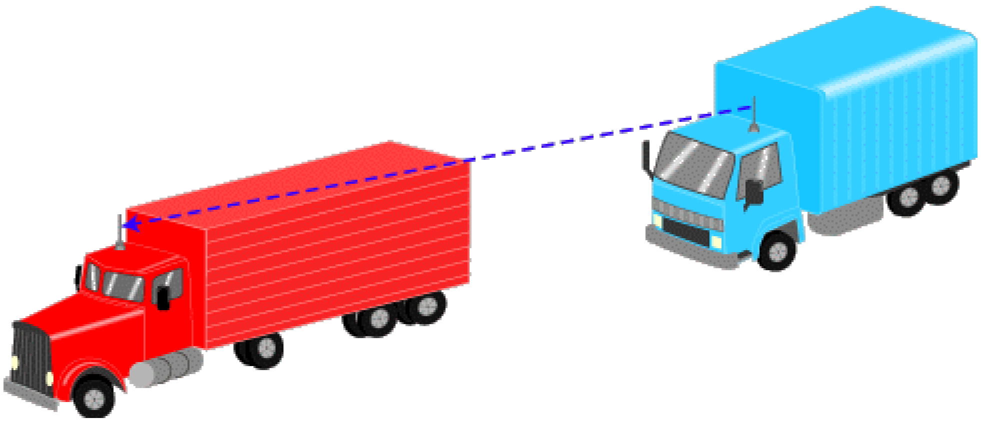
How Cell Phones Work

From Tibet to Tanzania to Toronto, no matter where you go you'll see someone talking on his or her cell phone. These days, cell phones provide an incredible array of functions, and new ones are being added at a breakneck pace. Depending on the cell phone model, you can:

- Store contact information
- Make task or to-do lists
- Keep track of appointments and set reminders
- Use the built-in calculator for simple math
- Send or receive e-mail
- Get information (news, entertainment, stock quotes) from the Internet
- Play games
- Watch TV
- Send text messages
- Take photos and videos
- Integrate other devices such as PDAs, MP3 players and GPS receivers

You might hear terms like 4G, LTE, GSM and CDMA thrown around and wonder what they refer to. At its most basic, a cell phone is a radio -- an extremely sophisticated radio, but a radio nonetheless. We'll show you what we mean.

Cell-phone Frequencies

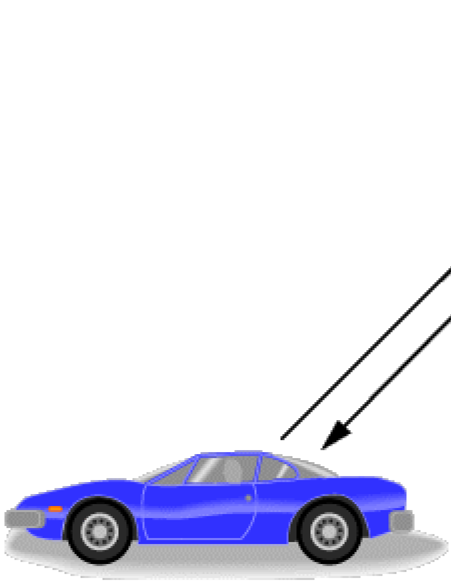


In half-duplex radio, both transmitters use the same frequency. Only one party can talk at a time.

In the dark ages before cell phones, people who really needed mobile-communications ability installed radio telephones in their cars. In the radio-telephone system, there was one central antenna tower per city, and perhaps 25 channels available on that tower. This central antenna meant that the phone in your car needed a powerful transmitter -- big enough to transmit 40 or 50 miles (about 70 kilometers). It also meant that not many people could use radio telephones -- there just were not enough channels.

The genius of the cellular system is the division of a city into small cells. This allows extensive frequency reuse across a city, so that millions of people can use cell phones simultaneously.

A good way to understand the sophistication of a cell phone is to compare it to a CB radio or a walkie-talkie.



In full-duplex radio, the two transmitters use different frequencies, so both parties can talk at the same time.Cell phones are full-duplex.

