



Principle of Communications

Introduction



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Outline

- Mature communications & networking technology
- Communications & networking technology for today and tomorrow
- Challenges and what you will learn here

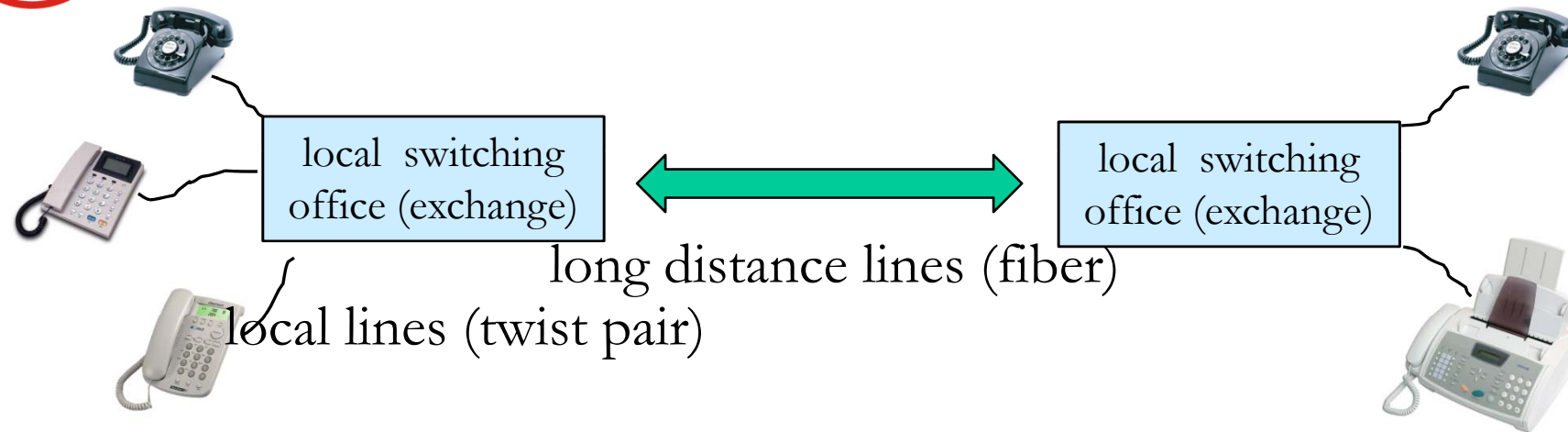


Roadmap

- Mature communications & networking technology
- Communications & networking technology for today and tomorrow
- Challenges and what you will learn here



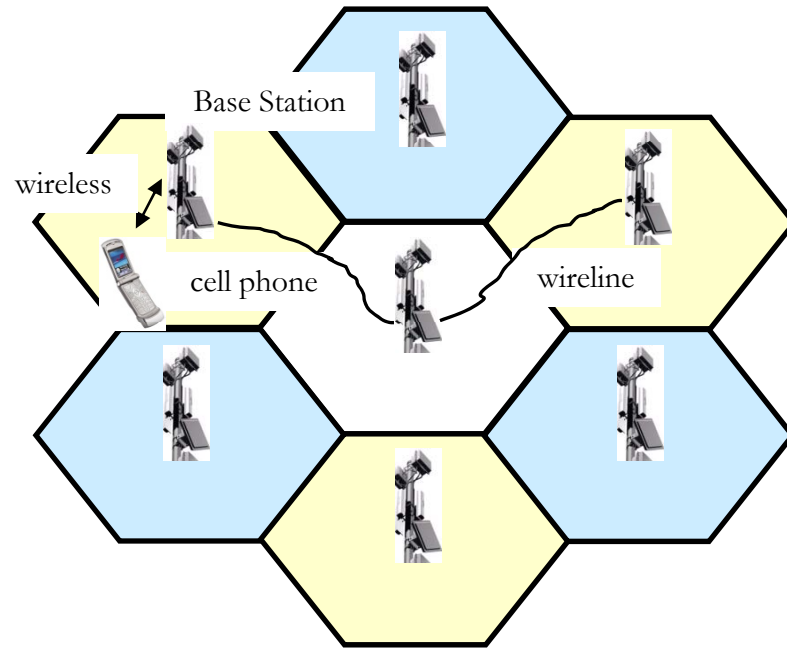
Telephone Network



- Local switching office:
 - Handles local calls
 - Routes long distance calls over high-capacity lines
- Circuit switched network tailored for voice communication
- Support low rate data communication by modulating data to voice tones (e.g. fax)
- DSL (digital subscriber line) & ISDN (integrated services digital network) use advanced modulation to achieve high (1.5Mbps) data rate.



