Multiuser Radio Communications

by

Dr. Amitava Chatterjee
Electrical Measurement and Instrumentation Laboratory,
Electrical Engineering Department,
Jadavpur University, Kolkata, India.

Multiuser Communication Systems

Two important multiuser communication systems are:

- **satellite communications and**

- **wireless communications.**

Multiple-Access Techniques

- **A multiple-access technique permits the communication resources of the channel to be shared by a large number of users seeking to communicate with each other.**

Any difference between multiple-access and multiplexing ??

- **YES. Multiple access refers to the remote sharing of a communication channel such as a satellite or radio channel by users in highly dispersed locations. On the other hand, multiplexing refers to the sharing of a channel such as a telephone channel by users confined to a local site.**

- **Also, in a multiplexed system, user requirements are ordinarily fixed. In contrast, in a multiple-access system, user requirements can change dramatically with time. In that case provisions are necessary for dynamic channel allocation.**

Multiple-Access Techniques

Desirable feature …

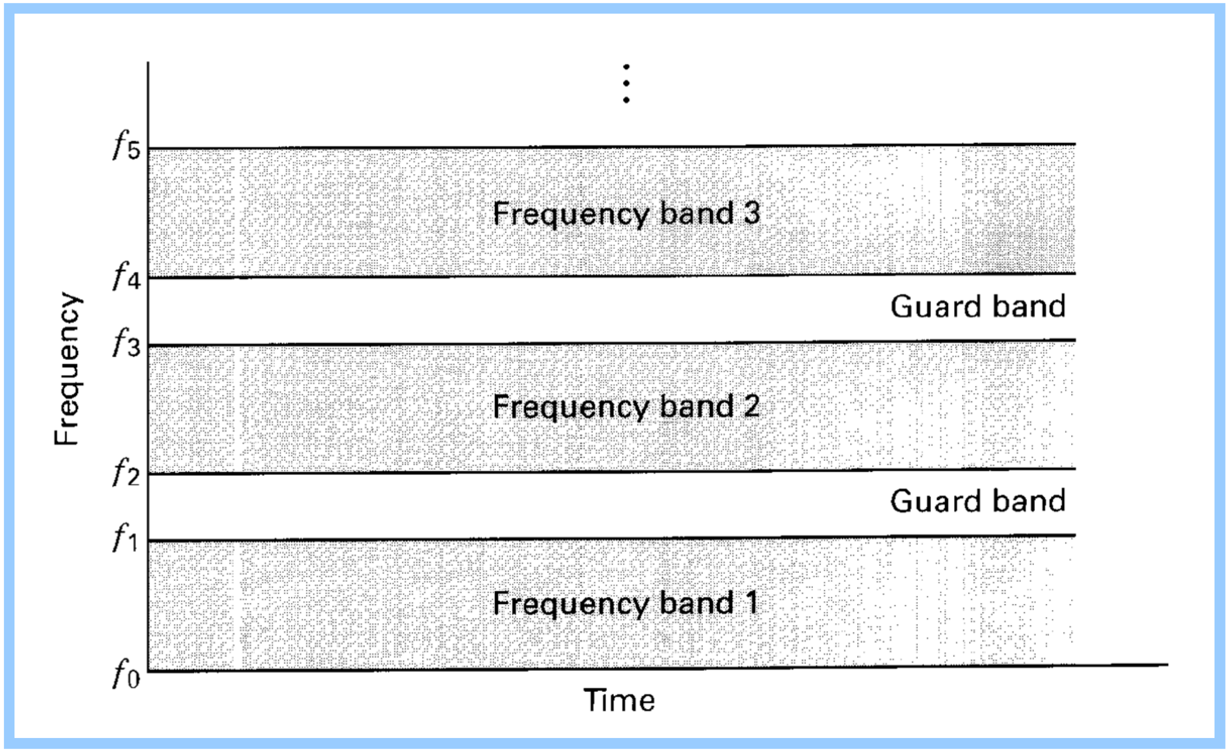
➢ **It is desirable that in a multiple-access system the sharing of resources of the channel be accomplished without causing serious interference between users of the system.**

Basic types of multiple access are:

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

Frequency Division Multiple Access (FDMA)

- **In this technique, disjoint subbands are allocated to the different users on a continuous-time basis.**

