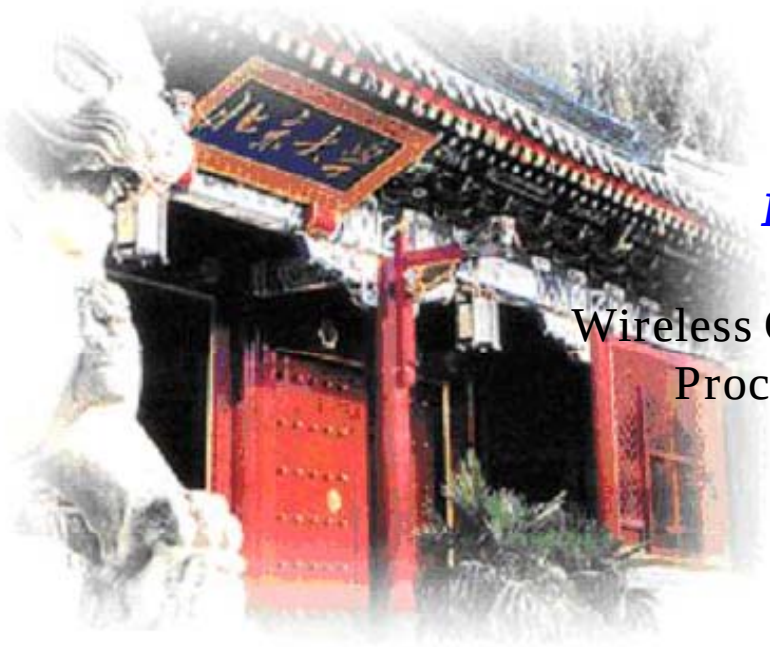
Principle of Communications

Introduction



Dr. Xiang Cheng

Wireless Communications and Signal Processing Research Center
Peking University

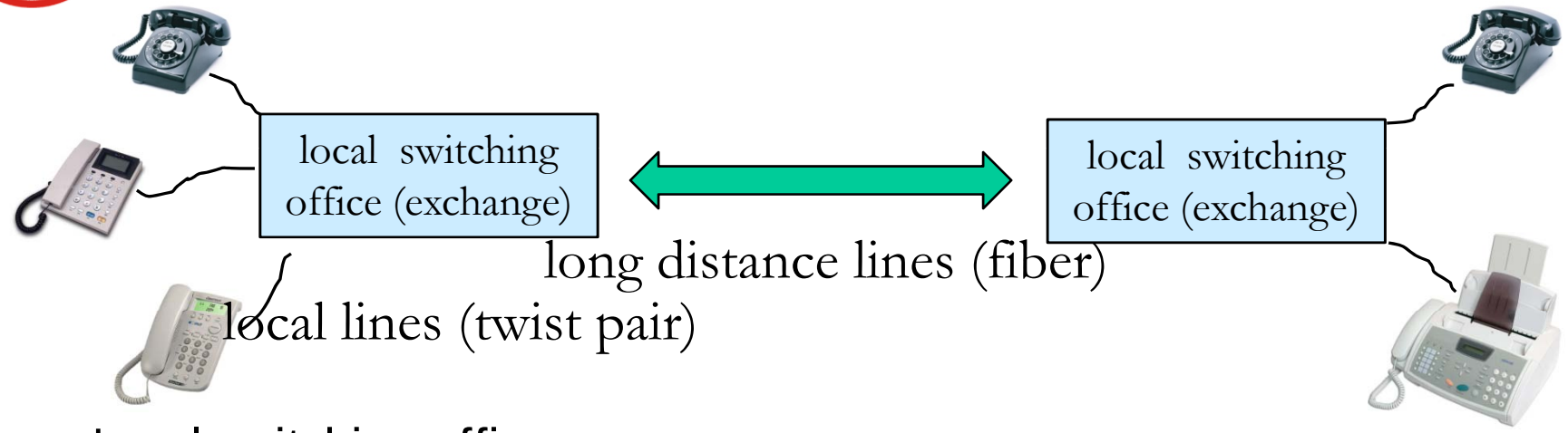
Outline

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

Roadmap

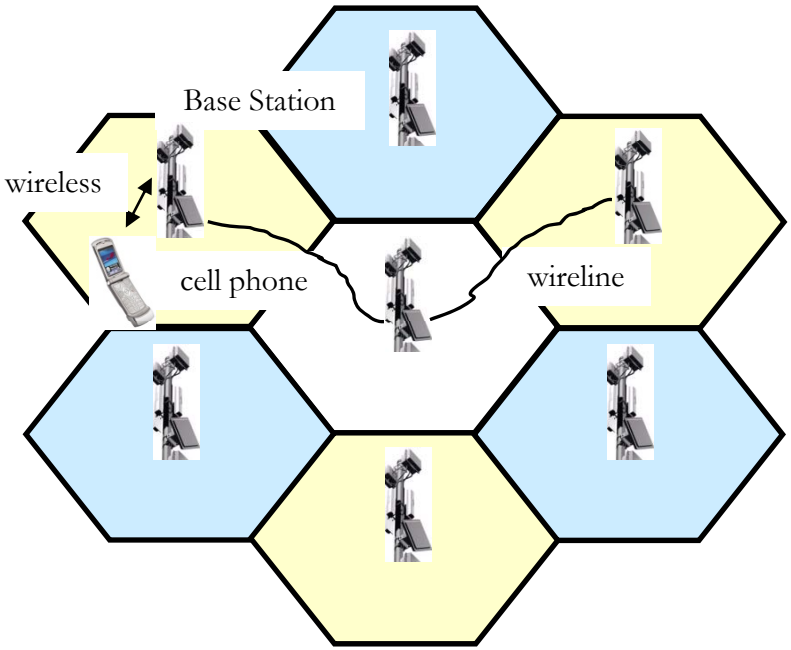
- Mature communications & networking technology
- Communications & networking technology for today and tomorrow
- Challenges and what you will learn here