Cellular System Basics



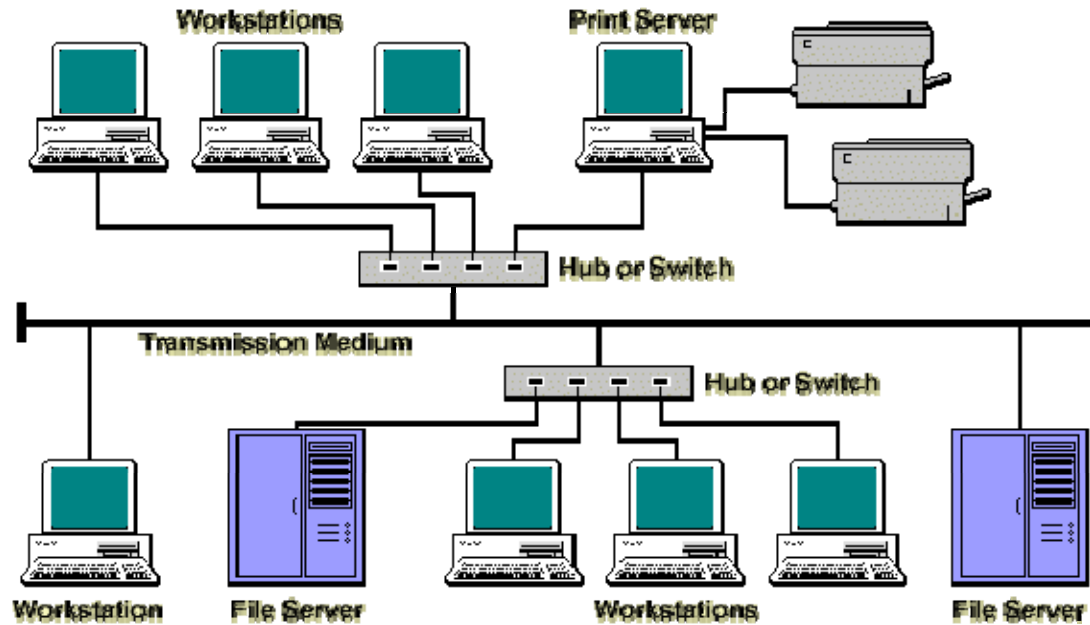
- A more advanced version
- Cells can be different in size
- Can be combined with other wireless and wireline networks

- Geographical regions divided into cells
- Frequency/time/codes reused at spatially separated cells
- Co-channel interference between cells with the same color
- Handoff and control coordinated through cell base stations





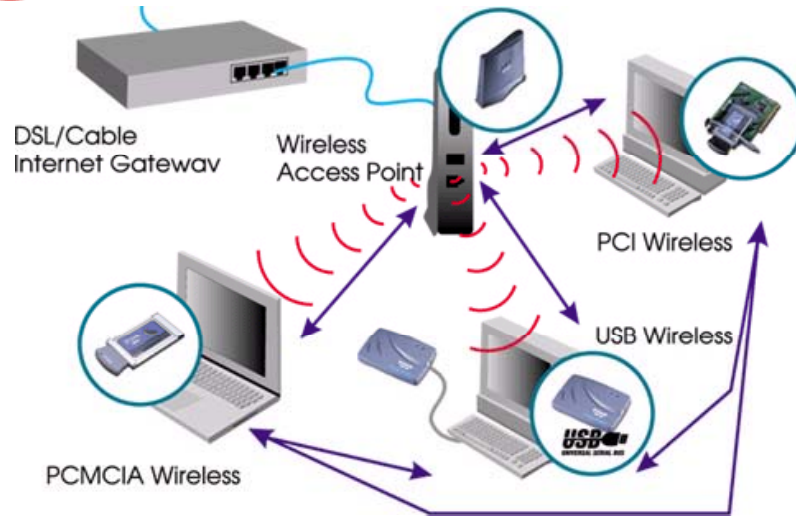
Local Area Network (LAN)



- Connects “local” computers and devices
- Breaks data into packets
- Packet switch, no dedicated channels
- Proprietary protocols (medium access, routing, etc.)



Wireless Local Area Network (WLAN)



- Connects "local" computers and devices (100m range)
- Breaks data into packets
- Channel access is shared (parallel transmissions cause interference)
- Backbone internet provides best effort service

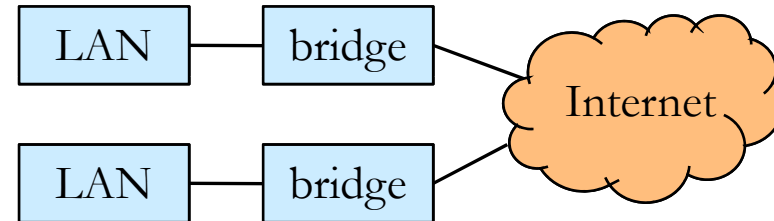
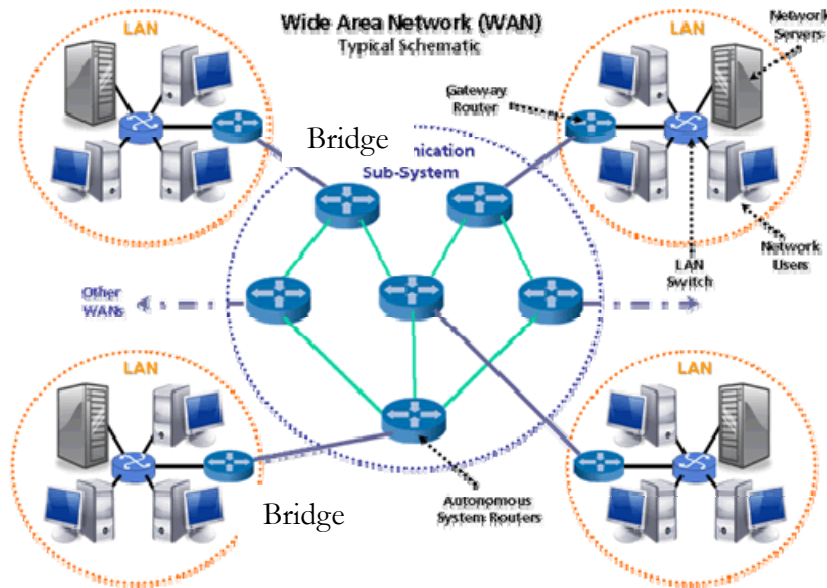


WLAN Standards

- 802.11b
 - Standard for 2.4GHz band
 - Modulation and multiple access: DSSS (direct sequence spread spectrum)/CDMA (code division multiple access)
 - Speeds of 11 Mbps, approximately 500ft in range
- 802.11a
 - Standard for 5GHz band
 - Modulation: OFDM (orthogonal frequency division modulation)
 - Multiple access: TDMA (time division multiple access)
 - Speeds up to 54 Mbps, approximately 100ft in range
- 802.11g
 - Standard for 2.4GHz band
 - Speeds up to 54 Mbps, approximately 200ft in range
- 802.11n
 - Standard for 5GHz band
 - MIMO (multi-input multi-output) capability
 - Speeds up to 600 Mbps, approximately 300ft in range



