UNIT I

Mobile Computing

- Ability to compute remotely while on the move
- Access information from anywhere and at anytime

Computing - capability to automatically carry out certain processing related to service invocations on a remote computer

Mobility – provides capability to change the location while communicating to invoke computing services at some remote computers

Adv:

- Tremendous flexibility it provides to the user
- User can move locally or even far away places and at the same time achieve what used to be performed while sitting in front of the desktop

Wired Networks	Mobile Networks
high bandwidth	low bandwidth
low bandwidth variability	high bandwidth variability
can listen on wire	hidden terminal problem
high power machines	low power machines
high resource machines	low resource machines
need physical access(security)	need proximity
low delay	higher delay
connected operation	disconnected operation

Mobile Computing	Wireless networking
Denotes accessing information and remote computational services while on the move	Provides the basic communication infrastructure necessary to make mobile computing possible
Based on wireless networking	Important ingredient of mobile computing

Mobile Computing

- Also requires the applications themselves (their design and development, and the hardware at the client and server sides)
- Mobile computing subsumes the area of wireless networking

Wireless networking

Replacing traditional networks because of the low setup time and low initial investment required to set up the wireless network

Various forms of wireless networks:

- WLANs (Wireless LANs)
- Mobile cellular networks
- PANs (Personal Area Networks)
- Ad hoc networks

Two basic types of Wireless networks:

1. **Extension of wired networks – uses fixed infrastructures** such as base stations to provide essentially single hop wireless communication with a wired network or a two-hop wireless cellular communication with another mobile

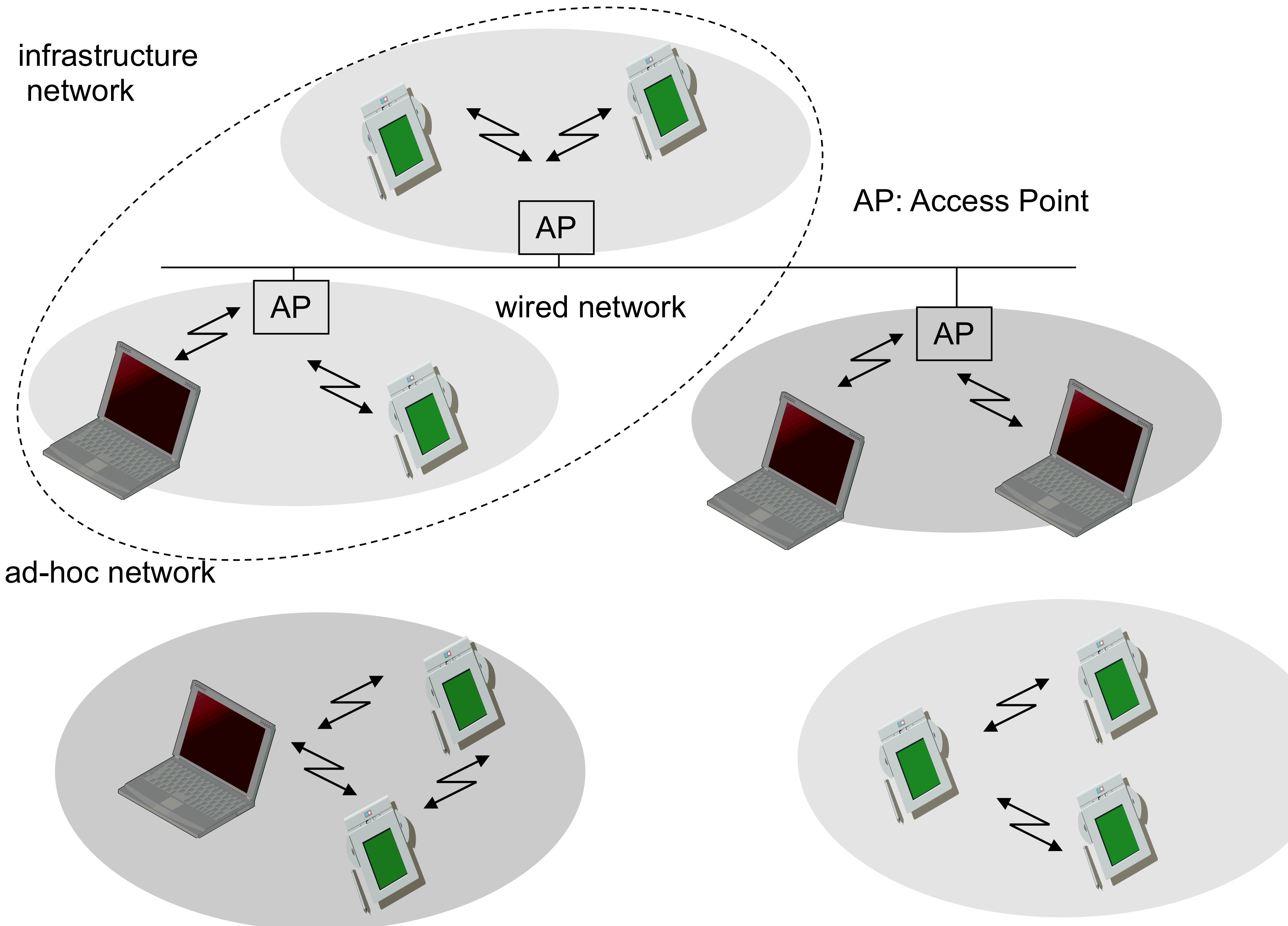
   One popular example of a fixed infrastructure wireless network is a wireless LAN (WLAN) – implements the IEEE 802.11 protocol.last hop is through the wireless medium

Access point - provides the last hop connectivity of the mobile nodes to a wired network and performs bridging between the wireless and the wired mediums

2. **Ad hoc network** – does not use any fixed infrastructure and is based on multi-hop wireless communication

   - infrastructureless network – communication between hosts occurs directly or via a few intermediate nodes that from the hops.

