CS621: Mobile Computing

Nityananda Sarma
nitya@tezu.ernet.in

Topic 1

Introduction to Mobile Computing

What is Mobile Computing ?

According to a dictionary:

- Mobile:
  - Able to move freely
- Computing:
  - The activity of using a computer
- Wireless network:
  - Communications without a wire

What is Mobility?

- **Mobility: 2 types**
  - **User Mobility**:
    - Users can access the same network services at different places
    - User can be mobile, and the services will follow him/her
    - Examples: **Call forwarding and Computer Desktop supporting roaming (e.g., in Windows – enable Remote Desktop, use mstsc.exe)**
    - **User communicates Anytime, Anywhere with Anyone**
  - **Device Portability**:
    - Communication device can move and **mechanisms in the network** and **inside the device** must make sure that communication is still possible.
    - Example: **Cell phone system (1G, 2G, 3G, 4G, 5G ….)**
    - **Devices can be connected Anytime, Anywhere to the network**
  - In most of the cases, both user mobility and device portability are available.

Communication Devices

- **Fixed and Wired**
  - Examples: Typical desktop computers connected to the fixed network
- **Mobile and Wired**
  - Examples: carrying laptops from one place to another and connecting to the organizations network through different network access methods
- **Fixed and Wireless**
  - Examples: Installing Networks in historical buildings where installing wires is not allowed. Trade shows
- **Mobile and Wireless**
  - Examples: Users can roam between different wireless networks. Cellular networks (GSM, UMTS).
- The demand for seamless and ubiquitous connection has driven integration of wireless networks into existing fixed networks:
  - LANs: standardization of **IEEE 802.11**, Internet: **Mobile IP** extension of the internet protocol IP, wide area networks: e.g., internetworking of GSM and ISDN, VoIP over WLAN and POTS (plain old telephone service)

History of Wireless Communication

- Marconi invented the **wireless telegraph in 1897** (2 years after Prof. J. C. Bose) [in late 1800s and early 1900s]

[In 1895, J.C. Bose demonstrated the first wireless communication using millimeter radio waves (around 60 GHz)]

  - Communication by encoding alphanumeric characters in analog signal (**Morse Codes**: **dots** and **dashes**)
  - Sent telegraphic signals across the Atlantic Ocean

- **First-Generation Wireless Telephony (1920s - 1980s):**
  - 1920s, commercial radio broadcasting began (voice & music)
  - Radio technology continued to evolve over the decades, improving the quality and range of wireless voice communication

History Wireless Commn(cont'd...)

- **Second-Generation (2G) Mobile NWs (1990s - Early 2000s):**
  - Digital cellular technology to the masses
  - GSM was the most widely adopted 2G standard
  - offering **improved voice quality**, introducing **basic data services** like SMS
- **Third-Generation (3G) Mobile Networks (Early 2000s - Mid-2010s):**
  - 3G brought significant advancements, enabling mobile data services beyond SMS
  - offered **higher data speeds**
  - facilitated the widespread adoption of mobile internet, **multimedia messaging**, and **video calling**

History Wireless Commn(cont'd...)

- **Fourth-Generation (4G) Long Term Evolution (LTE) (Mid-2010s - Late 2010s):**
  - A major leap forward in wireless communications, providing even faster data speeds and enhanced network capacity
  - enabled seamless streaming of HD video, online gaming, and the proliferation of mobile applications and services
- **Fifth-Generation (5G) Networks (Early 2020s - Present and Beyond):**
  - current focus is on 5G networks which promises to revolutionize the way we connect and interact with the world
  - offers significantly **higher data speeds**, **ultra-low latency**, and **massive device connectivity**
  - opens the door to various applications, including AR, VR, IoT devices, smart cities, and autonomous vehicles

History Wireless Commn(cont'd...)

- **Beyond 5G and Future Networks:**
  - The evolution of wireless communications continues beyond 5G
  - Researchers and industry experts are already exploring potential technologies and concepts for future networks, such as 6G and beyond
  - These networks may further push the boundaries of wireless communications, unlocking even more advanced applications and services

History of wireless communications has been marked by - continuous innovation and advancements, leading to increasingly sophisticated and efficient Wireless Networks that have transformed the way we communicate and access information.

Broadband Wireless Technology

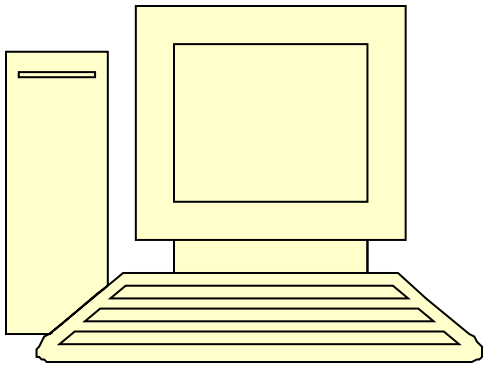
- Higher data rates (typically above 25Mbps in modern standards) obtainable with broadband wireless technology
  - Graphics, video, audio
- Examples: WiMAX (IEEE 802.16), Wi-Fi, 4G/5G Mobile Networks, Satellite Internet (e.g., Starlink by SpaceX)
- Shares same advantages of all wireless services: convenience and reduced cost
  - Service can be deployed faster than fixed service
  - No cost of cable plant
  - Service is mobile, deployed almost anywhere

