CHAPTER 6
CONCLUSIONS AND FUTURE RECOMMENDATIONS

6.1 Contributions and Discussions

This thesis investigates different routing protocols in wireless sensor networks through comprehensive simulations as well as theoretical modeling and optimization. We are convinced by our theoretical and simulation results that the goal of rigorous assessment, energy models realization and enhancement in the existing framework of wireless sensor networks through trust and reputation models can be achieved, providing a significant improvement in overall system. The contributions of this research work are summarized as follows.

1. We have developed an integrated platform which provides the real terrain conditions required to implement wireless sensor network routing protocols and applications. This platform leverages QoS based evaluation model for their adaptability in the said domain. Additionally, we estimated the capabilities of linear and service life estimator battery models with routing protocols. We concluded that the dynamic on demand based routing protocol performance outweigh the rest of the protocols in our proposal and service life estimator model outperforms the linear model in all the cases of energy consumption. Simulation results show that choosing an appropriate routing protocol is promising in further prolonging the overall system efficiency.

2. We have presented a generalized method to analyze the performance of AODV routing protocol with respect to scalability issue. This method has emerged out to
judge QoS parameters like average jitter, end to end delay, broadcast send, broadcast receive and packets from and to application layer for AODV routing protocol. Moreover, these performers used to optimize the protocol parameters for a desirable performance. We concluded with the influence of the scalability issue on the behavior of application, MAC, transport and physical layer. We argued that the scalability issue must be present in the system architecture in order to support wireless sensor network applications.

3. To validate our general architecture, we first presented the general, mica-mote and micaZ energy models. In evaluation of this platform, we demonstrated these energy models shows significant performance improvements with DSR protocol. We investigated the impact of DSR protocol on the energy consumption basis on transmits, receive and idle mode. We concluded that energy consumption is higher in the generic model and lowest in micaZ model. The energy consumption remains in between in the mica-mote model. These findings are validated by comparing the theoretical predictions with the simulated environment. The Mica platform has proven itself both in theory and through deployment in long term battery operated application scenarios.

4. Wireless sensor networks are continuously changing our lives. Today's capability of instantaneously communicating with somebody else at the other end of the world, as well as sharing information, or even doing business through electronic transactions, was certainly a dream only some years ago. Nevertheless, besides the wide range of opportunities that are offered to us which promote the economic growth of the nations. There are unfortunately several threats that hinder such developments. The final stage of adoption for wireless sensor networks will be when mission critical
information is trusted to them. Trust and reputation management has been recently proposed as a novel and accurate alternative of dealing with wireless sensor networks where a lack of information about the rest of the members composing the community could lead to a set of highly harmful attacks. Trust and reputation models evaluation has emerged as an innovative solution for wireless sensor networks. We investigated the impact of malicious sensors on the BTRM-WSN, Eigen trust, peer trust, power trust and LFTM trust and reputation models in wireless sensor networks. Additionally, we evaluated a WSN framework with respect to static, dynamic, oscillatory and a combination of dynamic and oscillatory WSN. We concluded with trust and reputation models performance evaluation aspects like accuracy, path length and energy consumption in wireless sensor networks. A new energy consumption function for trust and reputation model is proposed to find with the actual estimation. This function greatly prolongs the network operations specific investigations, especially in the wireless sensor networks. We also made a detailed investigation over collusion issue for a WSN system. Hence, in our opinion, an appropriate trust and reputation management in wireless sensor networks might be definitely helpful in increasing the security and confidence of end users, supporting this way a prosperous information society development.

5. We have made the leap beyond the capabilities of general wireless sensor network by fully realizing our general architecture in the form of highly dense wireless sensor networks. Unconstrained by the capabilities of general WSN available, we have integrated a suite of data dissemination protocols and sensor node operations in order to realize order of magnitude improvements on key evaluation metrics.
These include crucial metrics such as sense count, transmit count and receive redundant count. We concluded with the realization that gossiping protocol performance outweighs flooding protocols in highly dense wireless sensor networks. We judged evaluation metrics based on node operations in WSN from an efficiency viewpoint.

6. In addition to micro-benchmarks and theoretical analysis, we have also presented an integrated deployment combining data dissemination protocols and sensor node distribution strategies under a single roof. We have also tracked sensing and transmission specific node operations. This analysis underscores the performance impact of the strategies presented. Additionally, sensor node distribution strategies presented demonstrate the flexibility and validate the platform. We concluded that the performance of the routing protocols changes along with the different sensor network distributions and event present in the scenario.

7. We provided a new representation for the chi-squared distribution over underlying correlated data dissemination protocol. This includes a summary of research efforts that have been layered on top of the system to judge the impact DOF with respect to scalability in wireless sensor networks. We investigated that the lesser the number of DOF more the linear behavior in the node operation will be exhibited by the wireless sensor network system. We presented a comprehensive investigation over chi-squared distribution strategy with data dissemination routing protocol. We concluded the impact of DOF on the chi-squared node distribution strategy for wireless sensor network.
6.2 Recommendations for Future Work

We will like to focus and explore our future research around the under mentioned aspects.

1. Our future work will emphasize on utilization of heuristic methods towards selection of routing protocols for a particular WSN system. Additionally, we would like to focus on three major aspects viz enhancement, restructuring and extending the experiments carried out to demonstrate accuracy of our proposed scenario.

2. We would like to add new distribution in our evaluation as well as will work towards development of an optimal distribution for the wireless sensor network domain. Moreover, we would like to add and develop newer sensor node distribution strategy in the wireless sensor network domain.

3. Regarding our particular ongoing and future work, we are studying two concrete and real scenarios where to apply and deploy a trust and reputation mechanism, showing this way the utility of these approaches for final users. Those environments are: Secure University Management Systems and Wireless Micro Sensor Networks. Besides, we are currently benefiting from the advantages of fuzzy logic and fuzzy set representation in order to provide a more human-sensible trust model, while preserving the accuracy of our already developed solutions.

4. We are also planning to develop a newer trust and reputation model simulator combining the routing protocols and security aspects on a single integrated platform. Our goal is for it to become one of the reference tools within this area of knowledge.

5. Lastly, we consider two final real scenarios that would benefit from the application of trust and reputation management. Those are University-to-University (U2U) or
Faculty-to-Faculty (F2F) networks. In fact, there is too few works done in this direction, so it constitutes an excellent starting point for a new research line.

Thus, the work carried out as part of this PhD thesis helped us to achieve a better knowledge about wireless sensor networks with continuous and comprehensive survey of the state of art done thoroughly. The effectiveness of the terrain conditions, scalability, routing protocols, energy models and resource consumption has been demonstrated with the incorporation of trust and reputation models in this sense. Ten years from now, wireless sensors will be a “Universal” technology that has grown to impact every aspect of our lives. All industries, machinery and control systems will have switched over to relying on wireless sensing and control points. The severe wiring system for any creation will be replaced by an invisible wireless mesh. All the devices will be operated through a common place as like light switches and thermostats etc. Today, we give little vision to the modern electrical grid and what our lives would be like without it. Tomorrow, we will give a little vision to wireless sensor network technology and the systems that have grown to influence every sphere of our lives.