SNS COLLEGE OF ENGINEERING

Kurumbapalayam(Po), Coimbatore – 641 107

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Department of Information Technology

Introduction to Mobile Communication

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Course Objective

- Understand the basic concepts of Mobile Computing.
- Understand Wireless LAN,Bluetooth and WIFI Technologies.
- Be familiar with the network protocol stack.
- Learn the basics of mobile telecommunication system.
- Be exposed to Ad-Hoc Networks.

Unit –I Syllabus

UNIT I INTRODUCTION **9**

Introduction to Mobile Computing – Applications of Mobile Computing- Generations of Mobile Communication Technologies-MAC Protocols – SDMA- TDMA- FDMA- CDMA

Mobile Computing Definition

Mobile Computing is a technology that allows transmission of data, voice and video via a computer or any other wireless enabled device without having to be connected to a fixed physical link.

Introduction to Mobile Communicatio

- Difference Between **Mobile and wireless**
- **User mobility** (call forwarding) and **device portability**(mobile phone system)
- **Types of devices:**
  - ✓ Fixed and wired (desktop)
  - ✓ ` Mobile and wired(laptop)
  - ✓ Fixed and wireless(wifi router)
  - ✓ Mobile and wireless(wifi dongle)

Applications of Mobile Computing

Vehicles:

- Vehicles contain many wireless communication system and mobility aware applications.
- These involves the current position of the car is determined via the global positioning system(GPS).
- It can also build a local ad-hoc network for exchange of information in an emergency situation.

Applications of Mobile Computing

Emergencies:

- Ambulance with a high quality wireless connection to a hospital.
- All the necessary steps for the type of the accident can be prepared and specialists can be consulted for an early diagnosis.

Business:

- For accessing the company's databases remotely.

Replacement of wired network:

- Sometimes it is impossible to provide wired network for remote sensors, earthquake detection etc…,
- Excess Cabling may destroy valuable walls or floors.

Applications of Mobile Computing

Infotainment and more:

- Wireless network can provide up-to-date information at any appropriate

Location dependant services:

Follow-on services: using wireless enabled devices a follow on service is enabled.

Location aware service :Based on the location of the user the service is provided ex:OLA,swiggy.

Privacy: We can use the location dependant services but privacy should also be handled.

Information Services: For information also we will use the service whenever we go to a new city we will browse for best hotels.

Support Services: Many Support services are available when the mobile node travels from one place to another it caches some contents once the mobile node is reconnected it transfers all the information.

Applications of Mobile Computing

Mobile and Wireless devices:

Some of the wireless devices are:

Sensor: Simple wireless device represented by a sensor transmitting state information.

Embedded controllers: Many appliances already contain a simple or complex controller .Washing machine, coffee machine, dishwasher are some examples of controllers.

Pager: Simple receiver it can receive only short messages and cannot send any message.

Mobile Phones: The traditional mobile is black and white text display and could send /receive only short messages but now it is more advanced.

Applications of Mobile Computing

Personal Digital Assistant:

It offers simple version of office software (calendar,notepad,mail).The input device is a pen, with built in character recognition translating handwriting into characters.

Pocket Computers:

Pocket computers offering tiny keyboards,color displays and simple version of programs found on desktop computers.

Laptop:

It offers more or less the same performance of the desktop.

The main drawback of the wireless devices is the energy problem the wireless devices consumes lot of energy.

Generations of Mobile Communication Technologies

- The mobile communication technology evolved from 0^{th} generation to 5^{th} generation.
- Each generation differs from the access control mechanisms, performance and each has its own advantages and disadvantages.

0^{th} Generation

- Pre-cell phone mobile telephony technology.
- It is also called as radio telephones which are mounted in cars or trucks before the arrival of cell phones.
- Communication was possible only through voice.
- It uses Half Duplex Communication
- Technologies used are PTT(Push to talk),MTS(Mobile telephony system),IMTS(Improved MTS).

0th Generation

First Mobile Radio Telephone-
1924

1st Generation

- It is called as Analog cell Phones.
- A voice call getting modulated to a higher frequency of about 150 MHZ and it is transmitted between radio towers.
- It is done using a technique called FDMA(Frequency Division Multiple Access).
- The technologies used are FDMA,NMT(Nordic Mobile Telephone),AMPS(Advanced Mobile Phone System).The main disadvantage is no security and prone to distortions.

1st Generation

2nd Generation

- It is also called as Digital cell phones.
- The speed is 10Kbits/sec
- Time to download a 3 min MP3 song will take around 30 -40 min.
- The services offered are digital voice calling and short message service.
- The standards used are GSM,CDMA,TDMA.
- The advantages of the 2nd generation mobiles are it consumes less battery power, improves the voice clarity, reduces noise in the line and security to the data over voice calls.

2nd Generation

3rd Generation

- 2G networks were built mainly for voice data and slow transmission. Due to rapid changes in user expectation, they do not meet today's wireless needs.
- 3G networks provide the ability to transfer voice data and non voice data over the same network simultaneously.
- The applications used are Internet,e-mail,fax,e-commerce,music,video clips and video conferencing.
- The aim of the 3G is to allow for more coverage and growth with minimum investment.

3rd Generation

The features included in the 3rd generation mobile phones are:

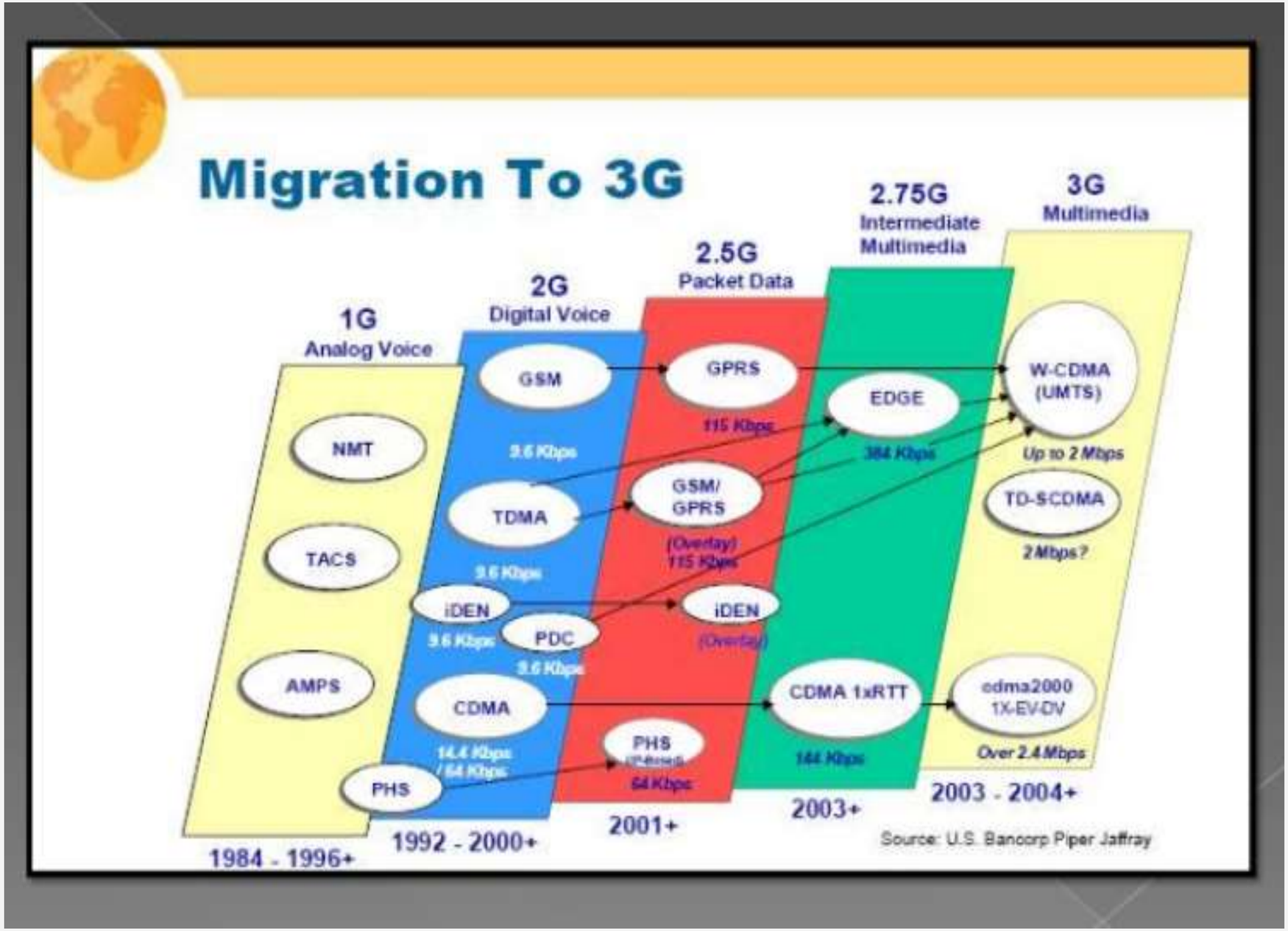
- Phone calls
- Global Roaming
- Send/receive large email messages.
- High-speed Web
- Navigation/maps
- Video Conferencing
- TV Streaming
- Electronic agenda meeting reminder
- GPS

3rd Generation

- The speed of data transfer is 144kb/sec-3mb/sec ie..,1 million bits or 125,000 bytes ,of data are being transferred per second.
- Time to download a 3 min MP3 song:11 sec-1.5 min

- 3G has the following enhancements over 2.5G and previous networks.

  - Enhanced audio and video streaming
  - Several times higher data speed.
  - Video Conferencing support.


Migration To 3G
1G
Analog Voice
2G
Digital Voice
2.5G
Packet Data
2.75G
Intermediate Multimedia
3G
Multimedia
NMT
TACS
AMPS
GSM
9.6 Kbps
TDMA
9.6 Kbps
iDEN
9.6 Kbps
PDC
9.6 Kbps
CDMA
14.4 Kbps / 64 Kbps
PHS
GPRS
115 Kbps
GSM/ GPRS
(Overlay) 115 Kbps
iDEN
(Overlay)
PHS
64 Kbps
EDGE
384 Kbps
CDMA 1xRTT
144 Kbps
W-CDMA (UMTS)
Up to 2 Mbps
TD-SCDMA
2 Mbps?
edma2000 1X-EV-DV
Over 2.4 Mbps
1984 - 1996+
1992 - 2000+
2001+
2003+
2003 - 2004+
Source: U.S. Bancorp Piper Jaffray

Drawbacks by Generation

- **1G-**Poor Voice quality, Poor Battery Life, Large Phone size, No Security, frequent call drops, Limited Capacity and poor handoff reliability.

- **2G-**The GSM is a circuit switched, connection oriented technology, where the end systems are dedicated for the entire call session.This causes inefficiency in usage of bandwidth and resources. They are unable to handle complex data such as video.

- **3G-**High Bandwidth Requirement, High spectrum licensing fees and Huge capital.