Limitations and Difficulties of Wireless Technologies

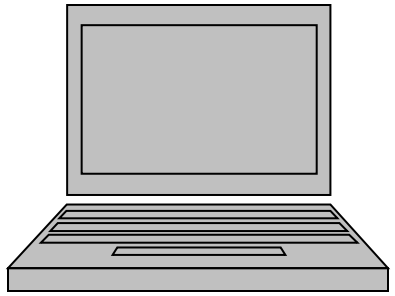
- It has advantages - Wireless is convenient and less expensive, but some limitations -
- Limitations and political and technical difficulties inhibit wireless technologies
- Lack of an industry-wide standard (for some services/applications)
- Device limitations
  - E.g., small LCD on a mobile telephone can only displaying a few lines of text
  - power
  - E.g., browsers of most mobile wireless devices use wireless markup language (WML) instead of HTML

Mobile Computing

Desktop



Laptop



Mobile Computing?

Computer Applications

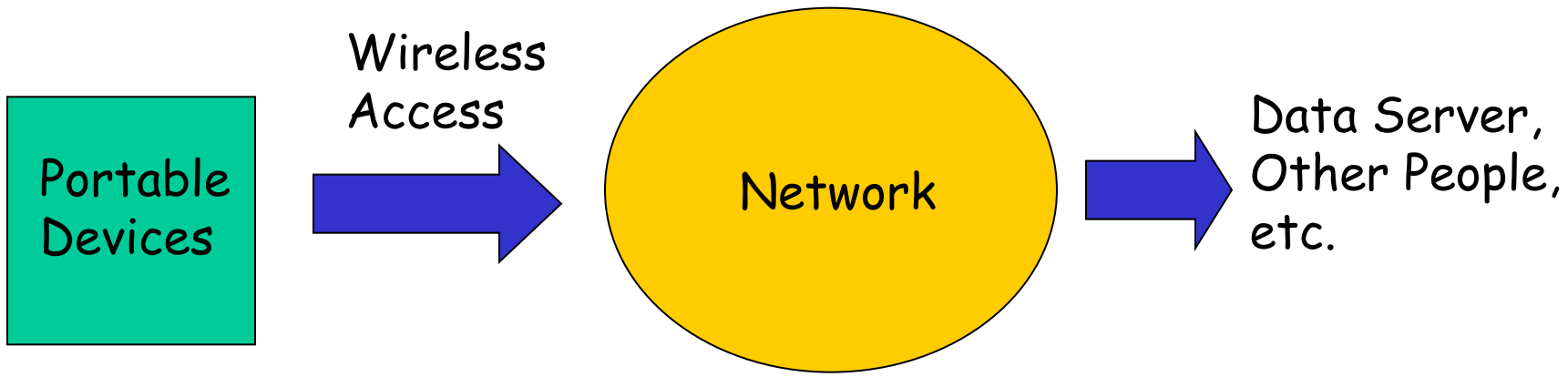
- Information Processing
  - word processing, spreadsheet, database, etc.
- Networking
  - email, web browsing, or accessing Internet based services etc.

Mobile Computing

- Able to communicate and access information

  anytime, and anywhere OR

  Computing that connects a mobile device to a network or another computing device, anytime, anywhere



