Velammal College of Engineering and Technology, Madurai – 625 009

Department of Information Technology

UNIT V MULTI-USER RADIO COMMUNICATION

Global System for Mobile Communications (GSM) - Code division multiple access (CDMA) – Cellular Concept and Frequency Reuse - Channel Assignment and Handover Techniques – Overview of Multiple Access Schemes - Satellite Communication - Bluetooth

CO5: Describe multi user radio communication techniques

INTRODUCTION

Global system for mobile communication (GSM) is a globally accepted standard for digital cellular communication. GSM is the name of a standardization group established in 1982 to create a common European mobile telephone standard that would formulate specifications for a pan-European mobile cellular radio system operating at 900 MHz. It is estimated that many countries outside of Europe will join the GSM partnership.

Subscriber Identity Module (SIM). It is a memory device that stores information such as the subscriber's identification number, the networks and countries where the subscriber is entitled to service, privacy tax and other user specific information A subscriber uses the SIM with a four-digit personal ID number to activate service from GSM phone.

Advanced Mobile Phone Services (AMPS)

AMPS is a Standard Cellular Telephone Service (CTS). The AMPS system uses a seven-cell reuse pattern with provisions for sectoring and cell splitting to increase se channel when needed. AMPS uses frequency modulation and frequency division duplex for radio transmission.

The concept of AMPS

- AMPS channel
- N AMPS
- Voice modulation and Demodulation
- Compandor
- Pre-emphasis
- Post Deviation Limiter filter.
- Supervisory signal.
- Division Limiter.

Cellular Concept and Frequency Reuse, Channel Assignment and Handoffs

• When a user/call moves to a new cell, then a new base station and new channel should be assigned (handoff)

• Handoffs should be transparent to users, while their number should be kept to minimum

• A threshold in the received power (Pr, handoff) should be determined to trigger the handoff process. This threshold value should be larger than the minimum acceptable received power (Pr, acceptable)

• Define: Δ=Pr, handoff - Pr, acceptable

– If Δ is large then too many handoffs

– If Δ is small then insufficient time to complete a handoff

• In order to correctly determine the beginning of handoff, we need to determine that a drop in the signal strength is not due to the momentary (temporary) bad channel condition, but it is due to the fact that the mobile is moving away from BS.

• Thus, the BS needs to monitor the signal level for a certain period of time before initiating a handoff. The length of the time (running average measurements of signal) and handoff process depends on speed and moving pattern.

• First generation systems typical time interval to make a handoff was 10 seconds (large Δ). Second generations and after typical time interval to make a handoff is 1-2 seconds (small Δ).

• **First generation systems:** handoff decision was made by BS by measuring the signal strength in reverse channels.

• **Second generation and after:** Mobile Assisted Hand-Off (MAHO).

Mobiles measure the signal strength from different neighboring BSs. Handoff is initiated if the signal strength from a neighboring BS is higher than the current BS's signal strength.

Cell Dwell Time

• It is the time over which a call maybe maintained within a cell (without handoff).

• It depends on: propagation, interference, distance between BS and MS, speed and moving pattern (direction), etc.

• Highway moving pattern: the cell dwell time is ar.v. with distribution highly concentrated around the mean.

• Other micro-cell moving patterns mix of different user types with large variations of dwell time (around the mean).

Prioritizing Handoffs

• **Guard Channels:** Fraction of total bandwidth in a cell is reserved for exclusive use of handoff calls. Therefore, total carried traffic is reduced if fixed channel assignment is used. However, if dynamic channel assignment is used the guard channel mechanisms may offer efficient spectrum utilization.

– Number of channels to be reserved: If it is low (under-reservation) the QoS on handoff call blocking probability can not be met. If reservation is high (over-reservation) may result in waste of resources and rejection of large number of new calls.

– Static and Dynamic schemes: Advantage of static scheme is its simplicity since no communication and computation overheads are involved.

- However, problems of under- reservation and over reservations may occur if traffic does not conform to prior knowledge.
- Dynamic schemes may adjust better to changing traffic conditions.

Queuing Handoffs: The objective is to decrease the probability of forced determination of a call due to lack of available channels. When a handoff call (and in some schemes a new call) cannot be granted the required resources at the time of its arrival, the request is put in a queue waiting for its admitting conditions to be met.

– This is achieved because there is a finite time interval between the time that the signal of a call drops below the handoff threshold, and the time that the call is terminated due to low (unacceptable) signal level. Queuing and size of buffer depends on traffic and QoS. Queueing in wireless systems is possible because signaling is done on separate control channels (without affecting the data transmission channels).