4th Generation

- 4G development focuses around achieving ultra broadband speeds, it competes with the speed of home internet.

- 4G average speeds are targeted to be in the 100Mbps to 1 Gbps range, roughly 10 to 100 times(dependent on location)faster than 3G networks.

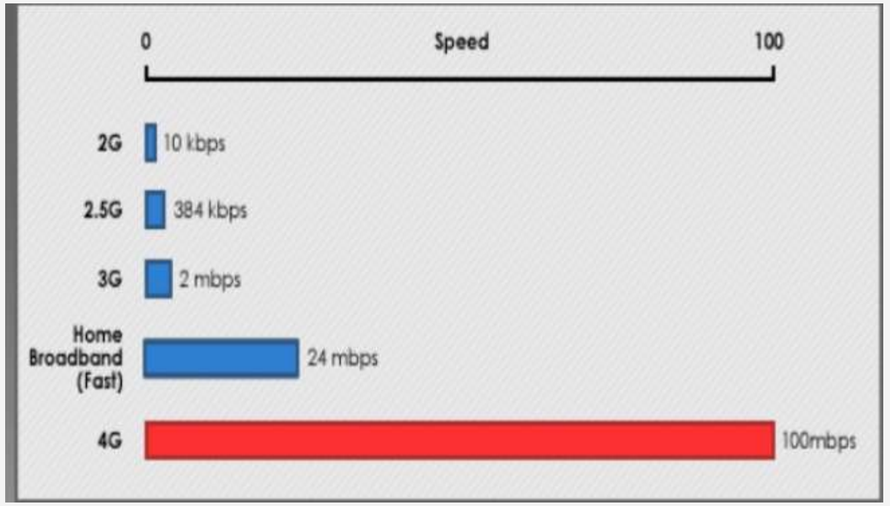
4th Generation

The features include:

- A spectrally efficient system
- High network Capacity
- Huge data rate
- Perfect connectivity and global roaming.
- High quality of service.
- Security and Privacy

4th Generation

The technology used in 4G is OFDM(orthogonal frequency Division Multiplexing) and other technological aspects are adaptive processing and smart antennas.



Applications of 4th Generation

Games:

- Games will be a major application segment in 4G.

Broadband Access in Remote Locations:

- 4G networks will provide a wireless alternative for broadband access to residential and business customers.
- In addition,4G will provide the first opportunity for broadband access in remote locations without an infrastructure to support cable or DSL Access.

Other Applications:

E-Commerce,Business,vehicular,Public Place, Entertainment and Education.

Applications of 4th Generation

Technology	3G	4G
Frequency band	1.8 - 2.5GHz	2 - 8GHz
Bandwidth	5-20MHz	15-200MHz
Data rate	Up to 2Mbps	100Mbps moving - 1Gbps stationary
Switching	Circuit/Packet	Packet

Comparison of Generations

Technology	1G	2G	2.5G	3G	4G
Design Began	1970	1980	1985	1990	2000
Implementation	1984	1991	1999	2002	2010?
Service	Analog voice, synchronous data to 9.6 kbps	Digital voice, short messages	Higher capacity, packetized data	Higher capacity, broadband data up to 2 Mbps	Higher capacity, completely IP-oriented, multimedia, data to hundreds of megabits
Standards	AMPS, TACS, NMT, etc.	TDMA, CDMA, GSM, PDC	GPRS, EDGE, 1xRTT	WCDMA, CDMA2000	Single standard
Data Bandwidth	1.9 kbps	14.4 kbps	384 kbps	2 Mbps	200 Mbps
Multiplexing	FDMA	TDMA, CDMA	TDMA, CDMA	CDMA	CDMA?
Core Network	PSTN	PSTN	PSTN, packet network	Packet network	Internet

5th Generation

- 5G is a technology used in research papers and projects to denote the next major phase of mobile telecommunication standards.
- It is a real wireless world that is a complete WWWW:WorldWide Wireless Web .
- The user can experience a high value technology in cell phones using very high bandwidth.
- It is a new mobile revolution in mobile market.
- It has Extra ordinary data capabilities and has ability to tie together unrestricted call volumes and infinite data broadcast within latest mobile operating system.

MAC Protocols

- The Data link layer has two sublayers: **Medium Access Control** layer and **Logical Link Control** layer.

- The main objective of Data link layer is to provide point to point or point to multipoint connection between different devices over wired or wireless medium.

- Specifically there are medium access control algorithms to the wireless domain.

MAC Protocols

- It comprises of all mechanisms that regulate user access to a medium using SDM,TDM,FDM or CDM.

- MAC works similarly the traffic regulations in the highway when several vehicles cross on same time the collision occurs.

MAC Protocols

- The standard MAC scheme is CSMA/CD it works such as, the sender senses the medium when it is free it transmits data whenever the collision is detected the sender stops transmitting and send the jamming signal.
- The signal strength will be same all through the line from sender to receiver. The sender detects the collision.

- It is not possible in the wireless networks the signal strength decreases proportionally to the square of the distance to the sender.

- The sender cannot detect collision and collision can apply in the receiver side also when two senders are trying to send data at the same time.

MAC Protocols

- To address these type of problems we need special MAC schemes for wireless domain .

- The standard MAC schemes fails in wireless domain due to the hidden and exposed terminal and Near and far terminal problem.

Hidden and Exposed Terminal

- Consider the scenario with three mobile phones .The transmission range of A reaches B, but not C(the detection range does not reach C either).

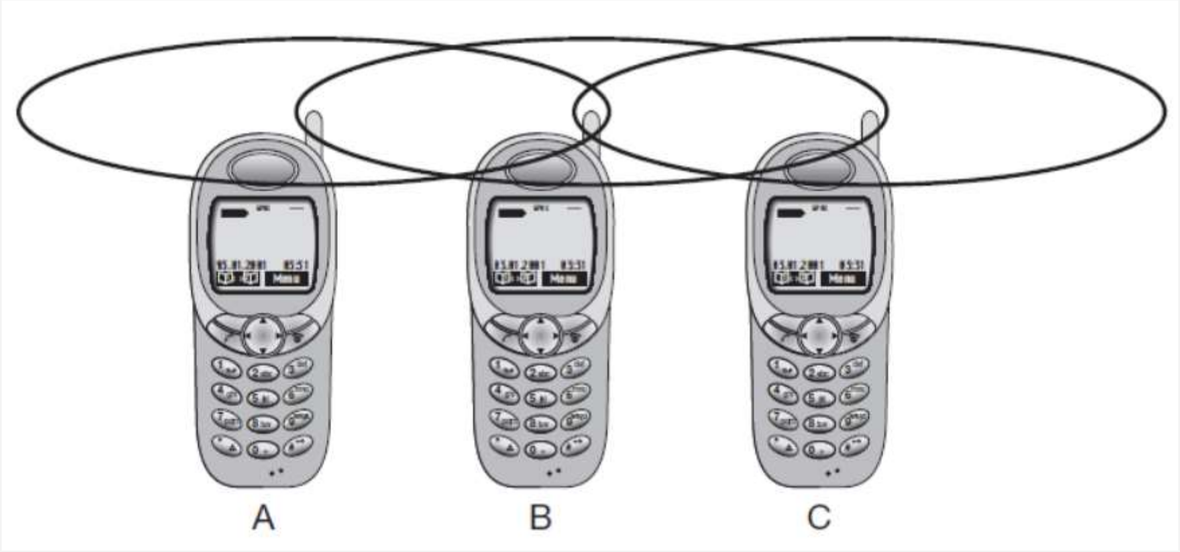
- The transmission range of C reaches B, but not A.Finally,the transmission range of B reaches A and C, i.e...,A cannot detect C and vice versa.
- A starts sending to B,C does not receive this transmission. C also wants to send something to B and senses the medium.

- The medium appears to be free, the carrier sense fails.C also starts sending causing a collision at B.

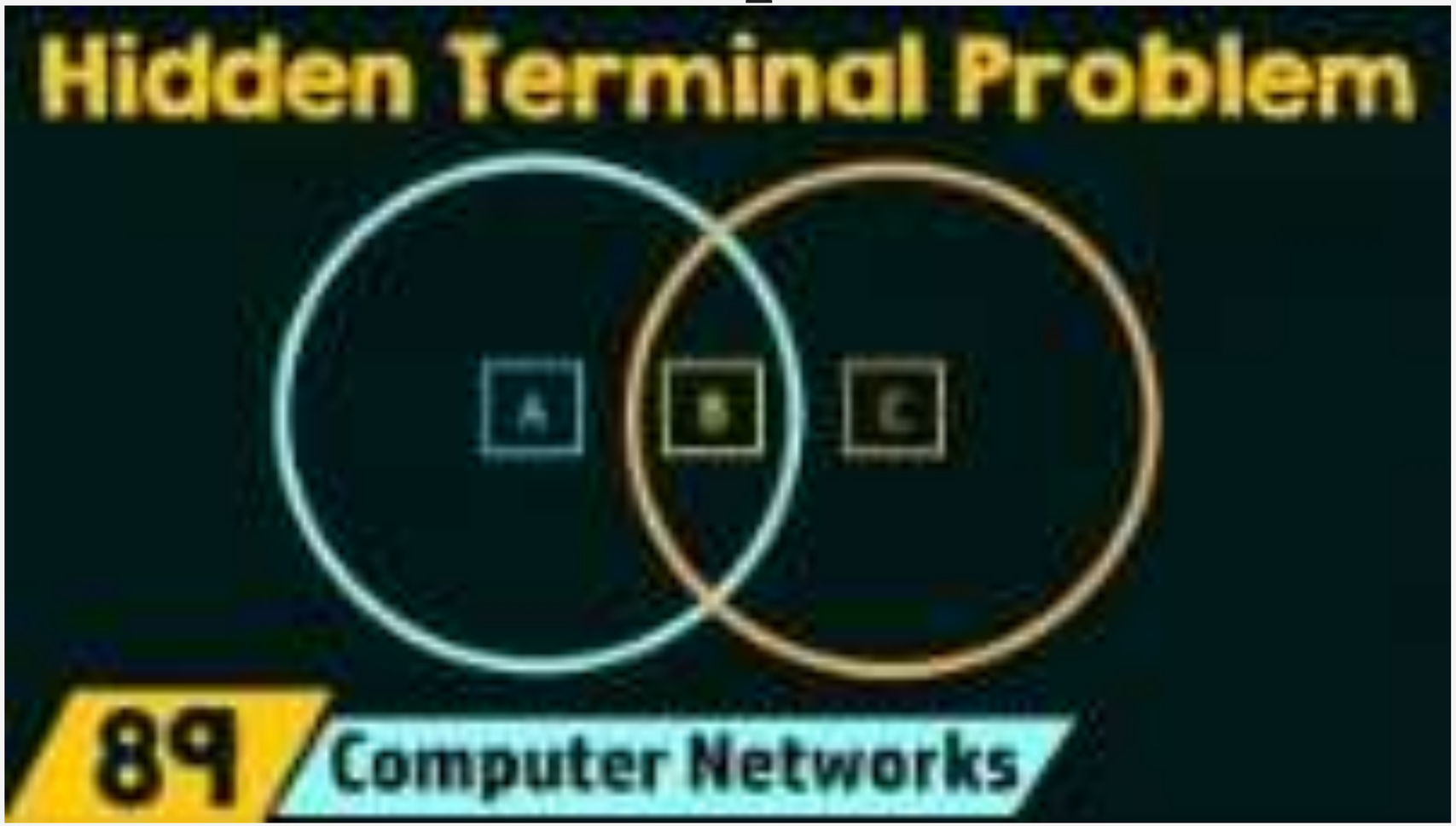
Hidden and Exposed Terminal

- But A cannot detect this collision at B and continues with its transmission.
- A is hidden for C and vice versa.

