Unit - I

INTRODUCTION

Mobile Computing – Mobile Computing Vs wireless Networking – Mobile Computing Applications – Characteristics of Mobile computing – Structure of Mobile Computing Application. MAC Protocols – Wireless MAC Issues – Fixed Assignment Schemes – Random Assignment Schemes – Reservation Based Schemes.

Basic Concepts

- Mobile Handsets, Wireless Communications, and server applications
- Cell Phone System
- Types of Telecommunication Networks
- Computer Networks
  - Controller Area Networks (CANs)
    - Network is used to connect the different components of an embedded controller. Eg, Automobiles industry
  - LANs - private owned, building or campus operate at 1 Gbps
  - Internetworks – several LANs connected
- LAN Architecture – topologies (ring, mesh..)

Basic Concepts

- Components of a wireless communication system
  - Transmitter, receiver, filter, antenna, amplifier, mixers
- Wireless Networking Standards (Table1.1)
  - ITU, IEEE and ISO
  - IEEE 802.11 standards (a,bc,d,e,f…u)
- WLAN Architecture
  - Components (Access point, bridge, and LAN card)
  - Applications
    - Campus WLANs
    - Streamlining inventory management
    - Providing LAN
    - WLAN connectivity to geographically dispersed computers
  - Advantages of wireless LAN over wired LAN
    - Mobility
    - Simplicity and speedy deployment

Wireless Networking Standards

TABLE 1.1 Wireless Networking Standards

Standard	*Data rate*	*Information*
IEEE 802.11	Up to 2 Mbps in the 2.4 GHz band	This specification has been extended into 802.11b.
IEEE 802.11a (Wi-Fi)	Up to 54 Mbps in the 5 GHz band	Products that adhere to this standard are considered "Wi-Fi Certified." Eight available channels. Less potential for RF interference than 802.11b and 802.11g. Better than 802.11b at supporting multimedia voice, video and large-image applications in densely populated user environments. Relatively shorter range than 802.11b. Not interoperable with 802.11b.
IEEE 802.11b (Wi-Fi)	Up to 11 Mbps in the 2.4 GHz band	Products that adhere to this standard are considered "Wi-Fi Certified." Not interoperable with 802.11a. Requires fewer access points than 802.11a for coverage of large areas. Offers high-speed access to data at up to 300 feet from base station. 14 channels available in the 2.4 GHz band (only 11 of which can be used in the U.S. due to FCC regulations) with only three non-overlapping channels.
IEEE 802.11g (Wi-Fi)	Up to 54 Mbps in the 2.4 GHz band	Products that adhere to this standard are considered "Wi-Fi Certified." May replace 802.11b. Improved security enhancements over 802.11. Compatible with 802.11b. 14 channels available in the 2.4 GHz band (only 11 of which can be used in the U.S. due to FCC regulations) with only three non-overlapping channels.
IEEE 802.16 (WiMAX)	Specifies WiMAX in the 10 to 66 GHz range	Commonly referred to as WiMAX or less commonly as WirelessMAN or the Air Interface Standard, IEEE 802.16 is a specification for fixed broadband wireless metropolitan access networks (MANs)
IEEE 802.16a (WiMAX)	Added support for the 2 to 11 GHz range.	Commonly referred to as WiMAX or less commonly as WirelessMAN or the Air Interface Standard, IEEE 802.16 is a specification for fixed broadband wireless metropolitan access networks (MANs)
HiperLAN/1 (Europe)	Up to 20 Mbps in the 5 GHz band	Only in Europe. HiperLAN is totally ad-hoc, requiring no configuration and no central controller. Does not provide real isochronous services. Relatively expensive to operate and maintain. No guarantee of bandwidth.
HiperLAN/2 (Europe)	Up to 54 Mbps in the 5 GHz band	Only in Europe. Designed to carry ATM cells, IP packets, Firewire packets (IEEE 1394) and digital voice (from cellular phones). Better quality of service than HiperLAN/1 and guarantees bandwidth.
Open Air	Pre-802.11 protocol, using frequency hopping and 0.8 and 1.6 Mbps bit rate	OpenAir is the proprietary protocol from Proxim. All OpenAir products are based on Proxim's module.

What Is Mobile Computing?

- What is computing?

Operation of computers (oxfords advance learner's dictionary)

- What is the mobile?

That someone /something can move or be moved easily and quickly from place to place

- What is mobile computing?

Users with portable computers still have network connections while they move

- **A simple definition could be:**
  Mobile Computing is using a computer (of one kind or another) while on the move
- **Another definition could be:**
  Mobile Computing is when a (work) process is moved from a normal fixed position to a more dynamic position.
- **A third definition could be:**
  Mobile Computing is when a work process is carried out somewhere where it was not previously possible.

Comparison to Wired Net.

- **Wired Networks**
- high bandwidth
- low bandwidth variability
- can listen on wire
- high power machines
- high resource machines
- need physical access(security)
- low delay
- connected operation

- **Mobile Networks**
- low bandwidth
- high bandwidth variability
- hidden terminal problem
- low power machines
- low resource machines
- need proximity
- higher delay
- disconnected operation

Why Go Mobile?

- Enable anywhere/anytime connectivity
- Bring computer communications to areas without pre-existing infrastructure
- Enable mobility
- Enable new applications
- An exciting new research area

Mobile Computing
Vs
Wireless Networking

Evolution of Wireless LAN

- In late 1980s, vendors started offering wireless products, which were to substitute the traditional wired LAN (Local Area Network) products.
- The idea was to use a wireless local area network to avoid the cost of installing LAN cabling and ease the task of relocation or otherwise modifying the network's structure.

Evolution of Wireless LAN

- The question of interoperability between different wireless LAN products became critical.
- IEEE standard committee took the responsibility to form the standard for WLAN.
- As a result IEEE 802.11 series of standards emerged.

Evolution of Wireless LAN

- WLAN uses the unlicensed Industrial, Scientific, and Medical (ISM) band that different products can use as long as they comply with certain regulatory rules
- WLAN is also known as Wireless Fidelity or WiFi in short
- There are many products which use these unlicensed bands along with WLAN.

Evolution of Wireless LAN

- Examples could be cordless telephone, microwave oven etc.
- There are 3 bands within the ISM bands.
  - These are 900-MHz ISM band, which ranges from 902 to 928 MHz;
  - 2.4-GHz ISM band, which ranges from 2.4 to 2.4853 GHz; and
  - the 5.4 GHz band, which range from 5.275 to 5.85 GHz.
- WLAN uses 2.4 GHz and 5.4 GHz bands.
- WLAN works both in ***infrastructure mode and ad hoc mode***

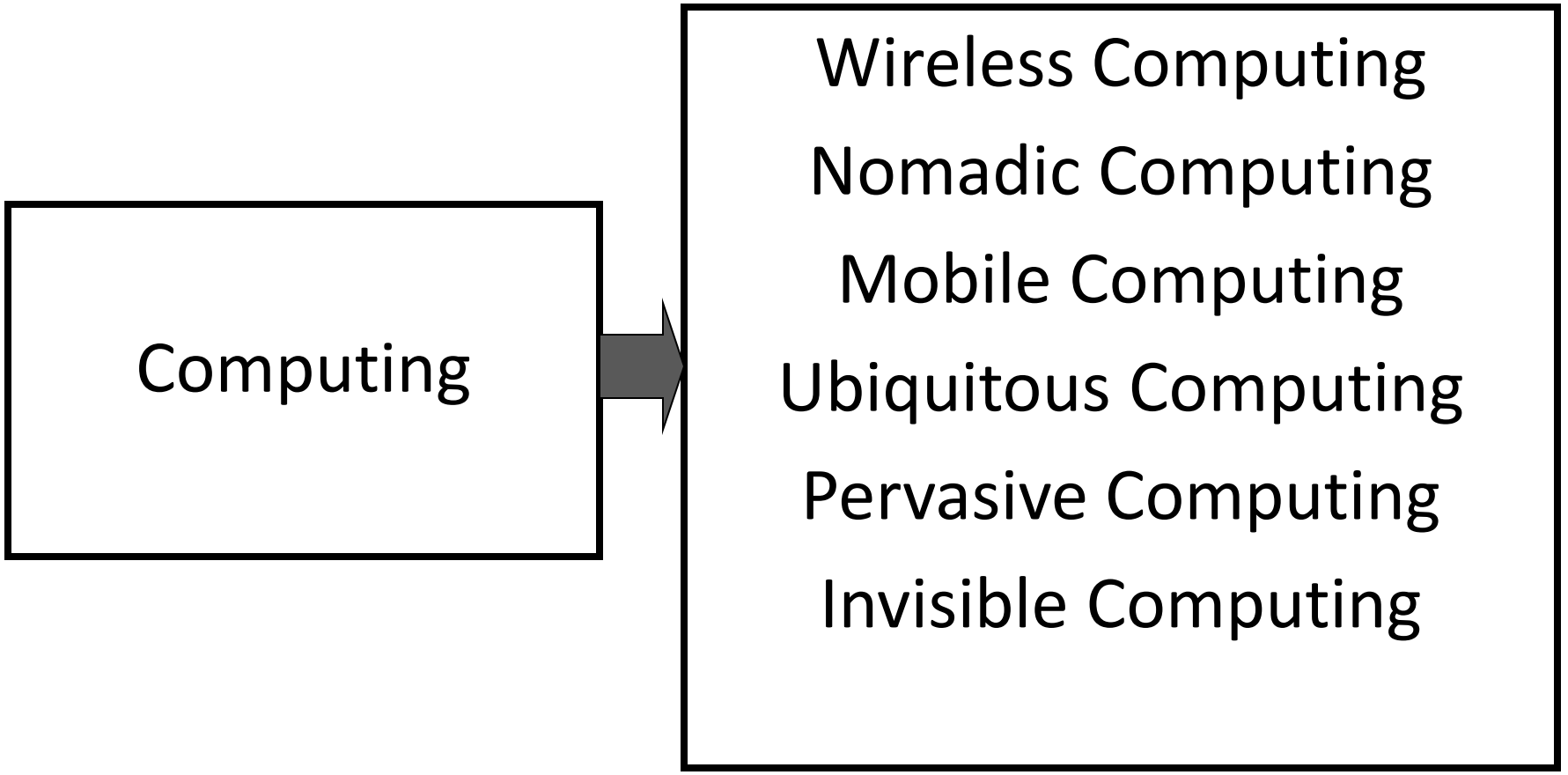
Evolution of Wireless PAN

- Techniques for WPANs are infrared and radio waves.
- Most of the Laptop computers support communication through infrared, for which standards have been formulated by IrDA (Infrared Data Association-www.irda.org).
- Through WPAN, a PC can communicate with another IrDA device like another PC or a Personal Digital Assistant (PDA) or a Cellular phone.

Evolution of Wireless PAN Cont.

- The other best known PAN technology standard is Bluetooth.
- Bluetooth uses radio instead of infrared.
- It offers a peak over the air speed of about 1 Mbps over a short range of about 10 meters.
- The advantage of radio wave is that unlike infrared it does not need a line of sight.
- WPAN works in **ad hoc mode** only

New Forms of Computing



MOBILE COMPUTING

- Mobile computing can be defined as a computing environment over physical mobility.
- The user of a mobile computing environment will be able to access data, information or other logical objects from any device in any network while on the move.

MOBILE COMPUTING Cont.

- Mobile computing system allows a user to perform a task from anywhere using a computing device in the public (the Web), corporate (business information) and personal information spaces (medical record, address book).

MOBILE COMPUTING Cont.

- Mobile computing is used in different contexts with different names. The most common names are:
  - **Mobile Computing:**
    - The computing environment is mobile and moves along with the user.
    - This is similar to the telephone number of a GSM (Global System for Mobile communication) phone, which moves with the phone.
    - The offline (local) and real-time (remote) computing environment will move with the user.
    - In real-time mode user will be able to use all his remote data and services online.

MOBILE COMPUTING Cont.

- **Anywhere, Anytime Information:** This is the generic definition of ubiquity, where the information is available anywhere, all the time.
- **Virtual Home Environment:** (VHE) is defined as an environment in a foreign network such that the mobile users can experience the same computing experience as they have in their home or corporate computing environment.
  - For example, one would like to put ones room heater on when one is about 15 minutes away from home.

MOBILE COMPUTING Cont.

- **Nomadic Computing:** The computing environment is nomadic and moves along with the mobile user.
  - This is true for both local and remote services.
- **Pervasive Computing:** A computing environment, which is pervasive in nature and can be made available in any environment.
- **Ubiquitous Computing:** A disappearing (nobody will notice its presence) everyplace computing environment. User will be able to use both local and remote services.

MOBILE COMPUTING Cont.

