CHAPTER 1
WIREDLESS SENSOR NETWORKS

1.1 Introduction

Wireless sensor networks have emerged as an equally valuable and novel platform for wireless communication and other areas of applications. The potential of wireless sensor networks include wider areas of coverage such as environmental monitoring, defense machinery and surveillance, ecology evaluation, industrial products manufacturing, home appliances, transportation, medical applications, general applications etc [Wang et al., 2011]. Wireless sensors are portable devices integrated with a combination of transmitter and receiver along with low energy sources. Common features of a wireless sensor node constitute memory, energy and economical processor for computation purpose [Alkalbani et al., 2012; Chen et al., 2007]. The primary goal of any wireless sensor network is to perform a distributed field’s task. This is accomplished by mutual coordination of different sensor nodes with specific operations like sensing, computing, transmitting and storage. The parameter nodes cooperation plays a pivotal role in overall performance determination of any wireless sensor network systems [Chong et al., 2003; Akyildiz et al., 2002]. In general terms, a wireless sensor network is a collection of sensor nodes linked with each other in a defined strategy to perform a distributed task. The deployment of wireless sensor network is a serious concern as the real time application may vary from simple to severe physical deployment conditions. The matter of security and reliability becomes the contemporary field of research in wireless sensor network and gaining more attention of scientists and researchers to work in the said context [Jim, 2010]. There always remains
probability of a collusive node in wireless sensor networks as the area of deployment ranges from close environment to open environment as well [Hurt et al., 2005]. These malicious nodes may spread wrong information on the entire network which results in overall system performance degradation. Therefore, it is quite mandatory to identify the collusive nodes and punish them in an accord manner. There are various strategies and policies to detect an opponent node in the wireless sensor networks. Conventional ways to secure a network includes various cipher techniques and methodologies. Availability of cipher based solutions addresses the common issues like authentication, access control, confidentiality, integrity and non-repudiation. But the designing requirements of wireless sensor networks applications are more critical than these conventional strategies. In the absence of adequate security policy, a node may bypass the traditional security means and can convey the false information and as a result reliability of the entire wireless sensor network (WSN) system may be compromised. The major limitation of cipher based solutions is the involvement of severe computations which consumes more energy resources. This makes these solutions more difficult to be adopted in wireless sensor network [Jing et al., 2008]. Some light weight cryptographic mechanisms are available in the literature but they are not serving the goal in entirety. So, there remains a dire need to probe wireless sensor network reliability aspect and search some complementary means to incorporate more faith in the overall WSN system. Trust and reputation models are the solution for the given problem to adhere to reliability in the wireless sensor networks. Due to this research on trust and reputation models has gained considerable momentum in the last few years. Many trust and reputation models have been proposed in the past. Some of them were centered around secure routing, data aggregation, cluster head selection and synchronized trust management [Hurt et al., 2005; Crosby et al., 2006; Sun et al., 2011]
but still there is need to address various issues like routing protocols, collusion, scalability, mobility, computability in the wireless sensor networks. At present, most of the trust evaluation frameworks belong to an algorithm based methodology over which entire behavior of nodes depend in terms of accuracy, resource usability and energy consumption. It is therefore necessary to concentrate on these issues in parallel with its performance and some real time aspects like collusion and fraudulent environment. Further, sections outline the foundation for the scope, aim and general character of our research work.