Wide Area Networks

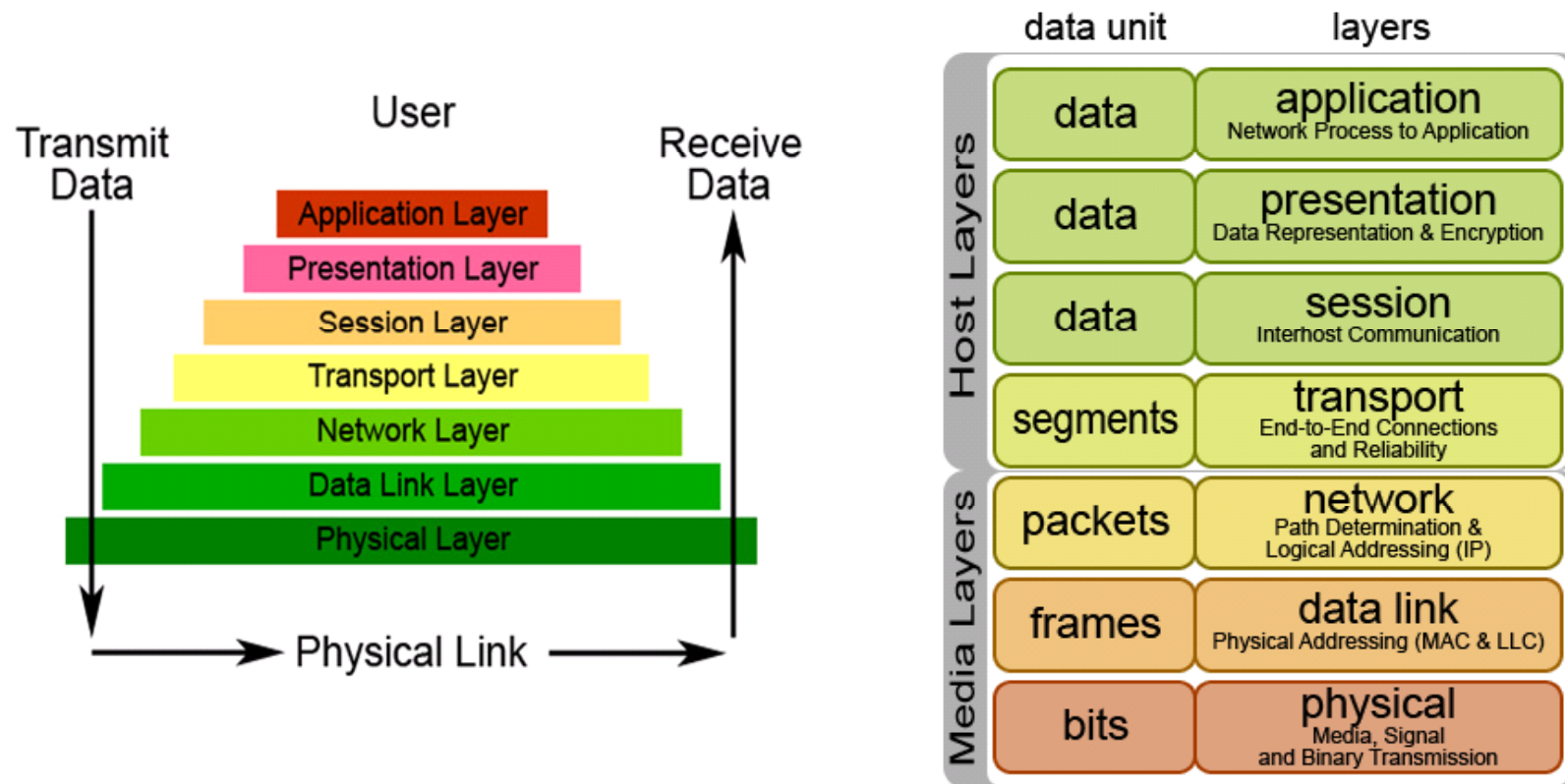


- Many LANs and WANs are bridged together
- Universal protocol: TCP/IP (packet based)
- No rate or delay guarantee
- Hard to support mobile users
- Highly scalable with flexible topology



Data Network Architecture

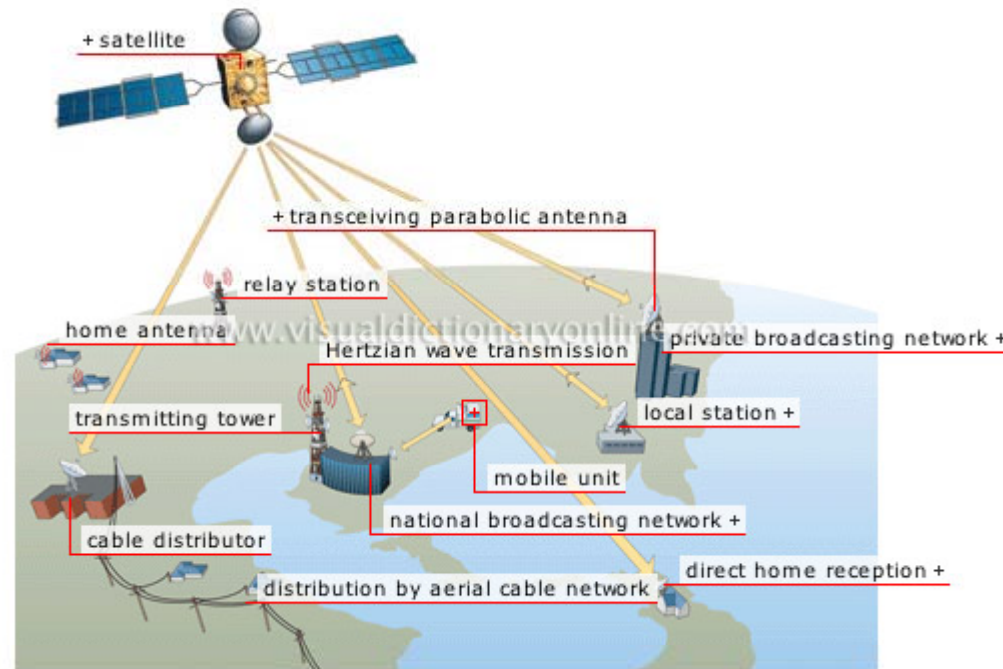
- The Open System Interconnection (OSI) Architecture