- **Full-duplex vs. half-duplex** - Both walkie-talkies and CB radios are **half-duplex** devices. That is, two people communicating on a CB radio use the same frequency, so only one person can talk at a time. A cell phone is a **full-duplex** device. That means that you use one frequency for talking and a second, separate frequency for listening. Both people on the call can talk at once.
- **Channels** - A walkie-talkie typically has one channel, and a CB radio has 40 channels. A typical cell phone can communicate on 1,664 channels or more.
- **Range** - A walkie-talkie can transmit about 1 mile (1.6 kilometers) using a 0.25-watt transmitter. A CB radio, because it has much higher power, can transmit about 5 miles (8 kilometers) using a 5-watt transmitter. Cell phones operate within **cells**, and they can switch cells as they move around. Cells give mobile phones incredible range. Someone using a cell phone can drive hundreds of miles and maintain a conversation the entire time because of the cellular approach.

In a typical analog cell phone system in the United States, the cell phone carrier receives about 800 **frequencies** to use across the city. The carrier chops up the city into cells. Each cell is typically sized at about 10 square miles (26 square kilometers). Cells are normally thought of as hexagons on a big hexagonal grid, like this:

Because cell phones and base stations use low-power transmitters, the same frequencies can be reused in nonadjacent cells. The two purple cells can reuse the same frequencies.

Each cell has a base station that consists of a tower and a small building containing the radio equipment. We'll get into base stations later. First, let's examine the "cells" that make up a cellular system.

Cell-phone Channels

A single cell in an analog mobile phone system uses one-seventh of the available duplex voice channels. That is, each cell (of the seven on a hexagonal grid) is using one-seventh of the available channels so it has a unique set of frequencies and there are no collisions:

- A cell phone carrier typically gets 832 radio frequencies to use in a city.
- Each cell phone uses two frequencies per call -- a duplex channel -- so there are typically 395 voice channels per carrier. (The other 42 frequencies are used for control channels -- more on this later.)

Therefore, each cell has about 56 voice channels available. In other words, in any cell, 56 people can be talking on their cell phone at one time. Analog cellular systems are considered first-generation mobile technology, or 1G. With digital transmission methods (2G), the number of available channels increases. For example, a TDMA-based digital system (more on TDMA later) can carry three times as many calls as an analog system, so each cell has about 168 channels available.

Cell phones have low-power transmitters in them. Many cell phones have two signal strengths: 0.6 watts and 3 watts (for comparison, most CB radios transmit at 4 watts). The base station is also transmitting at low power. Low-power transmitters have two advantages:

- The transmissions of a base station and the phones within its cell do not make it very far outside that cell. Therefore, in the figure on the previous page, both of the purple cells can reuse the same 56 frequencies. The same frequencies can be reused extensively across the city.
- The power consumption of the cell phone, which is normally battery-operated, is relatively low. Low power means small batteries, and this is what has made handheld cellular phones possible.

The cellular approach requires a large number of base stations in a city of any size. A typical large city can have hundreds of towers. But because so many people are using cell phones, costs remain low per user. Each carrier in each city also runs one central office called the **Mobile Telephone Switching Office** (**MTSO**). This office handles all of the phone connections to the normal land-based phone system and controls all of the base stations in the region.

Cell-phone Codes

All cell phones have special **codes** associated with them. These codes are used to identify the phone, the phone's owner and the service provider.

*A **system identification number** (**SID**) is broadcast by one or more [base stations] to identify a cellular network in a certain area (usually contiguous). It is globally unique within [AMPS], [TDMA] or [CDMA] networks (the first two systems are essentially obsolete). This number sometimes has conflicts (see [IFAST]).*

SID codes

These codes are broadcast as 15 bit values but transmitted as 16 bits by core network protocols. They can be listed within a [wireless device] to show preference for one network over another. The additional bit in core network protocols allows the range of codes above 32,767 to be used for internal purposes, such as segregating billing records within a large area identified by a single broadcast SID.

[Telecommunications Industry Association] committee TR-45.2 assigned ranges to every country extant in the 1980s and national regulators assigned individual numbers. [IFAST] took over in 1997. This number space is 90% utilized for country ranges, however many countries do not use all of their allocated codes so the majority of codes are not used.

SIDs are assigned to every carrier (e.g., Verizon, Sprint, Alltel) by national regulators or [IFAST]. SIDs are programmed into the phone when you purchase them. A phone will maintain a list of "preferred" systems identified by their SID code. The SID may also modify some signaling messages that are transmitted by mobiles (e.g. reducing the amount of information transmitted by "home" mobiles).

How SIDs work

When the phone is turned on, it listens for a signal. If it receives a signal, it looks at the SID (being carried by the signal), and compares it with the one that is stored in the phone. Originally, in analog systems, the mobile would simply turn on the [roaming] indicator if the SID was not the single value stored in the phone.