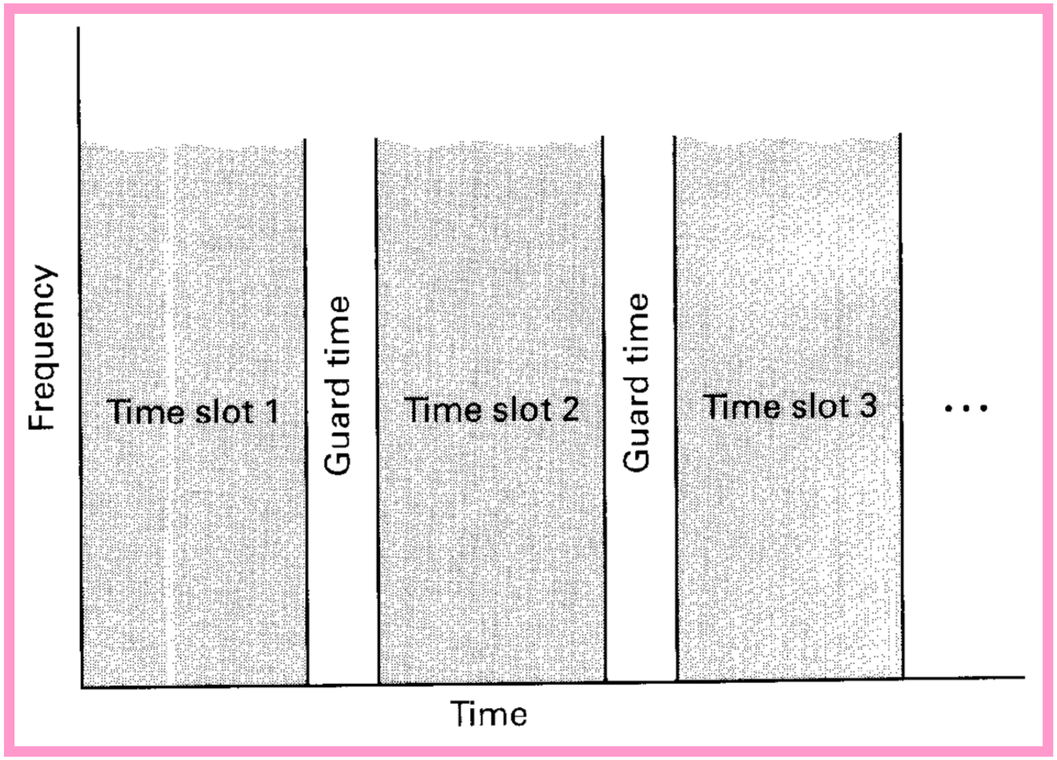


The FDMA Technique.

- ***Note:* The guard bands, used to act as buffer zones, are necessary because of the impossibility of achieving ideal filtering for separating the different users.**

Time Division Multiple Access (TDMA)

- **In this technique, each user is allocated the full spectral occupancy of the channel, but only for a short duration of time, called a time slot.**



The TDMA Technique.

- ***Note:* Here, the buffer zones, in form of guard times, are inserted between the assigned time slots to reduce interference between users by allowing for time uncertainty, arising due to system imperfections.**

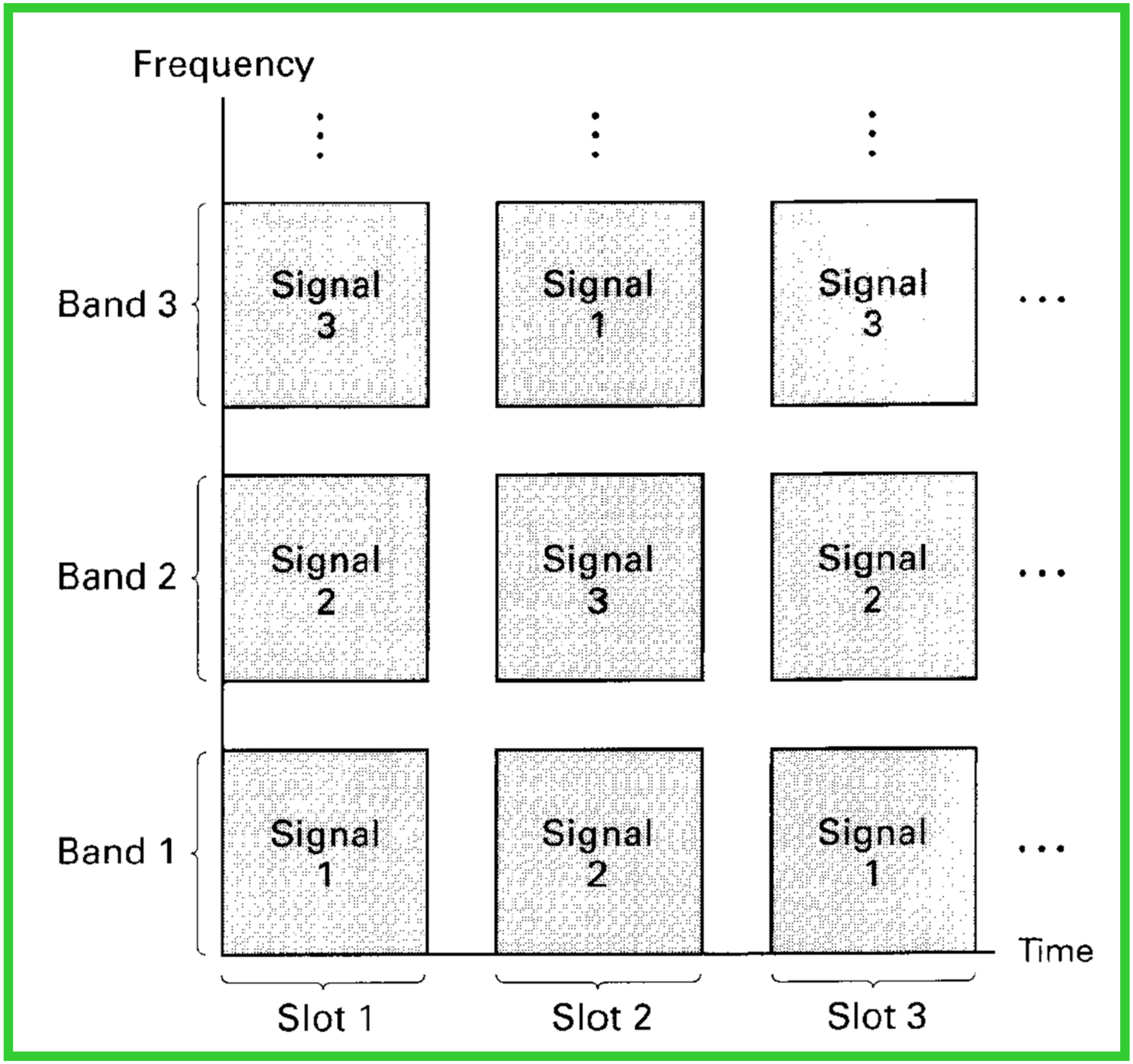
Code Division Multiple Access (CDMA)

- **CDMA is a hybrid combination of FDMA and TDMA. For example, frequency hopping may be employed to ensure that during each successive time slot, the frequency bands assigned to the users are reordered in an essentially random manner.**

- **CDMA is an application of spread spectrum techniques. An important advantage of CDMA over both FDMA and TDMA is that it can provide for secure communications.**

- **The frequency hopping mechanism can be implemented through the use of a pseudo-noise sequence.**

Code Division Multiple Access (CDMA)



The CDMA Technique.