• According to the types of calls that are queued, queuing priority schemes are classified as: handoff call queuing, new call queuing and handoff/new call queuing (handoff calls are given non-preemptive priority over new calls).

Practical Issues (Capacity/Handoff)

• To increase capacity, use more cells (add extra sites).

• Using different antenna heights and powers, we can provide ―large‖ and ―small‖ cells co-located at a signal location (it is used especially to handle high speed users and low speed users simultaneously.

• Reuse partitioning (use of different reuse patterns)

• Cell splitting: Change cell radius R and keep co-channel reuse ratio (D/R) unchanged. If R'=R/2 than the transmit power needs to be changed by (1/2)4 = 1/16.

• Another way is to keep cell radius R unchanged and decrease D/R ratio required (that is decrease the number of cells in a cluster). To do this it is required to decrease interference without decreasing transmit power.

• Sectoring: Use directional antennas (instead of omni-directional) and therefore you receive interference from only a fraction of the neighboring cells.

• Hard handoffs vs. soft handoffs: more than one BSs handle the call during handoff phase (used in CDMA systems)

Super Audio Tone (SAT): SAT is superimposed on the voice signal on both the forward and reverse link and is barely audible to the user

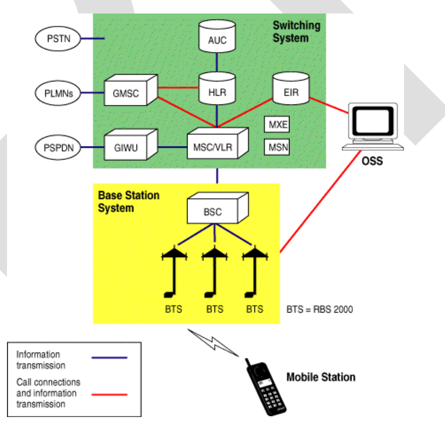
The particular frequency of the SAT denotes the particular base station location for a given channel and is assigned by the MSC for each call.

Global System for Mobile Communications (GSM)

Global system for mobile communication (GSM) is a globally accepted standardfor digital cellular communication. GSM is the name of a standardization groupestablished in 1982 to create a common European mobile telephone standardthat would formulate specifications for a pan-European mobile cellular radiosystem operating at 900 MHz. It is estimated that many countries outside ofEurope will join the GSM partnership.

Throughout the evolution of cellular telecommunications, various systems havebeen developed without the benefit of standardized specificat ions. This presented many problems direct ly related to compatibility, especially with the development of digital radio technology. The

GSM standard is intended to address these problems.



GSM SERVICES

- Telephone Services
- Data Services
- Supplementary Services
- GSM Features:

GSM System Architecture:

- **Base Station Subsystem (BSS)**
- Network and Switching Subsystems (NSS)
- Operation Support Subsystem

(OSS) GSM interface:

- Abis interface
- A – interface

GSM channel Types:

- Traffic channels
- Control channels

Frame structure for GSM

Signaling tone

The signaling tone is a 10-kbps data base which signals call termination by the subscriber. It is a special end of call message consisting of alternating 1s and 0s which is sent on the RVC by the subscriber unit for 200ms. The signaling tone alerts the base station that a subscriber has ended the call.

Telephone services in GSM: Teleservices provides communication between two end user applications according to a standard protocol. GSM mainly focuses on voice oriented tele services. This service includes emergency calling and facsimile. GSM also supports video text and tele text.

Handoff.

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Code-Division Multiple Access (CDMA)

CDMA (Code-Division Multiple Access) refers to any of several protocols used in second-generation (2G) and third-generation (3G) wireless communications. As the term implies, CDMA is a form of multiplexing, which allows numerous signals to occupy a single transmission channel, optimizing the use of available bandwidth. The technology is used in Ultra-High-Frequency (UHF) cellular phone systems in the 800 MH z and 1.9 Gigahertz (GHz) bands.

CDMA employs analog-to-digital conversion (ADC) in combination with spread spectrum technology. Audio input is first digitized into binary elements. The frequency of the transmitted signal is then made to vary according to a defined pattern code. This enables the signal to be intercepted only by a receiver whose frequency response is programmed with the same code, following along with the transmitter frequency. There are trillions of possible frequency sequencing codes, which enhances privacy and makes cloning difficult.

