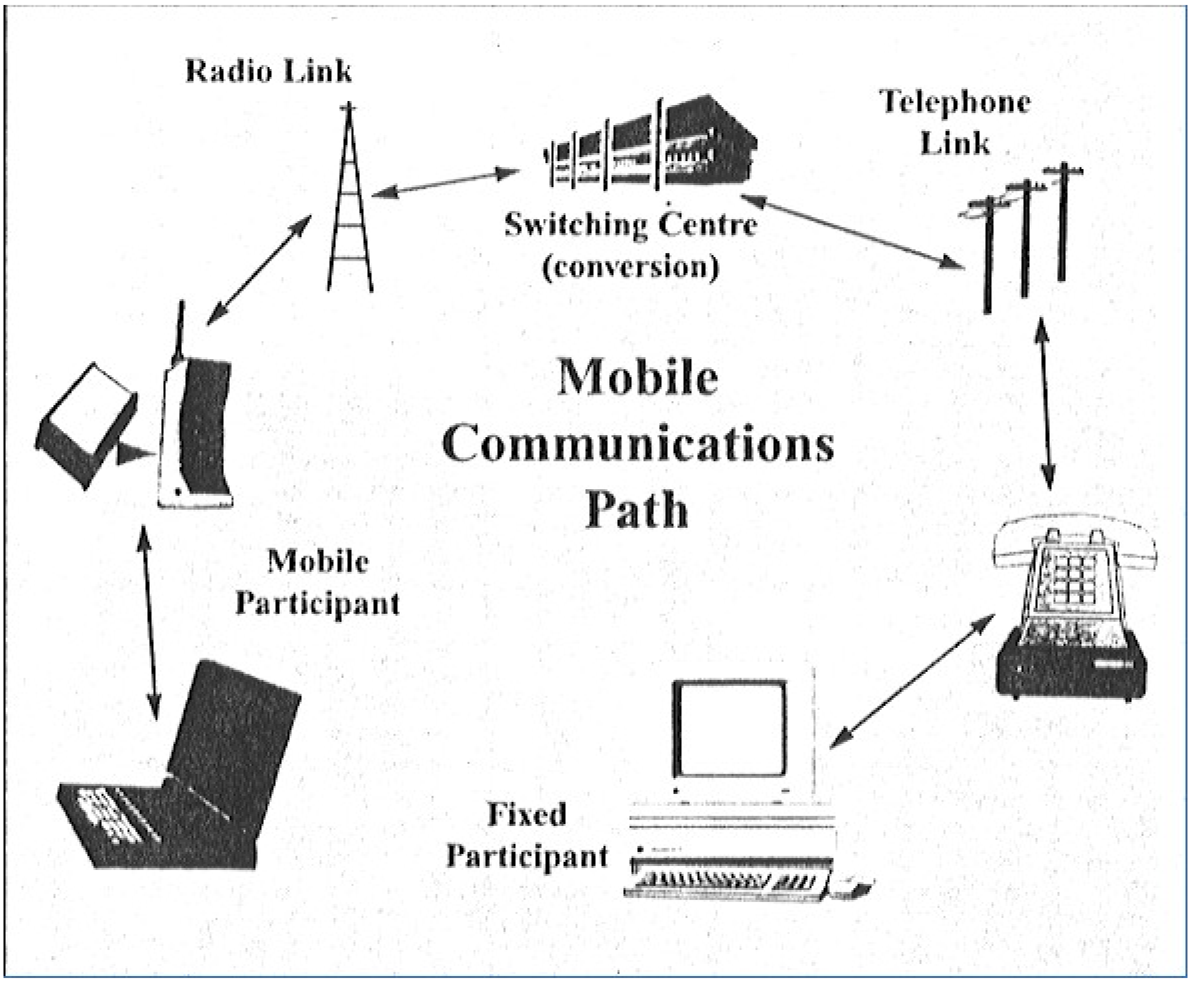
Lecture 1

Introduction to Mobile Computing: - Mobile computing′ is a form of [human–computer interaction] by which a [computer] is expected to be transported during normal usage. Mobile computing has three aspects: mobile communication, mobile hardware, and mobile software. The first aspect addresses communication issues in ad-hoc and infrastructure networks as well as communication properties, protocols, data formats and concrete technologies. The second aspect is on the hardware, e.g., mobile devices or device components. The third aspect deals with the characteristics and requirements of mobile applications.

Definitions

Mobile computing is "taking a computer and all necessary files and software out into the field."

"Mobile computing: being able to use a computing device even when being mobile and therefore changing location. Portability is one aspect of mobile computing."