However, with CDMA systems the [Preferred Roaming List] (PRL) is responsible for determining which areas a mobile can roam into. [Base stations] may also broadcast an [MCC] and [MNC] which can also be used by the PRL.

*A **mobile country code** (MCC) is used in combination with a **mobile network code** (MNC) (also known as a "MCC / MNC tuple") to uniquely identify a mobile phone operator (carrier) using the [GSM], [UMTS], [LTE], and [iDEN] [public land mobile networks] as well as some [CDMA], [TETRA], and [satellite] mobile networks.*

The following tables contain the complete list of mobile phone operators. Country information, including [ISO 3166-1 country codes] is provided for completeness.

Mobile Country Codes: http://en.wikipedia.org/wiki/Mobile_country_code

The ITU-T Recommendation E.212 defines mobile country codes as well as mobile network codes, and you may want to visit that list if technical correctness is a concern (for example: MNC of 001 is not the same as MNC of 01), or if you are looking for a normative reference. Note, though, that the official list may not contain disputed territories such as Abkhazia or Kosovo or additional details about bands or operator names

Let's say you have a cell phone, you turn it on and someone tries to call you. Here's what happens to the call:

- When you first power up the phone, it listens for an **SID** (see sidebar) on the control channel. The control channel is a special frequency that the phone and base station use to talk to one another about things like call set-up and channel changing. If the phone cannot find any control channels to listen to, it knows it is out of range and displays a "no service" message.
- When it receives the SID, the phone compares it to the SID programmed into the phone. If the SIDs match, the phone knows that the cell it is communicating with is part of its home system.
- Along with the SID, the phone also transmits a registration request, and the MTSO keeps track of the phone's location in a database -- this way, the MTSO knows which cell you are in when it wants to ring your phone.
- The MTSO gets the call, and tries to find you. It looks in its database to see which cell you are in.
- The MTSO picks a frequency pair that your phone will use in that cell to take the call.
- The MTSO communicates with your phone over the control channel to tell it which frequencies to use, and once your phone and the tower switch on those frequencies, the call is connected. Now, you are talking by two-way radio to a friend.
- As you move toward the edge of your cell, your cell's base station notes that your signal strength is diminishing. Meanwhile, the base station in the cell you are moving toward (which is listening and measuring signal strength on all frequencies, not just its own one-seventh) sees your phone's signal strength increasing. The two base stations coordinate with each other through the MTSO, and at some point, your phone gets a signal on a control channel telling it to change frequencies. This handoff switches your phone to the new cell.

As you travel, the signal is passed from cell to cell. Let's say you're on the phone and you move from one cell to another -- but the cell you move into is covered by another service provider, not yours. Instead of dropping the call, it'll actually be handed off to the other service provider.If the SID on the control channel does not match the SID programmed into your phone, then the phone knows it is **roaming**. The MTSO of the cell that you are roaming in contacts the MTSO of your home system, which then checks its database to confirm that the SID of the phone you are using is valid. Your home system verifies your phone to the local MTSO, which then tracks your phone as you move through its cells. And the amazing thing is that all of this happens within seconds.

The less amazing thing is that you may be charged insane rates for your roaming call. On most phones, the word "roam" will come up on your phone's screen when you leave your provider's coverage area and enter another's. If not, you'd better study your coverage maps carefully -- more than one person has been unpleasantly surprised by the cost of roaming. Check your service contract carefully to find out whether you're paying when you roam. Most of the larger phone companies do not charge for roaming within the U.S., but some of the discount companies do.

Internationally is another story. The roaming rates can be very high, assuming you have a phone that can work in multiple countries. Different countries use different cellular access technologies. More on those technologies later. First, let's get some background on analog cell phone technology so we can understand how the industry has developed.

Analog Cell Phones

Old school: DynaTAC cell phone, 1983

Photo courtesy Motorola, Inc.

In 1983, the analog cell phone standard called **AMPS** (Advanced Mobile Phone System) was approved by the U.S. Federal Communications Commission (FCC) and first used in Chicago. AMPS uses a range of frequencies between 824 megahertz (MHz) and 894 MHz for analog cell phones. In order to encourage competition and keep prices low, the U. S. government required the presence of two carriers in every market, known as A and B carriers. One of the carriers was normally the **local-exchange carrier** (LEC), a fancy way of saying the local phone company.

