COMP312-09A
Communications and Systems Software

Mobile Radio Multiplexing

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Mobile Radio Multiplexing

- Multiple Access – FDMA and TDMA
- Duplexing – FDD and TDD
- More Multiple Access – OFDMA, DSSS, CDMA
- Even More Multiple Access – Packet Radio

Mobile Radio Multiplexing

- For a communications system to be most useful and economically viable, it has to be available to many users in the same place at the same time.
- Cellular systems divide space into cells to allow frequency re-use in different locations, controlling power to limit the range, but this leaves us with multiple users in a cell that are within range of each other and would interfere if they used the same carrier frequencies at the same time.
- Solutions to this include Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA) and Code Division Multiple Access (CDMA).

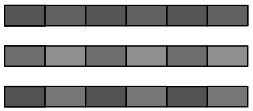
Mobile Radio Multiplexing

- There is also the arrangement needed to allow the mobile unit and the base station to transmit to each other in an apparently simultaneous fashion. This is called Duplexing.

Multiple Access

- By Frequency
- By Time
- Spread Spectrum
  - Frequency Hopping
  - CDMA
- Packet Radio

Time and Frequency



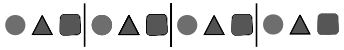
- One answer is to divide the available frequencies into channels and allocate a channel to each user. This is called Frequency Division Multiple Access, FDMA.
- Another is to divide time into small slots and let each user have a slot every few ms. This is called Time Division Multiple Access, TDMA.
- Some schemes use both time and frequency division. Spectrum is divided into frequency bands that are divided into timeslots. Users have access to the timeslots at intervals short enough that there seems to each user to be continuous access.

FDMA

- A frequency band – a channel – is assigned to one user or session.
- The channel bandwidth is kept as narrow as possible, given the data rate and BER required.
- This will depend on the modulation scheme used.
- Channels are separated by as small a distance in frequency as

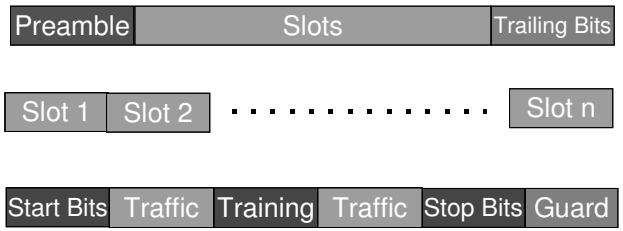
required to limit cross-channel interference. These gaps are called Guard Bands.

TDMA

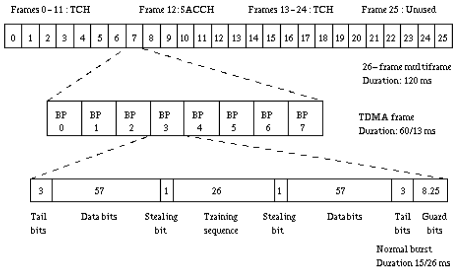


- Time Division Multiple Access
- Digital Circuit Sharing Technique
- Each user – channel – assigned a slot in a frame
- Generally small overhead required for frame structure

TDMA



GSM Frame



FDMA vs. TDMA

- TDMA requires synchronisation, which requires overhead "guard slots" between user time slots.
- TDMA transmission is not continuous, which allows
  - Lower mobile power requirements
  - Simpler handoff between cells, as the mobile can listen to more than one cell at once
- TDMA can allow different numbers of slots per user, giving different service levels.
- TDMA must use higher transmission rates because it has less time.
  - So must use equalisation to overcome inter-symbol interference (i.e. Earlier and later signals interfering with each other)
  - But is less vulnerable to inter-channel interference

FDMA vs. TDMA

- FDMA was implemented to provide narrowband service (e.g. AMPS – Telecom 025). Little used today in its original form.
- Both FDMA and TDMA are used at the same time by GSM, the most widely deployed cellular technology. Users are assigned a number of TDMA slots within an available FDMA channel.

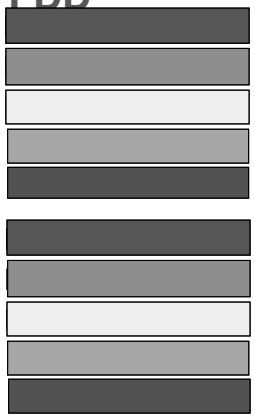
Problem - Duplexing

- A radio transmitting on a particular frequency will not be able to receive simultaneously on that same frequency.
- Since radio transmission power falls fast with distance the local transmitter will drown out any other transmissions.
- Therefore transmitting and receiving needs to be separated in time or frequency.

Frequency Division Duplexing (FDD)

- Similar in concept to FDMA.
- For each channel, have two bands separated by frequency. One is the transmission frequency for the base station, the other is the transmission frequency for the mobile.
- Base station and mobile transmit continuously and simultaneously.