Lecture 2

Issues:

- Wireless Issues
  - Mobile Computing
  - Wireless Architecture
  - Wireless Access Technologies
  - Wireless Applications
- Wireless Limitations
- Middleware for Mobile Computing

Limitations:

Insufficient bandwidth
Security standards
Power consumption
Transmission interferences
Potential health hazards
Human interface with device

Lecture 3

Introduction to Cellular Communications

1. Mobile Communications Principles

Each mobile uses a separate, temporary radio channel to talk to the cell site. The cell site talks to many mobiles at once, using one channel per mobile. Channels use a pair of frequencies for communication one frequency (the forward link) for transmitting from the cell site and one frequency (the reverse link) for the cell site to receive calls from the users. Radio energy dissipates over distance, so mobiles must stay near the base station to maintain communications. The basic structure of mobile networks includes telephone systems and radio services. Where mobile radio service operates in a closed network and has no access to the telephone system, mobile telephone service allows interconnection to the telephone network.

2. Cellular System Architecture

Increases in demand and the poor quality of existing service led mobile service providers to research ways to improve the quality of service and to support more users in their systems. Because the amount of frequency spectrum available for mobile cellular use was limited, efficient use of the required frequencies was needed for mobile cellular coverage. In modern cellular telephony, rural and urban regions are divided into areas according to specific provisioning guidelines. Deployment parameters, such as amount of cell-splitting and cell sizes, are determined by engineers experienced in cellular system architecture.

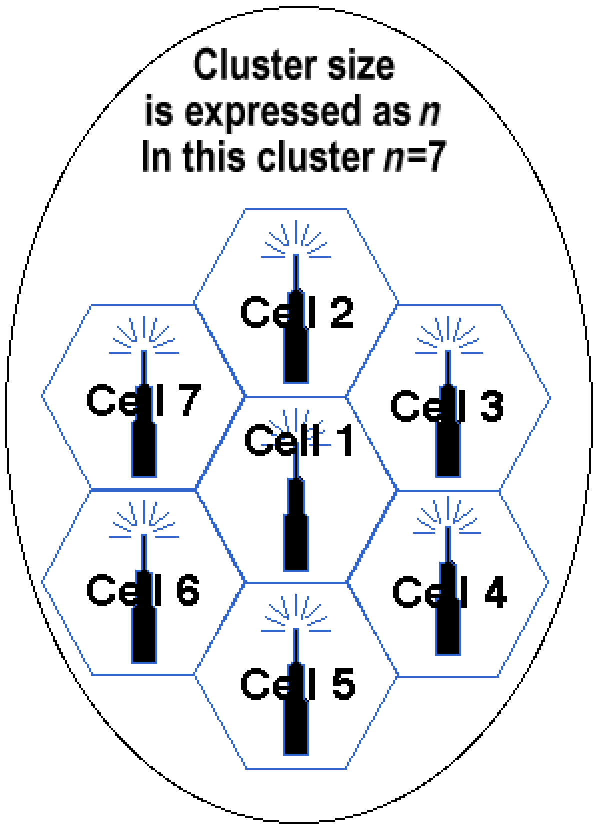
Provisioning for each region is planned according to an engineering plan that includes cells, clusters, frequency reuse, and handovers.

Cells

A cell is the basic geographic unit of a cellular system. The term cellular comes from the honeycomb shape of the areas into which a coverage region is divided. Cells are base stations transmitting over small geographic areas that are represented as hexagons. Each cell size varies depending on the landscape. Because of constraints imposed by natural terrain and man-made structures, the true shape of cells is not a perfect hexagon.

Clusters

A cluster is a group of cells. No channels are reused within a cluster. Figure 4 illustrates a seven-cell cluster.



Lecture 4

3. Cellular System Components

The cellular system offers mobile and portable telephone stations the same service provided fixed stations over conventional wired loops. It has the capacity to serve tens of thousands of subscribers in a major metropolitan area. The cellular communications system consists of the following four major components that work together to provide mobile service to subscribers.

- public switched telephone network (PSTN)
- mobile telephone switching office (MTSO)
- cell site with antenna system
- mobile subscriber unit (MSU)

PSTN

The PSTN is made up of local networks, the exchange area networks, and the long-haul network that interconnect telephones and other communication devices on a worldwide basis.

Mobile Telephone Switching Office (MTSO)

The MTSO is the central office for mobile switching. It houses the mobile switching center (MSC), field monitoring, and relay stations for switching calls from cell sites to wireline central offices (PSTN). In analog cellular networks, the MSC controls the system operation. The MSC controls calls, tracks billing information, and locates cellular subscribers.