Classical communication belongs to the physical layer



Satellite Systems



- Cover very large areas
- Different orbit heights: GEO (35000 km), LEO (1500 km)
- Optimized for one-way transmission: Radio, TV broadcasts
- Most two-way systems struggle or bankrupt
- Expensive alternative to terrestrial systems



Bluetooth



- Cable replacement for electronic devices: cell phones, laptop, PDAs, printers, etc.
- Short range connection (10~100m)
- 1 data (721 Kbps) and 3 voice (56 Kbps) channels
- Rudimentary networking capabilities

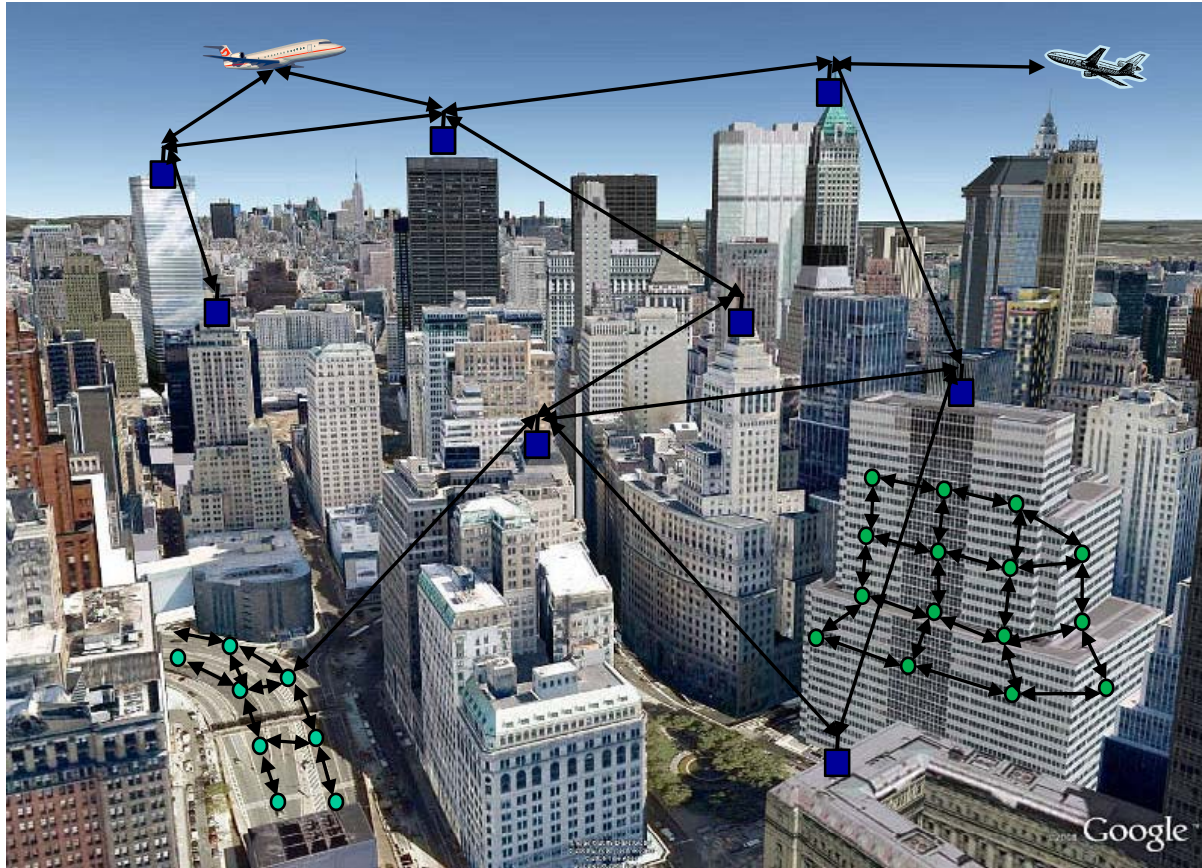


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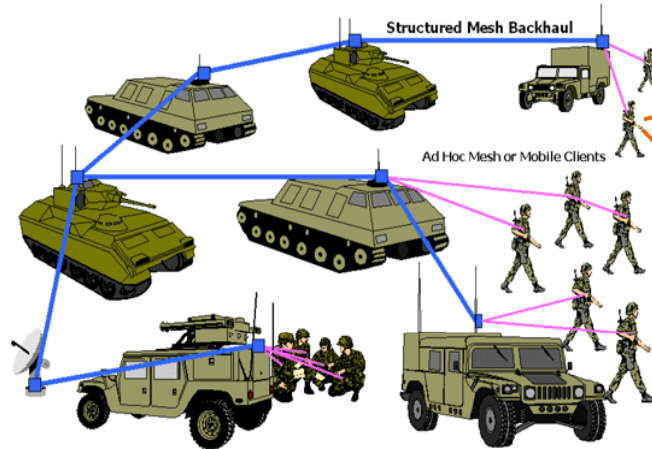
More Advanced Wireless Networks



next generation cellular, wireless ad hoc network, wireless multimedia, sensor network, smart home, automated traffic control, body area network, etc.