Cell clusters form the cellular structure of wireless CDMA networks. Each cell in a cell cluster has a transceiver. with the necessary transmitting power and mobile units distributed around the cell's coverage area. Every mobile unit runs a transceiver, which consists of a low-power transmitter and a sensitive receiver operating with a wireless cellular environment. The characteristics of the cellular environment include multipath propagation, access interference and fading.

The near-far (N-F) effect plays a significant role in the quality of service (QoS) for CDMA systems. It refers to a phenomenon that occurs when a user near the base station sends out a transmission that interferes with and overpowers a weaker transmission signal coming from a user further away. To this end, CDMA network providers use receivers that are resistant to the N-F effect; they also use tight power control schemes.

The CDMA channel is nominally 1.23 MHz wide. CDMA networks use a scheme called *soft handoff*, which minimizes signal breakup as a handset passes from one cell to another. The combination of digital and spread spectrum modes supports several times as many signals per unit of bandwidth as analog modes. CDMA is compatible with other cellular technologies; this enables nationwide roaming. The original CDMA standard, also known as CDMA One, offers a transmission speed of only up to 14.4 kilobits per second in its single channel form and up to 115 Kbps in an eight-channel form. CDMA2000 and Wideband CDMA (W-CDMA) deliver data many times faster.

Features of CDMA

- Frequency reuse
- Soft capacity
- Multipath fading
- Data Rate
- Soft Handoff
- Self-Jamming
- Flexibility.

Satellite Communication

TYPES OF SATELLITES (BASED ON ORBITS) Geostationary or Geosynchronous Earth Orbit (GEO)

GEO satellites are synchronous with respect to earth. Looking from a fixed point from Earth, these satellites appear to be stationary. These satellites are placed in the space in such a way that only three satellites are sufficient to provide connection throughout the surface of the Earth (that is; their footprint is covering almost 1/3rd of the Earth). The orbit of these satellites is circular.

There are three conditions which lead to geostationary satellites. Lifetime expectancy of these satellites is 15 years.

1) The satellite should be placed 37,786 kms (approximated to 36,000 kms) above the surface of the earth.

2) These satellites must travel in the rotational speed of earth, and in the direction of motion of earth, that is eastward.

3) The inclination of satellite with respect to earth must be 00.

Geostationary Satellite in practical is termed as geosynchronous as there are multiple factors which make these satellites shift from the ideal geostationary condition.

1) Gravitational pull of sun and moon makes these satellites deviate from their orbit. Over the period of time, they go through a drag. (Earth‟s gravitational force has no effect on these

satellites due to their distance from the surface of the Earth.)

2) These satellites experience the centrifugal force due to the rotation of Earth, making them deviate from their orbit.

3) The non-circular shape of the earth leads to continuous adjustment of speed of satellite from the earth station.

These satellites are used for TV and radio broadcast, weather forecast and also, these satellites are operating as backbones for the telephone networks.

Disadvantages of GEO

Northern or southern regions of the Earth (poles) have more problems receiving these satellites due to the low elevation above a latitude of 60°, i.e., larger antennas are needed in this case. Shading of the signals is seen in cities due to high buildings and the low elevation further away from the equator limit transmission quality.

The transmit power needed is relatively high which causes problems for battery powered devices. These satellites cannot be used for small mobile phones. The biggest problem for voice and also data communication is the high latency as without having any handovers, the signal has to at least travel 72,000 kms.

Due to the large footprint, either frequencies cannot be reused or the GEO satellite needs special antennas focusing on a smaller footprint. Transferring a GEO into orbit is very expensive.

Low Earth Orbit (LEO) satellites

These satellites are placed 500-1500 kms above the surface of the earth. As LEOs circulate on a lower orbit, hence they exhibit a much shorter period that is 95 to 120 minutes. LEO systems try to ensure a high elevation for every spot on earth to provide a high qualit y communication link. Each LEO satellite will only be visible from the earth for around ten minutes.

Using advanced compression schemes, transmission rates of about 2,400 bit/s can be enough for voice communication. LEOs even provide this bandwidth for mobile terminals with Omni-directional antennas using low transmit power in the range of 1W. The delay for packets delivered via a LEO is relatively low (approx 10 ms).

The delay is comparable to long-distance wired connections (about 5–10 ms). Smaller footprints of LEOs allow for better frequency reuse, similar to the concepts used for cellular networks. LEOs can provide a much higher elevation in Polar Regions and so better global coverage.

These satellites are mainly used in remote sensing an providing mobile communication services (due to lower latency).