Hidden and Exposed Terminal



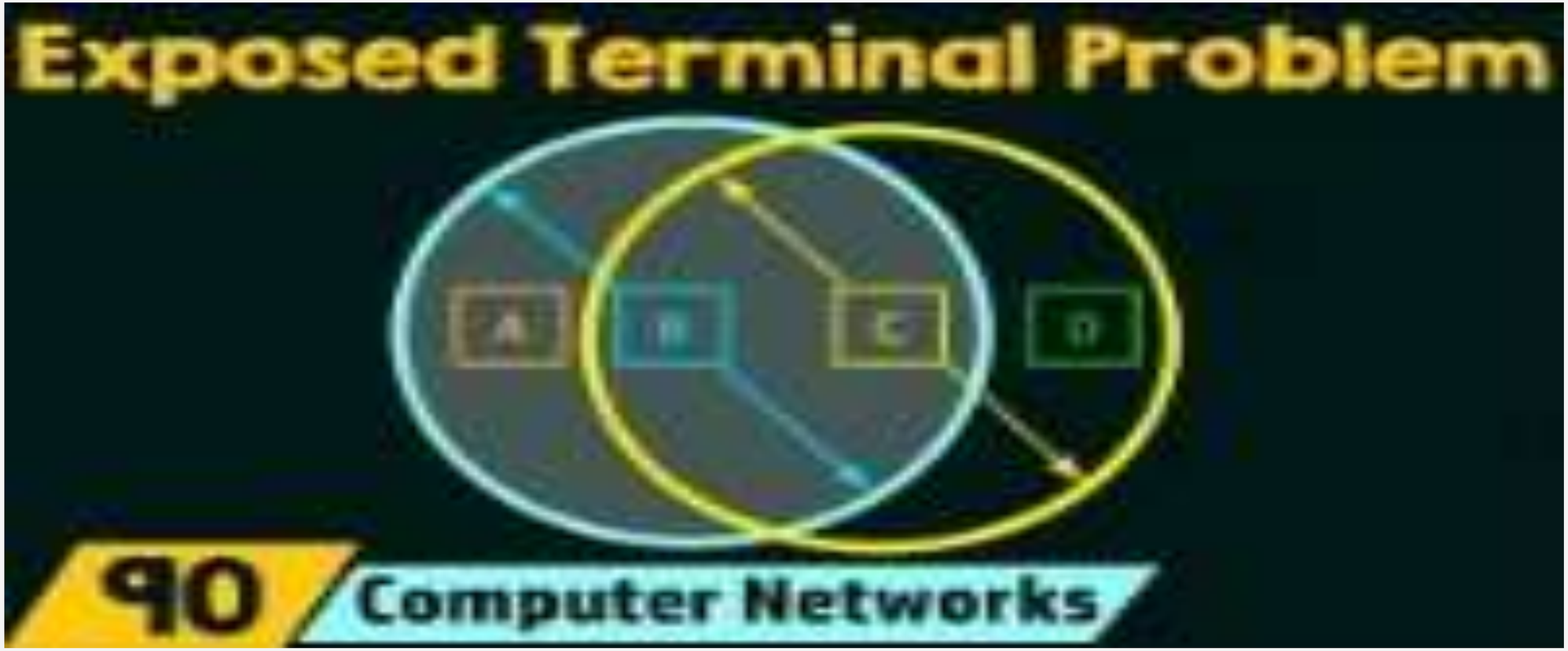
Hidden and Exposed Terminal



Exposed Terminal

- While hidden terminals causes collisions, the exposed terminal causes only unnecessary delay.
- B sends something to A and C wants to transmit data to some other mobile phone outside interference ranges of A and B.
- C senses the carrier and detects that the carrier is Busy(B’s signal).C postpones its transmission until it detects the medium as being idle again.
- A is outside the interference range of C,waiting is not necessary.

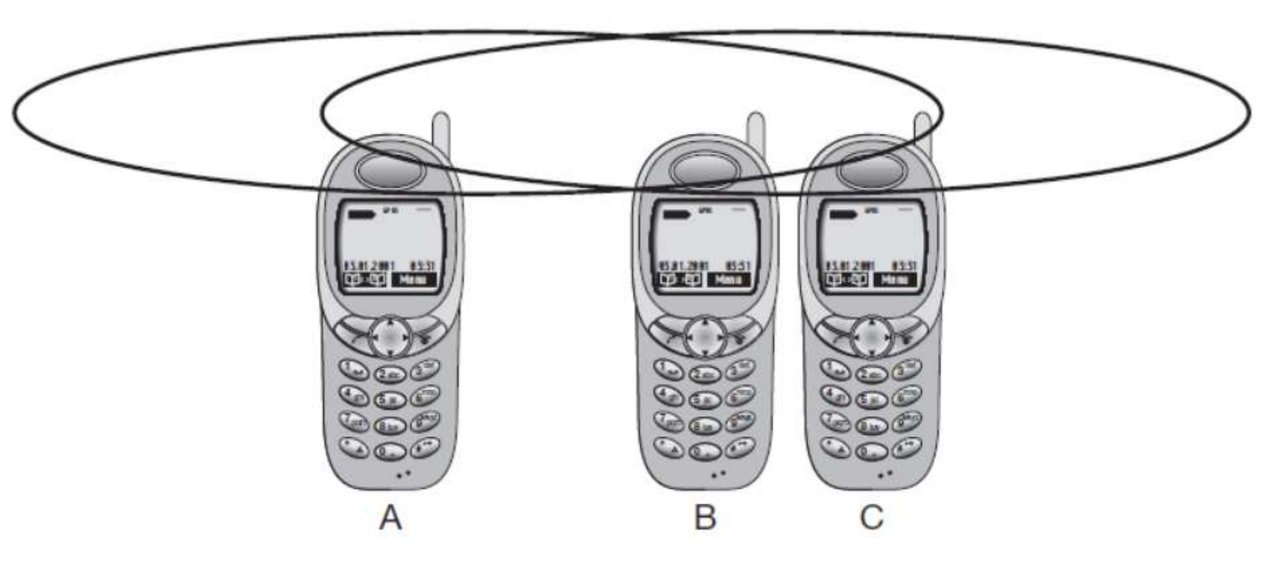
Exposed Terminal



Near and Far Terminal

- Consider there are three terminals A,B and C.
- Now A and B both are sending the signals to C.Signal strength decreases proportional to the square of the distance.
- The signal of B drowns out A’s Signal.So C cannot receive the A’s signal.Example:A person standing nearby always speak louder than the person further away.
- So precise power control is needed to receive all senders with the same strength.

Near and Far Terminal



SDMA

- Space division multiple access is used for allocating a separated space to users in wireless networks.
- A typical application involving assigning an optimal base station to a mobile phone user.
- The mobile phone may receive several base stations with different quality.
- A MAC algorithm could decide which base station is best,taking into account which frequencies (FDM),time slots(TDM)or code(CDM).

SDMA

- SDMA is never used in isolation but always in combination with one or more schemes.

- The basis for the SDMA algorithm is formed by cells and sectorized antennas which constitute the infrastructure implementing space division multiplexing.

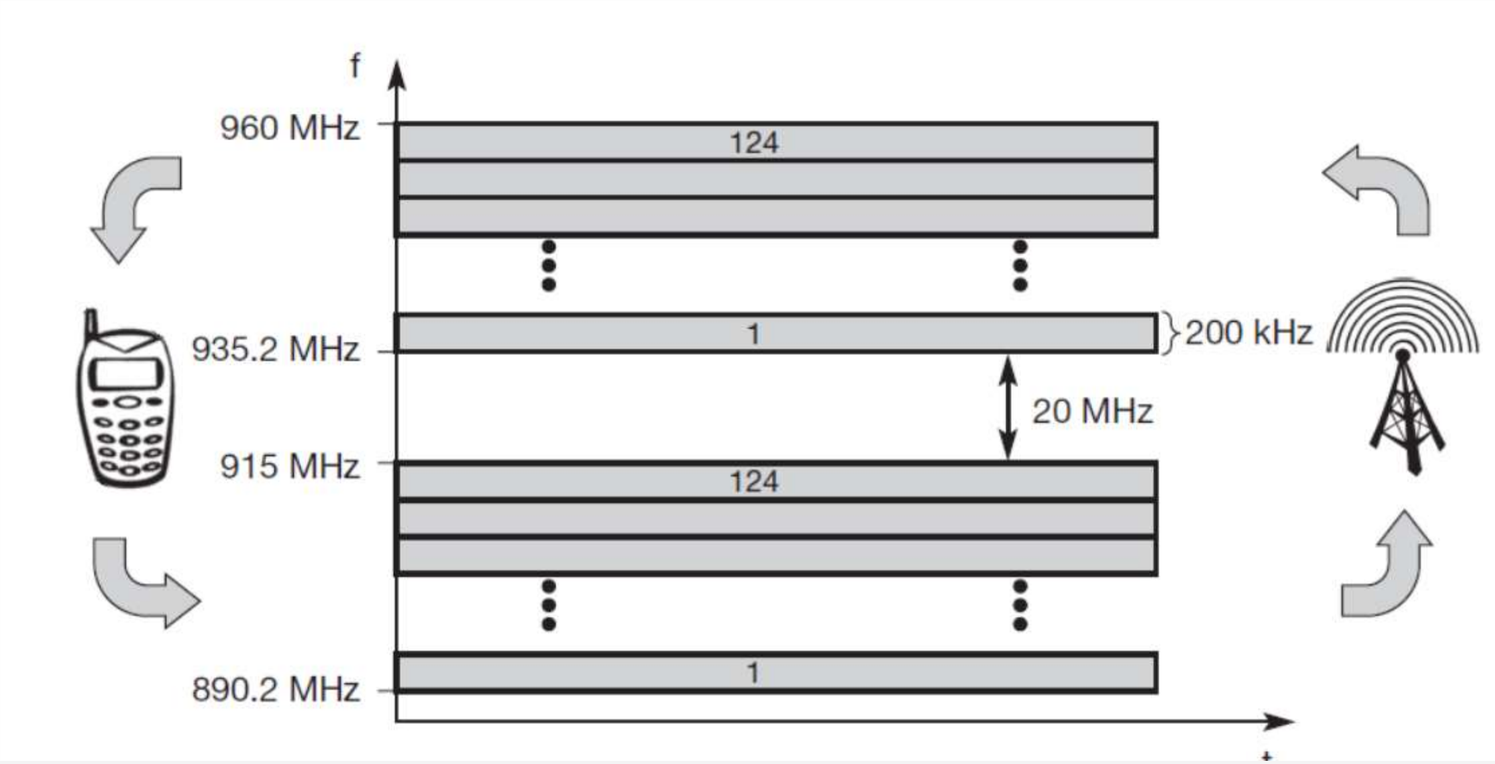
FDMA

- Frequency division multiple access (FDMA) comprises all algorithms allocating frequencies to transmission channels according to the frequency division multiplexing (FDM) scheme.
- Allocation can be either fixed or dynamic.
- FDM is often used for simultaneous access to the medium by base station and mobile station in cellular networks.
- The two partners establish a duplex channel ,i.e., a channel that allows for simultaneous transmission in both directions.

