



计算机网络

Computer Networks

Associate Prof. Zheng, Hong (郑宏)
Computer School
Beijing Institute of Technology



A bit about myself

■ Research interest in networking

- Computer Networks
- Parallel and Distributed Systems
- Big Data, Cloud Computing

■ Teaching

□ Graduates:

- Advanced Computer Networks

□ Undergraduates:

- Computer Networks,
- Computer Architectures



Office hours

■ Location

Room 920, Central Bldg.

■ Office Hours

9:00 to 16:00 .

■ Email

hongzheng@bit.edu.cn



Goals of this course

- Learn and get **familiar with** the basic concepts and aspects of computer networks;
 - ✓ Switching, Forwarding, Routing, Naming, ...
- **Thoroughly understand** network architectures, primary ideas of network engineering, as well as applications;
 - ✓ Layering, ...
- **Build up ground work** for further study and R&D in computer networks field.



What You Learn in This Course

- **Knowledge:** how the network (e.g. Internet) works
 - Network (Internet) architecture
 - TCP/IP Protocol suite
 - Applications (Web, e-mail, FTP, P2P, ...)
- **Insight:** key concepts in networking
 - Protocols
 - Layering
- **Skill:** network engineering/network programming
 - Network design/configuration/troubleshooting
 - Socket programming
 - Designing and implementing protocols



Focuses on the Internet

■ **Internet** only one that matters for computer science

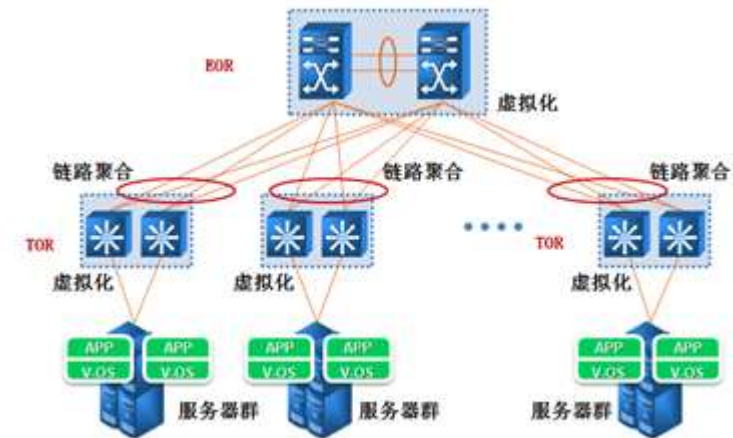
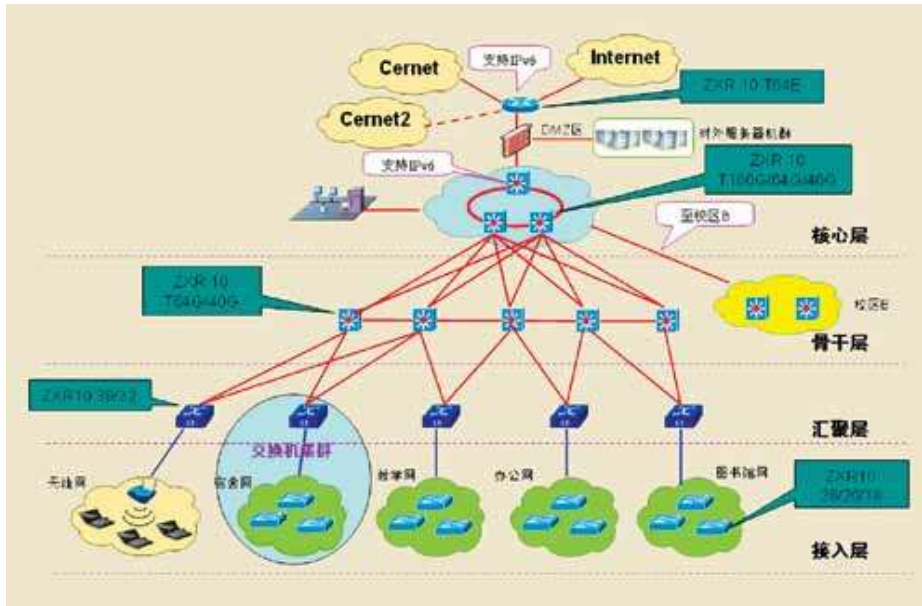
- When computers use these other networks for IP-based communication, they are part of the Internet!
- The Internet is not a network “technology”, it is the paradigm that ties networks together! (Internet)