1.2 Literature Review

Sensor network development was initiated by the United States during the Cold War. A network of acoustic sensors was placed at strategic locations on the bottom of the ocean to detect and track Soviet submarines. This system of acoustic sensors was called the Sound Surveillance System (SOSUS). During the same time period, the United States also deployed networks of radars for air defense. These sensor networks used hierarchical processing, where data is processed at different layers until the data of interest reaches the user. Human operators played an important role in these systems. Both of these sensor networks were wired networks and did not comply with the main design issues like energy or bandwidth constraints of wireless systems. Modern sensor network research started in the early 1980’s at the Defense Advanced Research Projects Agency (DARPA) in the United States [Chong et al., 2003]. The Distributed Sensor Networks (DSN) program assumed a network with many independent, low-cost sensing nodes. These nodes were spatially distributed but able to collaborate. Information was routed to the node that could use it best. In the mid 1980’s, Massachusetts Institute of Technology (MIT) developed a
demonstration DSN consisting of acoustic sensors designed to track low-flying aircraft. For this, microphones (arranged in arrays of six) were used for the acoustic sensing. The mobile vehicle nodes consisted of one computer and three processors with 256 KB memory and 512 KB shared memory for processing the acoustic signals. Energy was supplied by an acoustically quiet generator, mounted on the back of the vehicle node. The nodes communicated with microwave radio and Ethernet were used for fixed line communication. Wireless sensor networks have evolved immensely in the early 1980’s. One of the more recent WSN project is the Wireless Self-Sustaining Sensor Network (WSSN) developed by the Institute of Computer Technology at the Vienna University of Technology (TUV). Mahlknecht et al. [2004] observed the impact of different design space approaches in regard to energy efficiency in wireless sensor networks. Mahlknecht et al. [2005] signifies the impact of WSNs in the field of self-sustaining network. The research focused on the development of low-cost, energy efficient hardware and an energy efficient medium access control (MAC) protocol. The major considerations of any sensor node are its processing unit, wireless link and battery module. Their wireless interface consists of a 1 Mbps, 2.4 GHz transceiver. These nodes work within half degree temperature accuracy and also integrated with a sensor of ten bit interface. The energy conservation techniques employed by these nodes is very noteworthy. These nodes consume about 100 μW of power on average if certain environmental conditions are assumed, as well as that each node receives and transmits 120 bits of data every five seconds. These nodes would be able to operate for almost nine years, if each node was equipped with a 3200 mAh lithium battery that has an input voltage of two volts. This lifetime is achieved by using state of the art energy storage as well as energy scavenging. For storage, WSSN nodes use a combination of ultra capacitors and lithium accumulators. The advantage of ultra capacitors is the fact that they
can quickly absorb large amounts of energy but on the downside, their leakage current grows exponentially as the applied voltage increases. For energy scavenging, the nodes use solar cells. The solar cells use the environment more specifically the sun to charge the energy storage components. These design techniques have enabled the development of very small nodes that can operate for years by extracting energy from the environment. In the future, we are expecting more capable and versatile systems based on the advances in micro-electromechanical system (MEMS) technology. The company working in the field of MEMS technology is Dust Inc., Berkeley, CA. This company sprung from the late 1990s Smart Dust research project at the University of California, Berkeley, was building MEMS sensors. These sensors can sense and communicate as well as potable enough to fit inside a cubic millimeter. An individual Smart Dust optical mote uses MEMS to aim sub millimeter sized mirrors for communications. Smart Dust [University of California, 2003] sensors can be deployed using a $3 \times 10$ mm “wavelet” shaped like a maple tree seed and dropped to float to the ground. A wireless network with such sensors can provide close-in sensing capabilities in many novel applications based on criteria like ubiquitous, low-cost, disposability. Chong et al. [2003] examined the various aspects of sensor network like evolution, opportunities and challenges since its inception in wireless domain. Table 1.1 shows the evolution of sensor nodes reported by Chong et al. [2003]. It can be seen from table 1.1 that the state of the art technology available today is already far beyond that which was available in 2003 and tentatively for 2020. The sensor nodes developed by the Vienna University of Technology (TUV) already employ solar panels and theoretically achieve lifetime of some years. When comparing the MIT nodes from the mid 1980’s to the recent TUV WSSN nodes, it can be seen that there have been tremendous advances in technology in the twenty year period. The WSSN nodes can last for years on limited energy resources,
very small, integrated sensing, processing and communications. These nodes are of low-cost and can use a variety of sensors for numerous fs with ease of deployment in large numbers.