Ad Hoc Networks



Battlefield Networking



Robot Teams



Tactical Backbone Network



Emergency Communication

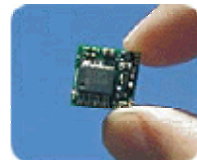
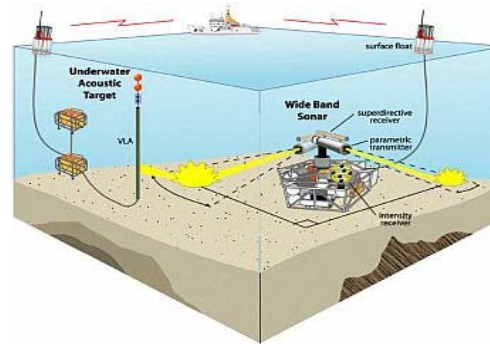
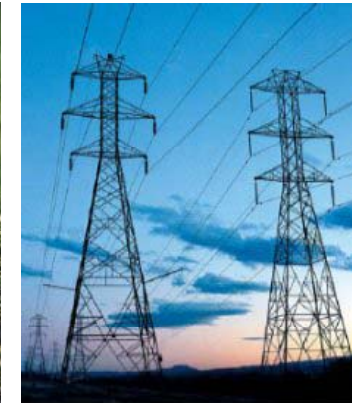
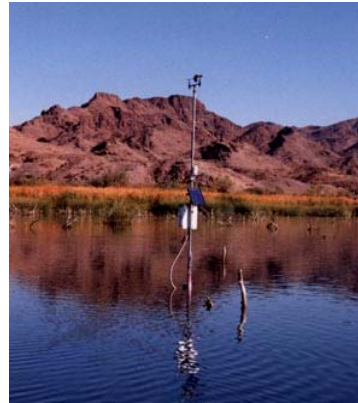
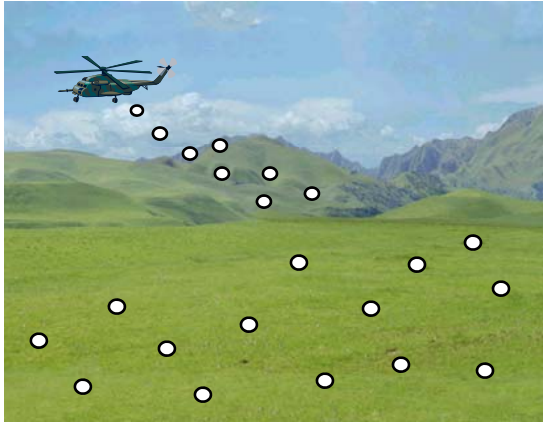


Advanced Cellular System

Infrastructure-
nondependent
Cost effective
Reliable
Robust
Scalable



Sensor Networks



Various Monitoring, Detection, Sensing

Easily deployable, Low cost, Long lifetime,
Limited processing, Limited mobility



Vehicular Networking based ITS

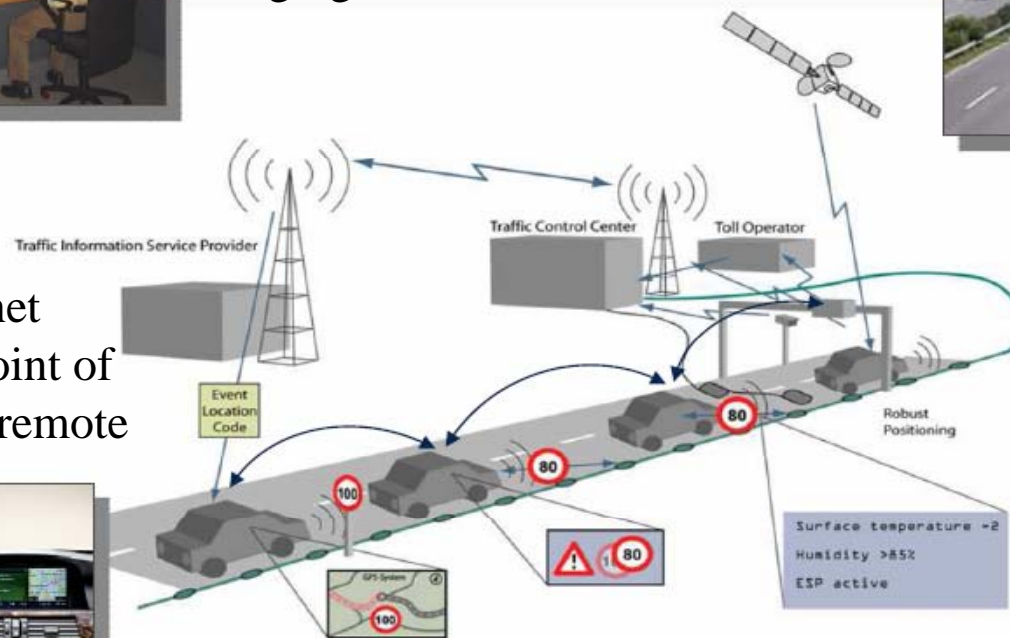
Traffic Efficiency:
enhanced route guidance
and navigation, M2M
merging assistance.



Active Safety: Cooperative
forward collision warning,
pre-crash sensing/warning,
hazardous location M2M
notification.



