UNIT-5 MULTI-USER RADIO COMMUNICATION

ADVANCED MOBILE PHONE SYSTEM

- Advanced Mobile Phone Service (AMPS) is a standard system for analog signal cellular telephone service in the United States and is also used in other countries.

- It is based on the initial electromagnetic radiation spectrum allocation for cellular service by the Federal Communications Commission (FCC) in 1970. Introduced by AT&T in 1983, AMPS became one of the most widely deployed cellular system in the United States.

- AMPS allocates frequency ranges within the 800 and 900 Megahertz (MHz) spectrum to cellular telephone. Each service provider can use half of the 824-849 MHz range for receiving signals from cellular phones and half the 869-894 MHz range for transmitting to cellular phones.

- The bands are divided into 30 kHz sub-bands, called channels. The receiving channels are called reverse channels and the sending channels are called forward channels. The division of the spectrum into sub-band channels is achieved by using frequency division multiple access (FDMA).

- The signals received from a transmitter cover an area called a cell. As a user moves out of the cell's area into an adjacent cell, the user begins to pick up the new cell's signals without any noticeable transition.

- The signals in the adjacent cell are sent and received on different channels than the previous cell's signals to so that the signals don't interfere with each other.

- The analog service of AMPS has been updated with digital cellular service by adding to FDMA a further subdivision of each channel using time division multiple access (TDMA). This service is known as digital AMPS (D-AMPS). Although AMPS and D-AMPS originated for the North American cellular telephone market, they are now used worldwide with over 74 million subscribers, according to Ericsson, one of the major cellular phone manufacturers.

GSM

GSM MSs consist of:

- **Mobile Equipment**
- **Subscriber Identity Module**

FUNCTIONS OF MS

- Voice and data transmission & receipt
- Frequency and time synchronization
- Monitoring of power and signal quality of the surrounding cells
- Provision of location updates even during inactive state

Mobile Station

- Can receive, store, send SMS up to 160 characters.
- MS identified by unique IMEI shown on pressing *#06#.
- Power levels of 20W, 8W, 5W, 2W and .8W

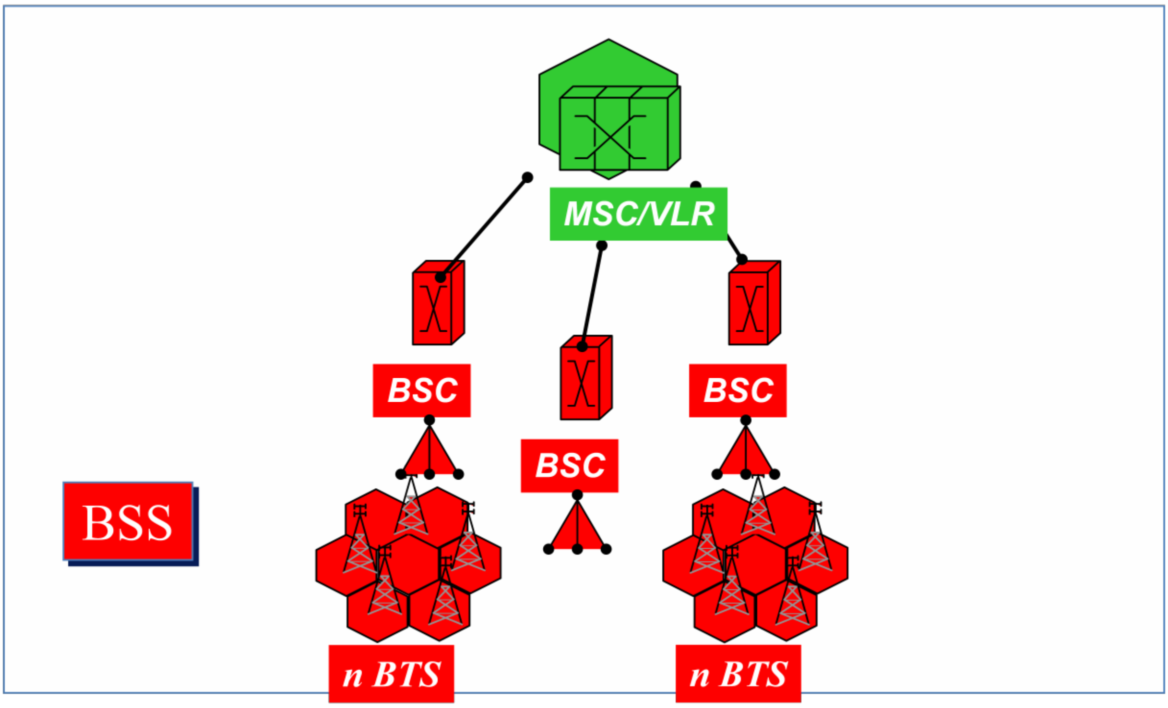
SIM

SIM has microprocessor and memory.

Fixed data stored for the subscription:

- IMSI,
- Authentication Key, Ki
- Security Algorithms:kc,A3,A8
- PIN & PUK

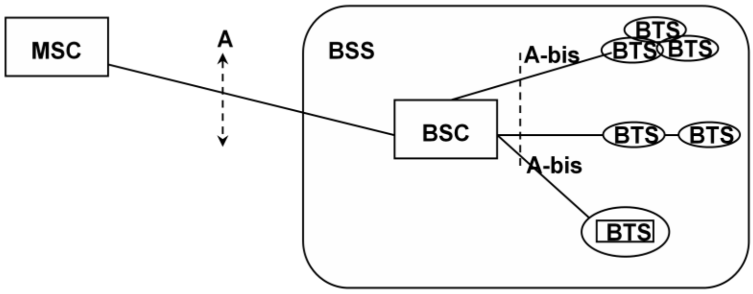
BASE STATION SYSTEM (BSS)



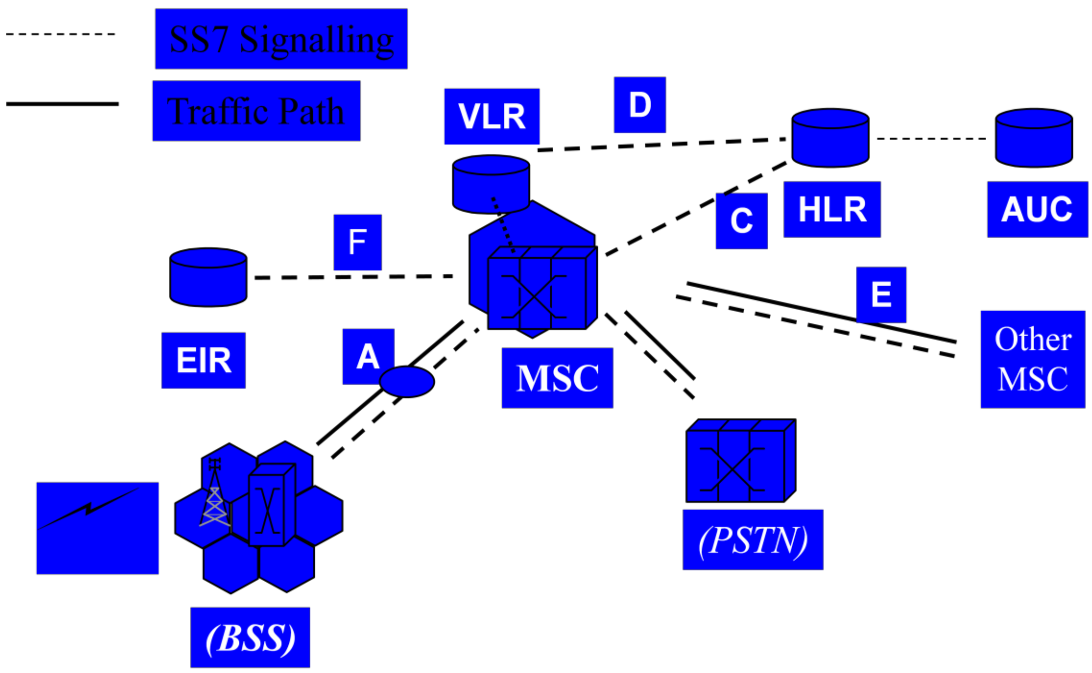
FUNCTIONS OF BTS (Base Transceiver Station)

