Mobile communication

Wireless communication is needed when the communicating stations are **mobile** (not necessarily at high speed) or where wired links are not practical.

Wireless communication typically uses **radio frequencies** although other possibilities abound, e.g. microwave communication. Radio is a broadcast medium, hence it is common to restrict the notion of **mobile communication** to wireless broadcast communication.

Point–to–point wireless communication has very little in common with broadcast wireless; it is widely used, but in a specialised context.

WiFi

WiFi architecture is based on the concept of a cell, called **basic service set**. It consists of a *base station* (*"access point"*).

The most popular WiFi architecture is 802.11.

Another approach: the *ad hoc network* architecture, which has no central access point and wireless stations communicate directly in broadcast mode. **Bluetooth** is an example of an ad hoc network; it is used to connect appliances within a small neighbouhood (if one of these appliances is a computer attached to the Internet, the Bluetooth **piconet** will have connectivity, too).

In each approach, the stations belonging to one "cell" must coordinate their use of the shared medium: a particular radio frequency band.

A completely different wireless telephony system exists: **satellite telephony**, which does not use cells.

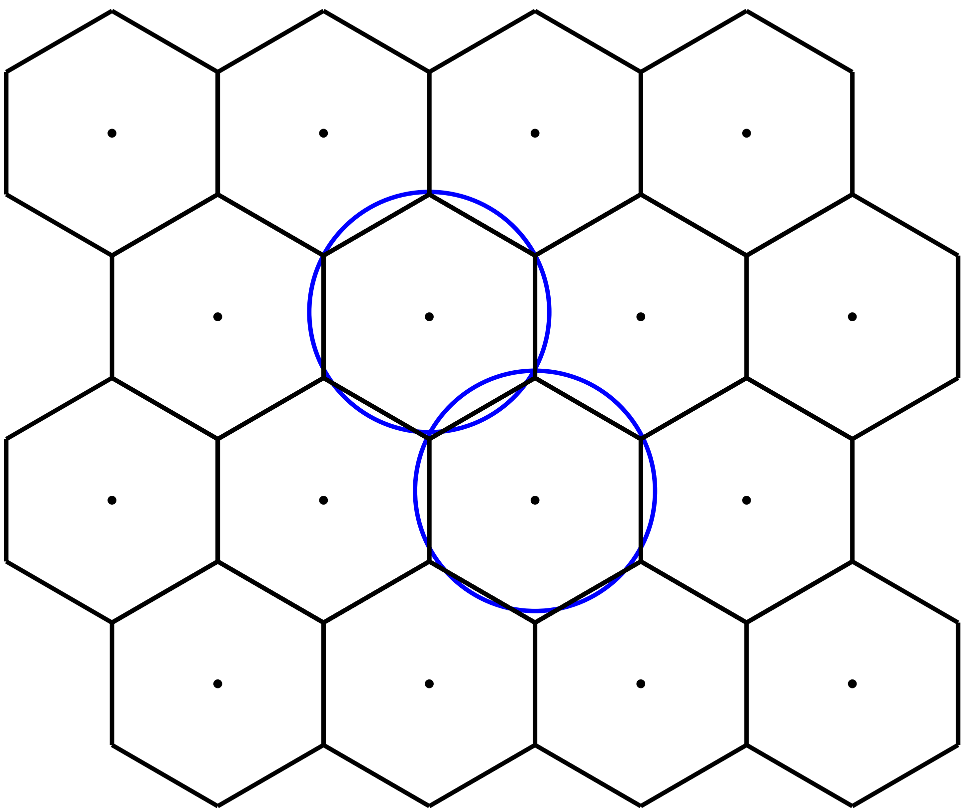
Cellular telephony

The Earth is (supposedly) divided into **hexagonal cells**, each cell operating a radio local area network based on a single multiple access link.

Reality has little to do with the theory: the cells have different sizes, often overlap; moreover, there are many competing networks in some popular cells (and none in most other cells).

A cell has a diameter of 1 to 40 km (limited by range which is an inverse function of frequency) and by user density. In cities large buildings may form impassable obstacles to radio waves limiting the actual range to less than 1 km. connections.

