

Computer Networks

Chapter 1. Introduction

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Information

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- ◆ Discussion Board
 - <http://learning.sem.tsinghua.edu.cn>
 - Public user name: 17a205100820
 - Password: 17a205100820



Question 1

◆ What do you expect to learn from this course?



Course description

- ◆ Overview: a comprehensive introduction
 - Concepts and principles about data communication and computer networking
- ◆ Topics to be discussed
 - Architectures / Protocols
 - Technologies: Hardware / Software
 - Applications
- ◆ What you may learn
 - Knowledge: Key concepts in networking
 - Insight: How the Internet works
 - Skill: Requirement analysis and network planning



Briefly

◆ We try to learn

- What is the Internet
- How it is formed
- How it works
- How to make use of it (more effectively)



Prerequisites & Textbook

◆ Prerequisites

- Programming Languages
- Computer Systems Architecture

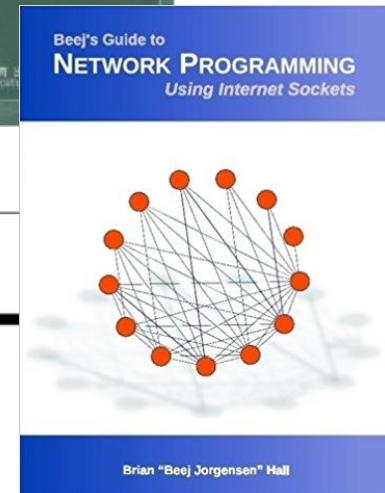
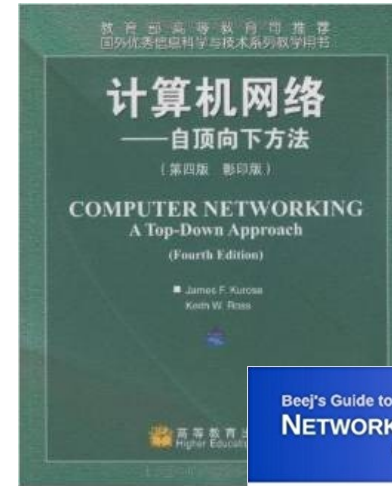
◆ Text Book

- Peterson, L.L., and Davie, B.S.
Computer Networks: A Systems Approach, (5 ed.) China Machine Press, Beijing, 2012. (Elsevier, 2012).



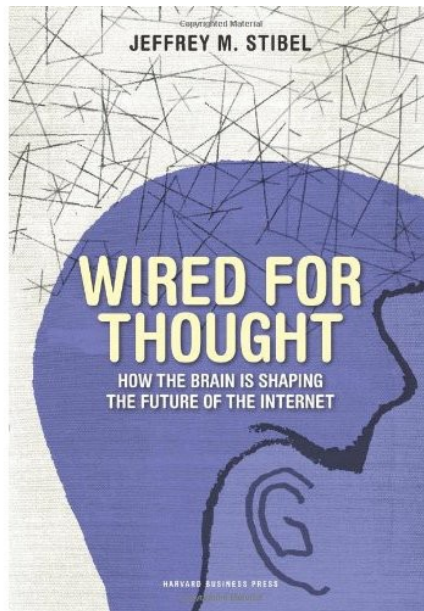
Reference Books

- ◆ Kurose, J.F., and Ross, K.W. 2016. *Computer Networking: A Top-Down Approach Featuring the Internet*, (5 ed.) Beijing: Higher Education Press. (Pearson, 2012).
- ◆ Hall, B.B.J. *Beej's Guide to Network Programming*, Jorgensen Publishing, 2016. (<http://beej.us/guide/bgnet/>)
- ◆ Oppenheimer, P. 2011. *Top-Down Network Design*, (3 ed.) Beijing: Post & Telecom Press. (Cisco Press, 2010).



Another reference book

- ◆ Stibel, J. M. *Wired for Thought: How the Brain Is Shaping the Future of the Internet*, Harvard Business School Press, 2009.
 - (Chinese translation: “我们改变了互联网，还是互联网改变了我们？”，中信出版社，2010)



Grading

- ◆ Assignments: 20%
- ◆ Course project: 30%
 - in groups
 - including weekly progress reports and a written report
 - possible topics:
 - ▶ Designing a corporate network
 - ▶ Programming an email client (like Outlook)
 - ▶ Planning and/or developing a website
 - ▶ “How does Bitcoin work?”
 - ▶ “Why Google and Facebook are (technically) not usable in China, and how we may make them usable?”
 - ▶ ...
- ◆ Participation: 10%
- ◆ Final exam: 40%



Introduction

- ◆ Computer networks and applications
 - Why networks?
- ◆ Connectivity
 - How are they connected?
- ◆ Networking resource sharing
 - How does the infrastructure support various applications?
- ◆ Architecture overview
 - How can the complexity be handled?



Computer Networks and Applications

◆ Why networks?

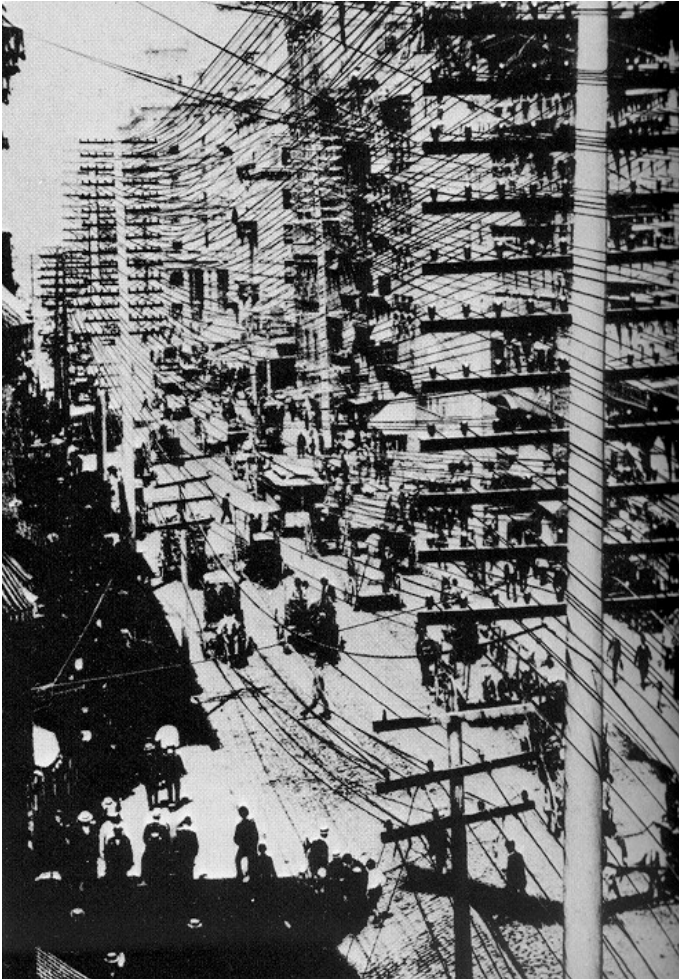


What kinds of networks are there in the world?

- ◆ Highway networks
- ◆ Railway networks
- ◆ Telephone networks
- ◆ **Computer networks**
- ◆ Electricity networks
- ◆ Television networks
- ◆ Social networks



Networking used to be complicated ...