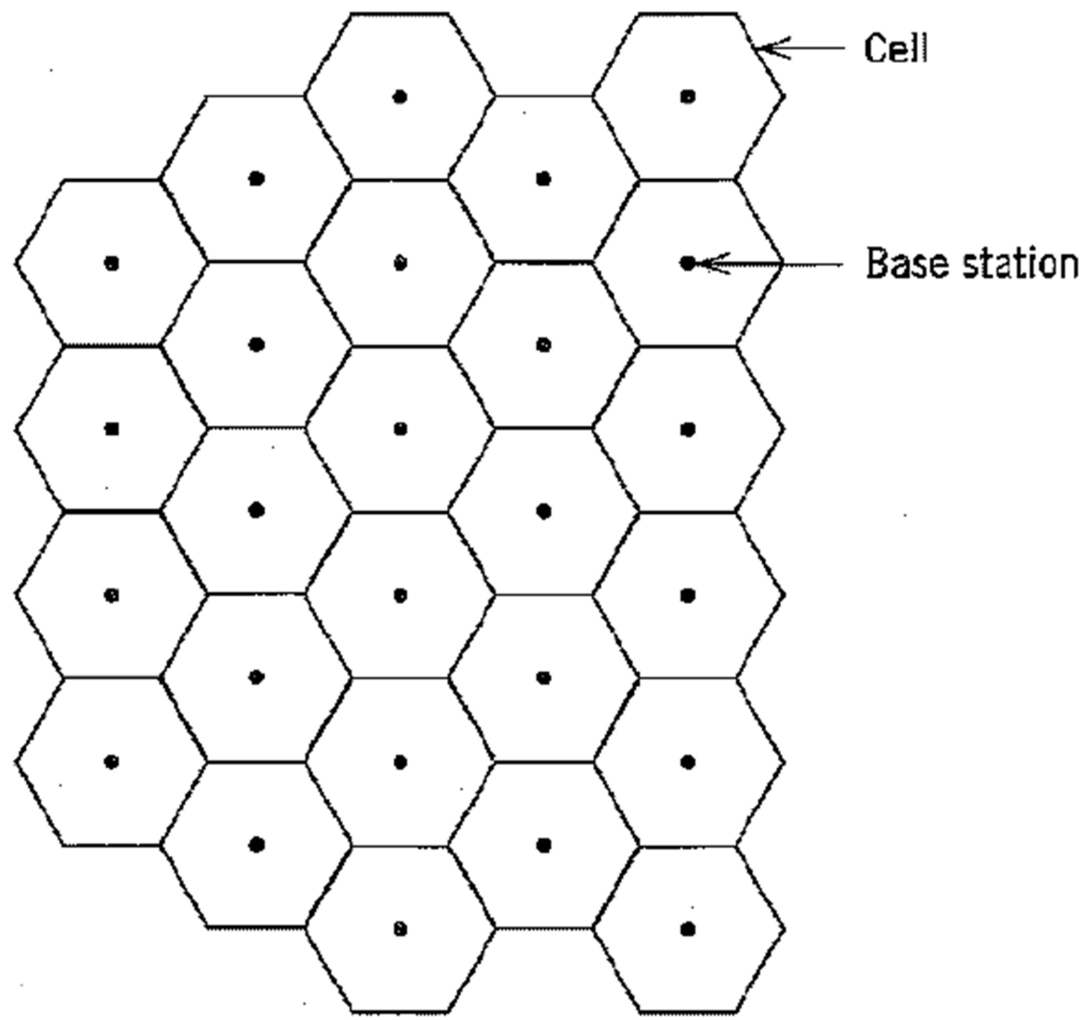
Wireless Communications

Wireless communication is another type of multiuser radio communication, which is synonymous with mobile radio.

Mobile radio refers to indoor or outdoor forms of wireless communications where a radio transmitter or receiver is capable of being moved, regardless of whether it actually moves or not.

Hence cellular radio has the inherent capability of building mobility into the telephone network. With such a capability, a user can move freely within a service area and simultaneously communicate with any telephone subscriber.

Wireless Communications



Idealized model of the cellular radio system.

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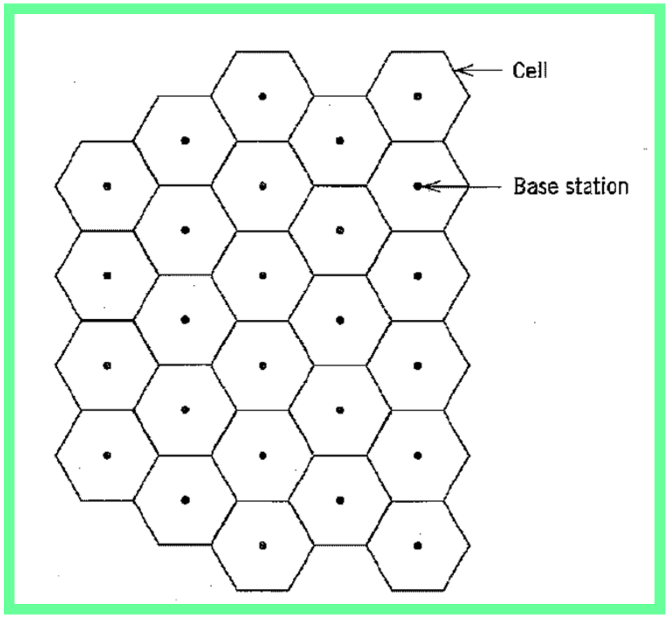

A base station is located at the center of each hexagonal cell. A typical cell has a radius of 1 to 12 miles.

A base station acts as an interface between mobile subscribers and cellular radio system. The base stations are themselves connected to a switching center by dedicated wirelines.