- **Global Service Portability:** Making a service portable and available in every environment. Any service of any environment will be available globally.
- **Wearable Computers:** Wearable computers are those computers that may be adorned by humans like a hat, shoe or clothes (these are wearable accessories).

Mobile Computing Functions

- We can define a computing environment as mobile if it supports one or more of the following characteristics:
- **User Mobility:**
  - User should be able to move from one physical location to another location and use the same service.
  - The service could be in the home network or a remote network.
  - Example could be a user moves from London to New York and uses Internet to access the corporate application the same way the user uses in the home office.

Mobile Computing Functions Cont.

- **Network Mobility:**
  - User should be able to move from one network to another network and use the same service.
  - Example could be a user moves from Hong Kong to New Delhi and uses the same GSM phone to access the corporate application through WAP (Wireless Application Protocol). In home network he uses this service over **GPRS** (General Packet Radio Service) whereas in Delhi he accesses it over the GSM network.

Mobile Computing Functions Cont.

- **Bearer Mobility:**
  - User should be able to move from one bearer to another and use the same service.
  - Example could be a user was using a service through WAP bearer in his home network in Bangalore. He moves to Coimbatore, where WAP is not supported, he switch over to voice or SMS(Short Message Service) bearer to access the same application.

Mobile Computing Functions Cont.

- **Device Mobility:**
  - User should be able to move from one device to another and use the same service.
  - Example could be sales representatives using their desktop computer in home office. During the day while they are on the street they would like to use their Palmtop to access the application.

Mobile Computing Functions Cont.

- **Session Mobility:**
  - A user session should be able to move from one user-agent environment to another.
  - Example could be a user was using his service through a CDMA (Code Division Multiple Access) IX network. The user entered into the basement to park the car and got disconnected from his CDMA network. User goes to home office and starts using the desktop. The unfinished session in the CDMA device moves from the mobile device to the desktop computer.

Mobile Computing Functions Cont.

- **Service Mobility:**
  - User should be able to move from one service to another.
  - Example could be a user is writing a mail. To complete the mail user needs to refer to some other information. In a desktop PC, user simply opens another service (browser) and moves between them using the task bar. User should be able to switch amongst services in small footprint wireless devices like in the desktop.

Mobile Computing Functions Cont.

- **Host Mobility:**
  - The user device can be either a client or server.
  - When it is a server or host, some of the complexities change.
  - In case of host mobility the mobility of **IP** needs to be taken care of.

Types of Wireless Devices

- Laptops
- Palmtops
- PDAs
- Cell phones
- Pagers
- Sensors

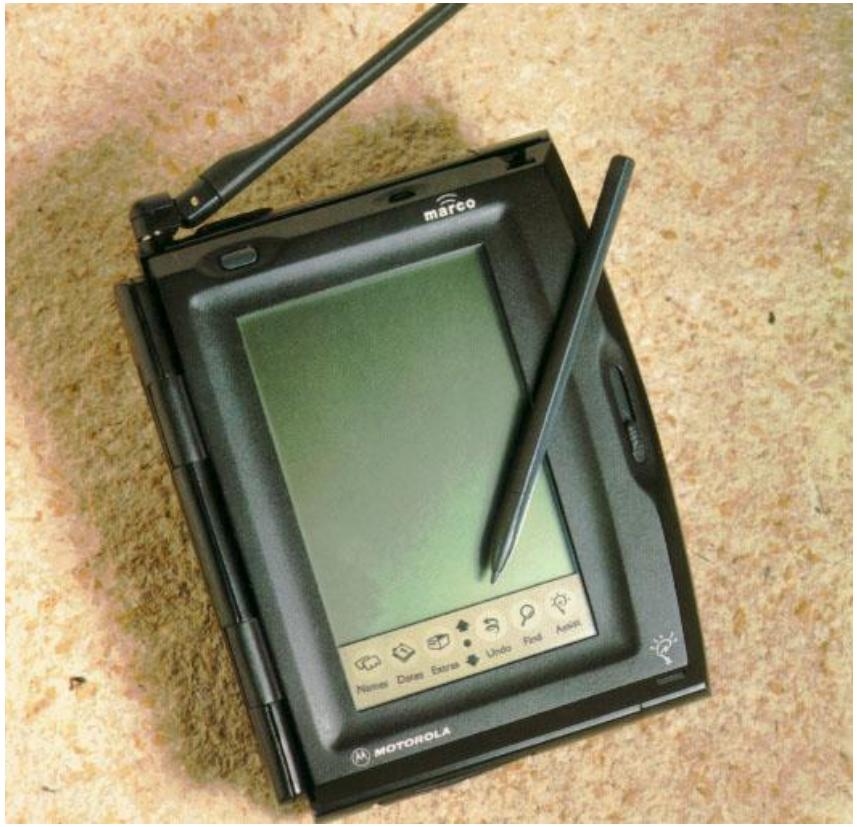
Apple's Newton

1987

The Palm

1990

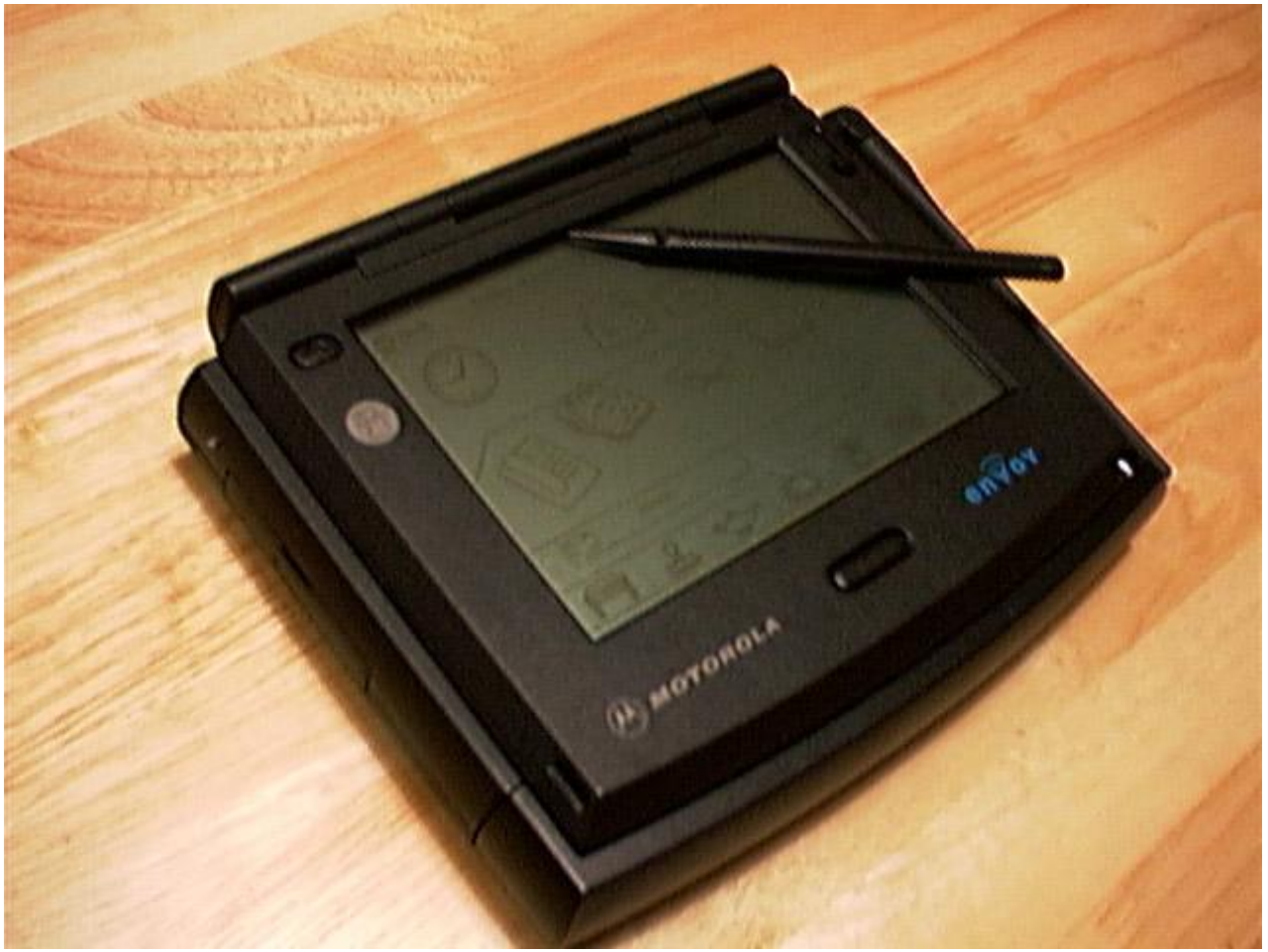
Motorola Marco



1995

- Newton OS 1.3
- 4MB ROM
- 687KB Flash RAM
- 320x240 Monochrome LCD resistive touchscreen
- RS422 serial port
- Localtalk support
- 1 PCMCIA Slot (5V or 12V)
- 1 Sharp ASK infrared port
- 4 AA batteries, rechargeable NiCd batteries may be used
- First released January 1995
- It weighs 1.8 pounds and is 7.5 inches high, 5.8 inches wide and 1.4 inches deep
- Street price: USD 900-1400

Motorola Envoy



1996

The Pocket PC

1998

The Nokia 9000 Communicator

1996

The Hand-Held Computer:Sharp Zaurus

1998

The Vadem Clio: Hand-Held?, Tablet? Other?