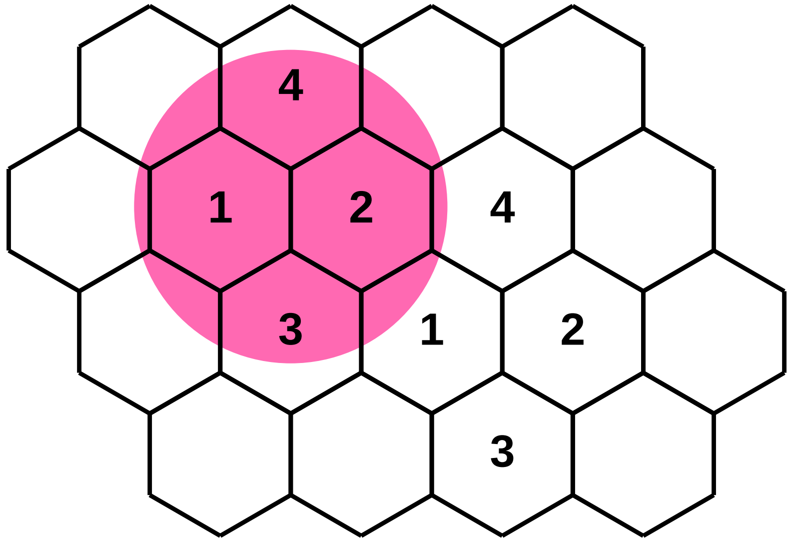
Cells usually overlap (remote sites being an exception) allowing mobile users to move from cell to cell without having to restart their communication sessions.

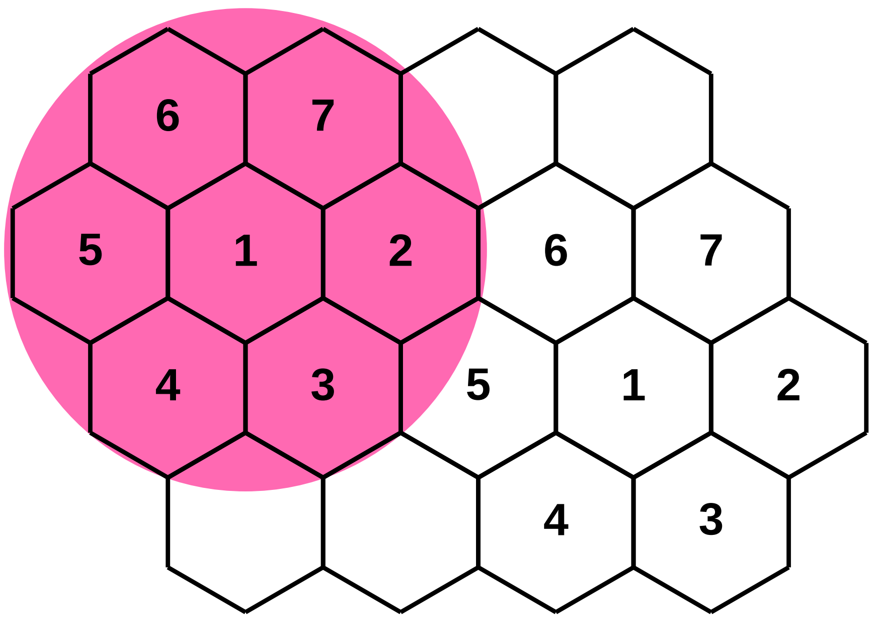


Frequencies

Since adjacent cells overlap, different frequencies must be used in adjacent cells. But the set of available frequencies is limited, so cells that are not adjacent do **reuse** the same frequencies as their non–neighbours.

Two basic schemes are used: a reuse factor of 4 and a reuse factor of 7. Cells are numbered according to a simple pattern. Cells with the same number use the same frequencies which are different from those used in cells with different numbers.

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Who’s who in wireless

The basic players in a cellular network are:

Handset: the mobile station.

Base Station: (Mobile Switch Centre) the LAN control point; also connected to the wired network.

Wired network: is used for long–distance wireless calls including roaming (and sometimes handoff).

Mode of operation

Transmitting: the handset must find a way to the BS.

Receiving: the telephone system must find a way to the receiver's handset.

Roaming: the sender's (or receiver's) handset is outside of the primary area of coverage.

Handoff: a handset moved from one cell to another.

Transmitting

- A number is dialed and the handset scans the frequency band (all the sub–bands) looking for the strongest signal (this takes some time).
- The strongest signal is assumed to be coming from the **BS** and the dialed number is sent on this frequency.
- The MSC passes the number to the central office (POTS). The receiver is found and, if free, connected to the MSC.
- The BS assigns a voice–grade channel to the sender (makes the sender connected).