Comparison: infrastructure vs. ad-hoc networks



Wireless networking of various types of devices using **Bluetooth technology – to implement a PAN (Personal Area Network)known as piconets and ad hoc networks known as scatternets.**

- Universal radio interface for ad-hoc wireless connectivity
- Interconnecting computer and peripherals, handheld devices, PDAs, cell phones – replacement of IrDA
- Embedded in other devices, goal: 5€/device (2005: 40€/USB bluetooth)
- Short range (10 m), low power consumption, license-free 2.45 GHz ISM
- Voice and data transmission, approx. 1 Mbit/s gross data rate

Using wireless PAN a dynamic group of less than 255 devices can be made to communicate within area of less than 10 metre diameter

Adv of bluetooth technology:

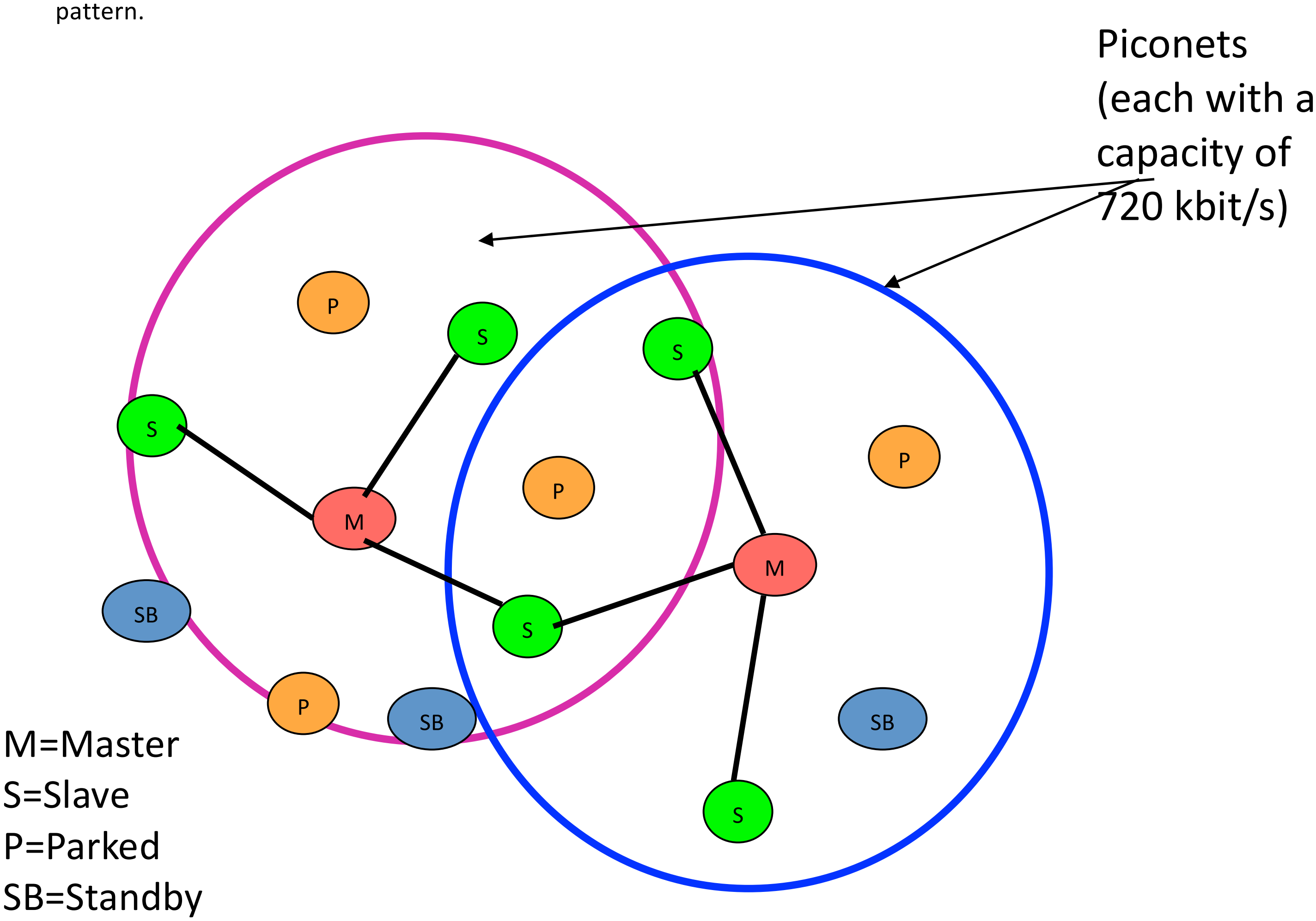
- To get rid of the mesh of wires required for interconnecting

Eg.Mouse, printer. Camera can communicate with computer using bluetooth tech.

Bluetooth connectivity among a set of devices is called a piconet.

Piconet

A piconet consists of two or more devices occupying the same physical channel (synchronized to a common clock and hopping sequence).It allows one *master* device to interconnect with up to seven active *slave* devices.The device which first establishes a piconet becomes master and others which discover the master become slaves in the piconetUp to 255 further slave devices can be inactive, or *parked*, which the master device can bring into active status at any time, but an active station must go into parked first.Collection of devices connected in an ad hoc fashion One unit acts as master and the others as slaves for the lifetime of the piconet Master determines hopping pattern, slaves have to synchronize Each piconet has a unique hopping pattern.



Participation in a piconet = synchronization to hopping sequence
Each piconet has one master and up to 7 simultaneous slaves (> 200 could be parked)
Slave units only respond to commands from the master – this allows Blutooth MAC to be simple, efficient and non-contention based.As a result, data transfer rates of upto 2.1Mbits is possible in a piconet

Scatternet

Linking of multiple co-located piconets through the sharing of common master or slave devices

- Devices can be slave in one piconet and master of another

- formed by various piconets within 100 m through a Bluetooth-enabled bridging device

Communication between piconets

Devices jumping back and forth between the piconets

Characteristics of mobile computing

- Ubiquity
- Location awareness:
- Adaptation
- Broadcast
- Personalization

Characteristics of Mobile Computing:

A computing environment is said to be “mobile”,when either the sender or receiver of information can be on the move while transmitting or receiving information.The following are some of the important characteristics of a mobile computer environment.