Telephone Network



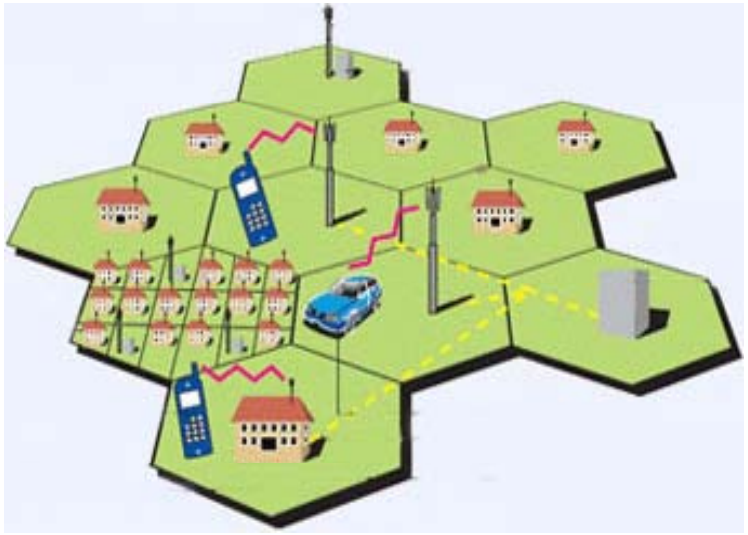
- Local switching office:
  - Handles local calls
  - Routes long distance calls over high-capacity lines
- Circuit switched network tailored for voice communication
- Support low rate data communication by modulating data to voice tones (e.g. fax)
- DSL (digital subscriber line) & ISDN (integrated services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

Cellular System Basics

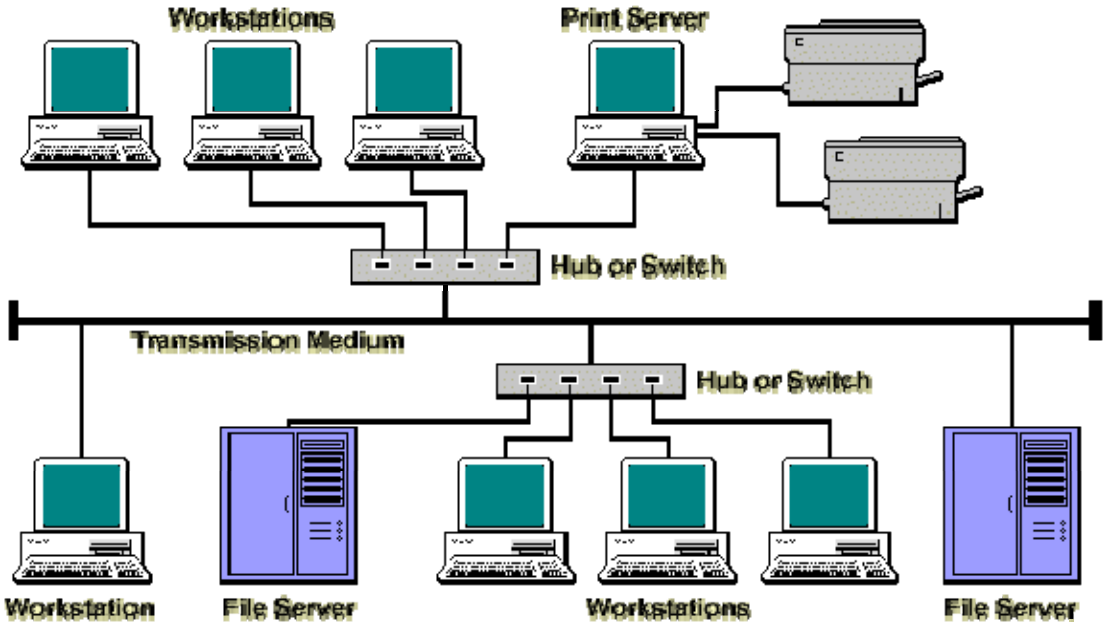


- Geographical regions divided into cells
- Frequency/time/codes reused at spatially separated cells
- Co-channel interference between cells with the same color
- Handoff and control coordinated through cell base stations

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

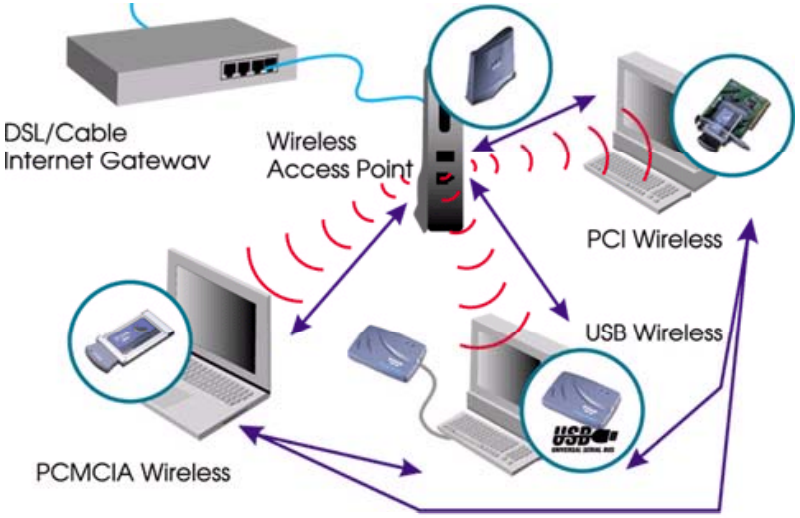


Local Area Network (LAN)



- 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)