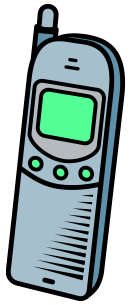
Mobile/Portable devices

Pager
- receive only
- tiny displays
- simple text messages

PDA
- simpler graphical displays
- character recognition
- simplified WWW

Laptop
- fully functional
- standard applications

Sensors, embedded controllers



Mobile phones
- voice, data
- simple graphical displays

Palmtop
- tiny keyboard
- simple versions of standard applications

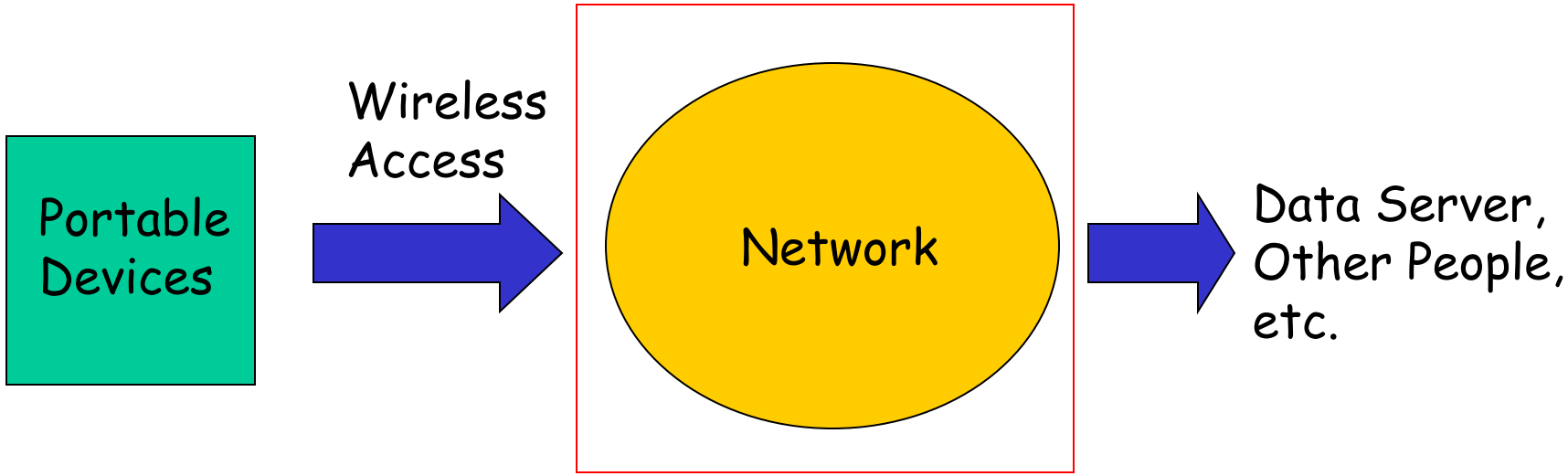
Effects of device portability

- Power consumption
  - limited computing power, low quality displays, small disks due to limited battery capacity
  - CPU: power consumption ~ $\mathbf{CV^2f}$
    - C: internal capacity, reduced by integration
    - V: supply voltage, can be reduced to a certain limit
    - f: clock frequency, can be reduced temporally
- Loss of data
  - higher probability, must be included in advance into the design (e.g., defects, theft)
- Limited user interfaces
  - compromise between size of fingers and portability
  - integration of character/voice recognition, abstract symbols
- Limited memory
  - limited value of mass memories with moving parts
  - flash-memory or ? as alternative

Wireless networks in comparison to fixed networks

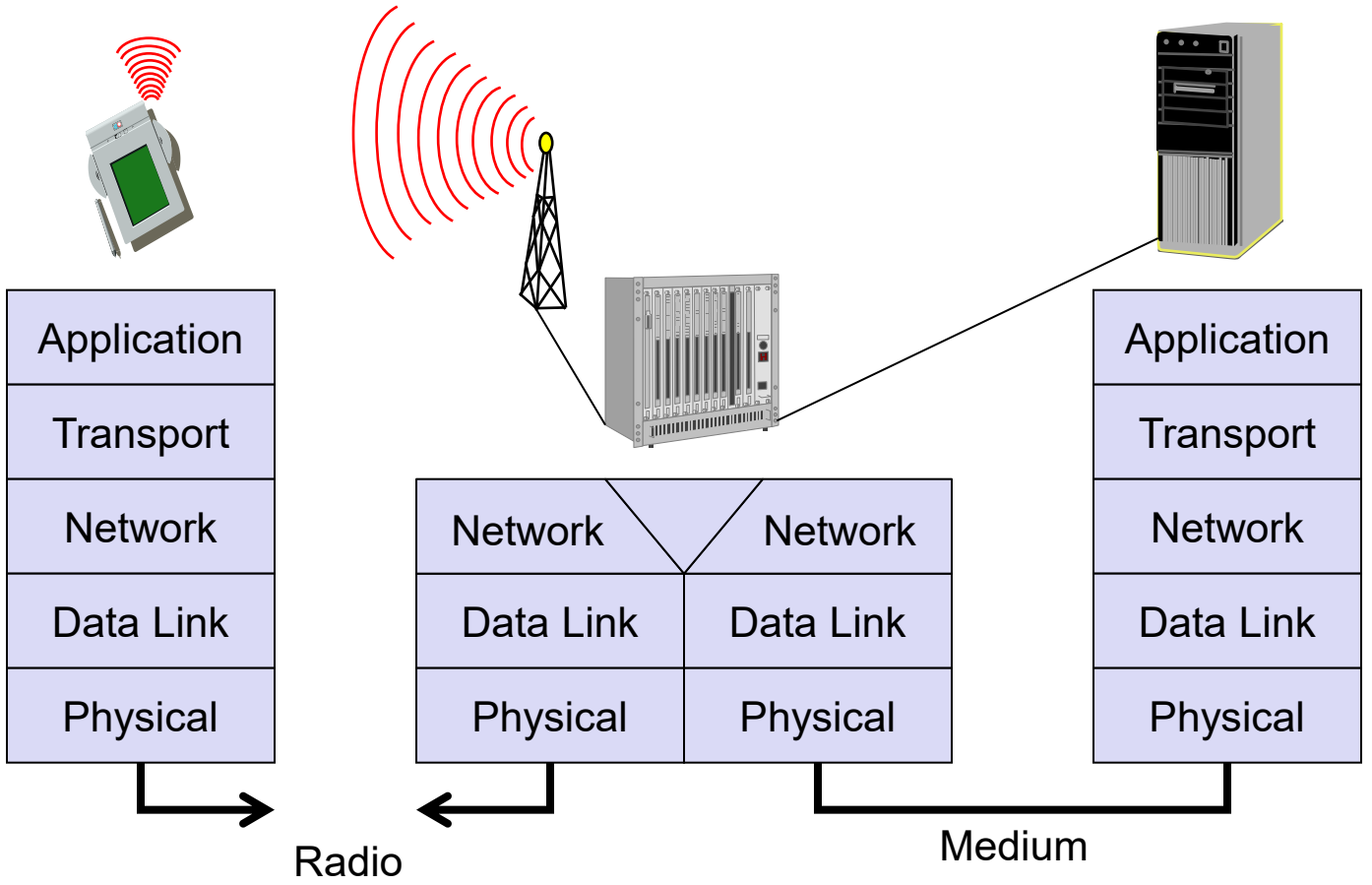
- **Higher loss-rates due to interference**
  - emissions of, e.g., engines, lightning
- **Restrictive regulations of frequencies**
  - frequencies have to be coordinated; useful frequencies are almost all occupied
- **Low transmission rates**
  - local some Mbit/s, regional currently, e.g., 9.6kbit/s with GSM, 384kbps with UMTS, 5-30Mbps with HSDPA, 100-200Mbps with LTE, 0.5-1Gbps with LTE-A, 1Gbps and higher with OFDM
- **Higher delays, higher jitter**
  - connection setup time with GSM in the second range, several hundred milliseconds for other wireless systems
- **Lower security, simpler active attacking**
  - radio interface accessible for everyone, base station can be simulated, thus attracting calls from mobile phones
- **Always shared medium**
  - secure access mechanisms important