Ubiquity:
The dictionary meaning of ubiquity is present everywhere.In the context of mobile computing,ubiquity means the ability of a user to perform computations from anywhere and at anytime.E.g A business executive can receive business notifications and issue business transactions as long as he is in the wireless coverage area.

Location Awareness:
A hand held device equipped with global positioning system can transparently provide info about the current location of the user to a tracking station.Many applications,ranging from the strategic to personalized services require or get value additions by location based services.(Eg)A person travelling by road in a car,may need to find out a car maintanence service through mobile computing where an

application may show the nearby maintanence shop.A few other examples are traffic control,fleet management,emergency services etc.In a traffic control application,the density of traffic along various roads can be dynamically monitored and traffic can be directed appropriately to reduce congestions.In a fleet management application,the manager of a transport company can have up-to-date info regarding the position of it's fleet of vehicles,thus enabling him to plan accurately and provide accurate info to customers regarding the state of the consignments.Location awareness can also make emergency services more effective by directing the emergency service to the site of the call.

Adaptation:
Adaptation in the context of mobile computing implies the ability of a system to adjust to bandwidth fluctuation without inconviencing the user.In a mobile computing environment,adaptation is crucial because of intermittent disconnections and bandwidth fluctuations that can arise due to a number of factors such as handoff,obstacles,environmental noise etc.

Broadcast:
Due to the broadcast nature of the underlying communication network of a mobile comupting environment,efficient delivery of data can be made simultaneously to hundreds of mobile users.(Eg)All users at a specific location such as those near a railway station may be sent advertising information by a taxi service operator.

Personalization:
Services in a mobile environment can be easily personalized according to a user's profile.This is required to let the users easily avail information with their hand-held devices.(Eg)A mobile user may need only a certain type of information from specific sources.This can be easily done through personalization.

Mobile computing Applications

1. **Vehicles:**

Music, news, road conditions, weather reports, and other broadcastinfo are received via digital audio broadcasting (DAB) with 1.5 Mbit/s.

For personal commn, a universal mobile telecommunications system (UMTS) phone might be available offering voice and data connectivity with 384 kbit/s.

The current position of the car is determined via the global positioning system (GPS). Cars driving in the same area build a local ad-hoc network for the fast exchange of information in emergency situations or to help each other keep a safe distance.

In case of an accident, not only will the airbag be triggered, but the police and ambulance service will be informed via an emergency call to a service provider.

Buses, trucks, and trains are already transmitting maintenance and logistic information to their home base, which helps to improve organization (fleet management), and saves time and money.

2. Emergencies:

An ambulance with a high-quality wireless connection to a hospital cancarry vital information about injured persons to the hospital from the scene of the accident.

All the necessary steps for this particular type of accident can be prepared and specialists can be consulted for an early diagnosis.

Wireless networks are the only means of communication in the case of natural disasters such as hurricanes or earthquakes. In the worst cases, only decentralized, wireless ad-hoc networks survive.

3. Business:

Managers can use mobile computers say, critical presentations to majorcustomers. They can access the latest market share information. At a small recess, they can revise the presentation to take advantage of this information.

They can communicate with the office about possible new offers and call meetings for discussing responds to the new proposals. Therefore, mobile computers can leverage competitive advantages.

A travelling salesman today needs instant access to the company's database: to ensure that files on his or her laptop reflect the current situation, to enable the company to keep track of all activities of their travelling employees, to keep databases consistent etc.

With wireless access, the laptop can be turned into a true mobile office, but efficient and powerful synchronization mechanisms are needed to ensure data consistency.

4. Credit Card Verification:

At Point of Sale (POS) terminals in shops and

Supermarkets, **when customers use credit cards for transactions,** the intercommunication required between the bank central computer and the POS terminal, in order to effect **verification of the card usage**, can take place quickly and securely over cellular channels using a mobile computer unit.

This can speed up the transaction process and relieve congestion at the POS terminals.

5. Replacement of Wired Networks:

wireless networks can also be used to replace wirednetworks, e.g., remote sensors, for tradeshows, or in historic buildings.

Due to economic reasons, it is often impossible to wire remote sensors for weather forecasts, earthquake detection, or to provide environmental information.

Wireless connections, e.g., via satellite, can help in this situation.

Other examples for wireless networks are computers, sensors, or information displays in historical buildings, where excess cabling may destroy valuable walls or floors.