Table 1.1: Evolution of sensor nodes

<table>
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<tbody>
<tr>
<td>Manufacturer</td>
<td>Custom contractors</td>
<td>Crossbow Technology Inc.</td>
<td>Sensoria Corp. Ember Corp.</td>
<td>EDust Inc. and others</td>
</tr>
<tr>
<td>Size</td>
<td>Large shoe box and up</td>
<td>Pack of cards to small shoe box</td>
<td>Minute particle</td>
<td>Dust particle</td>
</tr>
<tr>
<td>Weight</td>
<td>Kilograms and up</td>
<td>Grams</td>
<td>Nanograms</td>
<td>Negligible</td>
</tr>
<tr>
<td>Node Architecture</td>
<td>Separate sensing, processing and communication</td>
<td>Integrated sensing, processing and communication</td>
<td>Integrated sensing, processing and communication</td>
<td>Complete integrated structure</td>
</tr>
<tr>
<td>Topology</td>
<td>Point-to-point, Star</td>
<td>Client server, Peer to peer</td>
<td>Peer to peer</td>
<td>Hybrid Approach</td>
</tr>
<tr>
<td>Power Supply &amp; Lifetime</td>
<td>Large batteries; Hours, days and longer</td>
<td>AA batteries; Days to weeks</td>
<td>Solar; Months to years</td>
<td>Solar &amp; Battery power; Years and more</td>
</tr>
<tr>
<td>Deployment</td>
<td>Vehicle-placed or air-dropped single sensors</td>
<td>Hand-placed</td>
<td>Embedded, “sprinkled”, left behind</td>
<td>Fully integrated and embedded</td>
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MIT nodes in turn needed a generator for energy with separate sensing, processing and communication systems. These expensive nodes were specifically designed for acoustic sensing and deployed in small numbers. If the size of a self-sustaining sensor node could be decreased from the size of a motor vehicle (MIT node) to the size of a one Euro coin (WSSN node) in a matter of twenty years, then how small will these nodes be in twenty years from now? A self-sustaining sensor may be as small as five square millimeters within
ten years and even smaller in twenty years time. Kahn et al. [1999] observed the frugal energy budget of sensor networks and predicts that a significant amount of work focus is needed on energy-aware network protocols. As the size of a sensor node is shrinking, there is a continuous need to evaluate the behavior of a node under severe terrain conditions correspond to the various routing protocols. The final motto of this thesis is to achieve optimization and enhancement in existing wireless sensor network framework available. The key components of a typical wireless sensor network (WSN) device comprise the following.

**1.2.1 Low Power Embedded Processor**

The computational tasks on a WSN device include the processing of locally sensed information as well as remote information communicated by other sensors. Due to economic constraints of such processors, devices typically run specialized component based embedded operating systems such as TinyOS [University of California, 2003]. A network based strategy for portable equipments was suggested by Culler et al. [2001]. This strategy can also be applied to heterogeneous models in wireless sensor networks. If the sensor network is heterogeneous, some nodes have greater computational power. Moreover, given Moore’s law for the future WSN devices may pose extremely powerful embedded processors.

**1.2.2 Memory / Storage**

Storage in the form of random access memory and read only memory includes both program memory and data memory. The quantity of memory in the wireless sensor node is also limited. It is expected to improve with time.
1.2.3 Radio Transceiver

WSN devices include a low rate short range wireless radio having a bit rate 10–100 kbps and a range of less than 100 m. These radios are likely to improve over time. Improvements in cost, spectral efficiency, tenability and immunity to noise, fading and interference are likely to improve with time. Radio communication being the most power intensive mode, hence radio must incorporate energy efficient sleep and wake up modes.

1.2.4 Sensors

Due to bandwidth and power constraints, the WSN devices primarily support only low data rate sensing. Many applications call for multimodal sensing, so each device may have several sensors on board. The applications are highly dependent on the specific sensors used. They may be temperature sensors, light sensors, humidity sensors, pressure sensors, accelerometers, magnetometers, chemical sensors, acoustic sensors, or even low resolution imagers.

1.2.5 Geo-positioning System

In many WSN applications, it is important for all sensor measurements to be location stamped. The simplest way to obtain positioning is to reconsider sensor locations for deployment but this may only be feasible in limited deployment particularly for outdoor operations when the network is deployed in an ad hoc manner. Such information is easily obtained via satellite based Global Positioning System (GPS). However, in such applications, only a fraction of nodes may be equipped with GPS capability due to the economic and environmental constraints. In such cases, other nodes may get their locations indirectly through network localization algorithms. Bruck et al. [2005] described the impact of local angle information on localization and routing in wireless sensor network.
1.2.6 Power Source

The wireless sensor node is battery powered. In some applications, it is possible to recharge the batteries but mostly the nodes have finite energy.

So, an ideal wireless sensor should be networked, scalable, consumes very little power with smart and software programmable. It should also capable of fast data acquisition, reliable and accurate over the long term, costs less, easy to install and requires no real maintenance. Selecting the optimum sensors and wireless communication link requires knowledge of the major design considerations like application, problem definition, battery life, sensor update rates and size.