Our Focus



- Mobile Cellular Systems
  - GSM, CDMA
- Wireless LAN
- Bluetooth

Layered Architecture



This course will focus on -

Mostly, anything above and including the data link layer.

Effect of Mobility on Protocol Stack

- **Application**
  - new applications and adaptations
- **Transport**
  - congestion and flow control
- **Network**
  - addressing and routing
- **Link**
  - media access and handoff
- **Physical**
  - transmission errors and interference

Why study this course?

- **Reason 1:**

  Mobile computing is popular?

  More and more people use cell phones, wireless technology is built into many cars, wireless data services are available in many regions, and WLAN are used in many places.

e.g. no of cell phone subscribers more than 7.0 billions (2015), i.e. 96% of world population. 1.282 billions (India), 93.15% of population (Jan, 2019) (Cuba, North Korea around 11-12%, 2015)

Why study this course?

- Reason 2:

  Mobile computing is interesting?

  Hope all of you find it interesting after studying this course.

  (Q: How to make it interesting?)

Why study this course?

- You have studied Computer Networks before. What makes wireless/mobile networks different?

- In principle, TCP/IP can work on top of any physical and data link layer.
  - Can we simply transport IP packets over a wireless channel?

Challenges in Mobile Computing

- **Three major challenges:**
  - Wireless Channel
  - Mobility
  - Device Limitation