Clio™

The ideal PC Companion

1999

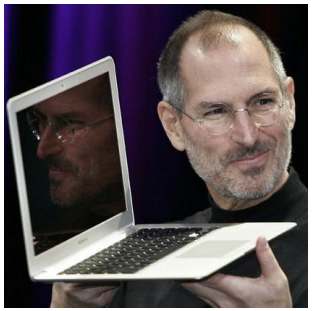
The Tablet PC

Fujitsu Stylistic 2300/3400

2002

Laptops, Notebook, Sub Notebooks & Netbooks

Laptops: 1991
Notebooks: 1996
Netbooks: 2006

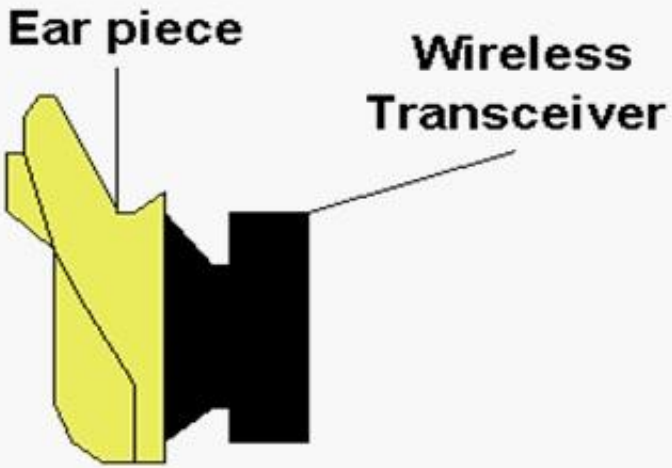


The First Wrist PC: Ruputer, 2000

Japan's PHS Phone, Year 2001

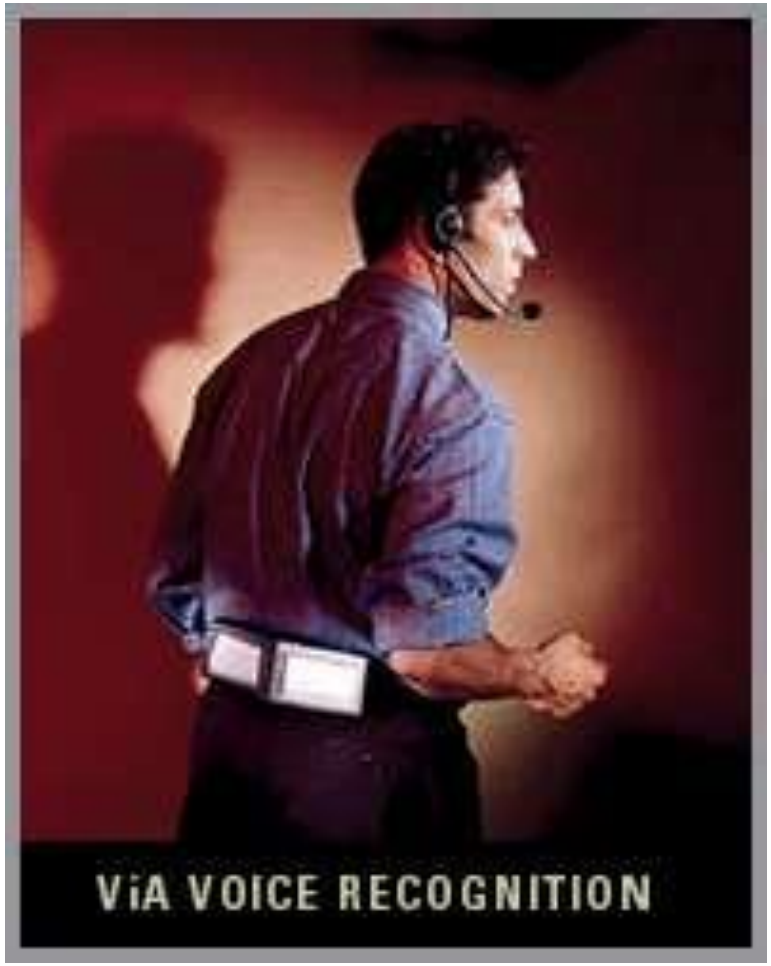
Ear Phone, 2000

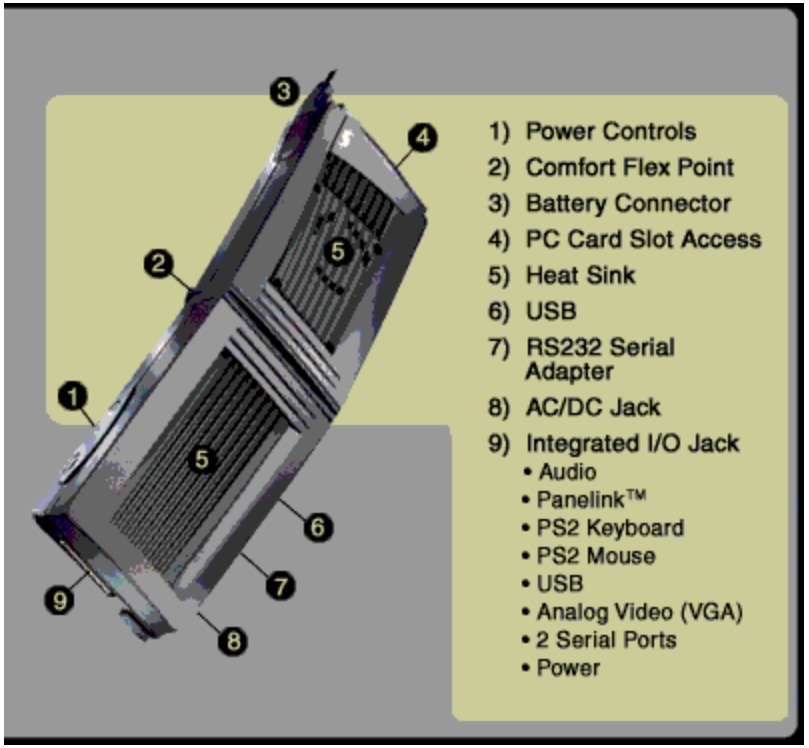
- Hearing aid form factor
- Integrated microphone & speaker
- Low power / short range RF (like Blue Tooth)
- Embedded IP address
- Voice processing: external to unit, controlled by software agents



Wearable Computers, 2000

More Wearable -- Via PC





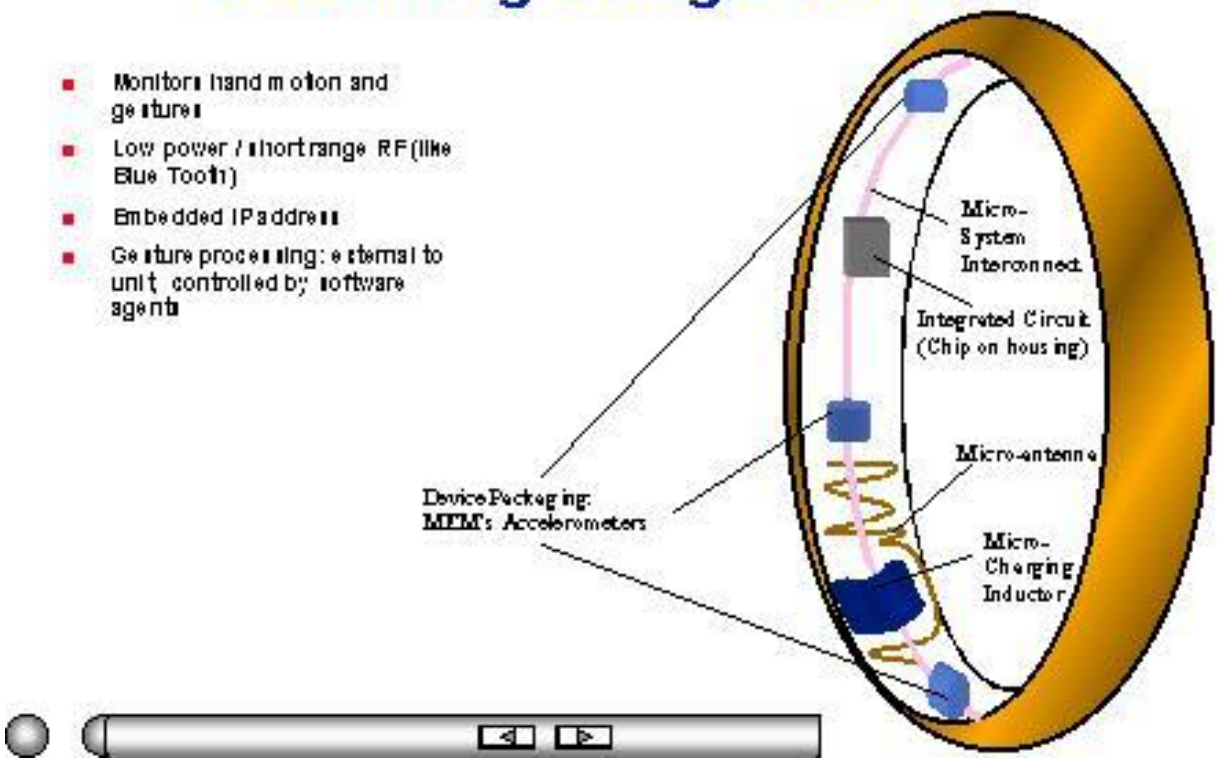
Http://ww.via-pc.com
2007

Wireless Helmet?

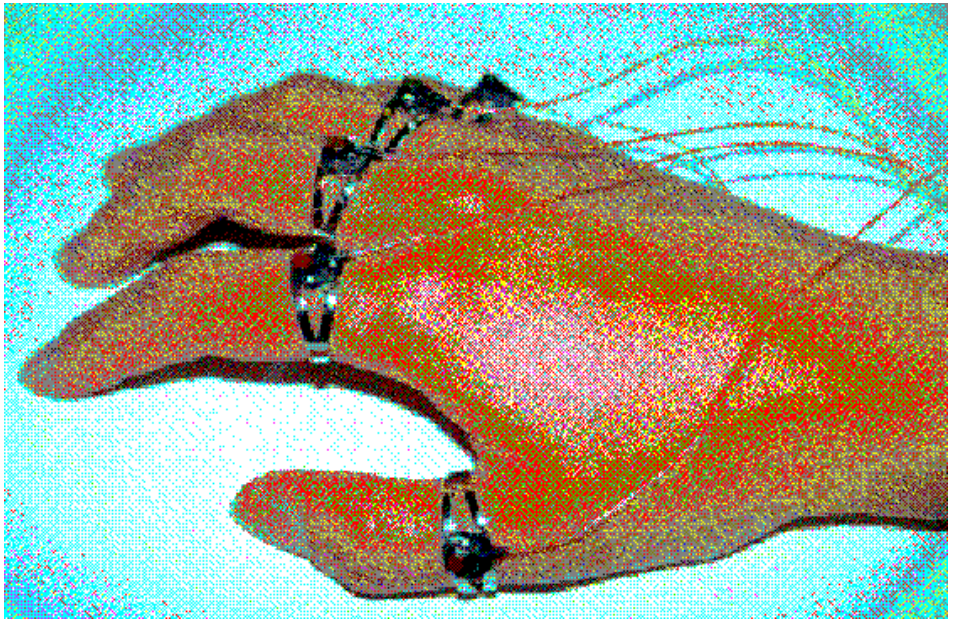
The Power Ring

Power Ring & Magic Wand

- Monitors hand motion and gestures
- Low power / short range RF (like Blue Tooth)
- Embedded IP address
- Gesture processing: external to unit, controlled by software agents



NTT Key Fingers



The Projection Keyboard

http://www.canesta.com

Today

The iphone

The iPad

Andriod

MyVu

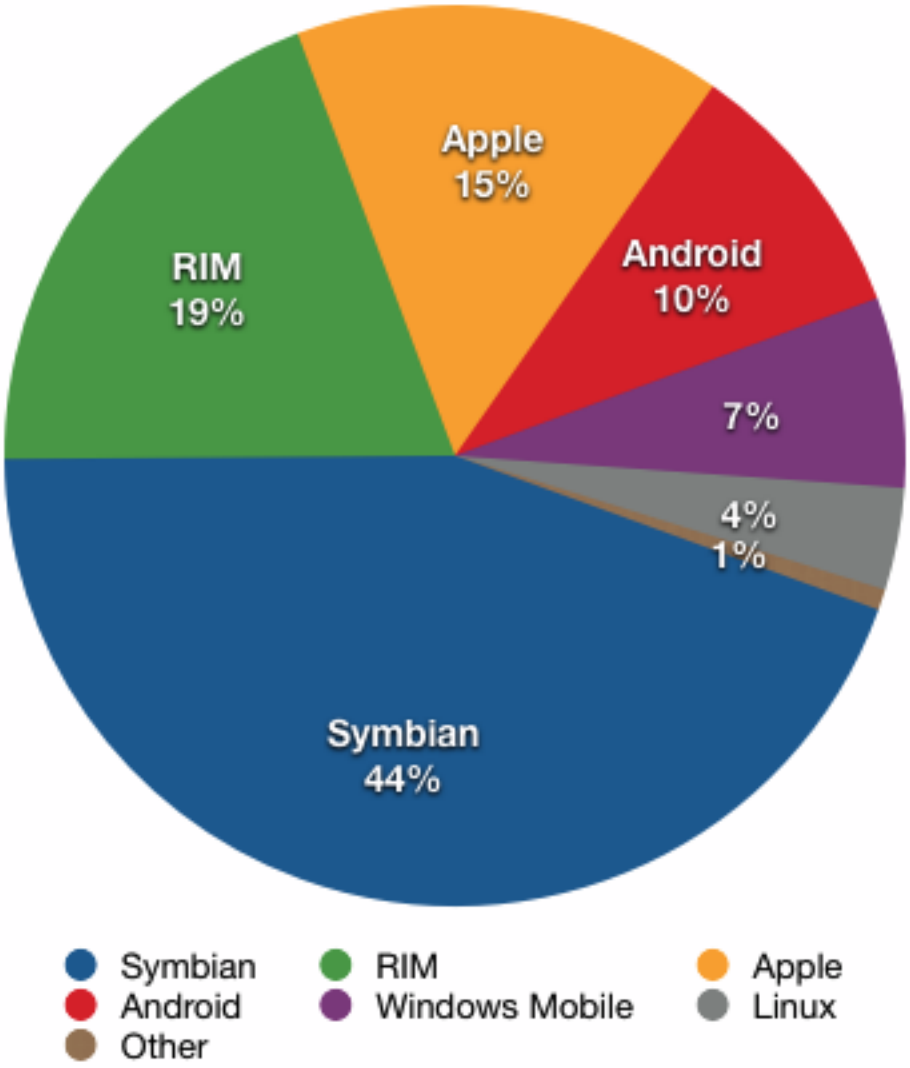
Plastic Logic QUE

22Moo

Portable projectors

Smart Phones

Smart Phones

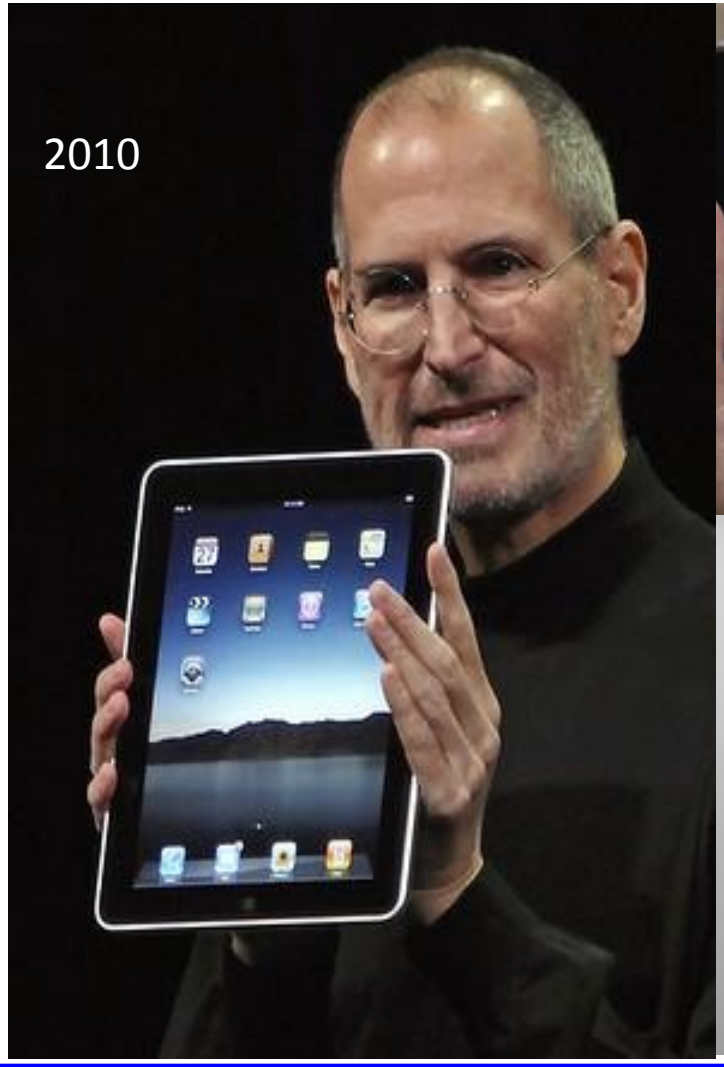


2009

www.getmyuni.com

Re-Inventing the Tablet:

The New War of the PADs



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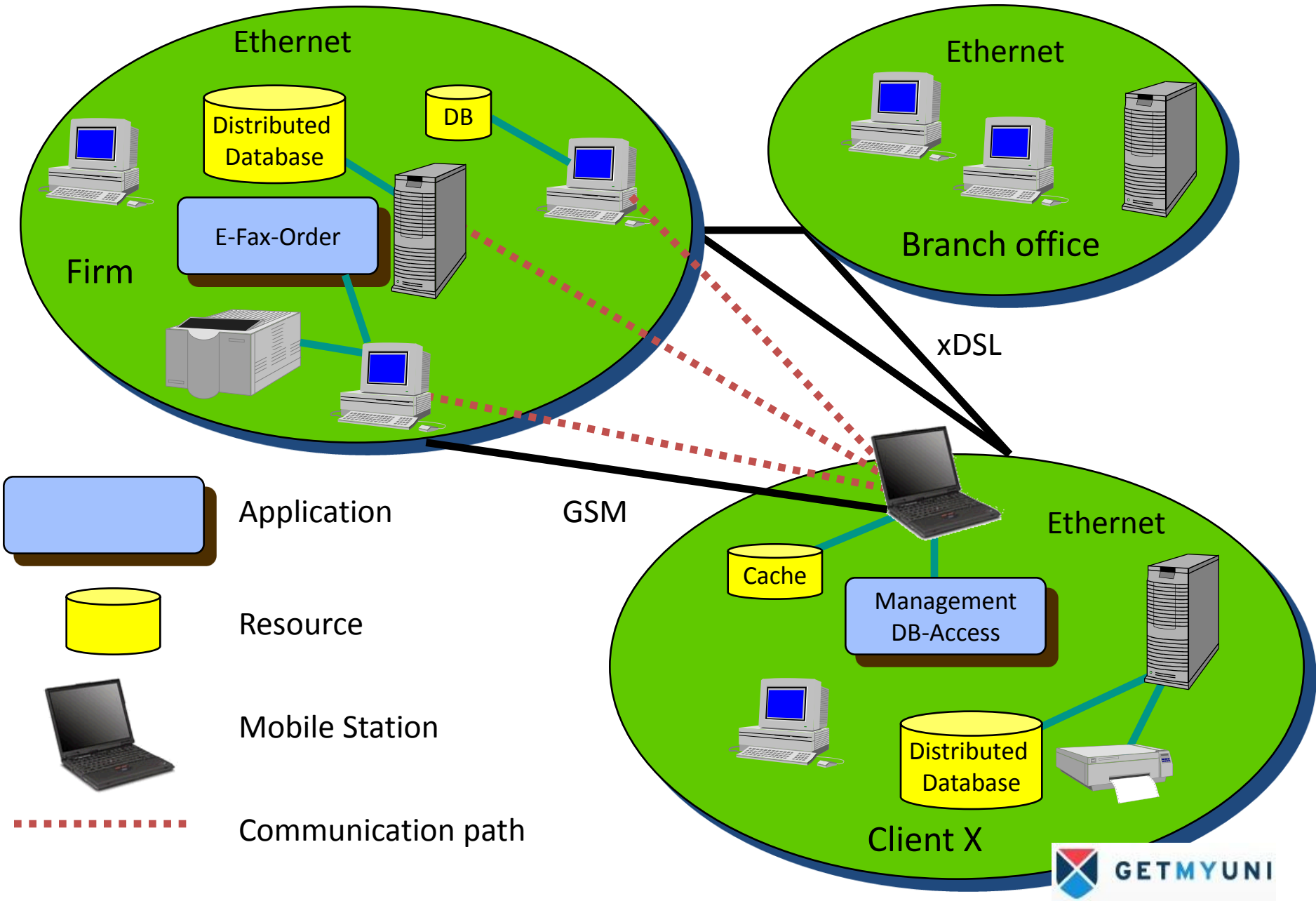
Applications for mobile computing

- There are several applications for mobile computing including wireless remote access by travelers and commuters, point of sale, stock trading, medical emergency care, law enforcement, package delivery, education, insurance industry, disaster recovery and management, trucking industry, intelligence and military.
- Most of these applications can be classified into:
  - wireless and mobile access to the Internet
  - wireless and mobile access to private Intranets
  - wireless and adhocly mobile access between mobile computers.

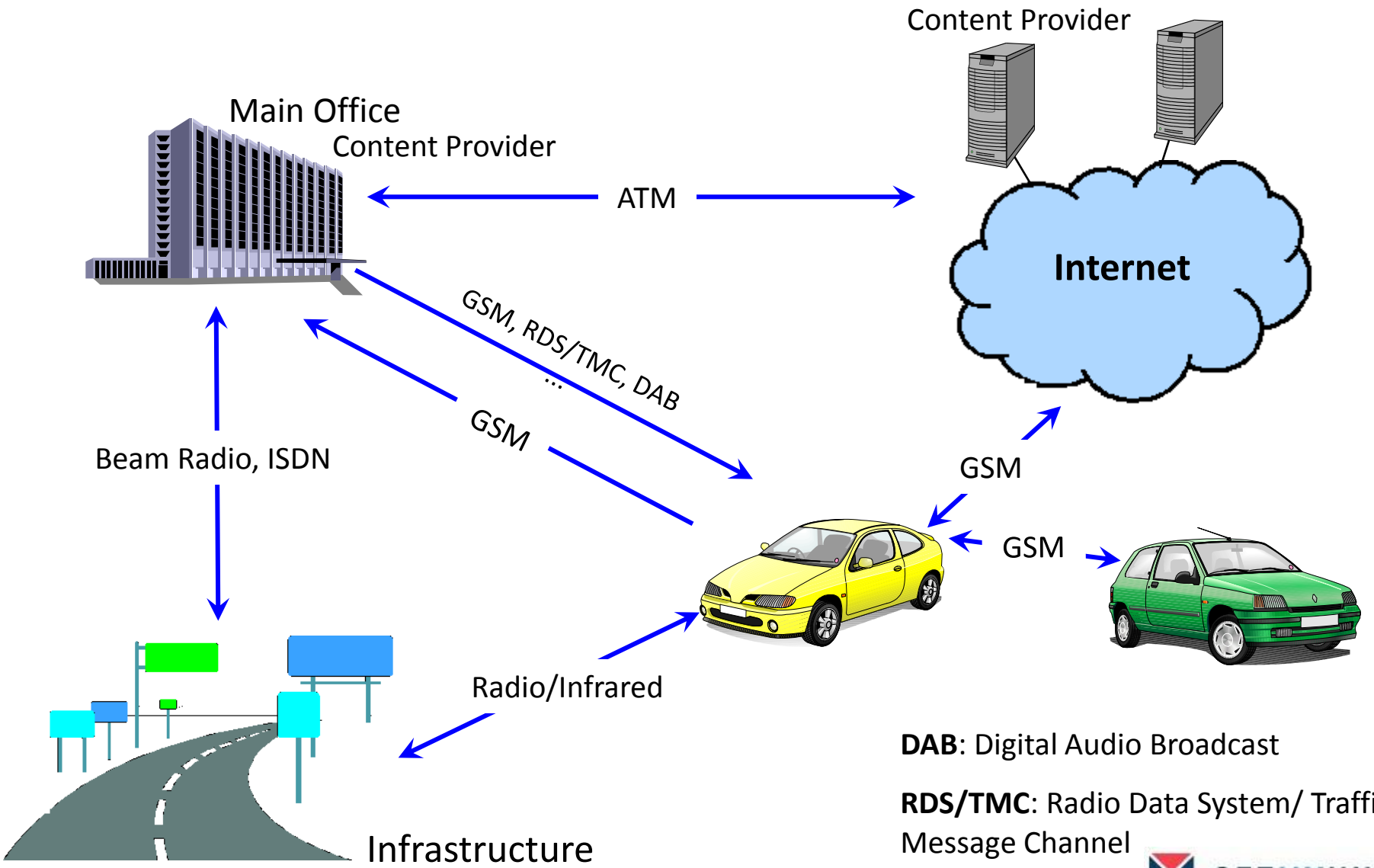
Mobile Computing - Characteristics

- Mobile devices
  - Laptops
  - Palmtops
  - Smart cell phones
- Requirements
  - Data access:
    - Anywhere
    - Anytime
  - Nomadic users
- Constraints
  - Limited ressources
  - Variable connectivty:
    - Performance
    - Reliability

Application Structure



Traffic Telematics Systems



DAB: Digital Audio Broadcast

RDS/TMC: Radio Data System/ Traffic Message Channel

Mobile Communication Networks: Examples

GSM (Global System for Mobile Communications): worldwide standard for digital, cellular Mobile Radio Networks

UMTS (Universal Mobile Telecommunications System): European Standard for future digital Mobile Radio Networks

AMPS (Advanced Mobile Phone System): analog Mobile Radio Networks in USA

DECT (Digital Enhanced Cordless Telecommunications): European standard for cordless phones

TETRA (Terrestrial Trunked Radio): European standard for circuit switched radio networks

ERMES (European Radio Message System): European standard for radio paging systems (Pager)

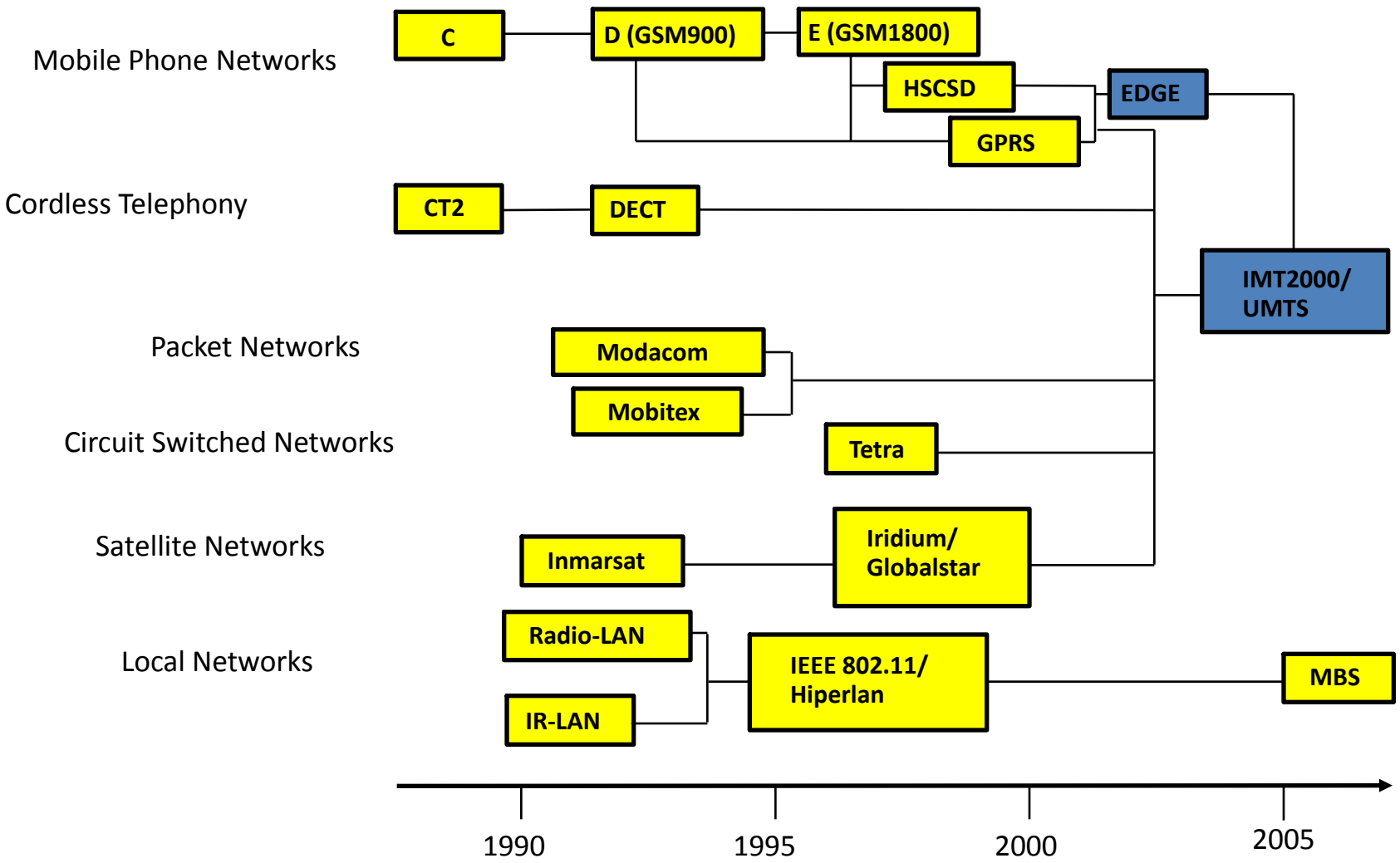
802.11: International standard for Wireless Local Networks

