1.1. INTRODUCTION

Cellular systems for mobile communications implement SDM. Each transmitter, typically called a base station, covers a certain area, a cell. Cell radii can vary from tens of meters in buildings, and hundreds of meters in cities, up to tens of kilometers in the countryside. The shape of cells are never perfect circles or hexagons (as shown in Figure), but depend on the environment (buildings, mountains, valleys etc.), on weather conditions, and sometimes even on system load. Typical systems using this approach are mobile telecommunication systems , where a mobile station within the cell around a base station communicates with this base station and vice versa.

Cellular system with three and seven cell clusters

Advantages of cellular systems with small cells are the following:

- ***Higher capacity:*** Implementing SDM allows frequency reuse. If one transmitter is far away from another, i.e., outside the interference range, it can reuse the same frequencies. As most mobile phone systems assign frequencies to certain users (or certain hopping patterns), this frequency is blocked for other users. But frequencies are a scarce resource and, the number of concurrent users per cell is very limited. Huge cells do not allow for more users. On the contrary, they are limited to less possible users per km2. This is also the reason for using very small cells in cities where many more people use mobile phones.

- ***Less transmission power:*** While power aspects are not a big problem for base stations, they are indeed problematic for mobile stations. A receiver far away from a base station would need much more transmit power than the current few Watts. But energy is a serious problem for mobile handheld devices.

- ***Local interference only:*** Having long distances between sender and receiver results in even more interference problems. With small cells, mobile stations and base stations only have to deal with 'local' interference.

- ***Robustness:*** Cellular systems are decentralized and so, more robust against the failure of single components. If one antenna fails, this only influences communication within a small area.

Small cells also have **some disadvantages**:

- **Infrastructure needed:** Cellular systems need a complex infrastructure to connect all base stations. This includes many antennas, switches for call forwarding, location registers to find a mobile station etc, which makes the whole system quite expensive

- **Handover needed:** The mobile station has to perform a handover when changing from one cell to another. Depending on the cell size and the speed of movement, this can happen quite often.

- **Frequency planning:** To avoid interference between transmitters using the same frequencies, frequencies have to be distributed carefully. On the one hand, interference should be avoided, on the other, only a limited number of frequencies is available.

To avoid interference, different transmitters within each other's interference range use FDM. If FDM is combined with TDM (see Figure), the hopping pattern has to be coordinated. The general goal is never to use the same frequency at the same time within the interference range (if CDM is not applied). Two possible models to create cell patterns with minimal interference are shown in Figure. Cells are combined in clusters – on the left side three cells form a cluster, on the right side seven cells form a cluster. All cells within a cluster use disjointed sets of frequencies. On the left side, one cell in the cluster uses set f1, another cell f2, and the third cell f3. In real-life transmission, the pattern will look somewhat different. The hexagonal pattern is chosen as a simple way of illustrating the model. This pattern also shows the repetition of the same frequency sets. The transmission power of a sender has to be limited to avoid interference with the next cell using the same frequencies.

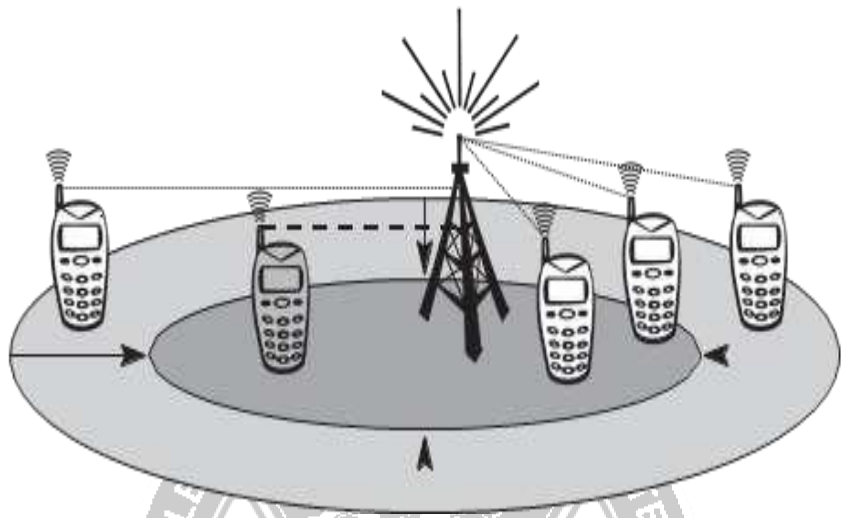
To reduce interference even further (and under certain traffic conditions, i.e., number of users per km2) sectorized antennas can be used. Figure shows the use of three sectors per cell in a cluster with three cells. Typically, it makes sense to use sectorized antennas instead of omni-directional antennas for larger cell radii.

The fixed assignment of frequencies to cell clusters and cells respectively, is not very efficient if traffic load varies. For instance, in the case of a heavy load in one cell and a light load in a neighboring cell, it could make sense to 'borrow' frequencies. Cells with more traffic are dynamically allotted more frequencies. This scheme is known as **borrowing channel allocation (BCA)**, while the first fixed scheme is called **fixed channel allocation (FCA)**. FCA is used in the GSM system as it is much simpler to use, but it requires careful traffic analysis before installation.

A **dynamic channel allocation (DCA)** scheme has been implemented in DECT .In this scheme, frequencies can only be borrowed, but it is also possible to freely assign frequencies to cells. With dynamic assignment of frequencies to cells, the danger of interference with cells using the same frequency exists. The 'borrowed' frequency can be blocked in the surrounding cells.

Cellular system with three cell clusters and three sectors per cell

Cellular systems using CDM instead of FDM do not need such elaborate channel allocation schemes and complex frequency planning. Here, users are separated through the code they use, not through the frequency. Cell planning faces another problem – the cell size depends on the current load. Accordingly, CDM cells are commonly said to 'breathe'. While a cell can cover a larger area under a light load, it shrinks if the load increases. The reason for this is the growing noise level if more users are in a cell. The higher the noise, the higher the path loss and the higher the trans- mission errors. Finally, mobile stations further away from the base station drop out of the cell. (This is similar to trying to talk to someone far away at a crowded party.) Figure illustrates this phenomenon with a user transmit- ting a high bit rate stream within a CDM cell. This additional user lets the cell shrink with the result that two users drop out of the cell. In a real-life scenario this additional user could request a video stream (high bit rate) while the others use standard voice communication (low bit rate).



Cell breathing depending on the current load