1.3 Wireless Sensor Networks Application Areas

Due to the improvement of wireless sensors over the traditional sensors, many WSN scenarios ensure a wide range of applications. The applications of wireless sensor networks perform various tasks such as information collection, storage, processing, metrology and transmission to the base station. In a pioneer application, a wireless sensor network is disseminated in a zone to collect data through sensor nodes. The applications include health monitoring of patients and assist disabled patients, managing inventory, product quality, monitoring disaster areas, monitoring ecological habitat, seismic monitoring and military applications, structural health monitoring and industrial applications. Some of the widely used applications are:
1.3.1 Ecological Habitat Monitoring

This is a major field of application of the wireless sensor networks as the variable like temperature is dispersed over a particular area. Sensor networks can be easily applied to the environment and habitat monitoring applications. Steere et al. [2000] examined the research challenges of environmental observation and forecasting systems in WSNs. The Center for Embedded Network Sensing (CENS) was the first to take initiative about this field. Charny et al. [2002] demonstrates the new paradigms for research issues in the future of wireless sensor networks. Jensen [2002] enhances the concept of wireless sensor network towards the avionics sector based on the communication, navigation and surveillance. Scientific studies of ecological habitat such as plants, animals and microorganisms are conducted through hands on field activities by the investigators. One serious concern in these studies is sometimes referred “observer effect” - the very presence and the intrusive potential activities of the field investigators may affect the behavior of the organisms in the monitored habitat and thus bias the observed results. Scattered wireless sensor networks promise a cleaner remote observer approach to habitat monitoring. Moreover, sensor networks promise a cleaner remote observer approach to habitat monitoring. Further, sensor networks can provide experimental data of an unprecedented richness due to their potentially large scale and high spatiotemporal density.

1.3.2 Military Surveillance and Target

As with many other information technologies, wireless sensor networks originated primarily in military related research. The controllers of military systems, very early recognize the benefits of sensor network because it was directly related to nuclear centric warfare [Alberts et al., 1999]. In other terms, sensor forms a base as a hidden weapon for
the battlefield as they can be controlled by remote entity. John Hopkins [1995] demonstrated a new cooperative engagement capability (CEC) approach. This approach allowed the combat systems to share unfiltered sensor measurements data (associated with tracks) and with rapid timing to enable the battle group units to operate as one. Scattered sensor networks are envisioned as the key ingredient in moving towards network centric warfare systems. They can be rapidly deployed for surveillance and used to provide battlefield intelligence. This includes information regarding location, numbers, movement and identity of the troops, vehicles, detection of chemical, biological and nuclear weapons.

1.3.3 Structural and Seismic Monitoring

Another class of application for the sensor networks pertains to monitoring the condition of civil structures. The structures could be buildings, bridges, roads etc. At present the health of such structures is monitored primarily through manual and visual inspections or occasionally through expensive and time consuming technology such as X-rays and ultrasound. Unattended networked sensing techniques can automate the process for providing rich and timely information about incipient cracks or other structural damage. Wireless sensors networks can help in monitoring the health of a structure if deployed properly during the construction of the civil structure, especially during any destruction events such as earthquakes or explosions. Xu et al. [2004] introduces a new minimum preamble sampling MAC protocol for low power wireless sensor network structures. A compelling future vision for the use of sensor networks involves the deployment of controllable structures. These contain actuators that react to real time sensor information to perform "echo cancellation" on seismic waves, so that the structure is unaffected by any external disturbance.
1.3.4 Industrial Applications

In industrial manufacturing facilities, sensors and actuators are used for process monitoring and control. For example in chemical processing and control, where temperature, pressure and chemical concentration can be monitored by placing the sensors at different point of the process. The information from such real time monitoring may be used to vary process controls such as adjusting the amount of a particular ingredient or changing the heat settings. The key advantage of creating wireless sensor networks in these environments is that they can significantly improve both the cost and the flexibility associated with installing, maintaining and upgrading wired system. Manges [1999] indicate that the trends are moving towards the integration of wireless communications with sensors. Without such a plan, the life of this new technology can be cut short before the true success is demonstrated.

1.4 Design Challenges

Wireless sensor networks are designed as per the application area. The important design challenges are discussed in the subsequent subsections.

1.4.1 Extended Lifetime

As mentioned above, a wireless sensor node is intensely affected by the hindrance of power sources. In this direction, Heinzelman et al. [2000] emphasizes on the energy efficient communication protocol for wireless micro sensor network. For a large network much longer lifetimes are desired over the expense of the batteries as it is potentially infeasible to monitor and replace batteries rapidly. In practice, it will be necessary in many applications to provide guarantees that a network of unattended wireless sensors can remain operational
without any replacement of batteries for several years. Hardware improvements in battery
design and energy harvesting techniques will offer only partial solutions. This is the reason
that most protocol designs are made explicit with energy efficiency as the primary goal in
wireless sensor networks.

