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CS3282: Digital Communications ‘06

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Section 10

Multiple access for wireless communications

1. Multiple user access for wireless communications

Allow many users to share given amount of radio bandwidth.
Three main techniques are:

- Frequency division multiple access (**FDMA**)
- Time-division multiple access (**TDMA**)
- Code division multiple access (**CDMA**)

(CDMA is type of "spread spectrum multiple access" technique).
To these add:

- Space division multiple access (**SDMA**)
  (same band-width is re-used in different places)
- Packet radio (**PR**)"
  (a form of time division multiplexing)

'**CSMA/CA'** as used by IEEE802.11 is a form of 'packet radio'.

Narrow-band systems: bandwidth used by a single channel lower than coherence bandwidth (B_C Hz).

Wide-band systems have bandwidth >> B_C.

B_C is range of frequencies over which channel fading can be considered flat

i.e. all frequencies have same attenuation & delay.

Two sinusoids with frequency separation >> B_C Hz affected quite differently.

- $B_C \propto 1/\sigma_t$ where σ_t is " r.m.s. delay spread",
  i.e. spread of delays due to multi-path.

- In a city $\sigma_t \approx$ 1 to 10 μs for 900 MHz wireless system.

- About 0.3 μs inside the buildings.

- If $B_C \approx$ 30 kHz analogue mobile phone system with 30 kHz channels works without equaliser.

- 900 MHz GSM system with 200 kHz bandwidths requires equalisation.

(Correct p.10.1, 2nd para, l.14: replace 'delay spread' by B_C)

FDMA:-

Divides available bandwidth by assigning one band to each channel.

American "AMPS" cellular mobile phone system:

Uses 70 MHz band (824 to 894 MHz)
Divided into 1664 channels,
each 30 kHz, with 10 kHz "guard-bands".
832 reverse & 832 forward channels.
Each forward & reverse pair separated by fixed frequency.

Each company allocated 416 channels & must use space division multiplexing.

FDMA usually has narrow-band channels; equalisation not needed

TDMA:-

Uses available band by transmitting a high frequency bit-stream containing data from many users.

Each user allocated cyclically repeating time-slot within bit-stream.

Digital encoding & transmission techniques used.
Transmissions interlaced into repeating frame structure.

Each frame has:

- "preamble" bits for synchronisation.
- bit-stream containing data from all users,
- a few "tail bits" to terminate the frame.

GSM cellular systems:-

25 MHz bands (890 to 960 MHz) for forward & reverse links split into 200 kHz channels (by FDM).

Each channel supports eight 24.7 kb/s speech channels.

Interleaved in 270.833 kb/s bit-stream.

GSM transmits 270,833 kb/s in each 200 kHz sub-band by binary MSK with Gaussian pulse shaping.

Adaptive equalisation needed as 200 kHz > B_C

Frequency selective fading will occur in some 200kHz channels.

There are 250 such channels thus allowing 1000 users.

Each has 24.7 kb/s forward & 24.7kb/s reverse channel.

Space division multiplexing (cellular) increases number.

SSMA:-

Spread transmission over bandwidth much wider than ordinary PSK, FSK or ASK.

May seem inefficient.

Done in such a way that many users can transmit simultaneously.

Transmissions separable at a receiver.

Two main types of SSMA:

- "frequency hopped" (FH)
- "direct sequence" (DS) = CDMA.

FH-MA:-

Applied to schemes such as PSK by varying carrier frequency in pseudo-random fashion within wide-band channel.

Data split into blocks of equal duration,

Each block transmitted with different carrier frequency.

- "fast hopping" : hopping rate >> symbol rate (1/T).
- "slow hopping" : hopping rate < symbol rate.

Choice of frequencies according to known pseudo random sequence.

Synchronised at transmitter and receiver.

FH-MA provides security & immunity to fading.

Effect of deep fades spread out among all users.

Each user degraded for just a short period of time (until he "hops" onto another carrier).

Effect of short duration degradation minimised by error coding or "diversity" transmissions.

CDMA

Multiply base-band signal by "spreading signal".

Pseudo-random sequence of bits at high bit-rate called "chip-rate".

Chip rate >> data-rate

E.g. for 24.7 kb/s speech, 1228.8k chips/s is factor of 50.

Multiplication done digitally.

Each data bit modulates about 50 pseudo random "chips".

Stream of chips transmitted as very wide-band signal.

The receiver, knowing the chip sequence can recover each data bit by a cross-correlation process.

CDMA has "soft" capacity limit;

Effects of multi-path fading reduced because of spreading.

Power control is a difficulty with CDMA due to "near-far" problem.

Packet radio:

as used by wireless networks.

Many users attempting to access a single channel in uncoordinated (or minimally co-ordinated) way.

Access occurs in short bursts for each user.

Techniques for avoiding collisions needed as on wired networks.

CSMA with Collision Detection and/or Collision Avoidance

• With earlier forms of wired Ethernet, all hosts connected to single coaxial cable acting as a "bus”.

• All users competed for access according to CSMA protocols:

• CSMA/CA : i.e. sensing channel before attempting transmission & waiting until it is clear.

•CSMA/CD while transmitting to determine whether another device is transmitting at same time, rendering transmission useless. Can happen when 2 devices start to transmit at once.

• If collision detected, further collisions avoided by a ‘random back-off’ mechanism.

Important difference between wireless LAN medium access protocols & Ethernet strategy :

Unlike an Ethernet device, a wireless LAN device cannot listen while it is transmitting

So "collision detection" (CSMA/CD) is not possible.

Wireless LANs must rely on CA mechanisms.

‘Short’ and ‘distributed’ inter-frame spaces SIFS and DIFS used to delay access allowing some devices priority.

The 'hidden node’ problem

- Occurs with WLAN when 2 devices A & B are in range with a third device, C, but out of range with each other.
- If A transmits to C, & B cannot sense or detect this transmission, B may start transmitting also.
- Would cause collision with A's message rendering it useless.
- For short messages, we may choose to take a chance and allow such collisions to occur from time to time.
- Rely on retransmissions (with randomised time-delays or back-off) to achieve corrected transmissions.

- In other cases it is safer to use RTS/CTS protocol between devices before any of them starts a transmission.
- RTS/CTS protocol requires the sending device to send a short RTS (request to send) control packet & to receive a short CTS (clear to send) control packet before attempting a transmission.
- CTS is sent to tell just one device that it may transmit and to tell all other devices to stay quiet for a period of time.
- Other devices stay quiet by setting their 'network allocation vectors' NAVs for a specified period of time.
- This is 'virtual carrier sensing'
- RTS/CTS packets can also collide with other hidden node transmissions, but are made very short to minimise this occurrence.