- Radio resources
- Signal Processing
- Signaling link management
- Synchronization
- Local maintenance handling
- Functional supervision and Testing

MSC-BSS Configurations



Switching System (SS)



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VISITOR LOCATION REGISTER (VLR)

- **It contains data of all mobiles roaming in its area.**
- **One VLR may be incharge of one or more LA.**
- **VLR is updated by HLR on entry of MS its area.**
- **VLR assigns TMSI which keeps on changing.**

Home Location Register(HLR)

- Reference store for subscriber's parameters, numbers, authentication & Encryption values.

- Current subscriber status and associated VLR.

- Both VLR and HLR can be implemented in the
same equipment in an MSC.

- one PLMN may contain one or several HLR.

EQUIPMENT IDENTITY REGISTER (EIR)

- This data base stores IMEI for all registered mobile equipments and is unique to every ME.
- Only one EIR per PLMN.
- ***White list*** : IMEI, assigned to valid ME.
- ***Black list*** : IMEI reported stolen
- ***Gray list*** : IMEI having problems like faulty software, wrong make of equipment etc.

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AUthentication Center (AUC)

To authenticate the subs. attempting to use a network.

AUC is connected to HLR which provides it with authentication parameters and ciphering keys used to ensure network security.

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CDMA

Code division multiple access

From Wikipedia, the free encyclopedia

This article is about a channel access method. For the mobile phone technology referred to as CDMA, see IS-95 and CDMA2000.

Multiplex techniques

Analog modulation

- AM
- FM
- PM
- QAM
- SM
- SSB

Circuit mode (constant bandwidth)

- TDM
- FDM / WDM
- SDM
- Polarization multiplexing
- Spatial multiplexing
- OAM multiplexing

Statistical multiplexing (variable bandwidth)

- Packet switching
- Dynamic TDM
- FHSS
- DSSS
- OFDMA

- SC-FDM
- MC-SS

Related topics

- Channel access methods
- Media access control

- v
- t
- e

Code division multiple access (**CDMA**) is a channel access method used by various radio communication technologies.

CDMA is an example of multiple access, which is where several transmitters can send information simultaneously over a single communication channel. This allows several users to share a band of frequencies (see bandwidth). To permit this to be achieved without undue interference between the users, CDMA employs spread-spectrum technology and a special coding scheme (where each transmitter is assigned a code).

CDMA is used as the access method in many mobile phone standards such as cdmaOne, CDMA2000 (the 3G evolution of cdmaOne), and WCDMA (the 3G standard used by GSM carriers), which are often referred to as simply CDMA.

ode division multiplexing (synchronous CDMA)

The digital modulation method is analogous to those used in simple radio transceivers. In the analogue case, a low frequency data signal is time multiplied with a high frequency pure sine wave carrier, and transmitted. This is effectively a frequency convolution (Weiner-Kinchin Theorem) of the two signals, resulting in a carrier with narrow sidebands. In the digital case, the sinusoidal carrier is replaced by Walsh functions. These are binary square waves that form a

complete orthonormal set. The data signal is also binary and the time multiplication is achieved with a simple XOR function. This is usually a Gilbert cell mixer in the circuitry.

Synchronous CDMA exploits mathematical properties of orthogonality between vectors representing the data strings. For example, binary string 1011 is represented by the vector (1, 0, 1, 1). Vectors can be multiplied by taking their dot product, by summing the products of their respective components (for example, if u = (a, b) and v = (c, d), then their dot product u·v = ac + bd). If the dot product is zero, the two vectors are said to be orthogonal to each other. Some properties of the dot product aid understanding of how W-CDMA works. If vectors a and b are orthogonal, then $\mathbf{a}\cdot\mathbf{b}=0$ and:

$$\mathbf{a}\cdot(\mathbf{a}+\mathbf{b}) = \|\mathbf{a}\|^2 \quad \text{since} \quad \mathbf{a}\cdot\mathbf{a}+\mathbf{a}\cdot\mathbf{b} = \|a\|^2+0$$

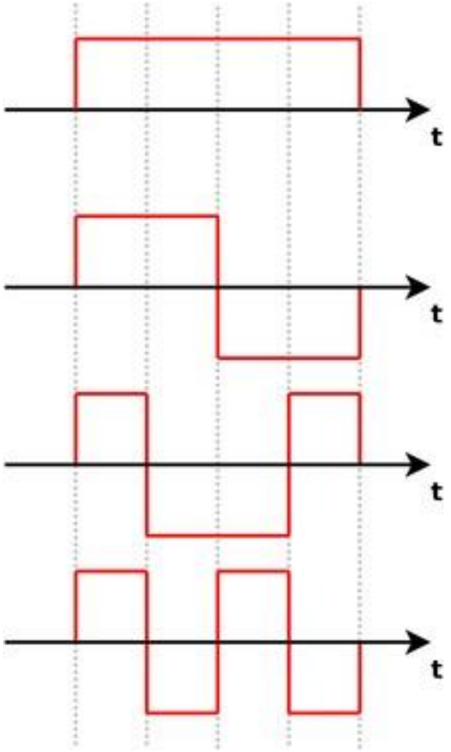
$$\mathbf{a}\cdot(-\mathbf{a}+\mathbf{b}) = -\|\mathbf{a}\|^2 \quad \text{since} \quad -\mathbf{a}\cdot\mathbf{a}+\mathbf{a}\cdot\mathbf{b} = -\|a\|^2+0$$

$$\mathbf{b}\cdot(\mathbf{a}+\mathbf{b}) = \|\mathbf{b}\|^2 \quad \text{since} \quad \mathbf{b}\cdot\mathbf{a}+\mathbf{b}\cdot\mathbf{b} = 0+\|b\|^2$$

$$\mathbf{b}\cdot(\mathbf{a}-\mathbf{b}) = -\|\mathbf{b}\|^2 \quad \text{since} \quad \mathbf{b}\cdot\mathbf{a}-\mathbf{b}\cdot\mathbf{b} = 0-\|b\|^2$$

Each user in synchronous CDMA uses a code orthogonal to the others' codes to modulate their signal. An example of four mutually orthogonal digital signals is shown in the figure. Orthogonal codes have a cross-correlation equal to zero; in other words, they do not interfere with each other. In the case of IS-95 64 bit Walsh codes are used to encode the signal to separate different users. Since each of the 64 Walsh codes are orthogonal to one another, the signals are channelized into 64 orthogonal signals. The following example demonstrates how each user's signal can be encoded and decoded.