1.4.2 Responsiveness

One of the general solutions to enhance the lifetime of sensor node is to actuate it in sleep
and wake up manner. While concurrent execution of nodes is challenging in itself, an
arbitrary long sleep periods can reduce the responsiveness and effectiveness of sensors.
Particularly in applications, where it is critical that certain events in the environment be
detected and reported rapidly. The latency induced by sleep schedule must be kept within
strict bounds to avoid network congestion. Paganini et al. [2009] derived a unified
approach to congestion control and node-based multipath routing in wireless sensor
network.

1.4.3 Robustness

The vision of wireless sensor networks is to provide large scale and fine-grained coverage
for the real time applications. Meguerdichian et al. [2001] examines optimal polynomial
time algorithm for the solution of the best and worst case associated with coverage in
wireless sensor network. This motivates the use of large numbers of inexpensive devices.
However, inexpensive devices can be unreliable and prone to failures. Rates of the device's
failure will also be high whenever the sensor devices are deployed in harsh or hostile
environments. Protocol design must have built-in mechanism to provide robustness. It is
important to ensure that the global performance of the system is not sensitive to individual
device failures. Further, it is desirable that the performance of the system degrade as gracefully as possible with respect to component failures.

1.4.4 Synergy

The term synergy may be referred to that the whole WSN system exhibits better behaviour than the sum of individual nodes capability. Keyes et al. [2006] demonstrates the impact of Moore's law in the performance evaluation of sensor nodes. Moore’s law type advances that device capability in terms of processing power, memory, storage, radio transceiver performance and even accuracy of sensing. However, if economic considerations dictate that the cost per node is reduced. It is possible that the capabilities of individual’s nodes will remain constrained to some extent. Therefore, the challenge is to design a synergistic protocol which ensures that the system as a whole is more capable than the sum of capabilities of its individual’s components. The protocols must provide an efficient collaborative use of storage, computation, and communication resources.

1.4.5 Scalability

The combination of fine granularity sensing and large coverage area implies that wireless sensor networks have the potential to deploy in extremely large scale envisioned applications. Meguerdichian et al. [2001] proposed an optimal polynomial time algorithm that uses graph theoretic and computational geometry constructs for solving for the best and worst case associated with coverage in wireless sensor network. Routing protocols should address the criterion of easy distribution and localized communication. Sensor networks must utilized hierarchical architecture in order to improve scalability. The vision of large number of nodes will remain unrealized in practice until some fundamental problems such as failure handling and in-situ reprogramming will not be addressed. This should be equally
true even in small settings involved tens to hundreds of nodes. There are also some fundamental limits such as throughput and capacity that affects the scalability of wireless sensor network.

1.4.6 Heterogeneity

The term heterogeneity may be referred as the WSN system behavior should be unaffected with the variation of hardware and software constraints of an individual node. There will be heterogeneity of device capabilities in realistic settings. This heterogeneity has a number of important design consequences. Chakeres et al. [2003] highlighted the specifications of the sensor node in order to predict its efficiency in wireless sensor networks. For instance, the presence of small number of devices of higher computational capacity along with a large number of low-capability devices can dictate two tier and cluster-based network architecture. The presences of multiple sensing modalities require pertinent sensor fusion techniques. A key challenge is often to determine the right combination of heterogeneous devices capabilities for a given applications.

1.4.7 Self Configuration

Wireless sensor networks are inherently unattended due to the scale and nature of their applications. Autonomous operations of the network are the key design challenge. The nodes in a wireless sensor network have to configure their own network topology (localize, synchronize and calibrate) themselves (coordinates inter-node communication) and determine other important operating parameters.

1.4.8 Self-Optimization and Adaptation

Traditionally, most engineering systems are optimized prior to operate efficiently in the face of expected or well-modeled operating conditions. In wireless sensor networks, there
may often be significant uncertainty about operating conditions prior to deployment. Under such conditions, it is important that there should be flexible inbuilt mechanisms to autonomously learn from sensor and network measurements. Further, inbuilt mechanism should be able to collect information over design methodologies that sacrifice some performance. Marron et al. [2005] predicts a new a flexible and adaptive framework with tiny cubes for wireless sensor networks. Performance optimization is very important over given the severe resource constraints in wireless sensor networks. Systematic design methodologies, reuse, modularity and run time adaptation are other constraints that should be addressed by practical considerations.

