# REPORT-6

# WIRELESS COMMUNICATIONS

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## 3G Systems: (CDMA2000, UMTS WCDMA) - WiMaX - LORA System

# 3G Systems: (CDMA2000, UMTS WCDMA)

# CDMA2000

## Introduction

CDMA2000 is a wireless communication technology that uses Code Division Multiple Access (CDMA) to transmit and receive data. CDMA2000 is an evolution of IS95, which was the first CDMA-based cellular technology. CDMA2000 supports both voice and data communication and is widely used in 2G and 3G cellular networks.

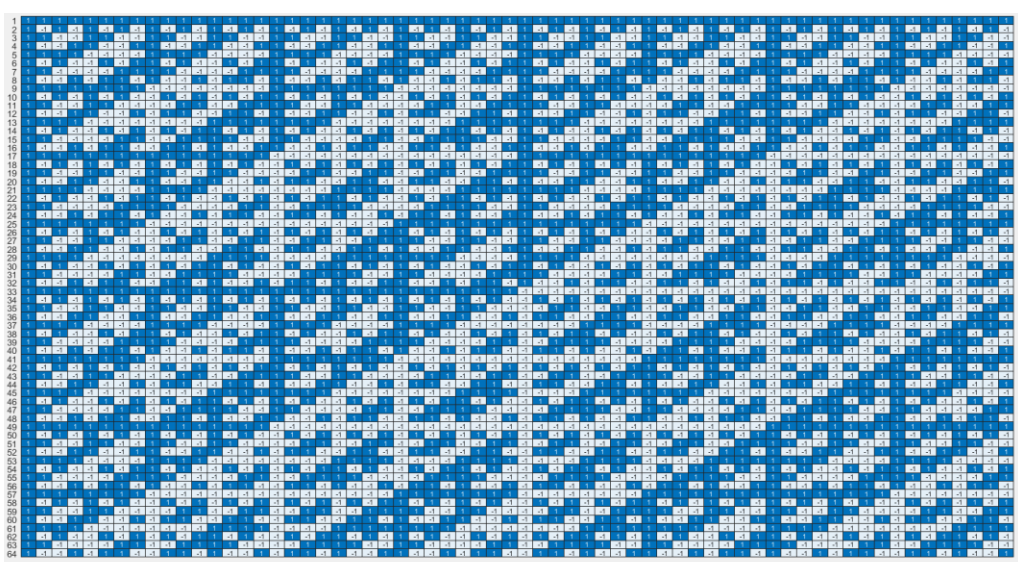
It uses spread spectrum techniques to transmit and receive data. Spread spectrum is a technique that spreads the signal over a wide range of frequencies to reduce interference and improve the reliability of the transmission. In CDMA2000, this is achieved by using a unique code to spread the signal across the frequency spectrum.

Multiple users can share the same frequency band at the same time. Each user is assigned a unique code that is used to spread their signal across the frequency spectrum. This allows multiple users to transmit and receive data simultaneously without interfering with each other.

## Spread Spectrum Coding

As deducted from the name alone, CDMA uses DSSS Codes that are unique to each user, which can de-spread its message spectrum from the transmitter that uses the same code to spread the message and make it hidden in the noise. It uses Walsh-64 code; the codes are generated by a matrix that is formed by recursively applying a simple algorithm. The resulting codes are orthogonal, meaning that they have no correlation with each other. This property ensures that the codes do not interfere with each other, even if they are transmitted simultaneously.

$$\boldsymbol{W_N} = \begin{pmatrix} \boldsymbol{W_{\frac{N}{2}}} & \boldsymbol{W_{\frac{N}{2}}} \\ \boldsymbol{W_{\frac{N}{2}}} & -\boldsymbol{W_{\frac{N}{2}}} \end{pmatrix}$$



The 64-chip code is divided into two parts: the *sync channel* and the *paging channel*. The sync channel is used to synchronize the mobile device with the base station. The paging channel is used by the base station to inform the mobile device of incoming calls or messages.

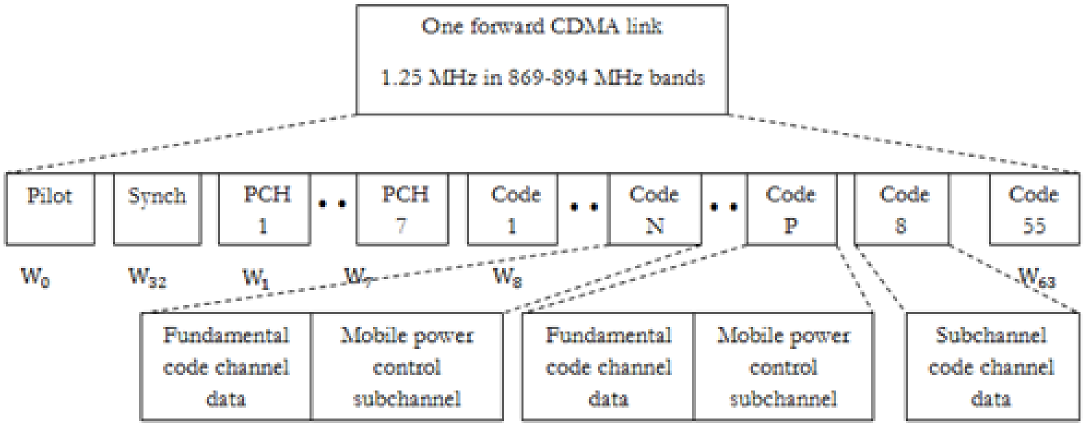



**Fig: IS-95 Forward Channel**

The sync channel uses a short code that is a subset of the Walsh-64 code. The short code is a 16-chip code that is repeated four times to form a 64-chip code. The short code is used to synchronize the mobile device with the base station by providing timing and phase information. The mobile device uses the short code to align its clock with the clock of the base station.