Bluetooth: wireless networking in close/local area

Inmarsat: geostationary satellite systems

Teledesic: planned satellite system on a non-geostationary orbit

Mobile Communication: Development



Used Acronyms

CT2: Cordless Telephone 2. Generation

HSCSD: High Speed Circuit Switched Data

GPRS: General Packet Radio Service

EDGE: Enhanced Data Rates for GSM Evolution

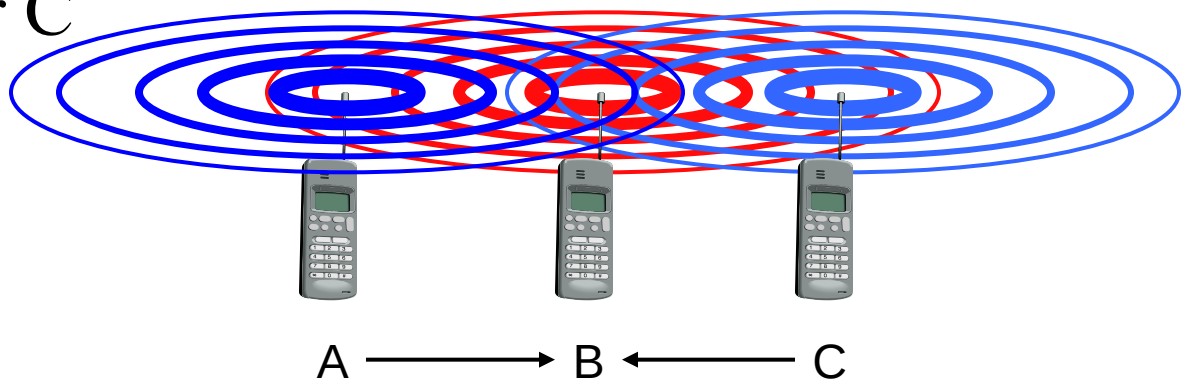
IMT2000: International Mobile Telecommunications by the year 2000

MBS: Mobile Broadband System

Wireless MAC Protocols - Issues

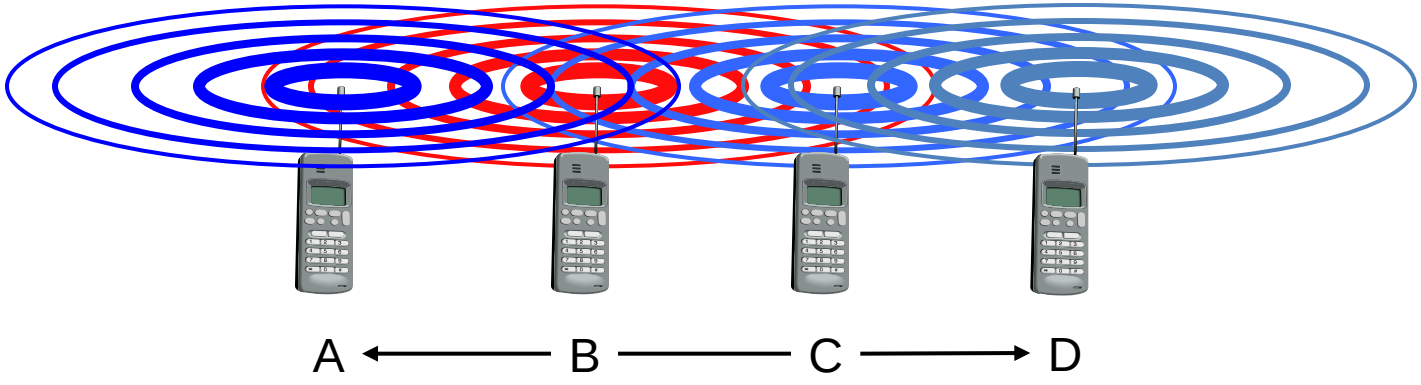
Hidden Terminal Problem

- A sends to B, C cannot receive A
- C wants to send to B, C senses a “free” medium (CS fails)
- collision at B, A cannot receive the collision (CD fails)
- A is “hidden” for C



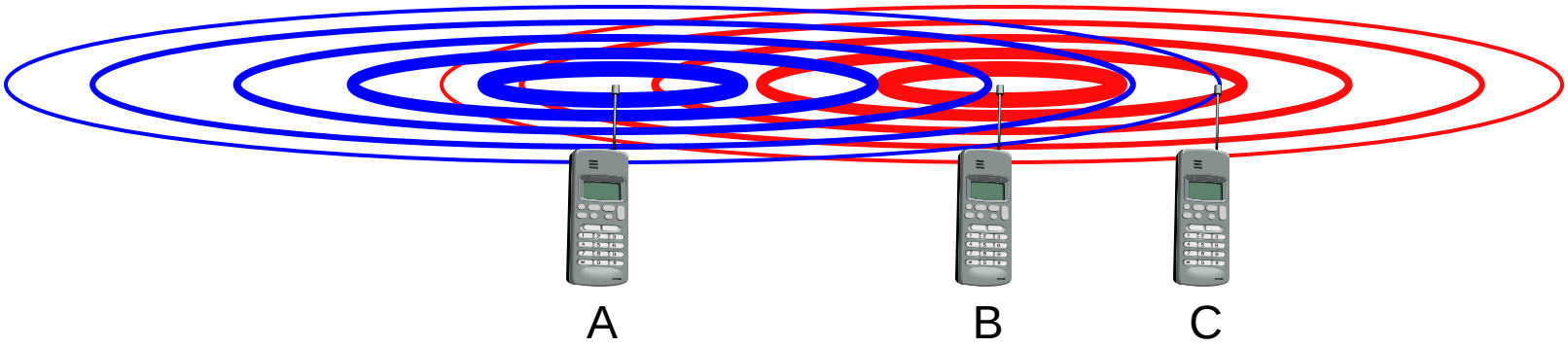
Exposed Terminal Problem

- B sends to A, C wants to send to D
- C has to wait, CS signals a medium in use
- since A is outside the radio range of C waiting is not necessary
- C is “exposed” to B



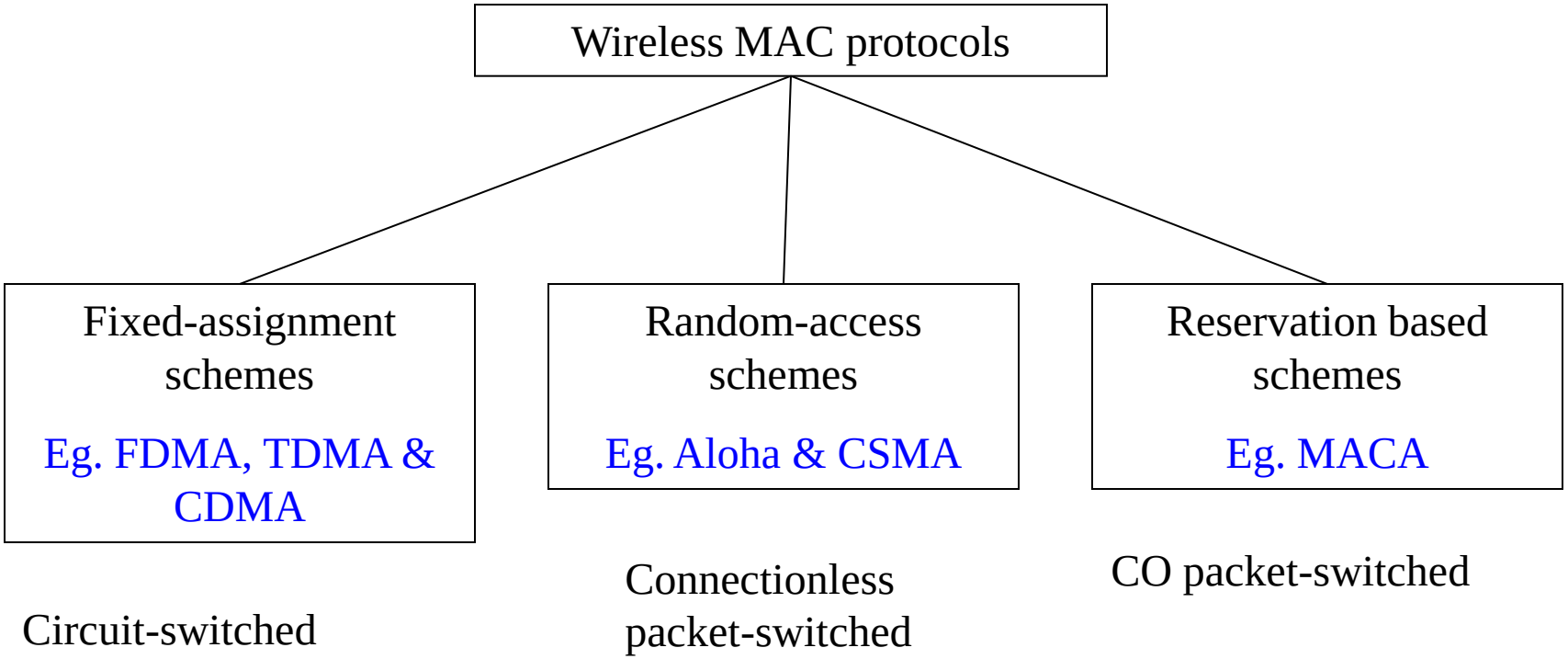
Near and Far Terminals

- Terminals A and B send, C receives
  - the signal of terminal B hides A's signal
  - C cannot receive A



- This is also a severe problem for CDMA networks
- precise power control required

Classification of wireless MAC protocols

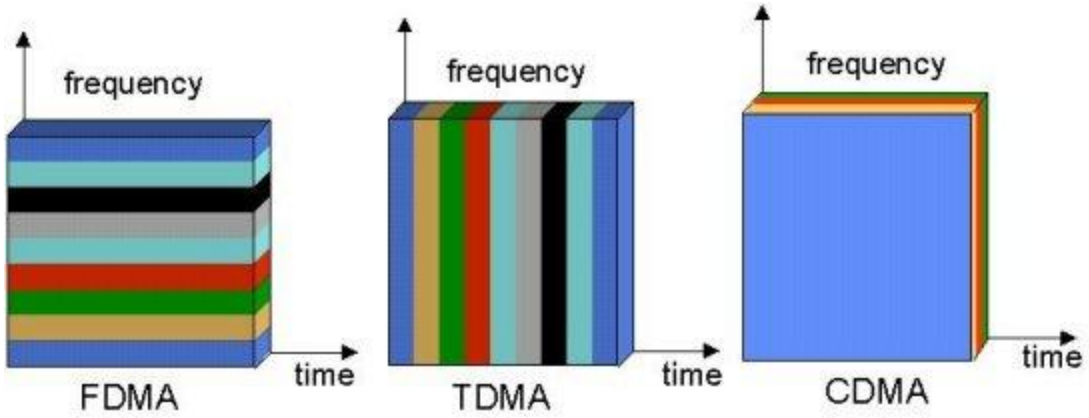


International Cocktail Party

- FDMA – Large room divided up into small rooms. Each pair of people takes turns speaking.
- TDMA – Large room divided up into small rooms. Three pairs of people per room, however, each pair gets 20 seconds to speak.
- CDMA – No small rooms. Everyone is speaking in different languages. If voice volume is minimized, the number of people is maximized.