Receiving

The called number is forwarded to all the cells within range (called **paging**). If the receiving handset is found, a ringing signal is sent to it. If the handset picks it up, the ringing BS assigns to it a voice–grade channel and reports the finding to the sender's MSC.

If no cell succeeds in finding the handset, **roaming** may be initiated.

Handoff

If a mobile station moves from one cell to another while connected, the signal will become weak. If it remains weak for a while, the MSC tries to find another cell that receives the same signal better (it has to be an adjacent cell so the signal cannot interfere with signalling inside that cell).

If a better cell is found, a new voice–grade subchannel is allocated to the mobile and the new cell (i.e. new BS/MSC takes over).

If no neighbouring cell wants the call, the connection will eventually die.

Roaming

Roaming refers to the ability to participate in a connection that spans between two distinct service locations. It is often identified (incorrectly) with **long–distance** calling using a cellular network.

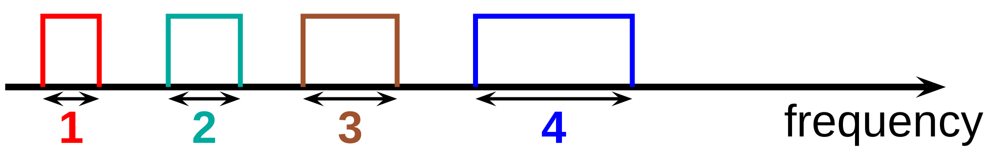
In general roaming takes place when the connection requires the service of another provider than the provider to the originator of the call. This could be a pair **WP** $\longrightarrow$ **WP** or a trio **WP** $\longrightarrow$ **POTS** $\longrightarrow$ **WP**.

Roaming may involve a digital conversion of transmission signal, although it is rare.

Licensed frequencies

In every country the government licenses the use of radio frequencies (and not only radio).

Several frequency bands were opened for unrestricted/semi–restricted use in wireless communication. these vary from country to country (it is one of the reasons why some phones do not work in some countries).



1: 902–928 MHz (Region 2 only).

2: 2.4–2.4835 GHz (“microwave band”).

3: 3.65–3.7 GHz.

4: 5.725–5.850 GHz.

1,2 and 4 are collectively called *Industrial, Scientific and Medical* bands. **3** used to be a radiolocation band for maritime use.

Wireless LANs

Besides cellular networks (which are not just voice) there are wireless data networks. These networks are regular LANs connected by radio signals.

Wireless LANs are broadcast networks so that it was natural to adapt Ethernet the DLL standard to a wireless medium.

802.11

An 802.11 system is based on a cell geometry with a base station, here called an **Access Point**.

Each cell is a LAN very similar to a star Ethernet: a central point called **Base Station** and mobile nodes around. The **BS** is a switch in the Ethernet sense–imposes collision control and provides a link to the outside world (wired and wireless). The main difference between 802.11 and “Star” Ethernet is that in 802.11 each frame (called **packet**) is broadcast to the whole cell.

There are several variants of the 802.11 protocol: 802.11–legacy (2Mbs), 802.11b (11Mbs), 802.11a (54Mbps), 802.11g (54Mbs) and new ones that are being finalised.

Technical data

Protocol	Freq.	Throughput	Indoors	Outdoors
11a	5.8 GHz	23Mbps	35 m	120 m
11b	2.4 GHz	4.3Mbps	38 m	140 m
11g	2.4 GHz	19Mbps	38 m	140 m
11n (09)	2.4/5.8 GHz	?	70 m	250 m
11n (08)	2.4/5.8 GHz	100Mbps	70 m	? m
11n (07)	3.7 GHz	74Mbps	50 m	5000 m

Protocol 802.11n is not official (standard draft 8.0 recommended without changes in March 2009) but several companies are selling “draft 2” models already. It operates at a nominal data rate of 300Mbps.

The MAC protocol is very similar to CSMA/CD and is called CSMA/CA (collision avoidance).

CSMA/CA operates in two modes:

- **Basic mode** (no collisions).
- **Backoff mode** (after a collision).

The main difference with CSMA/CD is that in a wireless network, the sender cannot detect all the collisions that result in CSMA/CA. This is due to the nature of the wireless medium: hidden terminal problem, fading, local interference, etc. can cause loss of a frame at some locations, but not elsewhere.

As a result, the sender does not try to detect collisions. Acknowledgments are used instead.

CSMA/CA

The cell operates on one frequency (called *channel*).

