CHAPTER 7

SUMMARY AND CONCLUSIONS

7.1 GENERAL

An attempt has been made in the present work to improve the capacity of the MCCDMA-MIMO system through power control using game theory. The subcarrier group assignment strategy in the MCCDMA-MIMO system improves further capacity performance by distributing users across the eligible subcarrier groups. The summary, salient conclusions and scope for further research work are presented in this chapter.

7.2 SUMMARY

The increasing number of users and the requirement for multimedia services with high quality has resulted in the emergence of successive generations of cellular systems from the first-generation (1G) to the fourth generation (4G). But this has certain unresolved problems affecting the quality and inability to increase the capacity beyond certain limits. This led the researchers to look for better schemes and application of many techniques either singly or in combinations. In this direction many developments have occurred. Multi-carrier techniques of various types have been investigated to cope with the high data rate transmission. OFDM and CDMA techniques are being used with assortment of limitations. This led to the development of MCCDMA systems, simultaneously exploiting the MIMO diversity scheme in MCCDMA system increases enormous throughput capacity without increasing the transmission bandwidth. Nonetheless when used in multi-path scenario; fading, shadowing and delay spread leads to ISI, multi-cell and co-channel interference. Diminishing the multi-cell interference not only improves the capacity
of the system but also increases the performance of the system. The power control and sub carrier grouping has been considered as solution of interference mitigation problem in MCCDMA-MIMO system.

The Game theory is an effective tool used to allocate the power for each user with independent knowledge of actual channel realization and gives solution for overall capacity maximization problem. In the power control game, each user seeks to choose its transmitting power over each carrier to maximize its capacity. The water-filling rule in game theoretic perspective is a tool used to allocate proper power for every user in order to improve system capacity performance with global constraint and imperfect CSI. In this research work, an attempt has been made to allocate power among the sub carriers of individual user using water filling game theory. Interference based sub carrier grouping and adaptive modulation at the physical layer is further considered for additional improvements of capacity in MCCDMA-MIMO system.

7.3 CONCLUSIONS

7.3.1 Power Control for MCCDMA-MIMO using Water Filling Game Theory

The power distribution to each user using IWFA is modeled based on the SINR value as an objective function, which is received from receiver. The further improvements of capacity and outage probability in MCCDMA are achieved by exploiting MIMO diversity of size $2 \times 2$ and $4 \times 4$.

- The mean capacity improvements and reduction of outage probability in MCCDMA-MIMO system using IWFA are analysed with various power constraint (Power budget levels $P_t = 0.5, 0.75$ and $1$). The MCCDMA-MIMO system with water filling game theory has a greater mean capacity as compared to the system without water filling game.
It can be seen from the result that MCCDMA-MIMO system provides higher channel capacity when water filling game is used in power allocation scheme. As the antenna diversity increases, both the capacities of MCCDMA-MIMO system with and without IWFA increases; however, the percentage of capacity improvements due to IWFA is nearly 15% for the entire range of SINR.

From the result, it is manifested that the increasing of power budget level induces the capacity improvements for both with and without IWFA. However, MCCDMA with SISO attained 15% of capacity improvements through IWFA. Incorporation of 2x2 and 4x4 MIMO diversity scheme in MCCDMA technique further enhanced the capacity by 21% and 27% respectively through IWFA.

7.3.2 Subcarrier Grouping and Power Control in MCCDMA-MIMO System

The capacity enhancement and outage probability reduction in MCCDMA-MIMO is achieved by IWFA based power control and subcarrier grouping assignment method. This module demonstrated that the interference based subcarrier grouping assignment strategy with power control through IWFA enhance the capacity and outage probability of the system by restricting interference noise. The further improvements of capacity and outage probability in MCCDMA are achieved by exploiting MIMO diversity of size 2×2 and 4×4.

From the result, it is observed that there is no capacity improvement for the system with and without IWFA in the lower range of SINR (eg. till 15dB for SISO, 6dB for 2x2 and 0dB for 4×4). However, the capacity improvement exponentially rises after these SINR values. This is due to the code limitations, where the number of users per group is limited to the spreading factor and there is no flexibility between the available groups and users demand at lower SINRs. The percentage of capacity improvements
is 32% for MCCDMA-SISO and 39%, 48% for 2x2 and 4×4 MIMO diversity scheme respectively.