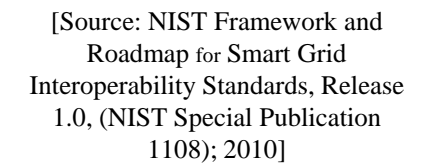
Infotainment: internet
access in vehicles, point of
interest notification, remote
diagnostics.



Source: COOPERS project

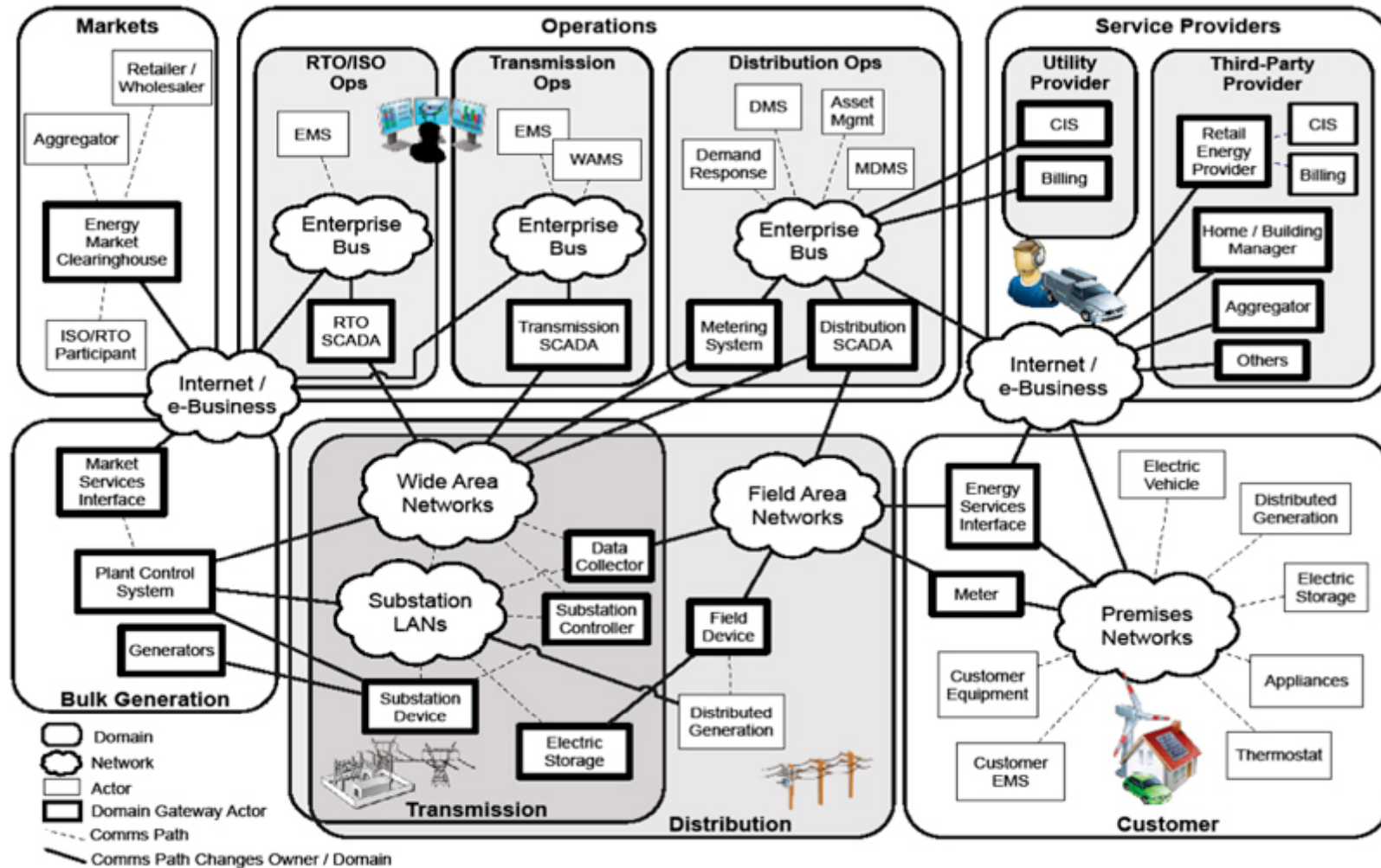
Traffic Efficiency:
green light optimal
speed advisory.







Signal Processing Communications Networking



[Source: NIST'2010]