FDMA

- The two directions ,mobile station to base station and vice versa are now separated using different frequencies.
- This scheme is then called frequency division duplex(FDD).
- Both partners have to know their frequencies in advance; they cannot just listen into the medium.
- The two frequencies are also known as uplink i.e., from mobile station to base station and downlink from base station to mobile station.

FDMA



FDMA

- The basic frequency allocation scheme for GSM is fixed and regulated by national authorities.
- All uplinks use the band between 890.2 and 915 MHZ,all downlinks use 935.2 to 960 MHZ.
- According to FDMA,the base station ,shown on the right side ,allocates a certain frequency for up and downlink to establish a duplex channel with a mobile phone.
- The uplink and downlink have a fixed relation.

FDMA

- The base station selects the channel.
- Each channel uplink and downlink has a bandwidth of 200 kHz.

TDMA

- Compared to FDMA,time division multiple access(TDMA) offers a much more flexible scheme, which comprises all technologies that allocate certain time slots for communication i.e., controlling TDM.

- Now tuning into a certain frequency is not necessary i.e, the receiver can stay at the same frequency the whole time.

- Listening to different frequencies at the same time is quite difficult ,but listening to many channels separated in time at the same frequency is simple .

TDMA

- Almost all MAC schemes for wired networks work according to this principle,e.g.,Ethernet, Token Ring, ATM etc.
- Synchronization between the sender and receiver is achieved in the time domain.
- Again this can be done by using a fixed pattern similar to FDMA techniques i.e., allocating certain time slot for channels, or by using a dynamic allocation scheme.

TDMA

- Dynamic allocation scheme require an identification for each transmission (e.g. .,sender address)or the transmission has to be announced before hand.

Fixed TDMA

- The simplest algorithm for using TDM is allocating time slots for channels in a fixed pattern .This results in a fixed bandwidth.
- These patterns guarantee a fixed delay –one can transmit ,e.g., every 10 ms as this is the case for standard DECT (Digital European Cordless Telephone)systems.
- MAC is quite simple ,as the only crucial factor accessing the reserved time slot at the right moment.
- If this synchronization is assured ,each mobile station knows its turn and no interference will happen.

Fixed TDMA

- The fixed pattern can be assigned by the base station ,where competition between different mobile stations that want access the medium is solved.

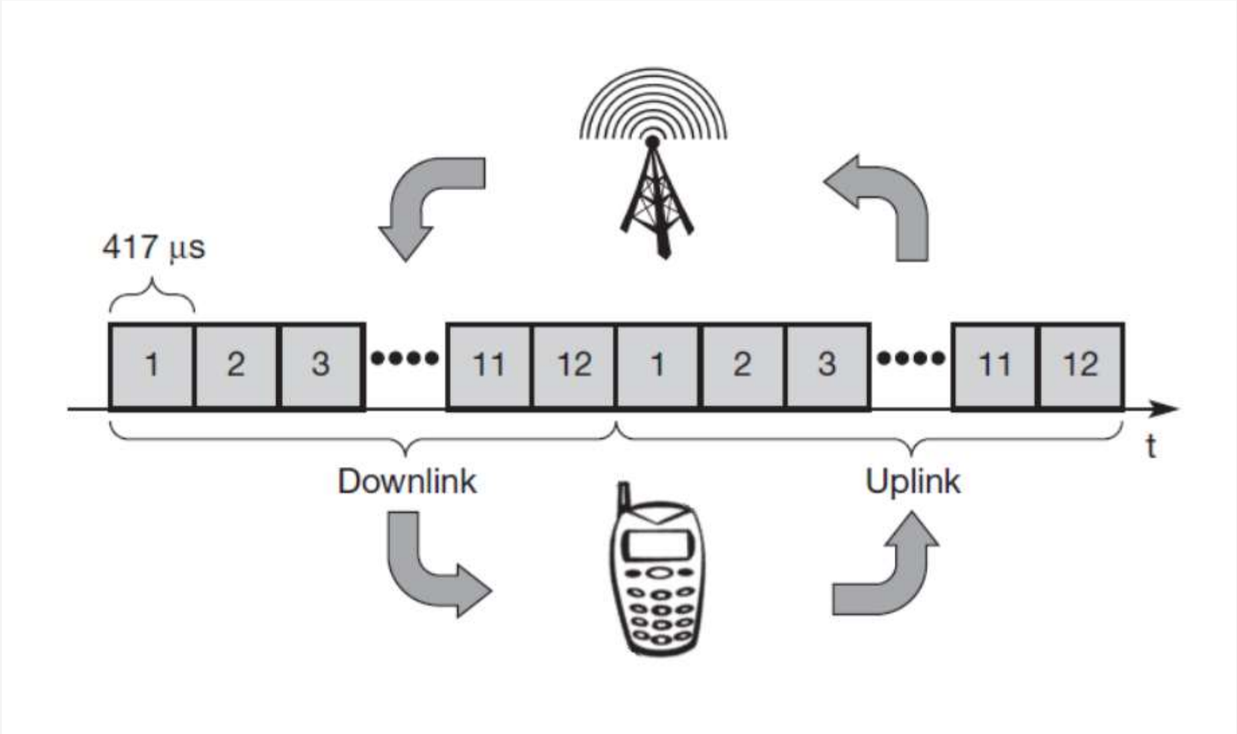
- Assigning different slots for uplink and downlink using the same frequency is called time division duplex.

Fixed TDMA

- The below figure shows how these fixed TDM patterns are used to implement multiple access and a duplex channel between a base station and a mobile station.

- As shown in the figure, the base station uses one out of 12 slots for the downlink, whereas the mobile station uses one out of 12 different slots for the uplink.

Fixed TDMA



Fixed TDMA

- Uplink and downlink are separated in time
- Up to 12 different mobile stations can use the same frequency without interference using this scheme.
- Each connection is allotted own up and downlink pair.
- In the above example which is the standard case for the DECT cordless phone system,the pattern is repeated every 10 ms ,i.e.,each slot has a duration of 417Ms.

Fixed TDMA

- This repetition guarantees access to the medium every 10 MS, independent of any other connections.
- DECT can at least allocate asymmetric bandwidth, this general scheme still wastes a lot of bandwidth. It is too static ,too flexible for data communication.
- In this case connection less demand oriented TDMA schemes can be used.

Fixed TDMA

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Classical Aloha

- A scheme which was invented at the university of Hawaii and was used in the ALOHANET for wireless connection of several stations.
- Aloha neither coordinates medium access nor does it resolve contention on the mac layer.
- Instead each station can access the medium at any time.
- This is a random access scheme, without a central arbiter controlling access and without coordination among the stations.

Classical Aloha

- If two or more stations access the medium at the same time ,a collision occurs and the transmitted data is destroyed.
- Resolving this problem is left to higher layers(e.g retransmission of data)
- The simple aloha works fine for a light load and does not require any complicated access mechanisms.
- On the classical assumption that data packet arrival follows a poisson distribution ,maximum throughput is achieved for an 18 per cent load.

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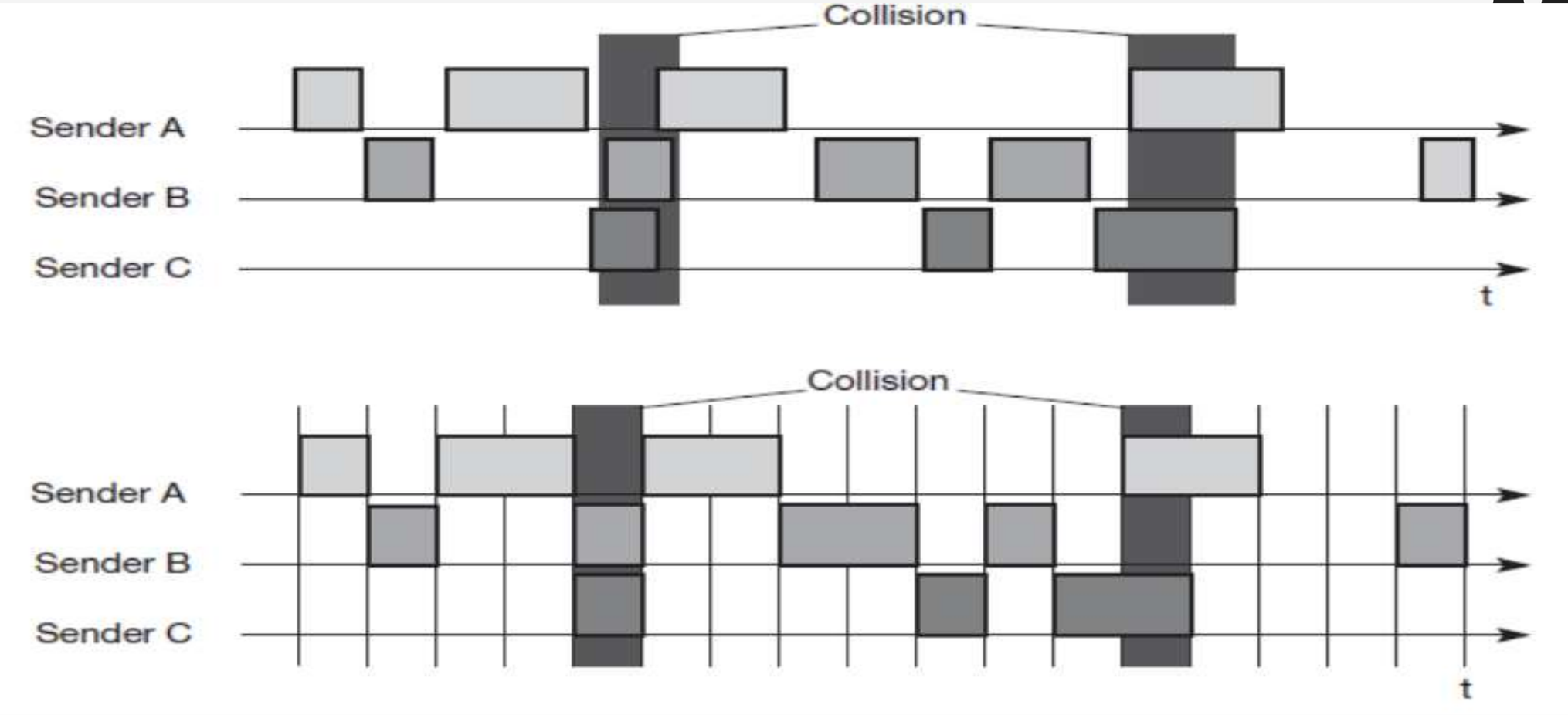
Classical Aloha



Slotted Aloha

- The first refinement of the classical aloha scheme is provided by the introduction of time slots (slotted Aloha).
- In this case, all senders have to be synchronized ,transmission can only start at the beginning of a time slots.
- Still, access is not coordinated.
- Under the assumption stated above, the introduction of slots raises the throughput from 18 per cent to 36 per cent i.e., slotting doubles the throughput.