FDD



- The duplex frequencies are as far apart as possible to stop a transmitter receiving from itself and swamping the signal from the station it is receiving from.
- This requires duplexers in the base station and subscriber unit to allow simultaneous transmission and reception.

Time Division Duplexing (TDD)

RX TX RX TX RX TX

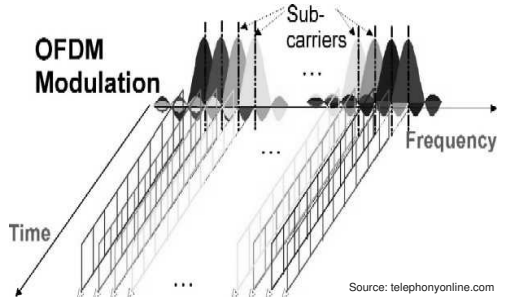
TX RX TX RX TX RX

- Similar in concept to TDMA
- Break the frequency channel into time slots, with separate times for the mobile and base station to transmit and receive on the same frequency.
- Allows simpler RF equipment at both ends using only one frequency at a time
- BUT costs in switching delay and reduced available time to send reduces available data rate.

TDMA/TDD etc.

- An FDMA or TDMA system can use either FDD or TDD.
- AMPS used FDMA/FDD
- DECT uses FDMA/TDD
- GSM uses TDMA/FDD

Orthogonal Frequency Division Multiplexing (OFDM)



- Split the frequency band into a series of sub-channels which do not interfere with each other.

Why Use OFDM?

- Coded OFDM (COFDM)
  - Spread transmission across multiple slowly-modulated signals rather than one quickly modulated signal.
  - Less susceptible to interference. (And if a bit at a time is spread across sub-carriers, single-frequency interference shows up as bit errors rather than burst errors.)
- Very similar to DMT in ADSL systems

OFDMA

- One or more subcarriers per session, allowing multiple users in the frequency range, compared to one for FDMA.
- Much higher aggregate data rates possible than FDMA.
- Multiple possible grades of service, as in TDMA.
- Lower minimum power use for low-rate users
- 802.16d “WiMAX” uses OFDM in its Fixed standard, OFDMA in its Mobile standard.

Multiple Access

- By Frequency
- By Time
- Spread Spectrum
  - Frequency Hopping
  - CDMA
- Packet Radio

Spread Spectrum Techniques

- Originally developed for covert communications
- Signal “smeared” across a large range of frequencies.
- Appears as (small) increase in noise to other signals.
- Two types
  - Frequency Hopping
  - Direct Sequence

Frequency Hopping

- FH uses multiple carriers, one at a time, changing in a predictable pattern known to all stations in the network.
- Fast hopping, e.g one hop per packet.
- Slow hopping, e.g. 1 per second. (Though distinction debatable.)
- e.g. Used by Bluetooth, Channels are 1MHz apart. 79 of them at 2.4 GHz hops at one hop per packet, every 625us.

Frequency Hopping

- Transmitter and receiver must be synchronised.
- Use a pseudo random sequence with known key
- Channels can be significantly affected by a narrowband interferer and vice-versa but only until next hop.
- Lost packets can be re-transmitted.

Frequency Hopping

- Hopping reduces the chance that communications can be blocked by a single frequency source, or other networks using FHMA or CDMA.
- Reduces effects of frequency selective fading because the frequency changes fast.
- Can be made adaptive (avoid known bad frequencies)

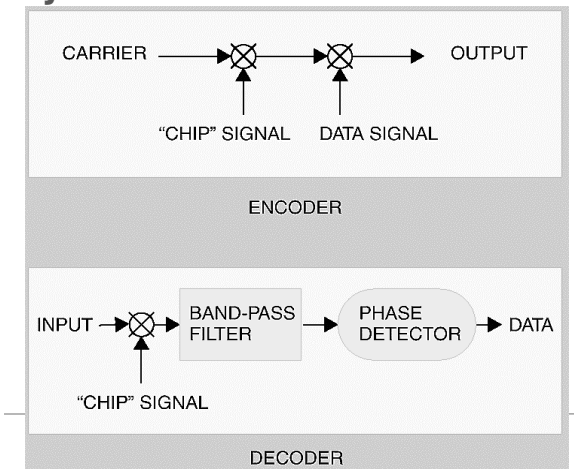
Frequency Hopping Multiple Access

- FHMA
- Other networks use a different pseudo random pattern.
- Allows multiple carriers to operate simultaneously.
- Different channels do not interfere (much).
- There is a limit.
- No co-ordination required between channels as long as they choose different psuedo random keys.