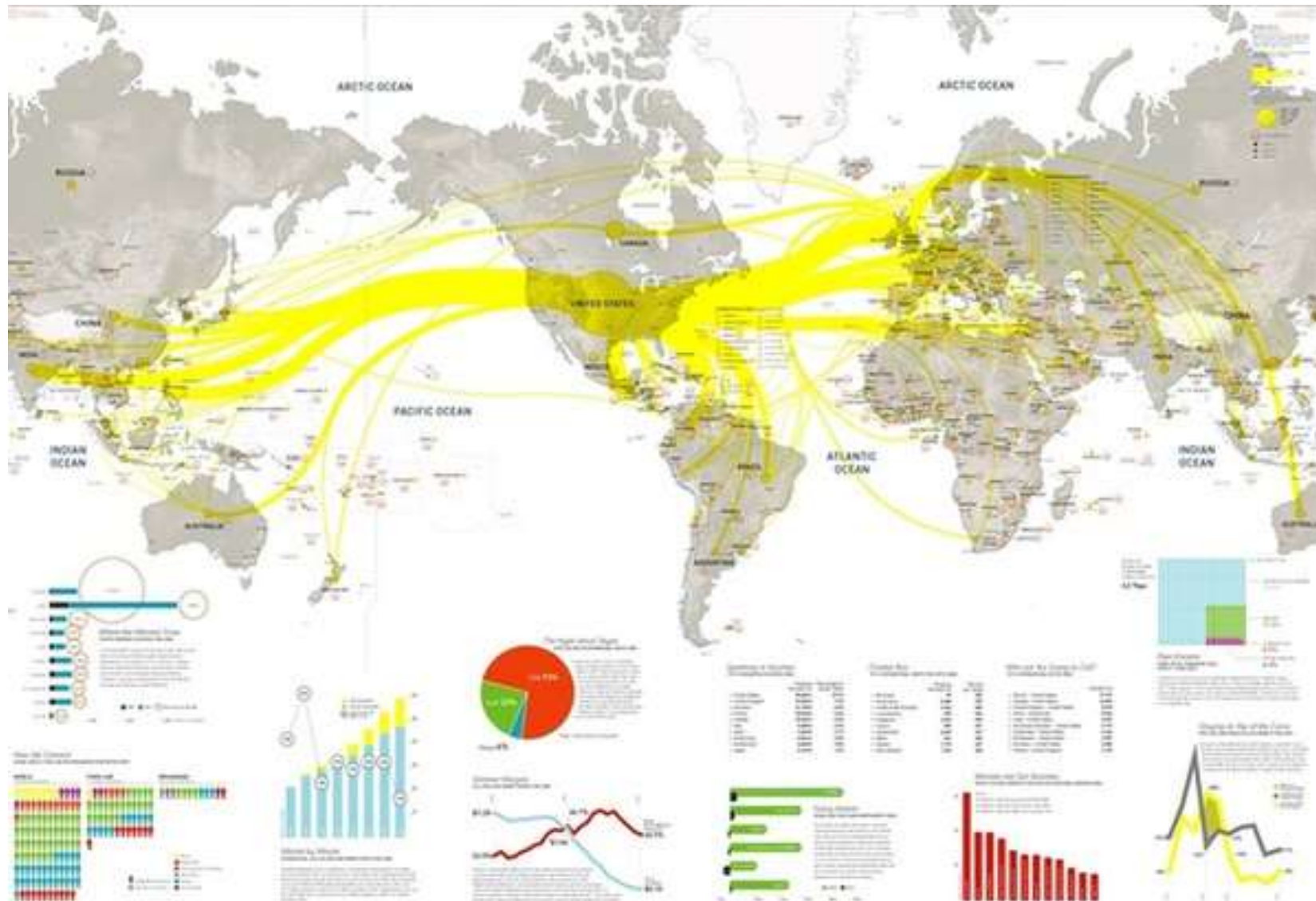
Focuses on the Internet

- **Can you draw the picture of networks being joined (for example , BIT Campus network)?**
- **Can you draw the picture of the Internet?**

Focuses on the Internet



The picture of a campus network



The picture of the part of the Internet



Various perspectives on Internet

■ Different levels of abstraction

- Basic concepts *vs.* actual protocols

■ Different geographic scales:

- LAN *vs.* Enterprise *vs.* WAN *vs.* Inter-domain

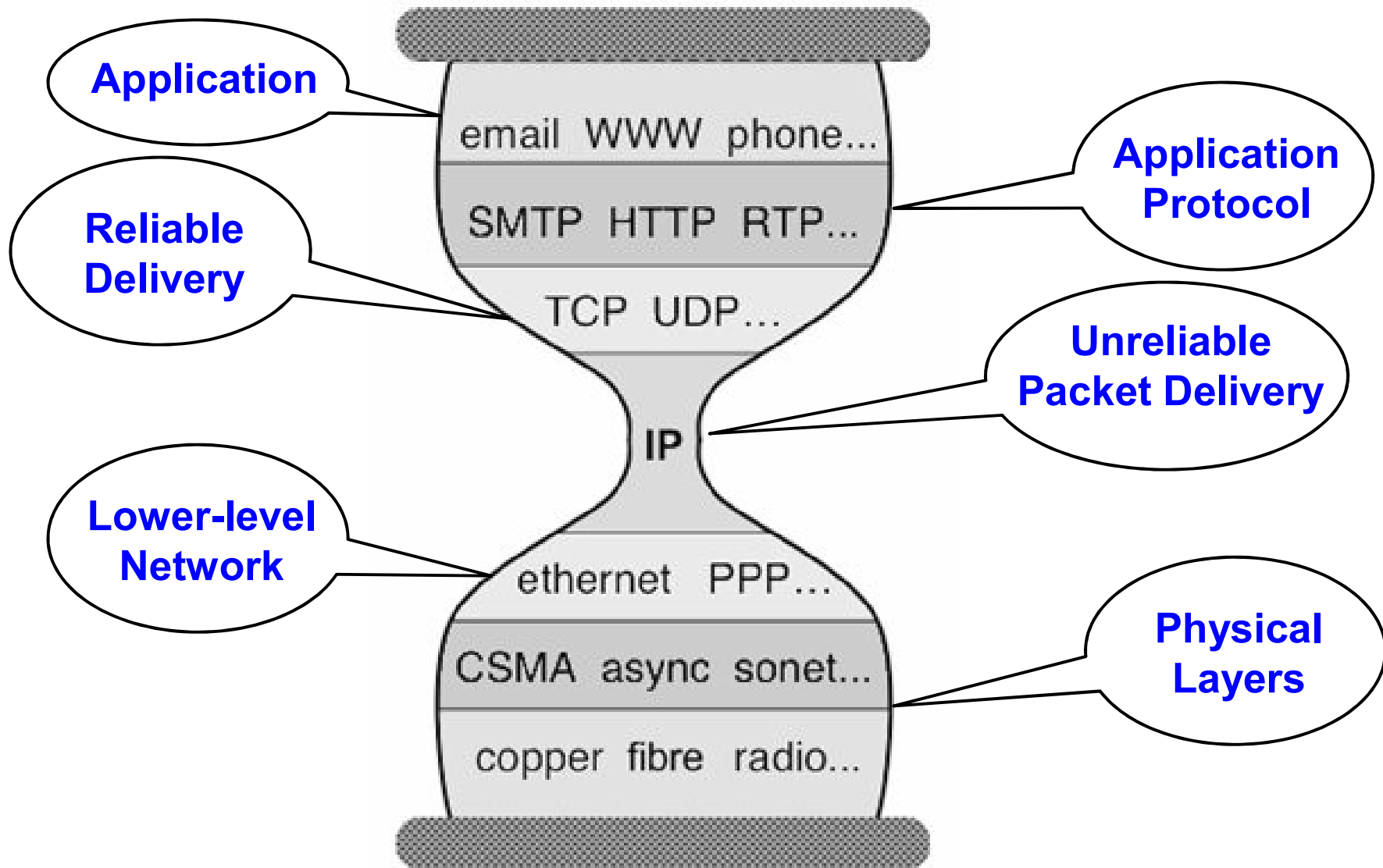
■ Different conceptual approaches:

