MOTOROLA

Chapter 1

Principles of Cellular Telecommunications

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Objectives

On completion of this section the student will be able to:

- Name the main components of a cellular network and describe their functionality.
- Understand the options available for site configuration.

Principles of Cellular Telecommunications

Overview

A cellular telephone system links mobile station (MS) subscribers into the public telephone system or to another cellular system's MS subscriber.

Information sent between the MS subscriber and the cellular network uses radio communication. This removes the necessity for the fixed wiring used in a traditional telephone installation.

Due to this, the MS subscriber is able to move around and become fully mobile, perhaps travelling in a vehicle or on foot.

Advantages of Cellular Communications

Cellular networks have many advantages over the existing "land" telephone networks. There are advantages for the network provider as well as the mobile subscriber.

Overview

Advantages to Mobile Subscriber

- Mobility
- Flexibility
- Convenience

Advantages to Network Provider

- Network expansion flexibility
- Revenue/profit margins
- Efficiency
- Easier re-configuration

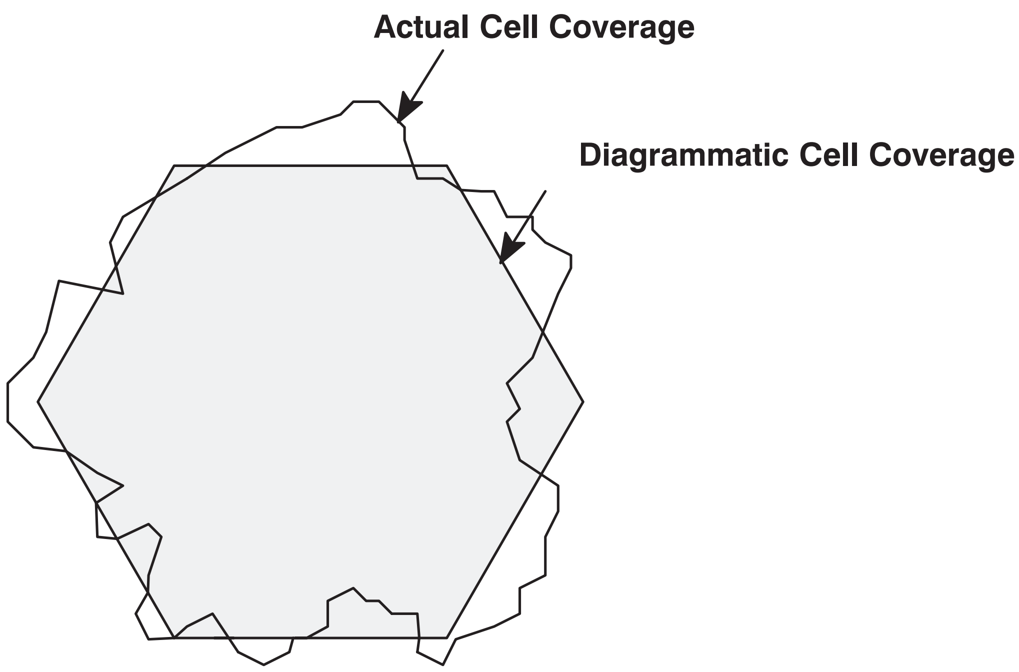
Network Components

GSM networks are made up of Mobile services Switching Centres (MSC), Base Station Systems (BSS)and Mobile Stations (MS). These three entities can be broken down further into smaller entities; such as, within the BSS we have Base Station Controllers, Base Transceiver Stations and Transcoders. These smaller network elements, as they are referred to, will be discussed later in the course. For now we will use the three major entities.