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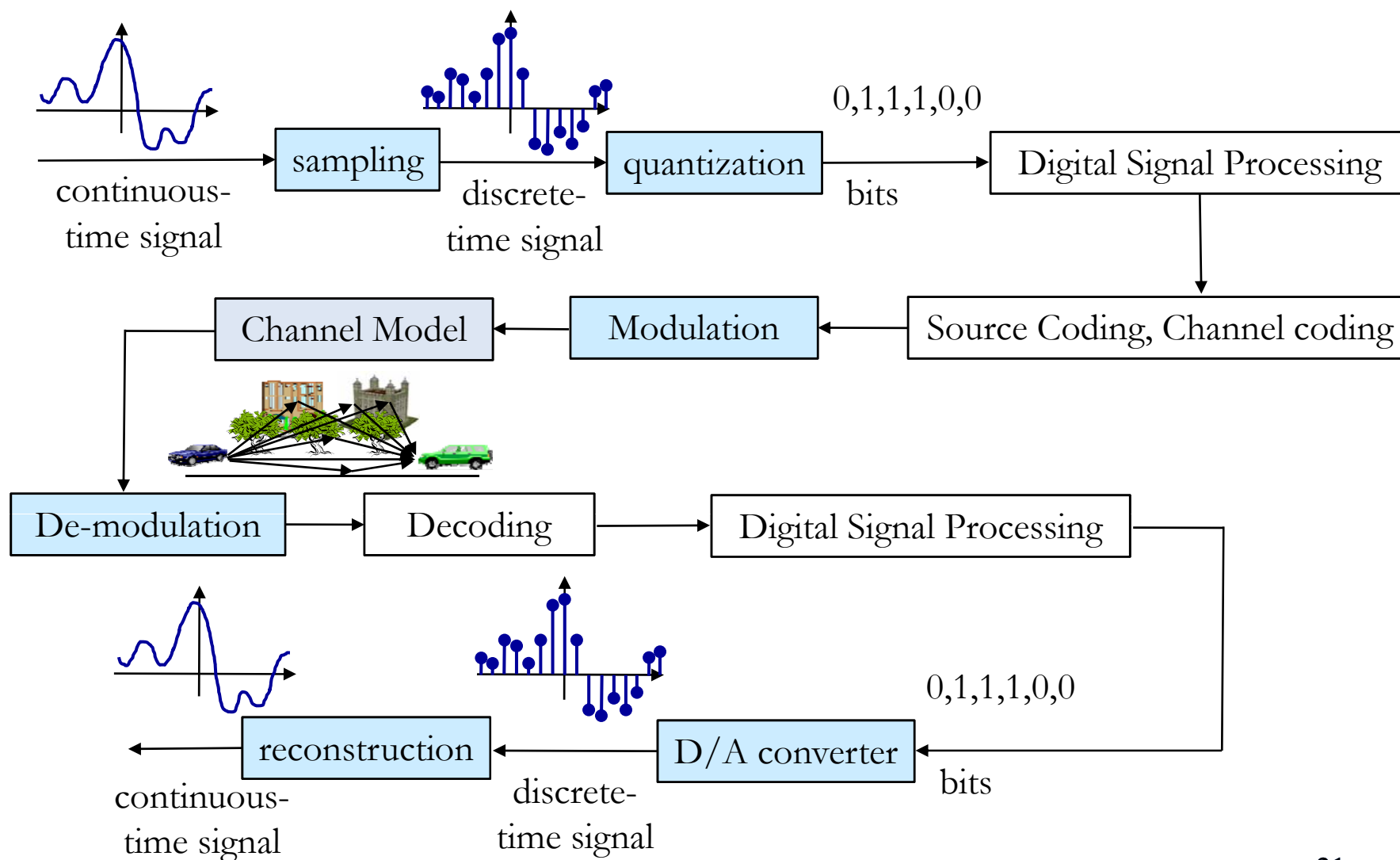
Design Challenges

- Hardware Perspective
 - Precise components
 - Small, lightweight, low power
 - Cheap
 - High processing power
- Communication Perspective
 - Converting and transmitting information
 - High data rates
 - Robust against noise and interference
 - Support many users
- Network Perspective
 - Consistent connectivity, high throughput, low delay
 - Energy constraints, fairness among users
 - Scalability, mobility, etc.