- Architecture *vs.* Protocol *vs.* Algorithm

■ Different aspects of functionality:

- Different “layers” focus on different tasks

The Internet: an hourglass *with layers*

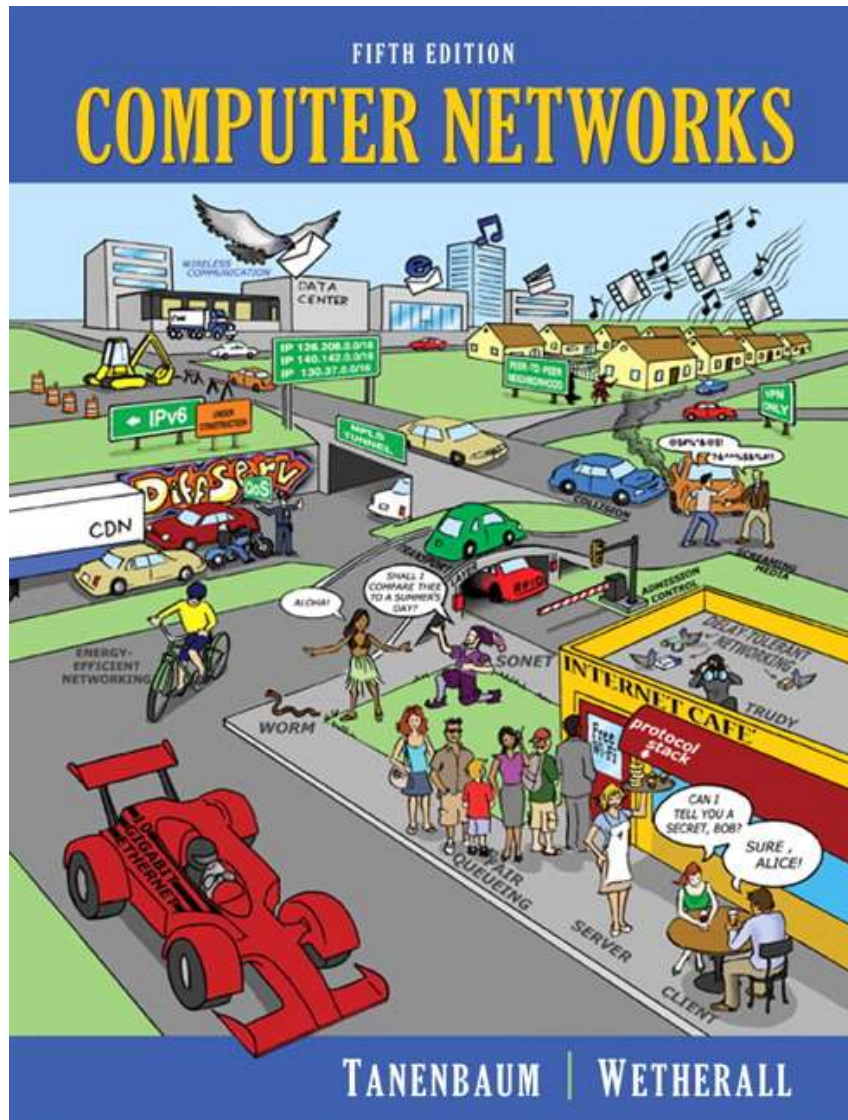




Fundamental conceptual questions

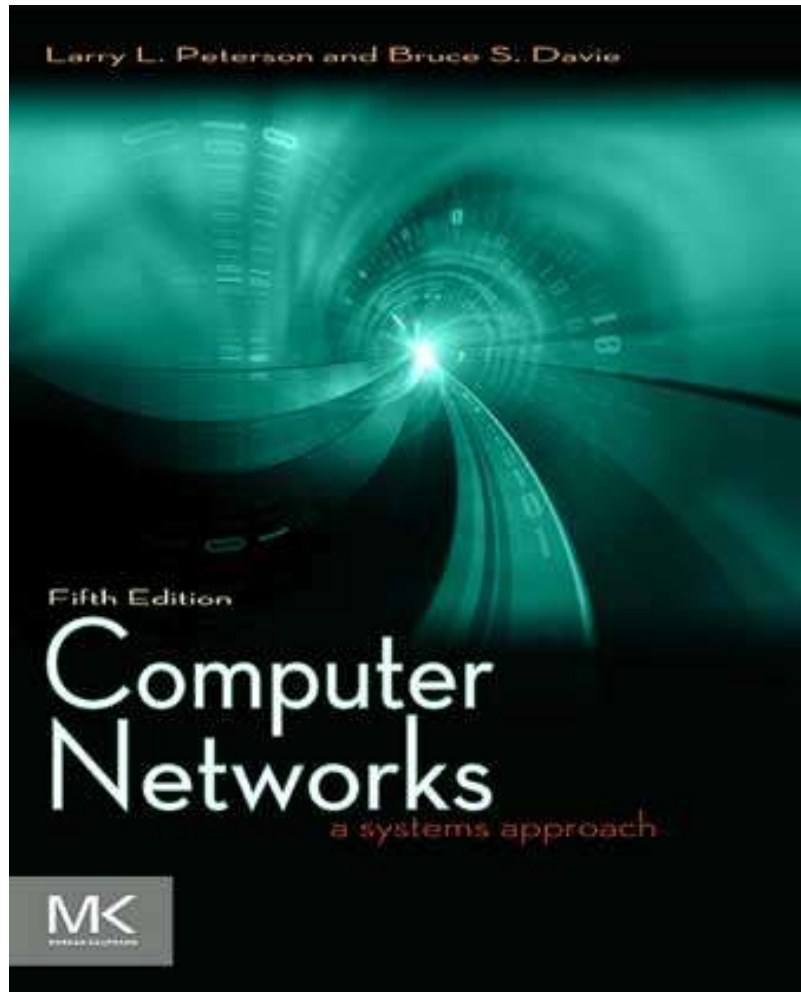
- **How can you deliver packets from source to destination?**
- **How do you build reliable transport on top of an unreliable network?**
- **How can you build applications on top of a packet delivery interface?**
