LIST OF FIGURES

FIGURE DETAILS	PAGE NO.
Figure 1.1. Pivotal features of Smart grid technology	2
Figure 3.1. Technology, characteristics, components and challenges of Smart gird	23
Figure 3.2. Various stakeholders of Smart grid technology	25
Figure 3.3. Various components of Smart Microgrid	27
Figure 3.4. Layered Smart grid infrastructure	29
Figure 3.5. Home Area Network	31
Figure 3.6. Components of AMI	33
Figure 3.7. Bluetooth protocol stack	39
Figure 3.8. Piconet and Scatternet	40
Figure 3.9. Communication stack of WirelessHART standard	42
Figure 3.10. WirelessHART protocol stack	44
Figure 3.11. Zigbee protocol stack	46
Figure 3.12. Zigbee network architecture	48
Figure 3.13. 6LOWPAN network architecture	51
Figure 3.14. 6LOWPAN protocol stack	52
Figure 3.15. WLAN protocol stack	53
Figure 3.16. WLAN architecture.	55
Figure 3.17. Z wave network architecture	56
Figure 3.18. WiMAX protocol stack	58
Figure 3.19. 5G protocol stack	60
Figure 3.20. Various components of 5G	60
Figure 3.21. Cognitive radio gateways	62

Figure 4.1. Conceptual diagram of cross layer design 71

Figure 4.2. Throughput of nodes for no RTS mechanis 76

Figure 4.3. Throughput of nodes for RTS threshold-1 77

Figure 4.4. Throughput of nodes for RTS threshold-25 78

Figure 4.5. Throughput of nodes for RTS threshold-102 79

Figure 4.6. Mean values of result 81

Figure 4.7. Media access delay of nodes for NO RT 82

Figure 4.8. Media access delay of nodes for RTS threshold-1 83

Figure 4.9. Media access delay of nodes for RTS threshold-25 84

Figure 4.10. Media access delay of nodes for RTS threshold-102 85

Figure 4.11. Mean values of results 87

Figure 4.12. Total packet delay of nodes for No RTS/CTS 88

Figure 4.13. Total packet delay of nodes for RTS threshold-16 89

Figure 4.14. Total packet delay of nodes for RTS threshold-256 90

Figure 4.15. Total packet delay of nodes for RTS threshold-1024 91

Figure 4.16. Mean values of results 93

Figure 4.17. Throughput of nodes for default EDCA parameters 95

Figure 4.18. Throughput of nodes for adapted EDCA-1 96

Figure 4.19. Throughput of nodes for adapted EDCA-2 97

Figure 4.20. Throughput of nodes for adapted EDCA-3 98

Figure 4.21. Throughput of nodes for adapted EDCA-4 99

Figure 4.22. Throughput of nodes for adapted EDCA-5 100

Figure 4.23. Mean values of results 101

Figure 4.24. Media access delay for default EDCA parameters 102

Figure 4.25. Media access delay of nodes for adapted EDCA-1 103

Figure 4.26. Media access delay of nodes for adapted EDCA-2 104

Figure 4.27. Media access delay of nodes for adapted EDCA-3 105

Figure 4.28. Media access delay of nodes for adapted EDCA-4 106

Figure 4.29. Media access delay of nodes for adapted EDCA-5 107

Figure 4.30. Mean values of Media access delay 109

Figure 4.31. Total packet delay for default EDCA parameters 110

Figure 4.32. Total packet delay of nodes for adapted EDCA-1 111

Figure 4.33. Total packet delay of nodes for adapted EDCA-2 112

Figure 4.34. Total packet delay of nodes for adapted EDCA-3 113

Figure 4.35. Total packet delay of nodes for adapted EDCA-4 114

Figure 4.36. Total packet delay of nodes for adapted EDCA-5 115

Figure 4.37. Mean values of total packet delay 117

Figure 4.38. Diagram of the network to be optimized 118

Figure 4.39. WLAN Throughput of different access points 119

Figure 4.40. Network load of different BSS 120

Figure 4.41. WLAN delay of different access points 120

Figure 4.42. WLAN Media access delay of different access points 121

Figure 4.43. WLAN throughput comparison for Block acknowledgement vs RTS mechanism 122

Figure 4.44. WLAN media access delay comparison for Block acknowledgement vs RTS mechanism 122

Figure 4.45. WLAN delay comparison for Block acknowledgement vs RTS mechanism 123

Figure 4.46. WLAN delay with and without fragmentation 124

Figure 4.47. WLAN Media access delay with and without fragmentation 124

Figure 4.48. WLAN retransmission attempts with and without fragmentation 125

Figure 4.49. WLAN throughput with and without fragmentation 125

Figure 4.50. WLAN delay for different fragmentation thresholds and without fragmentation 126

Figure 4.51. WLAN Media access delay for different fragmentation thresholds and without fragmentation 126

Figure 4.52. WLAN retransmission attempts for different fragmentation thresholds and without fragmentation 127

Figure 4.53. WLAN throughput for different fragmentation thresholds and without fragmentation 128

Figure 4.54. WLAN optimization with RTS and fragmentation mechanisms 128

Figure 4.55. WLAN delay optimization with RTS and fragmentation mechanisms... 129

Figure 4.56. WLAN retransmission attempts optimization with RTS and fragmentation mechanisms 129