Carriers A and B are each assigned 832 frequencies: 790 for voice and 42 for data. A pair of frequencies (one to transmit and one to receive) is used to create one channel. The frequencies used in analog voice channels are typically 30 kilohertz (kHz) wide -- 30 kHz was chosen as the standard size because it gives you voice quality comparable to a wired telephone.

The transmit and receive frequencies of each voice channel are separated by 45 MHz to keep them from interfering with each other. Each carrier has 395 voice channels, as well as 21 data channels to use for housekeeping activities like registration and paging.

A version of AMPS known as **Narrowband Advanced Mobile Phone Service** (**NAMPS**) incorporates some digital technology to allow the system to carry about three times as many calls as the original version. Even though it uses digital technology, it is still considered analog. AMPS and NAMPS only operate in the 800-MHz band and don't offer many of the features common in digital cellular service, such as e-mail and Web browsing.

Analog Comes Digital

The first digital cell phones were the second generation (2G) of cellular technology. Digital phones use the same radio technology as analog phones, but they use it differently. Analog systems don't fully use the signal between the phone and the cellular network -- analog signals can't be compressed and manipulated as easily as true digital signals. This is why cable companies switched to digital -- to fit more channels within a given bandwidth.

Digital phones convert your voice into binary information (1s and 0s) and then compress it (see How Analog-Digital Recording Works for details on the conversion process). This compression allows between three and 10 digital cell phone calls to occupy the space of a single analog call.

Many digital cellular systems rely on **frequency-shift keying** (FSK) to send data back and forth over AMPS. FSK uses two frequencies, one for 1s and the other for 0s, alternating rapidly between the two to send digital information between the cell tower and the phone. Clever modulation and encoding schemes are required to convert the analog information to digital, compress it and convert it back again while maintaining an acceptable level of voice quality. All of this means that digital cell phones have to contain a lot of processing power.

Let's take a good look inside a digital cell phone.

Inside a Digital Cell Phone

On a "complexity per cubic inch" scale, cell phones are some of the most intricate devices people use on a daily basis. Modern digital cell phones can process millions of calculations per second in order to compress and decompress the voice stream.

If you take a basic digital cell phone apart, you find that it contains just a few individual parts:

- A circuit board containing the brains of the phone
- An antenna
- A liquid crystal display (LCD)
- A keyboard (not unlike the one you find in a TV remote control)
- A microphone
- A speaker
- A battery

Inside a Cell phone Image Gallery

Inside a digital cell phone, youll find a circuit board, battery, speaker and more. Look inside a digital cell phone with photos and explanations of each part.

The circuit board is the heart of the system. The analog-to-digital and digital-to-analog conversion chips translate the outgoing audio signal from analog to digital and the incoming signal from digital back to analog. You can learn more about A-to-D and D-to-A conversion and its importance to digital audio in How Compact Discs Work. The digital signal processor (DSP) is a highly customized processor designed to perform signal-manipulation calculations at high speed.

The microprocessor handles all of the housekeeping chores for the keyboard and display, deals with command and control signaling with the base station and also coordinates the rest of the functions on the board.

The ROM and flash memory chips provide storage for the phone's operating system and customizable features, such as the phone directory. The radio frequency (RF) and power section handles power management and recharging, and also deals with the hundreds of FM channels. Finally, the **RF amplifiers** handle signals traveling to and from the antenna.

The display has grown considerably in size as the number of features in cell phones has increased. Most current phones offer built-in phone directories, calculators, games, calendars, notes, Web browsers, and cameras, as well as countless other applications, or apps, to serve practically any need or want.