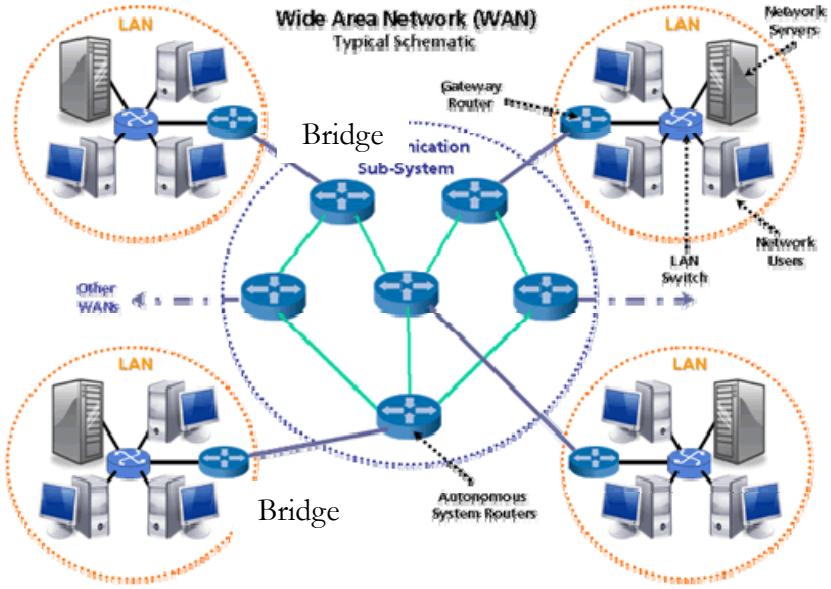


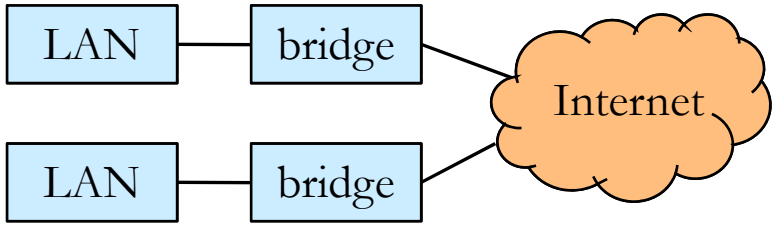
- Connects “local” computers and devices (100m range)
- Breaks data into packets
- Channel access is shared (parallel transmissions cause interference)
- Backbone internet provides best effort service

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

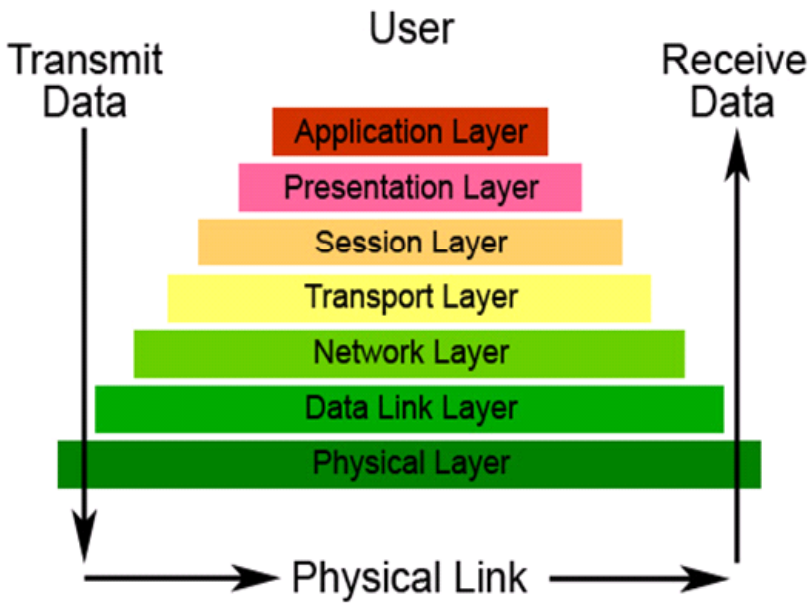


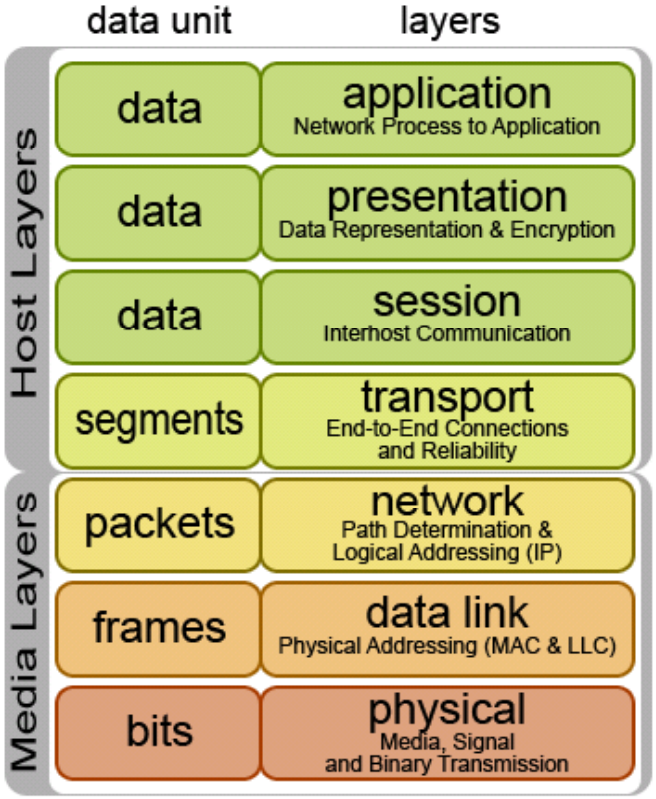


- Many LANs and WANs are bridged together
- Universal protocol: TCP/IP (packet based)
- No rate or delay guarantee
- Hard to support mobile users
- Highly scalable with flexible topology

Data Network Architecture

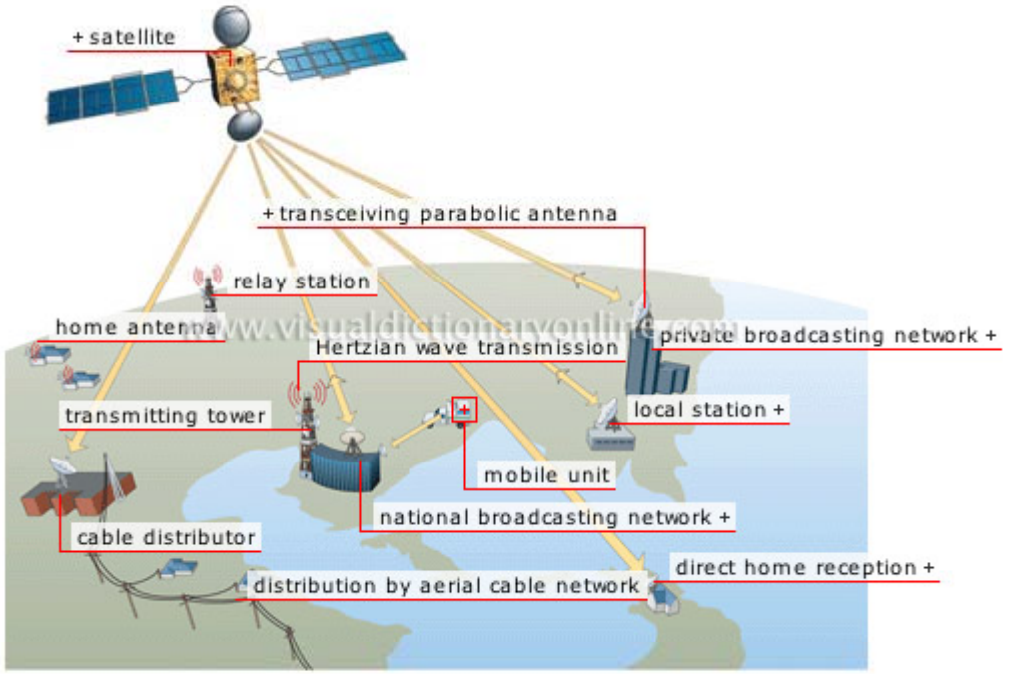
- The Open System Interconnection (OSI) Architecture