Disadvantages:

The biggest problem of the LEO concept is the need for many satellites if global coverage is to be reached. Several concepts involve 50–200 or even more satellites in orbit.

The short time of visibility with a high elevation requires additional mechanisms for connection handover between different satellites.

The high number of satellites combined with the fast movements resulting in a high complexity of the whole satellite system.

One general problem of LEOs is the short lifetime of about five to eight years due to atmospheric drag and radiation from the inner Van Allen belt1. Assuming 48 satellites and a lifetime of eight years, a new satellite would be needed every two months.

The low latency via a single LEO is only half of the story. Other factors are the need for routing of data packets from satellite to if a user wants to communicate around the world.

Due to the large footprint, a GEO typically does not need this type of routing, as senders and receivers are most likely in the same footprint.

Medium Earth Orbit (MEO) satellites

- MEOs can be positioned somewhere between LEOs and GEOs, both in terms of their orbit and due to their advantages and disadvantages.
- Using orbits around 10,000 km, the system only requires a dozen satellites which is more than a GEO system, but much less than a LEO system. These satellites move more slowly relative to the earth‟s rotation allowing a simpler system design (satellite periods are about six hours).
- Depending on the inclination, a MEO can cover larger populations, so requiring fewer handovers.
- Links in satellite communication

1. Uplink, 2. Downlink & 3. Crosslink.

Disadvantages

Again, due to the larger distance to the earth, delay increases to about 70 – 80 ms. the satellites need higher transmit power and special antennas for smaller footprints

The three orbits of satellite. Low Earth orbit: Medium Earth orbit & Geosynchronous Earth orbit

Visitor location register (VLR)—The VLR is a database that contains temporary information about subscribers that is needed bythe MSC in order to service visiting subscribers. The VLR is always integrated with the MSC. When a mobile station roams into a new MSC area, the VLR connected to that MSC will request data about the mobile station from the HLR. Later, if the mobile station makes a call, the VLR will have the information needed for call setup without having to interrogate the HLR each time.

Mobile services switching center (MSC)—The MSC performs the telephony switching functions of the system. It controls calls to and from other telephone and data systems. It also performs such functions as toll ticketing, network interfacing, common channel signaling, and others.

Home location register (HLR)—The HLR is a database used for storage and management of subscriptions. The HLR is considered the most important database, as it stores permanent data about subscribers, including a subscriber's service profile, location information, and activity status. When an individual buys a subscription from one of the PCS operators, he or she is registered in the HLR of that operator.

Kepler's laws of planetary motion

1. A satellite will orbit a primary body following an elliptical path
2. For equal intervals of time a satellite will sweep out equal areas in orbital plane
3. The square of the periodic time of orbit is proportional to the cube of the mean distance between the primary and the satellite.

The links in satellite communication

i) Uplink

ii) Downlink iii) Crosslink

Satellites are specifically made for telecommunication purpose. They are used for mobile applications such as communication to ships, vehicles, planes, hand-held terminals and for TV and radio broadcasting They are responsible for providing these services to an assigned reg ion (area) on the earth. The power and bandwidth of these satellites depend upon the preferred size of the footprint, complexity of the traffic control protocol schemes and the cost of ground stations.

A satellite works most efficiently when the transmissions are focused with a desired area. When the area is focused, then the emissions don‟t go outside that designated area and thus minimizing the interference to the other systems. This leads more efficient spectrum usage.

Satellite's antenna patterns play an important role and must be designed to best cover the designated geographical area (which is generally irregular in shape). Satellites should be designed by keeping in mind its usability for short and long term effects throughout its life time.

The earth station should be in a position to control the satellite if it drifts from its orbit it is subjected to any kind of drag from the external forces.

Kepler's laws

Kepler's first law

A satellite will orbit a primary body following an elliptical path

Kepler's second law

For equal intervals of time a satellite will sweep out equal areas in orbital plane

Kepler's third law

The square of the periodic time of orbit is proportional to the cube of the mean distance between the primary and the satellite

Bluetooth

Bluetooth is a standard developed by a group of electronics manufacturers that allows any sort of electronic equipment from computers and cell phones to keyboards and headphones to make its own connections, without wires, cables or any direct action from a user. Bluetooth is intended to be a standard that works at two levels.

Bluetooth is a wireless communication technology designed for short-range data exchange between devices using ultra-high frequency (UHF) radio waves in the 2.4 GHz ISM (Industrial, Scientific, and Medical) band. Developed by Ericsson in 1994 and later standardized by the Bluetooth Special Interest Group (SIG), Bluetooth eliminates the need for cables by allowing devices to connect and share data seamlessly. It is commonly used in consumer electronics such as wireless headphones, keyboards, mice, and for data transfer between smartphones and computers.