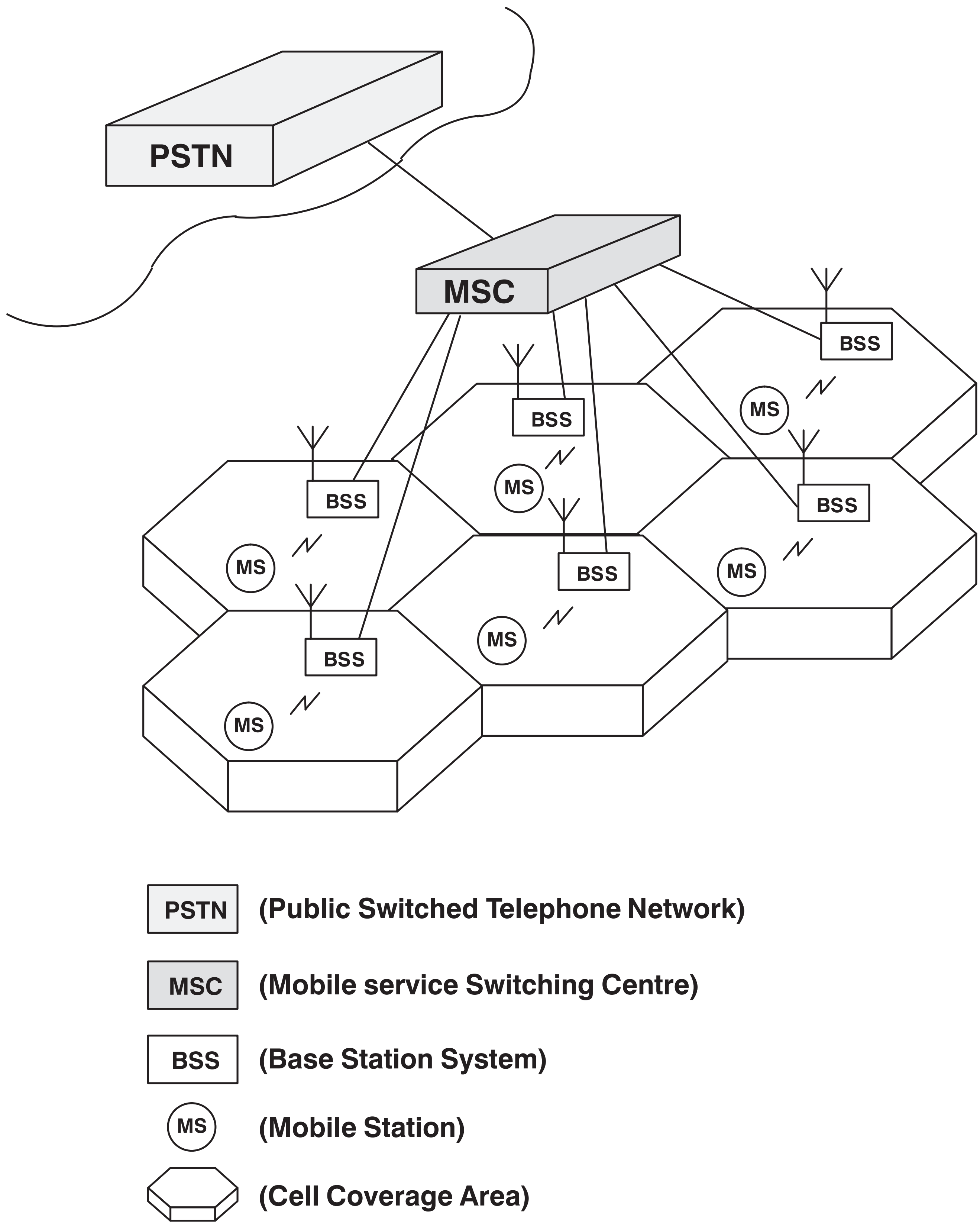
With the MSC, BSS and MS we can make calls, receive calls, perform billing etc, as any normal PSTN network would be able to do. The only problem for the MS is that all the calls made or received are from other MSs. Therefore, it is also necessary to connect the GSM network to the PSTN.

Mobile Stations within the cellular network are located in “cells”, these cells are provided by the BSSs. Each BSS can provide one or more cells, dependent on the manufacturers equipment.

The cells are normally drawn as hexagonal, but in practice they are irregularly shaped, this is as a result of the influence of the surrounding terrain, or of design by the network planners.