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

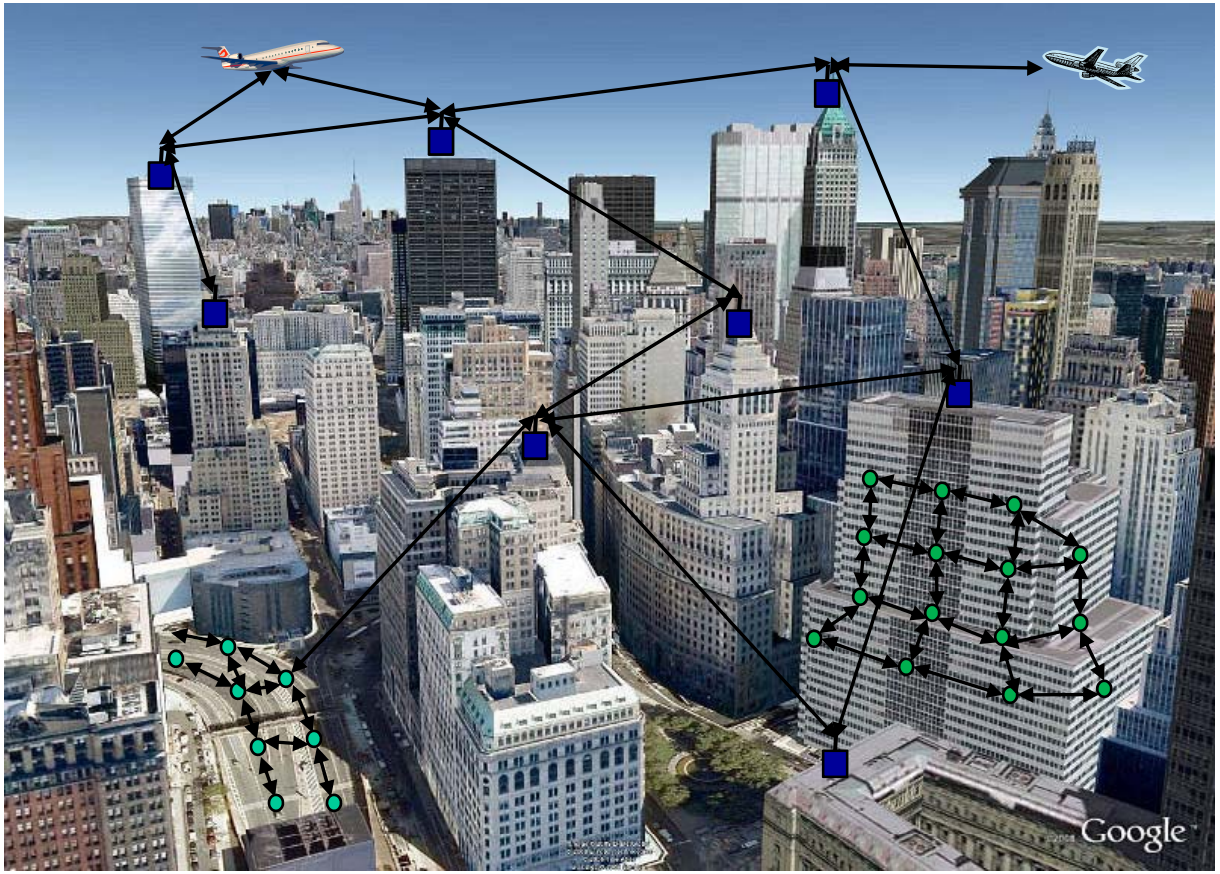
Bluetooth

- 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

Roadmap

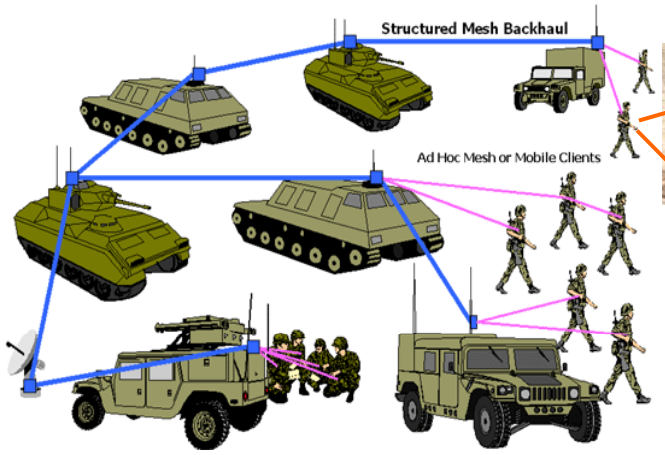
- Mature communications & networking technology
- Communications & networking technology for today and tomorrow
- Challenges and what you will learn here