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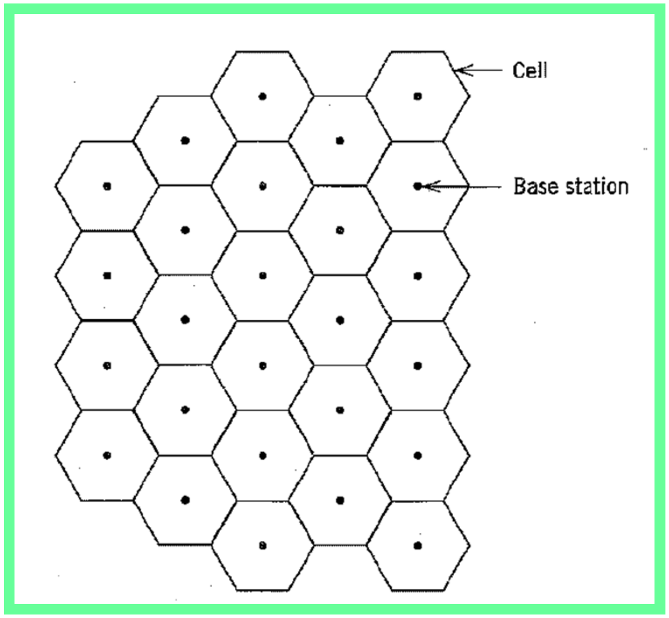
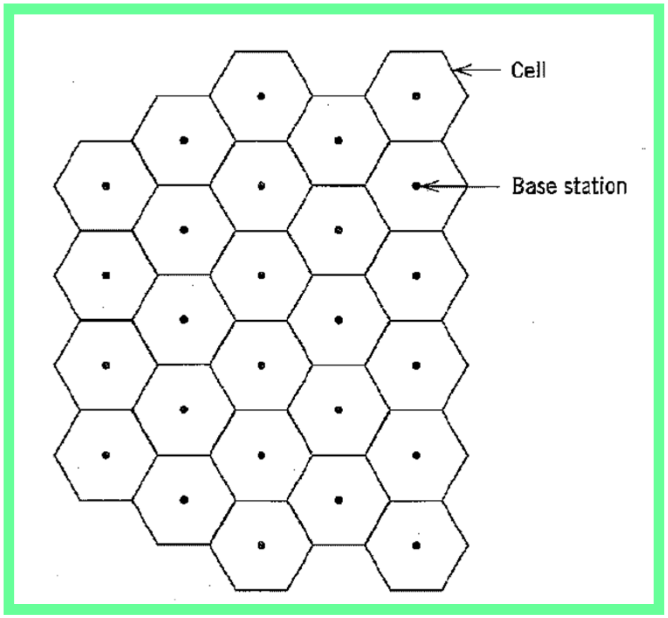


The mobile switching center has two important roles. First, it acts as the interface between the cellular radio system and the public switched telephone network. Second, it performs supervision and control of the mobile communications.

The mobile switching center performs a switching process, called handover or handoff, where a mobile subscriber is moved from one base station to another during a call in a transparent fashion, without interruption in service.

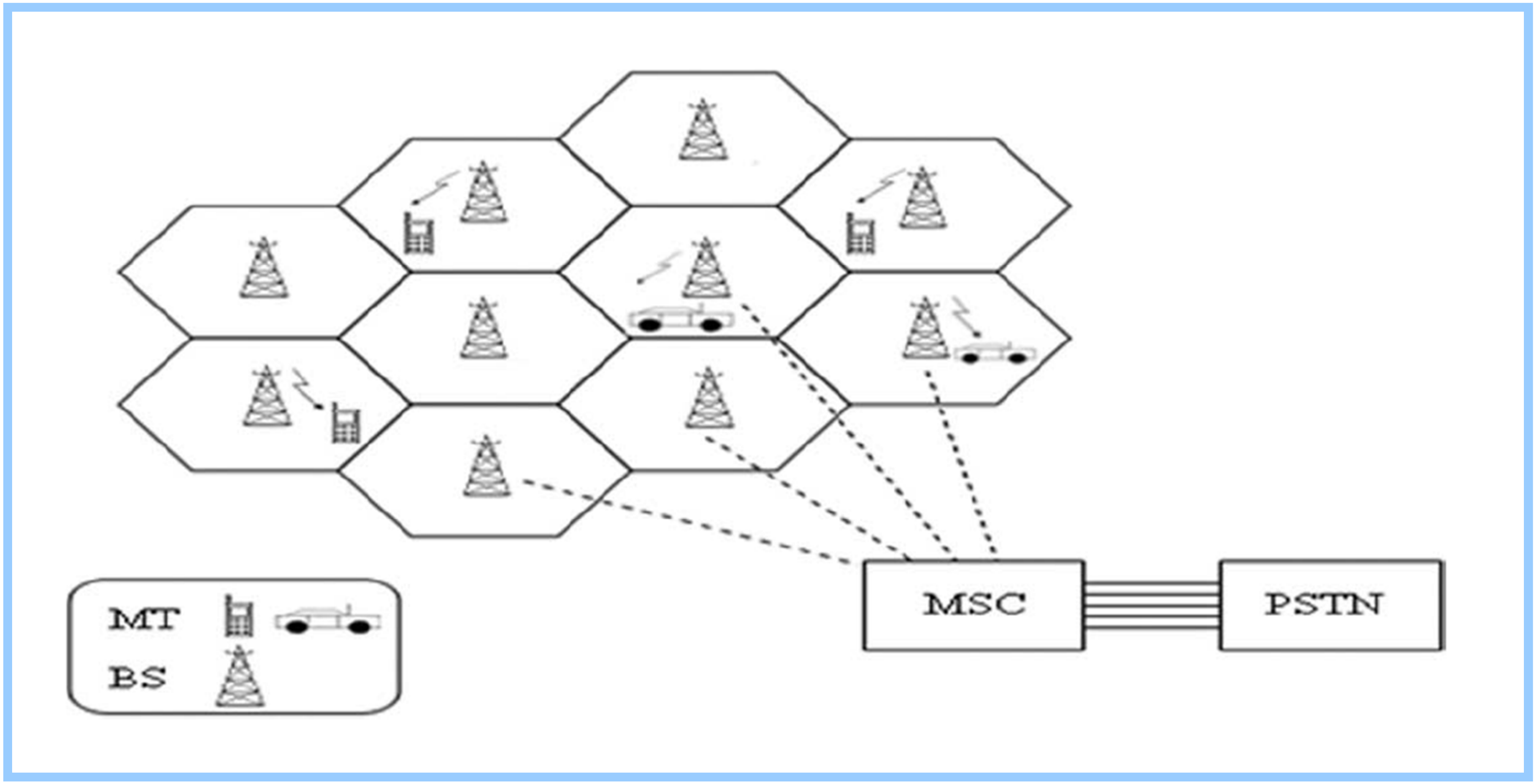
Wireless Communications



- **When considering geometric shapes which cover an entire region without overlap and with equal area, there are three candidate choices – square, equilateral triangle and hexagon. A cell must be designed to serve the weakest mobiles within the footprint (usually located at the edge of the cell).**