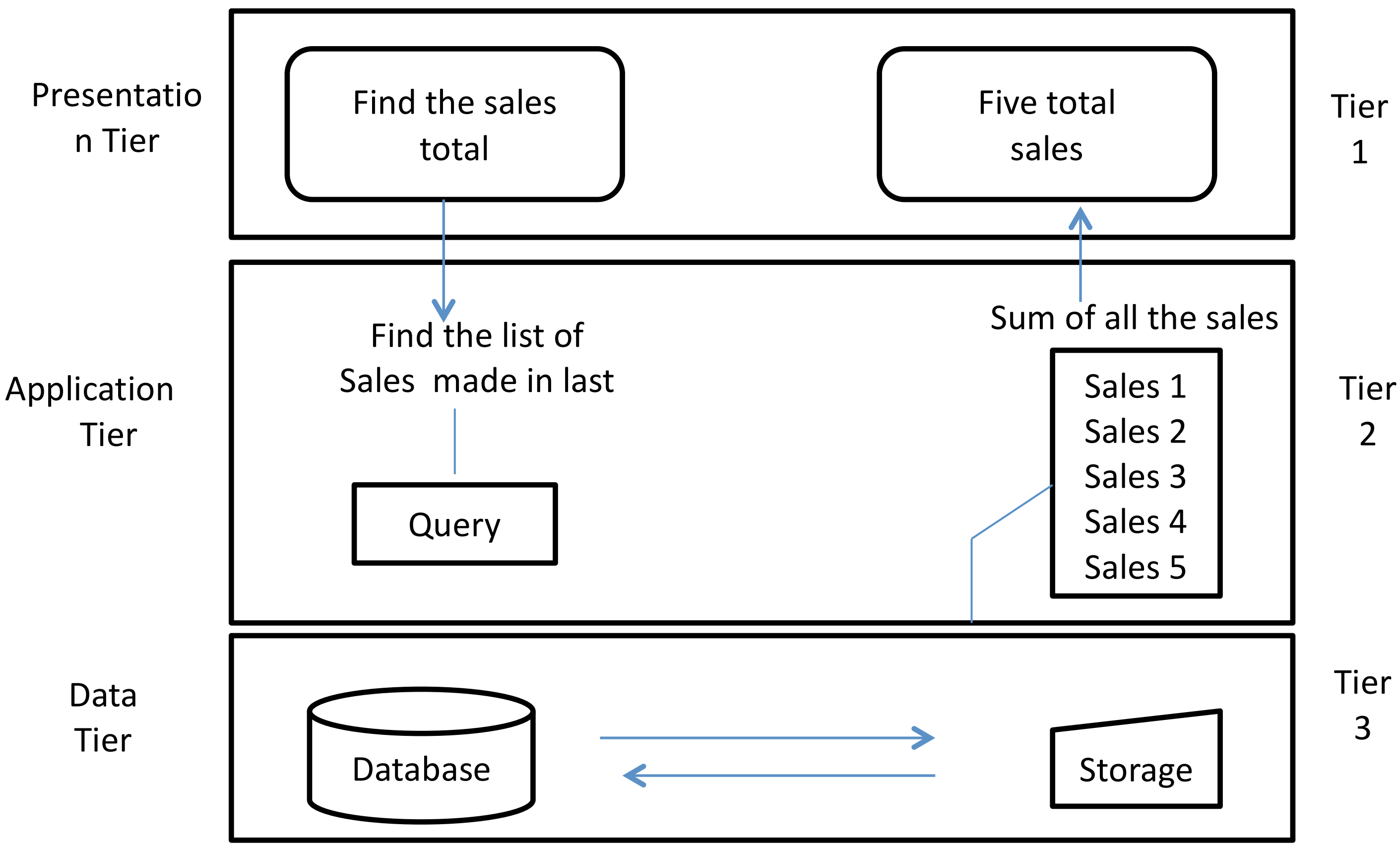
6. Infotainment:

wireless networks can provide up-to-date information at anyappropriate location.

The travel guide might tell you something about the history of a building (knowing via GPS, contact to a local base station, or triangulation where you are) downloading information about a concert in the building at the same evening via a local wireless network.

Another growing field of wireless network applications lies in entertainment and games to enable, e.g., ad-hoc gaming networks as soon as people meet to play together.

Mobile Computing Application Structure



STRUCTURE OF MOBILE COMPUTING APPLICATION:

A mobile computing application is usually structured in terms of the functionalities implemented.The simple three tier structure of a mobile computing application is depicted.As shown,the three tiers are called as presentation tier,application tier and data tier.

PRESENTATION TIER:

The topmost level of a mobile computing application concerns the user interface.A good user interface facilitates the users to issue requests and to present the results to them meaningfully.Obviously,the programs at this layer run on the client's computer.This layer usually includes web browsers and customized client programs for dissemination of information and for collection of data from the user.

APPLICATION TIER:

This layer has the vital responsibility of making logical decisions and performing calculations.It also moves and processes data between the presentation and data layers.We can consider the middle tier to be like an "engine" of an automobile.It performs the processing of user input,obtaining information and then making decisions.This layer is implemented using technologies like JAVA,.NET services,cold fusion etc.The implementation of this layer and the functionality provided by this layer should be database independent.This layer of functionalities is usually implemented on a fixed server.

DATA TIER:

The data tier is responsible for providing the basic facilities of data storage,access and manipulation.Often this layer contains a database.The information is stored and retrieved from this database.But,when only small amounts of data need to be stored,a file system can be used.This layer is also implemented on a fixed server.

Medium Access Control (MAC) Protocols

- sublayer of the data link layer protocol and it directly invokes the physical layer protocol

Primary responsibility of a MAC protocol

- to enforce discipline in the access of a shared channel when multiple nodes contend to access that channel

Two other objectives:

- maximization of the utilization of the channel and
- minimization of average latency of transmission

MAC protocol must be fair and ensure that no node has to wait for an unduly long time, before it is allowed to transmit

Properties required for MAC protocols

- It should implement some rules that help to enforce discipline when multiple nodes contend for a shared channel
- It should help maximize the utilization of the channel
- Channel allocation needs to be fair. No node should be discriminated against at any time and made to wait for an unduly long time for transmission
- It should be capable of supporting several types of traffic having different maximum and average bit rates.
- It should be robust in the face of equipment failures and changing network connections
- IEEE 802.11 - popular and standard MAC protocol for wireless networks
- **IEEE 802.11** is a set of media access control (MAC) and physical layer (PHY) specifications for implementing wireless local area network (WLAN) computer communication in the 900 MHz and 2.4, 3.6, 5, and 60 GHz frequency bands.
- IEEE802.11 based network cards and routers are available in the market that can be used inexpensively and easily setup wireless LANs (Wifi hotspots)

Wireless MAC Protocols : Some Issues

It is difficult to implement a collision detection scheme in a wireless env., since collisions are hard to be detected by the transmitting nodes.

In infrastructureless networks, the issue of hidden and exposed terminals make a MAC Protocol extremely inefficient, unless special care is taken to overcome these problems.

Hidden Terminal Problem

Exposed Terminal Problem

A Taxonomy of MAC Protocols

MAC Protocols can be broadly divided into the following categories:

- Fixed Assignment Schemes
- Random Assignment Schemes
- Demand-based schemes

I. Fixed assignment schemes

- usually called circuit-switched schemes

- resources required for a call are assigned for the entire duration of the call

Random Assignment Schemes and reservation schemes - packet switched schemes

Random Assignment Schemes -connection-less packet switching schemes

- no resource reservations are made, nodes simply start to transmit as soon as they have a packet to send

Reservation schemes

- a node makes explicit reservation of the channel for an entire call for before transmitting

-analogous to a connection-based packet-switching scheme

- suitable to handle calls with widely varying traffic characteristics

Important Categories of fixed assignment MAC protocols:

- **Frequency Division Multiple Access (FDMA)**
- **Time Division Multiple Access (TDMA)**
- **Code Division Multiple Access (CDMA)**

