Chapter 9

Conclusion and Further developments

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9.1 Research Contributions

The contributions of the research work are listed below:

- MIMO Wireless System is the mandatory technology for achieving high channel capacity demands to satisfy the needs of next generation wireless technologies. The theoretical Channel Capacity Analysis for MIMO System is carried out and comparative analysis with SISO, SIMO and MIMO is analyzed. GUI is developed to ease the channel capacity and performance analysis of MIMO Transmission Techniques.

- LTE-A is a pioneer technology to achieve the IMT-Advanced requirements. The MIMO Transmission modes in LTE-A technology are studied in detail. The comparative analysis between Transmit Diversity and Spatial Multiplexing modes is carried out in terms of Throughput and BLER. The Diversity-Multiplexing tradeoff for LTE-A Downlink Physical Layer is analyzed.

- MIMO Channel estimation affects the Throughput of LTE-A Downlink Physical layer. To increase the throughput performance ANN based MIMO Channel estimation techniques are designed and simulations are carried out. The GRNN based MIMO Channel Estimation technique is implemented on TMS320C6713 DSK for throughput analysis.

- Fuzzy Logic Decision model for MIMO mode switching in LTE-A Downlink Physical layer is designed. Throughput can be maximized by selecting the appropriate MIMO mode based on Channel Condition Number and Receive SNR. The FL Decision model developed is implemented on Atlys Spartan-6 Development Kit and TMS320C6713 DSK for throughput analysis.

These contributions are discussed in more detail hereafter.

9.1.1 Channel Capacity Analysis and Conceptual Design of MIMO Wireless System

Theoretical aspects of MIMO Channel capacity is analyzed using MATLAB simulations. The Channel Capacity v/s SNR analysis of i.i.d Rayleigh flat-fading MIMO channel with full CSI at the transmitter and receiver is carried out. From the channel capacity plots we can conclude that, as we increases the number of transmit or receive antennas the channel capacity increases linearly with minimum number of transmit or receive antennas. For MIMO system Diversity-Multiplexing trade-off is studied. From DMT plots we can conclude that as the diversity gain increases by increasing the number of transmit antennas, the spatial multiplexing gain remains same and vice versa. But both Diversity and Spatial Multiplexing gain cannot not be simultaneously achieved.

The System Design methodology for design and implementation of MIMO Wireless system from initial specifications to wireless platform development is presented in thesis. The Rapid prototyping of MIMO algorithms for real-time testing in conjunction with MATLAB on FPGA and DSP target hardware is carried out. The Mathworks design flow for FPGA and DSP prototyping is described in detail with list of supporting tools available in MATLAB.

9.1.2 Performance Analysis of LTE-A Downlink Physical Layer

The LTE-A Downlink Physical layer is studied in detail. Vienna LTE-A Link Layer Simulator is used for performance analysis of MIMO modes in LTE-A. Throughput and BLER analysis of Transmit Diversity, OLSM and CLSM MIMO modes is carried out. Diversity and Spatial Multiplexing tradeoff is concluded from LTE-A Downlink Physical layer simulations. Spatial multiplexing gives higher throughput as compare to Transmit Diversity Scheme but low BLER. Hence either high throughput can be achieved or low error rates can be obtained. Throughput is analyzed for LTE-A Downlink Physical Layer for different antenna configurations as shown in Figure 9.1. As we increase the number of antennas at transmitter and/or receiver the throughput increases.

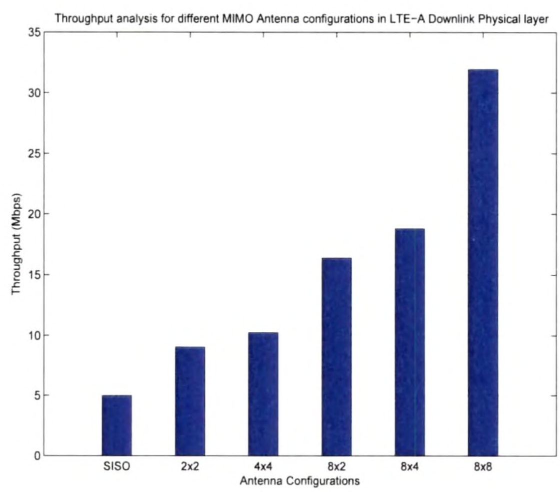

Figure 9.1: Throughput for different antenna configuration in LTE-A Downlink Physical Layer