More Advanced Wireless Networks



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

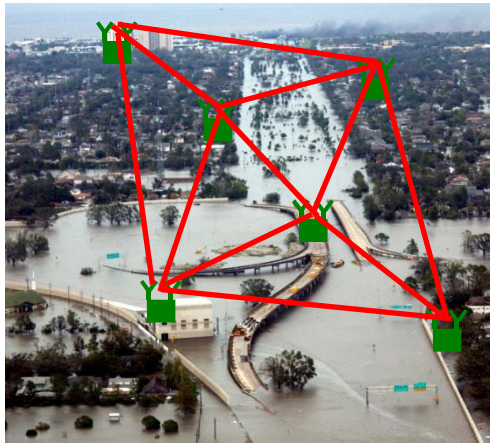
Ad Hoc Networks



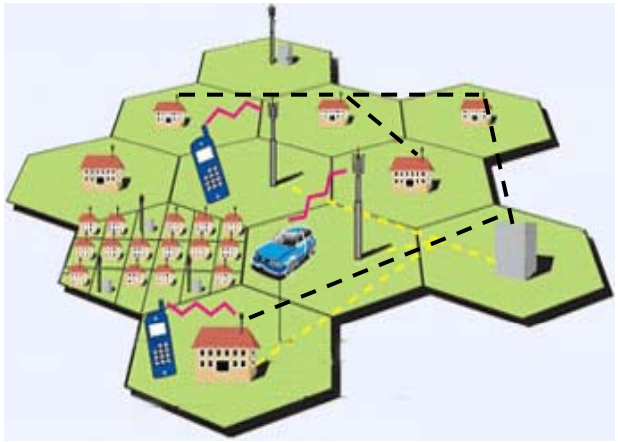
Battlefield Networking

Robot Teams

Tactical Backbone Network



Emergency Communication



Advanced Cellular System

Infrastructure-nondependent

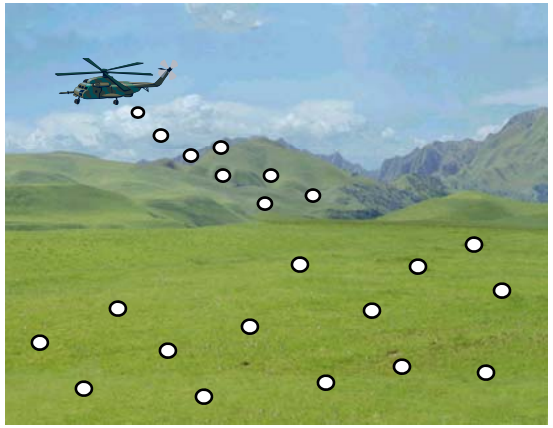
Cost effective

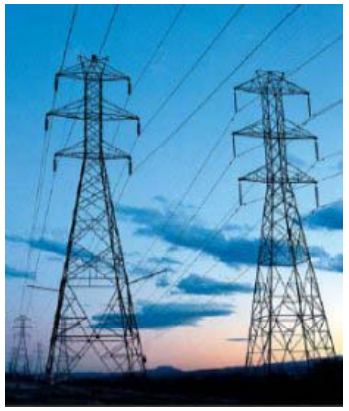
Reliable

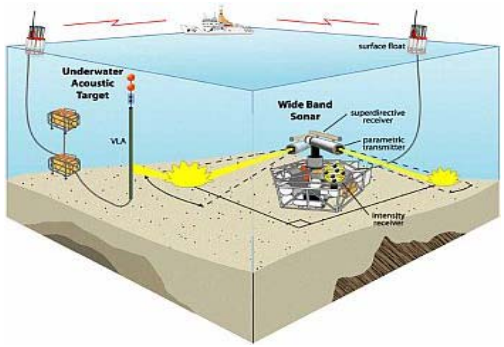
Robust

Scalable

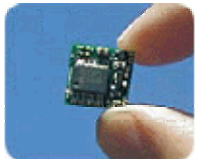
Sensor Networks

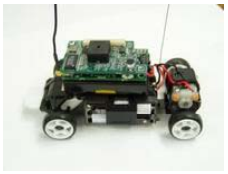










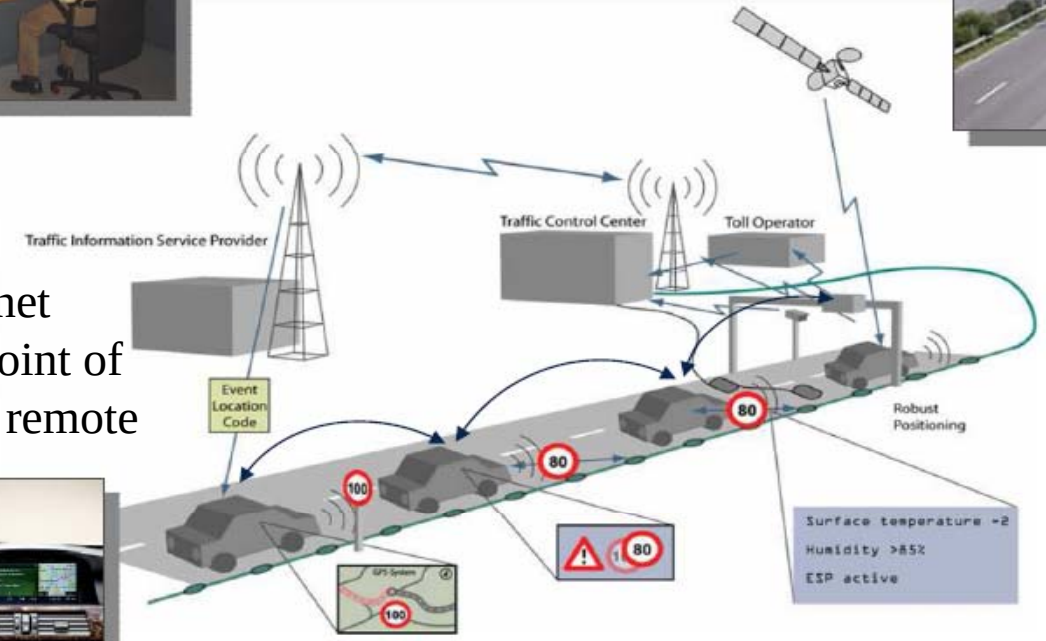
Various Monitoring, Detection, Sensing

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

Vehicular Networking based ITS

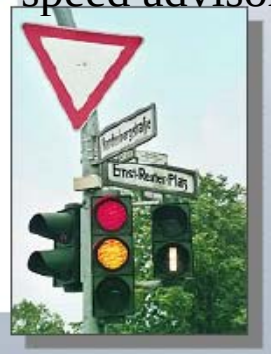
Traffic Efficiency: enhanced route guidance and navigation, M2M merging assistance.