Richard L. Nolan and Kelley A. Porter "Sun Microsystems and the N-tier Architecture", Harvard Business School case 399-037 (November 30, 1998):5.

... but it is becoming simpler



<http://blog.comparemymobile.com/what-do-you-use-your-phone-for/>

What network applications are you using?

- ◆ WWW (world wide web)
- ◆ Email
- ◆ Mobile apps
- ◆ Instance message
- ◆ IP telephone
- ◆ Video conference
- ◆ Online games
- ◆ Microblogging (Twitter/Weibo)
- ◆ Wechat (Weixin)
- ◆ FTP (file transfer protocol)
- ◆ BBS (bulletin board system)
- ◆



What kind of devices can be connected to networks?

- ◆ Computers (desktop, laptop, workstations, servers, ...)
- ◆ Mobile phones
- ◆ Tablets
- ◆ TV sets
- ◆



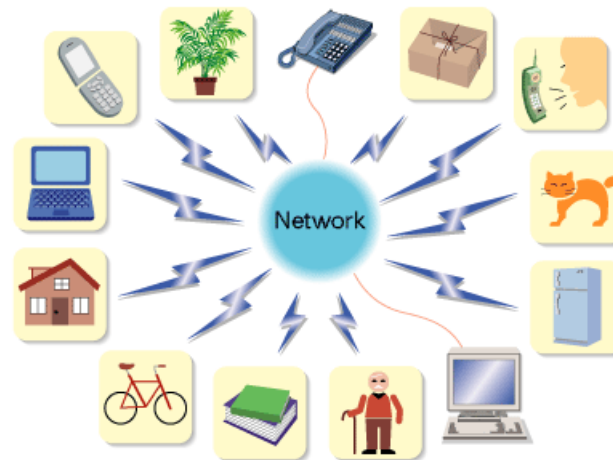
Web-enabled toaster +
weather forecaster



Internet of Things (物联网)

◆ “from *anytime, any place* connectivity for *anyone*, we will now have connectivity for *anything*”

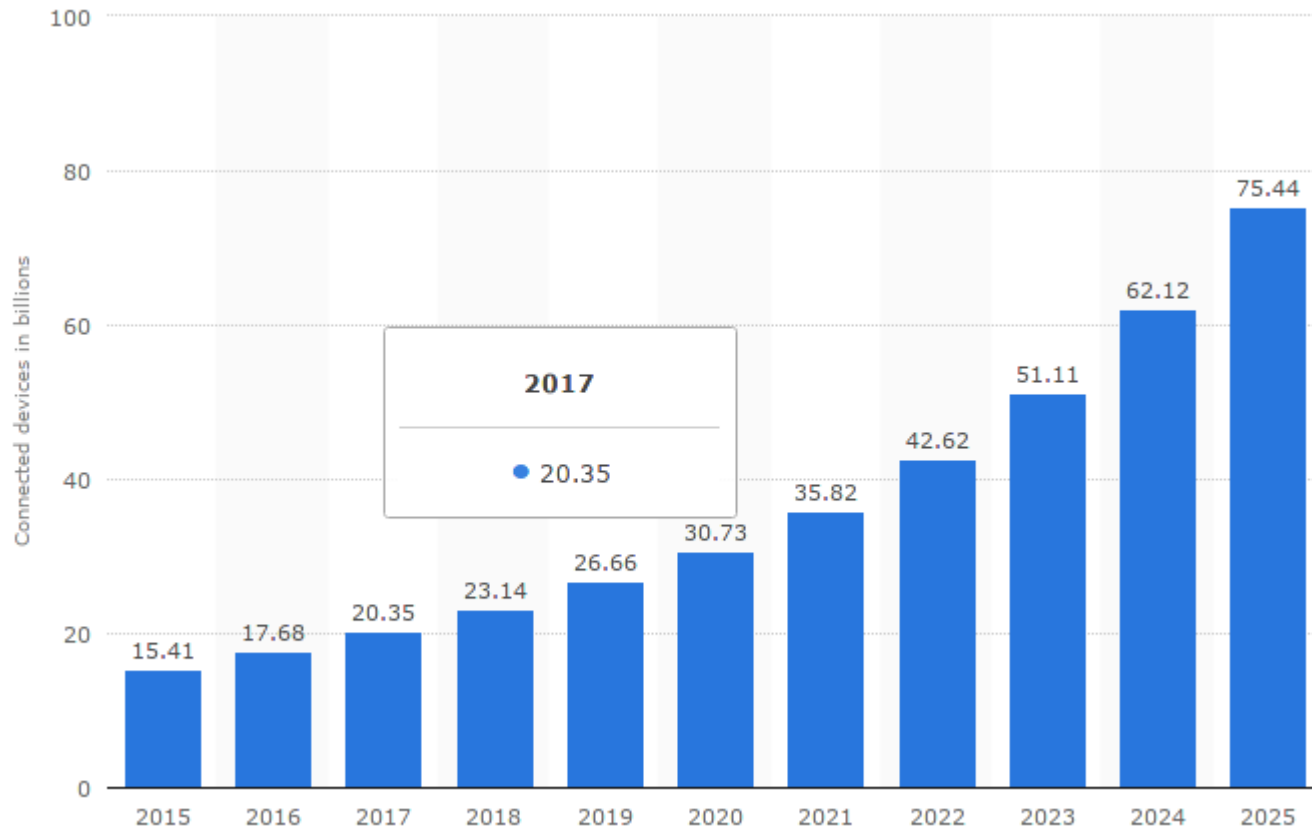
■ ITU Internet Reports 2005: *The Internet of Things*



Ubiquitous computing will enable diverse wireless applications, including monitoring of pets and houseplants, operation of appliances, keeping track of books and bicycles, and much more.

<http://quantumcinema.blogspot.com/2008/01/ubiquitous-computing.html>

Internet-connected devices



<https://www.statista.com/statistics/471264/iot-number-of-connected-devices-worldwide/>

What's more

◆ Girl said:

■ *Dad, I'm in love with a boy who is far away from me. I am in Australia and he lives in Scotland.*

■ *We met on a **dating website**, became friends on **Facebook**, had long chats on **Whatsapp**, he proposed to me on **Skype**, and now we've had two months of relationship through **Viber**.*

■ *I need your blessings and good wishes, daddy.*

◆ Dad said:

■ *Wow! Really!! Then get married on **Twitter**, have fun on **Tango**. Buy your kids on **Amazon**, receive them through **Gmail**, and pay for it all through **PayPal**. And if you are fed up with your husband...sell him on **EBay**.*

What's more

- ◆ Computer networks are evolving.
- ◆ They have been changing our lives ...
- ◆ ... and they still will.



After all, why computer networks?