1. Frequency Division Multiple Access (FDMA)

- the available bandwidth (frequency range) is divided in to many narrower frequency bands called channel

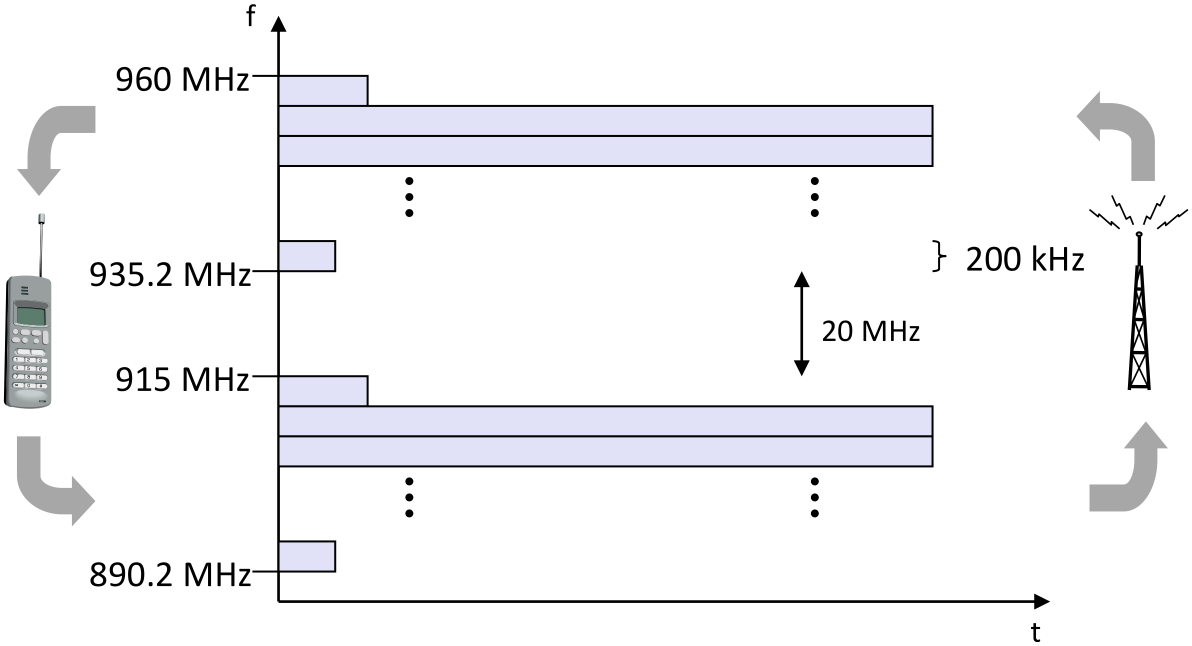
For Full duplex communication – each user is allocated a forward link (channel) for communicating from it (mobile handset) to the base station (BS), and a reverse channel for communication from the BS to it

Thus each user is making a call is allocated two frequency bands(channels), one for transmitting and the other for receiving signals during the call.

When a call is underway, no other user would be allocated the same frequency band to make a call.

Unused transmission time in a frequency band that occurs when the allocated caller pauses between transmissions, or when no user is allocated a band, goes idle and is wasted

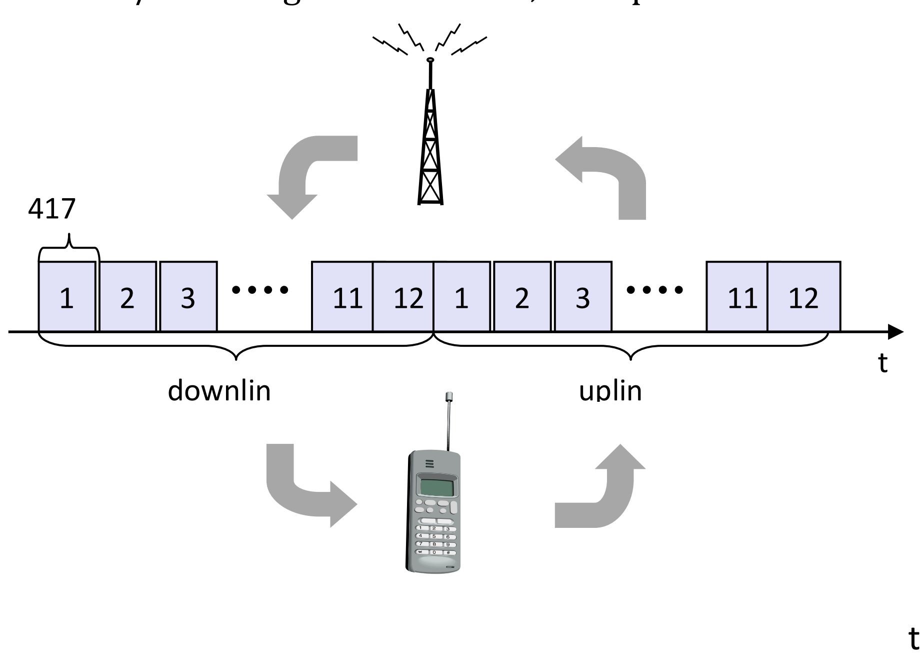
FDMA, does not achieve a high channel utilization



2. Time Division Multiple Access (TDMA)

- access methods in which nodes are allotted different time slots to access the same physical channel
- timeline is divided into fixed-sized time slots and these are divided among multiple nodes who can transmit in a round robin manner.
- each user of the channel owns the channel for exclusive use for one time slot at a time in a round robin fashion
- all sources use the same channel, but take turns in transmitting
- unused time slots go idle, leading to low channel utilization

TDD/TDMA - general scheme, example DECT



3. Code Division Multiple Access

- multiple users are allotted different codes that consist of sequences of 0 and 1 to access the same channel.

How to distinguish trn from different nodes?

- by ensuring following properties on the code

1. Code for a user should be orthogonal (non-interfering) to the codes assigned to other nodes.

- Two vectors are said to be orthogonal if their inner product =0.