Example



An example of four mutually orthogonal digital signals.

Start with a set of vectors that are mutually orthogonal. (Although mutual orthogonality is the only condition, these vectors are usually constructed for ease of decoding, for example columns or rows from Walsh matrices.) An example of orthogonal functions is shown in the picture on the right. These vectors will be assigned to individual users and are called the code, chip code, or chipping code. In the interest of brevity, the rest of this example uses codes, **v**, with only two bits.

Each user is associated with a different code, say **v**. A 1 bit is represented by transmitting a positive code, **v**, and a 0 bit is represented by a negative code, –**v**. For example, if **v** = (v_0, v_1) = (1, –1) and the data that the user wishes to transmit is (1, 0, 1, 1), then the transmitted symbols would be (**v**, –**v**, **v**, **v**) = (v_0, v_1, –v_0, –v_1, v_0, v_1, v_0, v_1) = (1, –1, –1, 1, 1, –1, 1, –1). For the purposes of this article, we call this constructed vector the transmitted vector.

Each sender has a different, unique vector **v** chosen from that set, but the construction method of the transmitted vector is identical.

Now, due to physical properties of interference, if two signals at a point are in phase, they add to give twice the amplitude of each signal, but if they are out of phase, they subtract and give a signal that is the difference of the amplitudes. Digitally, this behaviour can be modelled by the addition of the transmission vectors, component by component.

If sender0 has code (1, –1) and data (1, 0, 1, 1), and sender1 has code (1, 1) and data (0, 0, 1, 1), and both senders transmit simultaneously, then this table describes the coding steps:

Step	Encode sender0	Encode sender1
0	code0 = (1, –1), data0 = (1, 0, 1, 1)	code1 = (1, 1), data1 = (0, 0, 1, 1)
1	encode0 = 2(1, 0, 1, 1) – (1, 1, 1, 1) = (1, –1, 1, 1)	encode1 = 2(0, 0, 1, 1) – (1, 1, 1, 1) = (–1, –1, 1, 1)
2	signal0 = encode0 ⊗ code0 = (1, –1, 1, 1) ⊗ (1, –1) = (1, –1, –1, 1, 1, –1, 1, –1)	signal1 = encode1 ⊗ code1 = (–1, –1, 1, 1) ⊗ (1, 1) = (–1, –1, –1, –1, 1, 1, 1, 1)

Because signal0 and signal1 are transmitted at the same time into the air, they add to produce the raw signal:

(1, –1, –1, 1, 1, –1, 1, –1) + (–1, –1, –1, –1, 1, 1, 1, 1) = (0, –2, –2, 0, 2, 0, 2, 0)

This raw signal is called an interference pattern. The receiver then extracts an intelligible signal for any known sender by combining the sender's code with the interference pattern, the receiver combines it with the codes of the senders. The following table explains how this works and shows that the signals do not interfere with one another:

Step	Decode sender0	Decode sender1
0	code0 = (1, –1), signal = (0, –2, –2, 0, 2, 0, 2, 0)	code1 = (1, 1), signal = (0, –2, –2, 0, 2, 0, 2, 0)
1	decode0 = pattern.vector0	decode1 = pattern.vector1
2	decode0 = ((0, –2), (–2, 0), (2, 0), (2, 0)).(1, –1)	decode1 = ((0, –2), (–2, 0), (2, 0), (2, 0)).(1, 1)
3	decode0 = ((0 + 2), (–2 + 0), (2 + 0), (2 + 0))	decode1 = ((0 – 2), (–2 + 0), (2 + 0), (2 + 0))
4	data0=(2, –2, 2, 2), meaning (1, 0, 1, 1)	data1=(–2, –2, 2, 2), meaning (0, 0, 1, 1)

Further, after decoding, all values greater than 0 are interpreted as 1 while all values less than zero are interpreted as 0. For example, after decoding, data0 is (2, –2, 2, 2), but the receiver interprets this as (1, 0, 1, 1). Values of exactly 0 means that the sender did not transmit any data, as in the following example:

Assume signal0 = (1, –1, –1, 1, 1, –1, 1, –1) is transmitted alone. The following table shows the decode at the receiver:

Step	Decode sender0	Decode sender1
0	code0 = (1, –1), signal = (1, –1, –1, 1, 1, –1, 1, –1)	code1 = (1, 1), signal = (1, –1, –1, 1, 1, –1, 1, –1)
1	decode0 = pattern.vector0	decode1 = pattern.vector1
2	decode0 = ((1, –1), (–1, 1), (1, –1), (1, –1)).(1, –1)	decode1 = ((1, –1), (–1, 1), (1, –1), (1, –1)).(1, 1)
3	decode0 = ((1 + 1), (–1 – 1),(1 +	decode1 = ((1 – 1), (–1 + 1),(1

	1), (1 + 1))	– 1), (1 – 1))
4	data0 = (2, –2, 2, 2), meaning (1, 0, 1, 1)	data1 = (0, 0, 0, 0), meaning no data

When the receiver attempts to decode the signal using sender1's code, the data is all zeros, therefore the cross correlation is equal to zero and it is clear that sender1 did not transmit any data.

Asynchronous CDMA

See also: Direct-sequence spread spectrum and near-far problem

When mobile-to-base links cannot be precisely coordinated, particularly due to the mobility of the handsets, a different approach is required. Since it is not mathematically possible to create signature sequences that are both orthogonal for arbitrarily random starting points and which make full use of the code space, unique "pseudo-random" or "pseudo-noise" (PN) sequences are used in asynchronous CDMA systems. A PN code is a binary sequence that appears random but can be reproduced in a deterministic manner by intended receivers. These PN codes are used to encode and decode a user's signal in Asynchronous CDMA in the same manner as the orthogonal codes in synchronous CDMA (shown in the example above). These PN sequences are statistically uncorrelated, and the sum of a large number of PN sequences results in multiple access interference (MAI) that is approximated by a Gaussian noise process (following the central limit theorem in statistics). Gold codes are an example of a PN suitable for this purpose, as there is low correlation between the codes. If all of the users are received with the same power level, then the variance (e.g., the noise power) of the MAI increases in direct proportion to the number of users. In other words, unlike synchronous CDMA, the signals of other users will appear as noise to the signal of interest and interfere slightly with the desired signal in proportion to number of users.

All forms of CDMA use spread spectrum process gain to allow receivers to partially discriminate against unwanted signals. Signals

encoded with the specified PN sequence (code) are received, while signals with different codes (or the same code but a different timing offset) appear as wideband noise reduced by the process gain.

Since each user generates MAI, controlling the signal strength is an important issue with CDMA transmitters. A CDM (synchronous CDMA), TDMA, or FDMA receiver can in theory completely reject arbitrarily strong signals using different codes, time slots or frequency channels due to the orthogonality of these systems. This is not true for Asynchronous CDMA; rejection of unwanted signals is only partial. If any or all of the unwanted signals are much stronger than the desired signal, they will overwhelm it. This leads to a general requirement in any asynchronous CDMA system to approximately match the various signal power levels as seen at the receiver. In CDMA cellular, the base station uses a fast closed-loop power control scheme to tightly control each mobile's transmit power.