The Cell Site

The term cell site is used to refer to the physical location of radio equipment that provides coverage within a cell. A list of hardware located at a cell site includes power sources, interface equipment, radio frequency transmitters and receivers, and antenna systems.

Mobile Subscriber Units (MSUs)

The mobile subscriber unit consists of a control unit and a transceiver that transmits and receives radio transmissions to and from a cell site. The following three types of MSUs are available:

- the mobile telephone (typical transmit power is 4.0 watts)
- the portable (typical transmit power is 0.6 watts)
- the transportable (typical transmit power is 1.6 watts)
- The mobile telephone is installed in the trunk of a car, and the handset is installed in a convenient location to the driver. Portable and transportable telephones are hand-held and can be used anywhere. The use of portable and transportable telephones is limited to the charge life of the internal battery.

Lecture 5

GSM (Global System for Mobile communication):

GSM (**Global System for Mobile Communications**, originally ***Groupe Spécial Mobile***), is a standard set developed by the European Telecommunications Standards Institute (ETSI) to describe technologies for second generation (2G) digital cellular networks. Developed as a replacement for first generation(1G) analog cellular networks, the GSM standard originally described a digital, circuit switched network optimized for full duplex voice telephony. The standard was expanded over time to include first circuit switched data transport, then packet data transport via GPRS (General Packet Radio services). Packet data transmission speeds were later increased via EDGE(Enhanced Data rates for GSM Evolution). The GSM standard is more improved after the development of third generation (3G) UMTS standard developed by the 3GPP. GSM networks will evolve further as they begin to incorporate fourth generation (4G) LTE Advanced standards. "GSM" is a trademark owned by the GSM Association.

The network is structured into a number of discrete sections:

- The Base Station Subsystem (the base stations and their controllers).
- the Network and Switching Subsystem (the part of the network most similar to a fixed network). This is sometimes also just called the core network.
- The GPRS Core Network (the optional part which allows packet based Internet connections).
- The Operations support system (OSS) for maintenance of the network.

Location Management: Cells in a network are grouped into Location Areas (LAs). Users can move within these LAs, updating their location with the network based upon some predefined standard. When a user receives a call, the network must page cells within the LA (also referred to as polling) to find that user as quickly as possible.

This creates the dynamics behind much of Location Management (LM), and many of the reports and theories discussed within this paper. The network can require more frequent Location Updates (LUs), in order to reduce polling costs, but only by incurring increased time and energy expenditures from all the updates. Conversely, the network could only require rare LUs, storing less information about users to reduce computational overhead, but at a higher polling cost. Additionally, LAs themselves can be optimized in order to create regions that require less handoff and quicker locating of users. The goal of LM is to find a proper balance between all of these important considerations.

Lecture 6

CONVENTIONAL HLR/VLR SCHEME:

The major steps of the IS-41 location registration scheme are as follows Fig .

Step 1: The mobile terminal moves into a new LA and sends a location update message to the nearby base station.

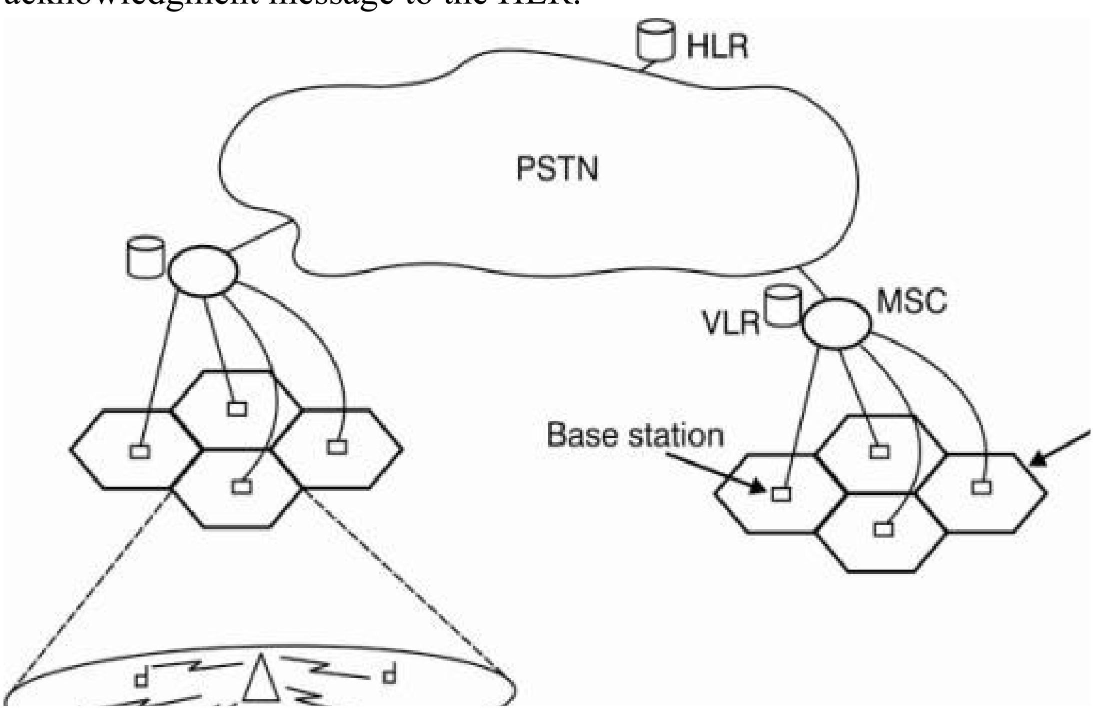
Step 2: The base station forwards this message to the new serving MSC.

