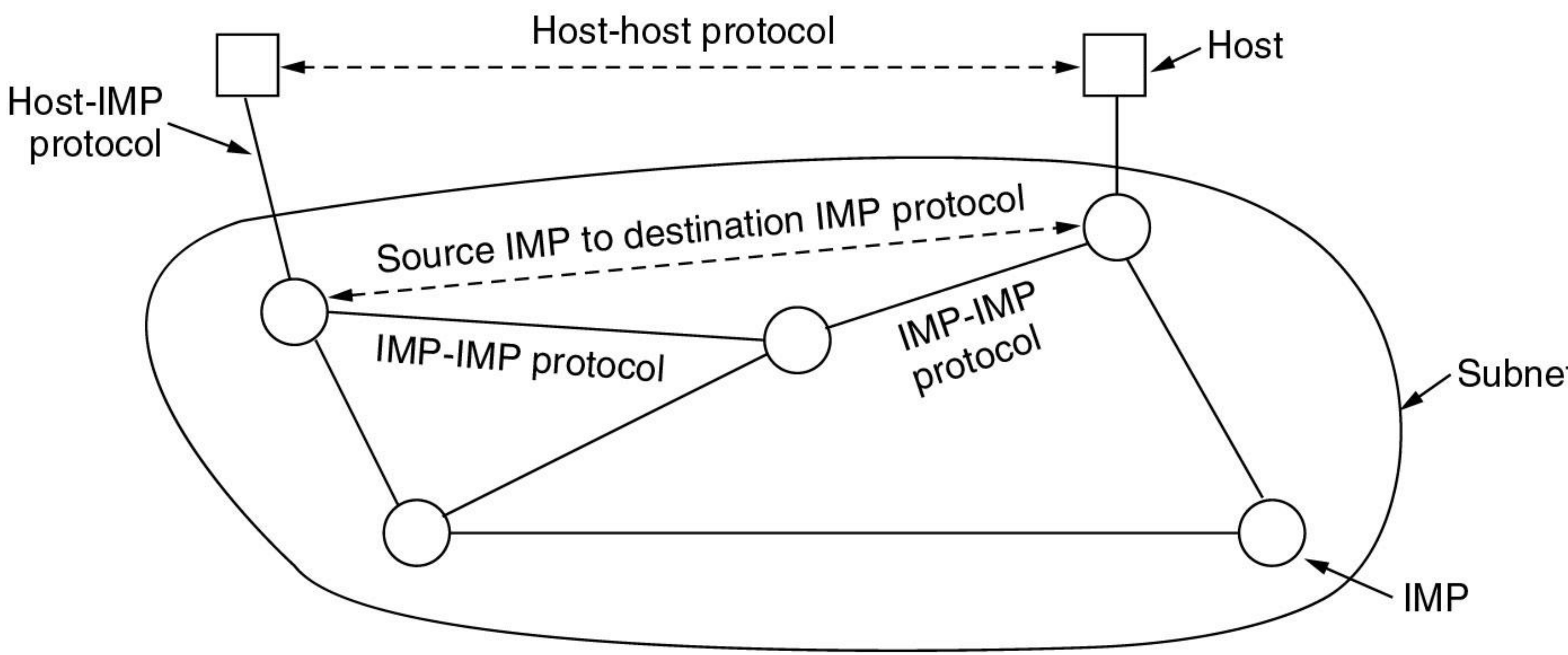
The ARPANET



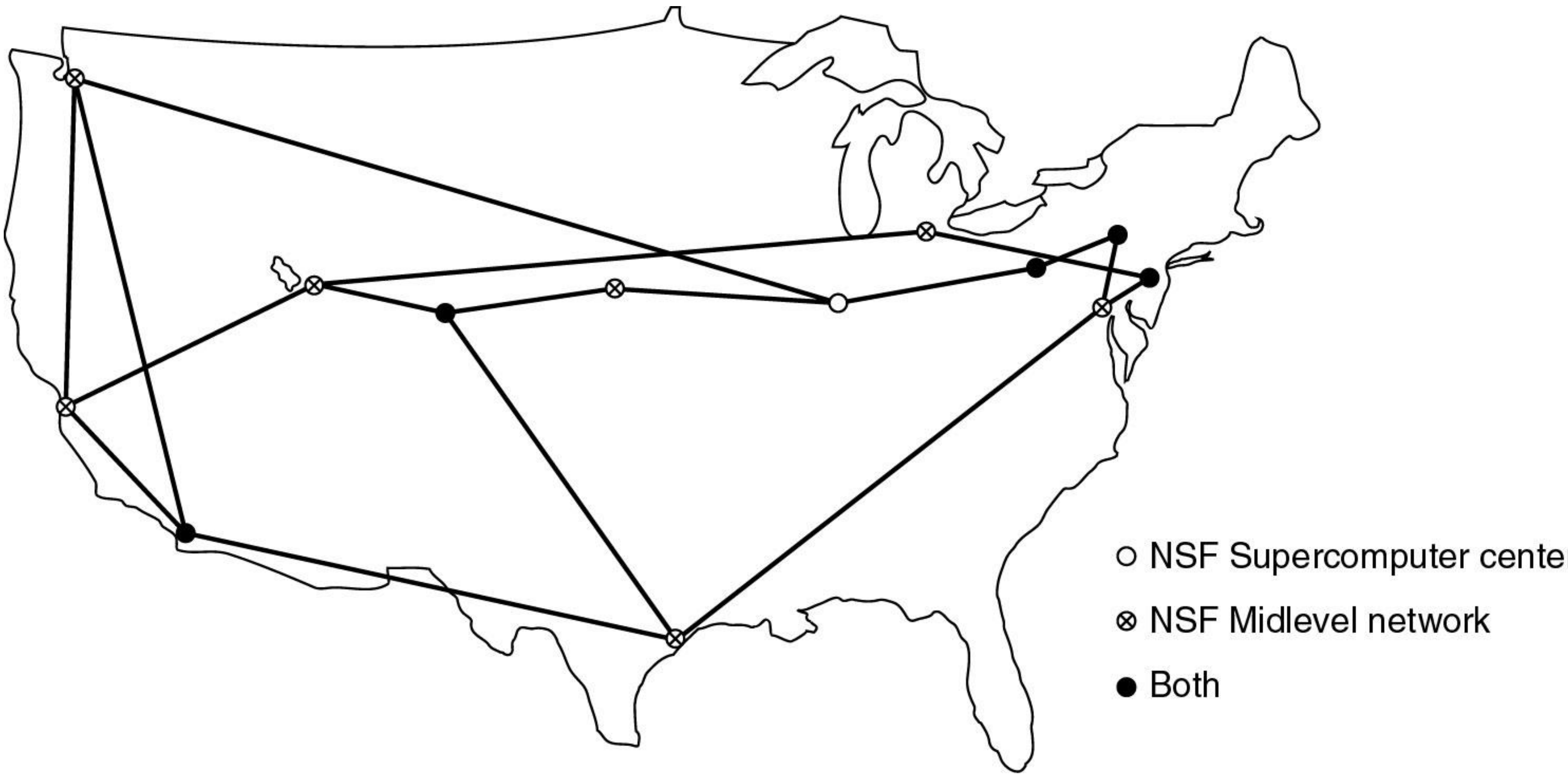
- (a) Structure of the telephone system.
- (b) Baran's proposed distributed switching system.

The ARPANET (2)