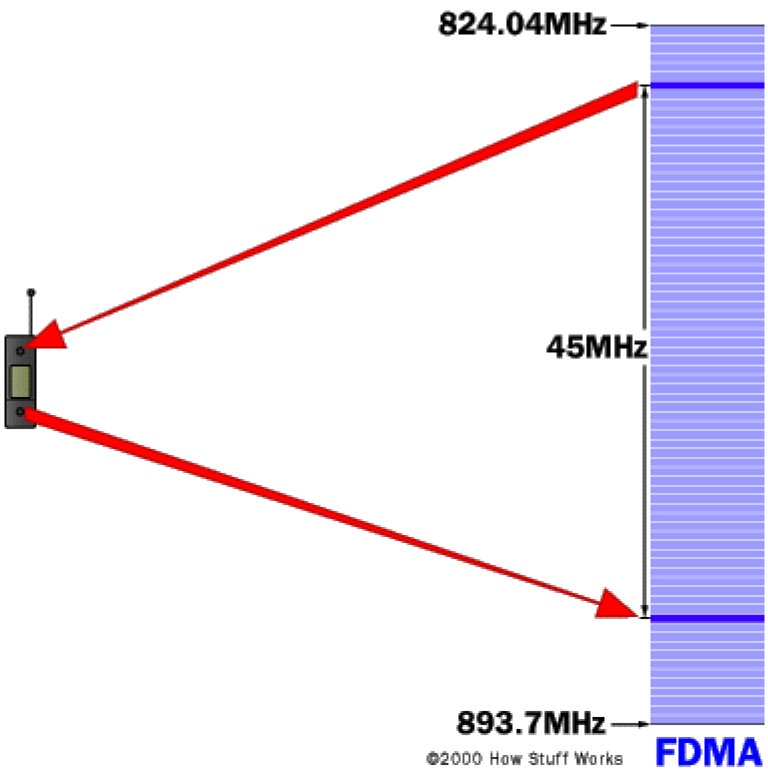
The SIM card on the circuit board

Some phones store certain information, such as the SID and MIN codes, in internal Flash memory, while others use external cards that are similar to SmartMedia cards.

Cell phones have such tiny speakers and microphones that it is incredible how well most of them reproduce sound. As you can see in the picture above, the speaker is about the size of a dime and the microphone is no larger than the watch battery beside it. Speaking of the watch battery, this is used by the cell phone's internal clock chip.

What is amazing is that all of that functionality -- which only 30 years ago would have filled an entire floor of an office building -- now fits into a package that sits comfortably in the palm of your hand!

Cell Phone Network Technologies: 2G



In FDMA, each phone uses a different frequency.

Cell phone networks fall into three categories: 2G, 3G and 4G. In 2G networks, there are three common technologies used for transmitting information:

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

Although these technologies sound very intimidating, you can get a good sense of how they work just by breaking down the title of each one.

The first word tells you what the access method is. The second word, "division," lets you know that it splits calls based on that access method.

- FDMA puts each call on a separate frequency.

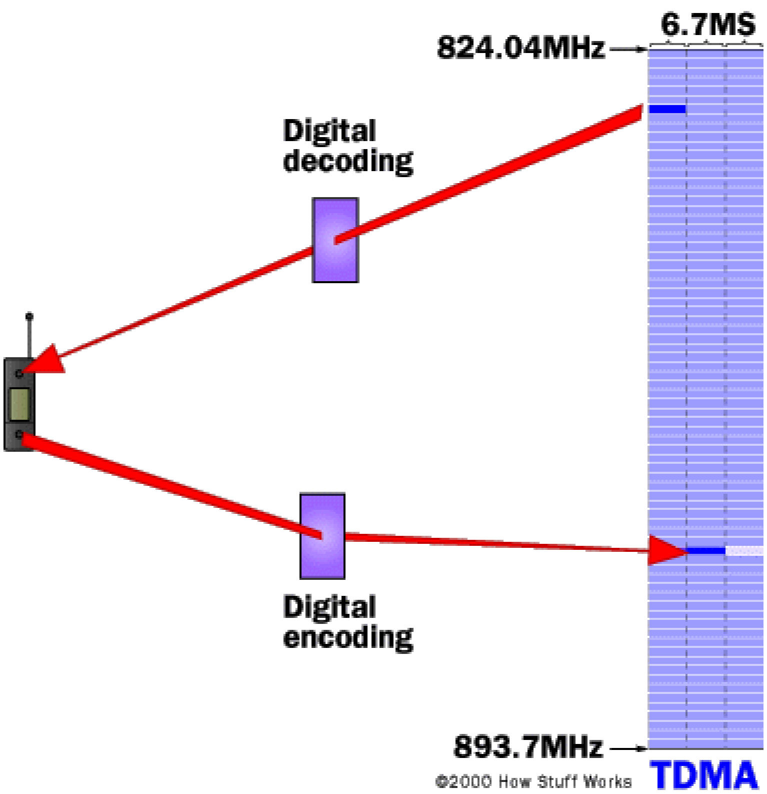
- TDMA assigns each call a certain portion of time on a designated frequency.
- CDMA gives a unique **c**ode to each call and spreads it over the available frequencies.

The last part of each name is "multiple access." This simply means that more than one user can use each cell.

FDMA separates the spectrum into distinct voice channels by splitting it into uniform chunks of bandwidth. To better understand FDMA, think of radio stations: Each station sends its signal at a different frequency within the available band. FDMA is used mainly for analog transmission. While it is certainly capable of carrying digital information, FDMA is not considered to be an efficient method for digital transmission.