Fixed-assignment schemes

- TDMA – Time Division Multiple Access
- FDMA – Frequency Division Multiple Access
- CDMA – Code Division Multiple Access



TDMA

- Each user transmits data on a time slot on multiple frequencies
- A time slot is a channel
- A user sends data at an accelerated rate (by using many frequencies) when its time slot begins
- Data is stored at receiver and played back at original slow rate

General Specification of TDMA

- Rx: 869-894MHz Tx: 824-849MHz
- 832 Channels spaced 30kHz apart (3 users/channel)
- DQPSK modulation scheme
- 48.6kbps bit rate
- Interim Standard (IS) – 54
- Digital AMPS (Advanced Mobile Phone System)
- Uses Time Division Duplexing (TDD) usually

TDMA Operation

- Efficiency of TDMA frame:

b_{OH} - overhead bits per frame

N_r - number of reference bursts per frame

N_t - number of traffic bursts per frame

b_r - number of overhead bits per reference burst

b_p - number of overhead bits per preamble per slot

b_g - number of equivalent bits in each guard time interval

T_f - frame duration

R_{rf} - bit rate of the radio-frequency channel

$$b_{OH} = N_r b_r - N_t b_p - \left(N_t - N_r\right) b_g$$

$$b_{total} = T_f \cdot R_{rf}$$

$$\eta_f = \left[1 - \frac{b_{OH}}{b_{total}}\right] \cdot 100\%$$

Advantages of TDMA

- Flexible bit rate
- No frequency guard band required
- No need for precise narrowband filters
- Easy for mobile or base stations to initiate and execute hands off
- Extended battery life
- TDMA installations offer savings in base station equipment, space and maintenance
- The most cost-effective technology for upgrading a current analog system to digital

Disadvantages to using TDMA

- Requires network-wide timing synchronization
- Requires signal processing fro matched filtering and correlation detection
- Demands high peak power on uplink in transient mode
- Multipath distortion

FDMA

- Similar to broadcast radio and TV, assign a different carrier frequency per call
- Modulation technique determines the required carrier spacing
- Each communicating wireless user gets his/her own carrier frequency on which to send data
- Need to set aside some frequencies that are operated in random-access mode to enable a wireless user to request and receive a carrier for data transmission

General Specification of FDMA

- Rx: 869-894MHz Tx: 824-849MHz
- 832 Channels spaced 30kHz apart (3 users/channel)
- DQPSK modulation scheme
- 48.6kbps bit rate
- Used in analog cellular phone systems (AMPS)
- Uses Frequency Division Duplexing (FDD)
- ISI (Intersymbol Interference) is low

FDMA Operation

- Number of FDMA Channels

$$N = \frac{\beta_f - 2 \cdot \beta_{guard}}{\beta_c}$$

β_f - total spectrum

β_{guard} - guard band

β_c - channel bandwidth

- In the U.S. each cellular carrier is allocated 416 channels where:

$$\beta_f = 12.5MHz$$

$$\beta_{guard} = 10kHz$$

$$\beta_c = 30kHz$$

$$N = \frac{12.5MHz - 2 \cdot 10kHz}{30kHz} = 416$$

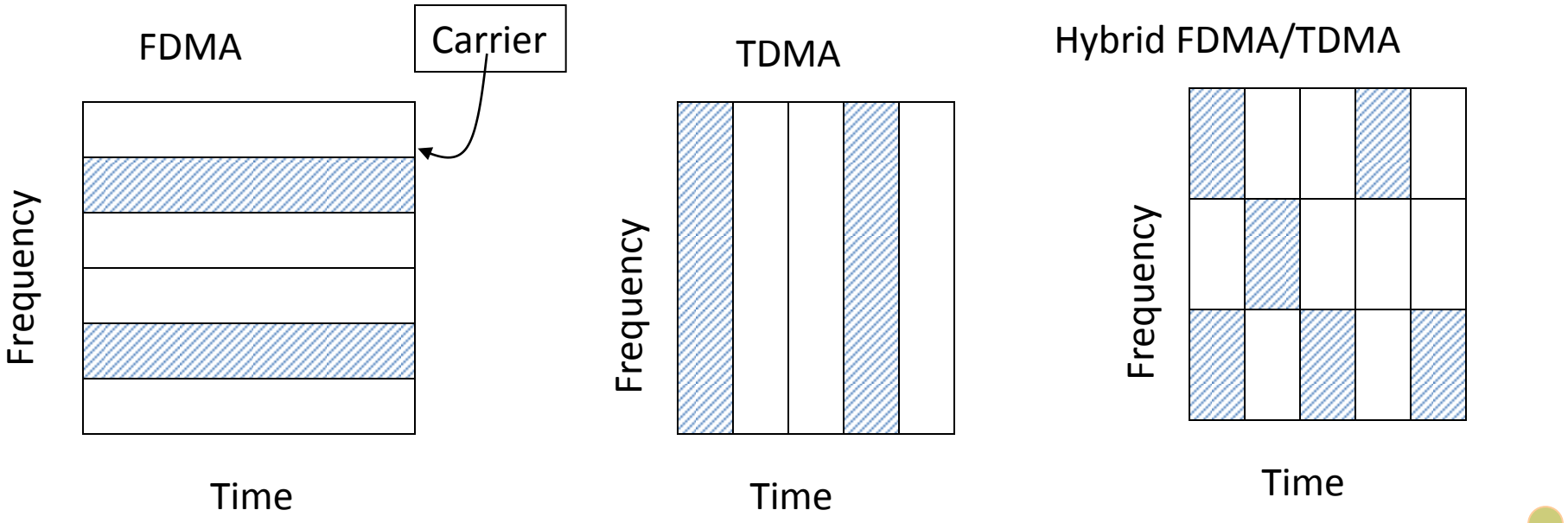
Advantages of FDMA

- If channel is not in use, it sits idle
- Channel bandwidth is relatively narrow (30kHz)
- Simple algorithmically, and from a hardware standpoint
- Fairly efficient when the number of stations is small and the traffic is uniformly constant
- Capacity increase can be obtained by reducing the information bit rate and using efficient digital code
- No need for network timing
- No restriction regarding the type of baseband or type of modulation

Disadvantages to using FDMA

- The presence of guard bands
- Requires right RF filtering to minimize adjacent channel interference
- Maximum bit rate per channel is fixed
- Small inhibiting flexibility in bit rate capability
- Does not differ significantly from analog system

Frequency vs Time



Basic principle of communication: Two regions in the time-frequency plane with equal areas can carry the same amount of information

General Specification of CDMA

- Rx: 869-894MHz Tx: 824-849MHz
- 20 Channels spaced 1250kHz apart (798 users/channel)
- QPSK/(Offset) OQPSK modulation scheme
- 1.2288Mbps bit rate
- IS-95 standard
- Operates at both 800 and 1900 MHz frequency bands

CDMA Operation

- Spread Spectrum Multiple Access Technologies

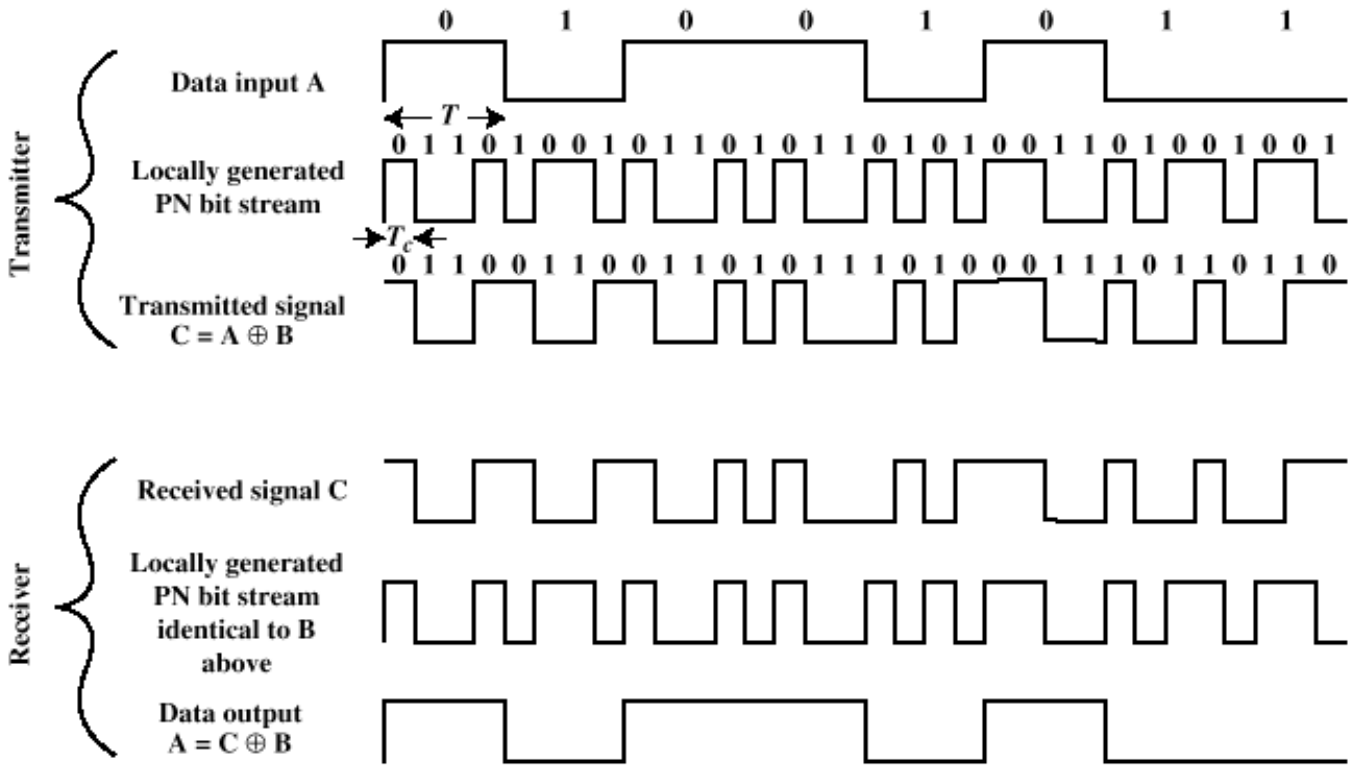


Figure 7.6 Example of Direct Sequence Spread Spectrum

Advantages of CDMA

- Many users of CDMA use the same frequency, TDD or FDD may be used
- Multipath fading may be substantially reduced because of large signal bandwidth
- No absolute limit on the number of users
- Easy addition of more users
- Impossible for hackers to decipher the code sent
- Better signal quality
- No sense of handoff when changing cells

Disadvantages to using CDMA

- As the number of users increases, the overall quality of service decreases
- Self-jamming
- Near- Far- problem arises

Random Access Scheme

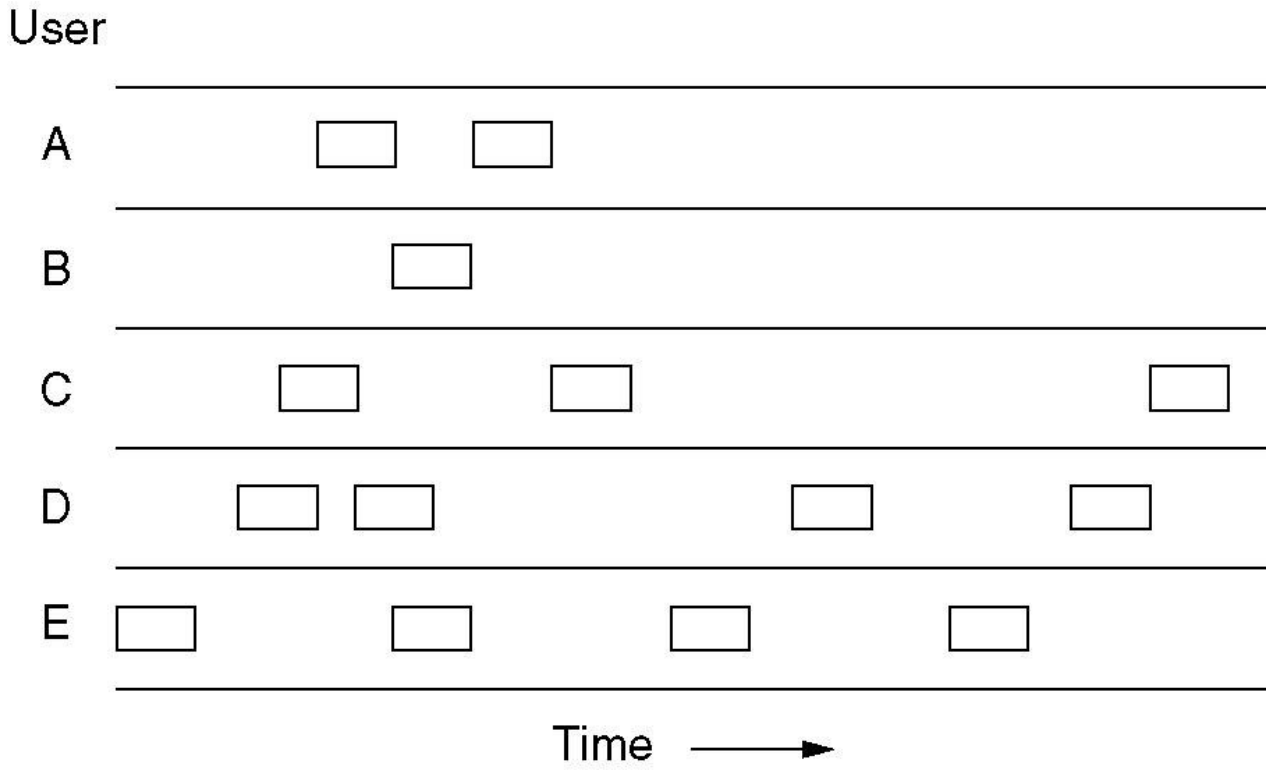
- ALOHA
- CSMA

The ALOHA Protocols

- Developed @ U of Hawaii in early 70's.
- Packet radio networks.
- "Free for all": whenever station has a frame to send, it does so.
  - Station listens for maximum RTT for an ACK.
  - If no ACK, re-sends frame for a number of times and then gives up.
  - Receivers check FCS and destination address to ACK.