Wireless Channel

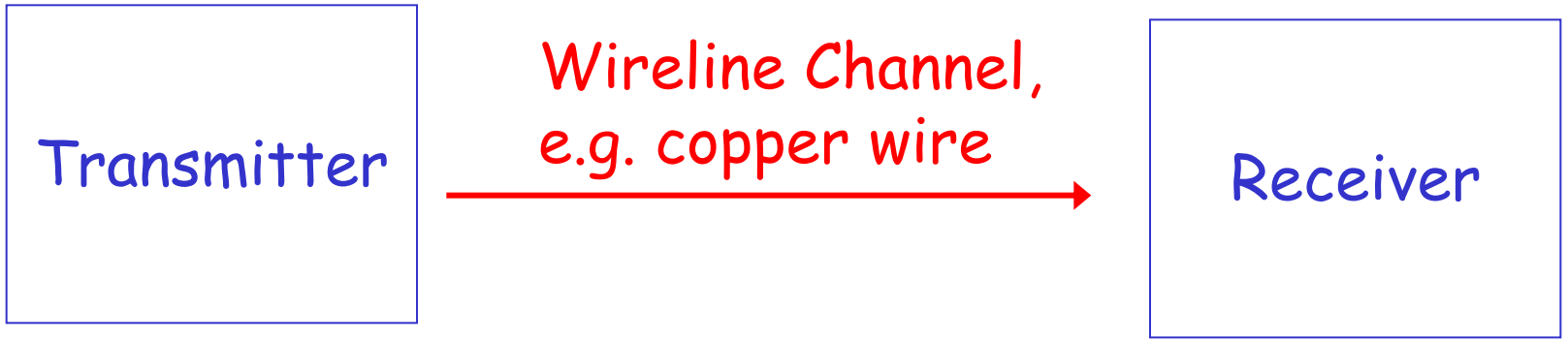
The 1st challenge

Communication Channel

The medium used to transmit the signal from the transmitter to the receiver

Wireline / Wireless channel

Wireline/Wired Channel



Too many noises? Shielded against electromagnetic noise

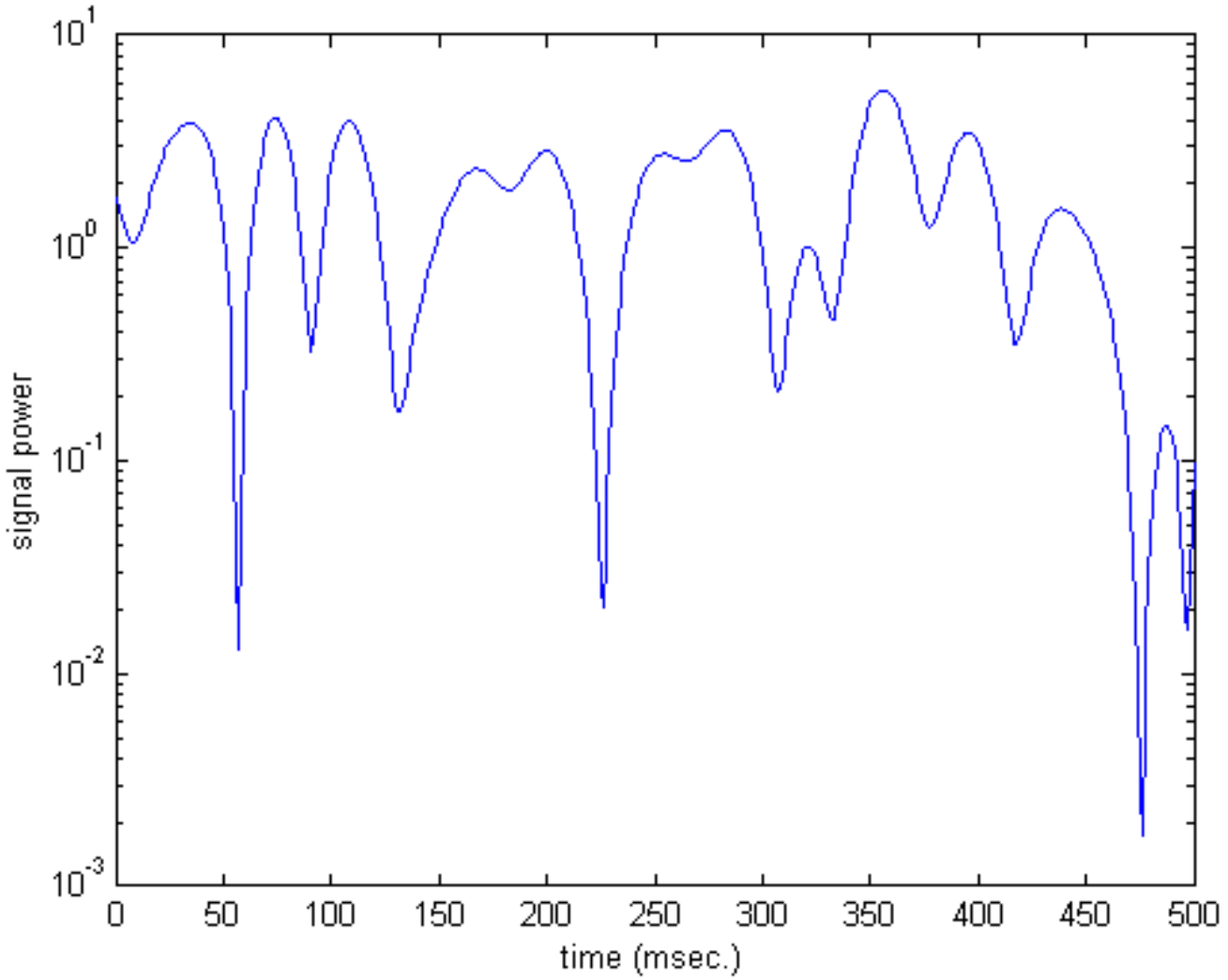
Large signal attenuation? Use repeaters

Data speed too low? Upgrade to coaxial cable

Data speed still too low? Upgrade to optical fiber

Fading Effect

- Typical Indoor Wireless Environment
  - Signal strength fluctuates significantly
- Wireless channel cannot be engineered.
  - You can only **improve** your **transmission** and **reception** techniques.



Bit Error Rate (BER)