- **The hexagon is the best option because, for a given distance between the center of a polygon and its farthest perimeter points, the hexagon has the largest area of the three.**

Wireless Communications



MT: mobile terminal. **BS:** base station. **MSC:** mobile switching center. **PSTN:** public switched telephone network.

Wireless Communications

Handoff Strategies

- **During a call, the serving BS monitors the signal quality/strength (C/*I* ratio) from the mobile. If the signal quality/strength falls below a pre-designated threshold, the network requests the neighboring base stations to measure the signal quality from the mobile.**

- **If another BS indicates better signal quality/strength than the serving BS, a signaling message is sent to the mobile on the speech channel from the current BS requesting the mobile to retune to a free channel in the neighboring cell.**

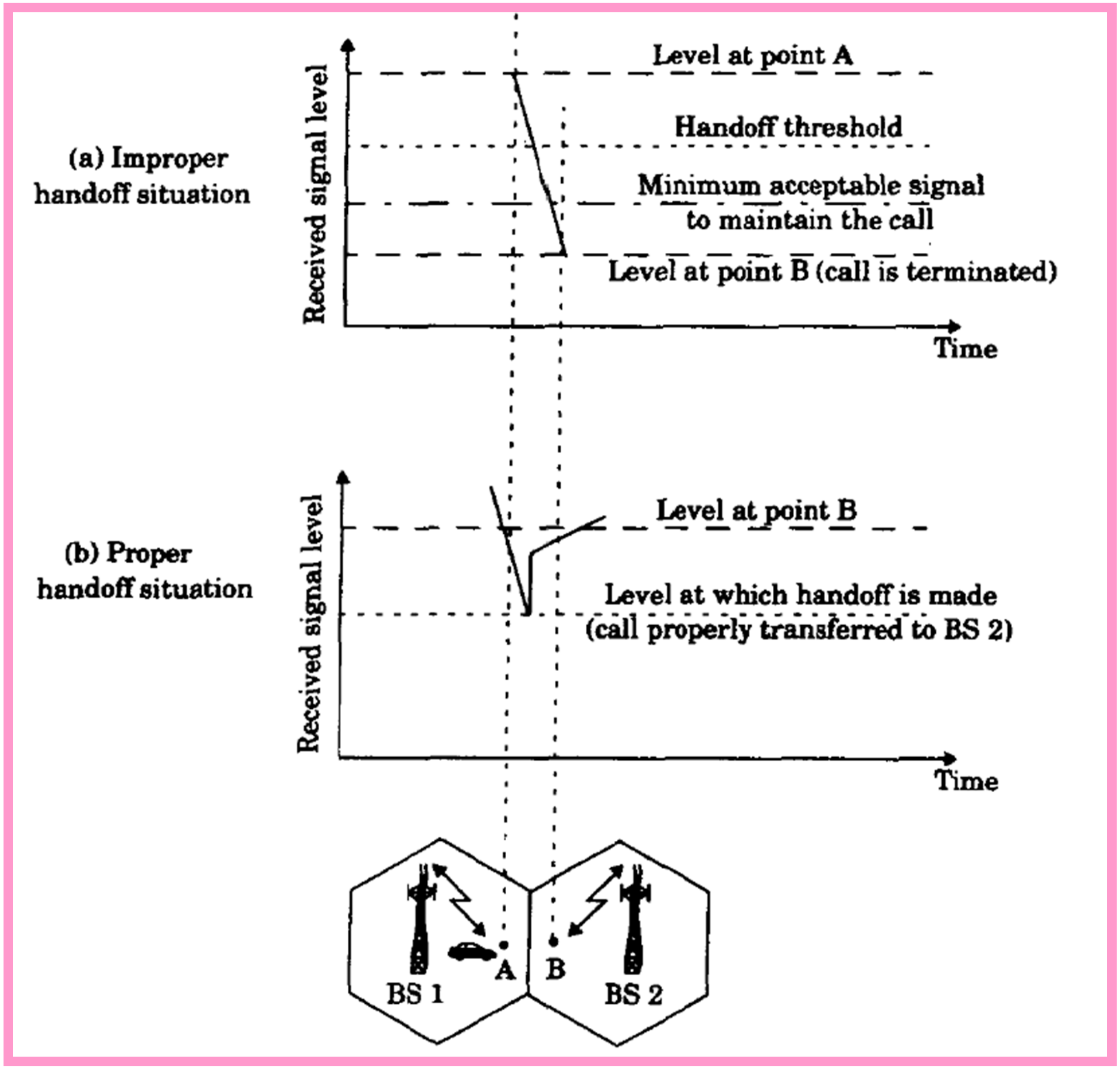
- **The mobile retunes to the new channel (in the new cell) and, simultaneously, the network switches the call to the new BS.**

- **Signal quality measurements and new cell selection generally take several seconds, but the change of speech channels (handoff) is essentially transparent to the user except for a very brief break in transmission in FDMA- or TDMA-based systems.**

Wireless Communications

Handoff Strategies

A handoff scenario at cell boundary.