Network Components



Frequency Spectrum

Introduction

The frequency spectrum is very congested, with only narrow slots of bandwidth allocated for cellular communications. The list opposite shows the number of frequencies and spectrum allocated for GSM, Extended GSM 900 (EGSM), GSM 1800 (DCS1800) and PCS1900.

A single Absolute Radio Frequency Channel Number (ARFCN) or RF carrier is actually a pair of frequencies, one used in each direction (transmit and receive). This allows information to be passed in both directions. For GSM900 and EGSM900 the paired frequencies are separated by 45 MHz, for DCS1800 the separation is 95 MHz and for PCS1900 separation is 80 MHz.

For each cell in a GSM network at least one ARFCN must be allocated, and more may be allocated to provide greater capacity.

The RF carrier in GSM can support up to eight Time Division Multiple Access (TDMA) timeslots. That is, in theory, each RF carrier is capable of supporting up to eight simultaneous telephone calls, but as we will see later in this course although this is possible, network signalling and messaging may reduce the overall number from eight timeslots per RF carrier to six or seven timeslots per RF carrier, therefore reducing the number of mobiles that can be supported.

Unlike a PSTN network, where every telephone is linked to the land network by a pair of fixed wires, each MS only connects to the network over the radio interface when required. Therefore, it is possible for a single RF carrier to support many more mobile stations than its eight TDMA timeslots would lead us to believe. Using statistics, it has been found that a typical RF carrier can support up to 15, 20 or even 25 MSs. Obviously, not all of these MS subscribers could make a call at the same time, but it is also unlikely that all the MS subscribers would want to make a call at the same time. Therefore, without knowing it, MSs share the same physical resources, but at different times.

Frequency Range

GSM 900

- Receive (uplink) 890–915 MHz
- Transmit (downlink) 935–960 MHz
- 124 Absolute Radio Frequency Channels (ARFCN)

EGSM 900

- Receive (uplink) 880–915 MHz
- Transmit (downlink) 925–960 MHz
- 174 Absolute Radio Frequency Channels (ARFCN)

GSM 1800 (DCS1800)

- Receive (uplink) 1710–1785 MHz
- Transmit (downlink) 1805–1880 MHz
- 374 Absolute Radio Frequency Channels (ARFCN)

PCS 1900

- Receive (uplink) 1850–1910 MHz
- Transmit (downlink) 1930–1990 MHz
- 299 Absolute Radio Frequency Channels (ARFCN)

ARFCN

- Bandwidth = 200 KHz
- 8 TDMA timeslots

Cell Size

The number of cells in any geographic area is determined by the number of MS subscribers who will be operating in that area, and the geographic layout of the area (hills, lakes, buildings etc).

Large Cells

The maximum cell size for GSM is approximately 70 km in diameter, but this is dependent on the terrain the cell is covering and the power class of the MS. In GSM, the MS can be transmitting anything up to 8 Watts; obviously, the higher the power output of the MS the larger the cell size. If the cell site is on top of a hill, with no obstructions for miles, then the radio waves will travel much further than if the cell site was in the middle of a city, with many high-rise buildings blocking the path of the radio waves.

Generally large cells are employed in:

- Remote areas.
- Coastal regions.
- Areas with few subscribers.
- Large areas which need to be covered with the minimum number of cell sites.

Small Cells

Small cells are used where there is a requirement to support a large number of MSs, in a small geographic region, or where a low transmission power may be required to reduce the effects of interference. Small cells currently cover 200 m and upwards.