- The performances of BER reduction of the system is due to the proper power allocation to all users by IWFA and the sub carrier group assignment according to the QoS requirements. The algorithm limits the interference noise among all users by avoiding excess power to any particular user that selfishly maximize its own data rate. The percentage of BER enhancement is 22% for MCCDMA-SISO and 25%, 27% for 2x2 and 4×4 MIMO diversity scheme respectively.

- The minimization of the outage probability is achieved through intelligent way of determining transmission power of each user using IWFA. The results shown that the outage probability is minimized using IWFA. The zero outage probability of MCCDMA system is at 20 dB by 2x2 MIMO diversity scheme and the same is achieved at 16 dB by the same system when IWFA is used.

- The outage capacity is also minimized through IWFA. The zero outage capacity of MCCDMA system is at 1bps by 2x2 MIMO diversity scheme and the same is achieved at 6bps by the same system when IWFA is used.

7.3.3 Adaptive Modulation and Power Control in Grouped MCCDMA-MIMO System

This module adopted user grouping algorithms and adaptive modulation algorithms in addition to power control to improve the system performance of MCCDMA-MIMO systems. The algorithm assigns users into group and allocates power and modulation under the given BER bound and the channel condition for each user.
Simulation results show that the solution through IWFA scheme outperform the reference scheme and can achieve high spectral efficiency with BER and power constraints. The further improvements of capacity and BER reduction in adaptive modulation based MCCDMA are achieved by exploiting MIMO diversity of size 2×2 and 4×4. The capacity in MCCDMA is enhanced nearly 15% for SISO and 27% for MIMO due to power allocation using IWFA.

The results show the comparison of throughput in terms of Bits per Symbol (BPS) for adaptive modulation based MCCDMA-MIMO technique. With 48 users, the BPS for fixed BPSK modulation is 48. The required SINRs to achieve BPS higher than 48 are above 0 dB and the same BPS is achieved after 5 dB value using without IWFA. Regarding to performance comparison between with and without IWFA algorithms, the IWFA algorithm performs 18% of improvements.

From the BER result, it is inferred that the increasing of modulation level induces the error rate for both with and without IWFA. However, MCCDMA with SISO attained 15% of BER reduction through IWFA. By incorporation of 2x2 and 4x4 MIMO diversity scheme in MCCDMA technique further reduced the BER by 21% and 27% respectively through IWFA.

7.3.4 Capacity Performance of MCCDMA-MIMO System under Imperfect CSI using IWFA

The effect of CSI impairment caused by the channel variation during the unavoidable delay, the noisy channel estimation and the limited feedback in MCCDMA-MIMO system is considered in this module. With this uncertainty conditions, the capacity enhancement and BER reduction in MCCDMA-MIMO is achieved by IWFA based power control and sub carrier group assignment method.
The results show the capacity improvement analysis of MCCDMA-MIMO (SISO, 2×2, 4×4) using IWFA with interference based subcarrier grouping under the Doppler frequency of 50, 100 and 150 respectively.

Results illustrate that the IWFA outperforms in capacity performance when compared to the without IWFA method. The capacity value of 5bps is achieved at the SINR value of 7dB by 2×2 MIMO multiplexing with $f_D=50\text{Hz}$. But the capacity value is achieved at the SINR value of 4dB by the same system consideration through water filling game theory.

The performance of BER reduction of MCCDMA-MIMO system using IWFA is illustrated in simulation results under three Doppler frequencies ($f_D=50$, $f_D=100$ and $f_D=150$). It can be observed that the BER value of $10^{-3}$ is achieved at the SINR value of 20dB by 2×2 MIMO multiplexing with $f_D=100\text{Hz}$ and the same can be achieved at 11dB by the same system consideration through IWFA.

### 7.4 SCOPE FOR FURTHER WORK

The following potential areas that might be interesting for researchers to pursue and explore in future are mentioned below.

- Efforts can be made to implement the power control algorithm using water filling game theory in real time video transmission in the error prone wireless environment, which offers end-to-end video quality degradation. Moreover, the limited battery life span of the network nodes pose challenges on the management of power consumption.

- The IWFA can be played in MCCDMA-MIMO system with joint quality enhancement and power control (QEPC) problem based on
bi–objective criteria that reflect both the benefit in terms of video quality and the cost in terms of transmission power.

- The IWFA can be played in MCCDMA-MIMO system with channel dependent scheduling algorithm for the system to monitor the channel quality as a function of frequency for the each terminal and adapt subcarrier assignments to change in the channel frequency response of all the terminals.