Advantages of asynchronous CDMA over other techniques

Efficient practical utilization of the fixed frequency spectrum

In theory CDMA, TDMA and FDMA have exactly the same spectral efficiency but practically, each has its own challenges – power control in the case of CDMA, timing in the case of TDMA, and frequency generation/filtering in the case of FDMA.

TDMA systems must carefully synchronize the transmission times of all the users to ensure that they are received in the correct time slot and do not cause interference. Since this cannot be perfectly controlled in a mobile environment, each time slot must have a guard-time, which reduces the probability that users will interfere, but decreases the spectral efficiency. Similarly, FDMA systems must use a guard-band between adjacent channels, due to the unpredictable doppler shift of the signal spectrum because of user mobility. The guard-bands will reduce the probability that adjacent channels will interfere, but decrease the utilization of the spectrum.

Flexible allocation of resources

Asynchronous CDMA offers a key advantage in the flexible allocation of resources i.e. allocation of a PN codes to active users. In the case of CDM (synchronous CDMA), TDMA, and FDMA the number of simultaneous orthogonal codes, time slots and frequency slots respectively are fixed hence the capacity in terms of number of simultaneous users is limited. There are a fixed number of orthogonal codes, time slots or frequency bands that can be allocated for CDM, TDMA, and FDMA systems, which remain underutilized due to the bursty nature of telephony and packetized data transmissions. There is no strict limit to the number of users that can be supported in an asynchronous CDMA system, only a practical limit governed by the desired bit error probability, since the SIR (Signal to Interference Ratio) varies inversely with the number of users. In a bursty traffic environment like mobile telephony, the advantage afforded by asynchronous CDMA is that the performance (bit error rate) is allowed to fluctuate randomly, with an average value determined by the number of users times the percentage of utilization. Suppose there are 2N users that only talk half of the time, then 2N users can be accommodated with the same average bit error probability as N users that talk all of the time. The key difference here is that the bit error probability for N users talking all of the time is constant, whereas it is a random quantity (with the same mean) for 2N users talking half of the time.

In other words, asynchronous CDMA is ideally suited to a mobile network where large numbers of transmitters each generate a relatively small amount of traffic at irregular intervals. CDM (synchronous CDMA), TDMA, and FDMA systems cannot recover the underutilized resources inherent to bursty traffic due to the fixed number of orthogonal codes, time slots or frequency channels that can be assigned to individual transmitters. For instance, if there are N time slots in a TDMA system and 2N users that talk half of the time, then half of the time there will be more than N users needing to use more than N time slots. Furthermore, it would require significant overhead to continually allocate and deallocate the orthogonal code, time slot or frequency channel resources. By comparison, asynchronous CDMA

transmitters simply send when they have something to say, and go off the air when they don't, keeping the same PN signature sequence as long as they are connected to the system.

Spread-spectrum characteristics of CDMA

Most modulation schemes try to minimize the bandwidth of this signal since bandwidth is a limited resource. However, spread spectrum techniques use a transmission bandwidth that is several orders of magnitude greater than the minimum required signal bandwidth. One of the initial reasons for doing this was military applications including guidance and communication systems. These systems were designed using spread spectrum because of its security and resistance to jamming. Asynchronous CDMA has some level of privacy built in because the signal is spread using a pseudo-random code; this code makes the spread spectrum signals appear random or have noise-like properties. A receiver cannot demodulate this transmission without knowledge of the pseudo-random sequence used to encode the data. CDMA is also resistant to jamming. A jamming signal only has a finite amount of power available to jam the signal. The jammer can either spread its energy over the entire bandwidth of the signal or jam only part of the entire signal.[9]

CDMA can also effectively reject narrow band interference. Since narrow band interference affects only a small portion of the spread spectrum signal, it can easily be removed through notch filtering without much loss of information. Convolution encoding and interleaving can be used to assist in recovering this lost data. CDMA signals are also resistant to multipath fading. Since the spread spectrum signal occupies a large bandwidth only a small portion of this will undergo fading due to multipath at any given time. Like the narrow band interference this will result in only a small loss of data and can be overcome.

Another reason CDMA is resistant to multipath interference is because the delayed versions of the transmitted pseudo-random codes will have poor correlation with the original pseudo-random code, and will thus appear as another user, which is ignored at the receiver. In

other words, as long as the multipath channel induces at least one chip of delay, the multipath signals will arrive at the receiver such that they are shifted in time by at least one chip from the intended signal. The correlation properties of the pseudo-random codes are such that this slight delay causes the multipath to appear uncorrelated with the intended signal, and it is thus ignored.

Some CDMA devices use a rake receiver, which exploits multipath delay components to improve the performance of the system. A rake receiver combines the information from several correlators, each one tuned to a different path delay, producing a stronger version of the signal than a simple receiver with a single correlation tuned to the path delay of the strongest signal.[10]

Frequency reuse is the ability to reuse the same radio channel frequency at other cell sites within a cellular system. In the FDMA and TDMA systems frequency planning is an important consideration. The frequencies used in different cells must be planned carefully to ensure signals from different cells do not interfere with each other. In a CDMA system, the same frequency can be used in every cell, because channelization is done using the pseudo-random codes. Reusing the same frequency in every cell eliminates the need for frequency planning in a CDMA system; however, planning of the different pseudo-random sequences must be done to ensure that the received signal from one cell does not correlate with the signal from a nearby cell.[11]

Since adjacent cells use the same frequencies, CDMA systems have the ability to perform soft hand offs. Soft hand offs allow the mobile telephone to communicate simultaneously with two or more cells. The best signal quality is selected until the hand off is complete. This is different from hard hand offs utilized in other cellular systems. In a hard hand off situation, as the mobile telephone approaches a hand off, signal strength may vary abruptly. In contrast, CDMA systems use the soft hand off, which is undetectable and provides a more reliable and higher quality signal.[11]

Collaborative CDMA

In a recent study, a novel collaborative multi-user transmission and detection scheme called Collaborative CDMA[12] has been investigated for the uplink that exploits the differences between users' fading channel signatures to increase the user capacity well beyond the spreading length in multiple access interference (MAI) limited environment. The authors show that it is possible to achieve this increase at a low complexity and high bit error rate performance in flat fading channels, which is a major research challenge for overloaded CDMA systems. In this approach, instead of using one sequence per user as in conventional CDMA, the authors group a small number of users to share the same spreading sequence and enable group spreading and despreading operations. The new collaborative multi-user receiver consists of two stages: group multi-user detection (MUD) stage to suppress the MAI between the groups and a low complexity maximum-likelihood detection stage to recover jointly the co-spread users' data using minimum Euclidean distance measure and users' channel gain coefficients. In CDM signal security is high.

HAND OFF

In cellular telecommunications, the term **handover** or **handoff** refers to the process of transferring an ongoing call or data session from one channel connected to the core network to another channel. In satellite communications it is the process of transferring satellite control responsibility from one earth station to another without loss or interruption of service.