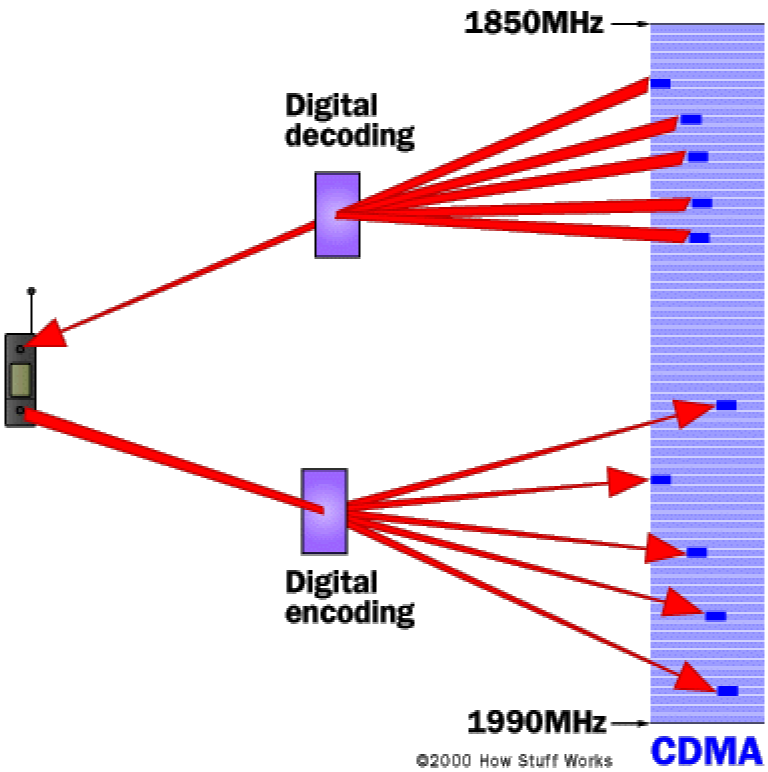
TDMA is the access method used by the Electronics Industry Alliance and the Telecommunications Industry Association for Interim Standard 54 (IS-54) and Interim Standard 136 (IS-136). Using TDMA, a narrow band that is 30 kHz wide and 6.7 milliseconds long is split time-wise into three time slots.

Narrow band means "channels" in the traditional sense. Each conversation gets the radio for one-third of the time. This is possible because voice data that has been converted to digital information is compressed so that it takes up significantly less transmission space. Therefore, TDMA has three times the capacity of an analog system using the same number of channels. TDMA systems operate in either the 800-MHz (IS-54) or 1900-MHz (IS-136) frequency bands.



TDMA splits a frequency into time slots.

GSM and CDMA



In CDMA, each phone's data has a unique code.

GSM and CDMA

TDMA is also used as the access technology for Global System for Mobile Communications (GSM). However, **GSM** implements TDMA in a somewhat different and incompatible way from IS-136. Think of GSM and IS-136 as two different operating systems that work on the same processor, like Windows and Linux both working on an Intel Pentium III. GSM systems use encryption to make phone calls more secure. GSM operates in the 900-MHz and 1800-MHz bands in Europe and Asia and in the 850-MHz and 1900-MHz (sometimes referred to as 1.9-GHz) band in the United States. It is used in digital cellular and PCS-based systems. GSM is also the basis for Integrated Digital Enhanced Network (IDEN), a popular system introduced by Motorola and used by Nextel. AT&T and T-Mobile use GSM.

CDMA takes an entirely different approach from TDMA. CDMA, after digitizing data, spreads it out over the entire available bandwidth. Multiple calls are overlaid on each other on the channel, with each assigned a unique sequence code. CDMA is a form of spread spectrum, which simply means that data is sent in small pieces over a number of the discrete frequencies available for use at any time in the specified range. Verizon, Sprint and most other U.S. carriers use CDMA, which means no SIM card.

All of the users transmit in the same wide-band chunk of spectrum. Each user's signal is spread over the entire bandwidth by a unique spreading code. At the receiver, that same unique code is used to recover the signal. Because CDMA systems need to put an accurate time-stamp on each piece of a signal, it references the GPS system for this information. Between eight and 10 separate calls can be carried in the same channel space as one analog AMPS call. CDMA technology is the basis for Interim Standard 95 (IS-95) and operates in both the 800-MHz and 1900-MHz frequency bands.