- The original ARPANET design.



NSFNET

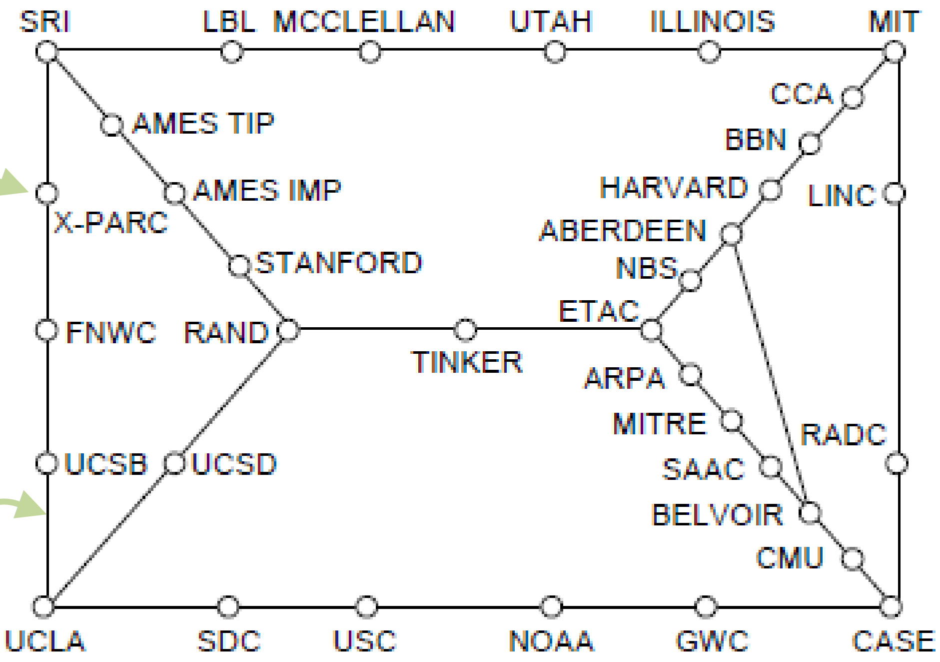
- 

Internet (1)

Before the Internet was the ARPANET, a decentralized, packet-switched network based on Baran's ideas.