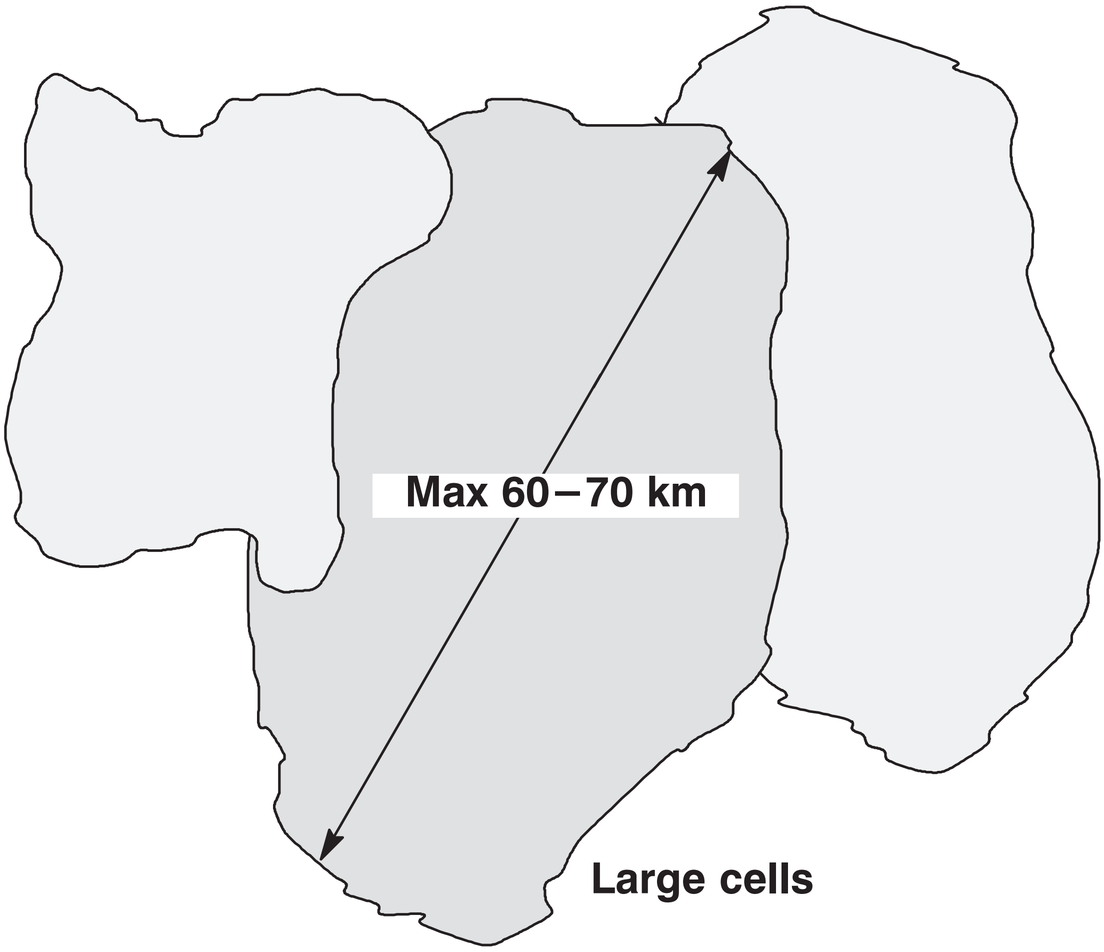
Typical uses of small cells:

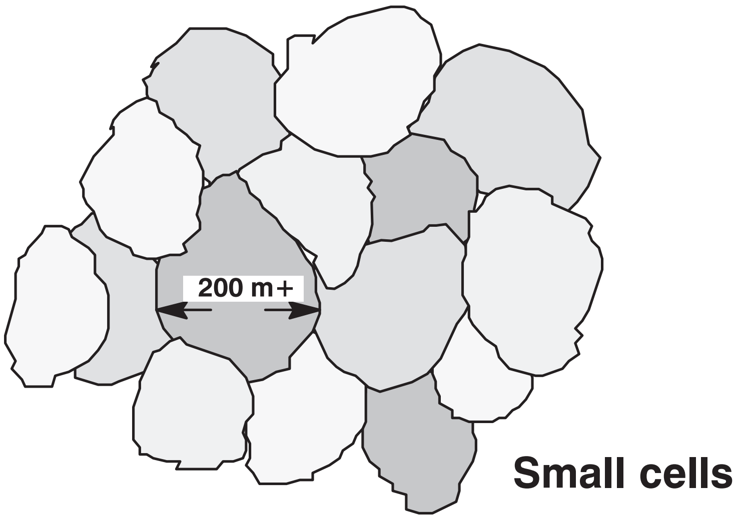
- Urban areas.
- Low transmission power required.
- High number of MSs.