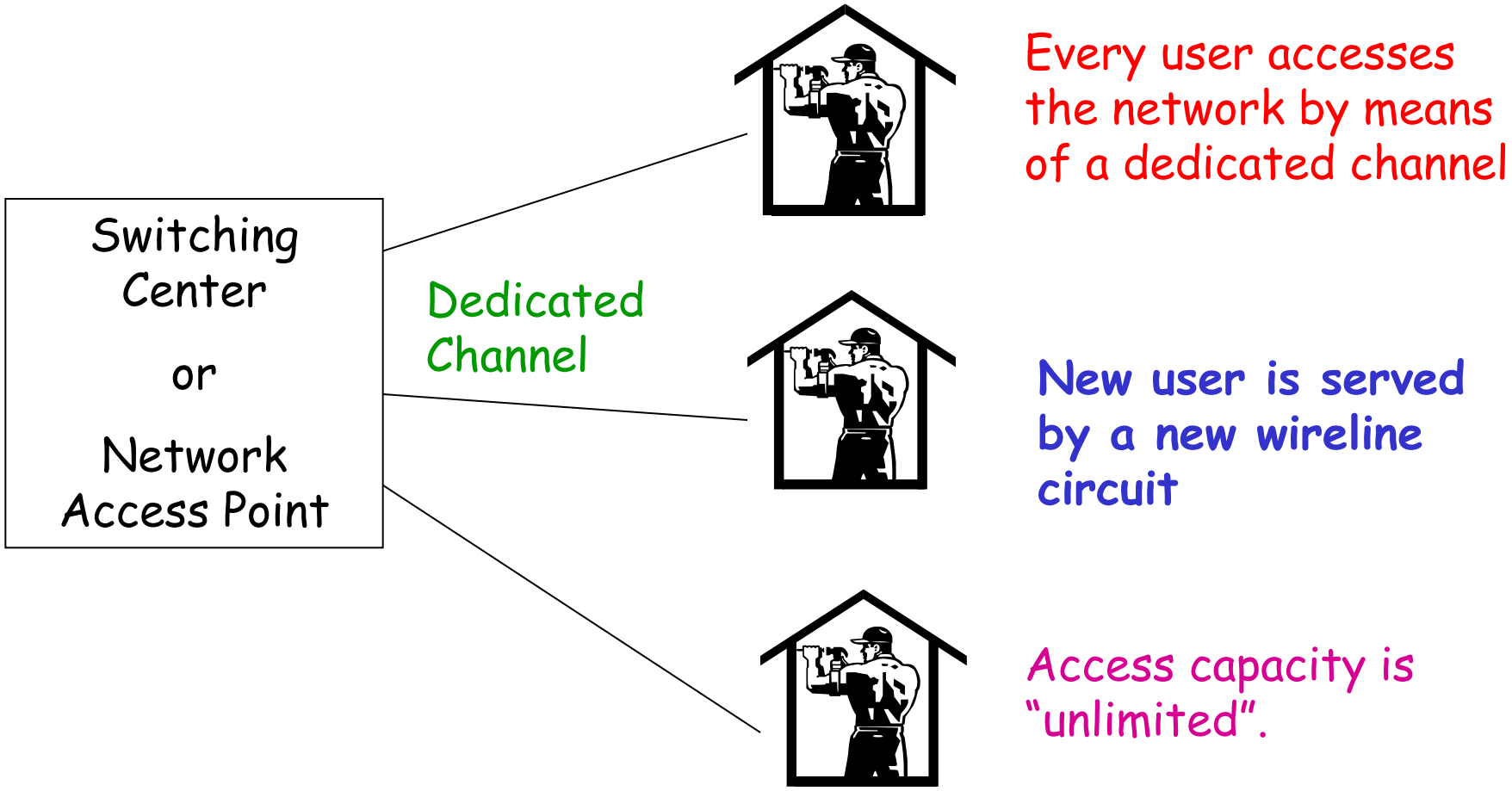
- Optical fiber: 10^{-11} or 10^{-12}

- Mobile/Wireless channel:
  - Good quality: 10^{-6}
  - **Actual condition**: 10^{-3} or worse

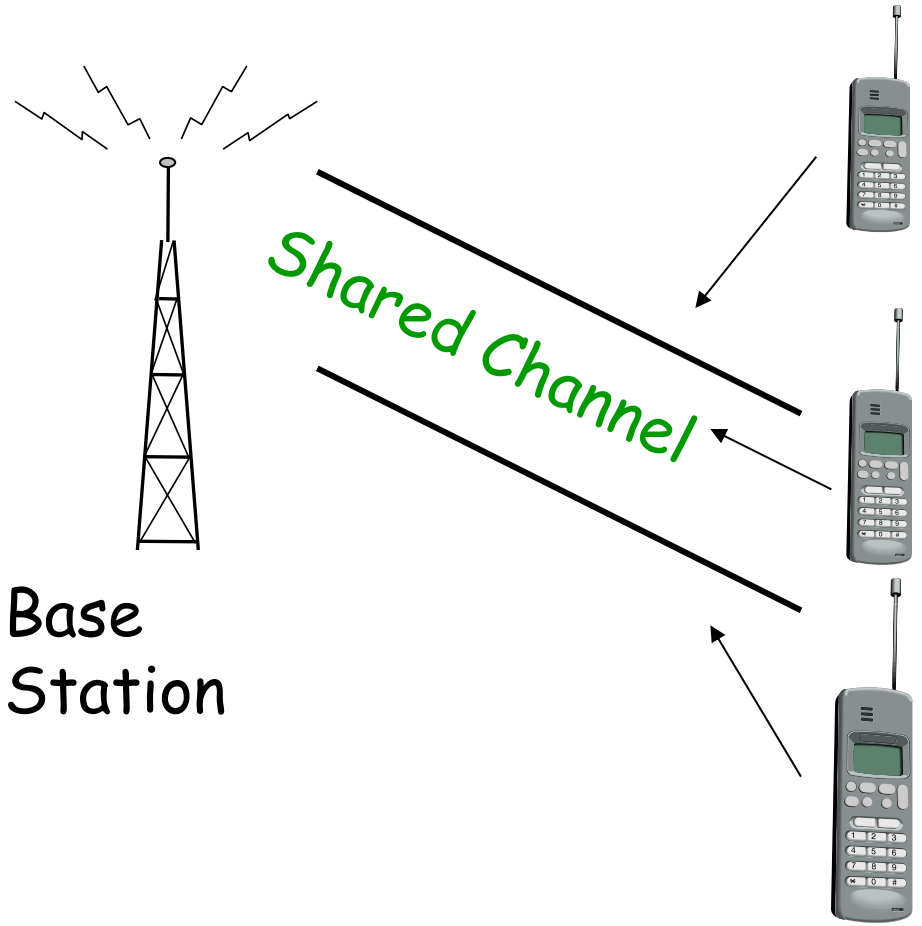
Implication

- For **wireline systems**, it is assumed that the channel is **error free**
- Many **Internet protocols** are designed with this assumption
- These protocols do not work well in a wireless environment
  - e.g. TCP (*why? Packet loss is assumed to be only due to congestion not due to error in channel*)

What if more than 1 transmitter?



How about wireless networks?



Wireless users access the network by means of a shared channel

Access capacity is inherently limited with increase in no. of users.

Implication

- For wireline/wired systems, we can simply install new cables to increase capacity.

- For wireless systems, the channel can only be shared by the users.
  - **Capacity does not increase**

Interference

- **Multiuser Interference**
  - Radio signals of different users interfere with each other
- **Self-Interference**
  - Multipath propagation effect (or environment)
  - Phase-shifted images of the signal at the receiver interact/superimpose and may cancel the entire signal, (i.e. destructive interference).

