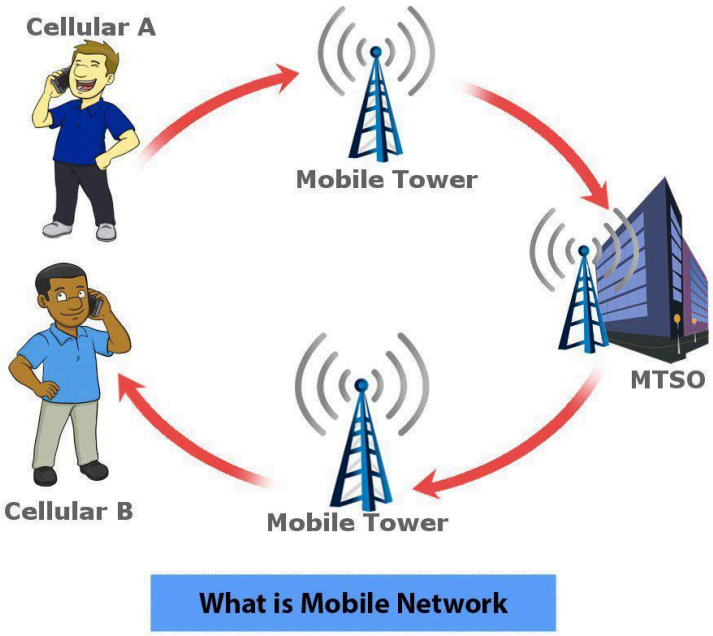
Code-Division Multiplexing Hands-on Activity with Walsh Codes

The problem that we are going to solve today is a basic one: How to serve more than one wireless device in a given area. All of the devices, such as phones, tablets and computers need to set up a **channel** between themselves and a **base station** (mobile tower), through which they can make phone calls, send text messages, or connect to the internet through a mobile tower switching office (MTSO)

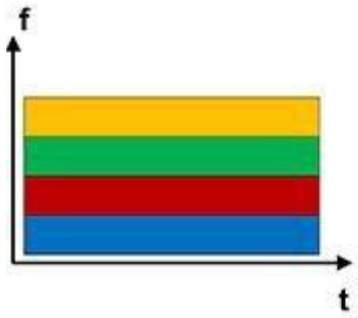


https://www.itrelease.com/2021/03/what-is-mobile-network-with-example/

There are several methods for doing this:

Frequency Division Multiple Access (FDMA)

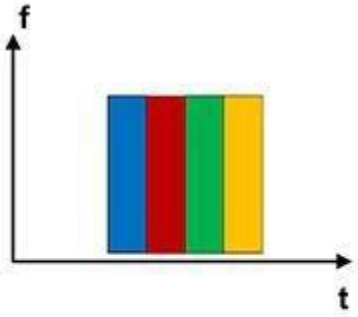
In this scheme, each user in a given area is given their own **frequency** channel. Think about this like all the devices are communicating at the same time, using the same language, but in separate rooms where they can only hear each other. This method is the simplest one, but is inefficient because there are only so many frequencies available; this is known as **spectral efficiency**. Each device uses their whole frequency while they are on, even if they aren't speaking at a given moment. It is also of course necessary to reuse these frequencies in a given geographical area, and so there's danger of **co-channel interference** which can definitely hurt the user experience.



https://www.researchgate.net/figure/Differences-among-CDMA-FDMA-and-TDMA_fig2_353856800

Time Division Multiple Access (TDMA)

In this method, a set of users take turns sharing a single frequency channel, but only use it for a short amount of time each. This can be many times more efficient than FDMA, but is much more difficult to coordinate. One major challenge here is **synchronization** since each device must begin communicating at the precise beginning of their allocated slot, and stop precisely when their slot is over. It is also not as flexible as other methods, as each slot must be the same duration.

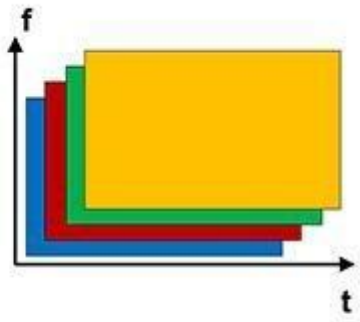


https://www.researchgate.net/figure/Differences-among-CDMA-FDMA-and-TDMA_fig2_353856800

Code Division Multiple Access (CDMA)

The most advanced of these methods, CDMA utilizes **spreading codes** to differentiate between users. All users transmit any time they have data, and receive only when the MTSO has data destined for them. Think about this as how you're able to talk to your friend in a classroom when everyone else is talking at the same time. If you know what your friend's voice sounds like, and they know what you sound like, it's possible to hear them over other people. Computers do this in a similar way, using specially designed codes that are mathematically dissimilar to each other (low **cross correlation**). The codes chosen also have good autocorrelation[1] properties, which can provide help with synchronization. Autocorrelation is a measure of the similarity between the elements of a series and others from the same series separated from them by a given interval.

[1] Autocorrelation is a measure of the similarity between the elements of a series and others from the same series separated from them by a given interval.



https://www.researchgate.net/figure/Differences-among-CDMA-FDMA-and-TDMA_fig2_353856800

For today's exercise, we will utilize codes to communicate a unique message to our MTSO using Walsh Codes[2] which is a series of numbers either -1 or 1.

Today's exercise: Walsh Codes

For this exercise, we will use a set of codes to transmit a message. Each group will select their message as either 0 or 1, and **they will be assigned a code that is 8 bits long (see all the codes below in the table)**

Position	1	2	3	4	5	6	7	8
Code 1	1	1	1	1	1	1	1	1
Code 2	1	1	1	1	-1	-1	-1	-1
Code 3	1	1	-1	-1	1	1	-1	-1
Code 4	1	1	-1	-1	-1	-1	1	1
Code 5	1	-1	1	-1	1	-1	1	-1
Code 6	1	-1	1	-1	-1	1	-1	1
Code 7	1	-1	-1	1	1	-1	-1	1
Code 8	1	-1	-1	1	-1	1	1	-1

All you have to do to transmit the number 1 is to recite your sequence as above. If you want to transmit the number 0, you will instead read the opposite of the sequence. So for example, if I had code number 4 and I wanted to transmit 1, my transmitted code would be 1, 1, -1, -1, -1, -1, 1, 1 as listed in the table. If I wanted to transmit 0, I would reverse each digit in place and use the transmitted code -1, -1, 1, 1, 1, 1, -1, -1. ***Be very careful, it's easy to mess this up.***

[2] Also known as Hadamard codes.

Real life application

In 3G networks, the code that is used to communicate from the mobile towers to the wireless devices (known as the “short code” is 32,767 digits long and is sent so fast it repeats once every 37.5 seconds. The code that is used to transmit from the device back to the mobile towers (the “long code”) must be much longer because there are so many more devices than towers. The code is 2^{42} bits long, and when transmitted at the same rate, repeats once every 41.2 days![3].

In 4G and 5G networks, the communication has gotten very advanced, and uses a combination of FDMA, TDMA, and CDMA all at the same time. This is possible because of advances in computer technology that can do all the necessary **digital signal processing** very quickly and efficiently.

[3] https://www.gaussianwaves.com/2011/02/codes-used-in-cdma-2/