- **How do you manage such networks?**
- **How can you federate a set of competing ISPs?**

Recommended Reference Textbooks



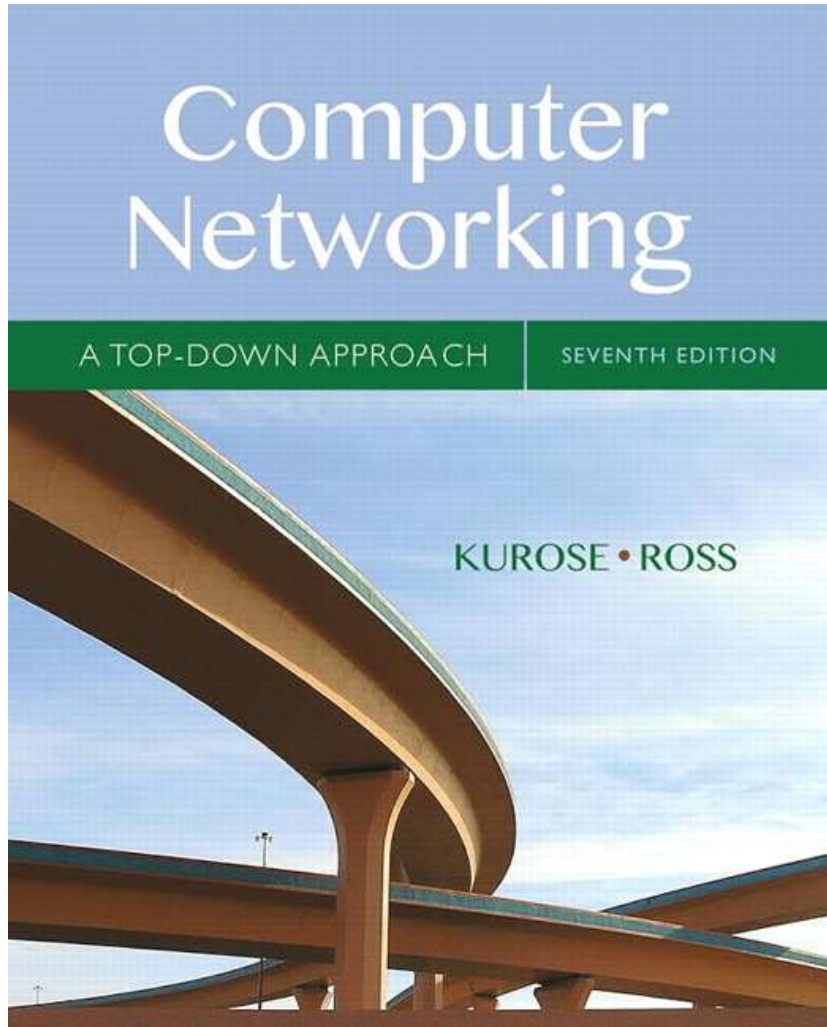
- Computer Networks, 5th edition
 - Andrew Tanenbaum
 - Prentice Hall, 2010

Recommended Reference Textbooks



- Computer Networks: A Systems Approach (5th Edition), Larry L.Peterson, Bruce S.Davie.

Recommended Reference Textbooks



- Computer Networking:
A Top-Down
Approach Featuring
the Internet
(6th Edition / 7th
Edition), James F.
Kurose, Keith W. Ross.



