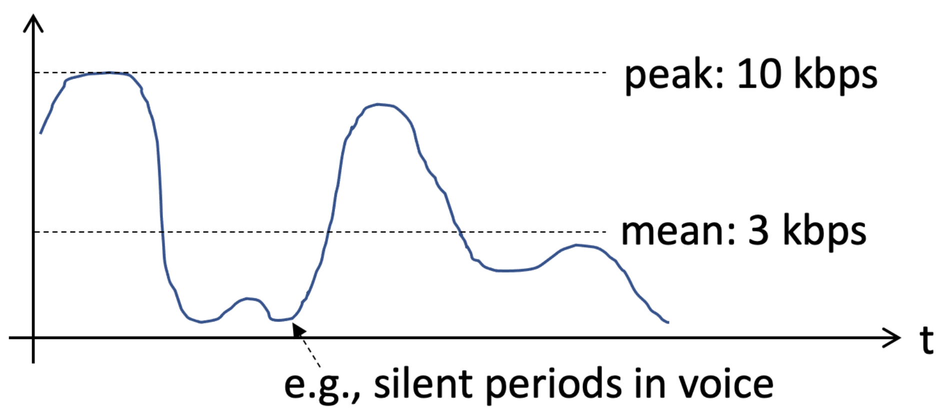
CDMA and Statistical Multiplexing Gain

We have pointed out that CDMA can obtain significant capacity advantages over FDMA/TDMA. On the one hand, it gives universal reuse. On the other hand, each CDMA frequency channel also occupies about 60 times the bandwidth as GSM. So, how are these capacity gains obtained? The answer lies in the concept of statistical multiplexing.

Wired Channel Example

Consider a wired channel with a capacity of 1000 kbps. The traffic of users accessing the channel might look something like this:



How many users can we support? If we design by the "worst case," since the peak rate is 10 kpbs, we can support $1000K/10K = 100$ users.

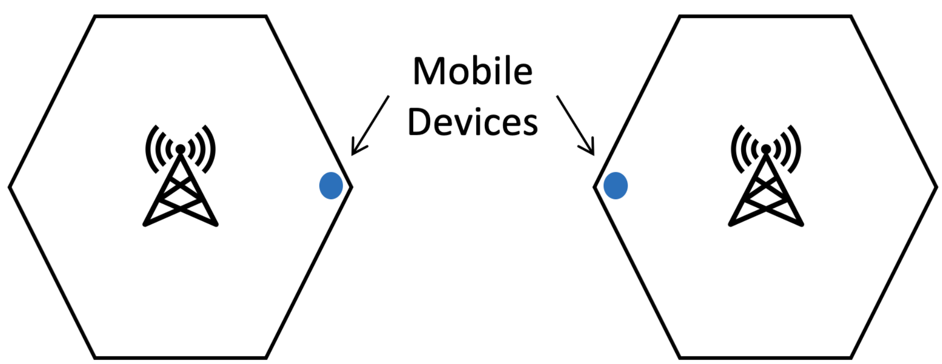
But the peak rate of these 100 users will rarely occur at the same time! Instead, we may consider a statistical model for user traffic. Suppose the variance of each user's traffic is $(3K)^2$. Then, the total traffic of 100 users (assuming they are independent and identically distributed) will have a mean $3K \times 100 = 300K$ and variance $(3K)^2 \times 100 = (30K)^2$. We could have supported these 100 users with, say,

$$\text{mean} + 3 \times \text{std} = 300 \text{ kbps} + 30 \text{ kbps} \times 3 = 390 \text{ kbps}$$

of capacity! With 1000 kbps of capacity, we could easily support 200 users or more, while ensuring a low probability of conflicting uses on the channel. This gain that we obtain by basing our design on statistical performance is called **statistical multiplexing gain**.

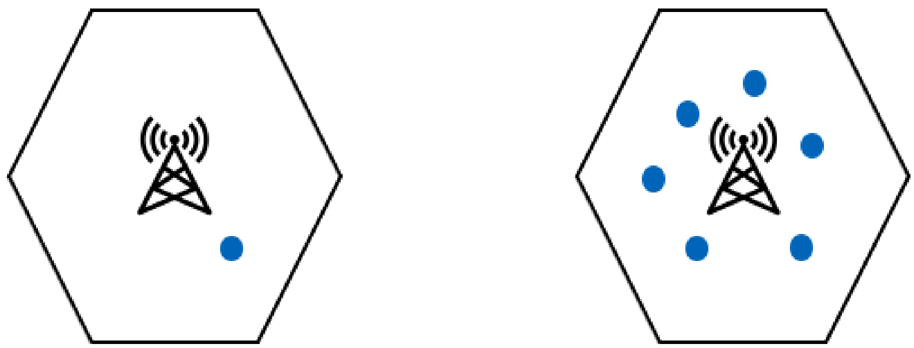
The Analogy to Wireless Networks

In TDMA/FDMA, channel allocation has to be based on a "worst case" analysis. Specifically, in order to determine whether two cells can use the same channel, we have to consider the case when mobile phones are placed in the worst position relative to one another, resulting in (i) the signal strength being the lowest, (ii) the interference being the highest, and (iii) the worst-case propagation parameters. The following diagram gives an example.



The resulting worst-case calculation determines the reuse factor, which in turn determines the capacity of the cellular system.

In CDMA, on the other hand, the number of channels can be determined by the actual amount of interference. Since there are typically a large number of mobile devices, we can compute the interference by assuming a certain distribution of mobile position, voice traffic intensity, and propagation parameters. This allows us to exploit the statistical multiplexing gain by determining the number of channels according to a probabilistic guarantee.



The bottom line is that the choice of multiple access scheme can make a large impact on the resulting capacity. We will study in depth how the capacity of TDMA/FDMA and CDMA systems can be calculated.