- ◆ Communication
- ◆ Resource sharing
- ◆ Collaboration

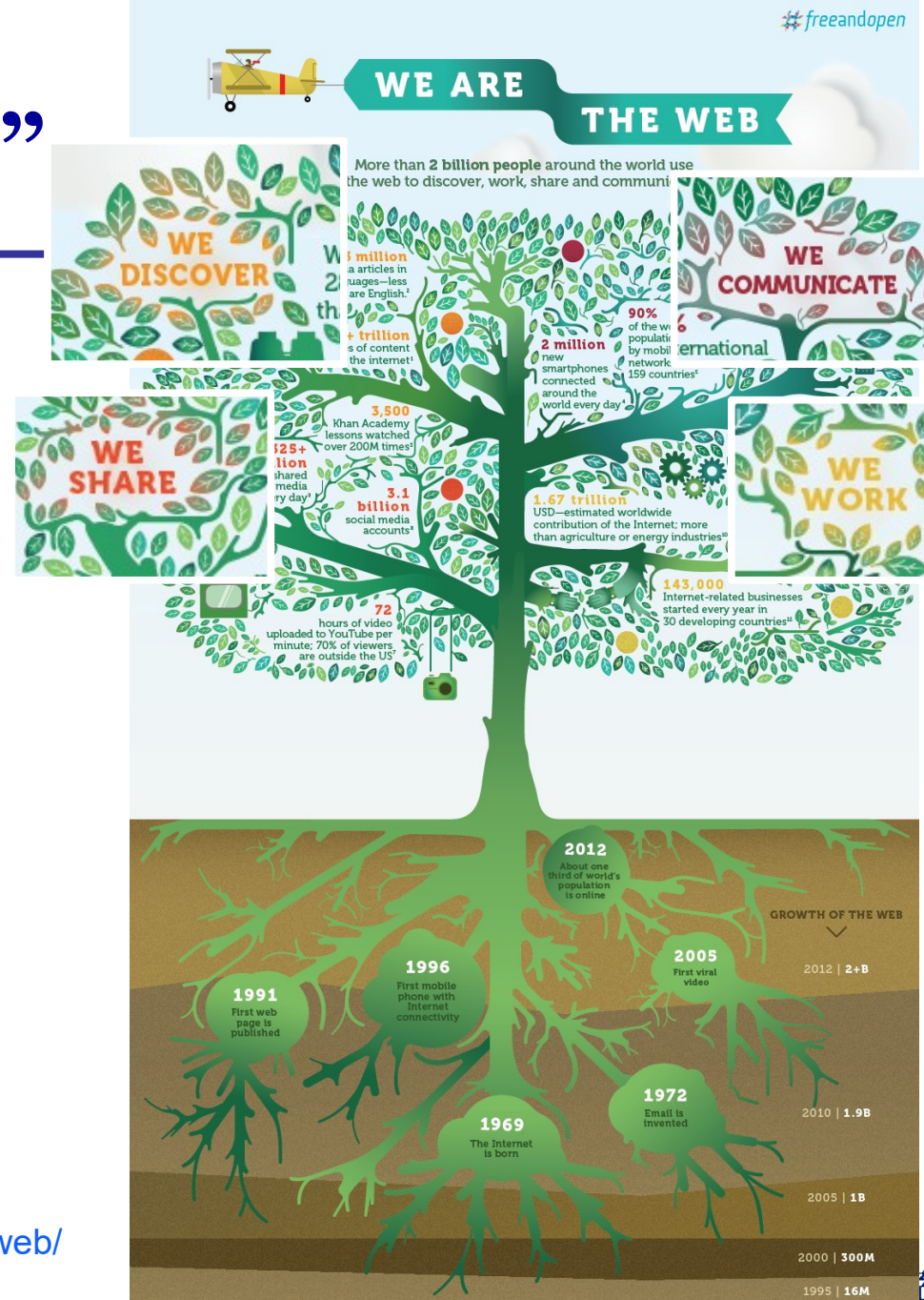


Computer networks

- ◆ two or more computers connected so that they can
 - communicate with each other
 - share information, software, peripheral devices, and/or processing power
 - collaborate with each other



“We are the Web”



<https://www.google.com/intl/en/takeaction/we-are-the-web/>

So, how does it work?



What is behind the applications?

The image shows a composite view of a web browser displaying the Tsinghua University website and a Wireshark network traffic analysis window.

Web Browser (Tsinghua University - Chromium):

- Address bar: www.tsinghua.edu.cn/publish/newthuen/index.html
- Page content: Tsinghua University logo, navigation menu (News & Events, About TH, Admissions, Faculties, Research), a large image of a laboratory, and a news section titled "Global Innovation Exchange (GIX) Opening..." dated 15/2017.09.

Wireshark (*wlp3s0 [Wireshark 2.4.1]):

- Filter:
- Expression:
- Table of captured packets:

No.	Time	Source	Destination	Protocol	Length	Info
1333	9.337054104	192.168.121.102	52.73.135.114	TLSv1.2	421	Application Data
1334	9.602987936	52.73.135.114	192.168.121.102	TLSv1.2	2728	Application Data
1335	9.603063486	192.168.121.102	52.73.135.114	TCP	66	36750 → 443 [ACK] Seq=1421 Ack=26785 Win=1137 Len=0
1336	11.90164181	220.132.35.148	192.168.121.102	TCP	667	15000 → 40296 [PSH, ACK] Seq=5410 Ack=1 Win=1448 Len=601
1337	11.90176898	192.168.121.102	220.132.35.148	TCP	66	40296 → 15000 [ACK] Seq=1 Ack=6011 Win=1436 Len=0 TS
1338	12.42161761	220.132.35.148	192.168.121.102	TCP	667	15000 → 40296 [PSH, ACK] Seq=6011 Ack=1 Win=1448 Len=601
1339	12.42174781	192.168.121.102	220.132.35.148	TCP	66	40296 → 15000 [ACK] Seq=1 Ack=6612 Win=1436 Len=0 TS

Packet Details (Frame 1336):

- Frame 1336: 667 bytes on wire (5336 bits), 667 bytes captured (5336 bits) on interface 0
- Ethernet II, Src: Netgear_9f:14:85 (a0:21:b7:9f:14:85), Dst: IntelCor_1f:a1:5d (34:02:86:1f:a1:5d)
- Internet Protocol Version 4, Src: 220.132.35.148, Dst: 192.168.121.102
- Transmission Control Protocol, Src Port: 15000, Dst Port: 40296, Seq: 5410, Ack: 1, Len: 601
- Source Port: 15000
- Destination Port: 40296
- [Stream index: 0]
- [TCP Segment Len: 601]
- Sequence number: 5410 (relative sequence number)
- [Next sequence number: 6011 (relative sequence number)]
- Acknowledgment number: 1 (relative ack number)

Packet Bytes:

```
0000 34 02 86 1f a1 5d a0 21 b7 9f 14 85 08 00 45 00 4...].! .....E.
0010 02 8d 00 0d 40 00 2a 06 14 37 dc 84 23 94 c0 a8 ...@.*. .7..#...
0020 79 66 3a 98 9d 68 41 13 ba ad 9a 1d 01 0f 80 18 yf:..hA. ....
0030 05 a8 b6 79 00 00 01 01 08 0a 22 d3 a4 e2 eb c9 ..y.... ".....
0040 87 99 a0 38 8a 3e 02 1a 9f cb 5b c3 42 21 a8 e0 ...8.>... [.B!...
0050 1b 9a 92 96 92 c0 a8 5c 21 0f 44 0d 10 15 95 f9 ..... \ !D.....
0060 17 4c 8a 04 71 e0 2a 8b c1 50 dc 52 0e 20 18 a7 .L..q.*. .P.R. ..
0070 cd dc cf f9 11 38 24 31 cd 3a 1a 00 d8 98 21 8f ....8$! .:.....!
0080 23 5c 56 d0 db 4e 8c 78 86 2d d2 32 62 30 ee 17 #\V..N.x ..2b0..
0090 fa 8f 92 f2 6f 39 e1 59 24 a3 ca 9a 09 92 f0 89 ...Y $...
```

