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Acronyms

3G 3^{rd} Generation of Mobile Communications.

3GPP 3^{rd} Generation Partnership Project.

4G 4^{th} Generation of Mobile Communications.

CA Carrier Aggregation.

CoMP Coordinated Multi Point.

HSPA+ High-Speed Packet Access Plus.

IMT-Advanced International Mobile Telecommunications-Advanced.

ITU-R International Telecommunication Union Radiocommunication Sector.

LTE Long Term Evolution.

LTE-A Long Term Evolution Advanced.

MIMO Multiple Input Multiple Output.

OFDM Orthogonal Frequency Division Multiplexing.

OFDMA Orthogonal Frequency Division Multiple Access.

RN Relay Node.

UFR Universal Frequency Reuse.

WCDMA Wide-band Code Division Multiple Access.

Chapter 1

Introduction

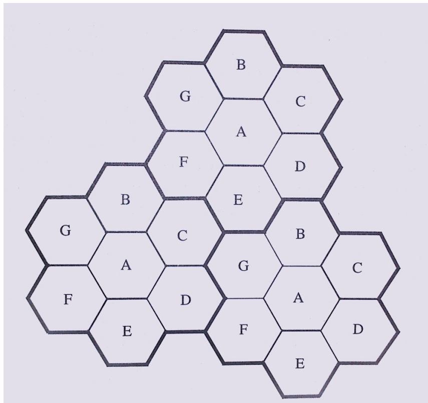
Every new generation of cellular network technologies comes with a new set of requirements, dictated by the trends in the use of the mobile connectivity. A common requirement to every single generation is their striving for higher data rates and greater power efficiency. This motivates research and techology innovation in order to achieve the goals set for each generation.

The research associated usually requires revisiting old paradigms used in previous generations, and updating them with novel ideas.

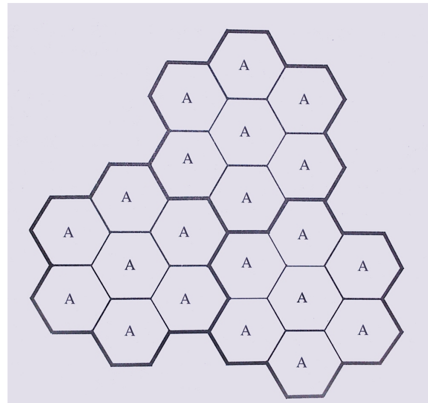
The *release 7* of the 3^{rd} Generation Partnership Project (3GPP) 3^{rd} Generation of Mobile Communications (3G) specifications [3GPP, 2007], also known as High-Speed Packet Access Plus (HSPA+), inluded the use of Multiple Input Multiple Output (MIMO) as a means to increase the rates of transmission.

Release 8, more well known by its commercial name Long Term Evolution (LTE) [3GPP, 2014a], introduced a new physical layer, based on Orthogonal Frequency Division Multiplexing (OFDM) instead of Wide-band Code Division Multiple Access (WCDMA) as in 3G. Although the rates attainable with WCDMA may be comparable to those obtained with OFDM, the latter provides a much easier equalization mechanism that makes dealing with multipath channels a simpler task. Apart from that OFDM provides a higher flexibility in the resource allocation and user and enables the use of Orthogonal Frequency Division Multiple Access (OFDMA).

LTE did not meet the requirements issued by the International Telecommunication Union Radiocommunication Sector (ITU-R) International Mobile Telecommunications-Advanced (IMT-Advanced) radio interface [ITU-R, 2014] for what is known as 4^{th} Generation of Mobile Communications (4G) though.



(a) Frequency reuse factor of 1/7.



(b) Frequency reuse factor of 1.

Figure 1.1: Different frequency planning options

The introduction of Long Term Evolution Advanced (LTE-A) in *release 10* of the LTE specification [3GPP, 2014b] met the requirements to be considered an IMT-Advanced system. The main novelties included in LTE-A are Carrier Aggregation (CA), enhanced use of MIMO techniques and support for Relay Node (RN).

Release 11 [3GPP, 2011] included in the specification the support for Coordinated Multi Point (CoMP) operation. CoMP was included in order to improve the network performance at cell edges, for it uses several transmitters to provide coordinated transmission in the downlink, and a number of receivers to provide coordinated reception in the uplink.

The CoMP operation considered in [3GPP, 2011] is just a part of a much broader field of multi-cell cooperation or coordinated communications where several cells are assumed to cooperate, in the sense that they take measures in order to alleviate to a certain degree the level of interference introduced into other parts of the network, or the use of that interference to their advantage.

In the search for higher spectral data rates and a more efficient use of the resources, Universal Frequency Reuse (UFR) arises as an alternative in order to make the most out of the scarce resource that the radio frequency spectrum is. The conventional approach for cellular networks was to perform a careful frequency planning in order to avoide the interference among neighboring cells. Clusters of N cells were grouped together, and assigned N frequency bands to be used, and the pattern is repeated for different clusters, yielding what is called a *frequency reuse factor* of $1/N$, as exemplified in Figure 1.1a.

The problem that this poses is that the available spectrum must be split, which is an inherent inefficiency in the use of the resources.

UFR, in turn, implies that neighboring cells share a common spectrum, as it can be seen in Figure 1.1b, which means that they would be interfering each other. Therefore, "A new look at the interference" [Gesbert et al., 2010] is needed.

In multi-cell cooperative communications, multiple cells are assumed to cooperate, in the sense that they take measures in order to alleviate to a certain degree the level of interference introduced into other parts of the network, or to use that interference to their advantage. The conventional concept of the interference as being an impairment shifts to a new point of view where the interference can be used to improve the overall performance of the network.

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