9.1.3 Throughput Optimization of LTE-A Downlink Physical Layer

9.1.3.1 ANN based Channel Estimation Technique

MIMO Channel Estimation being the vital part for detecting the received data at receiver, is studied in detail. The imperfect CSI at receiver affects the Throughput of LTE-A Downlink Physical Layer. Various ANN based MIMO Channel estimation techniques are designed and simulation are carried out in this work. ANN based channel estimation methods developed for channel estimation are based of ANN Architectures: FNN, GRNN, RBFN and LRN. The throughput analysis shows that the proposed techniques gives better throughput performance of the system as compared to traditional LS Channel estimator. The ANN is further trained by GA to optimize the ANN weights to enhance the throughput of physical layer. By using ANN-GA based Channel Estimation technique the throughput can be maximized as compared to traditional LS Channel estimation method.

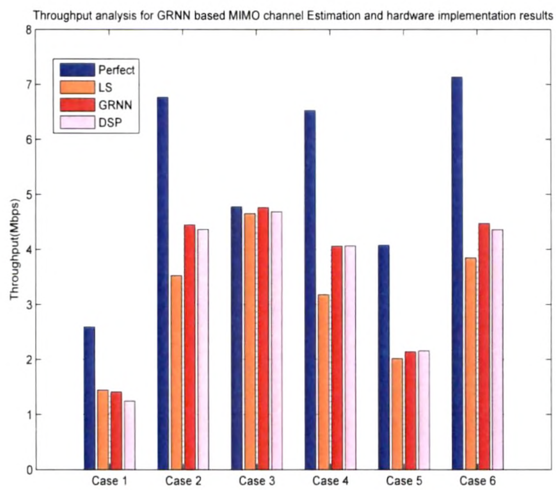

Figure 9.2: Comparison of Throughput for GRNN channel estimation and implementation

The proposed GRNN based MIMO Channel Estimation technique is implemented on TMS320C6713 DSK. Processor-in-loop simulations are carried out for verification of the developed channel estimation technique with LTE-A Link Level Simulator. The hardware implementation of GRNN based channel estimation gives approximately similar results in terms of throughput as of MATLAB Simulations as shown in Figure 9.2 for different Case scenarios.

9.1.3.2 FL Decision model for MIMO mode switching

FL Decision model for MIMO mode switching for Throughput Optimization in LTE-A Downlink Physical Layer is proposed in the research work. The model takes into account the channel condition number and the Receive-SNR and switches between Transmit Diversity or OLSM Transmission mode of LTE-A Downlink Physical Layer. Based on the Fuzzy Rule base it takes decision and switches to the appropriate MIMO mode. The rules are designed based on the relation between the Switching point between MIMO modes and Channel Condition Number. The FL Decision Model is able to maximize throughput for LTE Downlink Physical Layer for various Channel Configurations and Antenna Configurations. Simulation results shows that the FL Decision model is successfully able to select appropriate MIMO mode to maximize throughput of LTE-A Physical Layer.

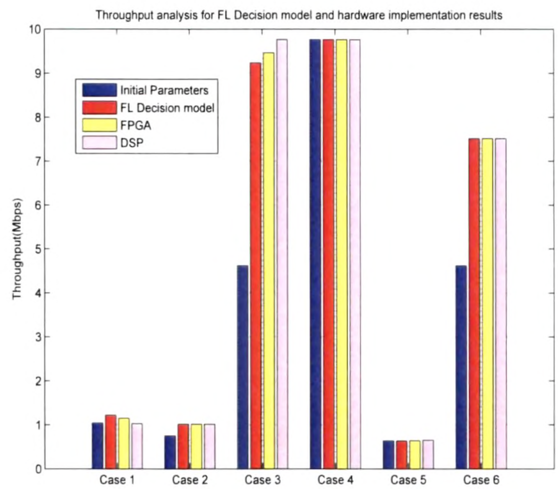

Figure 9.3: Comparison of throughput for FL Decision model and hardware implemntation