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



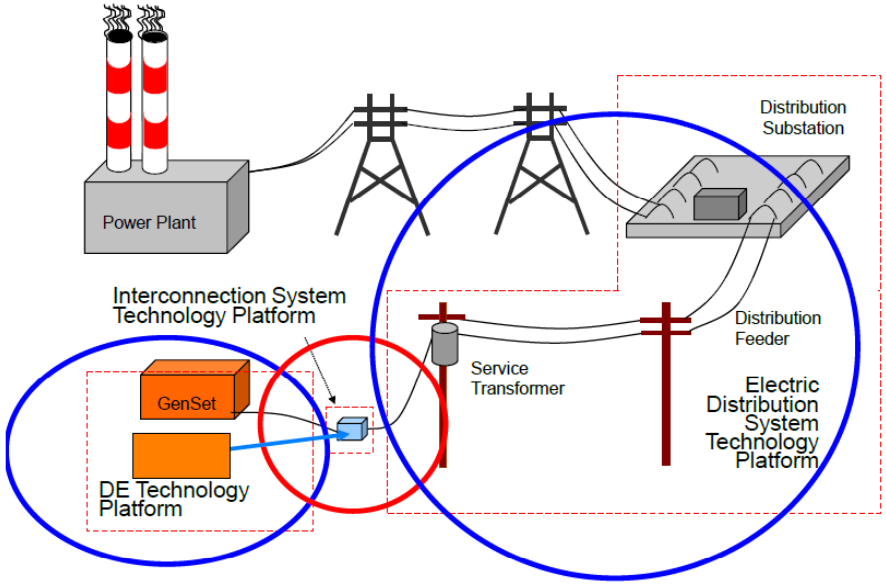
Infotainment: internet access in vehicles, point of interest notification, remote diagnostics.

Traffic Efficiency: green light optimal speed advisory.

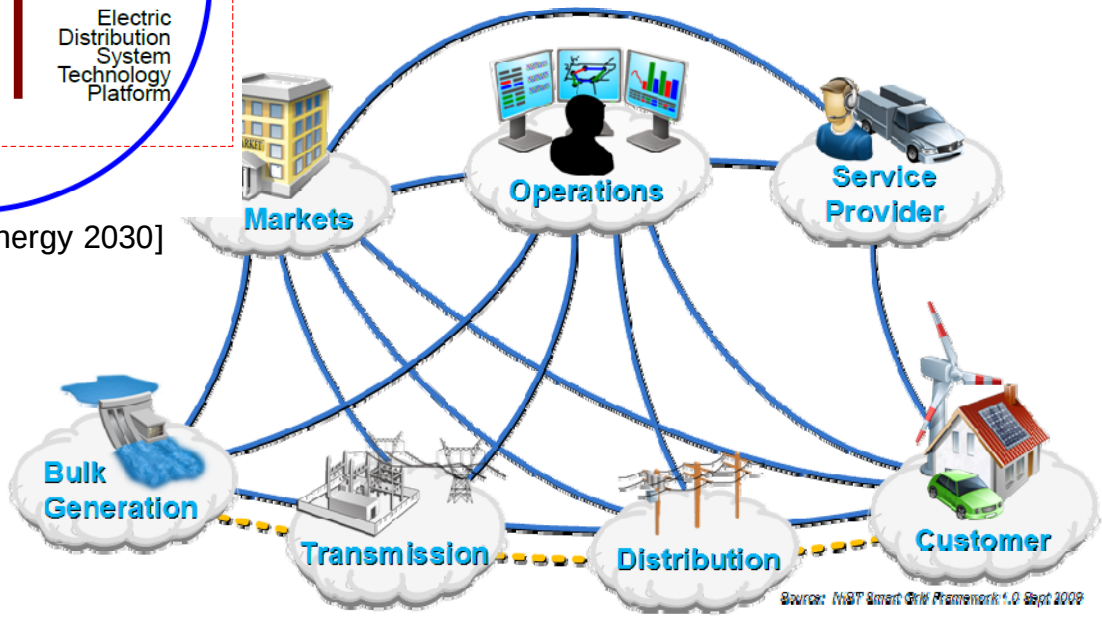


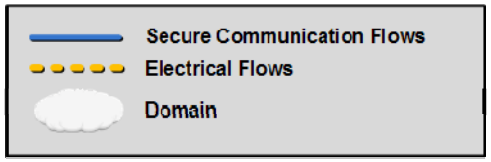
Courtesy Dr. Rockey Luo, Colorado State University

Energy System: Today vs. Tomorrow



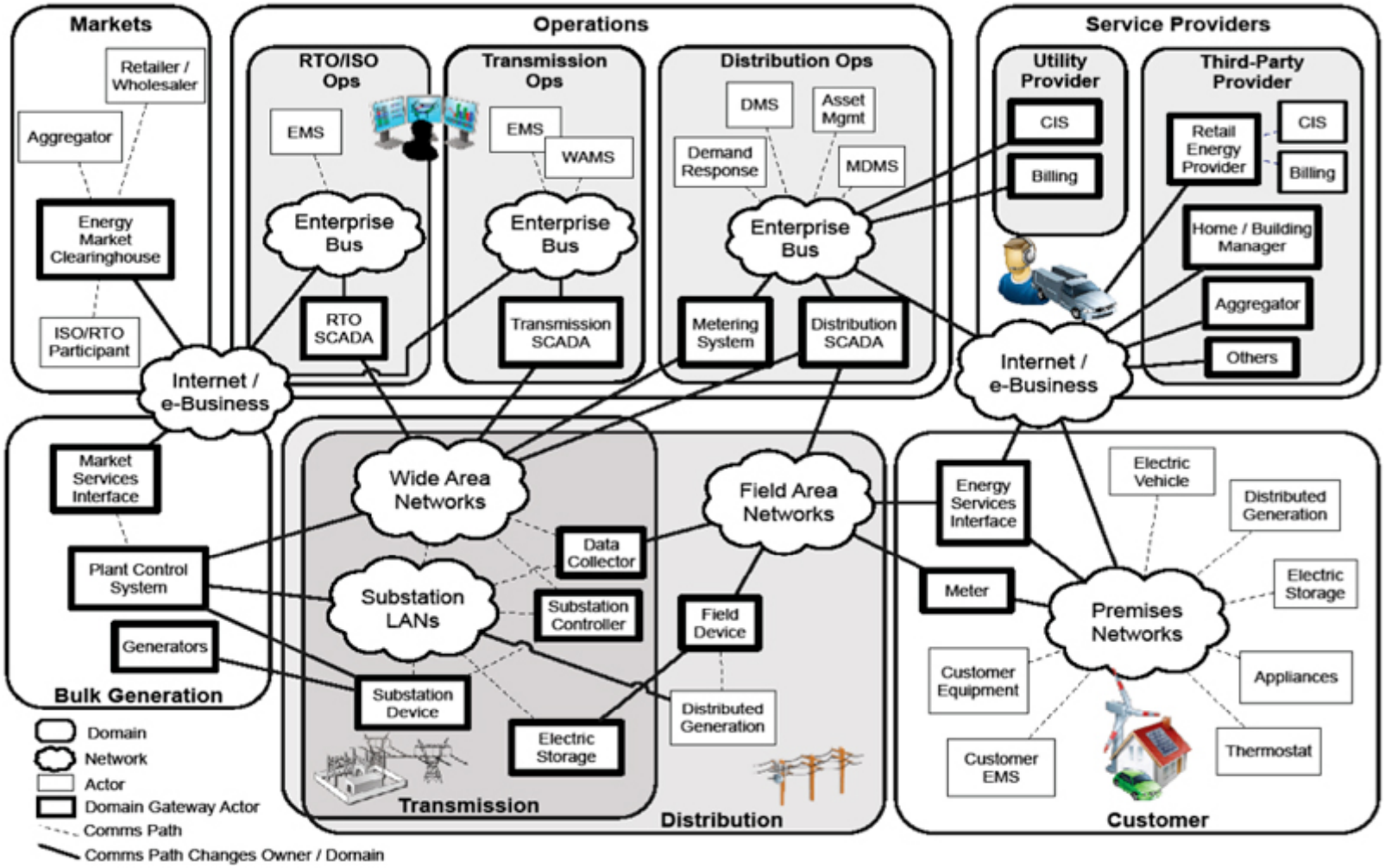
[Richard DeBlasio, Cherry Tom @ IEEE Energy 2030]