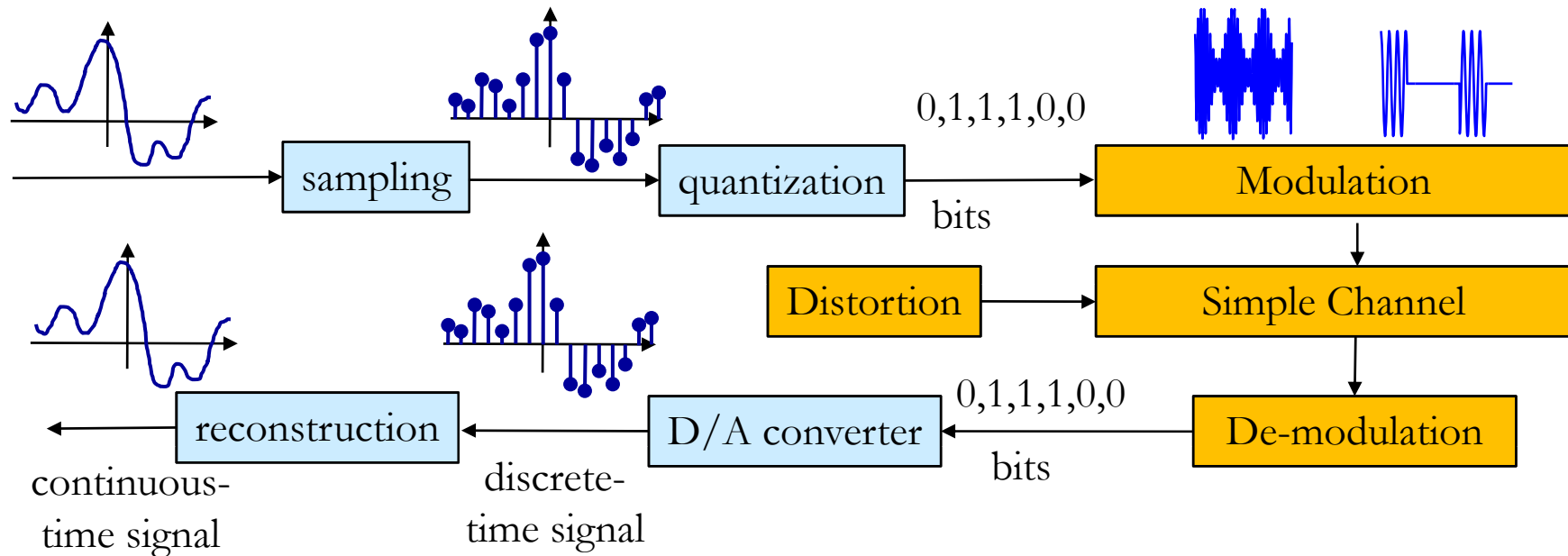


Communications Courses at PKU





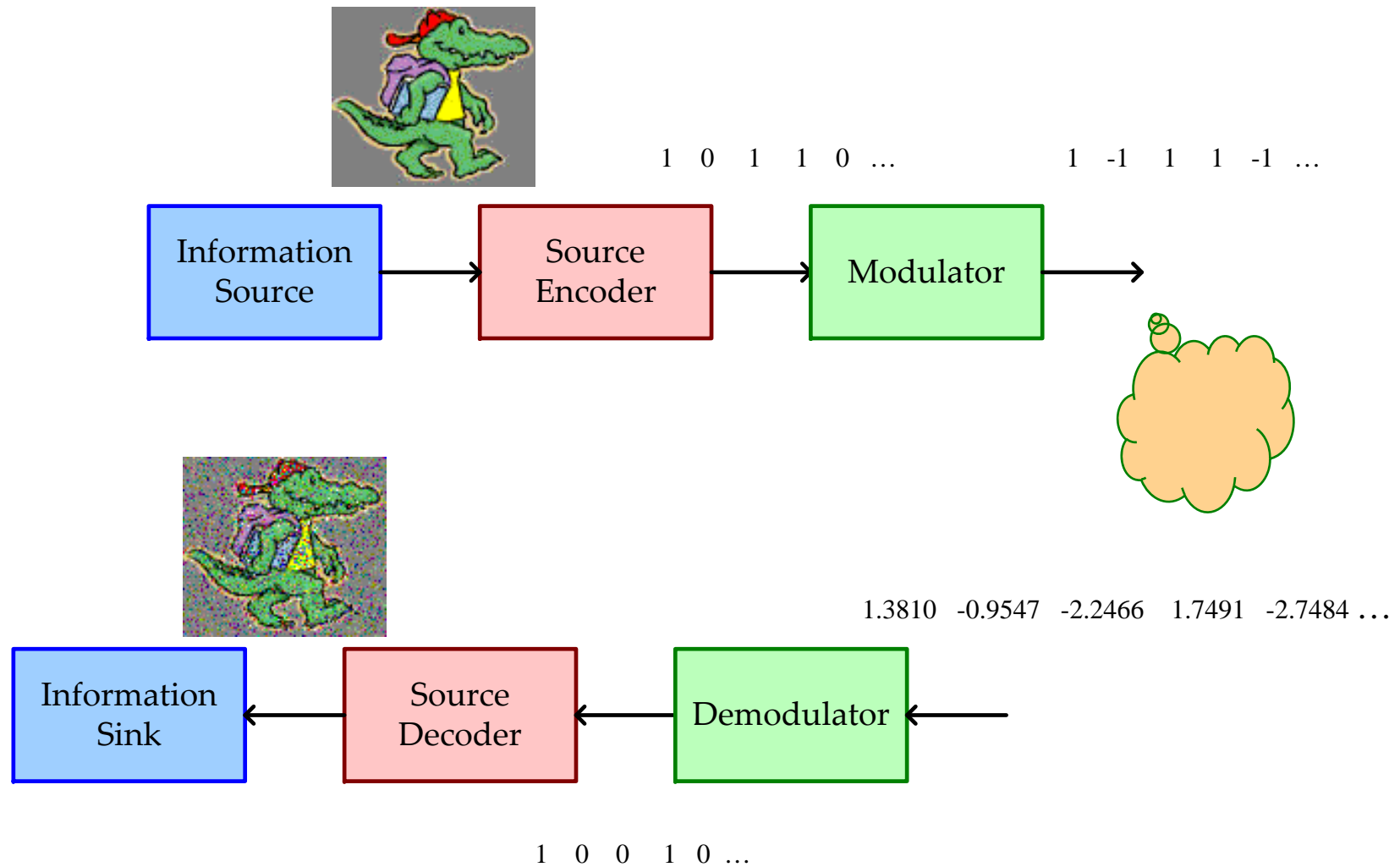
Simplified Communications System Diagram



- Source encoder: message \rightarrow signals/bits
- Modulator: signals/bits \rightarrow format appropriate for channel transmission (analog/digital)
- Channel: introduces distortion, noise, and interference
- Demodulator: received waveform \rightarrow signals or bits
- Decoder: signals/bits \rightarrow original message



A Simple Example





Communication Resources

- Transmit Power: average power of the transmitted signal
 - Power-limited channels: wireless channels, satellite channels, deep-space links, underwater acoustic channels
- Channel Bandwidth: width of the passband of the channel
 - Band-limited channel: telephone channels, television channels, underwater acoustic channels
- Objective: Under these resource constraints, minimize signal distortion or maximize data reliability.
- Additional concerns:
 - computing power at the receiver
 - efficient and flexible sharing of bandwidth
 - channel fading: time-, frequency-, and/or space- selectivity



Underpinning Topics

- Modulation Theory
 - How to convert baseband signal to waveforms suitable for transmission over a communication channel, how to convert the modulated signal back to baseband signal.
- Fourier Analysis
 - Frequency-domain description of signals (baseband signal, modulated signal, processed signal, signal after passing the communication channel)
- Detection Theory
- Analog communication
 - Assessing communication performance in the presence of noise. Performance comparisons.
- Digital communication
 - Recover the digital source signal from a noisy observation. Error probability analysis. Handling uncontrollable factors. Performance comparison.



Underpinning Theories

- Probability Theory and Random Processes
 - Probability theory for describing the behavior of randomly occurring events in mathematical terms.
 - Statistical characterization of random signals and noise.
- Information Theory
 - source coding, channel coding, and their performance analysis
- Coding Complexity
 - error performance and complexity analysis of coding schemes.
- Network Architecture
 - Interaction between signal transmission and network operation concerns.
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Reading Assignment

- Sections 2.1-2.9
- FTP Website:
ele.pku.edu.cn/pub/讲义/通信原理_程翔/通信原理2014资料/