Step 3: The new MSC updates its associated VLR, indicating that the mobile terminal is now residing in its services area and sends a location registration message to the HLR.

Step 4: The HLR sends a registration acknowledgment message to the new MSC/VLR together with a copy of the subscriber's user profile.

Step 5: The HLR sends a registration cancellation message to the old MSC/VLR.

Step 6: The old MSC removes the record for the mobile terminal at its associated VLR and sends a cancellation acknowledgment message to the HLR.



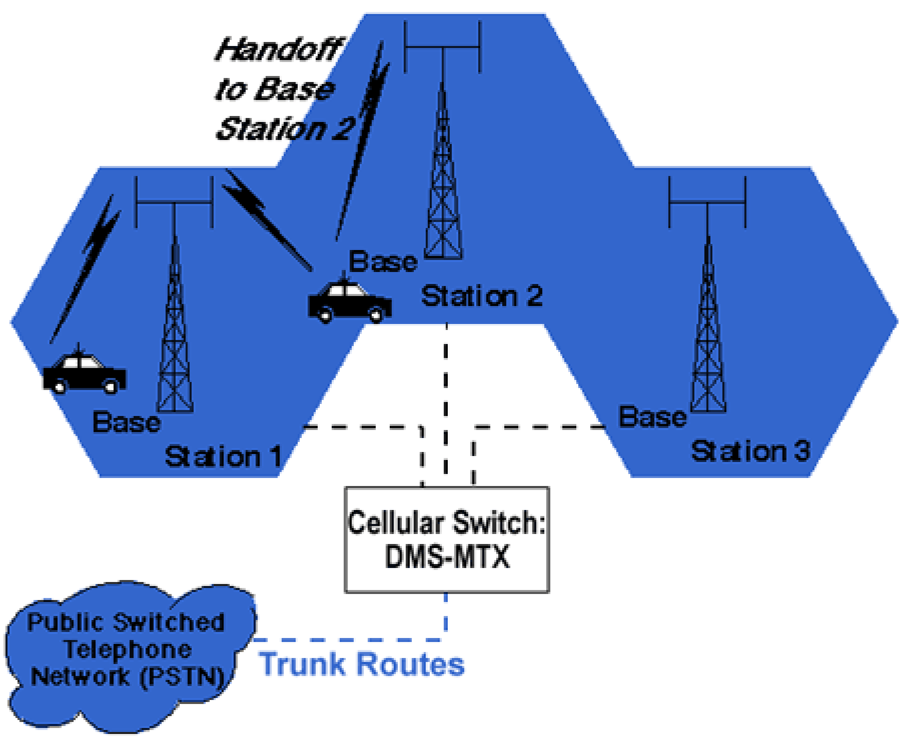
Lecture 7

MODIFIED HLR/VLR SCHEME: In conventional approach when a MT moves from one LA to another LA, which are served by different VLRs, for registration of MT at new VLR a signal message is transferred to HLR from it, which sends a signal message to old VLR to deregister the MT and upon getting an acknowledgement of deregistration from old VLR, HLR acknowledges to new VLR for registration. This deregistration method is referred to as *explicit deregistration*

In modified HLR-VLR scheme we try to ignore explicit deregistration message to old VLR and its acknowledgement to HLR. So when new VLR finds a new mobile unit it simply send a message to HLR which acknowledges the new VLR to register it

Handsoff: Handoff

The final obstacle in the development of the cellular network involved the problem created when a mobile subscriber traveled from one cell to another during a call. As adjacent areas do not use the same radio channels, a call must either be dropped or transferred from one radio channel to another when a user crosses the line between adjacent cells. Because dropping the call is unacceptable, the process of handoff was created. Handoff occurs when the mobile telephone network automatically transfers a call from radio channel to radio channel as mobile crosses adjacent cells.