The Trade Off – Large vs Small

There is no right answer when choosing the type of cell to use. Network providers would like to use large cells to reduce installation and maintenance cost, but realize that to provide a quality service to their customers, they have to consider many factors, such as terrain, transmission power required, number of MSs etc. This inevitably leads to a mixture of both large and small cells.

Cell Size





Frequency Re-use

Standard GSM has a total of 124 frequencies available for use in a network. Most network providers are unlikely to be able to use all of these frequencies and are generally allocated a small subset of the 124.

Example:

A network provider has been allocated 48 frequencies to provide coverage over a large area, let us take for example Great Britain.

As we have already seen, the maximum cell size is approximately 70 km in diameter, thus our 48 frequencies would not be able to cover the whole of Britain.

To overcome this limitation the network provider must re-use the same frequencies over and over again, in what is termed a "frequency re-use pattern".

When planning the frequency re-use pattern the network planner must take into account how often to use the same frequencies and determine how close together the cells are, otherwise co-channel and/or adjacent channel interference may occur. The network provider will also take into account the nature of the area to be covered. This may range from a densely populated city (high frequency re-use, small cells, high capacity) to a sparsely populated rural expanse (large omni cells, low re-use, low capacity).

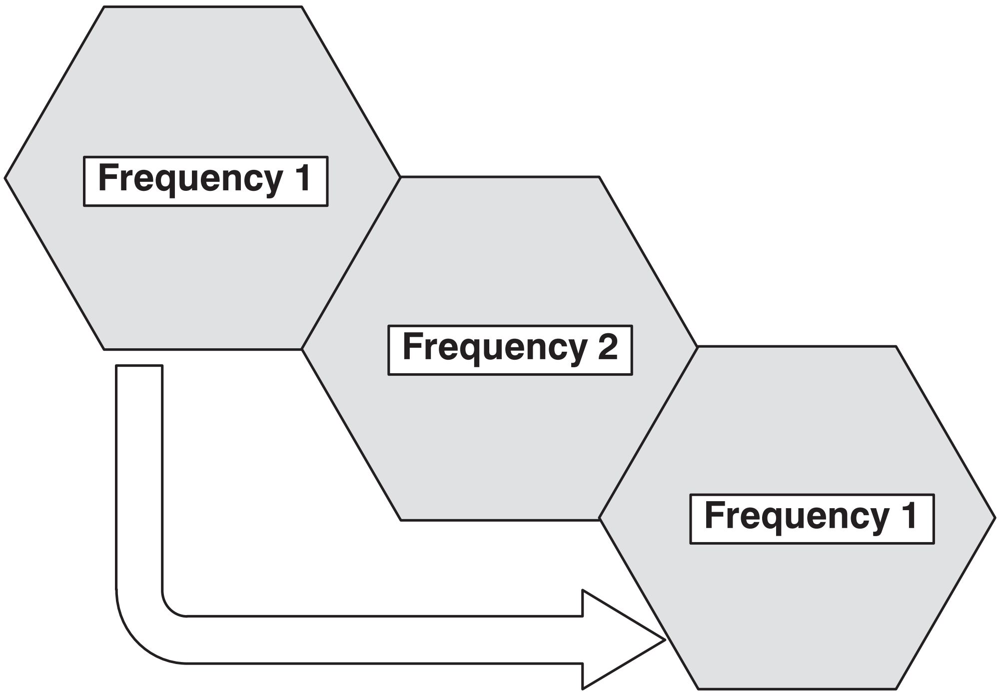
Co-channel Interference

This occurs when RF carriers of the same frequency are transmitting in close proximity to each other, the transmission from one RF carrier interferes with the other RF carrier.

Adjacent Channel Interference

This occurs when an RF source of a nearby frequency interferes with the RF carrier.