Let p and q be 2 vectors and suppose

p = (2, 5, 0) and q = (0, 0, 17), then

inner product of p*q = (2*0+5*0+0*17) = 0

2. Good autocorrelation uses the bipolar notation

- For good autocorrelation, binary 0 is represented as -1 and binary 1 is represented as +1.

  let the binary sequence be 1001, then the representation sequence is +1-1-1+1

On the receiving end, only the same PN sequence is able to demodulate the signal to successfully convert the input data

Pseudorandom sequence generator(PRSG)

- To generate a series of pseudorandom numbers,
  - ✓ a seed(starting point) is required
  - ✓ Based on the seed selected, the next number can be generated using a deterministic mathematical transformation or can be generated probabilistically

a) In CDMA, a code actually denotes a stating point (seed) for a PSRG.

b) PSRG generates a series of bits at a frequency which is much higher than the actual user data (such as digitized voice)

c) These bits are XORd with the user data and subsequently the results are transmitted. This occurs in the case of multiple transmitters

If someone listens to this signal with the help of a suitable wideband receiver, the person will hear something similar to what is produced by random noise all other users who are on the same frequency will send a similar signal, but with a different PSRG seed. so these apparent random noises will all coexist in the band of frequencies, but would not interfere with each other. This due to the reason that the exact frequency of any transmitter at any instant (which is in effect determined by the seed) is almost always unique error correction takes care of occasional bit errors The receiver is aware of the PRSG seed for each transmitter.

It hears just one of the transmitters by correlating the noise it receives, against its own PRSG, which is also running with the same seed. It is slightly similar to FDMA, but the difference is that the transmitters do not stay on one frequency.

They hop around many times per bit of user data.

> The pseudorandom sequence determines this hopping, rather than a fixed assignment to each transmitter

Steps:

1. For simplicity we assume that all nodes transmit on the same frequency at the same time using the entire bandwidth of the transmission channel.

2. Each sender has a unique random number key, and the sender XORs the signal with this random number key.

3. The receiver can tune into this signal if it knows the pseudorandom number.

Example:

X, Y - transmitters
Z – receiver
Sender X_data =1 and X_key = (010011)
Its autocorrelation representation is (-1, +1, -1, -1, +1, +1)
Signal to be calculated at sender X is
Xs = X_data * X_key = +1 * X_key = (-1, +1, -1, -1, +1, +1)
Sender Y_data =0 and Y_key = (110101)
Its autocorrelation representation is (+1, +1, -1, +1, -1, +1)
Signal to be calculated at sender Y is
Ys = Y_data * Y_key = -1 * Y_key = (-1, -1, +1, -1, +1, -1)
Signal received at Z is Xs + Ys = (-2, 0, 0, -2, +2, 0)
At the receiver, in order to receive the data sent by sender X, the signal Z is dispread.
If Z wants to get info of sender X data, then
Z * X_key = (-2, 0, 0, -2, +2, 0) * (-1, +1, -1, -1, +1, +1)
= 2+0+0+2+2+0 = 6 > 0 (positive) that is original bit was 1.
If Z wants to get info of sender Y data, then
Z * Y_key = (-2, 0, 0, -2, +2, 0) * (+1, +1, -1, +1, -1, +1)
= -2+0+0-2-2+0 = -6 < 0 (negative) that is Y data original bit was 0.

II .Random Assignment Schemes

- ALOHA
- Slotted ALOHA

- ❖ CSMA
- ❖ CSMA/CD
- ❖ CSMA/CA

ALOHA

- Simple communication scheme developed at the university of Hawaii

  - Basic called pure ALOHA scheme

  - if a node has data to send, it begins to transmit

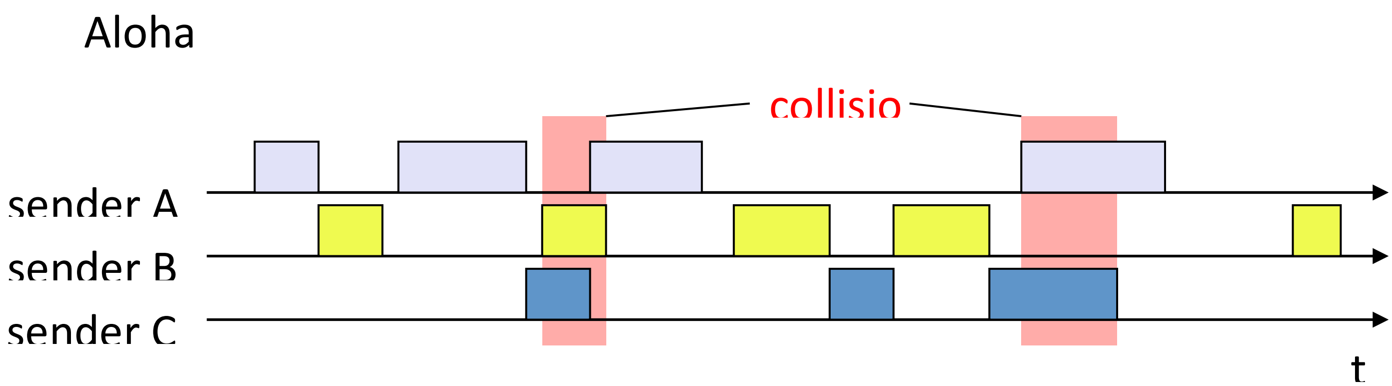
  - it does not check whether the channel is busy before transmitting

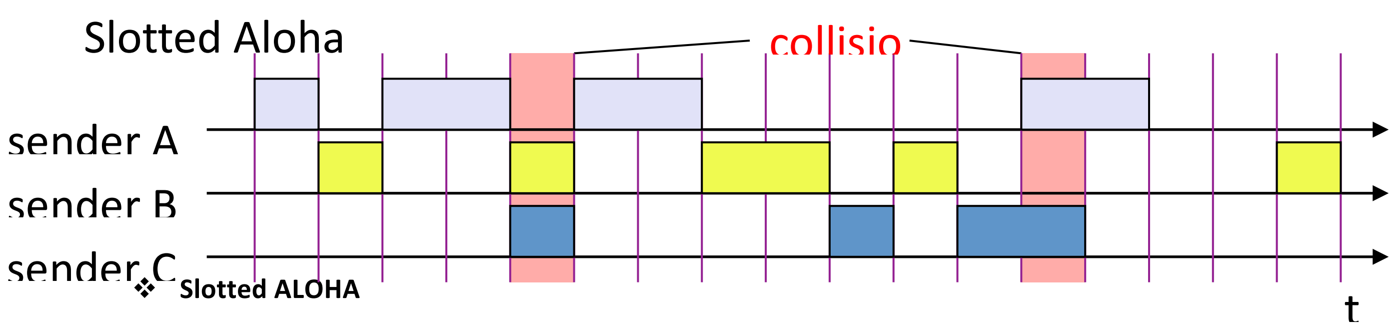
  - if the frame successfully reaches the destination, the next frame is sent