The paging channel uses a long code that is a random sequence of Walsh codes. The long code is a 42,719-chip code that is used to distinguish between different users in the same cell. The long code is unique to each user and is used to spread the data and voice signals. The long code is also used to provide privacy to the user by making it difficult for others to intercept the signal.

**A. Pilot channel:**

It provides phase for coherent demodulation, time, signal strength, comparison with reference signal for determining when to hand off for all mobile stations.

It is used to uniquely identify sectors or cells.

It is 4-6 dB stronger than all other channels. It is used to lock onto another channel.

It is obtained using all zero Walsh code i.e. it contains no information except the RF carrier.

**B. Synch channel:**

It is used to acquire initial time synchronization.

Synch messages include System ID (SID), Network ID (NID), the offset of the PN short code and the paging channel data rate.

It broadcasts synch messages to the mobile station and operates at 1200 bps.

It uses Walsh code 32 for spreading.

**C. Paging channel:**
There are 7 paging channels used to page the mobile station in case of an incoming call, or to carry the control messages for call set up.

It uses Walsh code 1-7. There is no power control.

It is additionally scrambled by PN long code, which is generated by LFSR of length 42.

It operates at the rate of 4.8 kbps or 9.6 kbps.

**D. Traffic channel:**
There are 55 traffic channels used to carry actual information. It supports variable data rates-RS1={9.6. 4.8, 2.4, 1.2 kbps} and RS2={14.4, 7.2, 3.6, 1.8 kbps}

RS1 is mandatory for IS-95. But support for RS2 is optional. It also carries power control bits for the reverse channel.

**Bandwidth**
There are several versions of CDMA2000, each with its own bandwidth specification. The most common versions of CDMA2000 are:

1. CDMA2000 1x: This is the first version of CDMA2000 and is also known as 1xRTT (1x Radio Transmission Technology). It uses a single 1.25 MHz carrier frequency and provides a maximum data rate of 153.6 kbps.
2. CDMA2000 1xEV-DO: This is an enhanced version of CDMA2000 1x and is also known as EV-DO (Evolution-Data Optimized). It uses multiple carrier frequencies and provides a maximum data rate of up to 3.1 Mbps.
3. CDMA2000 1xEV-DV: This is another enhanced version of CDMA2000 1x and is also known as EV-DV (Evolution-Data and Voice). It uses multiple carrier frequencies and provides a maximum data rate of up to 2.4 Mbps.

The bandwidth specification of CDMA2000 depends on the carrier frequency band. The most common carrier frequency bands used in CDMA2000 are:

- 450 MHz band: This band is used for CDMA2000 1x and provides a bandwidth of 1.25 MHz .
- 800 MHz band: This band is used for CDMA2000 1x and provides a bandwidth of 1.25 MHz .
- 1900 MHz band: This band is used for CDMA2000 1x and CDMA2000 1xEV-DO and provides a bandwidth of up to 5 MHz .
- 1700/2100 MHz band: This band is used for CDMA2000 1xEV-DO and provides a bandwidth of up to 5 MHz .

In addition to the carrier frequency band, the bandwidth specification of CDMA2000 also depends on the channelization scheme used. The channelization scheme determines the number of channels that can be used in the system. The most common channelization schemes used in CDMA2000 are:

- 1x: This channelization scheme provides a single 1.25 MHz channel for CDMA2000 1x.
- 3x: This channelization scheme provides three 1.25 MHz channels for CDMA2000 1xEV-DO.
- 6x: This channelization scheme provides six 1.25 MHz channels for CDMA2000 1xEV-DO.

# Pros and Cons

**Low interference**

One of the advantages of using DSSS code in CDMA2000 is its resistance to interference. The spreading code makes the signal appear as noise to other users who are not using the same code. This property ensures that the signal is not affected by interference from other users or from external sources such as radio frequency (RF) interference. This makes CDMA2000 a reliable communication system that can provide high-quality voice and data services even in areas with high levels of interference.

**Inherited Multiple Access**

Another advantage of using DSSS code in CDMA2000 is its ability to support multiple users in the same cell simultaneously. Each user is assigned a unique long code that is used to spread the data and voice signals. The orthogonal property of the Walsh-Hadamard codes ensures that the signals do not interfere with each other. This makes CDMA2000 an efficient communication system that can support a large number of users in the same cell.

The use of Walsh-64 code in CDMA2000 allows for both frequency division multiple access (FDMA) and time division multiple access (TDMA). FDMA allows multiple users to share the same frequency band by dividing it into different frequency channels, which is inheritably done by multiplying the signal onto its assigned Walsh code, while TDMA allows multiple users to share the same frequency channel by dividing it into different time slots. The use of Walsh-64 code in CDMA2000 allows for both FDMA and TDMA, which increases the flexibility and efficiency of the system.