Purpose

In telecommunications there may be different reasons why a handover might be conducted:

- when the phone is moving away from the area covered by one cell and entering the area covered by another cell the call is transferred to the second cell in order to avoid call termination when the phone gets outside the range of the first cell;

- when the capacity for connecting new calls of a given cell is used up and an existing or new call from a phone, which is located in an area overlapped by another cell, is transferred to that cell in order to free-up some capacity in the first cell for other users, who can only be connected to that cell;
- in non-CDMA networks when the channel used by the phone becomes interfered by another phone using the same channel in a different cell, the call is transferred to a different channel in the same cell or to a different channel in another cell in order to avoid the interference;
- again in non-CDMA networks when the user behaviour changes, e.g. when a fast-travelling user, connected to a large, umbrella-type of cell, stops then the call may be transferred to a smaller macro cell or even to a micro cell in order to free capacity on the umbrella cell for other fast-traveling users and to reduce the potential interference to other cells or users (this works in reverse too, when a user is detected to be moving faster than a certain threshold, the call can be transferred to a larger umbrella-type of cell in order to minimize the frequency of the handovers due to this movement);
- in CDMA networks a handover (see further down) may be induced in order to reduce the interference to a smaller neighboring cell due to the "near-far" effect even when the phone still has an excellent connection to its current cell;
- etc.

The most basic form of handover is when a phone call in progress is redirected from its current cell (called source) to a new cell (called target). In terrestrial networks the source and the target cells may be served from two different cell sites or from one and the same cell site (in the latter case the two cells are usually referred to as two sectors on that cell site). Such a handover, in which the source and the target are different cells (even if they are on the same cell site) is called inter-cell handover. The purpose of inter-cell handover is to maintain the call as the subscriber is moving out of the area covered by the source cell and entering the area of the target cell.

A special case is possible, in which the source and the target are one and the same cell and only the used channel is changed during the handover. Such a handover, in which the cell is not changed, is called intra-cell handover. The purpose of intra-cell handover is to change one channel, which may be interfered or fading with a new clearer or less fading channel.

Types of handover

In addition to the above classification of inter-cell and intra-cell classification of handovers, they also can be divided into hard and soft handovers:

- A hard handover is one in which the channel in the source cell is released and only then the channel in the target cell is engaged. Thus the connection to the source is broken before or 'as' the connection to the target is made—for this reason such handovers are also known as break-before-make. Hard handovers are intended to be instantaneous in order to minimize the disruption to the call. A hard handover is perceived by network engineers as an event during the call. It requires the least processing by the network providing service. When the mobile is between base stations, then the mobile can switch with any of the base stations, so the base stations bounce the link with the mobile back and forth. This is called ping-ponging.
- A soft handover is one in which the channel in the source cell is retained and used for a while in parallel with the channel in the target cell. In this case the connection to the target is established before the connection to the source is broken, hence this handover is called make-before-break. The interval, during which the two connections are used in parallel, may be brief or substantial. For this reason the soft handover is perceived by network engineers as a state of the call, rather than a brief event. Soft handovers may involve using connections to more than two cells: connections to three, four or more cells can be maintained by one phone at the same time. When a call is in a state of soft handover, the signal of the best of all used channels can be used for the call at a given moment or all the signals can be combined

to produce a clearer copy of the signal. The latter is more advantageous, and when such combining is performed both in the downlink (forward link) and the uplink (reverse link) the handover is termed as softer. Softer handovers are possible when the cells involved in the handovers have a single cell site.

Comparison of handovers

An advantage of the hard handover is that at any moment in time one call uses only one channel. The hard handover event is indeed very short and usually is not perceptible by the user. In the old analog systems it could be heard as a click or a very short beep; in digital systems it is unnoticeable. Another advantage of the hard handoff is that the phone's hardware does not need to be capable of receiving two or more channels in parallel, which makes it cheaper and simpler. A disadvantage is that if a handover fails the call may be temporarily disrupted or even terminated abnormally. Technologies which use hard handovers, usually have procedures which can re-establish the connection to the source cell if the connection to the target cell cannot be made. However re-establishing this connection may not always be possible (in which case the call will be terminated) and even when possible the procedure may cause a temporary interruption to the call.

One advantage of the soft handovers is that the connection to the source cell is broken only when a reliable connection to the target cell has been established and therefore the chances that the call will be terminated abnormally due to failed handovers are lower. However, by far a bigger advantage comes from the mere fact that simultaneously channels in multiple cells are maintained and the call could only fail if all of the channels are interfered or fade at the same time. Fading and interference in different channels are unrelated and therefore the probability of them taking place at the same moment in all channels is very low. Thus the reliability of the connection becomes higher when the call is in a soft handover. Because in a cellular network the majority of the handovers occur in places of poor coverage, where calls would frequently become unreliable when their channel is interfered or fading, soft handovers bring a significant improvement to the reliability of the calls in these places by making

the interference or the fading in a single channel not critical. This advantage comes at the cost of more complex hardware in the phone, which must be capable of processing several channels in parallel. Another price to pay for soft handovers is use of several channels in the network to support just a single call. This reduces the number of remaining free channels and thus reduces the capacity of the network. By adjusting the duration of soft handovers and the size of the areas in which they occur, the network engineers can balance the benefit of extra call reliability against the price of reduced capacity.

Possibility of handover

While theoretically speaking soft handovers are possible in any technology, analog or digital, the cost of implementing them for analog technologies is prohibitively high and none of the technologies that were commercially successful in the past (e.g. AMPS, TACS, NMT, etc.) had this feature. Of the digital technologies, those based on FDMA also face a higher cost for the phones (due to the need to have multiple parallel radio-frequency modules) and those based on TDMA or a combination of TDMA/FDMA, in principle, allow not so expensive implementation of soft handovers. However, none of the 2G (second-generation) technologies have this feature (e.g. GSM, D-AMPS/IS-136, etc.). On the other hand, all CDMA based technologies, 2G and 3G (third-generation), have soft handovers. On one hand, this is facilitated by the possibility to design not so expensive phone hardware supporting soft handovers for CDMA and on the other hand, this is necessitated by the fact that without soft handovers CDMA networks may suffer from substantial interference arising due to the so-called near-far effect.

In all current commercial technologies based on FDMA or on a combination of TDMA/FDMA (e.g. GSM, AMPS, IS-136/DAMPS, etc.) changing the channel during a hard handover is realised by changing the pair of used transmit/receive frequencies.

Implementations

For the practical realisation of handoffs in a cellular network each cell is assigned a list of potential target cells, which can be used for handing-off calls from this source cell to them. These potential target cells are called neighbours and the list is called neighbour list. Creating such a list for a given cell is not trivial and specialised computer tools are used. They implement different algorithms and may use for input data from field measurements or computer predictions of radio wave propagation in the areas covered by the cells.

During a call one or more parameters of the signal in the channel in the source cell are monitored and assessed in order to decide when a handover may be necessary. The downlink (forward link) and/or uplink (reverse link) directions may be monitored. The handover may be requested by the phone or by the base station (BTS) of its source cell and, in some systems, by a BTS of a neighbouring cell. The phone and the BTSs of the neighbouring cells monitor each other others' signals and the best target candidates are selected among the neighbouring cells. In some systems, mainly based on CDMA, a target candidate may be selected among the cells which are not in the neighbour list. This is done in an effort to reduce the probability of interference due to the aforementioned near-far effect.