Network in the Weilun Building

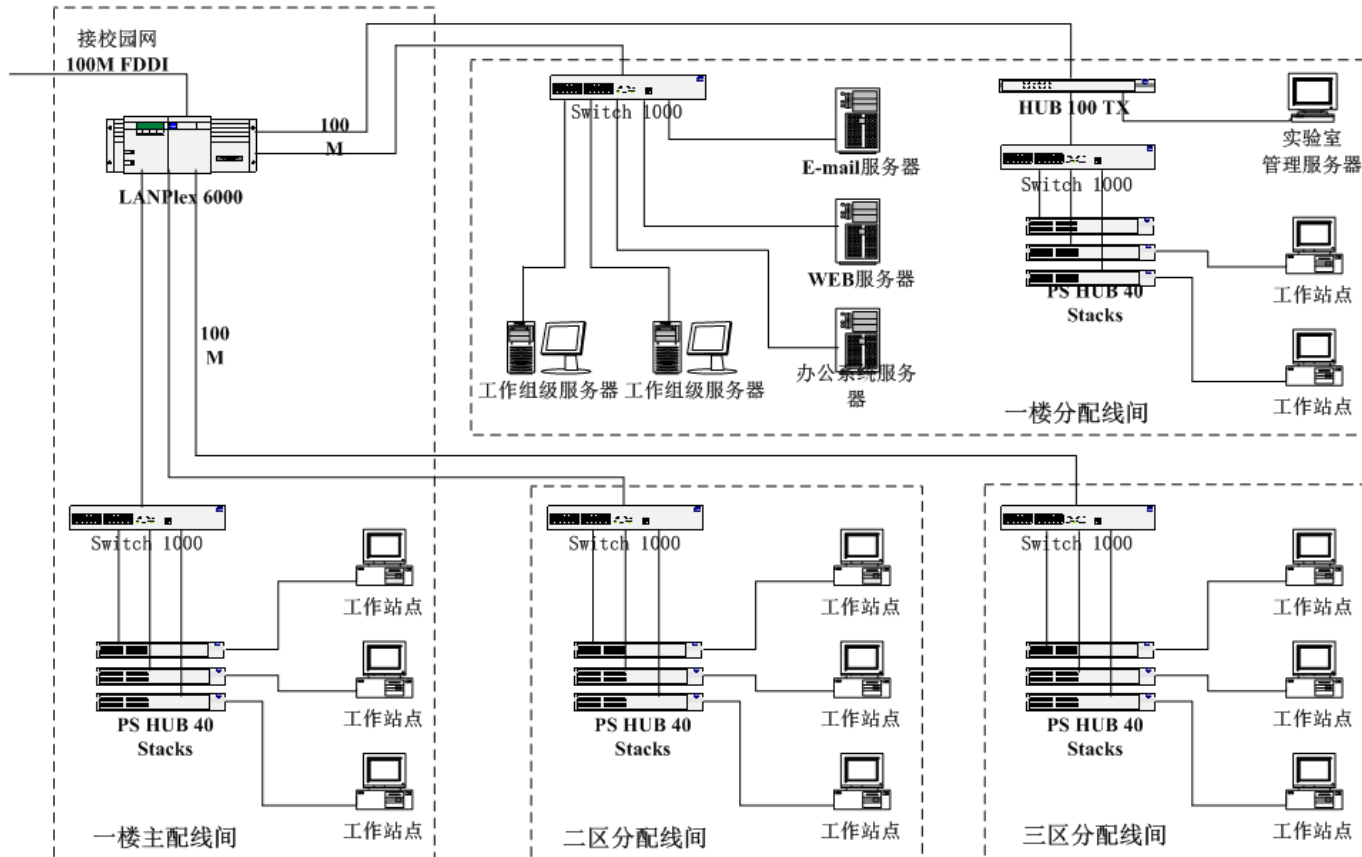


图2-1 伟伦楼计算机网络拓扑结构图

The most basic questions to be addressed

- ◆ How are things connected together?
 - Connectivity
- ◆ How can different applications run on the same infrastructure at the same time?
 - Networking resource sharing
- ◆ How to keep it simple?
 - Architecture overview: common services support and layered structure



Connectivity

◆ How are they connected?



What do we need to connect two computers?

- ◆ Computers: with connection component in hardware system
 - Network adapter / Modem
- ◆ Links: Connection media
 - Twisted pair cable (双绞线)
 - Coaxial cable (同轴电缆)
 - Optical fiber (光纤)
 - Radio (无线电波)
 - ...

Building blocks

◆ Nodes (节点): PCs, servers, workstations, ...

- Hosts (主机): work for the users.

- Switches (交换机): work for the network.

◆ Direct links: coax cable, optical fiber...

