Cellular Data Standards

This lecture introduces cellular data standards.

Introduction

Cellular data networks provide ubiquitous (everywhere) data communication. Although slower, more expensive, and less reliable than wired access technologies such as DSL and cable modems, the advantage of having mobile access to internet-based services has made cellular data service very popular.

In addition, many developing countries have limited wired access infrastructure and in these countries cellular service is the only readily-available access technology for both voice and data. In 2012 there were about 5 billion cellular subscribers in the world and about a third of these had access to data services. ARPU from cellular services in the US in 2012 was about $50/month.

Cellular networks were originally designed to carry telephone calls. First-generation (analog) cellular systems allowed data communication using voice-band modems. Second-generation (digital voice) cellular systems could access dial-up data services through the PSTN using a voice-band modem at the MSC. However, this lecture describes more modern cellular systems that support packet-based data communications.

For competitive reasons two separate families of 2.5/3G cellular data standards evolved from second-generation voice-only digital cellular standards. One evolved from the Qualcomm's CDMA standard and the other from GSM's TDMA standard. The most commonly used standards that evolved from CDMA are commonly referred to as 1xRTT and EV-DO. The main standards that evolved from GSM are known as GPRS, WCDMA and HSDPA. Carriers have agreed on a common standard for 4G systems, LTE.

Unfortunately, much terminology for cellular standards has been chosen for marketing purposes. Many terms, for example "3G," no longer have much meaning.

Another issue is that data rates quoted for different standards are the highest supported. Often this will be under ideal conditions such as a strong signal with no interference or multi-path propagation.

As with other access technologies, data rates are often asymmetrical with higher rates on the forward (downlink) channel. This is both because of higher demand and because base stations can often support higher transmit powers and thus higher data rates than handsets.

Cellular Concept

Wireless cellular service is provided by a radio link between a base station and a (typically portable or mobile) subscriber device.

Since the available spectrum is limited, it must be re-used. This is done by allocating the same channels to geographical areas ("cells") that are located sufficiently far apart that their transmissions will not interfere with each other.

By making cells smaller ("cell splitting") we can reduce the number of subscribers per channel and thus increase the data rate available to each user. However, since one base station is required per cell, this increases the operator's cost since it requires installing more base stations.

The operator can thus tailor base station density to subscriber density to minimize overall costs.

Frequency Allocations

There are two frequency ranges that are commonly used by cellular services. The first range, around 800 MHz, was originally allocated to the "UHF" TV broadcast band and was not heavily used. The second range, around 1.8 GHz was allocated to cellular use in the 90's. Over time the amount of spectrum allocated to cellular services in these bands has grown.

Frequency allocations vary by country. Most modern phones operate in both frequency bands and in many cases on the specific frequency ranges used by more than one country.

Most cellular standards use FDD (Frequency Division Duplexing). Cellular frequency bands are typically divided into two parts, one for the forward and one for the reverse channel. This is called "paired spectrum." This minimizes the interference that might result if a mobile device were to transmit on a channel close to one that another nearby mobile was receiving on.

In addition to putting different groups of users on different channels (FDMA), cellular systems separate users using either CDMA (Code Division Multiple Access) or TDMA (Time Division Multiple Access).

CDMA2000 Family

This set of cellular data standards evolved from Qualcomm's CDMA-based 2G cellular system. It is currently standardized by the 3GPP2 project (not to be confused with 3G or 3GPP!). This family uses the original 1.25 MHz channel spacing.

1xRTT (1 times Radio Transmission Technology) uses CDMA and is limited to data rates of about 150 kb/s.

EV-DO (Evolution-Data Only) uses TDMA and supports data rates of up to about 3 Mb/s using 16-QAM modulation.

3GPP Family

This set of cellular data standards evolved from the GSM (Groupe Speciale Mobile)'s TDMA-based 2G cellular system. It is currently standardized by the 3GPP project. This family uses either 200 kHz (for GPRS) or 5 MHz (for WCDMA) channel spacing.

GPRS (General Packet Radio System) uses TDMA and operates at a PHY rate of 280 kb/s.

The UMTS standards use 5 MHz channels. WCDMA cellular data uses CDMA (at lower data rates) and supports data rates up to about 3 Mb/s. HSDPA uses TDMA with data rates of up to 14 Mb/s (16-QAM).

Both 3GPP2 and 3GPP standards continue to enhance their standards to increase data rates in a backward-compatible manner. This is done by using wider channel bandwidths, higher order modulation and MIMO. However, many carriers may choose to switch to LTE rather than upgrade existing 3G systems.

LTE

LTE (Long Term Evolution) is the only remaining contender for a 4G standard. It was designed from the start as a data-centric network, offering high data rates and low latencies. It uses uses only IP packet switching to simplify the architecture and reduce costs. Voice calls carried on LTE are actually VoIP (Voice over IP) calls.

The novel technologies used in LTE are OFDM and MIMO ("smart antennas").