In addition, the use of Walsh-64 code in CDMA2000 also provides benefits in terms of interference rejection and security. Since each user has a unique Walsh-64 code, the signal appears as noise to other users who are not using the same code. This makes it difficult for eavesdroppers to intercept the signal and provides a level of security. Furthermore, the use of Walsh-64 code provides resistance to interference from other signals and noise, which improves the overall quality of the communication system.

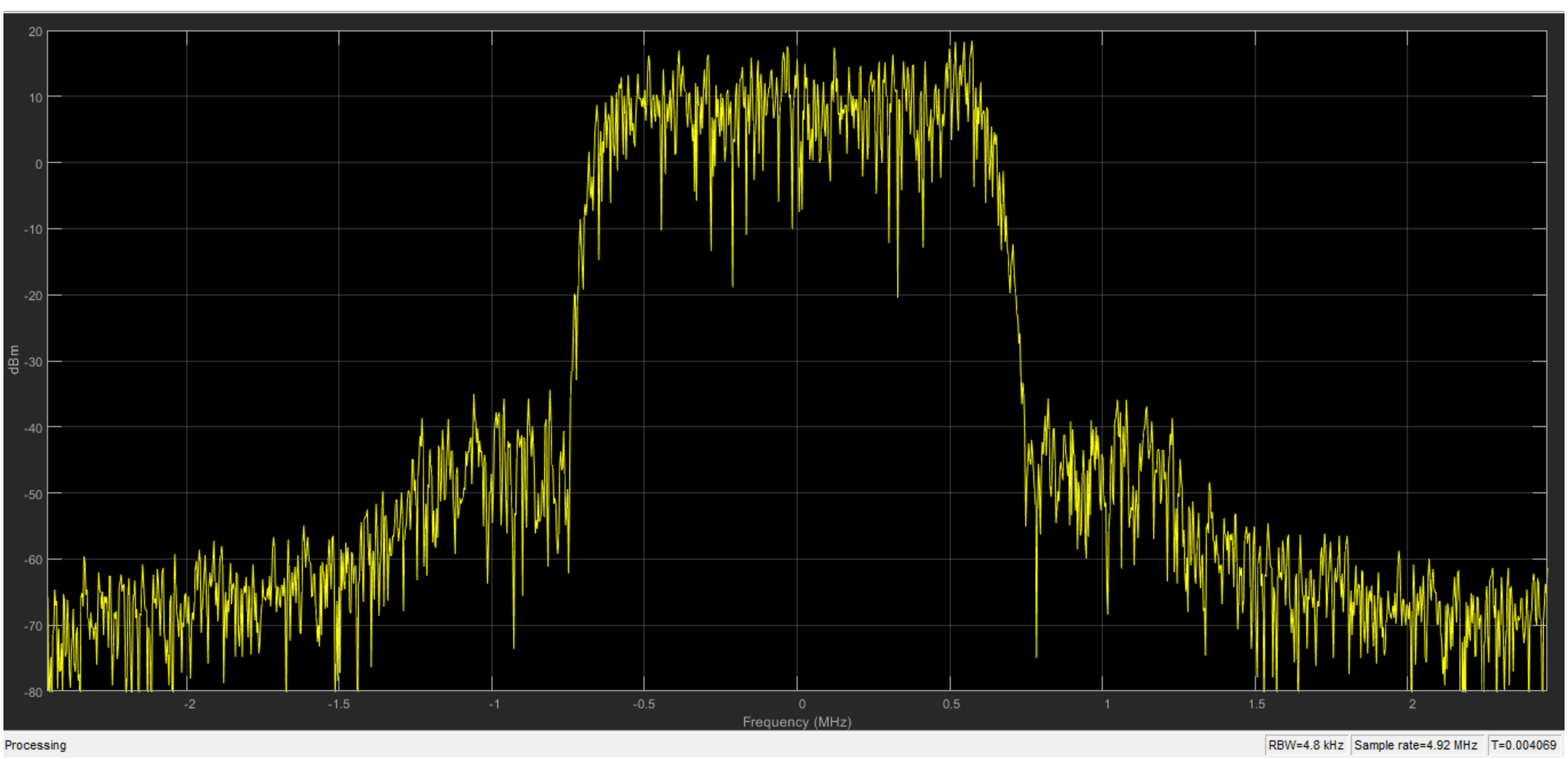
## MATLAB Code To Generate The 3G-CDMA2000 Forward Shared Channel (FSCH) for RF Traffic Between Different Users:

```
%% Generate Forward Traffic Channel
% Configure a cdma2000 forward link supporting a 307.2 kbps forward supplemental
% channel (F-SCH) using radio configuration 4.

config = cdma2000ForwardReferenceChannels('TRAFFIC-RC4-4800',5000, ...
    'F-SCH-307200-20');
%%
% Generate the waveform and plot its spectrum. The sample rate is equal
% to the product of the chip rate and the oversampling ratio. RC4 uses spreading
% rate 1, which is equivalent to a 1.2288 Mcps chip rate.
%%
wv = cdma2000ForwardWaveformGenerator(config);
fs = 1.2288e6 * config.OversamplingRatio;

sa = dsp.SpectrumAnalyzer('SampleRate',fs);
step(sa,wv)
%%
% Change the filter type to |'cdma2000Short'| and plot the spectrum.
%%
config.FilterType = 'cdma2000Short';
wv = cdma2000ForwardWaveformGenerator(config);
step(sa,wv)
%%
% The |'cdma2000Short'| filter does not provide as much out-of-band attenuation
% as does the |'cdma2000Long'| filter.
```