Interference Management

- How to manage multiuser interference?
  - i.e. how to share the channel?
  - Multiple Access Problem
    - FDMA, TDMA, CDMA, etc.
  - Media Access Control (Random Access schemes)
    - Aloha, CSMA, CSMA/CA etc.
- How to manage self-interference?
  - Physical layer issue
    - Equalization, coding, diversity, etc.

  (This issue will NOT be considered here)

Mobility

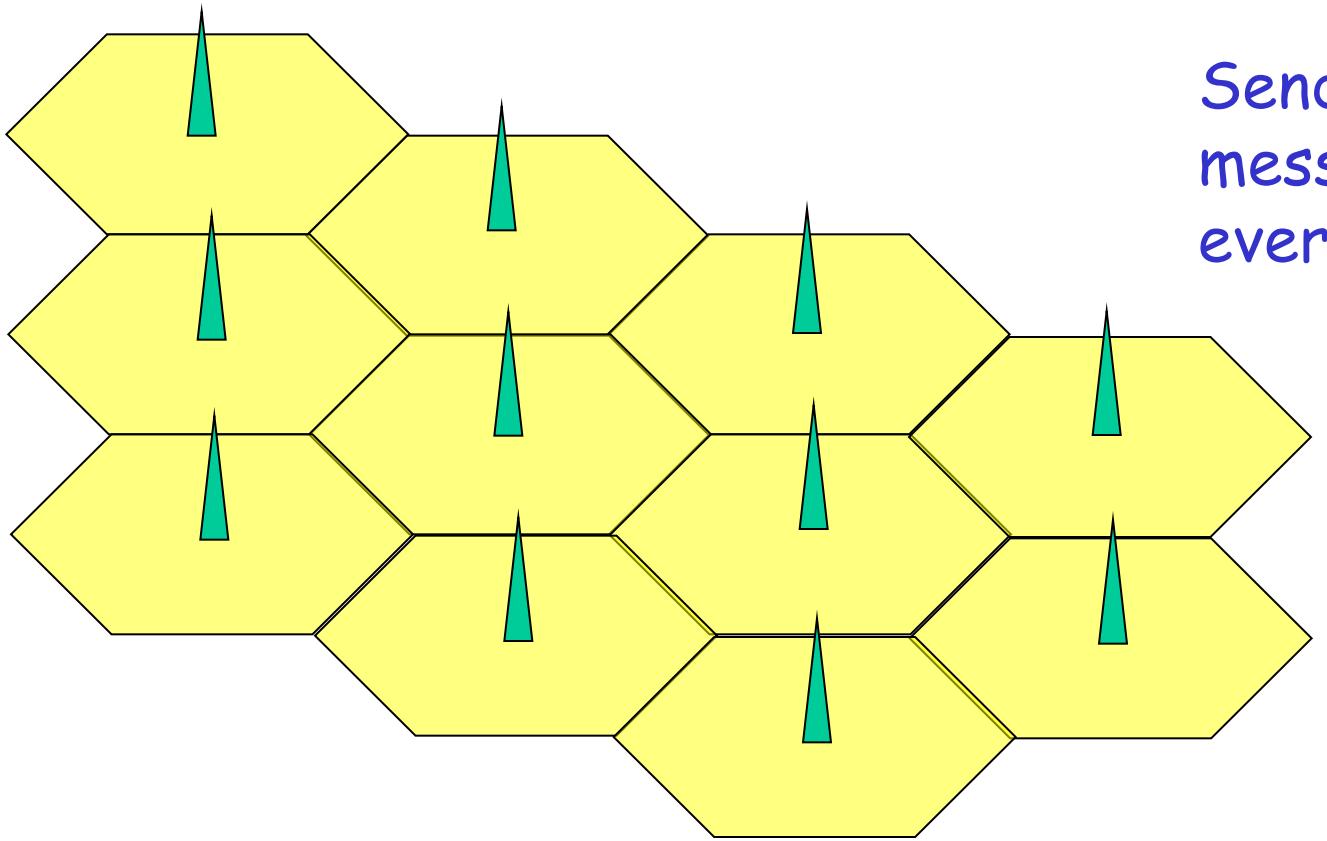
The 2nd challenge

User Mobility

- Location Management Problem
  - How does the network know where the intended recipient of a message/voice call (i.e. the receiver) is currently located?
  - E.g., consider the case of a cell phone user changing its Base Stations, or changing WiFi Access Points etc.