During a call, two parties are on one voice channel. When the mobile unit moves out of the coverage area of a given cell site, the reception becomes weak. At this point, the cell site in use requests a handoff. The system switches the call to a stronger-frequency channel in a new site without interrupting the call or alerting the user. The call continues as long as the user is talking, and the user does not notice the handoff at all.

Lecture 8 & 9

Channel allocation in cellular system

In radio resource management for wireless and cellular network, channel allocation schemes are required to allocate bandwidth and communication channels to base stations, access points and terminal equipment. The objective is to achieve maximum system spectral efficiency in bit/s/Hz/site by means of frequency reuse, but still assure a certain grade of service by avoiding co-channel interference and adjacent channel interference among nearby cells or networks that share the bandwidth. There are two types of strategies that are followed:-

1. Fixed: FCA, fixed channel allocation: Manually assigned by the network operator
2. Dynamic:
    1. DCA, dynamic channel allocation,
    2. DFS, dynamic frequency selection
    3. Spread spectrum

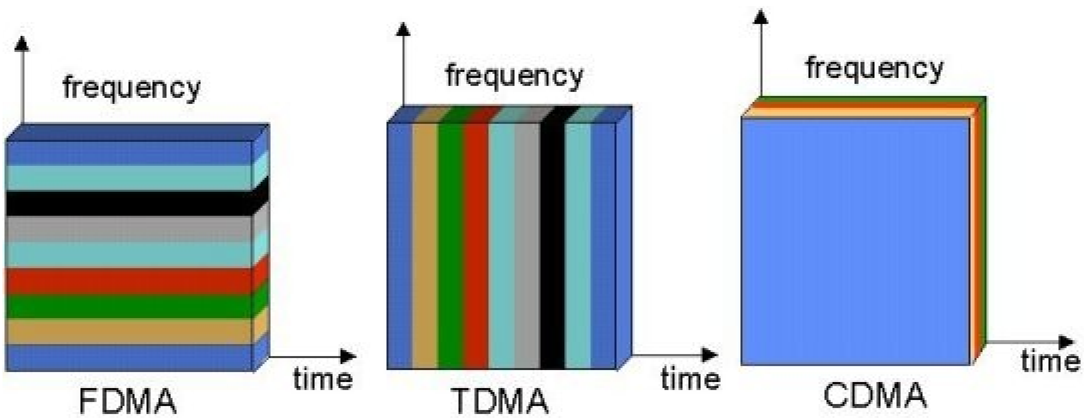
Fixed channel allocation: In Fixed Channel Allocation or Fixed Channel Assignment (FCA) each cell is given a predetermined set of frequency channels. FCA requires manual frequency planning, which is an arduous task in TDMA and FDMA based systems, since such systems are highly sensitive to co-channel interference from nearby cells that are reusing the same channel. Another drawback with TDMA and FDMA systems with FCA is that the number of channels in the cell remains constant irrespective of the number of customers in that cell. This result in traffic congestion and some calls being lost when traffic gets heavy in some cells, and idle capacity in other cells.

Dynamic Channel Allocation: A more efficient way of channel allocation would be Dynamic Channel Allocation or Dynamic Channel Assignment(DCA) in which voice channel are not allocated to cell permanently, instead for every call request base station request channel from MSC. The channel is allocated following an algorithm which accounts likelihood of future blocking within the cell. It requires the MSC to collect real time data on channel occupancy, traffic distribution and Radio Signal Strength Indications (RSSI). DCA schemes are suggested for TDMA/FDMA based cellular systems such as GSM, but are currently not used in any products.[citation needed] OFDMA systems, such as the downlink of 4G cellular systems, can be considered as carrying out DCA for each individual sub-carrier as well as each timeslot.