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Handoff Strategies

- **Many handoff strategies prioritize handoff requests over call initiation requests when allocating unused channels in a cell site. The system designers must specify an optimum signal level at which to initiate a handoff.**

- **Once a particular signal level is specified as the minimum usable signal for acceptable voice quality at the base station receiver (normally taken as between –90 dBm and –100 dBm), a slightly stronger signal level is used as a threshold at which a handoff is made. This margin $\Delta = P_{r\ handoff} - P_{r\ minimum\ usable}$, cannot be too large or too small.**

- **Too large Δ means unnecessary handoffs which burden the MSC. Too small Δ means there may be insufficient time to complete a handoff before a call is lost due to weak signal conditions.**

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Handoff Strategies

- **In deciding when to handoff, it is important to ensure that the drop in the measured signal level is not due to momentary fading and that the mobile is actually moving away from the serving base station. For this the base station monitors the signal level for a certain period of time (using a running average measurement).**

- **The time over which a call may be maintained within a cell, without handoff, is called the dwell time.**

- **The second generation cellular systems use mobile assisted handoffs (MAHO). In MAHO, every MS measures the received power from surrounding BSs and continually reports the results of these measurements to the serving BS. A handoff is initiated when the power received from the BS of a neighboring cell begins to exceed the power received from the current BS by a certain level or for a certain period of time.**

- **The MAHO method enables the call to be handed over between base stations at a much faster rate than in first generation analog cellular systems.**

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Power Control

- **Generally the size of cells within a given cellular system may vary a lot (small radius within a city and big radius in rural areas). Hence it is not necessary for the mobile station to transmit at full power at all times to maintain satisfactory signal level at the BS.**

- **Most cellular standards therefore allow the BS to signal the mobile to operate at one of a series of transmit power levels, depending on the distance between the mobile and the BS antenna.**

- **The main reason for such a feature is to minimize co-channel interference and to conserve terminal battery power.**

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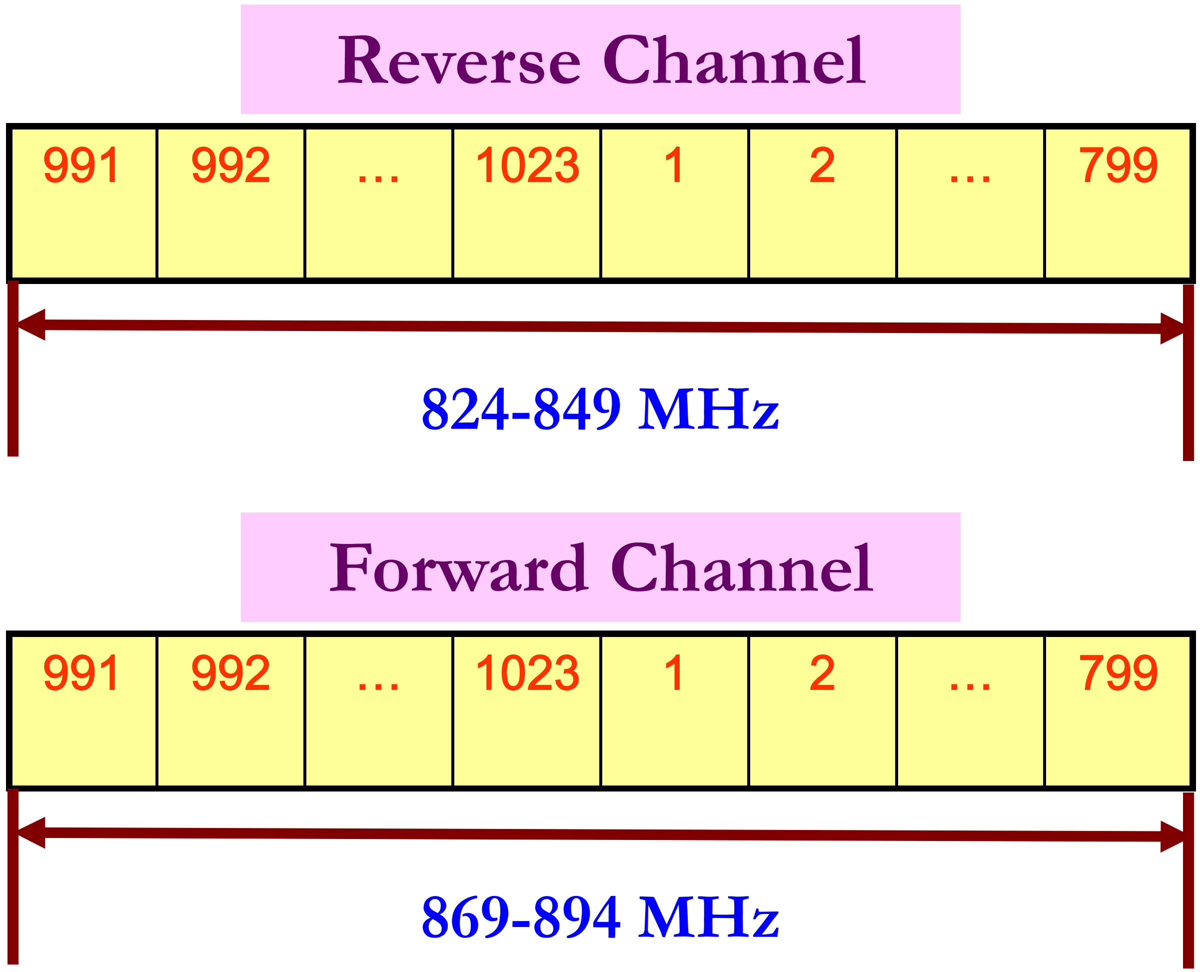

Frequency spectrum allocation for the U.S. cellular radio service.

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	Channel Number	Center Frequency (MHz)
Reverse Channel	$1 \leq N \leq 799$ $991 \leq N \leq 1023$	$0.030N + 825.0$ $0.030(N - 1023) + 825.0$
Forward Channel	$1 \leq N \leq 799$ $991 \leq N \leq 1023$	$0.030N + 870.0$ $0.030(N - 1023) + 870.0$

(Channels 800-990 are unused)

Frequency spectrum allocation for the U.S. cellular radio service.