## <u>The MATLAB resulting Graph for the CDMA2000 Wave Generator In FSCH:</u>



# UMTS WCDMA

## Introduction

The Universal Mobile Telecommunications System (UMTS) is a third-generation (3G) wireless communication technology that uses Wideband Code Division Multiple Access (WCDMA) to transmit and receive data. WCDMA is a form of CDMA that uses a wider bandwidth to transmit data at higher data rates. In this report, we will discuss the coding and modulation techniques used in 3G UMTS.

## Coding in 3G UMTS

Coding is used in 3G UMTS to add redundancy to the data to improve its robustness and reduce errors. The coding technique used in 3G UMTS is Turbo Coding, which is a type of channel coding that adds redundancy to the data to improve its robustness.

Turbo Coding uses two parallel convolutional encoders to encode the data. The output of the two encoders is combined to create the encoded data. Turbo Coding is a powerful coding technique that can provide a high level of error correction with relatively low redundancy.

**The Turbo Coding process can be represented mathematically as follows:**

Let m be the number of input bits and n be the number of output bits. Let G1 and G2 be the generator matrices of the two convolutional encoders. Let s be the input data vector of length m and c be the encoded data vector of length n. The encoding process can be represented as follows:

$$u = G1s$$

$$v = G2s$$

$$x = u + v$$

$$c = (u, x)$$

where u and v are the output vectors of the two convolutional encoders, x is the sum of the two vectors, and c is the final encoded data vector.

# Modulation in 3G UMTS

Modulation is the process of converting the digital data into an analog signal that can be transmitted over the air. 3G UMTS uses Quadrature Phase Shift Keying (QPSK) and Quadrature Amplitude Modulation (QAM) as its modulation techniques.

QPSK is a type of modulation that uses four different phase shifts to represent the binary data. In QPSK, the phase of the carrier signal is shifted by 0, 90, 180, or 270 degrees to represent the four possible combinations of two bits. The QPSK modulation can be represented mathematically as follows:

$$s(t) = A \cos(2\pi fct + \theta)$$

where A is the amplitude of the carrier signal, fc is the carrier frequency, and θ is the phase shift that represents the binary data.

QAM is a type of modulation that uses both amplitude and phase to represent the binary data. QAM is a more advanced modulation technique compared to QPSK and can support higher data rates. The QAM modulation can be represented mathematically as follows:

$$s(t) = A \cos(2\pi fct + \theta) + B \sin(2\pi fct + \phi)$$

where A and B are the amplitudes of the carrier signals, fc is the carrier frequency, θ and ϕ are the phase shifts that represent the binary data.

# Wideband CDMA in 3G UMTS

Wideband CDMA (WCDMA) is the specific form of CDMA used in 3G UMTS. WCDMA uses a wider bandwidth to transmit data at higher data rates compared to narrowband CDMA. WCDMA uses a spreading factor to spread the data across the frequency spectrum.

The spreading factor is the ratio of the chip rate to the data rate. The chip rate is the rate at which the spreading code is generated, and the data rate is the rate at which the data is transmitted. The spreading factor determines the amount of spreading that is applied to the data.

The WCDMA modulation scheme is based on a combination of QPSK and QAM. The data is first spread using a unique spreading code, and then modulated using QPSK or QAM. The WCDMA modulation can be represented mathematically as follows:

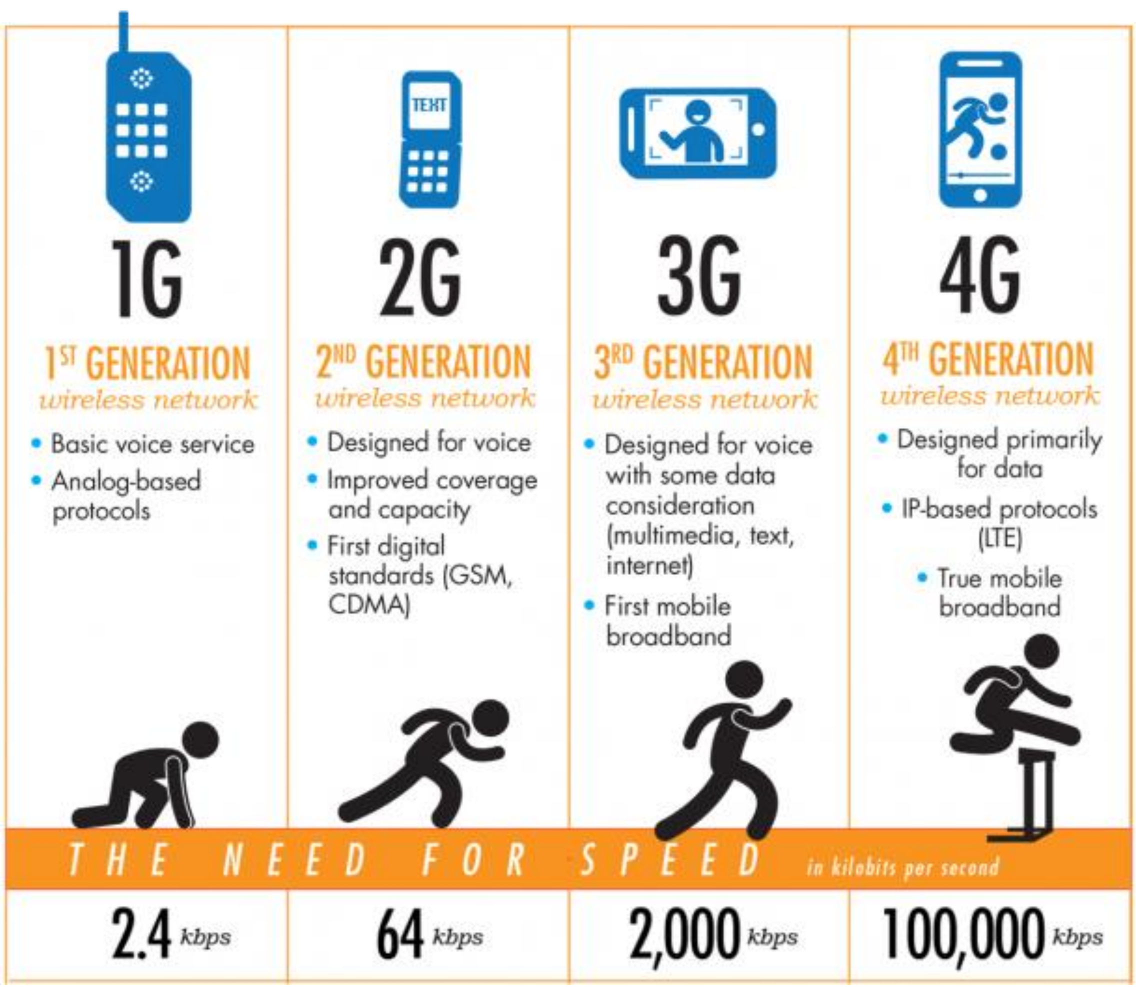
$$s(t) = A \cos(2\pi fct + \theta) + B \sin(2\pi fct + \phi) + C \cos(2\pi fct + \gamma) + D \sin(2\pi fct + \delta)$$

where A, B, C, and D are the amplitudes of the carrier signals, fc is the carrier frequency, θ, ϕ, γ, and δ are the phase shifts that represent the binary data.

The spreading code used in WCDMA is generated using a technique called Orthogonal Variable Spreading Factor (OVSF). OVSF is a technique that generates a set of spreading codes with different lengths and orthogonality properties. This allows the system to allocate the spreading codes to the users in a way that minimizes interference and maximizes the capacity of the system.

**To summarize:**

3G UMTS is a third-generation wireless communication technology that uses Wideband Code Division Multiple Access (WCDMA) to transmit and receive data. Turbo Coding is used in 3G UMTS to add redundancy to the data to improve its robustness and reduce errors. Quadrature Phase Shift Keying (QPSK) and Quadrature Amplitude Modulation (QAM) are used as the modulation techniques in 3G UMTS. Wideband CDMA (WCDMA) is the specific form of CDMA used in 3G UMTS, and it uses a wider bandwidth to transmit data at higher data rates. The spreading code used in WCDMA is generated using Orthogonal Variable Spreading Factor (OVSF) to minimize interference and maximize the capacity of the system. The mathematical representations of these techniques have been provided in this report.



# Worldwide Interoperability for Microwave Access (WiMAX)

**WHAT DOES WIMAX INTERNET MEAN?**

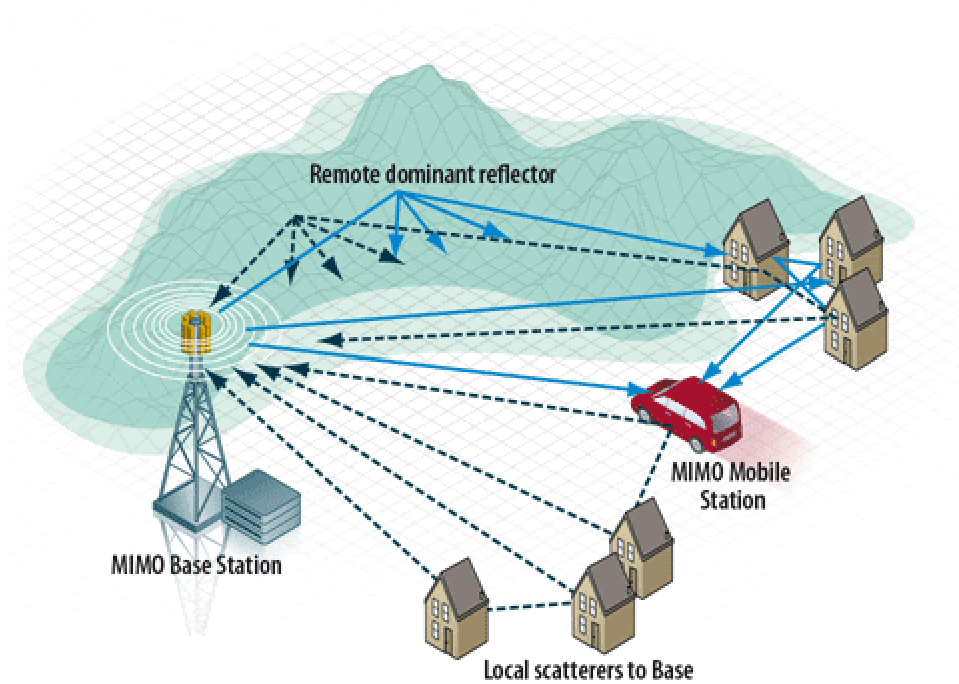
*Worldwide Interoperability for Microwave Access* is a technology standard for long-range wireless networking for both mobile and fixed connections. While WiMAX was once envisioned to be a leading form of internet communication as an alternative to cable and DSL, its adoption has been limited.