Nodes are IMPs, or early routers, linked to hosts

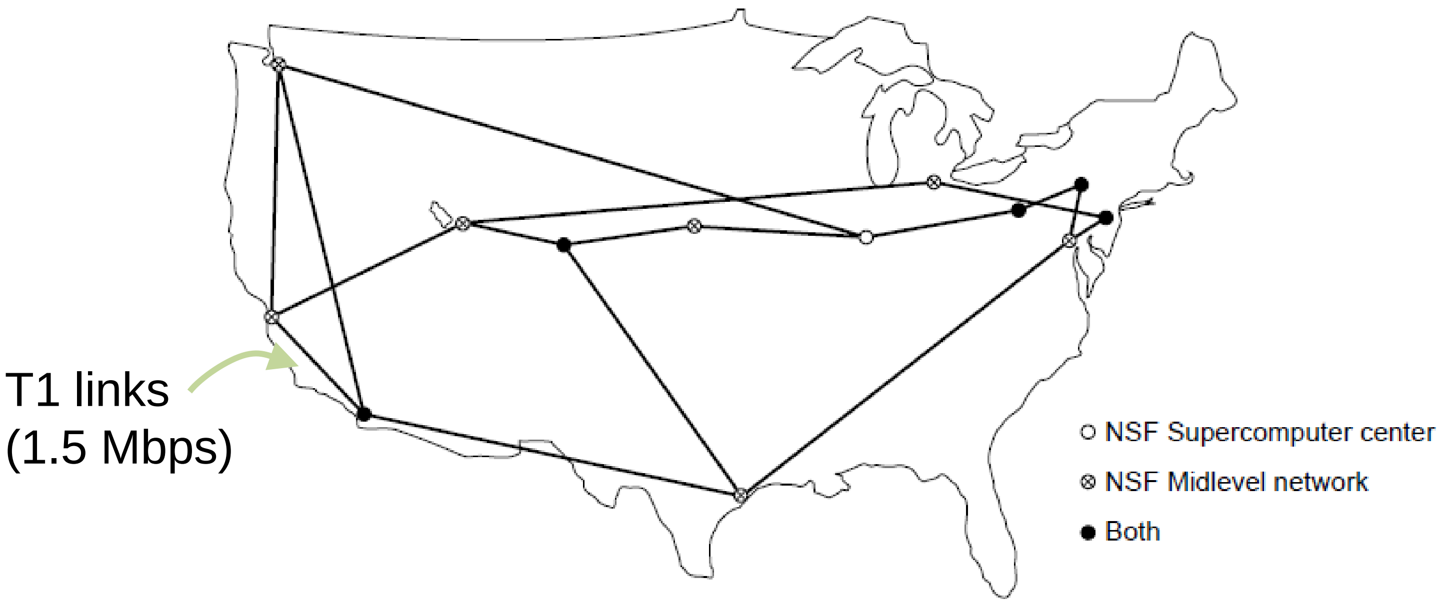
56 kbps links



ARPANET topology in Sept 1972.

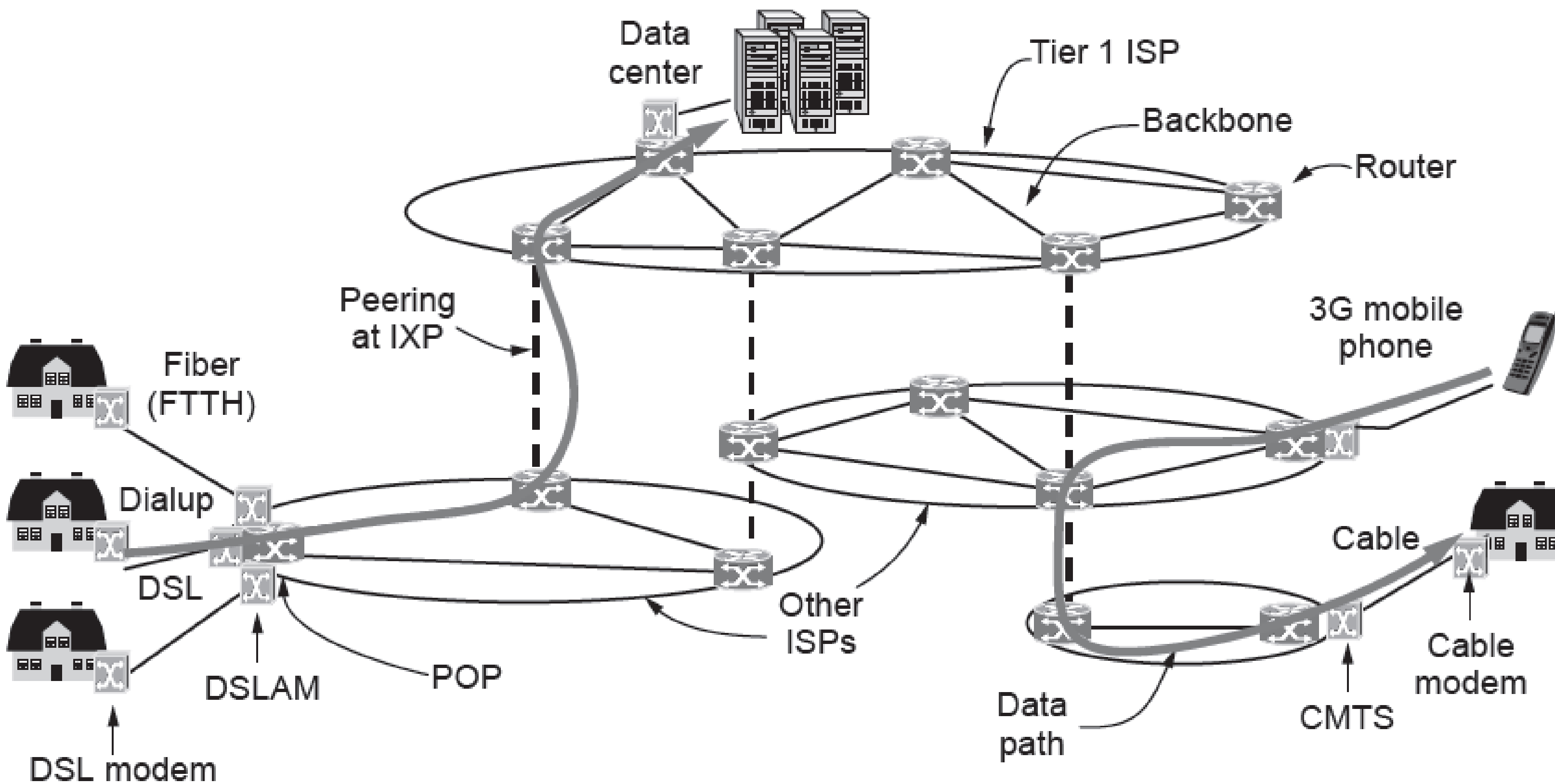
Internet (2)