Carrier Sense Multiple Access

- One improvement to the basic aloha is sensing the carrier before accessing the medium.
- Sensing the carrier and accessing the medium only if the carrier is idle decreases the probability of a collision.
- But, as already mentioned in the introduction ,hidden terminals cannot be detected.
- If a hidden terminal transmits at the same time as another sender ,a collision might occur at the receiver.This basic scheme is still used in many wireless LANs.

Carrier Sense Multiple Access

- Several versions of CSMA exists.
- In **non-persistent CSMA**, stations sense the carrier and start sending immediately if the medium is idle.
- If the medium is busy, the station pauses a random amount of time before sensing the medium again and repeating this pattern.
- In p-persistent CSMA systems nodes also sense the medium, but only transmit with a probability of p,wit the station deferring to the next slot with the probability 1-p,i.e.,access is slotted in addition.

Carrier Sense Multiple Access

- In 1-persistent CSMA systems,all stations wishing to transmit access the medium at the same time ,as soon as it becomes idle.
- This will cause many collisions if many stations wish to send and block each other.
- To create some fairness for stations waiting for a longer time, backoff alogorithms can be introduced ,which are sensitive to waiting time as this is done for standard Ethernet.

Carrier Sense Multiple Access

- CSMA with collision avoidance (CSMA/CA)is one of the access schemes used in wireless LANs following the standard IEEE 802.11

Demand Assigned Multiple Access

- A general improvement of Aloha access systems can also be achieved by reservation mechanisms and combinations with some (fixed) TDM patterns.
- These schemes typically have a reservation period followed by a transmission period.
- During the reservation period, stations can reserve future slots in the transmission period.

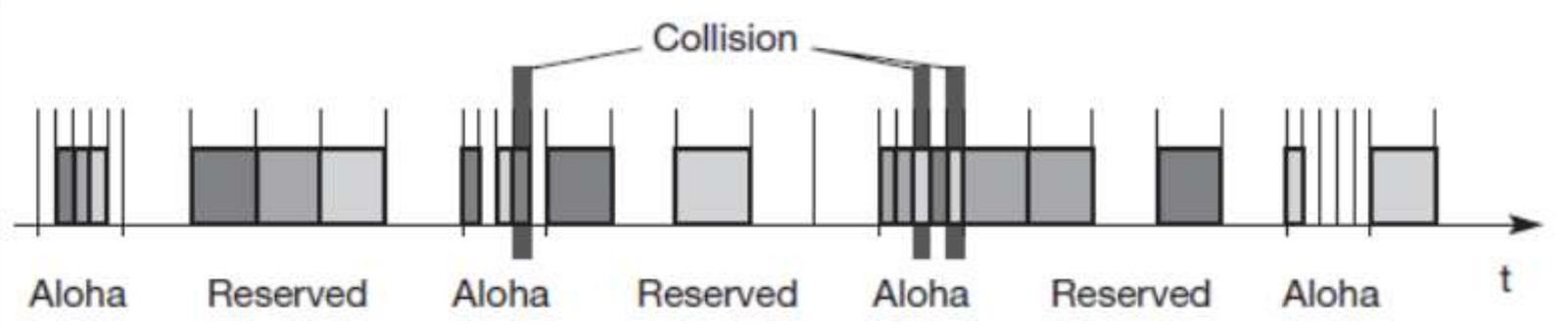
Demand Assigned Multiple Access

- While depending on the scheme collision may occur during the reservation period ,the transmission period can then be accessed without collision .
- Alternatively, the transmission period can be split into periods with and without collision.
- In general these schemes cause a higher delay under a light load (first the reservation has to take place),but allow higher throughput due to less collisions.

Demand Assigned Multiple Access

- One basic scheme is demand assigned multiple access (DAMA) also called reservation Aloha, a scheme typical for satellite systems.
- DAMA has two modes.
- During a contention phase following the slotted Aloha scheme ,all stations can try to reserve future slots.
- Collision during the reservation phase do not destroy data transmission ,but only the short requests for data transmission.

Demand Assigned Multiple Access



PRMA

- In PRMA,slots can be reserved implicitly according to the following scheme.
- A certain number of slots forms a frame.
- The frame is repeated in time i.e., a fixed TDM pattern is applied.
- A base station, which could be satellite, now broadcasts the status of each slot to all mobile stations.

PRMA

- All stations receiving this vector will then know which slot is occupied and which slot is currently free.
- A successful transmission of data is indicated by the station’s name.
- All stations wishing to transmit can now compete for this free slot in Aloha fashion.
- The already occupied slots are not touched.

PRMA

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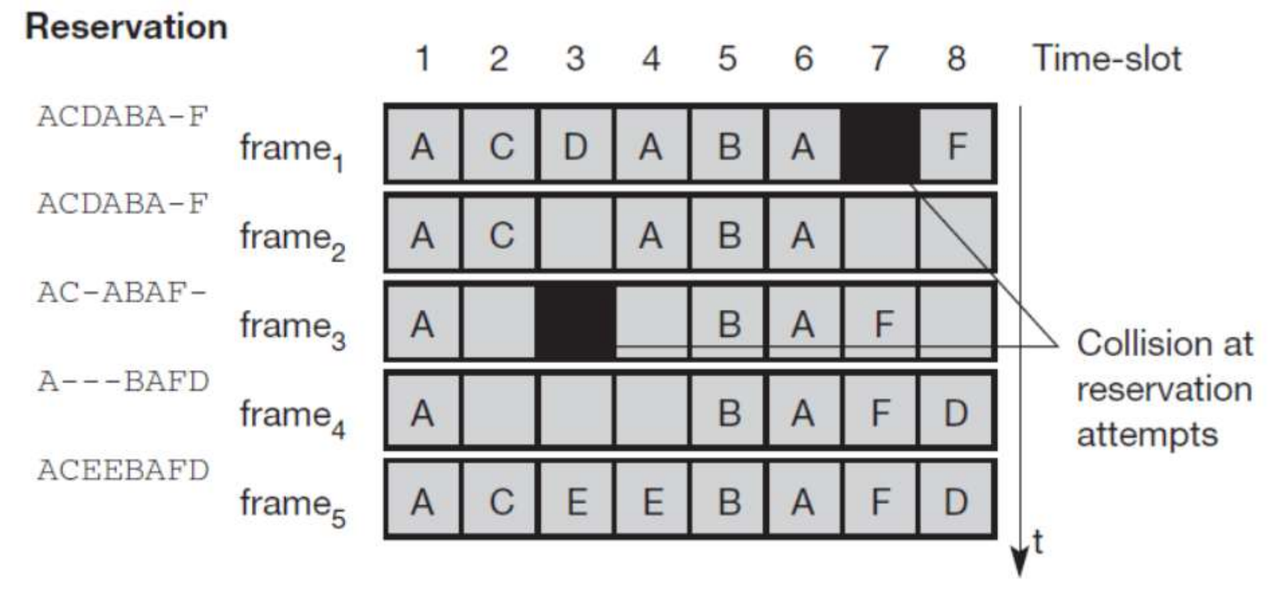
PRMA

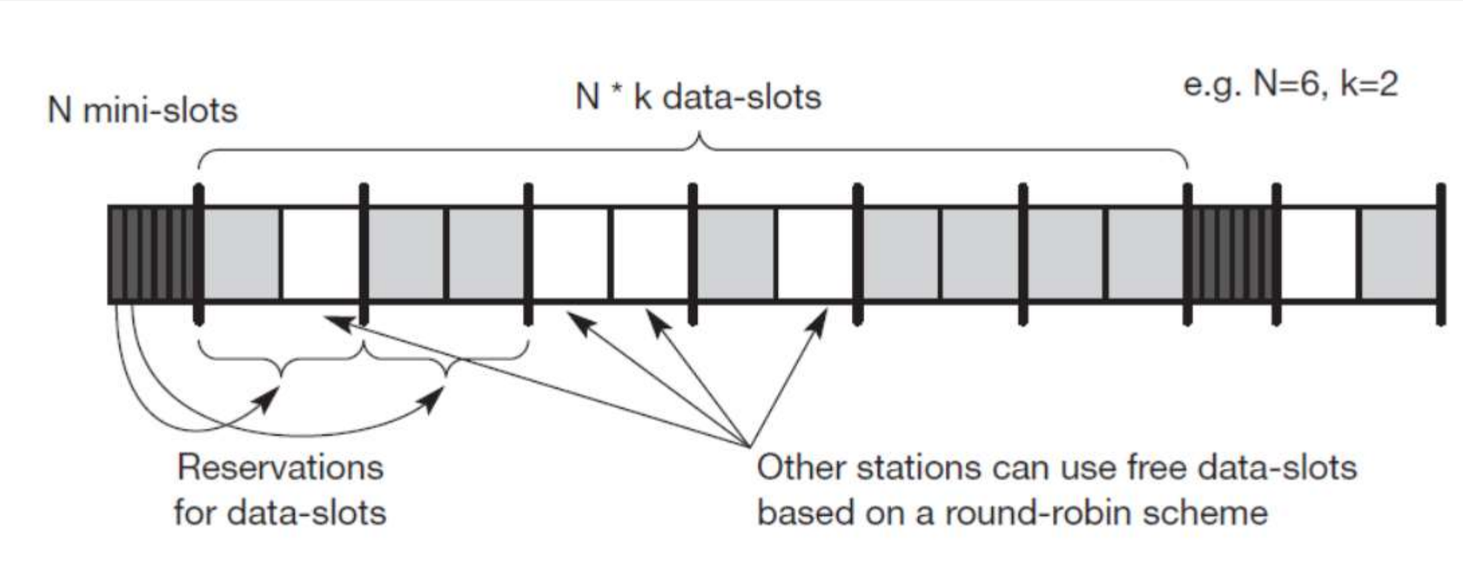

Reservation
1 2 3 4 5 6 7 8 Time-slot
ACDABA-F
frame1
A C D A B A F
ACDABA-F
frame2
A C A B A
AC-ABAF-
frame3
A B A F
A---BAFD
frame4
A B A F D
ACEEBAFD
frame5
A C E E B A F D
Collision at reservation attempts
t

Reservation TDMA

- An even more fixed pattern that still allows some random access is exhibited by reservation TDMA.
- In a fixed TDM scheme N mini-slots followed by N*K data slots form a frame that is repeated.
- Each station is allotted its own mini slot and can use it to reserve up to k data slots.
- This guarantees each station a certain bandwidth and a fixed delay.