1.4.9 Privacy and Security

The large scale, prevalence and sensitivity of the information collected by wireless sensor networks give rise to the final key challenge of ensuring both privacy and security. Evfimievski et al. [2002] introduces the concept of knowledge discovery and data mining for information extraction through sensors nodes in wireless sensor networks

1.5 Selection of Research Domain

Practically, wireless sensor network faces considerable problems in data processing, communication and sensor node management. This is because of uneven conditions like an uncertain and dynamic environment along with energy constraints. Wireless sensor network poses additional challenges in the field of network routing protocols, energy efficiency, sensor node assessment strategies and energy models. There is need to analyze the performance of existing routing protocols, in order to develop new protocols that can extend network lifetime as well as can be easily manageable on network of different sizes.
While the concept of wireless sensor networks looks practical and exciting on paper, the single most important consideration for a wireless sensor network is power consumption. If batteries need to be changed constantly, widespread adoption will not occur. The largest power consumption is being attributed to the radio link itself. There are a number of strategies that can be implemented to reduce the average supply current of the radio. These strategies are (i) Reduce the amount of data transmitted through data compression and reduction (ii) Lower the transceivers duty cycle and frequency of the data transmission (iii) Reduce the frame overhead (iv) Implement strict power management mechanisms (power down and sleep mode) (v) Implement an event driven transmission strategy; only transmit data when an event occurs (vi) Implement energy efficient routing protocols. There are many authors considered the term energy efficiency from different viewpoints, but there are additional issues like energy models, terrain conditions, mobility, scalability etc still needs more consideration to gain more and more energy efficiency. The major aim of this research is to evaluate and enhance the existing wireless sensor network framework available.

1.6 Objectives of Research Work

The major aim of this research is to analyze and enhance the capabilities of existing framework available for the wireless sensor networks. The main objectives of this research are as follows:

1. Performance evaluation of AODV and DSR routing protocols under terrain conditions.
2. Rigorous assessment of shortcoming in the wireless sensor nodes based on scalability and mobility.
3. Realization of energy efficient wireless sensor network by utilization of different energy models.

4. Selection and optimization of routing protocols to enhance capabilities of the wireless sensor network system.

1.7 Thesis Structure

This thesis is organized in 6 Chapters. **Chapter 1** elaborates the overview of the entire research work in a brief manner.

**Chapter 2** presents modularized view of five key routing protocols under terrain conditions. The work includes common routing protocol paradigms and their suitability in wireless sensor networks. It is intended to provide the background necessary for a general understanding of the issues discussed in later Chapters. Additionally, Chapter 2 provides a general outline of the capabilities of linear and service life estimator battery models. It culminates in describing a first initiation used as a baseline for comparison among aforesaid models. In this Chapter, we focused on static, distance vector and on demand based routing protocols of wireless sensor networks over linear and service life estimator battery models. The impact of different wireless sensor networks routing protocols has been judged for average jitter, first and last packet received, total bytes received, average end to end delay, throughput and energy consumption. For optimal performance of wireless sensor networks, challenging issues like energy consumption, network routing, localization, coverage and physical environment must be addressed. Low power and inexpensive nodes are required to meet the performance goal of the wireless sensor network system. Analytical modeling of WSN and real performance prediction is extremely critical to measure. This Chapter
emphasized towards the network routing protocol estimations with the battery model to achieve the optimal results for the proposed scenario.