Primarily owing to its much higher cost, WiMAX is not a replacement for Wi-Fi or wireless hotspot technologies. However, it can be cheaper to implement WiMAX instead of standard wired hardware as with DSL.

WiMAX equipment comes in two basic forms: base stations, installed by service providers to deploy the technology in a coverage area; and receivers, installed in clients.

WiMAX is developed by an industry consortium overseen by a group called the WiMAX Forum, which certifies WiMAX equipment to ensure that it meets technical specifications. Its technology is based on the IEEE 802.16 set of wide-area communications standards.

WiMAX has some great benefits when it comes to mobility, but that is precisely where its limitations are most painful.



# WiMAX Pros

WiMAX is popular because of its low cost and flexible nature. It can be installed faster than other internet technologies because it can use shorter towers and less cabling, supporting even non-line-of-sight coverage across an entire city or country.

WiMAX isn't just for fixed connections either, like at home. You can also subscribe to a WiMAX service for your mobile devices since USB dongles, laptops, and phones sometimes have the technology built-in.

In addition to internet access, WiMAX can provide voice and video-transferring capabilities as well as telephone access. Since WiMax transmitters can span a distance of several miles with data rates reaching up to 30-40 megabits per second (1 Gbps for fixed stations), it's easy to see its advantages, especially in areas where wired internet is impossible or too costly to implement.


**WiMAX supports several networking usage models:**

- A means to transfer data across an Internet Service Provider network — commonly called *backhaul*
- A form of fixed wireless broadband internet access, replacing satellite internet service
- A form of mobile internet access that competes directly with LTE technology

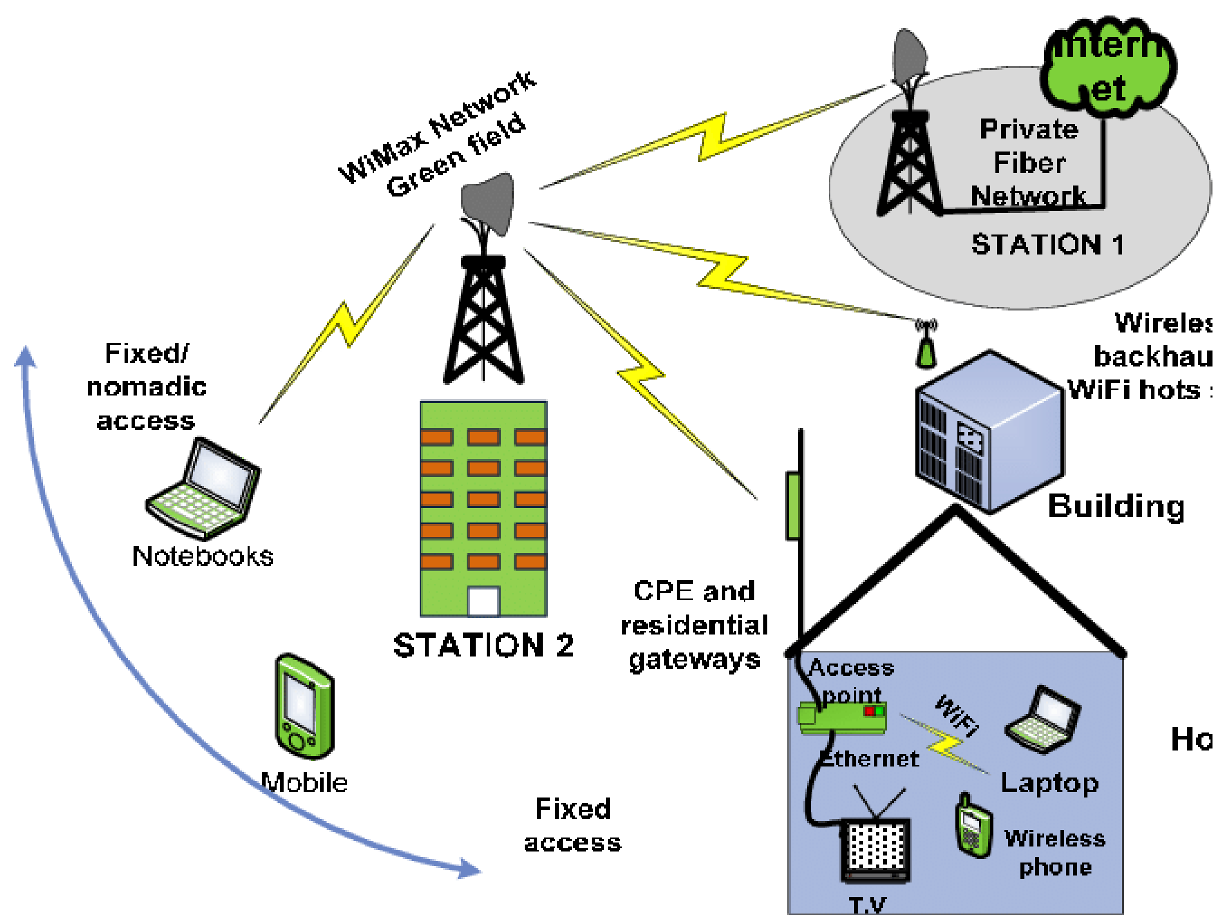
- Internet access for users in extremely remote locations where laying cable would be too expensive

