Worst-case vs Average-case - 10min

Tuesday, January 08, 2008 3:29 PM

Why does CDMA have an advantage in terms of system capacity?

- Universal reuse?
- But, each CDMA freq. channel also occupies about 60 times the bandwidth as GSM?

Need to understand statistical multiplexing gain.

Consider a wireline connection with capacity 1000 Kbps.

If the traffic of each user looks like this:

e.g. silent period in voice

How many users can we support?

① Design by worst case: Since peak rate is 10k bps

$$\frac{1000k}{10k} = 100 \text{ users}$$

② But the peak of these 100 users

rarely occur at the same time!

Say the variance of each user's traffic is $(3k)^2$
The total traffic of 100 users will have mean = $3k \times 100 = 300k$
variance = $(3k)^2 \times 100 = (30k)^2$

We could have supported these 100 users with
mean + 3 x std
$= 300k + 30k \times 3 = 390k$
of capacity!

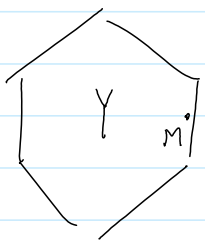
With 1000k bps of capacity, we could easily support 200+ users.

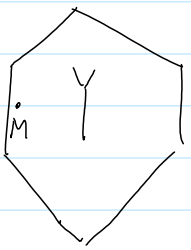
This gain that we just see by basing the design on statistical performance is called "statistical multiplexing gain".

The analogy to Wireless Networks

In TDMA/FDMA:

Channel allocation has to be based on "worst case".





In order to determine whether two cells can use the same channel,

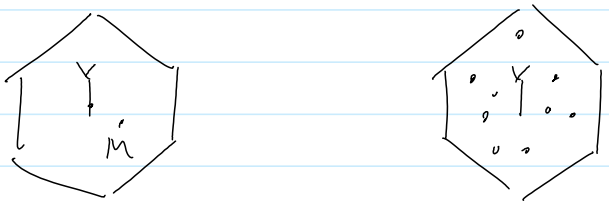
we have to consider the case when mobiles are placed in the worst position

- signal strength is lowest
- interference is highest
- worst-case propagation parameters

Such worst-case calculation determines the reuse factor, which in turn determine the capacity.

In CDMA:

# of channels can be determined by actual amount of interference



Since there are typically large # of mobiles, we can compute the interference by assuming certain distribution of

- mobile position
- voice traffic intensity
- propagation parameters.

This allows us to exploit the statistical multiplexing gain!

Bottom line: The choice of multi-access scheme can make a huge impact

on spectrum reuse / capacity

We will study in depth how the capacity of TDMA/FDMA/CDMA system can be calculated.

60min

Opportunistic scheduling and diversity - 10 min

Saturday, January 24, 2009 10:23 PM

- The users' channel condition is not fixed.
- Rather, they usually chage frequently in time.
- Three possibilities

① Allocate resources indep. of channel

② Allocate more resources (time/freq/power) to user with poor channel, so that their rates all get equalized.

③ Allocate more resources to users with good channels

Consider an example:

- Three
- With a unit bw, the rate of each user vary between 1 & 0.1 with prob 1/2.

Option ②:

- To maintain a constant rate of 1, we need 10 unit of bw for a user when it is in a bad channel
  - Avg. bw requirement per user

$$10 \times \frac{1}{2} + 1 \times \frac{1}{2} = 5.5$$

— Efficiency $1/5.5 \approx 0.2$

Option ①:

— Always allocate one unit of bw to each user

— Avg rate: $1 \times \frac{1}{2} + 0.1 \times \frac{1}{2} = 0.55$

efficiency: $\frac{0.55}{1} = 0.55$

Option ③:

— Allocate one unit of bw to the user with the best channel 1

— With prob. $\frac{7}{8}$, at least one user has the rate of 1

— Total rate over three users: $1 \times \frac{7}{8} + 0.1 \times \frac{1}{8} = \frac{7.1}{8}$

Efficiency: $\frac{\frac{7.1}{8}}{1} \approx 0.9$ ← almost as if the channel is always good!

— In summary, the idea here is that if we can take advantage of channel variations, we can attain much higher efficiency of the spectrum

— This is known as diversity.

Diversity is an important concept in wireless networks and is heavily exploited in modern systems

As we will see soon when we study channel models, Fading creates diversity

- in space : multiple antenna
- in freq :
- in time :
- in polarity

Diversity allows us to pick the best component, and thus increase system performance.

- MIMO
  exploits diversity in space
- OFDM
  exploits diversity in freq
- Opportunistic scheduling, Rake receiver
  exploits diversity in time

- Need to have mechanisms to estimate channel quality in time & frequency.