Frequency Re-use



Sectorization

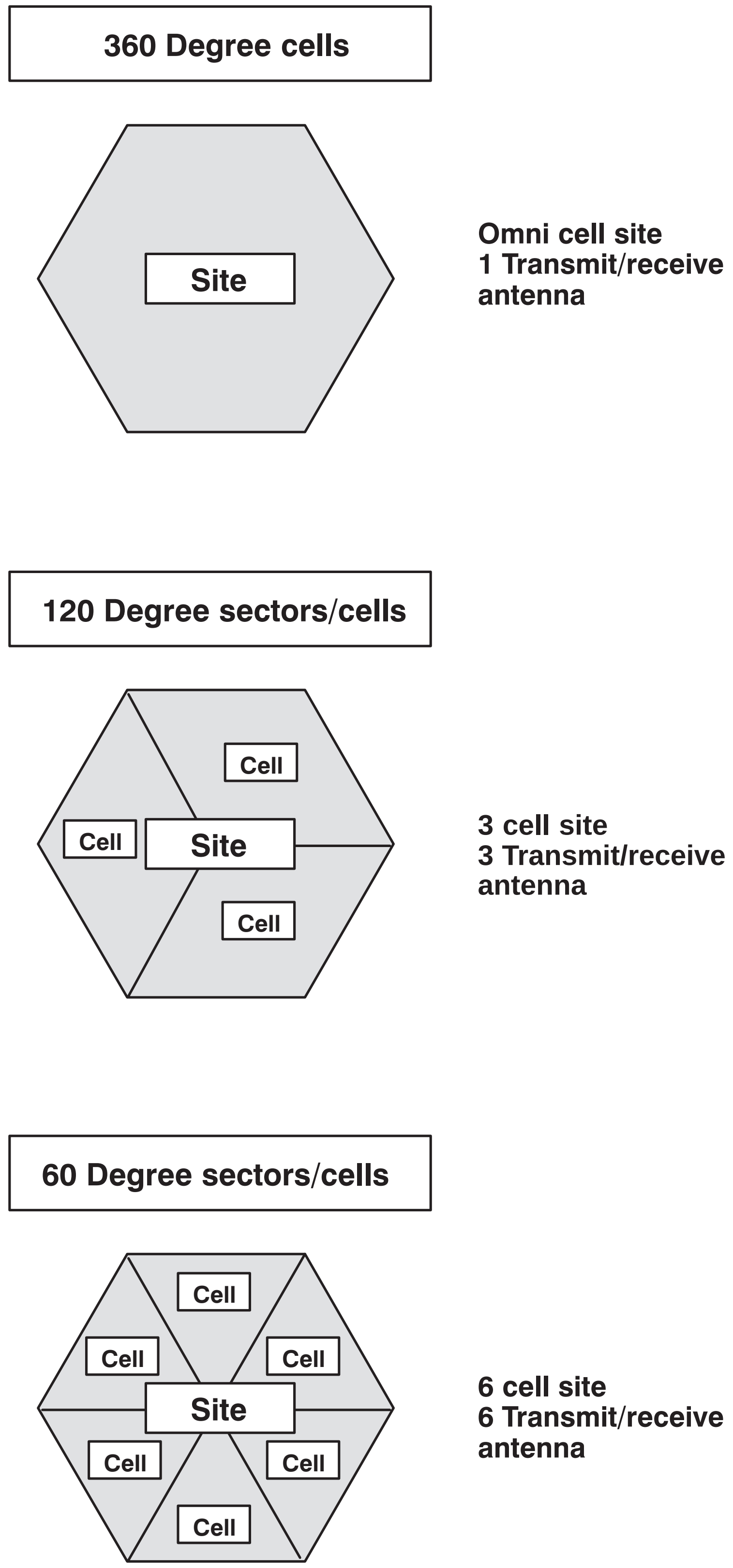
The cells we have looked at up to now are called omni-directional cells. That is each site has a single cell and that cell has a single transmit antenna which radiates the radio waves to 360 degrees.