Course Information

■ Credits

- 48 teaching hours with 3 credits

■ Course Web site:

- Login Name: your student ID
- Login Pass: your pw
- Join the course:

计算机网络（双语）（2019级本科生 计算机学院 2021-2022-2学期）

- Download PPT/PDF
- Upload your homework/papers/reports



Grading Policy

Final Grade	
Attendance	20%
Homework assignments	
Projects	10%
Course paper	10%
Final exam	60%

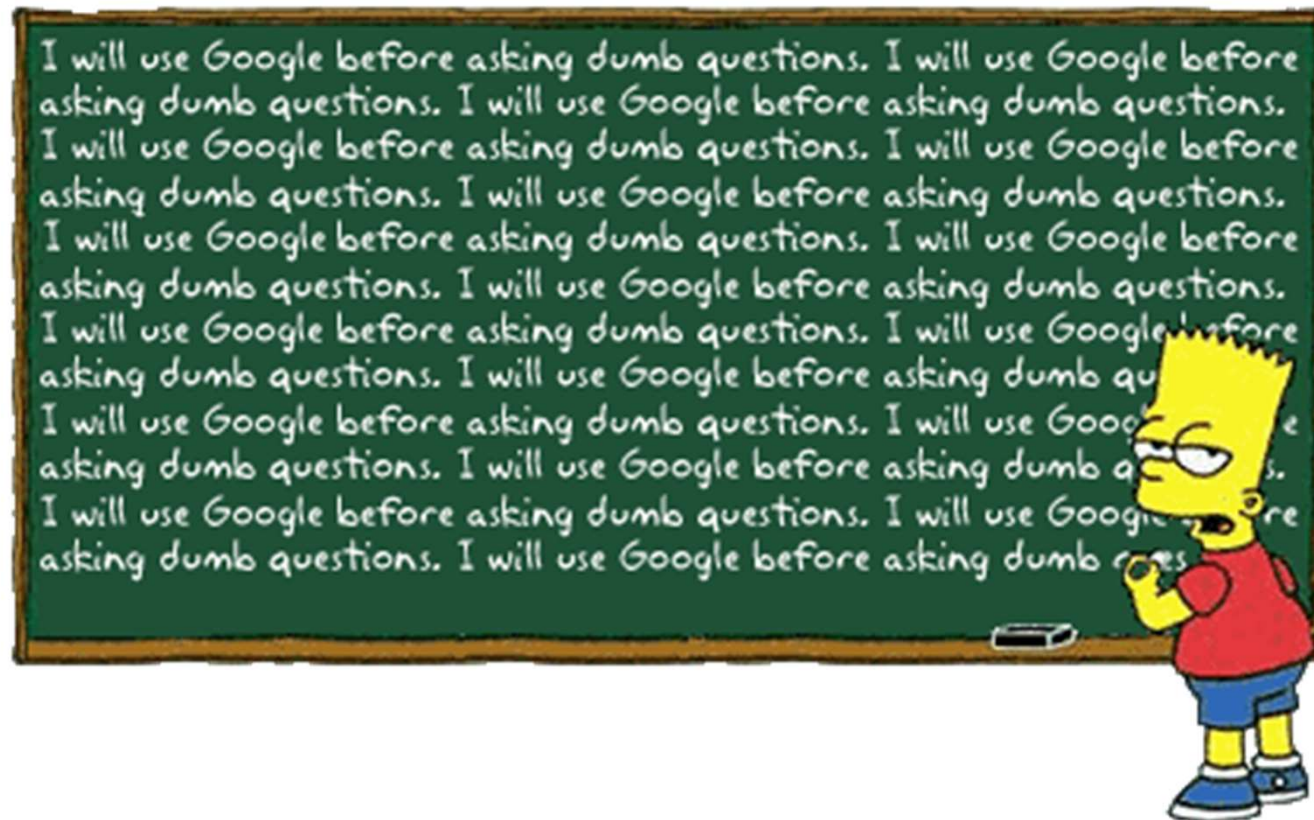


Assignments

- **All assignments are individual**
- **Start early**
- **Ask questions early**
- **Submit on time**

Asking questions

- **Make Google/Baidu your friend!**
 - **Can't beat the response time!**





Academic Integrity

■ Means

- No copying from anywhere
- Don't solve assignments for others
- Don't ask/give solutions.
- Protect your code

■ Dishonesty → Not fair to others.

- You may get a grade of F.



3 Questions

- **Why is it important to study networking?**
- **Why is this an exciting time for networking?**
- **Why is networking so hard?**



1: Why important to study networking?

- Huge impact
- New paradigm
- Unresolved challenges



Internet has had tremendous impact

- **Internet changed the way we gather information**

- Web, search engines

- **Internet changed the way we relate to each other**

- Email, facebook, twitter

- **Which would you choose?**

- Computers without the Internet (standalone PCs)

- Internet without modern computers



The Internet introduced new paradigm

- Completely different from the phone network
- Inventors had to overcome strong technical and commercial resistance to realize their dreams
- A true success story of “thinking differently”
 - Their strong vision kept the design on track
 - Brilliant in conception, sometimes weak in execution
- *While mired in details, leave room for awe*



Many challenges remain unsolved

■ Security

- Security of infrastructure
- Security of users

■ Availability

- Internet is very resilient
- But availability is not sufficient for critical infrastructures

■ Evolution

- It is too hard to change the Internet architecture



2: Why an exciting time in networking?