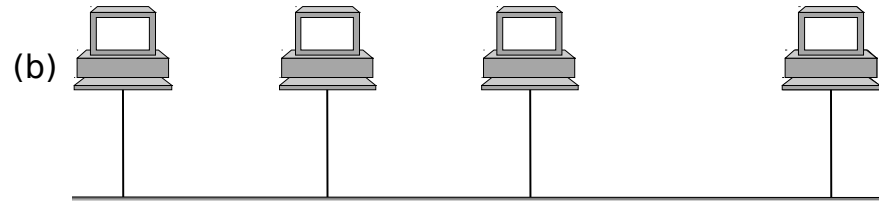
- point-to-point

点对点

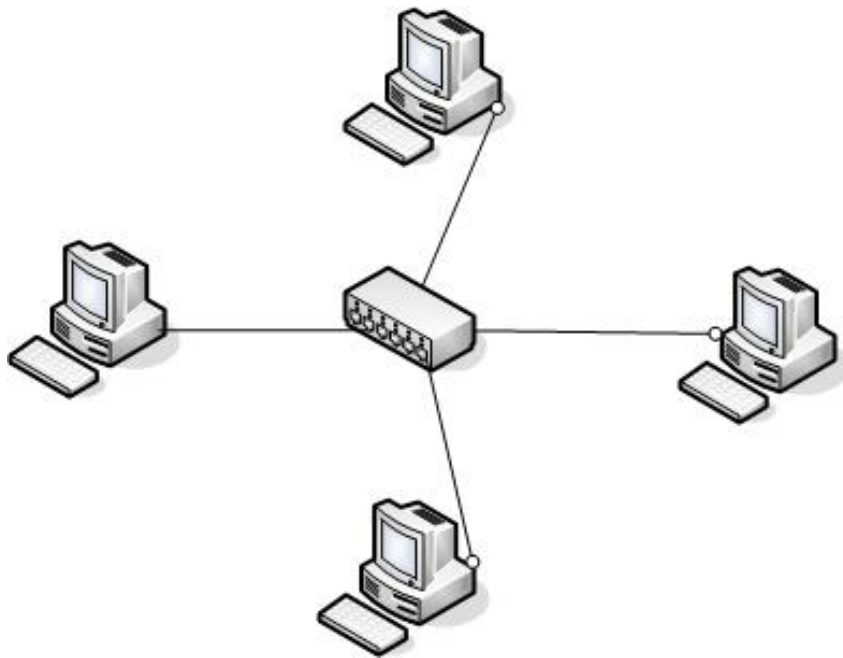


- multiple access

多路访问



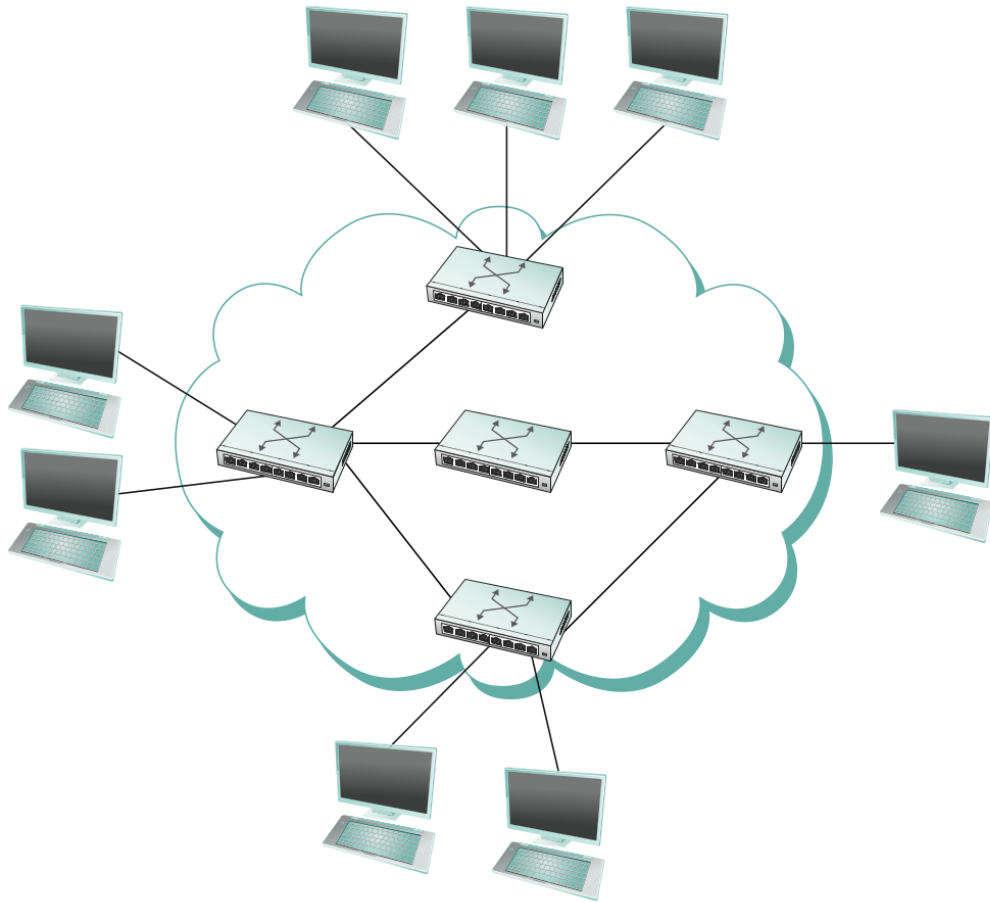
Scalable connectivity



- ◆ Device at the center
 - Hub (集线器)
 - **Switch (交换机)**
 - Router (路由器)
- ◆ We will learn more about the differences later

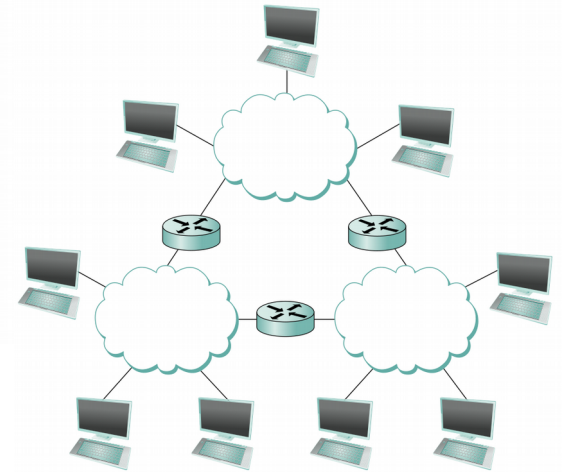
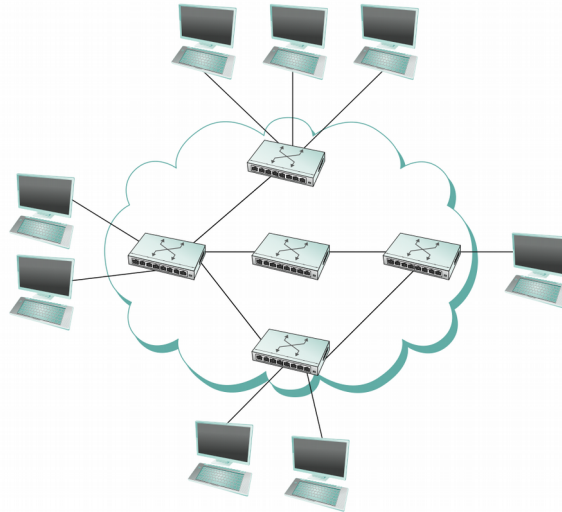
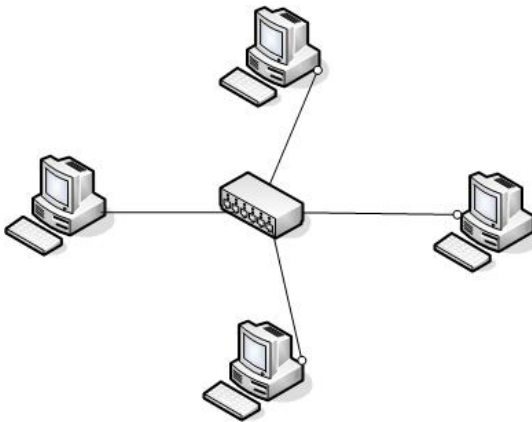
点对点或是多路访问，取决于中间设备是计算机或仅仅是线盒

Switched network (交换网络)



A switched network can be defined recursively as

- two or more nodes connected by a link, or
- two or more networks connected by a node



Network scales

- ◆ SAN: System Area Network (系统网络) / Storage Area Network (存储网络) 计算机与其它设备相连, 如打印机等
- ◆ LAN: Local Area Network (局域网)
- ◆ WAN: Wide Area Network (广域网)
- ◆ MAN: Metropolitan Area Network (城域网)
- ◆ INTERNET



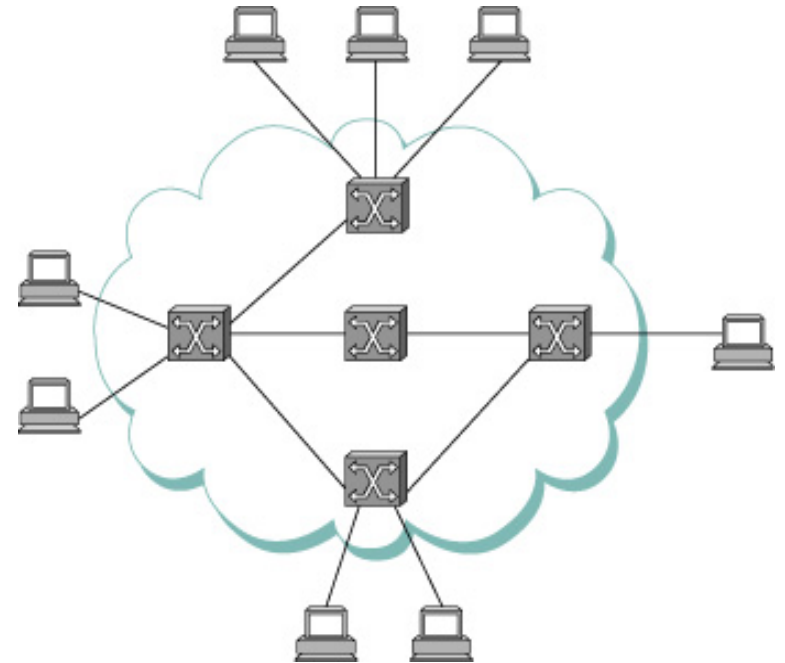
Networking resource sharing

- ◆ How does the infrastructure support various applications?