The problem with employing omni-directional cells is that as the number of MSs increases in the same geographical region, we have to increase the number of cells to meet the demand. To do this, as we have seen, we have to decrease the size of the cell and fit more cells into this geographical area. Using omni-directional cells we can only go so far before we start introducing co-channel and adjacent channel interference, both of which degrade the cellular network's performance.

To gain a further increase in capacity within the geographic area we can employ a technique called "sectorization". Sectorization splits a single site into a number of cells, each cell has transmit and receive antennas and behaves as an independent cell.

Each cell uses special directional antennas to ensure that the radio propagation from one cell is concentrated in a particular direction. This has a number of advantages: firstly, as we are now concentrating all the energy from the cell in a smaller area 60, 120, 180 degrees instead of 360 degrees, we get a much stronger signal, which is beneficial in locations such as "in-building coverage". Secondly, we can now use the same frequencies in a much closer re-use pattern, thus allowing more cells in our geographic region which allows us to support more MSs.

Site Sectorization



Using Sectored Sites

The distribution of RF carriers, and the size of the cells, is selected to achieve a balance between avoiding co-channel interference by geographically separating cells using the same RF frequencies, and achieving a channel density sufficient to satisfy the anticipated demand.

The diagram opposite illustrates how, by sectoring a site we can fit more cells into the same geographical area, thus increasing the number of MS subscribers who can gain access and use the cellular network.

This sectorization of sites typically occurs in densely populated areas, or where a high demand of MSs is anticipated, such as conference centres/business premises.

4 Site/3 Cell

A typical re-use pattern used in GSM planning is the 4 site/3 cell.

For example, the network provider has 36 frequencies available, and wishes to use the 4 site/3 cell re-use pattern he may split the frequencies up as follows:

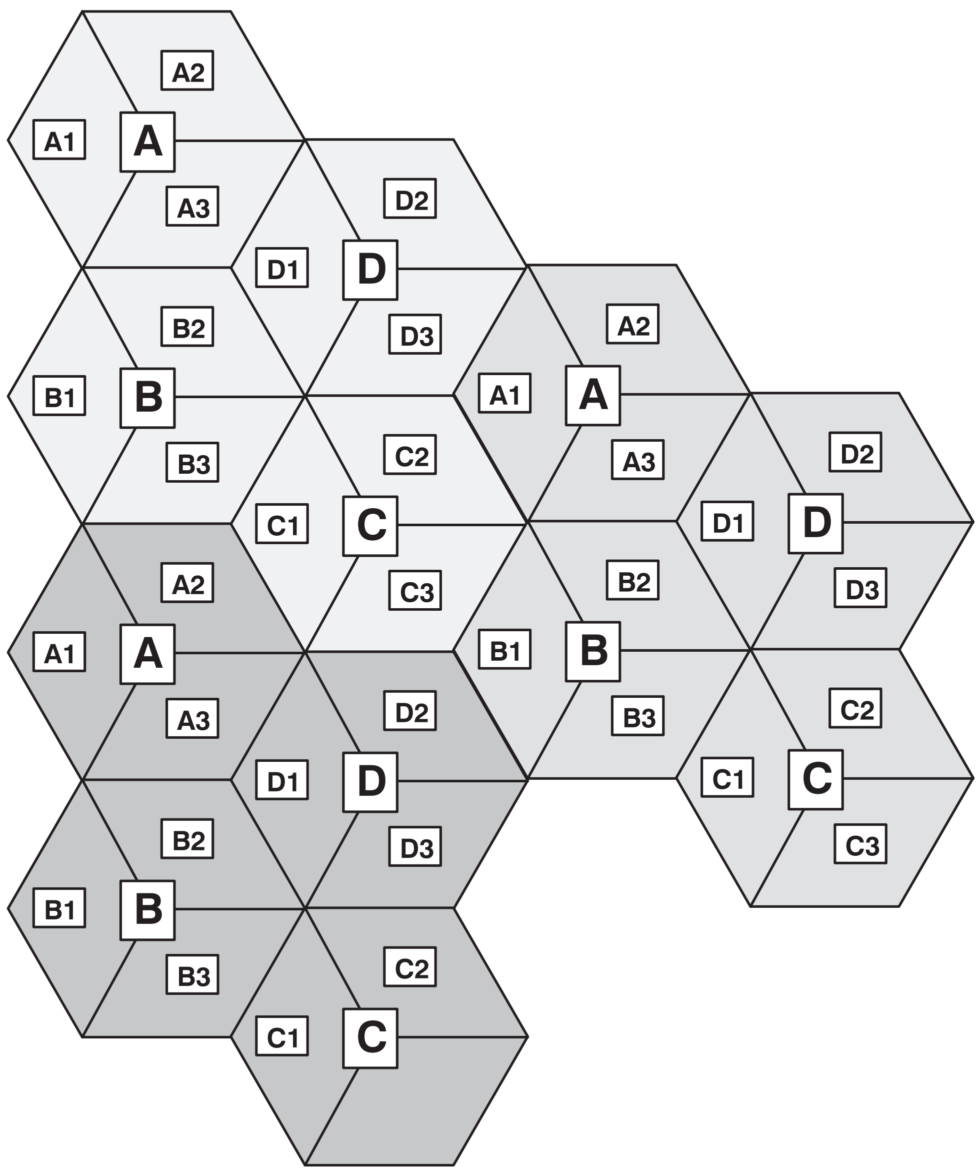
Cell A1	Cell A2	Cell A3	Cell B1	Cell B2	Cell B3	Cell C1	Cell C2	Cell C3	Cell D1	Cell D2	Cell D3
1	2	3	4	5	6	7	8	9	10	11	12
13	14	15	16	17	18	19	20	21	22	23	24
25	26	27	28	29	30	31	32	33	34	35	36