Bluetooth operates within the 2.402 to 2.480 GHz frequency band and uses modulation techniques like Gaussian Frequency Shift Keying (GFSK) for data transmission. Newer versions incorporate advanced techniques such as Phase Shift Keying (PSK). Bluetooth devices are classified based on their transmission range: Class 1 supports up to 100 meters, Class 2 (most commonly used in mobile devices) covers around 10 meters, and Class 3 is limited to less than 10 meters. Over the years, Bluetooth has seen significant improvements in speed and power efficiency—from an initial data rate of 1 Mbps in Bluetooth 1.2 to 24 Mbps in Bluetooth 3.0 with High-Speed support. Bluetooth 4.0 introduced Bluetooth Low Energy (BLE), which is optimized for low-power devices, while Bluetooth 5.0 and later versions enhanced range, speed, and broadcasting capabilities.

The Bluetooth protocol stack consists of multiple layers. The **Radio layer** handles raw data transmission and reception. Above it, the **Baseband layer** manages link establishment and packet organization. The **Link Manager Protocol (LMP)** facilitates link setup, security, and quality of service. The **Host Controller Interface (HCI)** enables communication between Bluetooth hardware and software. The **Logical Link Control and Adaptation Protocol (L2CAP)** is responsible for multiplexing and data reassembly, while **RFCOMM** provides serial port emulation. The **Service Discovery Protocol (SDP)** allows devices to find each other and understand available services.

Bluetooth networks are organized into two types: **piconets** and **scatternets**. A piconet consists of one master device and up to seven active slave devices. Scatternets are formed by connecting multiple piconets through shared devices that act as bridges, enabling broader device communication. This structure supports dynamic, low-power, and decentralized networking, making Bluetooth ideal for personal area networks (PANs).

Security is a vital aspect of Bluetooth communication. The **pairing process** establishes a trusted connection between devices, involving the exchange of a shared secret or link key. Bluetooth offers multiple **security modes**, ranging from no security to advanced link-level encryption and authentication. From version 2.1 onwards, Secure Simple Pairing (SSP) was introduced to protect against threats like man-in-the-middle attacks. Encryption algorithms, such as 128-bit AES, ensure data integrity and confidentiality.

Bluetooth has evolved significantly through its various versions. Initial versions (1.0 and 1.1) offered basic wireless functionality. Version 1.2 introduced Adaptive Frequency Hopping (AFH) to reduce interference. Version 2.0 added Enhanced Data Rate (EDR), boosting speed. Version 3.0 included high-speed transfer using Wi-Fi. Version 4.0 introduced BLE, focusing on energy efficiency. Later versions, such as 5.0, brought major upgrades like extended range (up to 240 meters), double the speed (2 Mbps), and higher broadcast capacity. Bluetooth 5.1 and 5.2 added direction-finding and isochronous channels, improving location services and audio streaming. Bluetooth 5.3 further enhanced energy efficiency and data handling capabilities.

Bluetooth Low Energy (BLE) is a subset introduced in Bluetooth 4.0, tailored for low-power applications such as fitness trackers, smartwatches, medical devices, and Internet of Things (IoT) gadgets. BLE supports short bursts of data transmission and uses an advertiser/scanner model where one device advertises its presence and another scans for it. It uses the Generic Attribute Profile (GATT) to organize and exchange data efficiently, making it highly suitable for applications requiring minimal power consumption.

The applications of Bluetooth span across various domains. In **consumer electronics**, Bluetooth is used in wireless headphones, speakers, and gaming controllers. **Mobile phones** use it for hands-free calling, file sharing, and tethering. In **healthcare**, it supports wearable devices and patient monitoring systems. **Home automation** applications include smart lighting and door locks. **Automotive systems** use Bluetooth for in-car entertainment and hands-free operation. **IoT ecosystems** heavily rely on BLE for inter-device communication, asset tracking, and environmental monitoring.

Bluetooth offers several advantages such as low power consumption, cost-effectiveness, wide device compatibility, and automatic discovery. Its license-free use of the 2.4 GHz band makes it globally available. However, it has some limitations.

Bluetooth has a relatively short range and lower data transfer rates compared to technologies like Wi-Fi. It can also be prone to interference from other devices operating in the same frequency band. Moreover, security concerns arise if devices are not correctly configured or updated.