# WiMAX Cons

Because WiMAX is wireless by nature, the further away from the source that the client gets, the slower their connection becomes. This means that while a user might pull down 30 Mbps in one location, moving away from the cell site can reduce that speed to 1 Mbps or next to nothing.

Similar to when several devices suck away at the bandwidth when connected to a single router, multiple users on one WiMAX radio sector reduce performance for the others.

Wi-Fi is much more popular than WiMAX, so more devices have Wi-Fi capabilities built into them than they do WiMAX. However, most WiMAX implementations include hardware that allows a whole household, for example, to use the service by means of Wi-Fi, much like how a wireless router provides internet for several devices.



# LoRa System

# LoRa : Long Range Wireless Communication for IoT Applications

**An introduction into LoRa:**

In an era of rapid technology breakthroughs and expanding connectivity, efficient and dependable device communication is critical. LoRa (Long Range) technology has emerged as a crucial enabler for long-range, low-power wireless communication. This article investigates the benefits of LoRa over various alternatives, explains how it works, discusses its superior range capabilities, and illustrates its widespread applications.

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**What is LoRa?**

LoRa is a wireless communication technology that was developed specifically for low-power, wide-area networks (LPWANs). It provides long-distance communication while consuming little power, making it perfect for Internet of Things (IoT) devices and sensor networks that require low data rates and long battery life.

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**Why choose LoRa rather than alternatives?**

Alternatives include; Narrowband-IoT, Sigfox, Weightless, LTE-M

LoRa offers several advantages that set it apart from other wireless communication methods:

Long Range: LoRa opens up communication across several kilometres; in built-up urban areas, it can provide up to 4.8km of range, while in rural areas, the range can occasionally be as much as 16km!

- Low Power Consumption: LoRa devices operate on low power, resulting in extended battery life for IoT devices.
- Scalability: LoRa networks can support a large number of devices within a single network, making it highly scalable for applications with massive deployments.
- Cost-Effectiveness: LoRa utilizes unlicensed radio spectrum and low-power devices, resulting in cost savings in terms of infrastructure and energy consumption.

These advantages make LoRa a preferred choice over alternatives for a wide range of IoT applications, as it provides dependable and efficient wireless communication while meeting requirements for range, power efficiency, scalability, and cost-effectiveness.

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**How does LoRa work?**

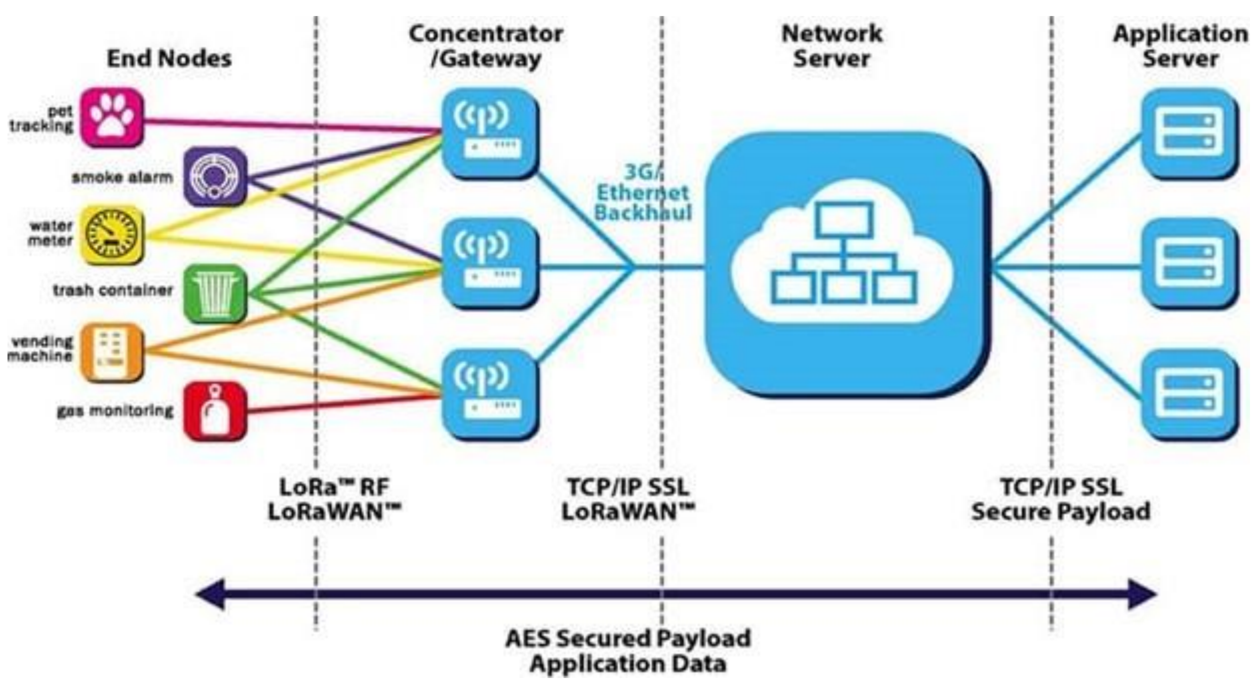
To attain its long-range capabilities, LoRa utilises a spread spectrum modulation technology known as Chirp Spread Spectrum (CSS). CSS modulation ensures that LoRa signals remain robust against interference and noise, allowing for dependable communication even in demanding circumstances.