  - if frame fails to be received, it is sent again

  -Works acceptably when the chances of contention are small

  - collisions can become unacceptably high if the number of contenders for transmission is high





❖ **Slotted ALOHA**

- chances of collisions are attempted to be reduced by enforcing the foll. retrictions.

- time is divided into equal-sized slots in which a pkt can be sent. Size of the pkt is restriced

- a node wanting to send a pkt, can start to do so only at the beginning of a slot

- employs beacon signals that are sent at precise intervals that mark the beginning of a slot, at which point the nodes having data to send and can start to transmit

- all senders have to be **synchronized, transmission can only start at the beginning of a time slot** & Still, access is not coordinated.

- does not work very well if the number of stations contending to send data is high

CSMA

- Carrier Sense Multiple Access
- a node senses the medium before starting to transmit
- if it senses that some transmission is underway, it defers its transmission
- Sensing the carrier and accessing the medium only if the carrier is idle decreases the probability of a collision.
- But hidden terminals cannot be detected, so, 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 most wireless LANs

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.

p-persistent CSMA

nodes also sense the medium, but only transmit with a probability of p, with the station defering to the next slot with the probability 1-p, i.e., access is slotted in addition.

persistent CSMA

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, back-off algorithms can be introduced, which are sensitive to waiting time as this is done for standard Ethernet

Two popualr extensions of the basic CSMA technique are

1. Collision detection (CSMA/CD) and
2. Collision Avoidance (CSMA/CA)

CSMA/CD

- sender starts to transmit if it senses the channel to be free

- even if it senses the channel to be free, there can be a collision during transmission

- in wireless network, it is very difficult for a transmitting node to detect a collision, since any received signal from other nodes would be too feeble compared to its own signal and can easily be masked by noise.

- As result, a transmitting node would continue to transmit frame, and only the destination node would notice the corrupted frame after it computes checksum.

This leads to retransmission and severe wastage of channel utilization

In a wired network when a node detects a collision, it immediately stops transmitting , thereby minimizing channel wastage

In wireless network, CA scheme works much better than CD.

CA scheme - based on the idea that is necessary to prevent collisions at the moment they are most likely to occur ie., when the bus is released after a pkt transmission

- During the time a node is transmitting, several nodes might be wanting to transmit

- these nodes would be monitoring the channel and waiting for it to become free

- the moment the transmitting node completes its transmission, these waiting nodes would sense the channel to be free, and would all start transmitting at the same time

To overcome such collisions, in CD scheme, all nodes are forced to wait for a random time and then sense the medium again, before starting their transmission

If the medium is sensed to be busy, a node waiting to transmit waits for a further random amount of time and so on. Thus, the chance of 2 nodes starting to transmit at the same time would be greatly reduced

III. Reservation-based Schemes

- RTS/CTS Scheme - short, fixed-length (32 byte) signaling packets

– a sender transmits an RTS (Ready To Send) pkt to receiver before the actual data transmission

- on receiving this, the receiver sends a CTS (Clear To Send) pkt, and the actual data transfer commences only after that

- when the other node sharing the medium senses the CTS pkt, they refrain from transmitting until the transmission from the sending node is complete

In contention-based MAC protocol a node wanting to send amsg first reserves the medium by using an appropriate control msg

Eg. Reservation of the medium can be achieved by transmitting a RTS msg and corresponding destination node accepting this request answers with a CTS msg

Every node that hears the RTS and CTS msgs defers its transmission during the specified tome period in order to avoid a collision

Egs of RTS-CTS based MAC protocols are

MACA - Multiple Access Collision Access
MACAW - MACA for wireless networks
MACA-BI - MACA by invitation
PAMAS - Power Aware Multi-Access **protocol** with Signalling for Ad Hoc Networks
DBTMA - Dual Busy Tone Multiple Access
MARCH - medium access control **protocol** for multihop **wireless** ad hoc **networks**
S-MAC – Sensor MAC
- Specifically designed for sensor networks

MACA

- Multiple Access Collision Avoidance

- solves the hidden/exposed terminal problems by regulating the transmitter power.

- node running MACA requests to use the medium by sending an RTS to the receiver

- Since radio signals propagate omni-directionally , every terminal within the sender's radio range will hear this and then refrain from transmitting

-as soon as the receiver is ready data, it responds with a CTS

MACA – solves hidden terminal problem

- before the start of its transmission, A sends a RTS. B receives the RTS that contains the sender's name and receiver's name , length of the future trn.