- **The “architecture” won’t change**

- But how we build and manage networks will

- **Industry has been closed, stagnant, and feudal**

- **But we are on the verge of a revolution!**

- Commodity hardware making inroads

- Developing intellectual (and practical) framework of applying systems principles of abstraction and modularity



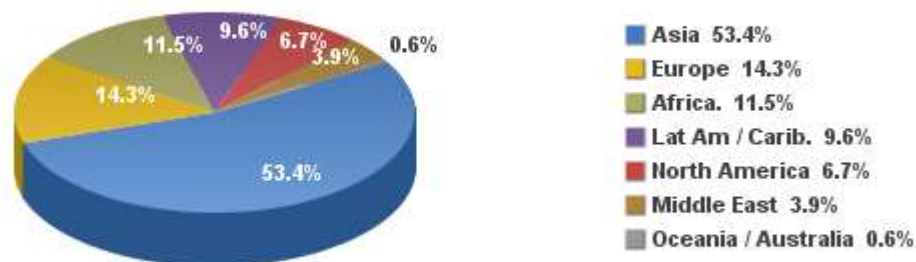
3: Why is Networking Hard?

- There are many **challenges** that make designing the Internet harder than just passing bits on a wire

Scale

WORLD INTERNET USAGE AND POPULATION STATISTICS 2021 Year-Q1 Estimates						
World Regions	Population (2021 Est.)	Population % of World	Internet Users 31 Mar 2021	Penetration Rate (% Pop.)	Growth 2000-2021	Internet World %
Asia	4,327,333,821	54.9 %	2,762,187,516	63.8 %	2,316.5 %	53.4 %
Europe	835,817,920	10.6 %	736,995,638	88.2 %	601.3 %	14.3 %
Africa	1,373,486,514	17.4 %	594,008,009	43.2 %	13,058 %	11.5 %
Latin America / Carib.	659,743,522	8.4 %	498,437,116	75.6 %	2,658.5 %	9.6 %
North America	370,322,393	4.7 %	347,916,627	93.9 %	221.9 %	6.7 %
Middle East	265,587,661	3.4 %	198,850,130	74.9 %	5,953.6 %	3.9 %
Oceania / Australia	43,473,756	0.6 %	30,385,571	69.9 %	298.7 %	0.6 %
WORLD TOTAL	7,875,765,587	100.0 %	5,168,780,607	65.6 %	1,331.9 %	100.0 %

**Internet Users Distribution
in the World - 2021**



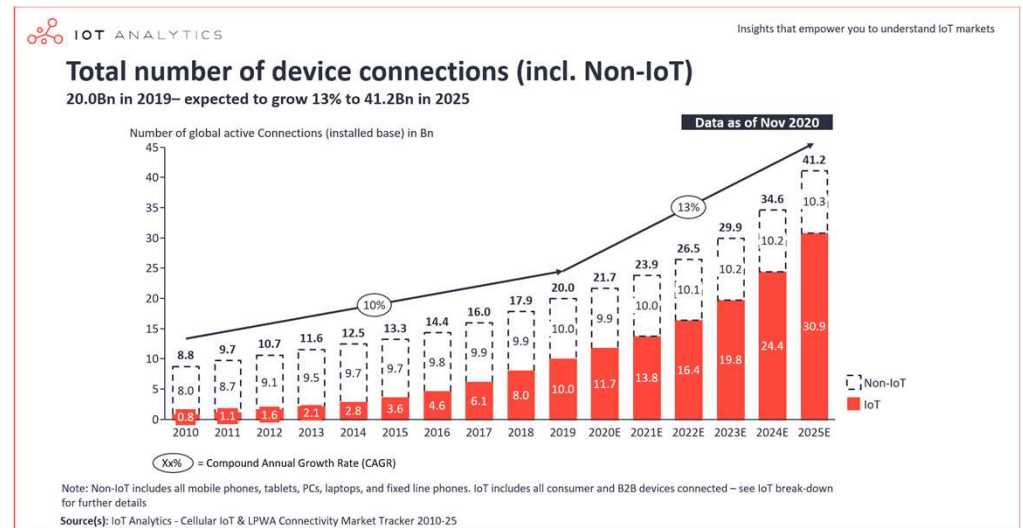
Source: Internet World Stats - www.internetworldstats.com/stats.htm
 Basis: 5,168,780,607 Internet users in March 31, 2021
 Copyright © 2021, Miniwatts Marketing Group

Dynamic Range

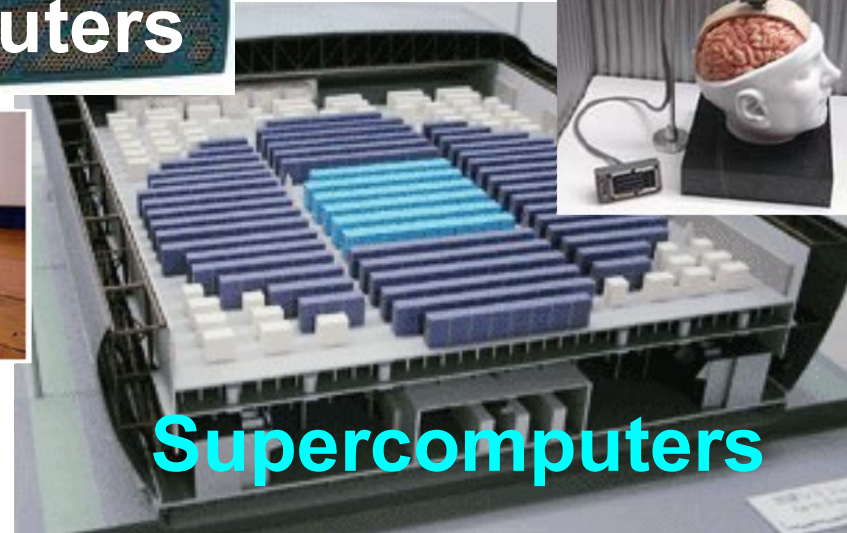
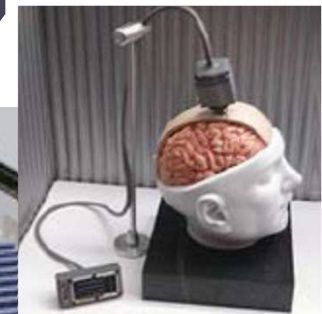
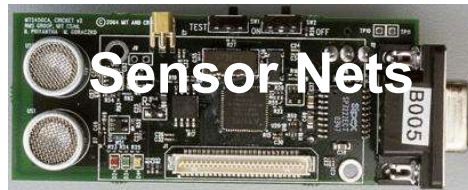
- Round-trip times (**latency**) from $10\mu\text{secs}$ to secs : 5 orders of magnitude
- Data rates (**bandwidth**) from kbps to 100 Gbps : 8 orders of magnitude
- **Queuing** delays in the network vary from 0 to secs
- **Packet loss** varies from 0 to 90+%
-