Lecture 10

CDMA Overview

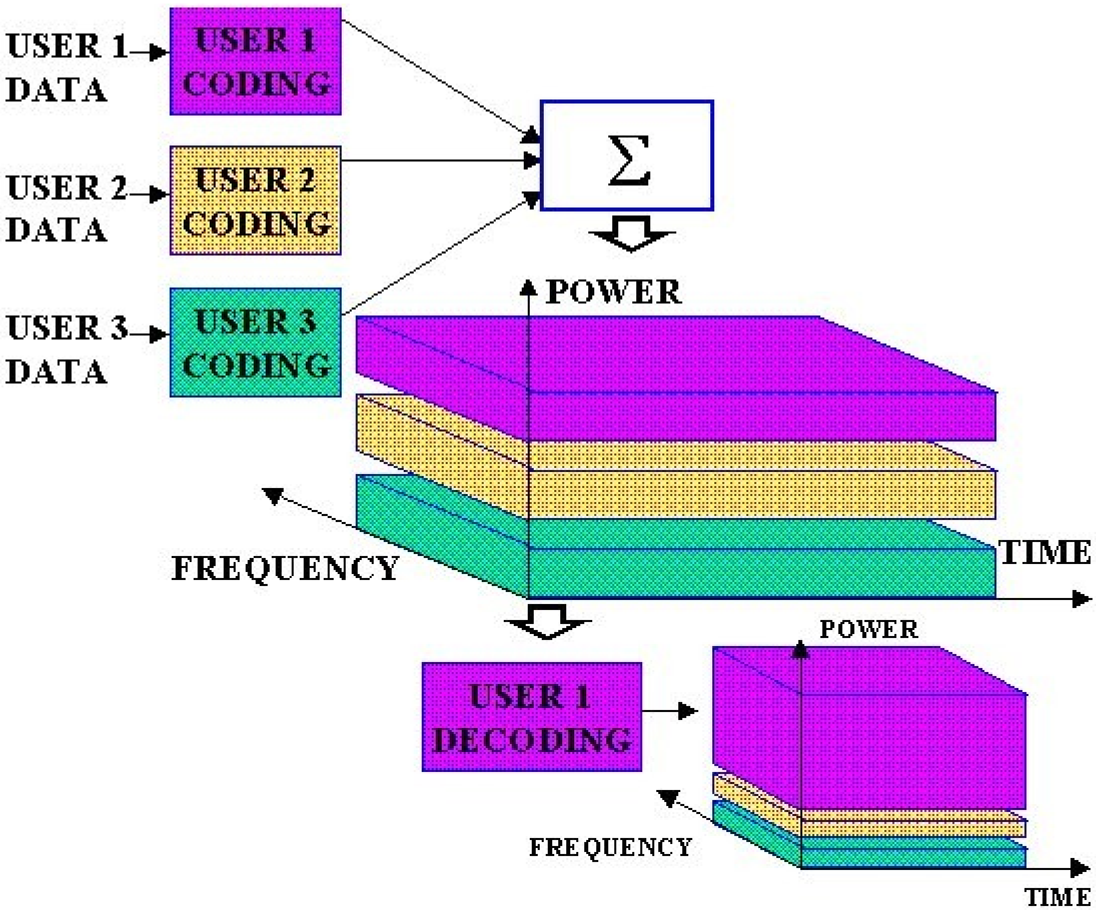
For radio systems there are two resources, frequency and time. Division by frequency, so that each pair of communicators is allocated part of the spectrum for all of the time, results in Frequency Division Multiple Access (FDMA). Division by time, so that each pair of communicators is allocated all (or at least a large part) of the spectrum for part of the time results in Time Division Multiple Access (TDMA). In Code Division Multiple Access (CDMA), every communicator will be allocated the entire spectrum all of the time. CDMA uses codes to identify connections.



Multiple Access Schemes

CDMA uses unique spreading codes to spread the baseband data before transmission. The signal is transmitted in a channel, which is below noise level. The receiver then uses a correlator to despread the wanted signal, which is passed through a narrow bandpass filter. Unwanted signals will not be despread and will not pass through the filter. Codes take the form of a carefully designed one/zero sequence produced at a much higher rate than that of the baseband data. The rate of a spreading code is referred to as chip rate rather than bit rate.

Lecture 10



CDMA spreading

Lecture 11

GPRS: Short for ***G****eneral* ***P****acket* ***R****adio* ***S****ervice*, a standard for wireless communications which runs at speeds up to 115 kilobits per second, compared with current GSM (Global System for Mobile Communications) systems' 9.6 kilobits.

GPRS, which supports a wide range of bandwidths, is an efficient use of limited bandwidth and is particularly suited for sending and receiving small bursts of data, such as e-mail and Web browsing, as well as large volumes of data.

In theory, GPRS packet-based services cost users less than circuit-switched services since communication channels are being used on a shared-use, as-packets-are-needed basis rather than dedicated to only one user at a time. It is also easier to make applications available to mobile users because the faster data rate means that middleware currently needed to adapt applications to the slower speed of wireless systems are no longer be needed. As GPRS has become more widely available, along with other 2.5G and 3G services, mobile users of virtual private networks (VPNs) have been able to access the private network continuously over wireless rather than through a rooted dial-up connection.

GPRS also complements Bluetooth, a standard for replacing wired connections between devices with wireless radio connections. In addition to the Internet Protocol (IP), GPRS supports X.25, a packet-based protocol that is used mainly in Europe. GPRS is an evolutionary step toward Enhanced Data GSM Environment (EDGE) and Universal Mobile Telephone Service (UMTS).