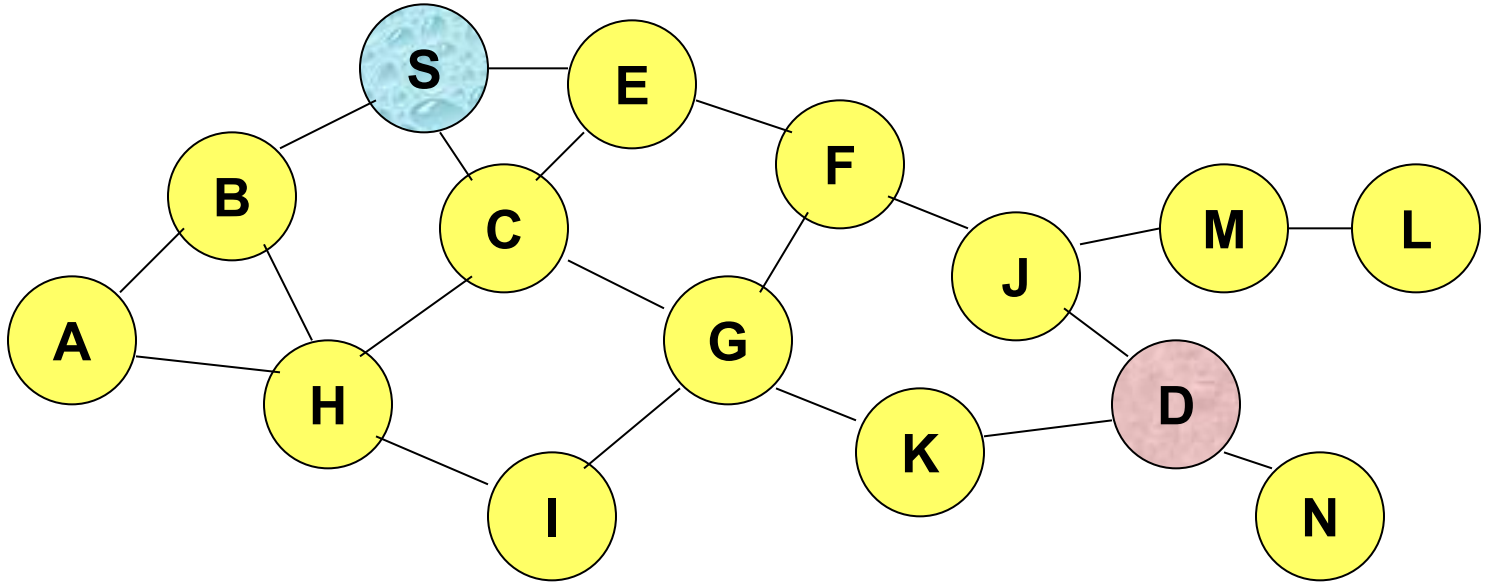
Cellular Network Scenario

Where is 9435055555?



Send broadcast messages from every base station?

Ad Hoc Network Scenario



How to find a **suitable** path from source S to destination D?
(here links are virtual link, representing wireless communication)

Device Limitation

The 3rd challenge

Device Limitation

- Mobile/Portable devices are Resource Poor
  - Limited Memory
  - Limited Computational Power
  - Small display
  - Limited battery life (runs only on battery power)

Applications of Mobile Computing

- **Vehicles**
  - transmission of news, road condition etc
  - ad-hoc network with near vehicles to prevent accidents
- **Emergencies**
  - early transmission of patient data to the hospital
  - ad-hoc network in case of earthquakes, cyclones
  - military ...
- **Traveling salesmen**
  - direct access to central customer files
  - consistent databases for all agents
  - mobile office

Applications of Mobile Computing

- **Web access**
  - outdoor Internet access
  - intelligent travel guide with up-to-date location dependent information
- **Location aware services**
  - find services in the local environment, e.g. printer
- **Information services**
  - push: e.g., stock quotes, Flood warning, News feeds etc.
  - pull: e.g., nearest cash ATM, Bus stop, Railway station, theater
- **Disconnected operations**
  - mobile agents, e.g., shopping
- **Entertainment**
  - ad-hoc networks for **multiuser games, mobile TV etc.**

End of Introduction

Wireless/Mobile Networks

- Need: Access computing and communication services, on the move

- **Infrastructure-based Networks**
  - traditional cellular systems (base station infrastructure)
  - Wireless LANs
  - Infrared (IrDA) or radio links (Wavelan)
  - very flexible within the reception area; ad-hoc networks possible
  - low bandwidth compared to wired networks (1-10 Mbit/s)

Wireless Networks

- **Ad hoc Networks**
  - useful when infrastructure not available, impractical, or expensive
  - military applications, rescue, home networking
  - Examples – Bluetooth, WLAN (adhoc mode) etc.

Limitations of Mobile Environments

- Limitations of the Wireless Network
  - heterogeneity of fragmented networks
  - frequent disconnections
  - limited communication bandwidth

- Limitations Imposed by Mobility
  - lack of mobility awareness by system/applications
  - route breakages

Limitations of Mobile Environments

- Limitations of the Mobile Computer
  - short battery lifetime
  - limited capacities

Application Adaptations for Mobility

- System-transparent, application-transparent
  - the conventional, "*unaware*" client/server model
- System-aware, application-transparent
  - the client/proxy/server model
  - the disconnected operation model
- System-transparent, application-aware
  - dynamic client/server model
  - data broadcasting/caching
- System-aware, application-aware
  - the mobile agent model

World Wide Web and Mobility

- HTTP/ HTML have not been designed for mobile applications/devices
- HTTP Characteristics
  - stateless, connection oriented overheads
  - big protocol headers, uncompressed content transfer
- HTML Characteristics
  - designed for computers with “high” performance, color high-resolution display, mouse, hard disk
  - typically, web pages optimized for design, not for communication; ignore end-system characteristics
- Adaptations for Mobile WWW
  - Enhanced browsers and/or servers
  - Client proxy: pre-fetching, caching, off-line use
  - Network proxy: adaptive content transformation for connections
  - Client and network proxy
  - New protocols/languages: WAP/WML