Wireless Networks

Introduction

- radio link establishes communication between the mobile user and base station
- the terrestrial network connecting base stations to other users is also important: it forwards speech or data to its destination
- complicated due to mobile user mobility
- user may move between base stations served by one carrier (handoff) or between different carriers' systems (roaming), or both, without terminating the call
- bandwidth of terrestrial ("landline") circuits is many orders of magnitude higher than that of the wireless links while the cost (per bit/s) is orders of magnitude lower

PSTN

- the public switched telephone network (PSTN) links a large (but economically important) minority of the world's population
- individual phones connect to a local telephone switch located in a central office (CO)
- CO's are interconnected by trunks between various types of switches to form a network
- all countries have government regulation of telephone service
- in 1984 the US government split the telephone system into local exchange companies (LECs) providing service only within a local area and inter-exchange carriers (IXCs) providing long-distance service
- the competitive situation is in a state of flux with mergers eliminating some companies and new CLECs (competitive LECs) entering the market
- deregulation, fibre and packet-based routing based on IP (internet protocol) are reducing the cost of switched bandwidth to the point where POTS (plain old telephone service) may become an insignificant revenue source
- originally the PSTN was completely analog
- long-distance (LD) trunks went digital in the 60's to avoid problems with noise introduced by amplifiers required on these circuits
- a hierarchy of digital trunk rates was established, the most widely used is the T1 multiplex which carries 24 DS-0 (64 kb/s) rate channels (in Europe the E1 multiplex carries 64 kb/s channels)
- eventually the local switches also became digital
- signaling information (e.g. called and calling number) was originally sent in-band over the same analog trunks used for voice
- digital switches now use out-of-band signaling (CCS, common-channel signaling) over a packet-based network although in-band signally is still common (e.g. for PBXs and subscriber "caller-id" devices)
- the protocol used between telephone switches is called SS7 (signaling system 7)

First-Generation (Analog) Networks

- base stations within a service are are connected to a MSC (mobile switching centre)
- the MSC is a digital telephone switch programmed to provide the special services required to support cellular radio functions (handoff, roaming)

- for roaming, MSCs communicate between each other using a terrestrial packet-switched network (see below)
- information about each subscriber, the home location register (HLR), is stored at each user's "home" MSC
- when a user moves outside the area covered by the home MSC, the foreign MSC establishes a visitor location register (VLR) entry and notifies the home MSC
- information is also exchanged between the two MSCs for authentication, billing, etc
- calls terminating at the wireless subscriber terminal are always placed to the home MSC
- if the user is roaming (as indicated by an entry in the HLR) a second call is placed to a temporary phone number at the remote MSC

Second-Generation (Digital) Networks

- GSM introduced BSC (base station controller) to support several base stations
- GSM also introduced standardized interfaces between MSC, BSC and the air interface to promote competition between equipment suppliers
- the digital air interface allows provision of circuit-switched mobile data services (for which there has not been much demand)

Third-Generation (Digital) Networks

- it's too early to tell what these networks will look like
- previous predictions have proven to be far off

Terrestrial Circuit Switched Networks

- often called "connection-oriented" services
- a "call" or connection is set up, data is transferred and the call is terminated
- typical example is a telephone call
- network resources (trunks) are allocated for the duration of the call
- widely used for isochronous (fixed rate) traffic such as voice, fax, video
- not very useful or widely used for data

Terrestrial Packet Switched Networks

- also called "connectionless" services
- each packet of data is routed independently
- network resources are allocated on a packet-by-packet basis
- isochronous traffic can be supported if network is designed for it and access is managed
- many companies and standards organizations have come up with (typically very complex) protocols for packet-switched networks (OSI, [B]ISDN)
- at the network level the most widely-used packet-switched protocol is IP (internet protocol), a simple, easy-to-implement, widely-used and vendor-neutral protocol
- at the link layer the most widely used protocol is Ethernet (CSMA/CD) (for the same reasons as above)
- many other packet-switched protocols (ISDN, Frame Relay, ATM, SONET) are used for specific purposes but in the long term these are likely to be replaced by IP and Ethernet

Wireless Data Networks

- there are many applications (e.g. digital dispatch, database lookup, paging, etc) where traffic is very bursty
- for these applications a wireless packet network is ideal
- four such networks have been deployed: two (RAM and ARDIS) are non-cellular (one channel is used to cover a whole city), one (CDPD) uses a conventional cellular structure and one (Metricom) uses a microcellular structure
- RAM (Motorola/IBM) and ARDIS (Ericsson) are relatively expensive on a per-byte basis and are used mainly for very short messages (paging, dispatch)
- CDPD was originally designed to use AMPS voice channels while they were idle, but due to limited demand for the service, it is generally deployed on dedicated channels with large cells
- RAM, ARDIS and CDPD coverage is available in most cities but high per-byte tariffs have limited their popularity
- Metricom's system is based on small wireless repeaters mounted on light posts; service is only available in selected cities
- while the above are public systems, there are also vendor-specific packet-radio systems designed for use by large customers on private channels (couriers, police, etc)
- wireless packet data protocols that will allow efficient wireless Internet access are a major goal of 2.5G systems such as GPRS

Packet Radio Protocols

- a multiple-access technique used for bursty traffic
- stations transmit their information in short bursts (packets)
- the main challenge is coordinating use of the channel with as little overhead as possible
- the two main performance parameters are throughput (bits/second) and average delay (seconds)
- with the Aloha protocol stations transmit packets as the data becomes available
- the packet is retransmitted after a randomly-chose delay if an ACKnowledgement packet is received from the destination
- if assume fixed-length packets, a large number of sources with Poisson distributed number of arrivals then, due to collisions, the maximum throughput is only 18% of the channel data rate
- Slotted Aloha requires that all stations synchronize their transmissions
- this reduces likelihood of collisions and doubles maximum throughput to about 36%
- on some channels it's possible to detect if another station is transmitting ("carrier sense")
- CSMA (carrier-sense multiple access) can be used to reduce the likelihood of collisions, but doesn't eliminate it due to propagation delays, transmit/receive switching delays and delays in the channel-sense circuits
- collision detection (CSMA/CD) is typically not available because of the differences in transmit and receive signal levels (unlike on a LAN)
- reservation protocols reserve future channel time slots and thus eliminate/reduce contention during these slots
- polling by a master station can be used to ensure controlled access to the channel
- many other schemes and combinations of the above methods have been developed to reduce collision probability and improve throughput
- for example, the IEEE 802.11 Wireless LAN protocol uses short slots equal to the carrier sense time, CSMA, an RTS/CTS reservation protocol, along with polling for certain types of traffic