Lecture 12

Wireless Networking: Wireless networks utilize radio waves and/or microwaves to maintain communication channels between computers. Wireless networking is a more modern alternative to wired networking that relies on copper and/or fiber optic cabling between network devices.

A wireless network offers advantages and disadvantages compared to a wired network. Advantages of wireless include mobility and elimination of unsightly cables. Disadvantages of wireless include the potential for radio interference due to weather, other wireless devices, or obstructions like walls.

Wireless is rapidly gaining in popularity for both home and business networking. Wireless technology continues to improve, and the cost of wireless products continues to decrease. Popular wireless local area networking (WLAN) products conform to the 802.11 "Wi-Fi" standards. The gear a person needs to build wireless networks includes network adapters (NICs), access points (APs), and routers.

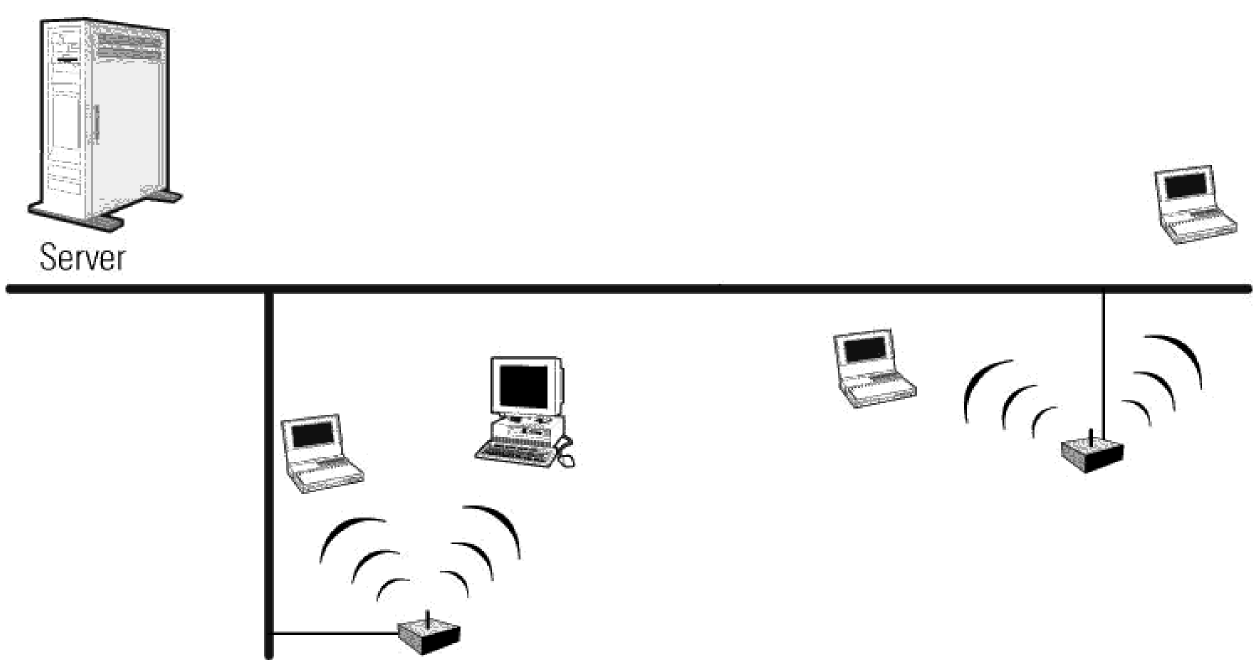
Lecture 13

Wireless LAN: A wireless LAN (or WLAN, for wireless local area network, sometimes referred to as LAWN, for local area wireless network) is one in which a mobile user can connect to a local area network (LAN) through a wireless (radio) connection. The IEEE 802.11 group of standards specify the technologies for wireless LANs. 802.11 standards use the Ethernet

protocol and CSMA/CA (carrier sense multiple access with collision avoidance) for path sharing and include an encryption method, the Wired Equivalent Privacy algorithm.

High-bandwidth allocation for wireless will make possible a relatively low-cost wiring of classrooms in the United States. A similar frequency allocation has been made in Europe. Hospitals and businesses are also expected to install wireless LAN systems where existing LANs are not already in place.

Using technology from the Symbionics Networks, Ltd., a wireless LAN adapter can be made to fit on a Personal Computer Memory Card Industry Association (PCMCIA) card for a laptop or notebook computer.



Lecture 14

Bluetooth: *Bluetooth* is a specification for the use of low-power radio communications to wirelessly link phones, computers and other network devices over short distances. The name Bluetooth is borrowed from Harald Bluetooth, a king in Denmark more than 1,000 years ago.