The early Internet used NSFNET (1985-1995) as its backbone; universities connected to get on the Internet



NSFNET topology in 1988

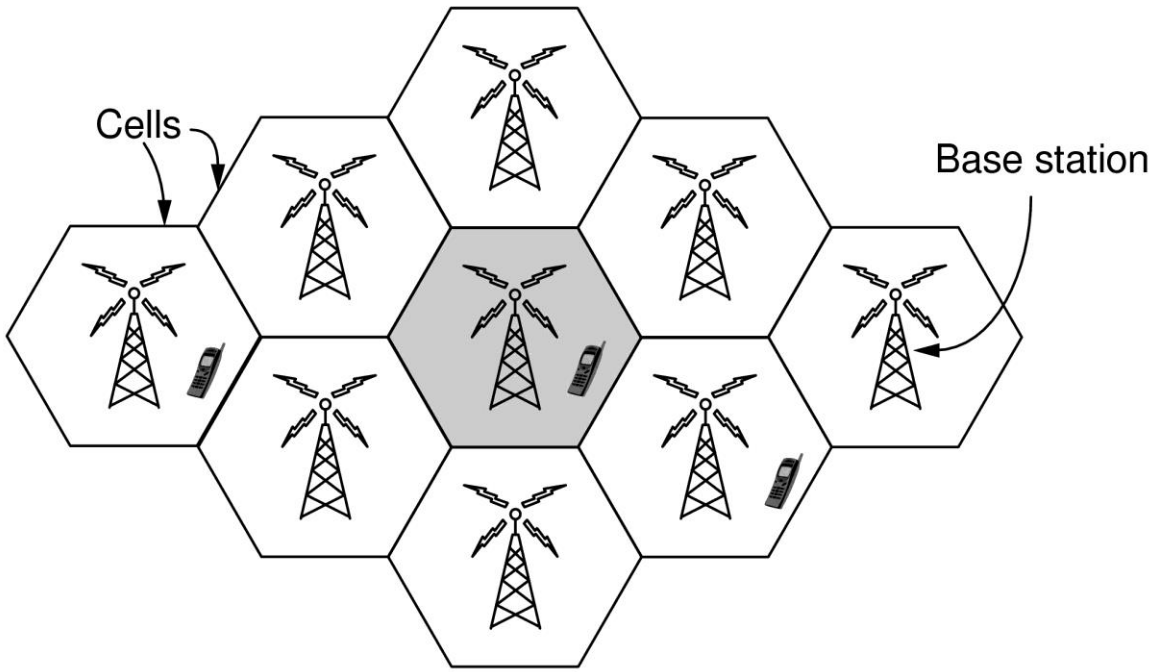
Internet (4)



Architecture of the Internet

3G Mobile Phone Networks (1)

3G network is based on spatial cells; each cell provides wireless service to mobiles within it via a base station