The Key components of a LoRa system include:

- Nodes (or end devices): These are devices that transmit data to the LoRa network
- Gateways: Gateways act as bridges between the nodes and the network server, receiving signals from multiple nodes and forwarding the data.
- Network Server: the network server processes and manages the data received from the gateways, enabling communication between devices and applications or services on the internet.

**To summarise;**

Nodes transmit data to the nearest gateway using a spread spectrum technique. The gateways receive the signals and forward the data to the network server. The network server then processes the data and routes it to the appropriate applications or services.

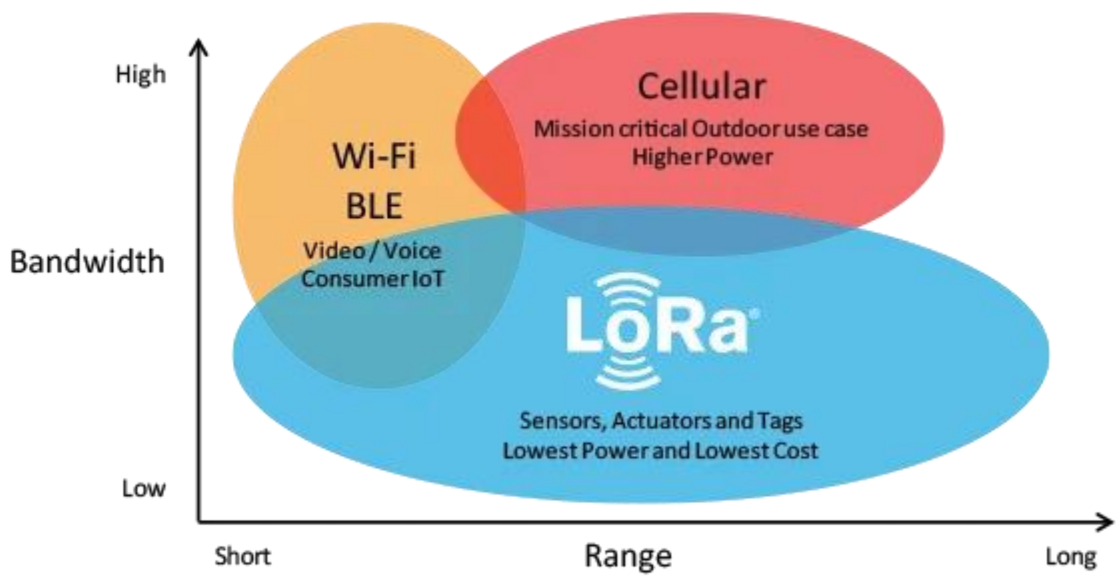


**LoRa’s Impressive Range & Applications**

One of LoRa's most notable features is its exceptional range capabilities. It can achieve long-distance communication of several kilometres(as discussed above), making it suitable for applications requiring connectivity over large geographic areas. The range enables IoT devices to communicate reliably across extensive urban or rural deployments.

LoRa technology finds applications in various industries, including but not limited to:

- Smart Cities: LoRa enables smart city applications such as smart metering, waste management, street lighting, and environmental monitoring. An example of this is Cambridge they are actively trying to make Cambridge a smart city using LoRa.
- Agriculture: It can be used for remote crop monitoring, soil moisture sensing, livestock tracking, and precision agriculture.
- Industrial Automation: LoRa facilitates asset tracking, predictive maintenance, and monitoring of critical infrastructure.
- Logistics and Supply Chain: It enables tracking and monitoring of goods, inventory management, and supply chain optimisation.




LoRa technology has transformed long-range, low-power wireless communication for Internet of Things applications. Its unique mix of long-range capabilities, low power consumption, scalability, and cost-effectiveness makes it an ideal choice for a wide range of deployments. LoRa continues to promote the expansion of IoT and contribute to the improvement of connected systems and services due to its dependable connectivity and diverse applications across industries.


thank you


BYE