Figure 4.57. WLAN throughput optimization with RTS and fragmentation mechanisms 130

Figure 4.58. WLAN throughput optimization with different values of RTS and fragmentation thresholds 130

Figure 4.59. WLAN delay optimization with different values of RTS and fragmentation thresholds 131

Figure 4.60. WLAN Media access delay optimization with different values of RTS and fragmentation thresholds 131

Figure 4.61. WLAN buffer size optimization for higher throughput 132

Figure 4.62. WLAN buffer size optimization for lower delay 133

Figure 4.63. WLAN buffer size optimization for lower media access delay 134

Figure 4.64. WLAN throughput optimization with Greenfield operation 135

Figure 4.65. WLAN throughput optimization with RTS, Fragmentation and Greenfield operation parameters 136

Figure 4.66. WLAN dealy optimization with RTS, Fragmentation and Greenfield operation parameters 136

Figure 4.67. WLAN Media access delay for optimized value of RTS, Fragmentation and Greenfield operation parameters 137
Figure 4.68. Default values of CWmin and CWmax 138
Figure 4.69. Optimized values of CWmin and CWmax 138
Figure 4.70. WLAN delay with and without Contention window optimization 139
Figure 4.71. WLAN Media access delay with and without Contention window optimization 139
Figure 4.72. Frame aggregation parameters 140
Figure 4.73.WLAN Media access delay with and without frame aggregation 141
Figure 4.74. WLAN Throughput with and without frame aggregation 141
Figure 4.75. WLAN Delay with and without Frame aggregation, RTS and Fragmentation mechanisms 142
Figure 4.76. WLAN Throughput with and without Frame aggregation, RTS and Fragmentation mechanisms 142
Figure 4.77. WLAN Media access delay with and without Frame aggregation, RTS and Fragmentation mechanisms 143
Figure 4.78. Values of various parameters 144
Figure 4.79. Network optimization by considering various parameters 145
Figure 4.80. Neighborhood area network 146
Figure 4.81. Default AODV parameters 148
Figure 4.82. Reduced routing traffic parameters 149
Figure 4.83. Reduced routing traffic parameters with gratuitous route reply flag disabled 149
Figure 4.84. AODV protocol optimization-Routing traffic sent 150
Figure 4.85. AODV protocol optimization-Routing traffic received 150
Figure 4.86. AODV protocol optimization-Route discovery time 151
Figure 4.87. AODV protocol optimization-Total route errors sent 151

Figure 4.88. Comparison of throughput of different routing protocols for network optimization 152
Figure 4.89. Comparison of WLAN delay of different routing protocols for network optimization 153
Figure 4.90. Comparison of WLAN Media access delay of different routing protocols for network optimization 153
Figure 4.91. Default OLSR parameters 155
Figure 4.92. Optimized OLSR parameter 155
Figure 4.93. WLAN Throughput for default and optimized OLSR parameters 156
Figure 4.94. Default parameters 157
Figure 4.95. Optimized parameters 157
Figure 4.96. WLAN Media access delay for default and optimized OLSR parameters 158
Figure 4.97. WLAN Throughput for default and optimized OLSR parameters 158
Figure 5.1. Block diagram of developed prototype 161
Figure 5.2. Sensing and measurement in ACS 712 162
Figure 5.3. Flow diagram of designed prototype 163
Figure 5.4. Circuit diagram of designed prototype 164
Figure 5.5. Flowchart of monitoring of prototype 165
Figure 5.6. Flowchart of control of prototype 166
Figure 5.7. Snapshot of monitoring and control of developed prototype 167
Figure 5.8. Block diagram of designed prototype 168
Figure 5.9. Flow diagram of designed prototype 169
Figure 5.10. Snapshot of developed prototype 171
Figure 5.11. Flowchart of monitoring of prototype 172
Figure 5.12. Flowchart of controlling of prototype 173
Figure 5.13. Snapshot of remote wireless monitoring and control of smart power system through HTML webpage 174

Figure 5.14. Snapshot of remote wireless monitoring and control of smart power system through HTML webpage 174
Figure 5.15. Snapshot of remote wireless monitoring and control of smart power system on Arduino serial monitor. 175
Figure 5.16. Snapshot of remote wireless monitoring and control of smart power system on serial terminal program 175
Figure 5.17. Graph of System-1 176
Figure 5.18. Graph of System-2 177
Figure 5.19. Graph of System-3 178
Figure 5.20. Graph of all three systems 178
Figure 5.21. Graph of System-1 179
Figure 5.22. Graph of System-2 179
Figure 5.23. Graph of System-3 180
Figure 5.24. Graph of all three systems 180
Figure 5.25. Snapshot of remote wireless monitoring and control of smart power system through HTML webpage in Wide Area Network 181
Figure 5.26. Snapshot of remote wireless monitoring and control of smart power system through HTML webpage in Wide Area Network 182
Figure 5.27. Snapshot of remote wireless monitoring and control of smart power system through HTML webpage in Wide Area Network 182
Figure 5.28. Snapshot of remote wireless monitoring and control of smart power system through HTML webpage in Wide Area Network 183
Figure 6.1. EMI Causes in Smart Grid 186
Figure 6.2. Conceptual model of Smart grid 189
Figure 6.3. Major challenges of WSN 192
Figure 6.4. Types of attacks in WSN 193