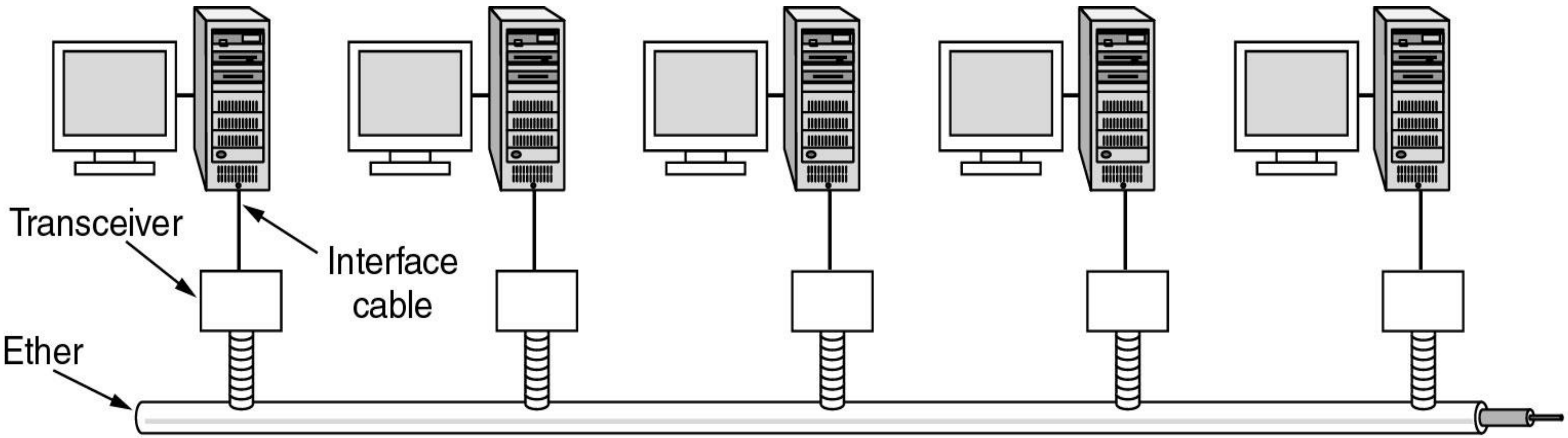


Fourth-Generation Mobile Phone Networks

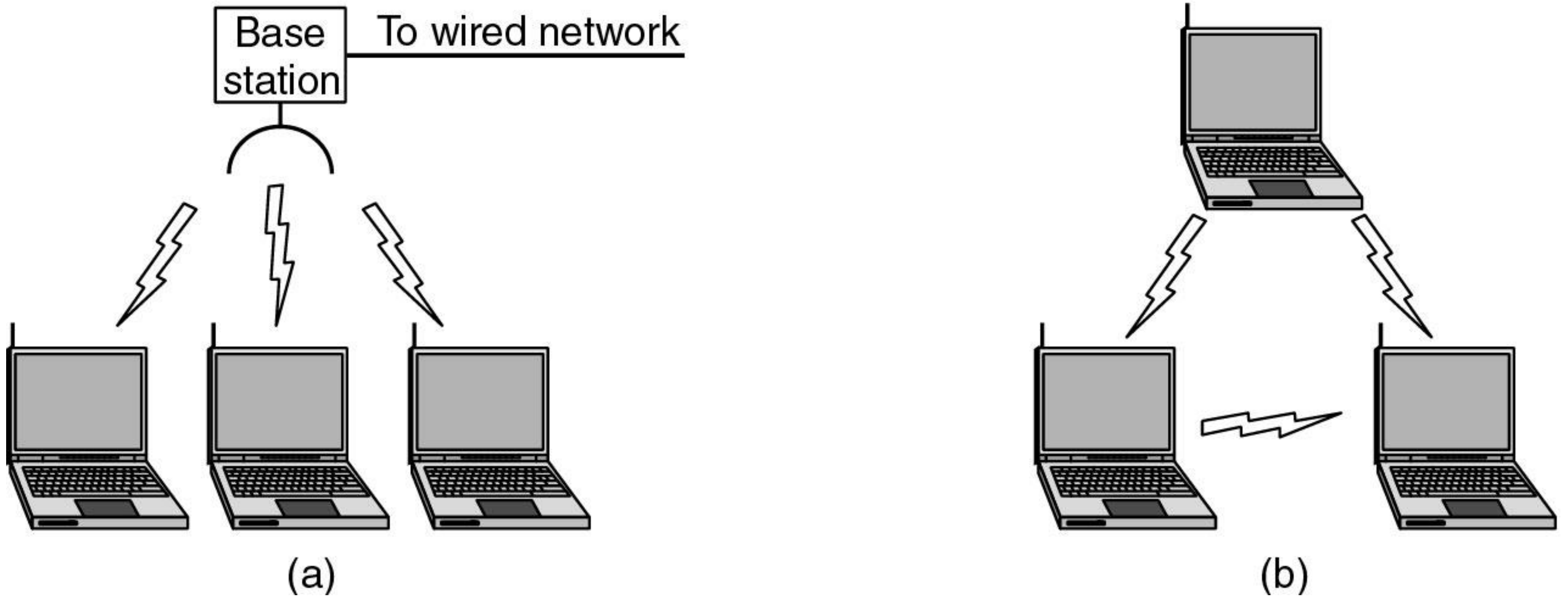
- Technologies
  - WiMAX
    - MAXWell Lab at UMd
  - LTE
- TDM Based
- Higher user level bandwidth

Ethernet

- Architecture of the original Ethernet.