The proposed FL Decision model is implemented on TMS320C6713 DSK. PIL simulations are carried out for verification of the developed FL based MIMO mode decision model. The proposed FL Decision model is also implemented on Atlys Spartan-6 Development Kit. FIL simulations are carried out for verification of the developed FL based MIMO mode decision model. The hardware implementation of FL Decision model gives approximately similar results in terms of throughput as of MATLAB Simulations as shown in Figure 9.3 for different Case scenarios.

9.1.3.3 GUI developed for performance analysis of MIMO Wireless System

MATLAB based user friendly GUI is developed for "Design and Implementation of Embedded Architecture Using Soft-Computing Techniques for Parametric Optimization of MIMO Wireless System". Analysis of MIMO Channel Capacity, MIMO Techniques and proposed throughput optimization techniques are simulated and real-time implementation is carried out. The operating procedure of the GUI is described in User Manual in Appendix A. The hardware implementation of the proposed techniques for throughput optimization is verified using PIL and FIL Simulation through developed GUI as shown in Figure 9.4.

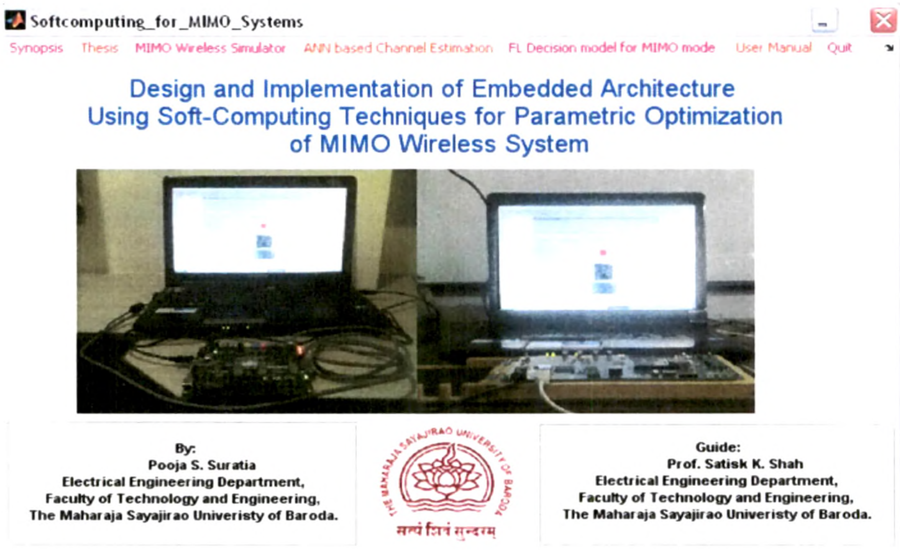

Figure 9.4: GUI for analysis of MIMO Communication System

9.2 Further Developments

Future work will explore some of the research directions as listed below:

- The capacity analysis for Flat Rayleigh fading channel with imperfect CSI at the transmitter and/ receiver can be carried out to gain better insight of the concepts.
- ANN based channel estimation technique developed is for 2x2 MIMO System. The same concept can be further verified with 4x4 or 8x8 MIMO Systems for performance analysis. The DSP and FPGA implementation challenges of the same can be explored.
- Further optimization of the developed ANN architectures for MIMO Channel Estimation can be done. The ANN parameters like connection weights and biases, number of nodes in hidden layer can be further optimized using Optimization algorithms such as GA or Particle Swarm Optimization Algorithm.
- The membership functions and fuzzy rules of the FL decision model can be tuned using Adaptive Neuro-Fuzzy Inference System (ANFIS), which allows FL model to learn the training data.
- The online-training ANFIS model can be implemented on FPGA and DSP for hardware prototyping.