Wireless Communications

Generations of Cellular Networks

- **First generation cellular networks:** Relied exclusively on FDMA/FDD (frequency division duplexing) and analog FM. First generation of analog mobile phone systems includes popular standards like AMPS, ETACS, and JTACS.

- **Second generation (2G) cellular networks:** Second generation standards use digital modulation formats and TDMA/FDD and CDMA/FDD multiple access techniques. The most popular 2G standards include three TDMA standards and one CDMA standard: (a) GSM, (b) IS-136 (also known as NADC or USDC), (c) PDC, and (d) IS-95.

- **Third generation (3G) cellular networks:** 3G systems can support multi-megabit Internet access, communications using Voice over Internet Protocol (VoIP), voice activated calls, huge network capacity etc. Popular 3G standards include 3G W-CDMA (UMTS), 3G cdma2000, and 3G TD-SCDMA.

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Major Cellular Mobile Radio Standards Around the World

Standard	Year of Introduction	Multiple Access	Frequency Band (MHz)	Modulation	Channel Bandwidth
AMPS	1983	FDMA	824-894	FM	30 kHz
NAMPS	1992	FDMA	824-894	FM	10 kHz
USDC	1991	TDMA	824-894	(π/4)-DQPSK	30 kHz
IS-95	1993	CDMA	824-894 1800-2000	QPSK/ BPSK	1.25 MHz
ETACS	1985	FDMA	900	FM	25 kHz
GSM	1990	TDMA	890-960	GMSK	200 kHz
JTACS	1988	FDMA	860-925	FM	25 kHz
PDC	1993	TDMA	810-1501	(π/4)-DQPSK	25 kHz

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There are two essential features in cellular concept:

- **Frequency reuse**. It refers to the use of radio channels on the same carrier frequency to cover different areas, which are physically separated from each other sufficiently to ensure that ***co-channel interference*** is not objectionable.

- **Cell splitting**. When the demand for service exceeds the number of channels allocated to a particular cell, cell splitting is used to handle the additional growth in traffic within the particular cell. The new cells, which have a smaller radius than the original cells, are called ***microcells***.

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Frequency Reuse

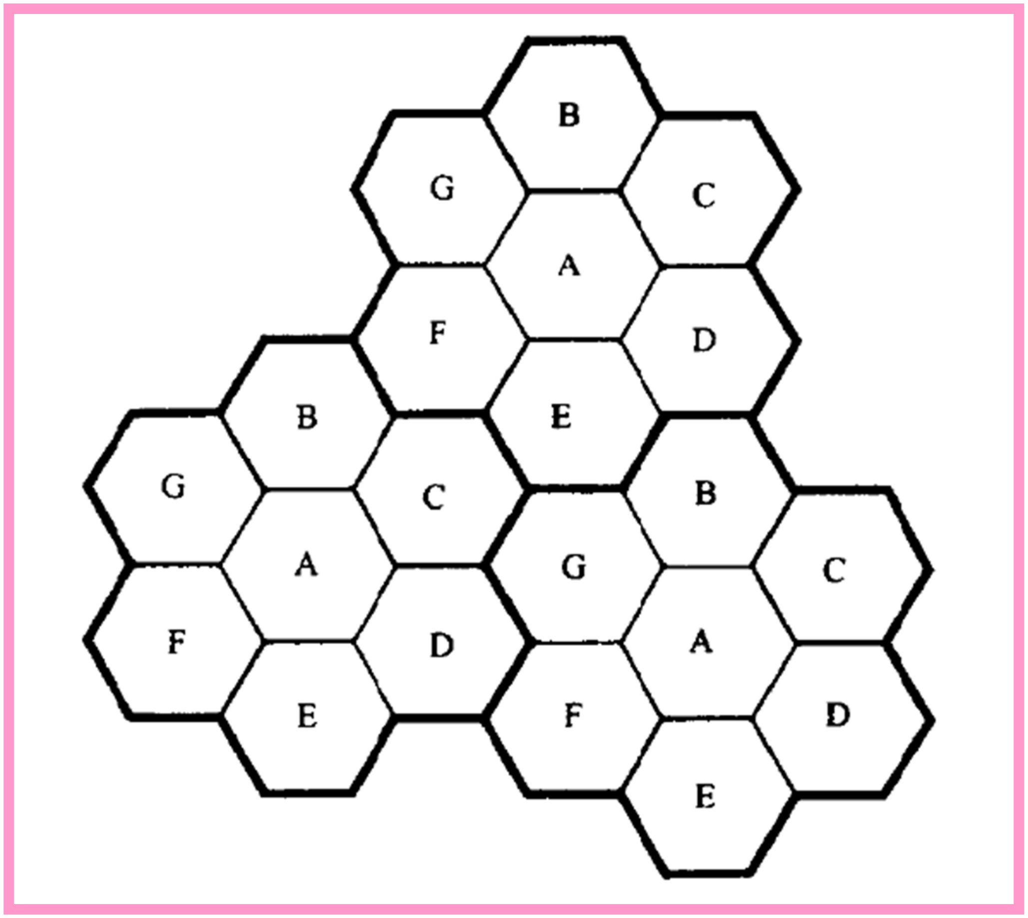

Illustration of the cellular frequency reuse concept (cells labeled with the same letter use the same group of channels or set of frequencies).