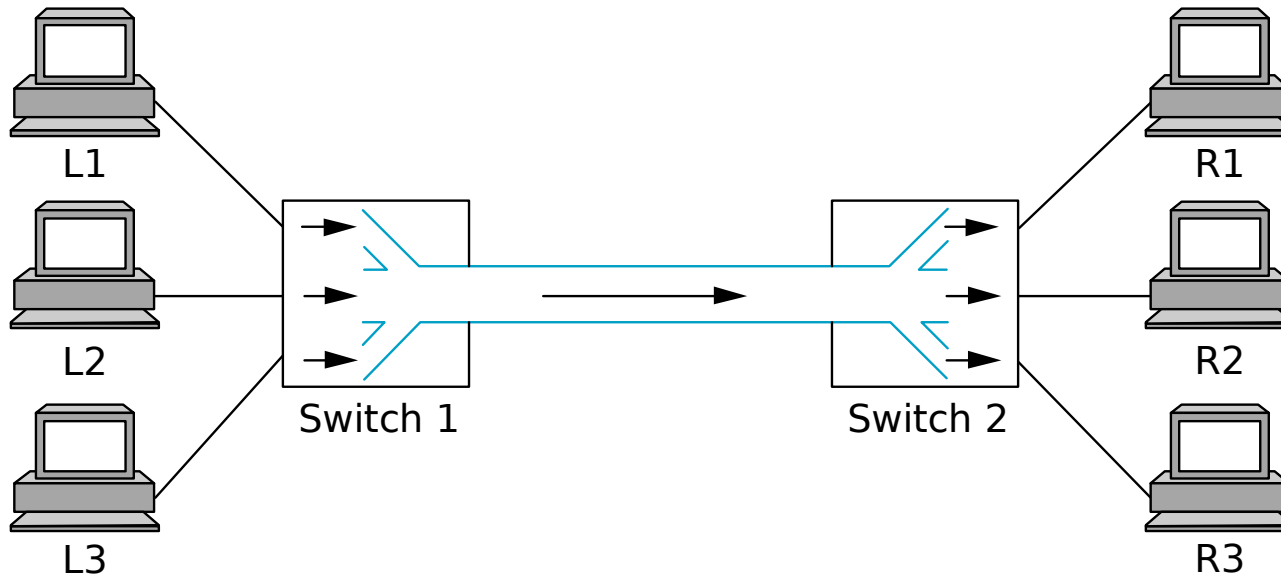


Resource Sharing

- ◆ How do hosts share the network resources?
 - Links
 - Routers
- ◆ Fundamental resource sharing concept
 - Multiplexing (复用)



Sharing the link: Multiplexing



◆ Early solutions:

■ Synchronous Time-Division Multiplexing

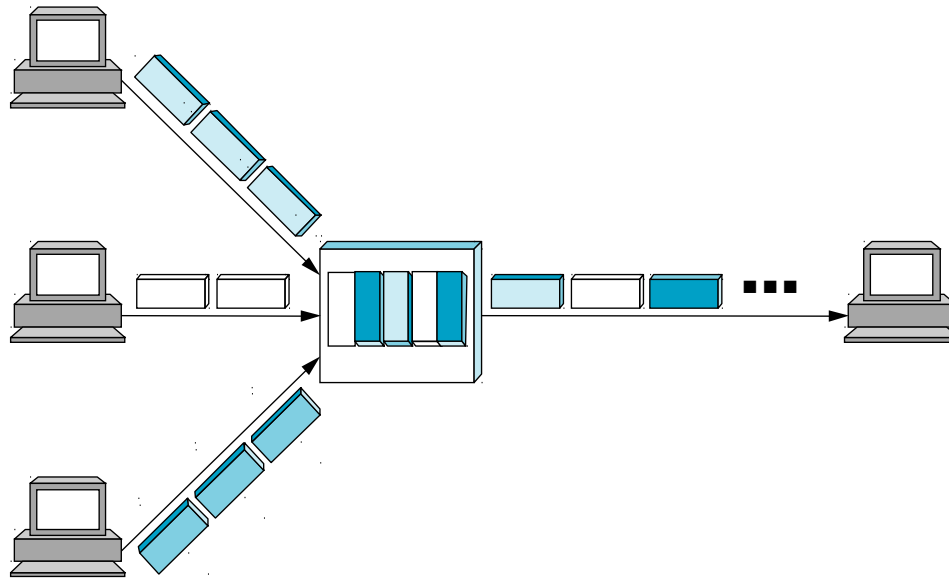
(STDM) 若某刻将权限交给L1，而L1没用使用，则存在浪费

■ Frequency-Division Multiplexing (FDM)

分频复用（每台计算机得到一条通道），存在浪费

Statistical Multiplexing

- ◆ On-demand time-division
- ◆ Packet switching (as compared with circuit switching)



Circuit vs. Packet switching

◆ Circuit switching (线路交换)