Pure ALOHA

- In pure ALOHA, frames are transmitted at completely arbitrary times.

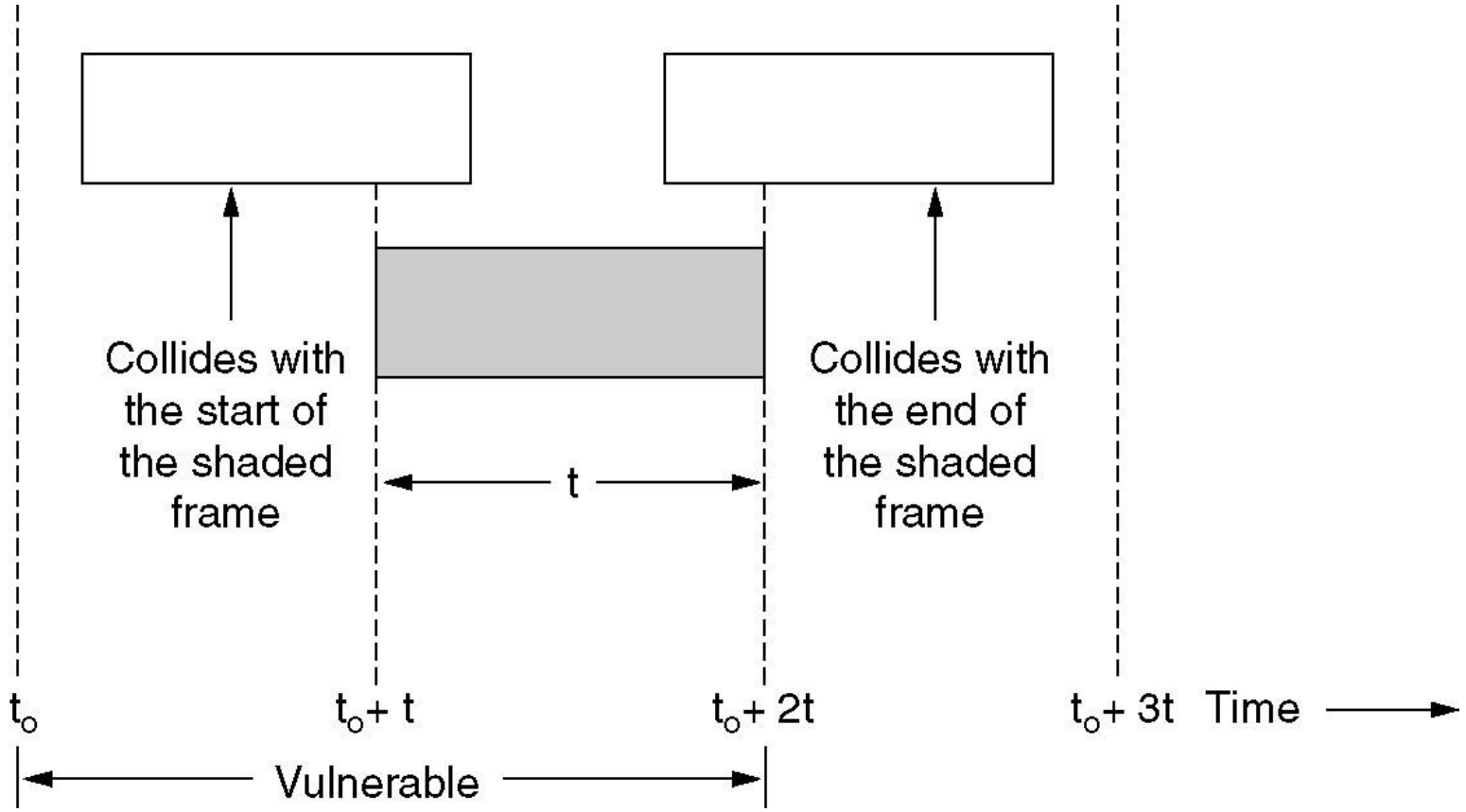


Collisions

- Invalid frames may be caused by channel noise or
- Because other station(s) transmitted at the same time: collision.
- Collision happens even when the last bit of a frame overlaps with the first bit of the next frame.

Pure ALOHA: Performance

- Vulnerable period for the shaded frame.



ALOHA's Performance (Cont'd)

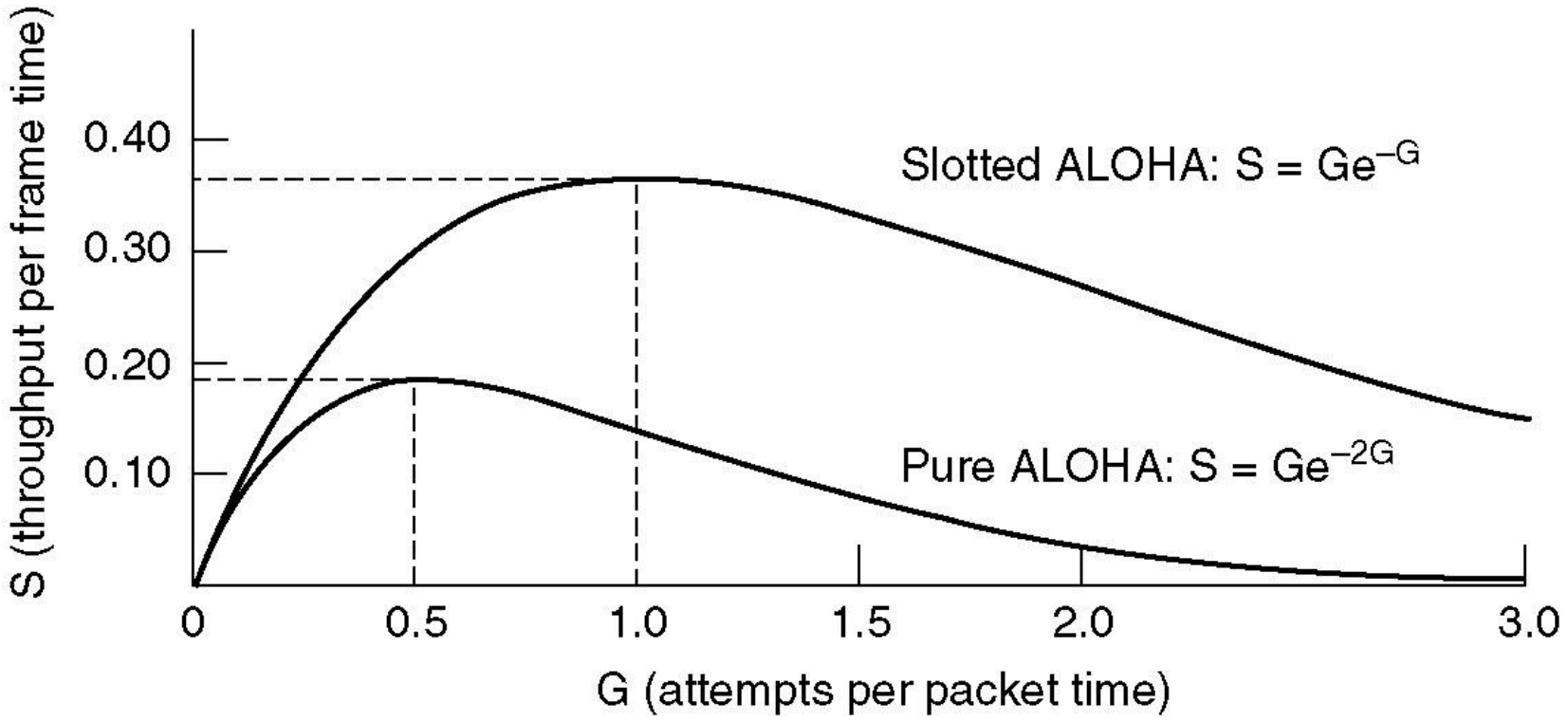
- $S = G\ e^{-2G}$, where S is the throughput (rate of successful transmissions) and G is the offered load.
- $S = S_{max} = 1/2e = 0.184$ for G=0.5.

Slotted Aloha

- Doubles performance of ALOHA.
- Frames can only be transmitted at beginning of slot: “discrete” ALOHA.
- Vulnerable period is halved.
- $S = G\, e^{-G}$.
- $S = S_{max} = 1/e = 0.368$ for $G = 1$.

ALOHA Protocols: Performance

- Throughput versus offered traffic for ALOHA systems.



ALOHA Protocols: Summary

- Simple.
- But, poor utilization…
  - When?

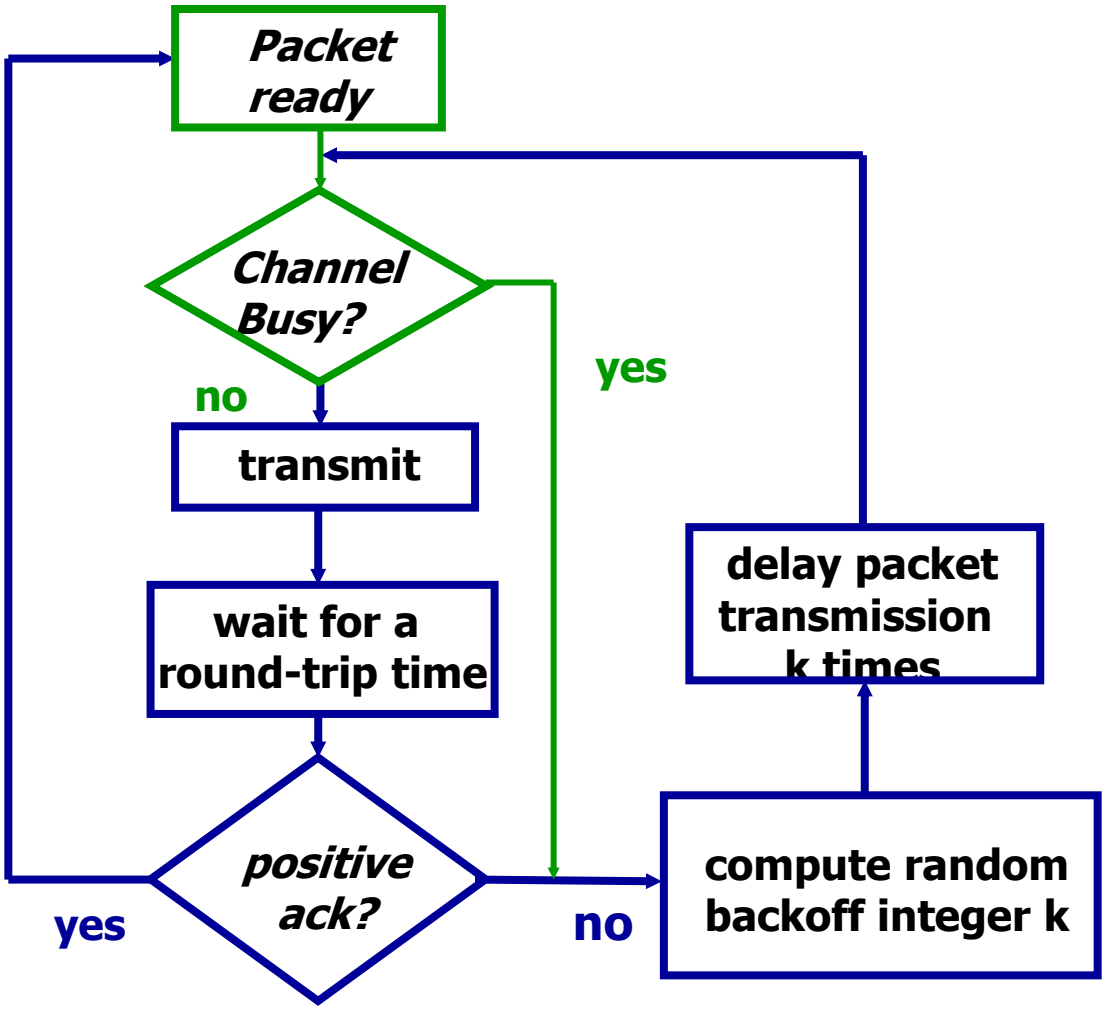
Carrier Sense Multiple Access

- The capacity of ALOHA or slotted ALOHA is limited by the large vulnerability period of a packet.
- By listening before transmitting, stations try to reduce the vulnerability period to one propagation delay.
- This is the basis of CSMA (Kleinrock and Tobagi, UCLA, 1975).