Wireless LANs

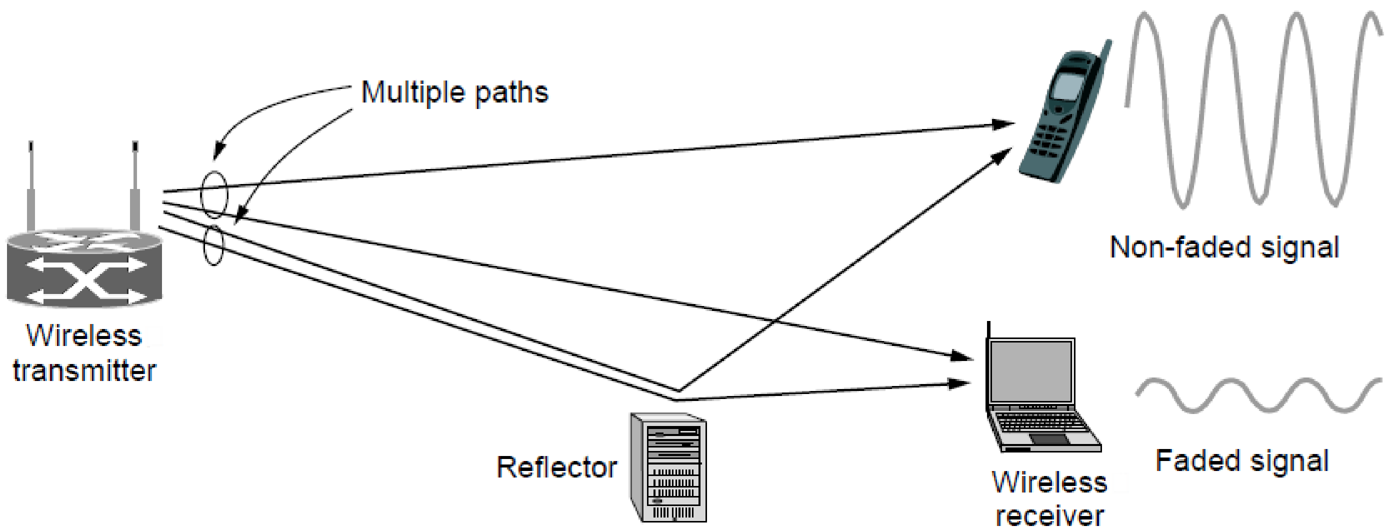


- (a) Wireless networking with a base station.
- (b) Ad hoc networking.

Wireless LANs (2)

Signals in the 2.4GHz ISM band vary in strength due to many effects, such as multipath fading due to reflections

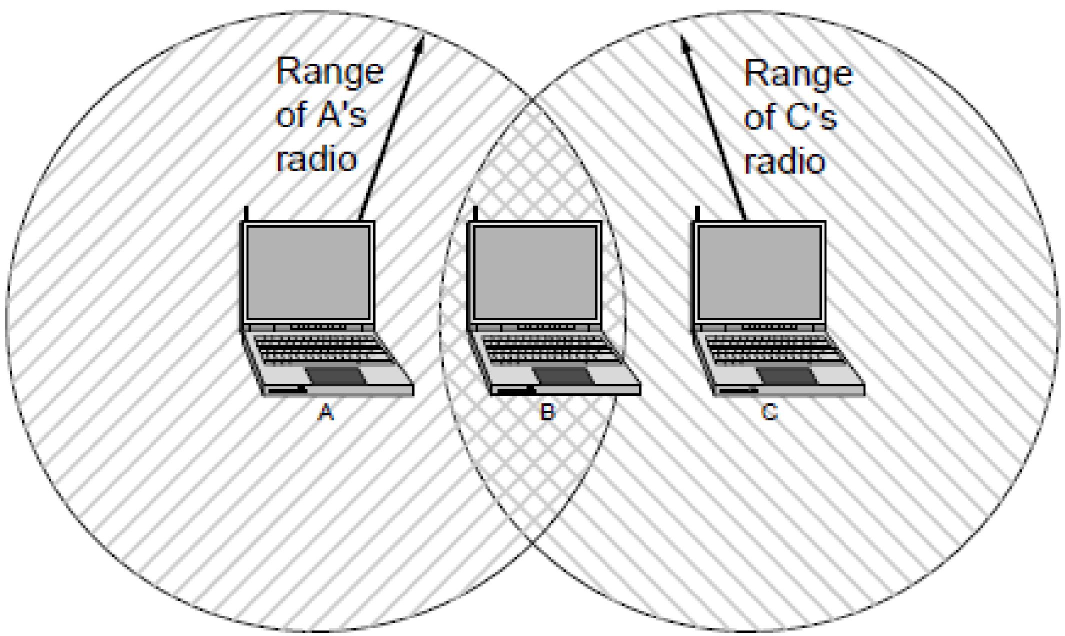
- requires complex transmission schemes, e.g., OFDM



Wireless LANs (3)

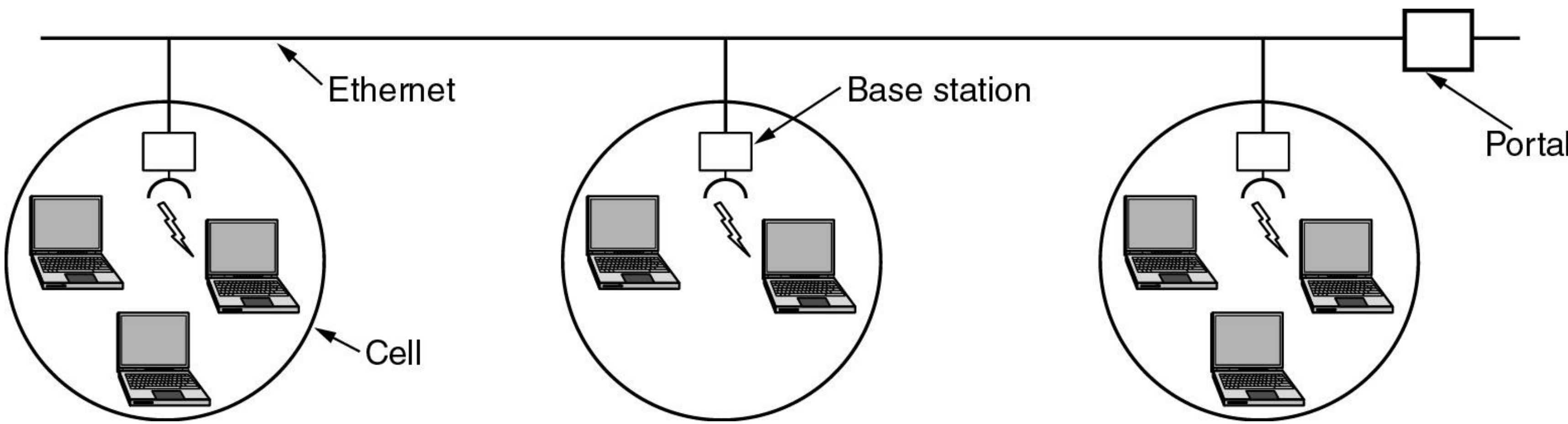
Radio broadcasts interfere with each other, and radio ranges may incompletely overlap