Reservation TDMA

Other station can now send data in unused data slots.



Multiple Access with Collision Avoidance

- **Multiple access with collision avoidance (MACA)** presents a simple scheme that solves the hidden terminal problem, does not need a base station ,and is still a random access Aloha scheme-but with dynamic reservation.

- MACA uses short signaling packets for collision avoidance.

- **-RTS(request to send):**A sender request the right to send from a receiver with a short RTS packet before it sends a data packet.

Multiple Access with Collision Avoidance

-CTS(clear to send): The receiver grants the right to send as soon as it is ready to receive .

Signaling packets contain

-Sender address
-Receiver address
-packet size

Multiple Access with Collision Avoidance-Hidden Terminal

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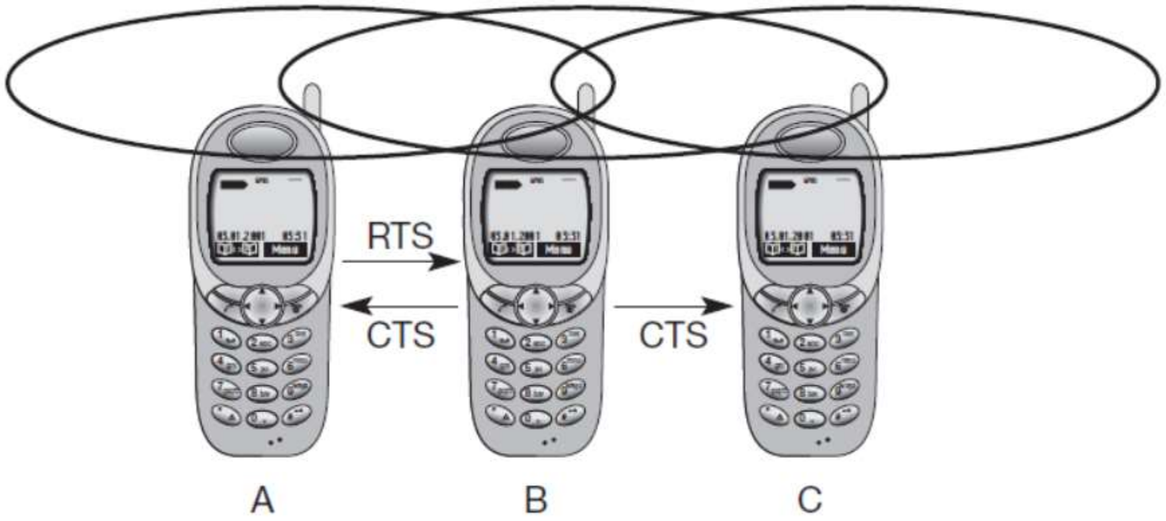

Multiple Access with Collision Avoidance-Exposed Terminal

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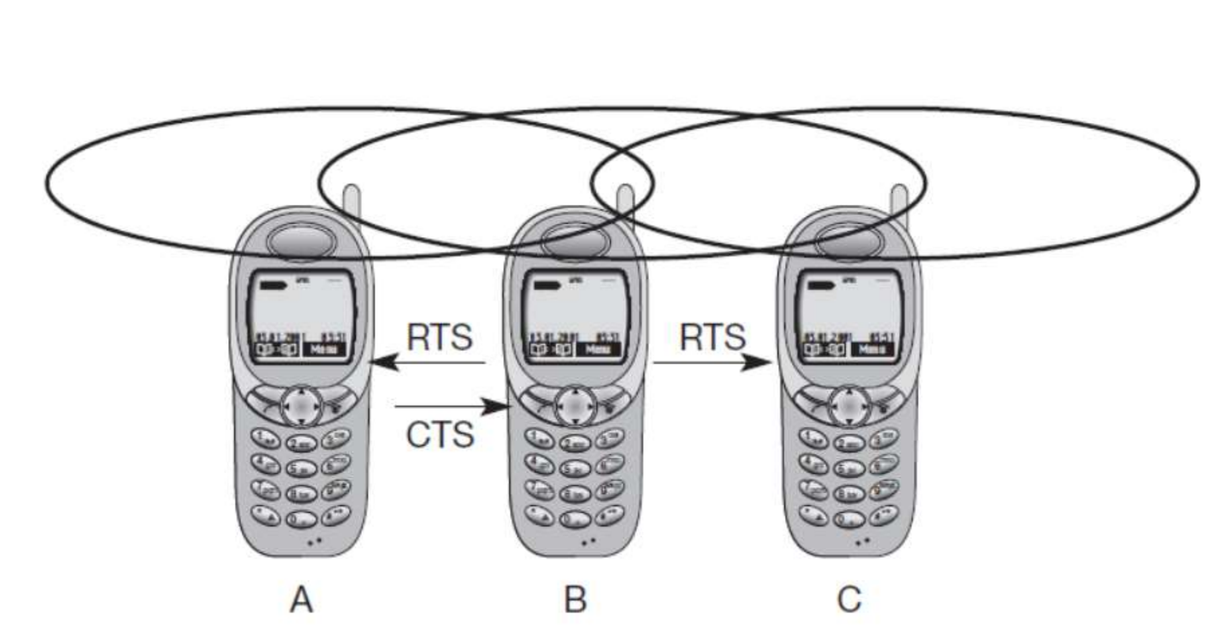

Multiple Access with Collision Avoidance

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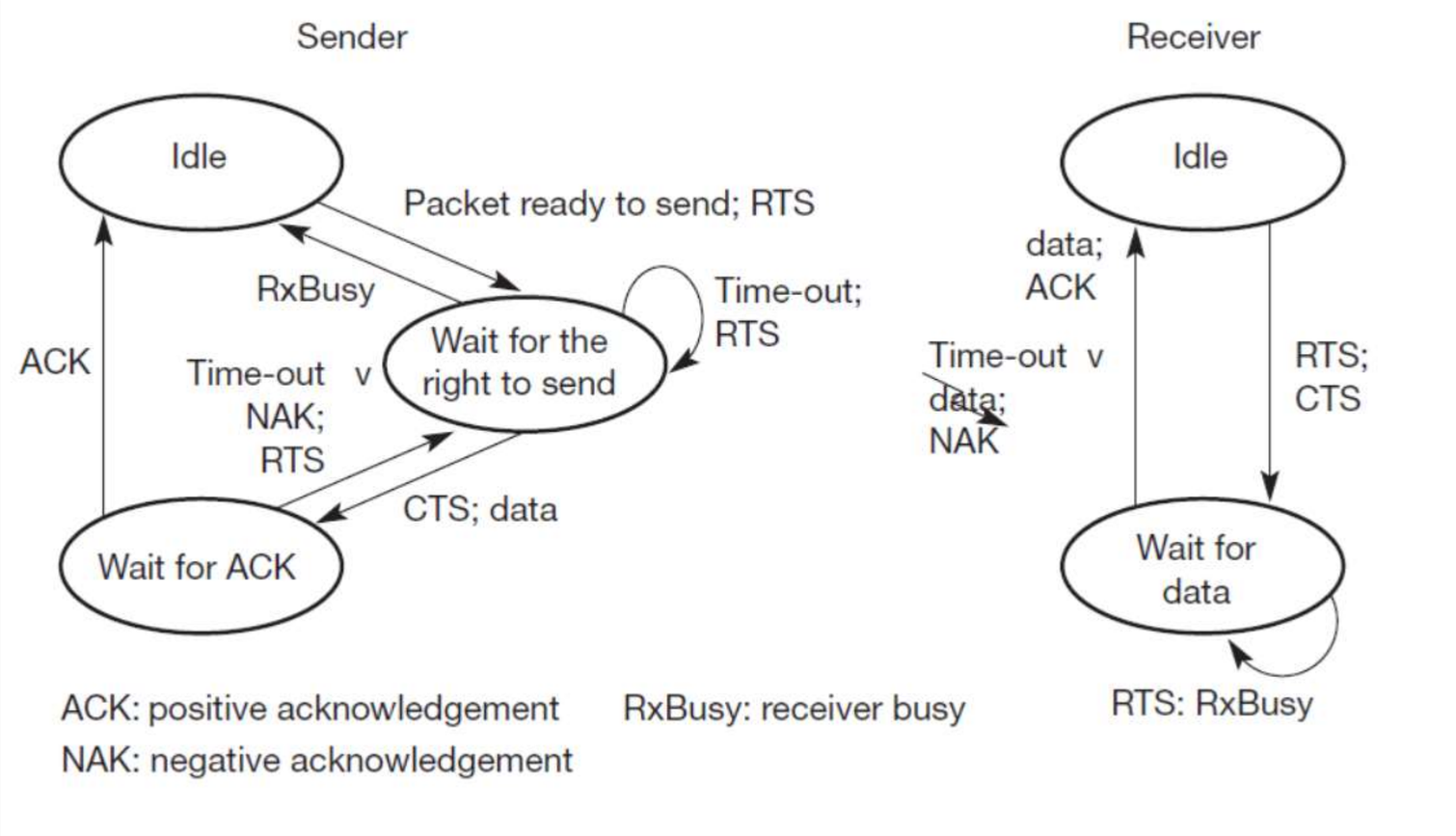


Polling

- Where one station is to be heard by all others ,polling schemes can be applied.
- Polling is a strictly centralized scheme with one master station and several slave stations.
- The master can poll the slaves according to many schemes: round robin, randomly ,according to reservations etc.…,
- The master could also establish a list of stations wishing to transmit during a contention phase.

Polling

- After this phase, the station polls each station on the list.
- Similar schemes are used e.g., in the Bluetooth wireless LAN and as one possible access function in IEEE 802.11 systems.

Inhibit Sense Multiple Access

- This scheme, which is used for the packet data transmission service Cellular Digital Packet Data (CDPD) in the AMPS mobile phone system, is also known as digital sense multiple access(DSMA).

- Here, the base station only signals a busy medium via a busy tone(called BUSY/IDLE indicator)on the downlink.

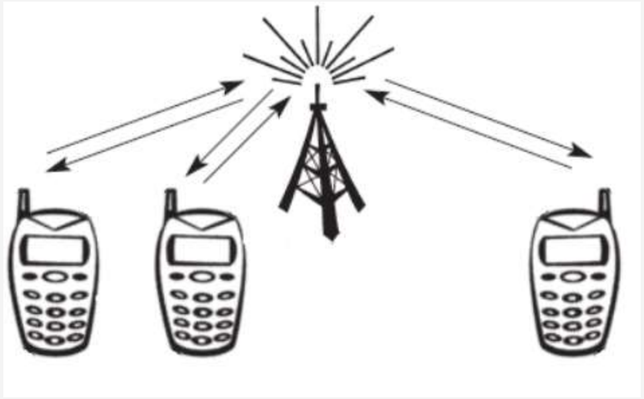
- After the busy tone stops, accessing the uplink is not coordinated any further.

