Chapter 1

Introduction

Future mobile communication systems are going to connect various intelligent terminals in the wireless world with fast and reliable radio networks [Ibr02]. Providing a high-speed Internet access and some other rich content services, a target peak rate of transmission will be as high as 100 Mbit/s for high mobility such as mobile access and 1 Gbit/s for low mobility such as nomadic or local wireless access [ITUR03]. Nevertheless, such a wireless system should have high flexibility and adaptivity to serve various applications with different transmission requirements. Comparing with the current second- and third-generations of mobile communications, the next system generation requires much more bandwidth and needs therefore a high computation power.

A transmission technique with high data rate applied in a multi-path radio channel environment shows a transfer function with large frequency selectivity. The resulting Inter-Symbol Interference (ISI) would require a complex equalizer technique at the receiver side, if a single-carrier transmission technique is applied. A multi-carrier transmission technique is proposed in this thesis, which is robust in multi-path propagation situations and leads to a simpler receiver structure by considering several narrow band subchannels processed in parallel. The Orthogonal Frequency Division Multiplexing (OFDM) transmission technique provides not only high spectrum efficiency, but also system flexibility and adaptivity. Different transmission parameters such as modulation and coding rate can be selected individually for each subcarrier. On the hardware side, the development of Digital Signal Processing (DSP) chips also promotes a practical large-scale application of the OFDM transmission technique.

With its above-mentioned characteristics, the OFDM digital transmission technique has been implemented already in several wireless applications today. It is integrated as the transmission technique in the IEEE Wireless Local Area Network (WLAN) standard. It is used in digitized radio broadcasting services, e. g. Digital Audio Broadcasting (DAB) and Digital Radio Mondiale (DRM), as well as for digital television such as Digital Video Broadcasting (DVB). It has been also adopted as the underlying technique for the next generation mobile cellular communication system Long Term Evolution (LTE).

Radio resource management is one of the most basic and important topics in the design of a wireless system. Given a minimum Quality of Service (QoS) and a limited available radio spectrum, the goal is to serve simultaneously many users inside a large coverage size. A scheme of radio resource management can be defined as a manager of resources, which can be frequency band, time slot, spreading code, or even beam of intelligent antennas in space. For example, a combination of Frequency/Time Division Multiple Access (FDMA/TDMA) is used in the second-generation (2G) mobile communication system like Global System for Mobile communications (GSM), and Code Division Multiple Access (CDMA) technique is used in third-generation (3G) networks such as Universal Mobile Telecommunications System (UMTS). The Spatial Division Multiple Access (SDMA) has been introduced as Multi-Input Multi-Output (MIMO) technique in High Speed Downlink Packet Access (HSDPA). All those schemes can be applied conveniently with the OFDM transmission technique.

By introducing the concept of resource reuse in a cellular structure, the network can have a theoretically unlimited coverage. In a cellular network, the dominant restriction element is the so-called Co-Channel Interference (CCI). A resource used exclusively by a single transmission can be reused by another transmission at the same time, as long as the communicator pairs, Base Station (BS) and Mobile Terminal (MT), are sufficiently far away from each other. Based on the flexibility of resource allocation in a cellular network, two different methods can be categorized: Fixed Resource Allocation (FRA) and Dynamic Resource Allocation (DRA). Those two terms are extended respectively from Fixed Channel Allocation (FCA) and Dynamic Channel Allocation (DCA) for conventional FDMA based systems like GSM. The concept of frequency channel is replaced by radio resource in OFDM based systems.

In FRA, all resources are grouped and preassigned to each cell. The assignment operation is done periodically and globally, based on a long-term prediction of service situation in future. Between two planning stages, a resource has a "fixed" relationship with cells, which is selected to ensure any communication inside those cells being robust against CCI. To keep up with new situations, the GSM networks in Europe were redesigned nearly every month during its high-growth phases. A detailed description of the network planning stages in the nowadays 3G mobile system UMTS is presented in [Hol02].

When the resource usage is more serious than predicted, for example during a two-hour sport match in a stadium, it is unworthy of reconfiguring the complete network. Several alternative strategies have been proposed to improve the short-term performance in such cases. Two often-used methods are resource borrowing and directed retry. The former enables a cell to borrow idle resources from the neighbors. In the latter, a request blocked by one cell will be forwarded to an adjacent cell, which is equivalent to a directed handoff.

In contrast when the DRA is applied, all available resources are pooled together and shared by all cells in a network. Radio resources are chosen by a predefined criterion and are allocated during the establishment of each new connection. When the call is terminated, its allocated radio resources will be released and can be used again by another connection.

Independent of the resulting overhead, the DRA scheme has the potential to increase significantly bandwidth efficiency. DRA algorithms can be further classified into three categories: centralized, distributed, and self-organized. In a centralized DRA, the allocation is processed at a Central Controller (CC), based on all information about the resource allocations collected from all nearby cells. By contrast in a distributed DRA, a CC is not needed for allocation. Each BS broadcasts its allocation results to the others. Based on that information, a BS makes its own decision independently on new allocations.

Self-Organized Radio Resource Management (SO-RRM) is a measurement based DRA scheme. Any BS does not send to or receive information about allocation status from other BSs. The BS and the MT makes decision of resource allocation based on their own knowledge from the measurement about the surrounding environment and the status of resource usage. In comparison with the centralized resource allocation scheme, such a scheme has several advantages. Delays due to the information exchange between BSs and CCs are eliminated. Moreover, the computation complexity due to seeking a global allocation solution at CCs can be greatly reduced. The construction and operation costs of those CCs are saved as well. Comparing with other distributed DRA algorithms based on channel usage in nearby cells, a self-organized algorithm saves the cost in information exchange between BSs, especially in situation of heavy traffic.

An OFDM based cellular mobile communication system is investigated and will be presented in detail in this thesis, applied with a self-organized resource allocation procedure. In this case, each BS allocates independently radio resources to its MT based on the current network condition. Resources with low interference will be selected for each connection. The necessary interference information is obtained from network sensing, which is done continuously in advance at both BS and MT sides. The orthogonality between subcarriers in the OFDM transmission technique enables also adaptive transmission in individual channels. Providing an identical quality of service, more data packets can be transmitted in a radio channel with a high Signal-to-Interference-and-Noise Ratio (SINR). The efficiency of radio resources is thus improved. The power of signals in transmission is estimated by a dedicated test signal, as ensures an interference free measurement environment.

In SO-RRM, a new allocation implies unexpected additional CCIs to all transmissions, which exist already in any related resources. This may cause in some cases a dropping of connection due to the insufficient transmission rate. Two solutions against that phenomenon are proposed in this thesis, one active and the other passive. The active policy reserves an additional margin to the estimated SINR in the resource allocation procedure. It works as the tolerance room for new interferences after allocation. The passive one triggers a channel reallocation process when a degradation of transmission quality is observed. Resources will be reselected according to the updated network condition.

One typical advantage of the self-organized allocation procedure comparing with static allocation is shown in the situation with non-uniform user distributions. SO-RRM supports natively free shift of radio resources on demand among the whole network. Therefore, it is self-adaptive to any distribution of mobile users or traffic demands, and is able to react seamlessly to any change of them.

When FDMA is applied, the independent channel fluctuation in subcarriers between different users brings the multi-user diversity. A proper rearrangement of resources between users can in this case improve the system performance, when the channel estimation is valid for relatively long time duration.

All above topics are discussed in this thesis.