Link Budgeting

- How much power do you need to be reasonably assured of good communication? – make a link budget.
- Link budgets are usually expressed as POWER (not amplitude) and in terms of dB.
- Take the starting power (at the transmitter), add all the gains, and subtract all the losses

(Eq. 1) $P_R = P_T + G_T + G_R - L_P - L_F - L_O$

- P_T: Transmitter power; G_T: Transmitter antenna gain; G_R: Receiver antenna gain; L_P: Path loss; L_F: Fading margin; L_O:Other losses; P_R:Receiver power (all in dB)

Path Loss

- Path loss term is L_P
- Before we said that the path loss is proportional to d^a, where a is the path loss exponent
- In dB, we have

(Eq. 2) $L_P = 10 \log_{10} kd^a = 10 \log_{10}k + 10a \log_{10} d$

Fading margin

- this amount is allocated to ensure a high probability that fading will not disrupt the signal
- Can use the probability of various amplitudes in Rayleigh fading to obtain an adequate margin

Example. You need -10dBm of power to ensure reliable communication. Required range is 500 m, with a path loss exponent of 3 (ignore the constant of proportionality). The transmit antenna has G_T=3 dB, and the receive antenna is isotropic. Allow 10 dB for the fade margin, and 0 dB for other losses. What is the required power at the transmitter in dBm?

(Answer: $P_R = P_T + G_T + G_R - L_P - L_F - L_O$ … solve for P_T. The only tricky part is that G_R = 0 dB because the antenna is isotropic.)

Data Link Layer: Access Control and Multiple Access

- The role of the data link layer is to ensure reliable communication between two connected terminals, and to allocate access to a shared medium
- E.g., in wired communication, Ethernet is a data link protocol
- These protocols become very important in wireless communications, because everyone in the world is sharing the same medium (i.e., the air)
- Compared to wired systems, the random delays and frequency shifts inherent in wireless systems are problematic and require special attention in protocol design
- Also at this layer is error detection/correction

Fixed multiple access protocols

- There are two traditional multiple access protocols, which divide up the medium in terms of time or frequency – both ensure that the users do not interfere with each other
- Frequency division multiple access (FDMA): The entire frequency band is divided up (equally or not) among the users. In each user's allocated band, the user can do as s/he pleases.

- Guard bands between users are given to prevent doppler frequency shifts from causing interference
- Example. 1 MHz of bandwidth to be shared among 10 users, with a 10 kHz guard band between each user. So each user gets 90 kHz (don't forget about half a guard band before the first user, and half a guard band after the last user).
- Time division multiple access (TDMA): Time is broken up into frames. Each frame is divided up (equally or not among the users. In each user's allocated time, the user can do as s/he pleases.
- Guard times between users are given to prevent random delays from causing interference
- Example. Frame duration of 10ms, guard time of 0.1ms, 10 users. So each user gets 0.9ms per frame.
- Problem with FDMA and TDMA: They require central control and make it difficult to quickly reuse resources … best for cellphone-like systems, where people need a full channel for a long period of time; bad for packet data systems, where data is sent less frequently

Exposed/hidden terminal problem

- Carrier sense multiple access (CSMA) solves this problem in Ethernet (i.e., sense whether the channel is free and then transmit) … this is decentralized and appropriate for packet data. Can we do the same thing here?
- Not exactly: there are two problems, the hidden terminal problem, and the exposed terminal problem

- Hidden terminal problem:
- There are three nodes: A, B, C
- Say B is in radio range of A and C. However, A and C are NOT in radio range of each other.

- A wants to send to B. A senses the medium and sees that it is clear, so A sends.
- While A is sending to B, C decides to send to B. C senses the medium – C can't tell that A is transmitting because A and C are not in radio range. Thus, C decides that the medium is clear and transmits.
- Messages from A and C collide at B, corrupting each other.

- Exposed terminal problem:
- There are four nodes: A, B, C, and D.
- A is in range of B, B is in range of A and C, C is in range of B and D, and D is in range of C. (i.e., the nodes are arranged in a line as A B C D, and each node can only see its neighbors)
- B sends to A, and at the same time, C wants to send to D. C senses the medium and decides the medium is busy, so C does not send. However, B's transmission cannot reach D, so in fact it is safe for C to transmit, and that time/bandwidth is wasted.

(For the above, draw figures to help the students understand the relationships among the users)