Inhibit Sense Multiple Access

- The base station acknowledges successful transmissions , mobile station detects a collision only via the missing positive acknowledgement.

- In case of collisions, additional back-off and retransmission mechanisms are implemented.

Inhibit Sense Multiple Access



Code Division Multiple Access

- Codes with certain characteristics can be applied to the transmission to enable the use of code division multiplexing(CDM).
- Code division multiple access(CDMA) systems use exactly these codes to separate different users in code space and to enable access to a shared medium without interference.
- A code for a certain user should have a good autocorrelation and should be orthogonal to other codes.

Code Division Multiple Access

- Two vectors are called orthogonal if their inner product is 0,as is the case for the two vectors (2,5,0) and (0,0,17): (2,5,0)*(0,0,17)=0+0+0=0.
- But also vectors like (3,-2,4) and (-2,3,3) are orthogonal: (3,-2,4)*(-2,3,3)=-6-6+12=0
- The Barker code (+1,-1,+1,+1,-1,+1,+1,+1,-1,-1,-1),for example ,has a good autocorrelation, i.e., the inner product with itself is large.

Code Division Multiple Access

- Two senders ,A and B ,want to send data .
- CDMA assigns the following unique and orthogonal key sequences :
- key Ak =010011 for sender A, key Bk=110101for sender B.
- Sender A wants to send the bit Ad=1 ,sender B sends Bd=0.
- For example ,let us assume that we code a binary=0 as -1,a binary 1 as +1.
- We can then apply the standard addition and multiplication rules.

Code Division Multiple Access

- Both senders spread their signals using their key as chipping sequence
- Sender A then sends the signal

$$As = A_d * A_k = +1*(-1, +1, -1, -1, +1, +1) = (-1,+1, -1, -1, +1, +1)$$

- Sender B does the same with its data to spread the signal with the code:

$$Bs = B_d*B_k = -1*(+1, +1, -1, +1, -1, +1) = (-1, -1, +1, -1, +1, -1)$$

Code Division Multiple Access

• Both signals are then transmitted at the same time using the same frequency, so, the signals superimpose in space.

- Discounting interference from other senders and environmental noise from this simple example, and assuming that the signals have the same strength at the receiver, the following signal C is received at a receiver:

$$C = As + Bs = (-2, 0, 0, -2, +2, 0)$$

• The receiver now wants to receive data from sender A and, therefore, tunes in to the code of A, i.e., applies A's code for de-spreading:

$$C * Ak = (-2, 0, 0, -2, +2, 0) * (-1, +1, -1, -1, +1, +1) =$$

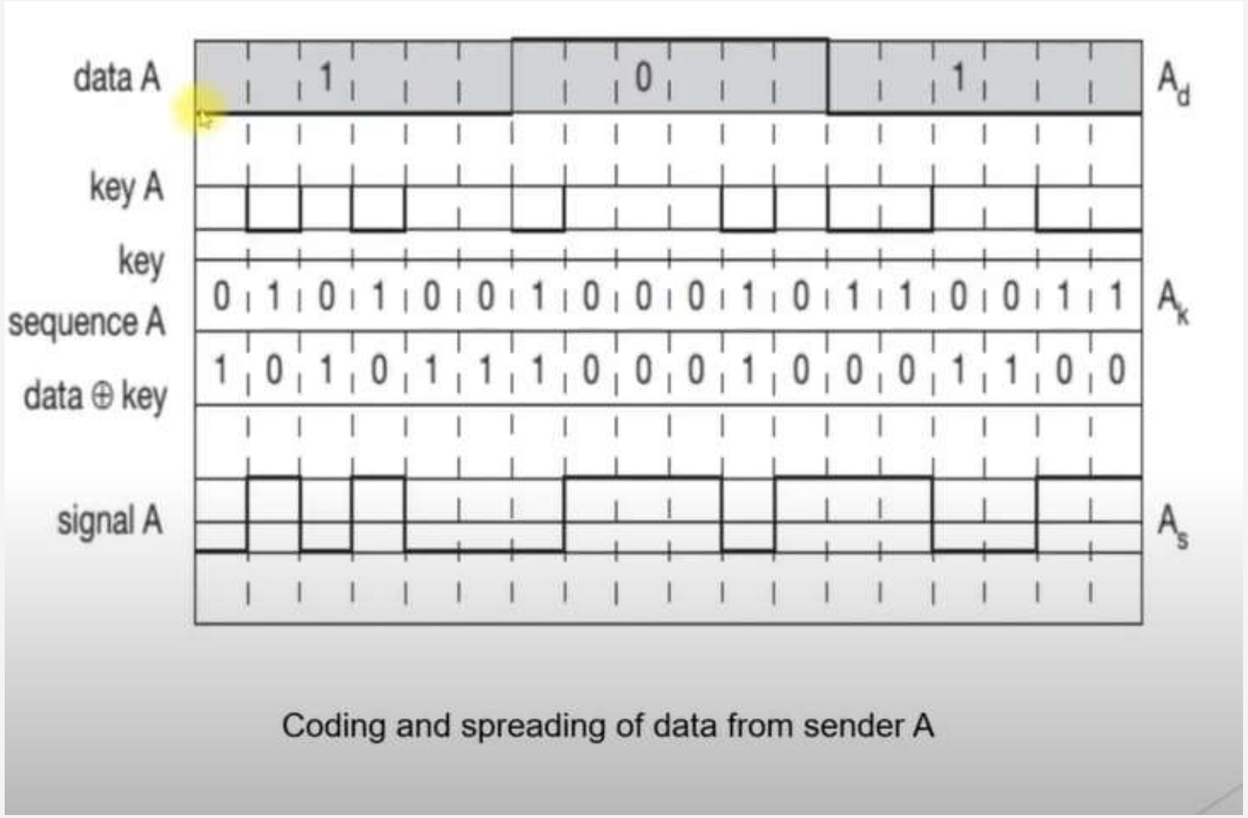
$$2 + 0 + 0 + 2 + 2 + 0 = 6 = \text{binary } 1$$

- Tuning in to sender B, i.e., applying B's code gives

$$C * Bk = (-2, 0, 0, -2, +2, 0) * (+1, +1, -1, +1, -1, +1) =$$

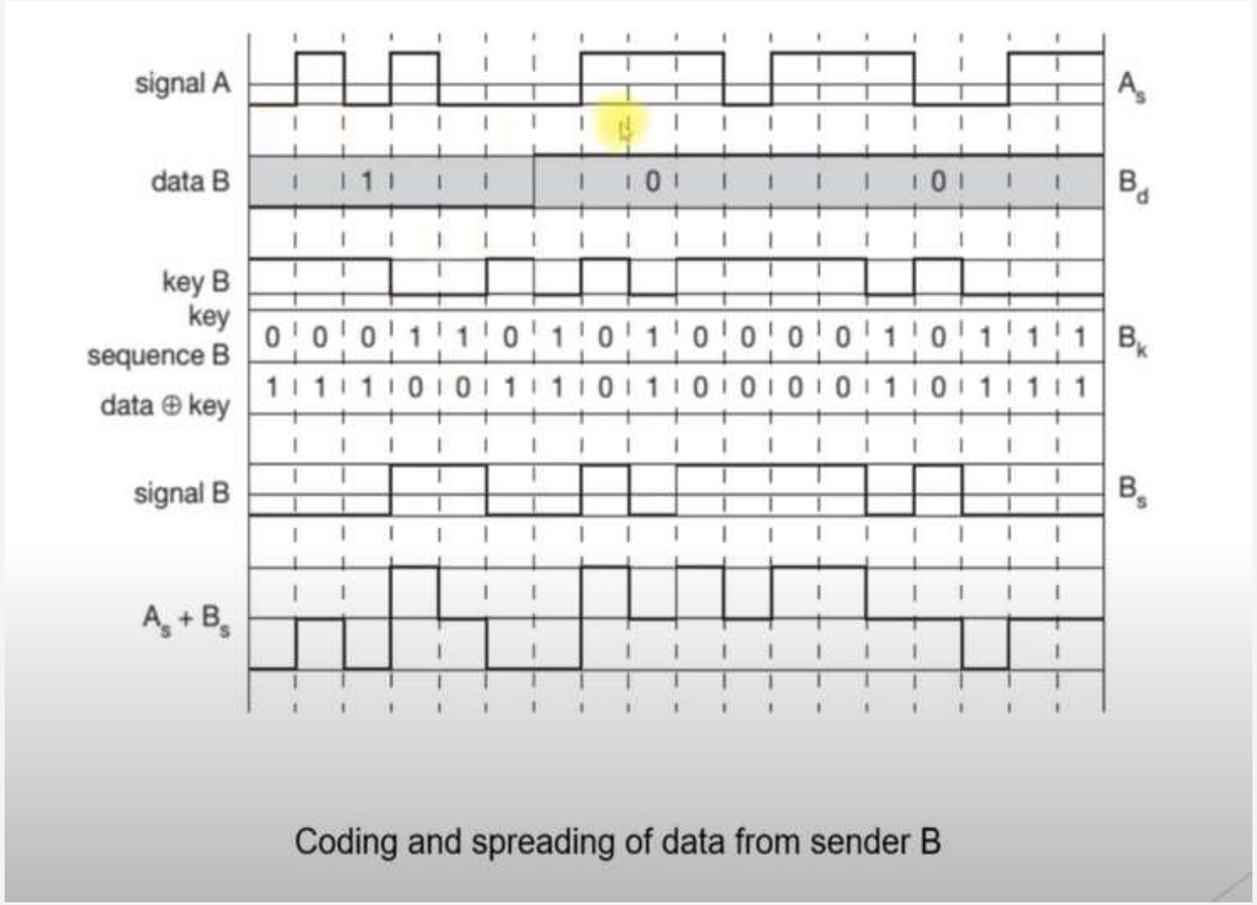
$$-2 + 0 + 0 - 2 - 2 + 0 = -6 = \text{binary } 0$$