[Source: NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0, (NIST Special Publication 1108); 2010]

Signal Processing Communications Networking



[Source: NIST'2010]

Roadmap

- Mature communications & networking technology
- Communications & networking technology for today and tomorrow
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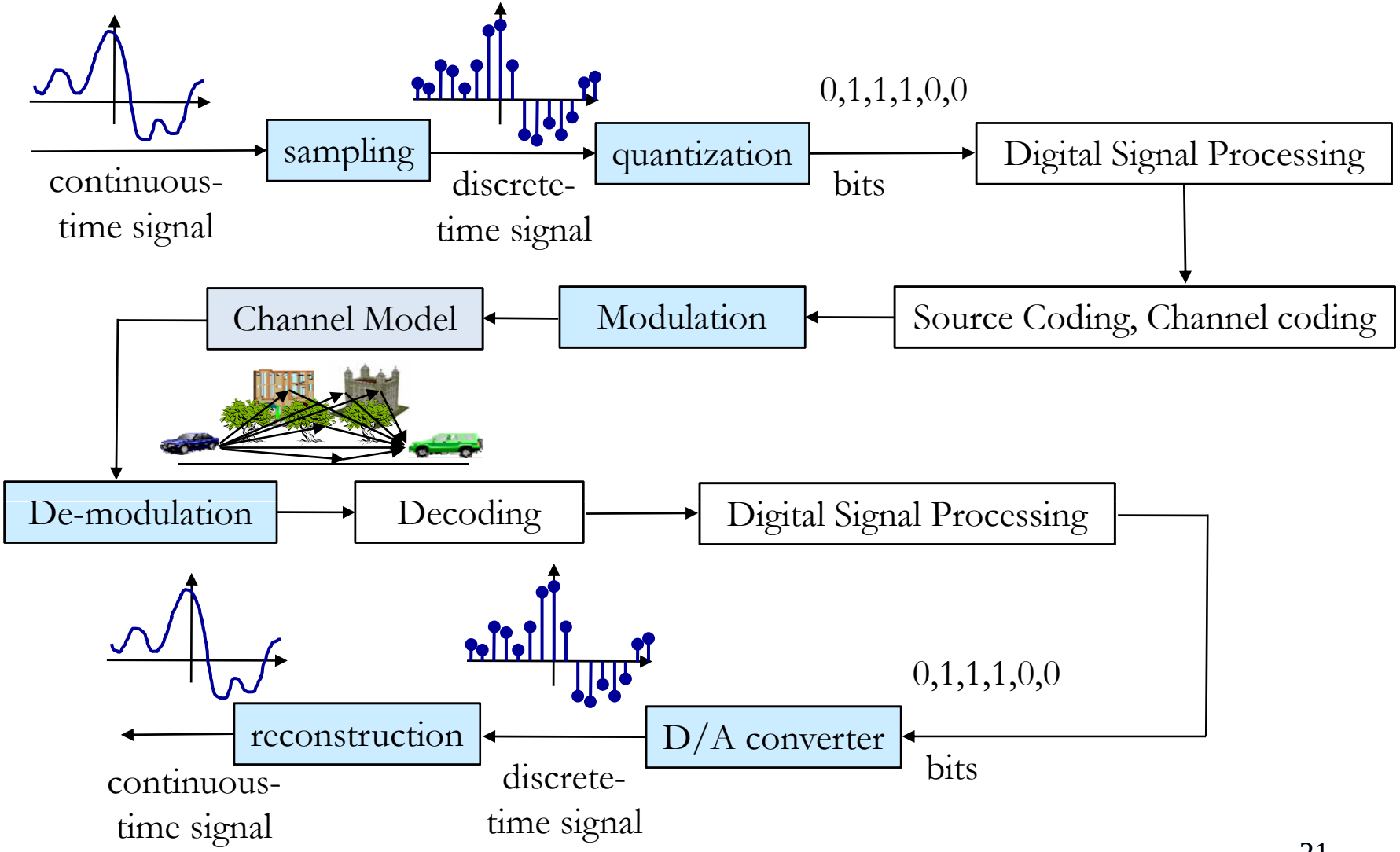
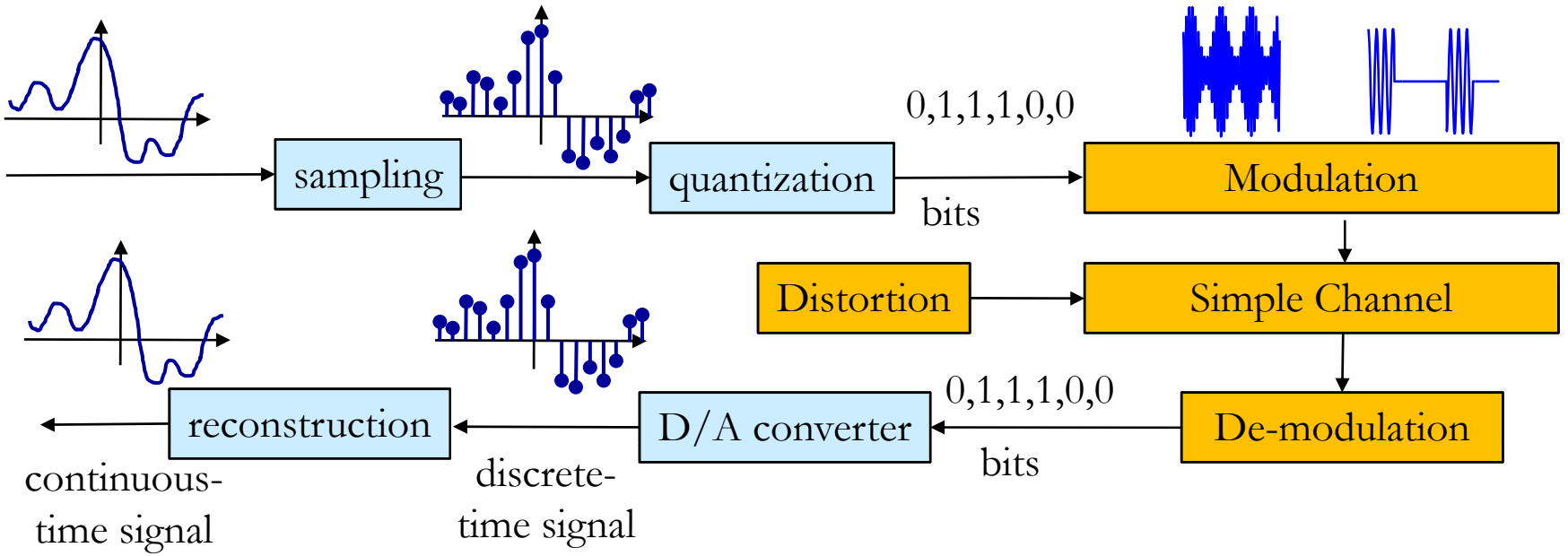
Design Challenges