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Frequency Reuse

- **To understand the concept of frequency reuse, let S be the total duplex channels available for use, each cell be allocated a group of k channels ($k < S$), and S channels are divided among N cells into unique and disjoint channel groups where each have the same number of channels. Then: $S = kN$.**

- **The N cells which collectively use the complete set of available frequencies is called a *cluster*. If a cluster is replicated M times within the system, the total number of duplex channels, C (used as a measure of capacity), is: $C = MkN = MS$.**

- **If the cluster size N is reduced while the cell size is kept constant, more clusters are required to cover a given area and hence more capacity (a larger value of C) is achieved. A larger cluster size means weaker co-channel interference. A small cluster size indicates the co-channel cells are located much closer together.**

Wireless Communications

Frequency Reuse

- **From a design viewpoint, the smallest possible value of N is desirable in order to maximize capacity over a given coverage area (i.e. to maximize C).**

- **The frequency reuse factor of a cellular system is $(1/N)$ since each cell within a cluster is only assigned $(1/N)$ of the total available channels in the system.**

- **Because of the hexagonal geometry, each cell has exactly six equidistant neighbors and the lines joining the centers of any cell and each of its neighbors are separated by multiples of 60 degrees. Hence there are only certain cluster sizes and cell layouts that are practically possible. Hence the number of cells per cluster, N, can only have values that satisfy the relation: $N = i^2 + ij + j^2$ (i and j are non-negative integers).**

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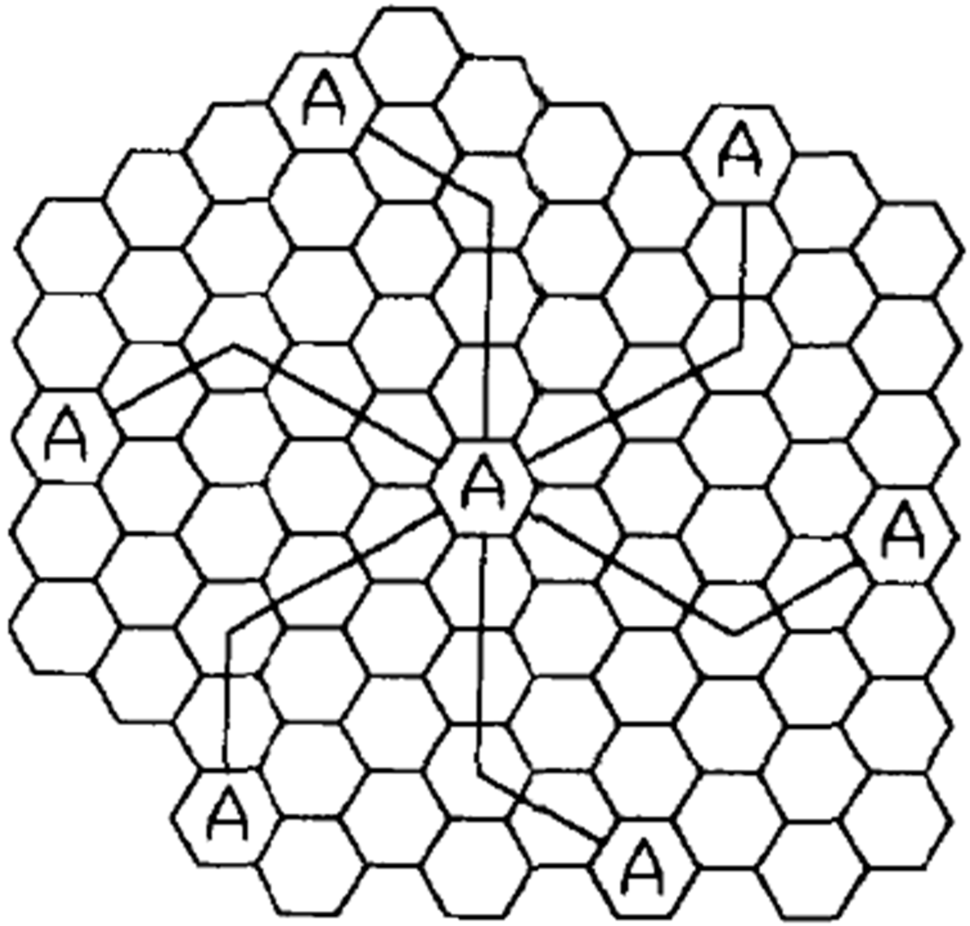
Frequency Reuse



Method of locating co-channel cells in a cellular system.
In this example $N = 19$ (with $i = 3$, $j = 2$).

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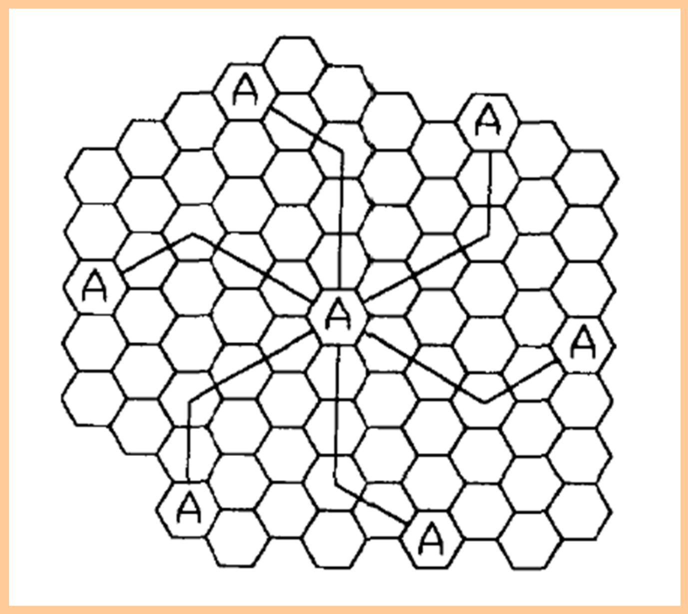
Frequency Reuse



Co-channel cells. Here $N = 19$ (with $i = 3$, $j = 2$).

To find the nearest co-channel neighbors of a particular cell, follow these two steps: 1) move *i* cells along any chain of hexagons and then 2) turn counterclockwise 60 degrees, and move *j* cells along the chain that lies on this new direction.

The *j*th cells so located and the reference cell constitute the set of co-channel cells.

This procedure is repeated for a different reference cell, until all the cells in the system are covered.

Wireless Communications

In North America, the band of radio frequencies assigned to the cellular system is 800-900 MHz. The sub band 824-849 MHz is used to receive signals from the mobile units, and the sub band 869-894 MHz is used to transmit signals to the mobile units.

In Europe and elsewhere, the base-mobile and mobile-base sub bands are reversed.

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Thank You …