CSMA

- Station that wants to transmit first listens to check if another transmission is in progress (carrier sense).
- If medium is in use, station waits; else, it transmits.
- Collisions can still occur.
- Transmitter waits for ACK; if no ACKs, retransmits.

CSMA Protocol



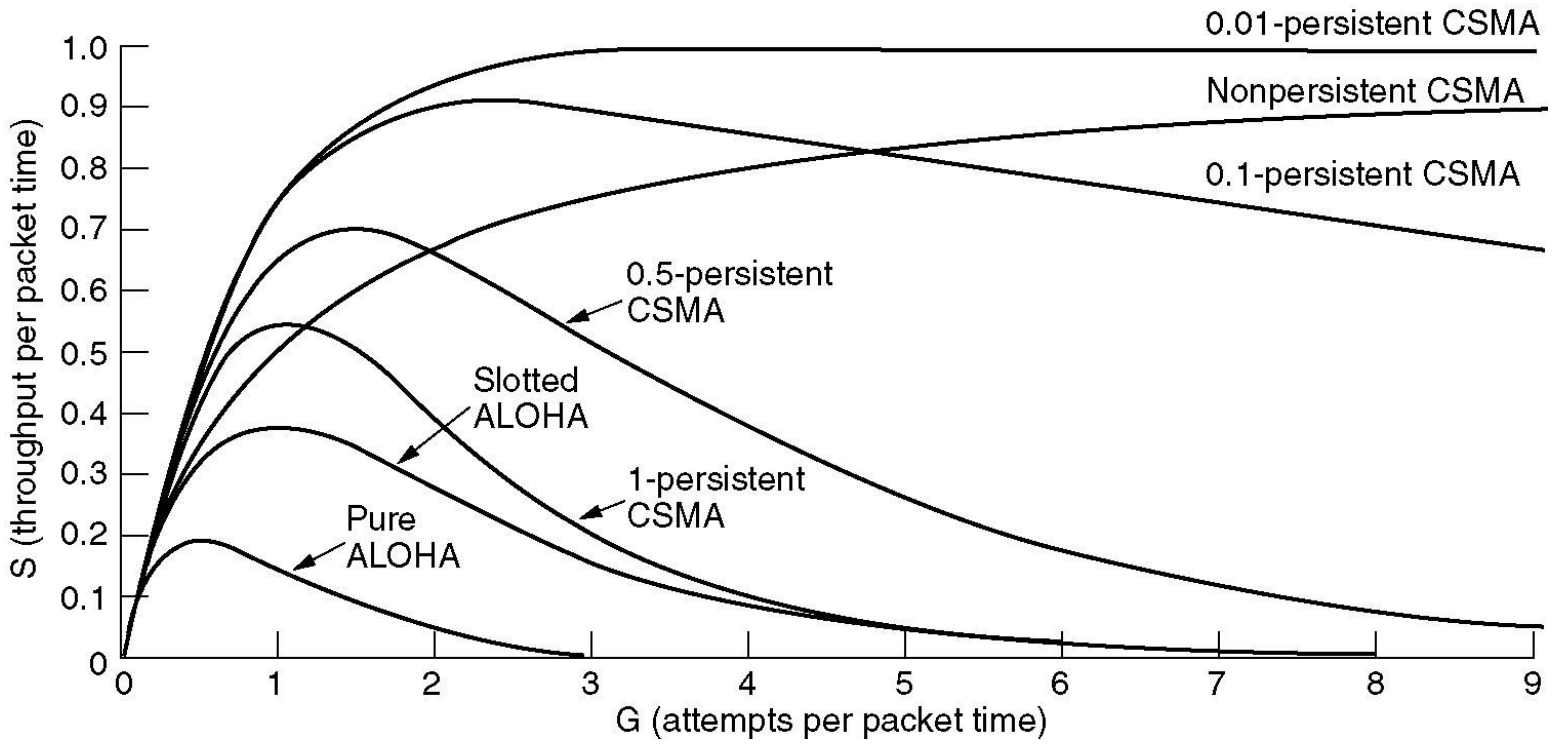
CSMA (cont'd)

- Collisions can occur only when 2 or more stations begin transmitting within short time.
- If station transmits and no collisions during the time leading edge of frame propagates to farthest station, then NO collisions.

CSMA Flavors

- After detecting carrier, a station can persist trying to transmit after the channel is idle again.
- 1-persistent CSMA (IEEE 802.3)
  - If medium idle, transmit; if medium busy, wait until idle; then transmit with p=1.
  - If collision, waits random period and starts again.
- Non-persistent CSMA: if medium idle, transmit; otherwise wait a random time before re-trying.
  - Thus, station does not continuously sense channel when it is in use.
- P-persistent: when channel idle detected, transmits packet in the first slot with p.
  - Slotted channel, i.e., with probability q = p-1, defers to next slot.

CSMA vs Aloha



- Comparison of the channel utilization versus load for various random access protocols.

CSMA/CD

- CSMA with collision detection.
- Problem: when frames collide, medium is unusable for duration of both (damaged) frames.
- For long frames (when compared to propagation time), considerable waste.
- What if station listens while transmitting?

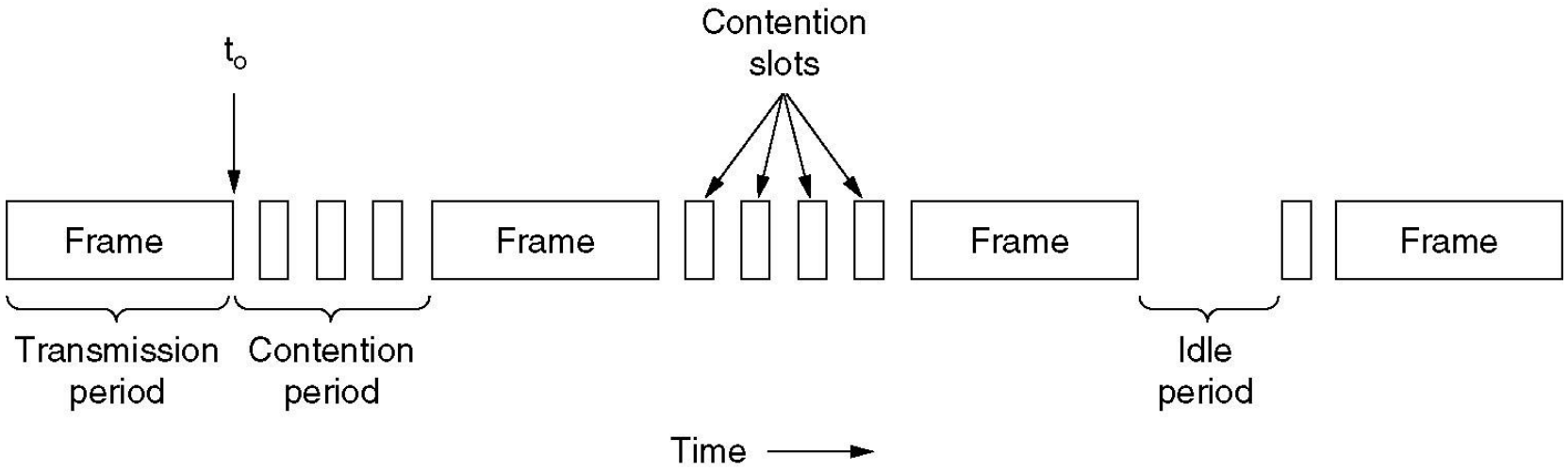
CSMA/CD Protocol

1. If medium idle, transmit; otherwise 2.
2. If medium busy, wait until idle, then transmit with p=1.
3. If collision detected, transmit brief jamming signal and abort transmission.
4. After aborting, wait random time, try again.

CSMA/CD Performance

- Wasted capacity restricted to time to detect collision.
- Time to detect collision < 2*maximum propagation delay.
- Rule in CSMA/CD protocols: frames long enough to allow collision detection prior to end of transmission.

CSMA with Collision Detection



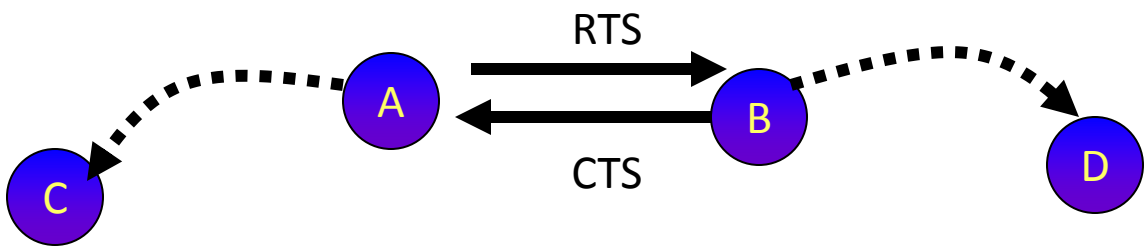
- CSMA/CD can be in one of three states: contention, transmission, or idle.

Ethernet

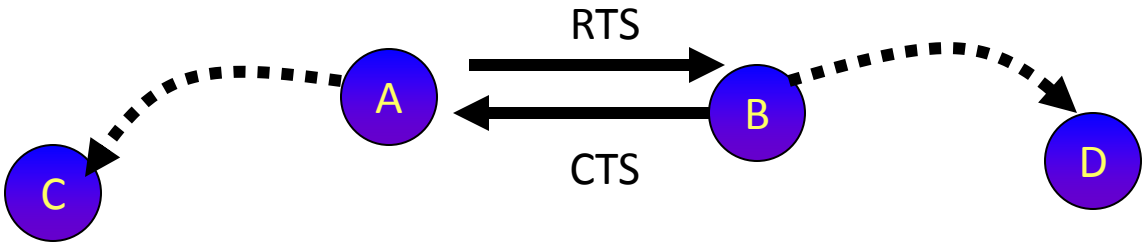
- IEEE 802. family.
  - Standards for LANs and MANs.
- Ethernet defined in the IEEE 802.3 standard.
  - PHY, MAC, and LLC.

MACA : Multiple Access with Collision Avoidance

- Exchange of two short messages – Request to Send (RTS), and Clear to Send (CTS).
- They are fixed size – when A wishes to transmit to B, it sends an RTS message.
    - RTS message contains duration of proposed transmission
- If B knows that the channel is free, it responds with a CTS message. (CTS also contains duration of proposed communication)
- How does this help ?



MACA



- Any station that hears the RTS message, defers all communication for some time until the associated CTS message has been finished.
- A CTS message defers communication for the duration of the time indicated in the CTS message.
- When A is transmitting data, C can go ahead and access the channel.
- What all could go wrong here ?

Some effects in MACA

- Node B's CTS message may not be heard by A.
    - B found that the channel was already busy.
    - RTS packet might collide.
- If A does not receive a CTS, it times-out and schedules the packet for retransmission.
- MACA uses the binary exponential back-off algorithm to select the retransmission time.
- B's CTS message collides at C.
    - This would cause C to be unaware of the pending communication between nodes A and B.
- NOTE: MACA is used (with Modifications) in the WaveLAN cards.

Exponential Back-Off

- RTS and CTS slot times (defined to be 30 bytes) form the basic slot size.
- If CTS is not heard, a station chooses a time that is uniformly distributed between 1 and BO (for Back-Off). What is BO ?
- If a CTS message is received then BO is set to BO_{min} .
- If a CTS is missed, then, if the previous BO was BO_{old}, the new BO, BO_{new} is set to $BO_{new} = Min (2 \times BO_{old}, BO_{min})$.
- BO_{min} and BO_{max} represent the minimum and maximum back-off intervals.