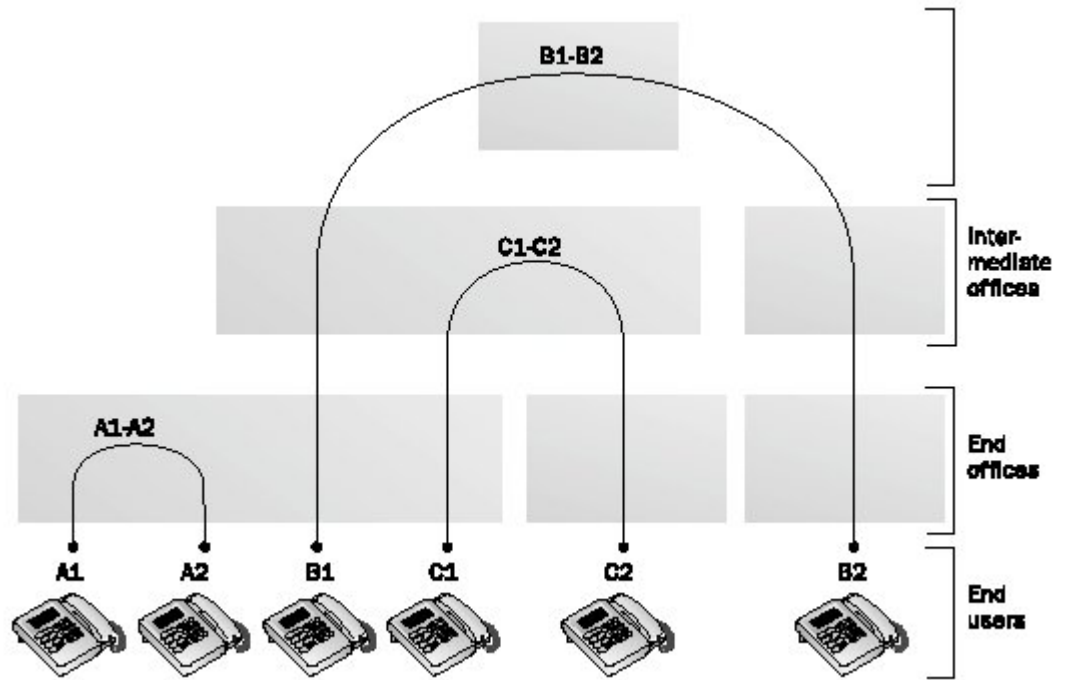
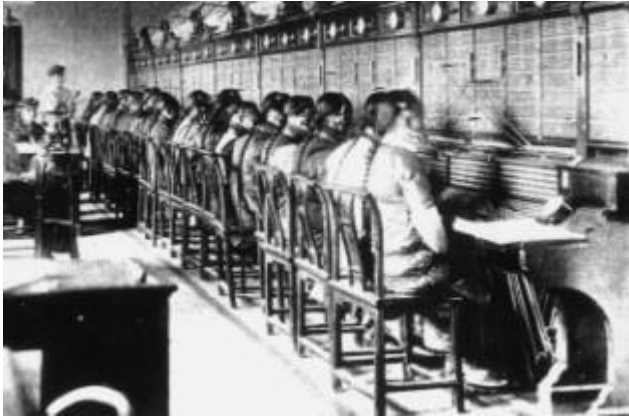
- carry bit streams
- original telephone network

◆ Packet switching (分组交换)

- store-and-forward messages
- Internet

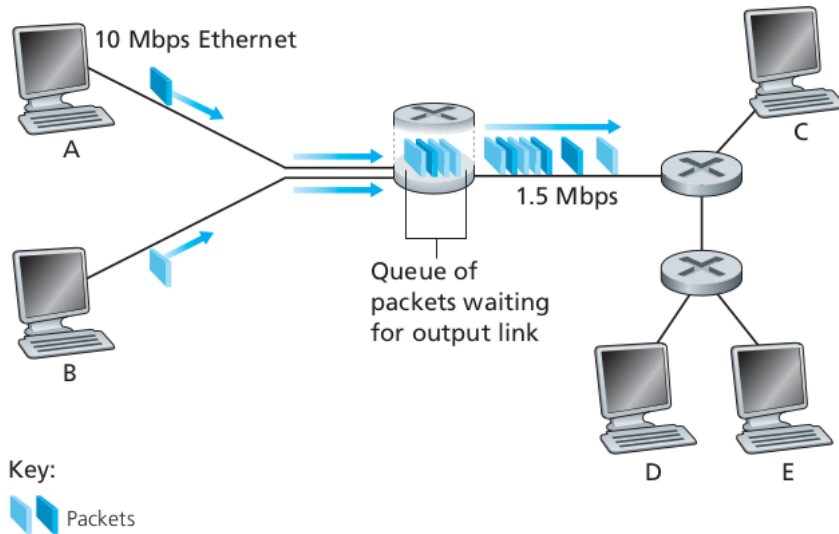


Circuit switching: telephone network



信息的去向由线路的去向决定

Packet switching



Architecture overview

◆ How to keep it simple?



The complexity

◆ So many applications

- WWW (world wide web), email, Instance message, IP telephone, Video conference, Online games, ...

◆ So diversified mediums

- Twisted pair cables, Radio, Satellite, Coaxial cables, Optical Fiber,

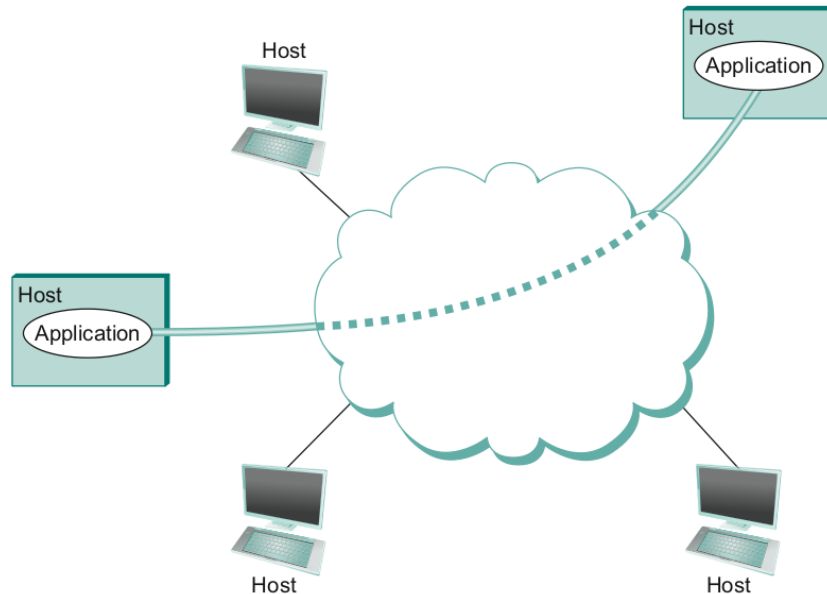
◆ Large amount of nodes

- PCs, laptops, mobile phones, servers, switches, routers, ...

◆ Long distance



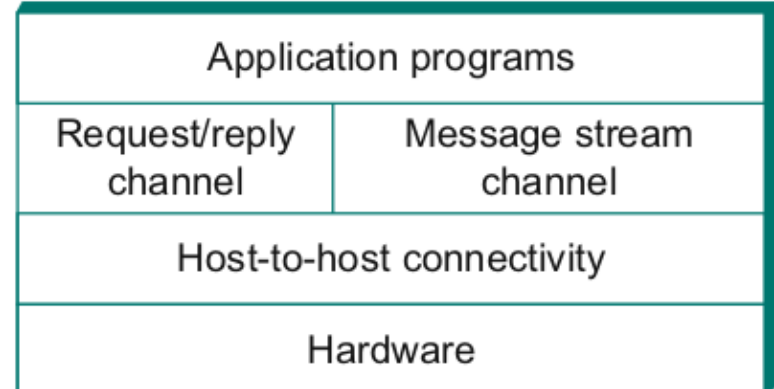
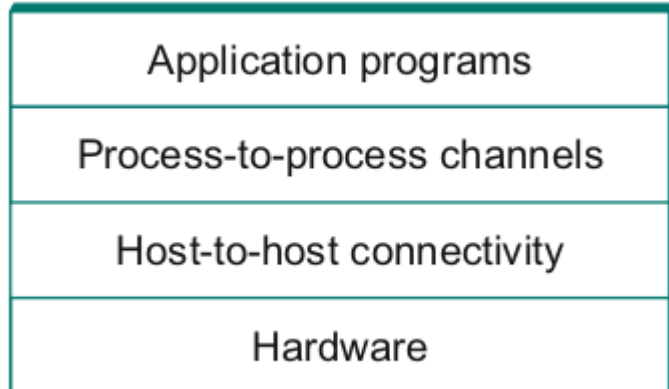
Support for common services