Ideally, TDMA and CDMA are transparent to each other. In practice, high-power CDMA signals raise the noise floor for TDMA receivers, and high-power TDMA signals can cause overloading and jamming of CDMA receivers.

2G is a cell phone network protocol. Click here to learn about network protocols for smartphones.

Next, we'll look at 3G.

Cell-phone Network Technologies: 3G

3G technology came along to support increased data needs. 3G stands for "third generation" -- this makes analog cellular technology generation one and digital/PCS generation two. 3G technology is intended for the true multimedia cell phone -- typically called smartphones -- and features increased bandwidth and transfer rates to accommodate Web-based applications and phone-based audio and video files.

3G comprises several cellular access technologies. Common ones include:

- CDMA2000 - based on 2G Code Division Multiple Access
- WCDMA (UMTS) - Wideband Code Division Multiple Access
- TD-SCDMA - Time-division Synchronous Code-division Multiple Access

3G networks have potential transfer speeds of up to 3 Mbps (about 15 seconds to download a 3-minute MP3 song). For comparison, the fastest 2G phones can achieve up to 144Kbps (about 8 minutes to download a 3-minute song). 3G's high data rates are ideal for downloading information from the Internet and sending and receiving large, multimedia files. 3G phones are like mini-laptops and can accommodate broadband applications like video conferencing, receiving streaming video from the Web, sending and receiving faxes and instantly downloading e-mail messages with attachments.

3G is a cell phone network protocol. Click here to learn about network protocols for smartphones.

Next we look at the latest network technology: 4G.

Cell-phone Network Technologies: 4G

The "4G" cell phone has been around for years – at least since 2006, if you go by Sprint's definition of 4G [source: Segan]. That original 4G network used a technology called WiMAX, one of several approaches to 4G implementation. Like previous generations, 4G is not a standardized designation. It's simply the next step up in speed.

All the top service providers have some type of 4G network now, in various stages of development and coverage, built on one of three main cellular-access technologies: LTE, HSPA+, and WiMAX [source: Gaylord].

WiMAX is somewhat unique among cell phone access methods in that it's based on 802.16 wireless standards – aka wireless broadband Internet which is used for homes and offices. The WiMAX approach takes the second iteration of those standards, 802.16e, which supports mobile access, and applies it to the cell phone realm [source: Phone Scoop]. Transmissions use orthogonal frequency division multiplexing, or OFDM, a method of dividing signal data into multiple channels to speed up delivery and then combining all the bits back into a single unit at the destination [source: 4G Americas]. WiMAX transmission can theoretically top out around 40 Mbps, but in reality it is much less [source: Segan].

HSPA+, on the other hand, is an upgrade to a long-existing approach to cellular: HSPA, or High-Speed Packet Access. HSPA builds on the 3G WCDMA infrastructure, which carries signals in either one or two frequency bands depending on mode [source: Tech FAQ]. In 3G form, HSPA networks have peak data-transfer speeds of 14.4 Mbps [source: 4G Americas]. By using higher-order QAM (quadrature amplitude modulation, which encodes multiple data streams into a single transmission, mimicking increased bandwidth), carriers can achieve HSPA+ speeds of up to 21 Mbps [sources: Tech Target, 4G Americas, Ruddock]. Antenna improvements may further increase HSPA+ transmission rates [source: 4G Americas].

Despite the obvious gains in speed, many in the cell phone world consider both WiMAX and HSPA+ to be transitional technologies [source: Gaylord]. The 4G most people are waiting for is LTE.

4G LTE

For decades, the mobile world has pushed for industry-wide standards to sync up the technology and allow for definable advances. Many see LTE, or Long Term Evolution, as the first real chance at standardization, as many top carriers have signed on to adopt the technology [source: 4G Americas].

LTE is being developed as the 4G standard, which is why you sometimes see "4G LTE" as opposed to simply "4G." 4G could mean support for any speed above 3G; 4G LTE means support for up to 86 Mbps based on specific technology and software infrastructures [source: 4G Americas].

The LTE network is based on Internet Protocol (IP) standards, the kind that delivers Web pages to your computer, and adds voice data to the transmission streams [source: 4G Americas]. It uses a schematic called OFDMA, or Orthogonal Frequency Division Multiple Access, which is similar to the OFDM approach in WiMAX. OFDMA also separates the bits in a single data transmission into multiple subcarriers to increase speed, reassembling it at the destination. The LTE protocol, though, has the added ability to assign particular data paths to particular users on the fly, optimizing the bandwidth available at any given time [source: 4G Americas].