Code Division Multiple Access



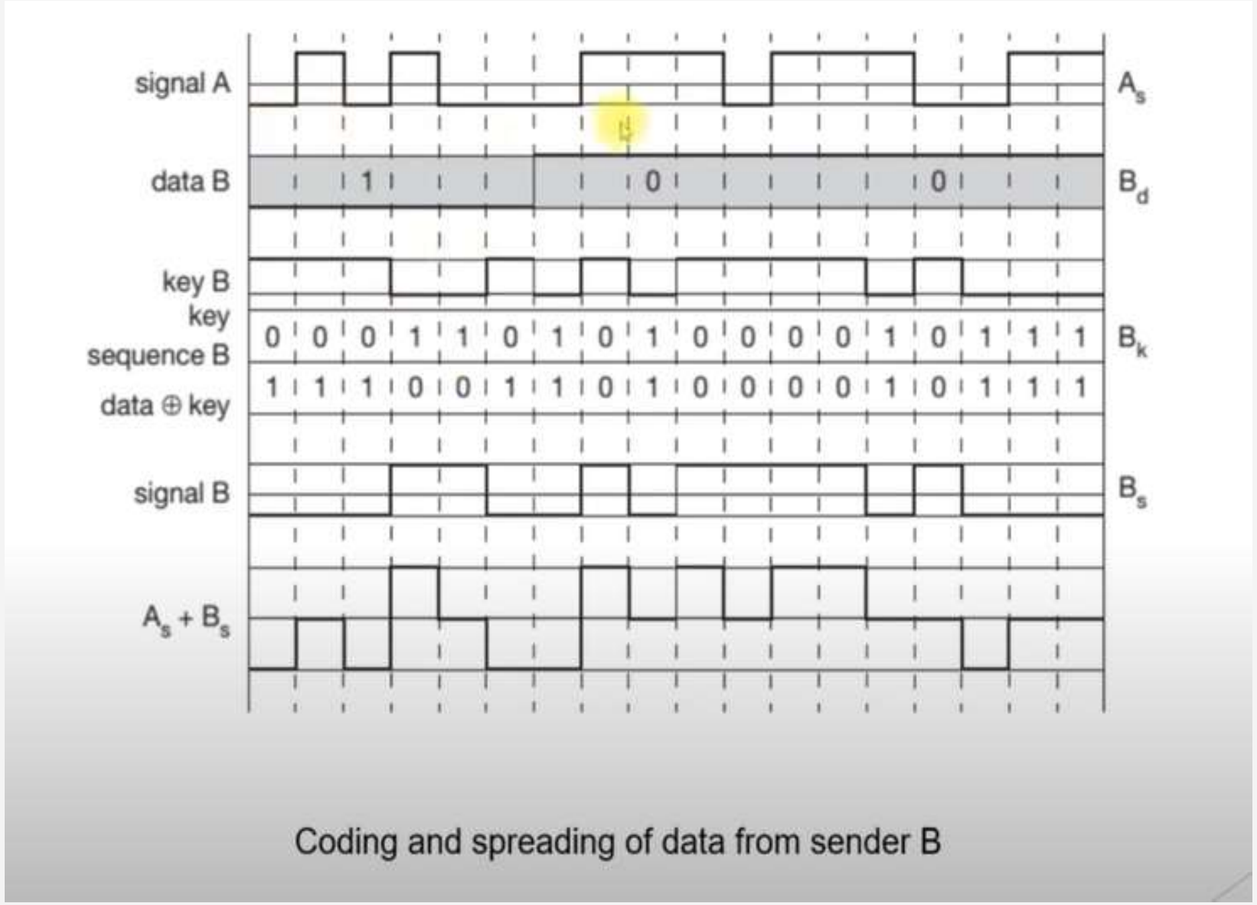
Coding and spreading of data from sender A

Code Division Multiple Access



Coding and spreading of data from sender B

Code Division Multiple Access



Coding and spreading of data from sender B

Code Division Multiple Access

Spread Aloha multiple access

- CDMA senders and receivers are not really simple devices.
- Communicating with n devices requires programming of the receiver to be able to decode n different codes.
- For mobile phone systems, a lot of the complexity needed for CDMA is integrated in the base stations.
- What happens if we combine the spreading of CDMA and the medium access of Aloha or, in other words, what if we use CDMA with only a single code, i.e., without CD?
- The resulting scheme is called spread Aloha multiple access (SAMA) and is a combination of CDMA and TDMA.

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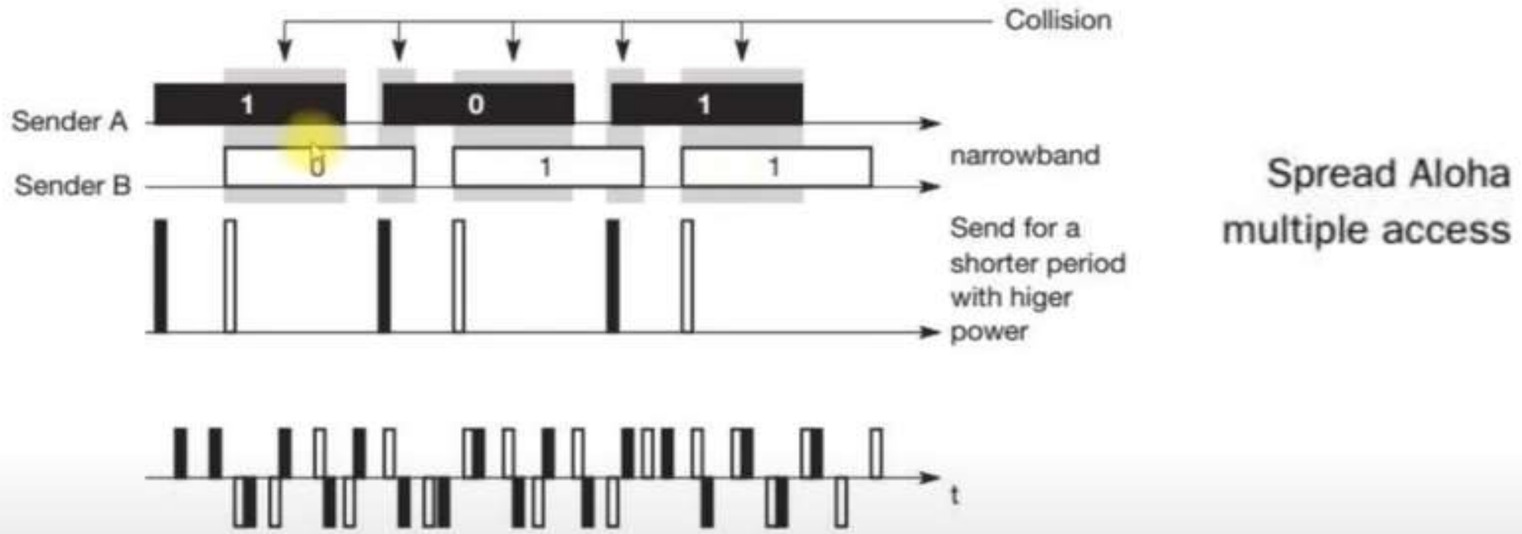
Code Division Multiple Access

- SAMA works as follows:

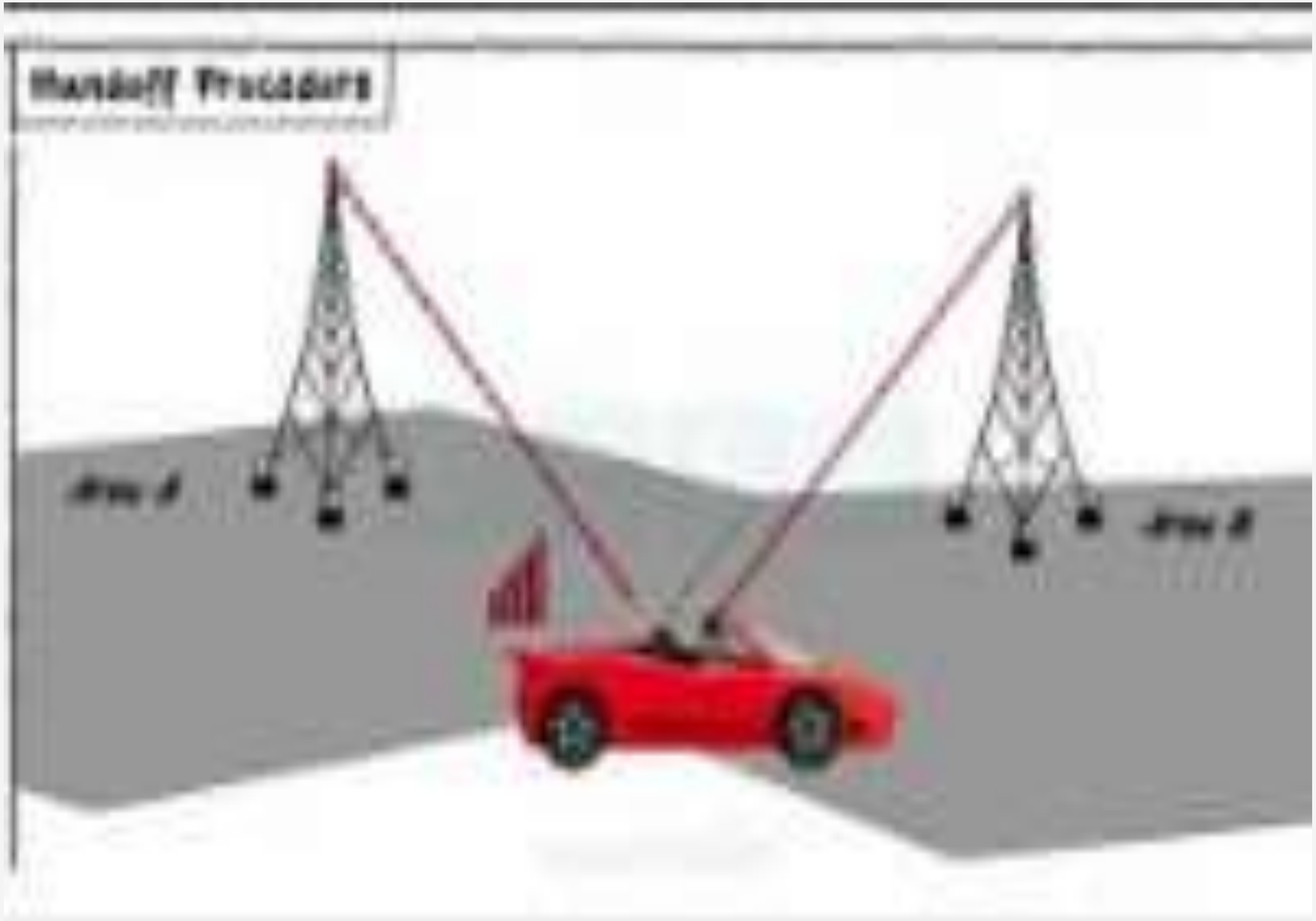


Spread Aloha multiple access

- Each sender uses the same spreading code. The standard case for Aloha access is shown in the upper part of the figure.

Code Division Multiple Access

- Sender A and sender B access the medium at the same time in their narrowband spectrum, so that all three bits shown cause a collision.
- The same data could also be sent with higher power for a shorter period as shown in the middle, but now spread spectrum is used to spread the shorter signals, i.e., to increase the bandwidth (spreading factor s = 6 in the example).
- Both signals are spread, but the chipping phase differs slightly.
- Separation of the two signals is still possible if one receiver is synchronized to sender A and another one to sender B.
- The signal of an unsynchronized sender appears as noise.


Handoff Procedure