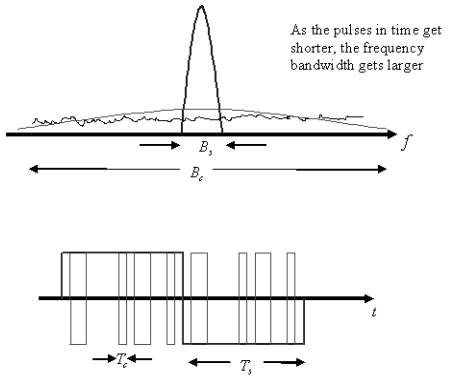
Direct Sequence Spread Spectrum (DSSS)

- A pseudo-random spreading code is clocked at some multiple of the data rate to spread the signal across the entire band
- Receiver uses an autocorrelation method to recover the signal out of relatively high noise.

DSSS System



DSSS Signals



DSSS

- Interference is “despread” into noise at receiver.
- Very resistant to interference and fading.
- Providing multiple access using a different spreading code for each session is called Direct Sequence Multiple Access or Code Division Multiple Access (CDMA)

CDMA

- FDMA, TDMA and variants used fixed frequency ranges.
- FHMA uses one discrete carrier at a time.
- CDMA spreads energy over the whole band.

CDMA

•CDMA distinguishes sessions using a code assigned to the mobile, not frequency or time.
•Spread-spectrum modulation does not cause cross-channel interference.

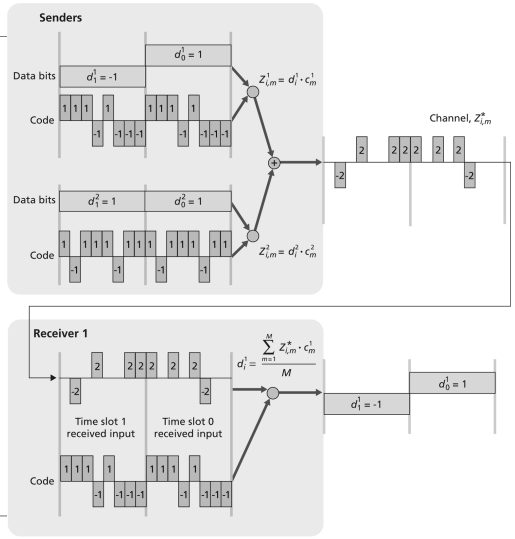


Figure 6.5 ♦ A two-sender CDMA example

CDMA and DSSS

- A CDMA system is a DSSS system, but not all DSSS systems are CDMA.
- e.g. 802.11b uses DSSS to minimise interference but not for multiple access.
- In DSSS orthgonal codes are used to spread the signal into a wider frequency band to minimise interference.

CDMA and DSSS

- In CDMA orthogonal codes are also used to define a particular user which allows multiple access.
- So a DSSS system in which each user has a unique spreading code is also a CDMA system.
  - e.g. 3G Mobile Radio
- A DSSS system where all uses use the same spreading code is NOT a CDMA system and only one user at a time can be active.
  - e.g. ISM Band radio

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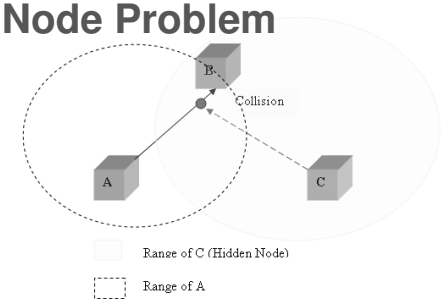
Packet Radio

- Same idea as packet switching on physical media. All stations share media and send packets.
- But in radio the medium really is shared, where in modern point-to-point communications (including all Ethernet from 100Mbps up), a full-duplex channel is available to all senders.

Packet Radio

- Receiver radio environment is different to transmitters
- Successful transmission of a signal does not imply successful reception.
- Need to have Acks.
- Can use RTS CTS signals before the packet

Hidden Node Problem



- A and C can both communicate with B.
- But A and C can't detect each other.
- Can lead to undetected collisions

Out There

- DECT – TDMA/TDD — Cordless Phone
- GSM – TDMA/FDMA/FDD — Vodafone/Telecom
- IS-95/cdmaOne – CDMA — Telecom
- TIA-856/cdma2000 EVDO
  - CDMA/TDMA/FDD — Telecom Data
- GPRS – Packet over GSM — Vodafone Data
- UMTS/HSDPA
  - CDMA/TDMA/FDD — Vodafone/Telecom
- 802.11 “WiFi” - DSSS or OFDMA
- 802.16 “WiMAX” - OFDMA

Out There

- UMTS, whose data service is HSDPA, runs over W-CDMA. This uses CDMA to provide multiple access, and also makes use of TDMA.
- W-CDMA is a set of “3G” standards. Not to be confused with earlier products using “CDMA” in the name, such as cdmaOne.
- W-CDMA devices backward-compatible with GSM.