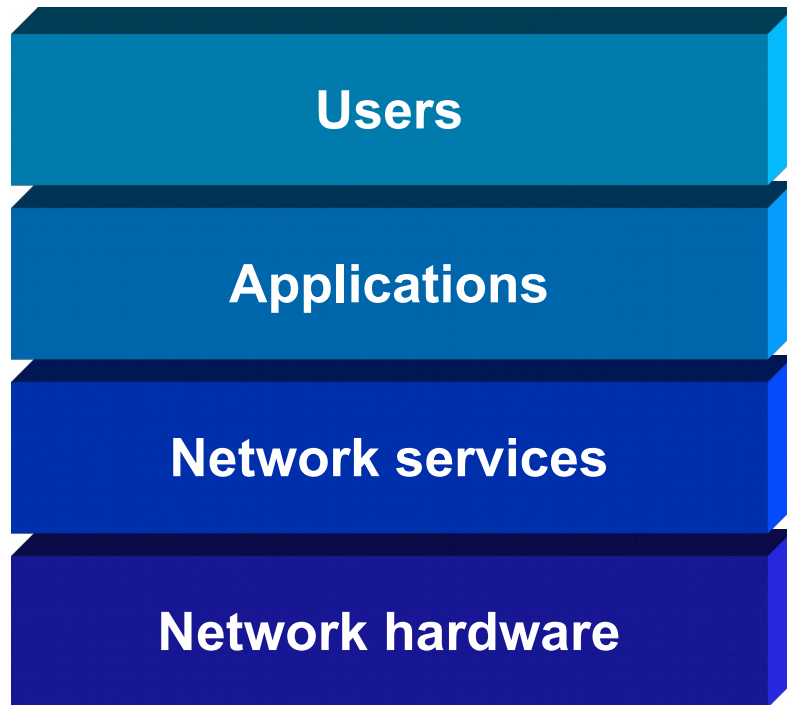
- ◆ Intuitively, the network provides **logical channels** over which applications communicate with each other
 - request/reply channels: applications such as file access and digital library
 - message stream channels: applications such as video conferences

Dealing with complexity: Layering

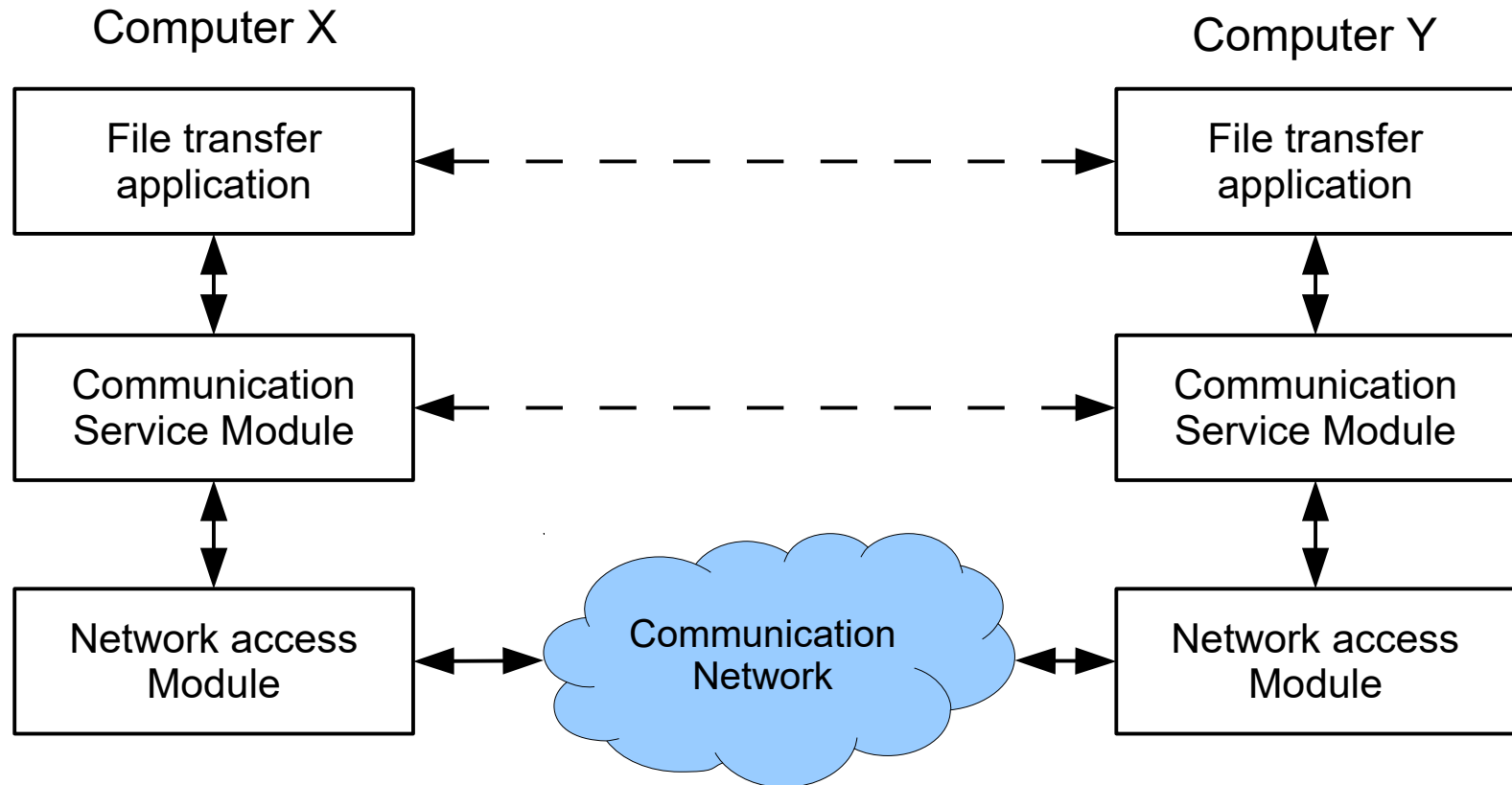
- ◆ Use abstractions to hide complexity
- ◆ Abstractions naturally lead to layering



Layers of network applications



Simplified File Transfer Architecture



Layers of ISO/OSI model

- ◆ The Open Systems Interconnection (OSI) model
- ◆ defined by International Standard Organization (ISO) in 1984.
- ◆ Open communication between different systems without changing the underlying architecture (software and hardware).
- ◆ An international standard that referenced by most network vendors for their products and services

Layer 7:

Application

Layer 6:

Presentation

Layer 5:

Session

Layer 4:

Transport

Layer 3:

Network

Layer 2:

Data link

Layer 1:

Physical

Summary

- ◆ Networks are used to share distributed resources
- ◆ Networking resources are shared by various applications
- ◆ Packet switching is the modern solution to networking resource sharing
- ◆ Layers are used to handle complexity
- ◆ The OSI model gives us a road map



Exercises

◆ Reading: Textbook, Sections 1.1-1.2.

◆ Questions

- What is packet switching? What are the advantages of packet switching?
- Why is layering useful?