- 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

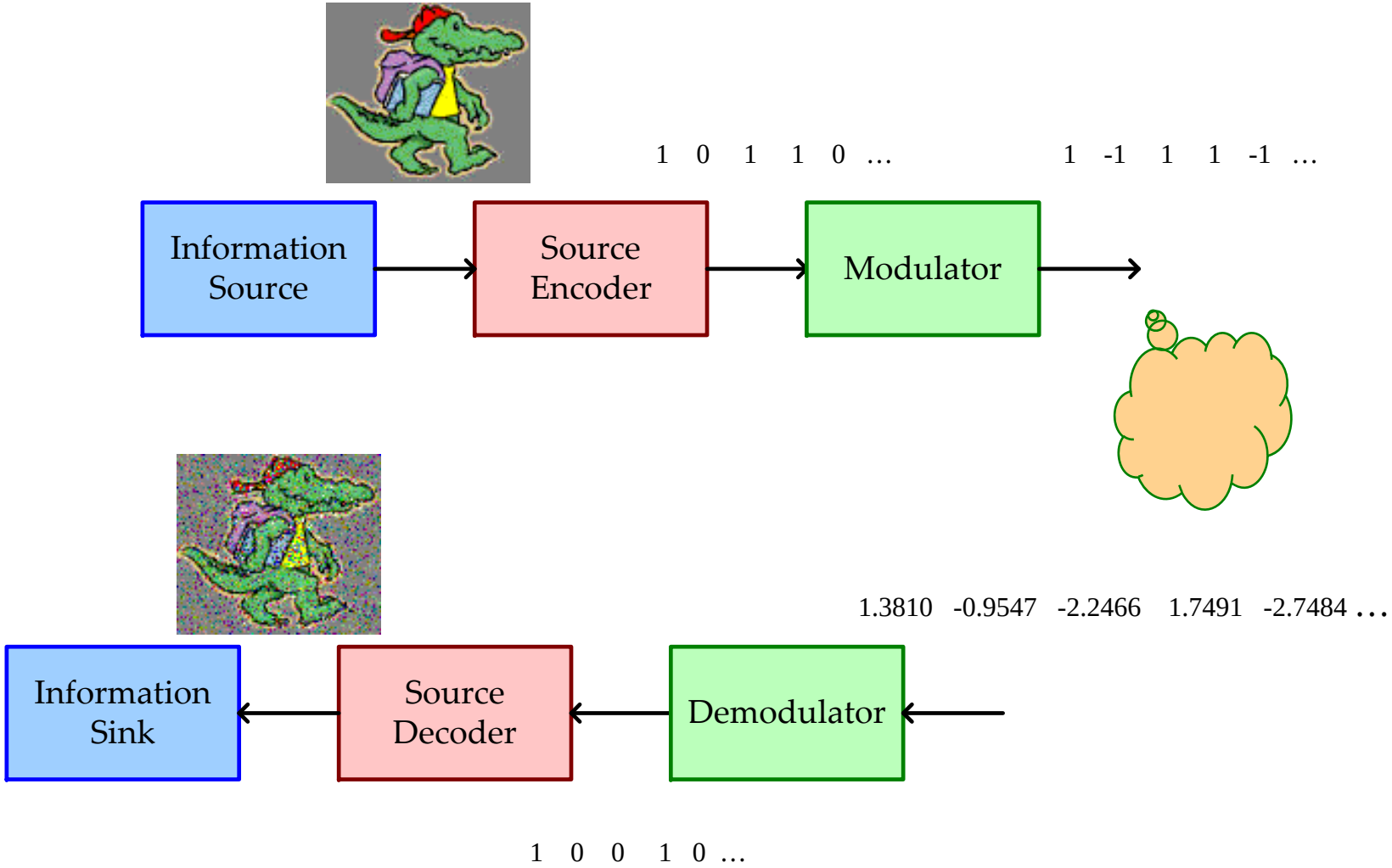


Simplified Communications System Diagram



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

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/