In analog systems the parameters used as criteria for requesting a hard handover are usually the received signal power and the received signal-to-noise ratio (the latter may be estimated in an analog system by inserting additional tones, with frequencies just outside the captured voice-frequency band at the transmitter and assessing the form of these tones at the receiver). In non-CDMA 2G digital systems the criteria for requesting hard handover may be based on estimates of the received signal power, bit error rate (BER) and block error/erasure rate (BLER), received quality of speech (RxQual), distance between the phone and the BTS (estimated from the radio signal propagation delay) and others. In CDMA systems, 2G and 3G, the most common criterion for requesting a handover is Ec/Io ratio measured in the pilot channel (CPICH) and/or RSCP.

In CDMA systems, when the phone in soft or softer handoff is connected to several cells simultaneously, it processes the received in parallel signals using a rake receiver. Each signal is processed by a module called rake finger. A usual design of a rake receiver in mobile phones includes three or more rake fingers used in soft handoff state for processing signals from as many cells and one additional finger used to search for signals from other cells. The set of cells, whose signals are used during a soft handoff, is referred to as the active set. If the search finger finds a sufficiently-strong signal (in terms of high Ec/Io or RSCP) from a new cell this cell is added to the active set. The cells in the neighbour list (called in CDMA neighbouring set) are checked more frequently than the rest and thus a handoff with a neighbouring cell is more likely, however a handoff with others cells outside the neighbor list is also allowed (unlike in GSM, IS-136/DAMPS, AMPS, NMT, etc.).

Satellite

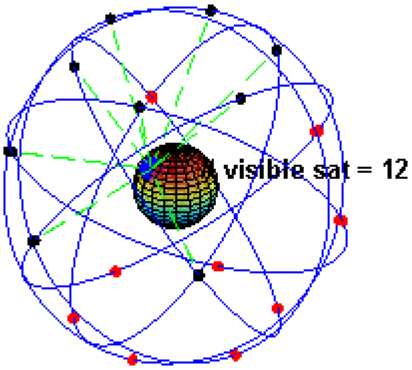
From Wikipedia, the free encyclopedia

This article is about artificial satellites. For natural satellites, also known as moons, see Natural satellite. For other uses, see Satellite (disambiguation).

This article is **outdated**. Please update this article to reflect recent events or newly available information. (December 2013)

Play media

NASA's Earth-observing fleet as of June 2012.



An animation depicting the orbits of GPS satellites in medium Earth orbit.

A full-size model of the Earth observation satellite ERS 2

In the context of spaceflight, a **satellite** is an artificial object which has been intentionally placed into orbit. Such objects are sometimes called **artificial satellites** to distinguish them from natural satellites such as the Moon.

The world's first artificial satellite, the Sputnik 1, was launched by the Soviet Union in 1957. Since then, thousands of satellites have been launched into orbit around the Earth. Some satellites, notably space stations, have been launched in parts and assembled in orbit. Artificial satellites originate from more than 50 countries and have used the satellite launching capabilities of ten nations. A few hundred satellites are currently operational, whereas thousands of unused satellites and satellite fragments orbit the Earth as space debris. A few space probes have been placed into orbit around other bodies and become artificial satellites to the Moon, Mercury, Venus, Mars, Jupiter, Saturn, Vesta, Eros, and the Sun.

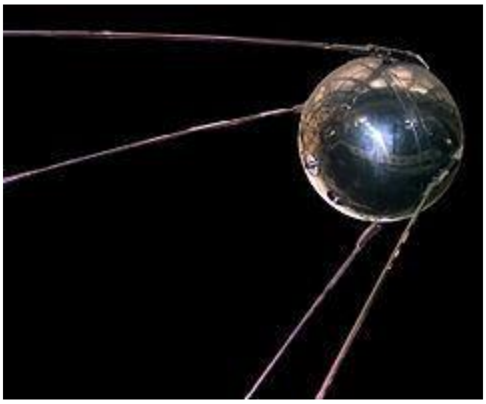
Satellites are used for a large number of purposes. Common types include military and civilian Earth observation satellites, communications satellites, navigation satellites, weather satellites, and research satellites. Space stations and human spacecraft in orbit are also satellites. Satellite orbits vary greatly, depending on the purpose of the satellite, and are classified in a number of ways. Well-known (overlapping) classes include low Earth orbit, polar orbit, and geostationary orbit.

About 6,600 satellites have been launched. The latest estimates are that 3,600 remain in orbit.[1] Of those, about 1,000 are operational;[2][3] the rest have lived out their useful lives and are part of the space debris. Approximately 500 operational satellites are in low-Earth orbit, 50 are in medium-Earth orbit (at 20,000 km), the rest are in geostationary orbit (at 36,000 km).[4]

Satellites are propelled by rockets to their orbits. Usually the launch vehicle itself is a rocket lifting off from a launch pad on land. In a minority of cases satellites are launched at sea (from a submarine or a mobile maritime platform) or aboard a plane (see air launch to orbit).

Satellites are usually semi-independent computer-controlled systems. Satellite subsystems attend many tasks, such as power generation, thermal control, telemetry, attitude control and orbit control.

History of artificial satellites



Sputnik 1: The first artificial satellite to orbit Earth.

The first artificial satellite was Sputnik 1, launched by the Soviet Union on October 4, 1957, and initiating the Soviet Sputnik program, with Sergei Korolev as chief designer (there is a crater on the lunar far side which bears his name). This in turn triggered the Space Race between the Soviet Union and the United States.

Sputnik 1 helped to identify the density of high atmospheric layers through measurement of its orbital change and provided data on radio-signal distribution in the ionosphere. The unanticipated announcement of Sputnik 1's success precipitated the Sputnik crisis in the United States and ignited the so-called Space Race within the Cold War.

Sputnik 2 was launched on November 3, 1957 and carried the first living passenger into orbit, a dog named Laika.[9]

In May, 1946, Project RAND had released the Preliminary Design of an Experimental World-Circling Spaceship, which stated, "A satellite vehicle with appropriate instrumentation can be expected to be one of the most potent scientific tools of the Twentieth Century."[10] The United States had been considering launching orbital satellites since

1945 under the Bureau of Aeronautics of the United States Navy. The United States Air Force's Project RAND eventually released the above report, but did not believe that the satellite was a potential military weapon; rather, they considered it to be a tool for science, politics, and propaganda. In 1954, the Secretary of Defense stated, "I know of no American satellite program."[11]

On July 29, 1955, the White House announced that the U.S. intended to launch satellites by the spring of 1958. This became known as Project Vanguard. On July 31, the Soviets announced that they intended to launch a satellite by the fall of 1957.

Following pressure by the American Rocket Society, the National Science Foundation, and the International Geophysical Year, military interest picked up and in early 1955 the Army and Navy were working on Project Orbiter, two competing programs: the army's which involved using a Jupiter C rocket, and the civilian/Navy Vanguard Rocket, to launch a satellite. At first, they failed: initial preference was given to the Vanguard program, whose first attempt at orbiting a satellite resulted in the explosion of the launch vehicle on national television. But finally, three months after Sputnik 2, the project succeeded; Explorer 1 became the United States' first artificial satellite on January 31, 1958.[12]

In June 1961, three-and-a-half years after the launch of Sputnik 1, the Air Force used resources of the United States Space Surveillance Network to catalog 115 Earth-orbiting satellites.[13]

Early satellites were constructed as "one-off" designs. With growth in geosynchronous (GEO) satellite communication, multiple satellites began to be built on single model platforms called satellite buses. The first standardized satellite bus design was the HS-333 GEO commsat, launched in 1972.