Bluetooth technology was designed primarily to support simple wireless networking of personal consumer devices and peripherals, including cell phones, PDAs, and wireless headsets. Wireless signals transmitted with Bluetooth cover short distances, typically up to 30 feet (10 meters). Bluetooth devices generally communicate at less than 1 Mbps.

Bluetooth Wireless Technology: Both of the terms 'scatternet' and 'piconet' are typically applied to Bluetooth wireless technology.

Piconet: A *piconet* is the type of connection that is formed between two or more Bluetooth-enabled devices such as modern cell phones or PDAs. Bluetooth enabled devices are "peer units" in that they are able to act as either master or slave. However, when a piconet is formed between two or more devices, one device takes the role of 'master', and all other devices assume a 'slave' role for synchronization reasons. Piconets have a 3-bit address space, which limits the maximum size of a piconet to 8 devices ($2^3 = 8$), i.e. 1 master and 7 slaves.

Scatternet: A *scatternet* is a number of interconnected piconets that supports communication between more than 8 devices. Scatternets can be formed when a member of one piconet (either the master or one of the slaves) elects to participate as a slave in a second, separate piconet. The device participating in both piconets can relay data between members of both ad-hoc networks. However, the basic bluetooth protocol does not support this relaying - the host software of each device would need to manage it. Using this approach, it is possible to join together numerous piconets into a large scatternet, and to expand the physical size of the network beyond Bluetooth's limited range.

Lecture 15,16

TCP overview

• Reliable point-to-point transport protocol
• Connection-oriented
• In-order data delivery
• Congestion& flow control
• Full duplex
• Accounts for roughly 90% of the Worldwide Internet traffic (4 PB/s)

TCP Congestion Control

• Slow start
• Congestion avoidance
• Fast retransmit/recovery

Mistaking wireless loss for congestion

- In wired - most often true
- In wireless - error induced packet loss is not rare
- Lost packets attributed to network congestion

Schemes for Enhancing TCP over Wireless

• Link layer
• End-to-end
• Split-connection

Link Layer Schemes

• Hide link losses from the TCP sender
– Local retransmissions
– Error correction (e.g., FEC)
– Link rate adaptation
• Might not fully protect the TCP sender from losses

End-to-end Schemes

• Selective ACKs
• Explicit Loss Notification (non-congestion loss)
• Require changes in the TCP/IP stack

Lecture 15,16

Split-connection Schemes

- Reliable TCP connection – "traditional" TCP
- Lossy TCP connection NACKs & SACKs
- Isolates TCP sender from wireless losses
- Changes in TCP/IP stack, more overhead, slow handoff

TCP over hybrid wireless/wired

Issues:

- TCP flow fairness issues (starvation of the lossy TCP flows)
- TCP segment reordering over different paths

***Possible schemes*:**
- Link layer
  – Rate adaptation: keep contention level in the wireless part as low as possible
  – Local retransmissions on wireless links
- End-to-end
  – Manage CWND limit for highest TCP throughput

TCP over fully wireless network

- Network utilization
  – Use multiple (wireless) paths
  – Out of order delivery
  – Use reassemble/reorder queues
- TCP flow fairness issues
  – Which node relays TCP connection?
  – Which TCP flow takes priority?
- "Reliable" TCP over inherently unreliable network
  – Lossy links + potential mobility (MANET, VANET)

<u>Lecture 17</u>

Mobile IP: A standard that allows users with mobile devices whose IP addresses are associated with one network to stay connected when moving to a network with a different IP address.

When a user leaves the network with which his device is associated (home network) and enters the domain of a foreign network, the foreign network uses the Mobile IP protocol to inform the home network of a care-of address to which all packets for the user's device should be sent.

Mobile IP is most often found in wireless WAN environments where users need to carry their mobile devices across multiple LANs with different IP addresses.

A common analogy to explain Mobile IP is when someone moves his residence from one location to another. Person moves from Boston to New York. Person drops off new mailing address to New York post office. New York post office notifies Boston post office of new mailing address. When Boston post office receives mail for person it knows to forward mail to person's New York address.

TERMINOLOGY:

Mobile node - A host or router that changes its point of attachment from one network or subnetwork to another, without changing its IP address. A mobile node can continue to communicate with other Internet nodes at any location using its (constant) IP address.

Home agent - A router on a mobile node’s home network which delivers datagrams to departed mobile nodes, and maintains current location information for each.

Foreign agent - A router on a mobile node’s visited network which cooperates with the home agent to complete the delivery of datagrams to the mobile node while it is away from home.

Mobility agent - Either a home agent or a foreign agent.