- CSMA (Carrier Sense Multiple Access) designs are



Wireless LANs (4)

- A multicell 802.11 network.



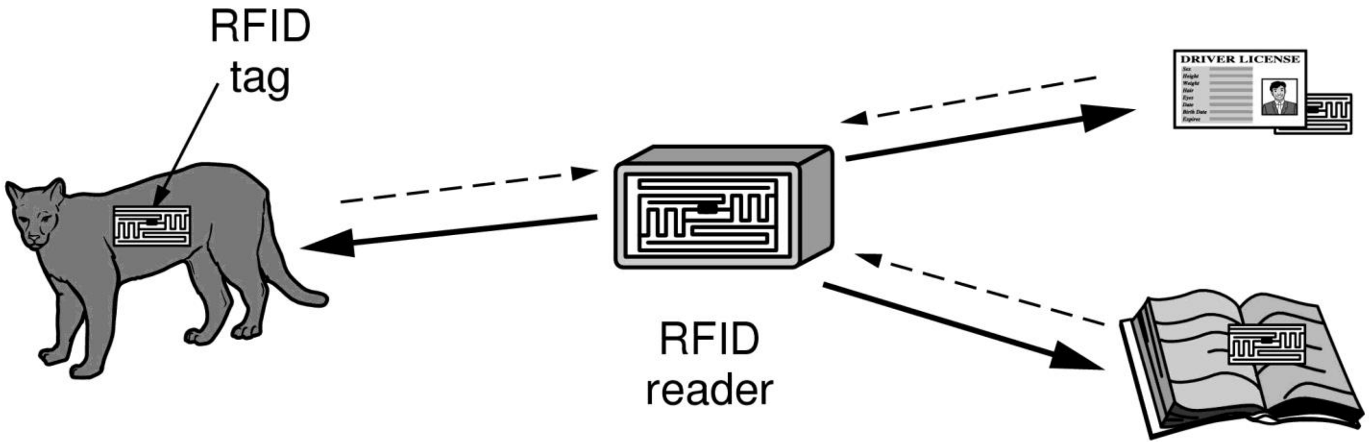
Ad hoc Networks

- Similar to Sensor Networks
- All nodes are equal
  - Some distinguished nodes may have servers/external connections
- Information moves from node to node

RFID and Sensor Networks (1)

Passive UHF RFID networks everyday objects:

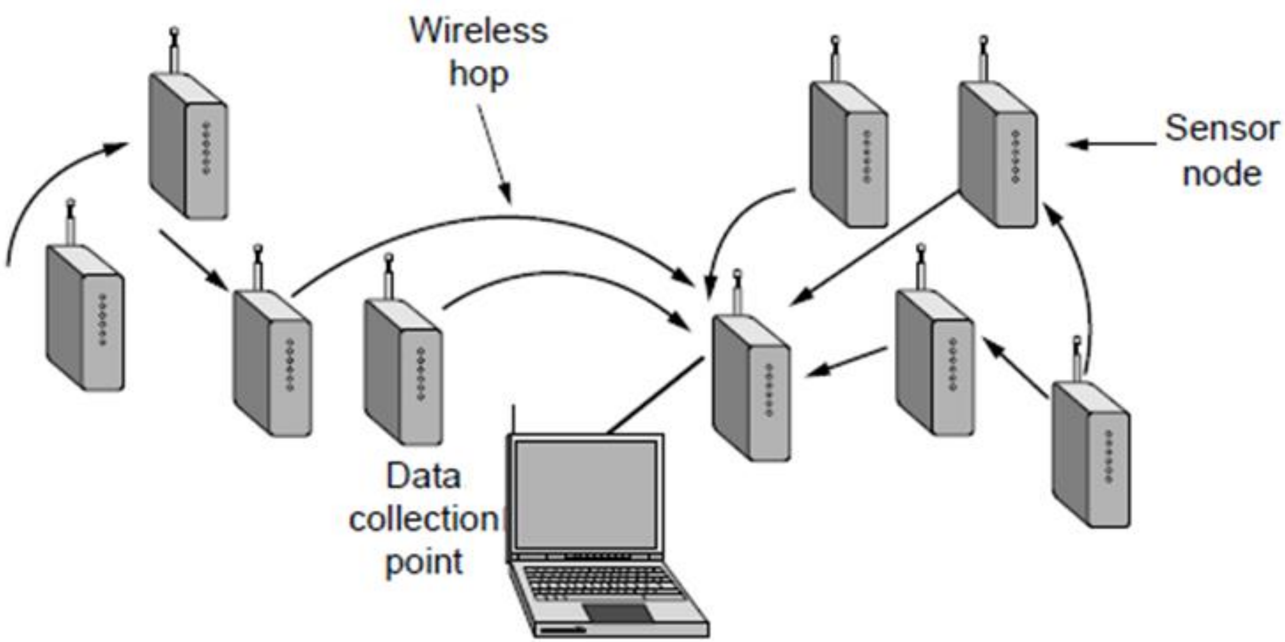
- Tags (stickers with not even a battery) are placed on objects
- Readers send signals that the tags reflect to communicate