In this configuration each cell has a total of 3 carriers and each site has a total of 9 carriers. If the provider wished to reconfigure to a 3 site/3 cell then the result would be:

Cell A1	Cell A2	Cell A3	Cell B1	Cell B2	Cell B3	Cell C1	Cell C2	Cell C3
1	2	3	4	5	6	7	8	9
10	11	12	13	14	15	16	17	18
19	20	21	22	23	24	25	26	27
28	29	30	31	32	33	34	35	36

As can be seen from the table, each cell now has 4 carriers and each site has 12 carriers. This has the benefit of supporting more subscribers in the same geographic region, but problems could arise with co-channel and adjacent channel interference.

4 site/3 cell


A2
A1
A
A3
D2
D1
D
D3
B2
B1
B
B3
C2
C1
C
C3
A2
A1
A
A3
D2
D1
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D3
B2
B1
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B3
C2
C1
C
A2
A1
A
A3
D2
D1
D
D3
B2
B1
B
B3
C2
C1
C
C3

Switching and Control

Having established radio coverage through the use of cells, both omni-directional and directional (sectored sites), now consider what happens when the MS is in motion (as MSs tend to be).

At some point the MS will have to move from one cell’s coverage area to another cell’s coverage area. Handovers from one cell to another could be for a number of reasons (e.g. the signal strength of the “serving cell” is less than the signal strength of a “neighbour cell”, or the MS is suffering a quality problem in the serving cell) and by handing over to one of its neighbours this may stop the quality problem.

Regardless of the reason for a “handover” it has to be controlled by some entity, and in GSM that entity is the Mobile services Switching Centre (MSC).

To perform a handover, the network must know which neighbour cell to hand the MS over to. To ensure that we handover to the best possible candidate the MS performs measurements of its surrounding neighbour cells and reports its findings to the network. These are then analyzed together with the measurements that the network performs and a decision is made on a regular basis as to the need for a handover. If a handover is required then the relevant signal protocols are established and the handover is controlled by the MSC.

Handovers must be transparent to the MS subscriber. That is the subscriber should be unaware that a handover has occurred.

As we will see later in this course, handovers are just one of the functions of the MSC, many more are performed by the MSC and its associated entities (e.g. such as authentication of MS, ciphering control, location updating, gateway to PSTN).

Note:

Some networks may allow certain handovers to be performed at the BSS level. This would be dependent on the manufacturer’s equipment.

Switching and Control