The largest artificial satellite currently orbiting the Earth is the International Space Station.

1U CubeSat ESTCube-1, developed mainly by the students from the University of Tartu, carries out a tether deployment experiment on the low Earth orbit.

Space Surveillance Network

Main article: United States Space Surveillance Network

The United States Space Surveillance Network (SSN), a division of The United States Strategic Command, has been tracking objects in Earth's orbit since 1957 when the Soviets opened the space age with the launch of Sputnik I. Since then, the SSN has tracked more than 26,000 objects. The SSN currently tracks more than 8,000 man-made orbiting objects. The rest have re-entered Earth's atmosphere and disintegrated, or survived re-entry and impacted the Earth. The SSN tracks objects that are 10 centimeters in diameter or larger; those now orbiting Earth range from satellites weighing several tons to pieces of spent rocket bodies weighing only 10 pounds. About seven percent are operational satellites (i.e. ~560 satellites), the rest are space debris.[14] The United States Strategic Command is primarily interested in the active satellites, but also tracks space debris which upon reentry might otherwise be mistaken for incoming missiles.

A search of the NSSDC Master Catalog at the end of October 2010 listed 6,578 satellites launched into orbit since 1957, the latest being Chang'e 2, on 1 October 2010.[15]

Non-military satellite services

There are three basic categories of non-military satellite services:[16]

Fixed satellite services

Fixed satellite services handle hundreds of billions of voice, data, and video transmission tasks across all countries and continents between certain points on the Earth's surface.

Mobile satellite systems

Mobile satellite systems help connect remote regions, vehicles, ships, people and aircraft to other parts of the world and/or other mobile or stationary communications units, in addition to serving as navigation systems.

Scientific research satellites (commercial and noncommercial)

Scientific research satellites provide meteorological information, land survey data (e.g. remote sensing), Amateur (HAM) Radio, and other different scientific research applications such as earth science, marine science, and atmospheric research.

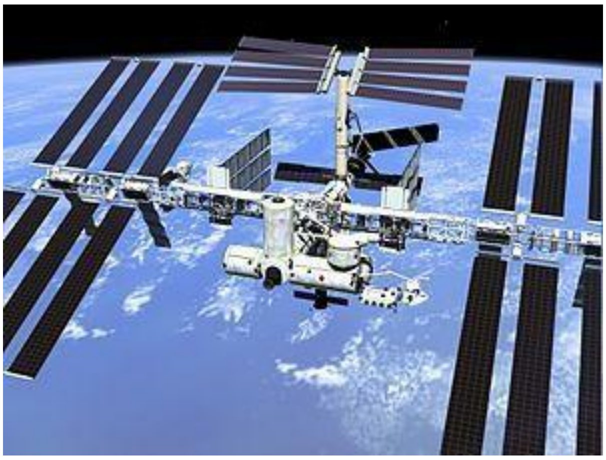
Types

MILSTAR: A communication satellite

- **"Killer Satellites"** are satellites that are designed to destroy enemy warheads, satellites, and other space assets.
- **Astronomical satellites** are satellites used for observation of distant planets, galaxies, and other outer space objects.

- **Biosatellites** are satellites designed to carry living organisms, generally for scientific experimentation.
- **Communications satellites** are satellites stationed in space for the purpose of telecommunications. Modern communications satellites typically use geosynchronous orbits, Molniya orbits or Low Earth orbits.
- **Miniaturized satellites** are satellites of unusually low masses and small sizes.[17] New classifications are used to categorize these satellites: minisatellite (500–100 kg), microsatellite (below 100 kg), nanosatellite (below 10 kg).[citation needed]
- **Navigational satellites** are satellites which use radio time signals transmitted to enable mobile receivers on the ground to determine their exact location. The relatively clear line of sight between the satellites and receivers on the ground, combined with ever-improving electronics, allows satellite navigation systems to measure location to accuracies on the order of a few meters in real time.
- **Reconnaissance satellites** are Earth observation satellite or communications satellite deployed for military or intelligence applications. Very little is known about the full power of these satellites, as governments who operate them usually keep information pertaining to their reconnaissance satellites classified.
- **Earth observation satellites** are satellites intended for non-military uses such as environmental monitoring, meteorology, map making etc. (See especially Earth Observing System.)
- **Tether satellites** are satellites which are connected to another satellite by a thin cable called a tether.
- **Weather satellites** are primarily used to monitor Earth's weather and climate.[18]
- **Recovery satellites** are satellites that provide a recovery of reconnaissance, biological, space-production and other payloads from orbit to Earth.
- **Manned spacecraft (spaceships)** are large satellites able to put humans into (and beyond) an orbit, and return them to Earth. Spacecraft including spaceplanes of reusable systems have

major propulsion or landing facilities. They can be used as transport to and from the orbital stations.



International Space Station as seen from Space

- **Space stations** are man-made orbital structures that are designed for human beings to live on in outer space. A space station is distinguished from other manned spacecraft by its lack of major propulsion or landing facilities. Space stations are designed for medium-term living in orbit, for periods of weeks, months, or even years.
- A **Skyhook** is a proposed type of tethered satellite/ion powered space station that serves as a terminal for suborbital launch vehicles flying between the Earth and the lower end of the Skyhook, as well as a terminal for spacecraft going to, or arriving from, higher orbit, the Moon, or Mars, at the upper end of the Skyhook.[19][20]

BLUETOOTH

This article is about a wireless technology standard. For the medieval King of Denmark, see Harald Bluetooth.

Bluetooth

Developed by	Bluetooth Special Interest Group
Industry	Mobile personal area networks
Compatible hardware	Mobile phones, Personal computers, Laptop computers
Physical range	Up to 60 metres[1]

Bluetooth is a wireless technology standard for exchanging data over short distances (using short-wavelength UHF radio waves in the ISM band from 2.4 to 2.485 GHz[2]) from fixed and mobile devices, and building personal area networks (PANs). Invented by telecom vendor Ericsson in 1994,[3] it was originally conceived as a wireless alternative to RS-232 data cables. It can connect several devices, overcoming problems of synchronization.

Bluetooth is managed by the Bluetooth Special Interest Group (SIG), which has more than 20,000 member companies in the areas of telecommunication, computing, networking, and consumer electronics.[4] Bluetooth was standardized as **IEEE 802.15.1**, but the standard is no longer maintained. The SIG oversees the development of the specification, manages the qualification program, and protects the trademarks.[5] To be marketed as a Bluetooth device, it must be qualified to standards defined by the SIG.[6] A network of patents is required to implement the technology, which is licensed only for that qualifying device.