When a station is in basic mode and wants to transmit, it senses the channel. If it finds it idle for a period of time equal to Distributed Inter Frame Space (**DIFS**), it starts **broadcasting** its frame. While transmitting, the sender ignores collisions that it senses.

The value of DIFS is equal to twice the time needed for a signal to travel the length of the diameter of the cell.

The receiver must acknowledge the frame: when it determines that the frame was correctly received, it waits for a short period of time (SIFS) and **broadcasts** an **ACK** acknowledgment frame.

For those who like numbers

SIFS = 10μs.

Slot time = time to travel the diameter of a cell = 20 μs.

DIFS = SIFS + 2 $\times$Slot = 50 μs.

Collisions

A collision is assumed implicitly when the ACK does not come within *EIFS* (Extended Interval Frame Space) period of silence.

Random backoff is used, in a similar way as in CSMA/CD, the main difference being that the duration of a backoff can be any value between 0 and ContentionWindow which is a variable derived in exactly the same way as the maximum backoff in Ethernet.

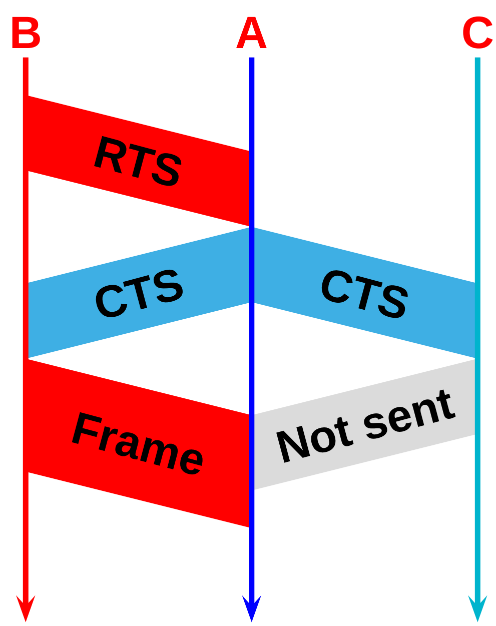
The backoff timer is decreased as long as the channel is idle for a DIFS. When the channel is busy, the timer is not decreased until silence is sensed.

When the timer equals 0, the node transmits a frame. If this frame collides, the value of *ContentionWindow* is doubled until a maximum value (the initial value of *ContentionWindow* is 1).

A reservation scheme is also available in CSMA/CA: a station can broadcast a short *Request To Send* frame. If it receives a confirmation from the receiver (a *Clear To Send* frame), it starts broadcasting the data frame.

The **RTS/CTS** exchange also happens to reduce collisions caused by the hidden terminal problem:

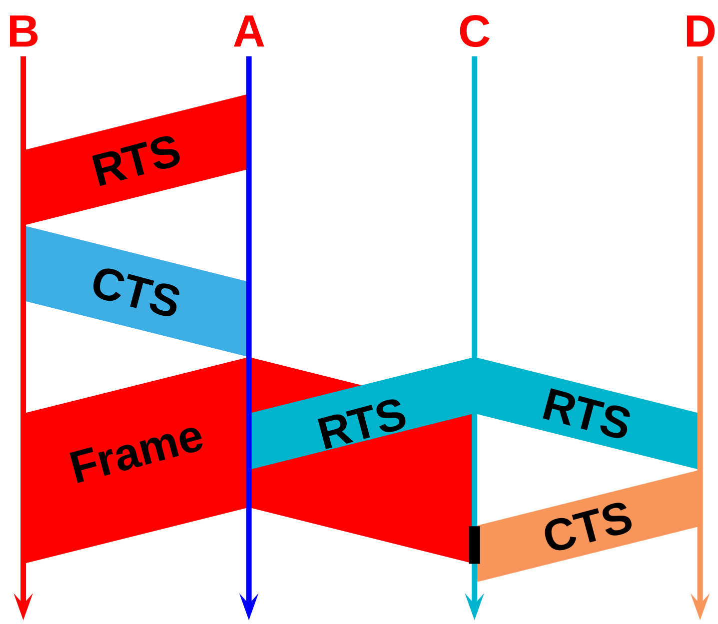
> If A hears both B and C, but B and C cannot hear each other, then a CTS response sent by A to B will be heard by C and will prevent C from transmitting.



The exposed terminal problem

The reservation exchange **RTS/CTS** creates a new problem: the case when the sudden appearance of a hidden terminal prevents a station from transmitting in a situation when the transmission would have been successful.

In this example, each station can hear its neighbours (in the diagram) and no other station.



There is a collision at C (▮).