Diversity of end systems

- *Cell phones*
- *Supercomputer clusters*
- *Tablets*
- *Televisions*
- *Gaming consoles*
- *Web cams*
- *Automobiles*
- *Sensing devices*
- *Picture frames*
- *Security systems*
- *Power grid*
- *.....*



Diversity of end systems



Diversity of application requirements

表 4 2020.12-2021.6 各类互联网应用用户规模和网民使用率

应用	2020.12		2021.6		增长率
	用户规模 (万)	网民使用率	用户规模 (万)	网民使用率	
即时通信	98111	99.2%	98330	97.3%	0.2%
网络视频 (含短视频)	92677	93.7%	94384	93.4%	1.8%
短视频	87335	88.3%	88775	87.8%	1.6%
网络支付	85434	86.4%	87221	86.3%	2.1%
网络购物	78241	79.1%	81206	80.3%	3.8%
搜索引擎	76977	77.8%	79544	78.7%	3.3%
网络新闻	74274	75.1%	75987	75.2%	2.3%
网络音乐	65825	66.6%	68098	67.4%	3.5%
网络直播	61685	62.4%	63769	63.1%	3.4%
网络游戏	51793	52.4%	50925	50.4%	-1.7%
网上外卖	41883	42.3%	46859	46.4%	11.9%
网络文学	46013	46.5%	46127	45.6%	0.2%

应用	2020.12		2021.6		增长率
	用户规模 (万)	网民使用率	用户规模 (万)	网民使用率	
网约车	36528	36.9%	39651	39.2%	8.5%
在线办公	34560	34.9%	38065	37.7%	10.1%
在线旅行预订	34244	34.6%	36655	36.3%	7.0%
在线教育	34171	34.6%	32493	32.1%	-4.9%
在线医疗	21480	21.7%	23933	23.7%	11.4%
互联网理财	16988	17.2%	16623	16.4%	-2.1%



Diversity of application requirements

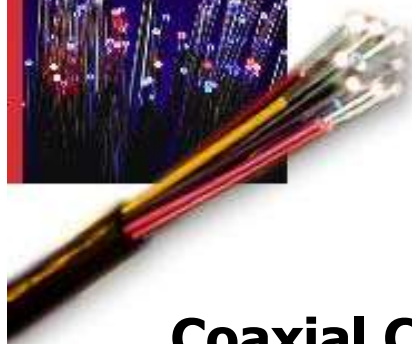
- **Size of transfers**
- **Bidirectionality (or not)**
- **Latency sensitive (or not)**
- **Tolerance of jitter (or not)**
- **Tolerance of packet drop (or not)**
- **Need for reliability (or not)**
- **Multipoint (or not)**
- **.....**

Networks contain many components

Links



Fibers



Coaxial Cable



Computer Networks

Interfaces

Ethernet card



Wireless card



CS BIT

Switches/routers

Large router



Telephone switch



They can all fail....

- **Consider communication that uses 50 components**

- Assume each work correctly 99% of the time

- What is likelihood communication fails?

- **Answer:** success requires that they all function, so failure probability = $1 - (.99)^{50} \approx 39.5\%$

- **Even if nodes are 99.9% reliable, failure probability is still close to 5%**

- **Must design the system to expect failure!**



Greed

- **There are greedy people out there who want to:**
 - Steal your financial information (bank, credit card, etc.)
 - Use your computer for attacks
- **There is a thriving underground economy for compromised computers and financial information**



Malice

- **There are malicious people out there who want to:**
 - Bring your system down and/or steal confidential data
- **When attacker is a nation-state, attacks are far harder to stop**
 - Many defensive techniques involve stopping attacks that have been seen before
 - But nation-states can use *new* attack vectors



Speed of Light

■ **Question:** how long does it take light to travel from Beijing to shanghai?

■ **Answer:**

□ **Distance Beijing → Shanghai: 1,088 km**

□ **Traveling 300,000 km/s, 3.63 msec**

Networking Latencies

■ Answer:

□ For sure ≥ 3.63 msec

□ Depends on:

- The *route* the packet takes (could be circuitous!)
- The propagation speed of the *links* the packet traverses
 - E.g., in optical fiber light propagates at about $2/3 C$
- The transmission rate (*bandwidth*) of the links (bits/sec)
 - and thus the size of the packet
- Number of *hops* traversed (*store-and-forward* delay)
- The “competition” for bandwidth the packet encounters (*congestion*). It may have to sit & wait in router *queues*.

□ In practice this boils down to: ≥ 10 msec

Implications for Networking

■ **Question:** how many cycles does your PC execute before it can possibly **get a reply** to a message it sent to a Shanghai web server?