LTE can operate on a wide range of radio frequency bands, which will allow many mobile carriers to switch over to LTE without starting from scratch [source: 4G Americas]. The migration has already begun: 4G LTE is operating in many U.S. and European cities in 2013 [source: Osborne]. It doesn't require a new phone. LTE can operate alongside 2G and 3G networks, and multi-mode phones can access any of them, using LTE where it's available and, say, HSPA where it's not [source: 4G Americas].

Having a multi-mode phone, then, is a huge benefit as LTE towers start popping up around the country and around the world.

Multi-band vs. Multi-mode Cell Phones

If you travel a lot, you will probably want to look for phones that offer multiple bands, multiple modes or both. Let's take a look at each of these options:

- **Multiple band:** A phone that has multiple-band capability can switch frequencies. For example, a dual-band TDMA phone could use TDMA services in either an 800-MHz or a 1900-MHz system. A quad-band GSM phone could use GSM service in the 850-MHz, 900-MHz, 1800-MHz or 1900-MHz band.
- **Multiple mode:** In cell phones, "mode" refers to the type of transmission technology used. So, a phone that supported AMPS and TDMA could switch back and forth as needed. It's important that one of the modes is AMPS -- this gives you analog service if you are in an area that doesn't have digital support.
- **Multiple band/Multiple mode:** This best of both worlds allows you to switch between frequency bands and transmission modes as needed.

Changing bands or modes is done automatically by phones that support these options. Usually the phone will have a default option set, such as 1900-MHz TDMA, and will try to connect at that frequency with that technology first. If it supports dual bands, it will switch to 800 MHz if it cannot connect at 1900 MHz. And if the phone supports more than one mode, it will try the digital mode(s) first, then switch to analog.

You can find both dual-mode and tri-mode phones. The term "tri-mode" can be deceptive. It may mean that the phone supports two digital technologies, such as CDMA and TDMA, as well as analog. In that case, it is a true tri-mode phone. But it can also mean that it supports one digital technology in two bands and also offers analog support. A popular version of the tri-mode type of phone for people who do a lot of international traveling has GSM service in the 900-MHz band for Europe and Asia and the 1900-MHz band for the United States, in addition to the analog service. Technically, this is a dual-mode phone, and one of those modes (GSM) supports two bands.

Of course, none of this would be possible without those soaring towers that carry cell phone signals from phone to phone.

Problems with Cell Phones

A cell phone tower is typically a steel pole or lattice structure that rises hundreds of feet into the air.

Pictured here is a tower with three different cell phone providers riding on the same structure. If you look at the base of a tower, you can see provider equipment.

The box houses the radio transmitters and receivers that let the tower communicate with the phones. The radios connect with the antennae on the tower through a set of thick cables.

If you look closely, you will see that the tower and all of the cables and equipment at the base of the tower are heavily grounded.

One sure sign that multiple providers share a tower is a five-way latch on the gate. Any one of five people can unlock this gate to get in.

Like all consumer electronics, cell phones come with their share of problems. Next, we'll take a look at some of them.

Cell-phone Towers

A cell phone, like any other electronic device, has its problems:

- Generally, non-repairable internal corrosion of parts results if you get the phone wet or use wet hands to push the buttons. Consider a protective case. If the phone does get wet, be sure it is totally dry before you switch it on so you can try to avoid damaging internal parts.
- Extreme heat in a car can damage the battery or the cell phone electronics. Extreme cold may cause a momentary loss of the screen display.
- Analog cell phones suffer from a problem known as "cloning." A phone is "cloned" when someone steals its ID numbers and is able to make fraudulent calls on the owner's account.

Cell Phone Cloning

Here is how cloning occurs: When your phone makes a call, it transmits the ESN (electronic serial number) and MIN (mobile identification number or phone number) to the network at the beginning of the call. The MIN/ESN pair is a unique tag for your phone -- this is how the phone company knows who to bill for the call. When your phone transmits its MIN/ESN pair, it is possible for nefarious sorts to listen (with a scanner) and capture the pair. With the right equipment, it is fairly easy to modify another phone so that it contains your MIN/ESN pair, which allows the crook to make calls on your account.

For more information about cell phones and related topics, check out the links on the next page and be sure to read How Buying a Cell phone Works for loads of helpful consumer tips.