RFID and Sensor Networks (2)

Sensor networks spread small devices over an area:

- Devices send sensed data to collector via wireless hops



Network Standardization

- Who’s Who in the Telecommunications World
- Who’s Who in the International Standards World
- Who’s Who in the Internet Standards World

Network Standardization

Standards define what is needed for <u>interoperability</u>

Some of the many standards bodies:

Body	Area	Examples
ITU	Telecommunications	G.992, ADSL H.264, MPEG4
IEEE	Communications	802.3, Ethernet 802.11, WiFi
IETF	Internet	RFC 2616, HTTP/1.1 RFC 1034/1035, DNS
W3C	Web	HTML5 standard CSS standard

ITU

- Main sectors
  - Radiocommunications
  - Telecommunications Standardization
  - Development
- Classes of Members
  - National governments
  - Sector members
  - Associate members
  - Regulatory agencies

Who's Who in International Standards (1)

Number	Topic
802.1	Overview and architecture of LANs
802.2 ↓	Logical link control
802.3 *	Ethernet
802.4 ↓	Token bus (was briefly used in manufacturing plants)
802.5	Token ring (IBM's entry into the LAN world)
802.6 ↓	Dual queue dual bus (early metropolitan area network)
802.7 ↓	Technical advisory group on broadband technologies
802.8 †	Technical advisory group on fiber optic technologies
802.9 ↓	Isochronous LANs (for real-time applications)
802.10 ↓	Virtual LANs and security
802.11 *	Wireless LANs (WiFi)
802.12 ↓	Demand priority (Hewlett-Packard's AnyLAN)

The 802 working groups. The important ones are marked with *.
The ones marked with ↓ are hibernating. The one marked with † gave up and disbanded itself.

Who's Who in International Standards (2)

802.13	Unlucky number; nobody wanted it
802.14 ↓	Cable modems (defunct: an industry consortium got there first)
802.15 *	Personal area networks (Bluetooth, Zigbee)
802.16 *	Broadband wireless (WiMAX)
802.17	Resilient packet ring
802.18	Technical advisory group on radio regulatory issues
802.19	Technical advisory group on coexistence of all these standards
802.20	Mobile broadband wireless (similar to 802.16e)
802.21	Media independent handoff (for roaming over technologies)
802.22	Wireless regional area network

The 802 working groups. The important ones are marked with *. The ones marked with ↓ are hibernating. The one marked with † gave up and disbanded itself.

Metric Units

The main prefixes we use:

Prefix	Exp.	prefix	exp.
K(ilo)	10^3	m(illi)	10^{-3}
M(ega)	10^6	μ(micro)	10^{-6}
G(iga)	10^9	n(ano)	10^{-9}

- Use powers of 10 for rates, powers of 2 for storage
  - E.g., 1 Mbps = 1,000,000 bps, 1 KB = 1024 bytes
- "B" is for bytes, "b" is for bits

Metric Units

Exp.	Explicit	Prefix	Exp.	Explicit	Prefix
10^{-3}	0.001	milli	10^{3}	1,000	Kilo
10^{-6}	0.000001	micro	10^{6}	1,000,000	Mega
10^{-9}	0.000000001	nano	10^{9}	1,000,000,000	Giga
10^{-12}	0.000000000001	pico	10^{12}	1,000,000,000,000	Tera
10^{-15}	0.000000000000001	femto	10^{15}	1,000,000,000,000,000	Peta
10^{-18}	0.0000000000000000001	atto	10^{18}	1,000,000,000,000,000,000	Exa
10^{-21}	0.000000000000000000001	zepto	10^{21}	1,000,000,000,000,000,000,000	Zetta
10^{-24}	0.000000000000000000000001	yocto	10^{24}	1,000,000,000,000,000,000,000,000	Yotta

- The principal metric prefixes.

Metric Units (1)

Exp.	Explicit	Prefix
10^{-3}	0.001	milli
10^{-6}	0.000001	micro
10^{-9}	0.000000001	nano
10^{-12}	0.000000000001	pico
10^{-15}	0.000000000000001	femto
10^{-18}	0.000000000000000001	atto
10^{-21}	0.000000000000000000001	zepto
10^{-24}	0.000000000000000000000001	yocto

The principal metric prefixes

Metric Units (2)

Exp.	Explicit	Prefix
10^3	1,000	Kilo
10^6	1,000,000	Mega
10^9	1,000,000,000	Giga
10^{12}	1,000,000,000,000	Tera
10^{15}	1,000,000,000,000,000	Peta
10^{18}	1,000,000,000,000,000,000	Exa
10^{21}	1,000,000,000,000,000,000,000	Zetta
10^{24}	1,000,000,000,000,000,000,000,000	Yotta

The principal metric prefixes