■ **Answer:**

- **Round trip** takes ≥ 20 msec
- PC runs at (say) 3 GHz
- $3,000,000,000 \text{ cycles/sec} \times 0.02 \text{ sec} = \mathbf{150,000,000,000}$ cycles
- Communication feedback is always ***dated***
- Communication fundamentally ***asynchronous***

Even a Problem for LANs

- **Question:** what about between machines directly connected (via a *local area network* or **LAN**)?

- **Answer:**

`% ping www.icir.org`

PING www.icir.org (192.150.187.11): 56 data bytes

64 bytes from 192.150.187.11: icmp_seq=0 ttl=64 time=0.214 ms

64 bytes from 192.150.187.11: icmp_seq=1 ttl=64 time=0.226 ms

64 bytes from 192.150.187.11: icmp_seq=2 ttl=64 time=0.209 ms

64 bytes from 192.150.187.11: icmp_seq=3 ttl=64 time=0.212 ms

64 bytes from 192.150.187.11: icmp_seq=4 ttl=64 time=0.214 ms

- **200 μ sec = 600,000 cycles**

- Still a loooong time ...

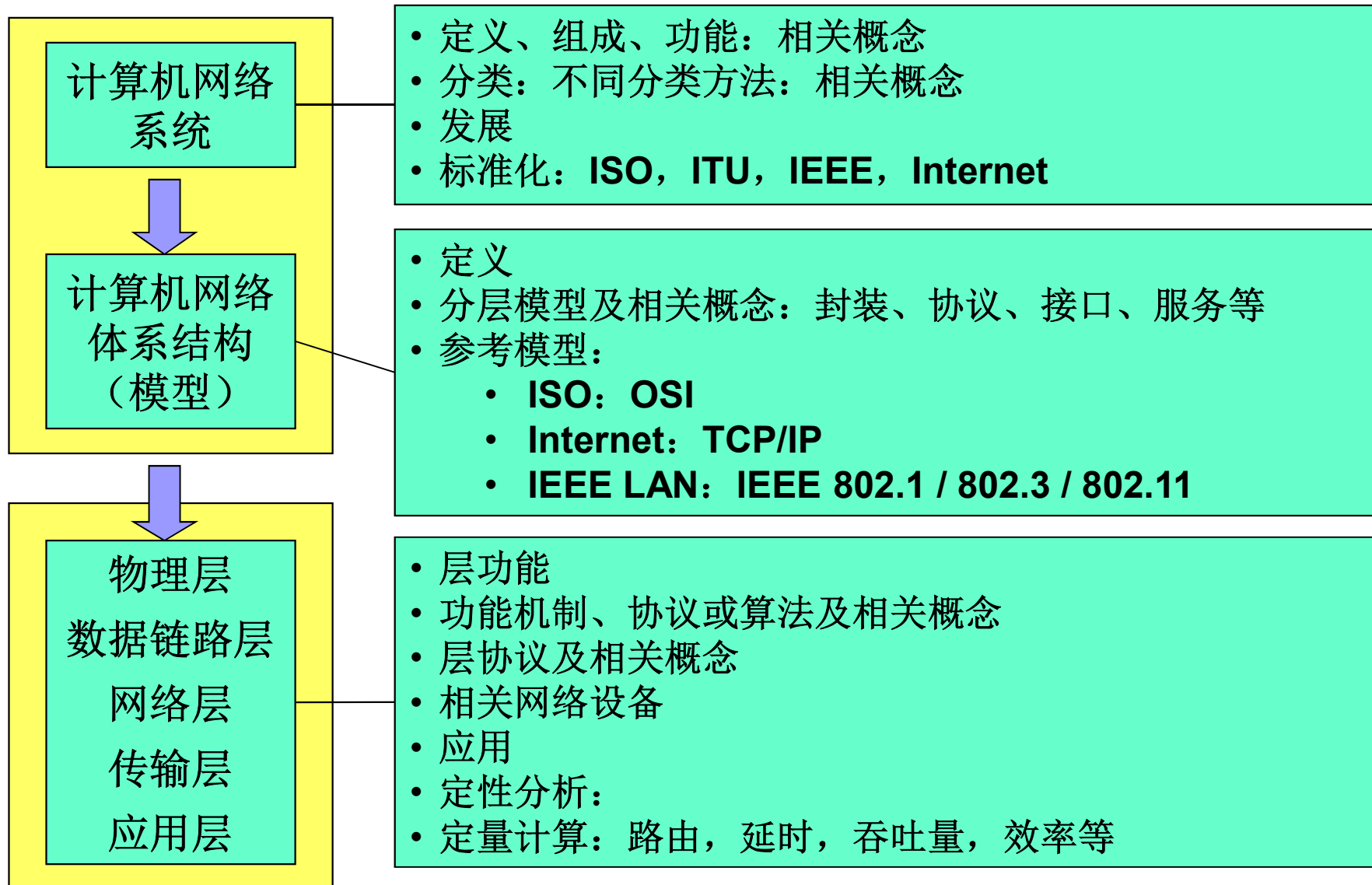
- ... and asynchronous



Summary

- **The Internet is a large complicated system that must meet an unprecedented variety of challenges**
 - Scale, dynamic range, diversity, ad hoc, failures, asynchrony, malice, and greed
- **An amazing feat of engineering**
 - Went against the conventional wisdom
 - Created a new networking paradigm
- **In hindsight, some aspects of design are terrible**

学习思路1



学习思路2

计算机网络
工程

- 相关概念：网络体系结构，资源子网，通信子网，交换，互连，路由等
- 网络设备：集线器，交换机/网桥，路由器
- 网络规划：子网
- 互连策略/方法
- **IP**地址规划与分配
- 路由协议与设置