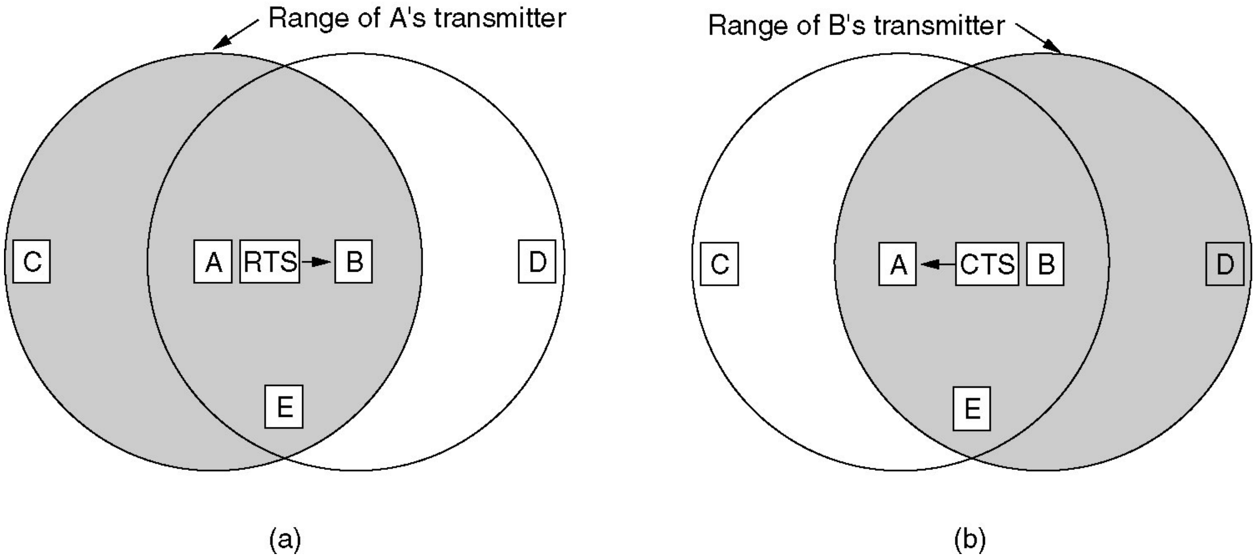
- inrespose to RTS, B triggered CTS as ack. CTS contains sender and receiver and the length of the planned trn.

- this CTS is heard by C and the medium is reserved for use by A for the duration of the trn.

- on receipt of CTS from B, C refrains from transmitting anything for the time indicated in the CTS. Thus collision cannot occur at B during data trn, and the hidden terminal problem is solved.

- When a node wants to transmit a data packet, it first transmit a **RTS** (**Request To Send)** frame.
- The receiver node, on receiving the RTS packet, if it is ready to receive the data packet, transmits a **CTS (Clear to Send)** packet.
- Once the sender receives the CTS packet without any error, it starts transmitting the data packet.
- If a packet transmitted by a node is lost, the node uses the binary exponential back-off (BEB) algorithm to back off a random interval of time before retrying.

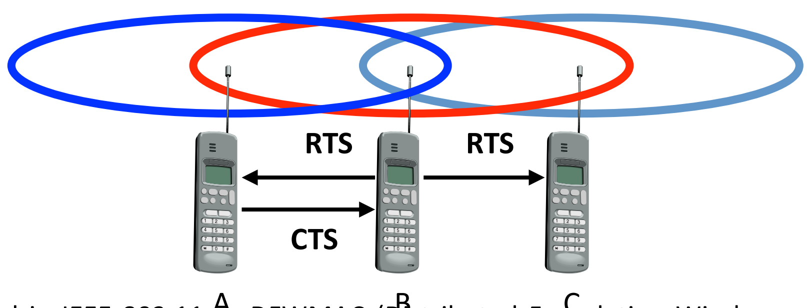
The binary exponential back-off mechanism used in MACA might starves flows sometimes. The problem is solved by MACAW.



The MACA protocol. (a) A sending an RTS to B. (b) B responding with a CTS to A.

MACA avoids the problem of exposed terminals

– B wants to send to A, C to another terminal
– now C does not have to wait for it cannot receive CTS from A



- Variants of this method can be found in IEEE 802.11 as DFWMAC (Distributed Foundation Wireless MAC),

- **MACAW (MACA for Wireless) is a revision of MACA**.
    - The sender senses the carrier to see and transmits a **RTS** (**Request To Send)** frame if no nearby station transmits a RTS.
    - The receiver replies with a **CTS** (**Clear To Send**) frame.
    - Neighbors
        - see CTS, then keep quiet.
        - see RTS but not CTS, then keep quiet until the CTS is back to the sender.
    - The receiver sends an ACK when receiving an frame.
        - Neighbors keep silent until see ACK.
    - Collisions
        - There is no collision detection.
        - The senders know collision when they don't receive CTS.
        - They each wait for the exponential backoff time.
- **Floor acquisition Multiple Access Protocols (FAMA)**

- Based on a channel access discipline which consists of a carrier-sensing operation and a collision-avoidance dialog between the sender and the intended receiver of a packet.
- Floor acquisition refers to the process of gaining control of the channel. At any time only one node is assigned to use the channel.
- Carrier-sensing by the sender, followed by the RTS-CTS control packet exchange, enables the protocol to perform as efficiently as MACA.
- Two variations of FAMA
    - RTS-CTS exchange with no carrier-sensing uses the ALOHA protocol for transmitting RTS packets.
    - RTS-CTS exchange with non-persistent carrier-sensing uses non-persistent CSMA for the same purpose.

▪ **Busy Tone Multiple Access Protocols (BTMA)**
- The transmission channel is split into two:
    - a data channel for data packet transmissions
    - a control channel used to transmit the busy tone signal
- When a node is ready for transmission, it senses the channel to check whether the busy tone is active.
    - If not, it turns on the busy tone signal and starts data transmissions
    - Otherwise, it reschedules the packet for transmission after some random rescheduling delay.
    - Any other node which senses the carrier on the incoming data channel also transmits the busy tone signal on the control channel, thus, prevent two neighboring nodes from transmitting at the same time.

▪ **Dual Busy Tone Multiple Access Protocol (DBTMAP)** is an extension of the BTMA scheme.
- a data channel for data packet transmissions
- a control channel used for control packet transmissions (RTS and CTS packets) and also for transmitting the busy tones.

▪ **Receiver-Initiated Busy Tone Multiple Access Protocol (RI-BTMA)**
- The transmission channel is split into two:
    - a data channel for data packet transmissions
    - a control channel used for transmitting the busy tone signal
- A node can transmit on the data channel only if it finds the busy tone to be absent on the control channel.
- The data packet is divided into two portions: a preamble and the actual data packet.

▪ **MACA-By Invitation (MACA-BI)** is a receiver-initiated MAC protocol.
- By eliminating the need for the RTS packet it reduces the number of control packets used in the MACA protocol which uses the three-way handshake mechanism.

▪ **Media Access with Reduced Handshake (MARCH)** is a receiver-initiated protocol.