Implementation

Bluetooth operates in the range of 2400–2483.5 MHz (including guard bands). This is in the globally unlicensed (but not unregulated) Industrial, Scientific and Medical (ISM) 2.4 GHz short-range radio frequency band. Bluetooth uses a radio technology called frequency-hopping spread spectrum. The transmitted data are divided into packets and each packet is transmitted on one of the 79 designated Bluetooth channels. Each channel has a bandwidth of 1 MHz. Bluetooth 4.0 uses 2 MHz spacing which allows for 40 channels. The first channel starts at 2402 MHz and continues up to 2480 MHz in 1 MHz steps. It usually performs 1600 hops per second, with Adaptive Frequency-Hopping (AFH) enabled.[12]

Originally, Gaussian frequency-shift keying (GFSK) modulation was the only modulation scheme available; subsequently, since the introduction of Bluetooth 2.0+EDR, π/4-DQPSK and 8DPSK modulation may also be used between compatible devices. Devices functioning with GFSK are said to be operating in basic rate (BR) mode where an instantaneous data rate of 1 Mbit/s is possible. The term Enhanced Data Rate (EDR) is used to describe π/4-DPSK and 8DPSK schemes, each giving 2 and 3 Mbit/s respectively. The combination of these (BR and EDR) modes in Bluetooth radio technology is classified as a "BR/EDR radio".

Bluetooth is a packet-based protocol with a master-slave structure. One master may communicate with up to seven slaves in a piconet; all devices share the master's clock. Packet exchange is based on the basic clock, defined by the master, which ticks at 312.5 µs intervals. Two clock ticks make up a slot of 625 µs; two slots make up a slot pair of 1250 µs. In the simple case of single-slot packets the master transmits in even slots and receives in odd slots; the slave, conversely, receives in even slots and transmits in odd slots. Packets may be 1, 3 or 5 slots long, but in all cases the master transmit will begin in even slots and the slave transmit in odd slots.

Communication and connection

A master Bluetooth device can communicate with a maximum of seven devices in a piconet (an ad-hoc computer network using Bluetooth technology), though not all devices reach this maximum. The devices can switch roles, by agreement, and the slave can become the master (for example, a headset initiating a connection to a phone will necessarily begin as master, as initiator of the connection; but may subsequently prefer to be slave).

The Bluetooth Core Specification provides for the connection of two or more piconets to form a scatternet, in which certain devices simultaneously play the master role in one piconet and the slave role in another.

At any given time, data can be transferred between the master and one other device (except for the little-used broadcast mode.[citation needed]) The master chooses which slave device to address; typically, it switches rapidly from one device to another in a round-robin fashion. Since it is the master that chooses which slave to address, whereas a slave is (in theory) supposed to listen in each receive slot, being a master is a lighter burden than being a slave. Being a master of seven slaves is possible; being a slave of more than one master is difficult.[citation needed] The specification is vague as to required behavior in scatternets.

Many USB Bluetooth adapters or "dongles" are available, some of which also include an IrDA adapter.[citation needed]

Uses

Class	Max. permitted power (mW)	(dBm)	Typ. range[13] (m)
1	100	20	~100
2	2.5	4	~10

3	1	0	~1

Bluetooth is a standard wire-replacement communications protocol primarily designed for low-power consumption, with a short range based on low-cost transceiver microchips in each device.[14] Because the devices use a radio (broadcast) communications system, they do not have to be in visual line of sight of each other, however a quasi optical wireless path must be viable.[4] Range is power-class-dependent, but effective ranges vary in practice; see the table on the right.

Version	**Data rate**	**Max. application throughput**
1.2	1 Mbit/s	>80 kbit/s
2.0 + EDR	3 Mbit/s	>80 kbit/s
3.0 + HS	24 Mbit/s	See Version 3.0 + HS
	24 Mbit/s	See Version 4.0 LE

The effective range varies due to propagation conditions, material coverage, production sample variations, antenna configurations and battery conditions. Most Bluetooth applications are in indoor conditions, where attenuation of walls and signal fading due to signal reflections will cause the range to be far lower than the specified line-of-sight ranges of the Bluetooth products. Most Bluetooth applications are battery powered Class 2 devices, with little difference in range whether the other end of the link is a Class 1 or Class 2 device as the lower powered device tends to set the range limit. In some cases the effective range of the data link can be extended when a Class 2 devices is connecting to a Class 1 transceiver with both higher sensitivity and transmission power than a typical Class 2 device.[15] Mostly however the Class 1 devices have a similar sensitivity to Class 2 devices. Connecting two Class 1 devices with both high sensitivity and high power can allow ranges far in excess of the typical 100m, depending on the throughput required by the

application. Some such devices allow open field ranges of up to 1 km and beyond between two similar devices without exceeding legal emission limits.[16][17][18]

While the Bluetooth Core Specification does mandate minimal for range, the range of the technology is application-specific and not limited. Manufacturers may tune their implementations to the range needed for individual use cases.

Bluetooth profiles

Main article: Bluetooth profile

To use Bluetooth wireless technology, a device has to be able to interpret certain Bluetooth profiles, which are definitions of possible applications and specify general behaviours that Bluetooth enabled devices use to communicate with other Bluetooth devices. These profiles include settings to parametrize and to control the communication from start. Adherence to profiles saves the time for transmitting the parameters anew before the bi-directional link becomes effective. There are a wide range of Bluetooth profiles that describe many different types of applications or use cases for devices.[19][20]

List of applications

A typical Bluetooth mobile phone headset.

- Wireless control of and communication between a mobile phone and a handsfree headset. This was one of the earliest applications to become popular.

- Wireless control of and communication between a mobile phone and a Bluetooth compatible car stereo system.
- Wireless control of and communication with tablets and speakers such as iPad and Android devices.
- Wireless Bluetooth headset and Intercom. Idiomatically, a headset is sometimes called "a Bluetooth".
- Wireless networking between PCs in a confined space and where little bandwidth is required.
- Wireless communication with PC input and output devices, the most common being the mouse, keyboard and printer.
- Transfer of files, contact details, calendar appointments, and reminders between devices with OBEX.
- Replacement of previous wired RS-232 serial communications in test equipment, GPS receivers, medical equipment, bar code scanners, and traffic control devices.
- For controls where infrared was often used.
- For low bandwidth applications where higher USB bandwidth is not required and cable-free connection desired.
- Sending small advertisements from Bluetooth-enabled advertising hoardings to other, discoverable, Bluetooth devices.[21]
- Wireless bridge between two Industrial Ethernet (e.g., PROFINET) networks.
- Three seventh and eighth generation game consoles, Nintendo's Wii.[22] and Sony's PlayStation 3, use Bluetooth for their respective wireless controllers.
- Dial-up internet access on personal computers or PDAs using a data-capable mobile phone as a wireless modem.
- Short range transmission of health sensor data from medical devices to mobile phone, set-top box or dedicated telehealth devices.[23]
- Allowing a DECT phone to ring and answer calls on behalf of a nearby mobile phone.
- Real-time location systems (RTLS), are used to track and identify the location of objects in real-time using “Nodes” or “tags” attached to, or embedded in the objects tracked, and

"Readers" that receive and process the wireless signals from these tags to determine their locations.[24]

- Personal security application on mobile phones for prevention of theft or loss of items. The protected item has a Bluetooth marker (e.g., a tag) that is in constant communication with the phone. If the connection is broken (the marker is out of range of the phone) then an alarm is raised. This can also be used as a man overboard alarm. A product using this technology has been available since 2009.[25]
- Calgary, Alberta, Canada's Roads Traffic division uses data collected from travelers' Bluetooth devices to predict travel times and road congestion for motorists.[26]