Chapter 3 presents preliminary work to address the scalability concern over Ad hoc on demand distance vector (AODV) protocol in wireless sensor network. Moreover, influence of scalability on the behavior of application, MAC, transport and physical layer performance is included. This design issue plays a critical role in exposing the capabilities of the entire WSN system. Wider coverage of wireless sensor networks has opened a new face of research in the field of distributed computing applications. Challenging issues like scalability, coverage problem, localization, energy consumption and physical environment etc. must be addressed for the optimal performance of a wireless sensor network system. For wireless and mobile environment, there is a great need of inexpensive and low power sensor node. Analytical modeling of WSN and actual performance prediction are extremely difficult. Deploying test bed study in order to obtain the actual behavior of WSN requires a tremendous effort. In the future, we are expecting a lot of real time WSN application as one of the efforts has already been explored in the same field. Further, Chapter 3 discusses the energy models that must be addressed by a wireless sensor network platform. We discuss and systematically explore the effect of generic, mica-mote and micaZ energy models on wireless sensor networks. Mica platform has been successfully used in hundreds of real-world sensor network deployments. In this Chapter, we systematically explore the effect of different energy models on wireless sensor networks. We describes three energy models - generic, mica-mote and micaZ. Generic energy model uses generic mote boards which constitute four mono audio jacks. These jacks provide connection to an analog to digital converter and power to a sensor. Digital output can be taken by changing two of the analog to digital converter (ADC) ports. As the mote board is not a plug and play, so the power
and signal pins have to be set accordingly. Mica-mote energy model uses mica-mote module *i.e.* MOT300 a product of Crossbow corporation. The Mica-mote is a small and low power consuming module used by the researcher for the development of wireless sensor networks and was invented by UC Berkeley research group. This Chapter introduces a novel way to realize energy consumption in wireless sensor network. We evaluated dynamic source routing protocol on the energy consumption basis in transmit, receive and idle mode. In transmit and receive mode, power consumption is highest in the generic model and the lowest in the mica-mote model. On the other hand in the idle mode, there is a sharp decrement in energy consumption value from generic model to mica-mote and further some decrement in energy consumption to micaZ model. Finally, we conclude that energy consumption is higher in case of both transmit and receive mode in generic model whereas lowest in mica-mote model. Considering the case of idle mode, energy consumption is higher in the generic model and lowest in micaZ model. The energy consumption remains in between in the mica-mote model. We validated these findings by comparing the theoretical predictions with the simulated environment.

**Chapter 4** deals with enhanced wireless sensor networks incorporating trust and reputation models. This chapter deals with the impact of malicious servers over different trust and reputation models with static, dynamic and oscillatory wireless sensor networks. Trust and reputation models in wireless sensor network have attracted wider appreciation among global community. Trust can be referred as a specific level of probability with which a particular node will perform an action, both before it can monitor its capacity and in a domain in which it affects its own function. Reputation may be defined as an expectation about a node's behavior based on its present information or past observations. Trustworthy nodes can only be identified with trust and reputation models. Many researchers have
proposed trust and reputation models for guaranteeing a specific security and accuracy level. Still, there is a dire need to give more emphasis in the said domain to enhance the coverage area of trust and reputation models in the wireless sensor network applications. Specifically, this Chapter covers different WSN modes, including static, dynamic and oscillatory as well as an experimental methodology for measuring the impact of malicious servers on the performance of different trust and reputation models in WSN systems. This chapter deals with the effect of static, dynamic and oscillating modes of wireless sensor networks over five trust and reputation model namely: Bio inspired trust and reputation model for wireless sensor networks (BTRM-WSN), Eigen Trust, Peer Trust, Power Trust, LFTM. The impact of different wireless sensor networks modes has been judged for accuracy, path length and energy consumption over deployed models. Further, we stressed in this Chapter over collusion issue. We observed that with the collusion adoption in the WSN modes, the result becomes much steeper, that means performance degradation. In case of static nodes, collusion affects less to WSN when it is incorporated in dynamic mode. Also, node operations remain more in case of collusion than without it. From this investigation, we can predict that the lesser the collusive nodes, more the probability of accuracy, the better resource utilization, the adequate satisfaction level, and the lesser the energy consumption of the entire WSN will be exhibited by the wireless sensor network system.

Chapter 5 presents and analyzed data dissemination flooding and gossiping protocols with Delphi random generator distribution strategy for highly dense wireless sensor networks. In this chapter, we have analyzed data dissemination flooding and gossiping routing protocols for wireless sensor network. We have designed and illustrated our proposed model for data dissemination based evaluation with Delphi random generator distribution strategy. We
have evaluated node operations in terms of performance metrics like sense count, transmit count, receive count and receive redundant count. Moreover, Chapter 5 presents an overview and analysis of eight sensor node distribution strategies in wireless sensor networks demonstration. Sensor node distribution strategies severely affect the event specific communication performance in wireless sensor networks. In this chapter, we analyzed eight sensor network distributions namely: normal, gamma, exponential, beta, generalized inverse Gaussian, Poisson, Cauchy and Weibull. We have designed and illustrated our proposed model with these node distributions for data dissemination.

Further, we have calculated node operations based on sense count transmit count and receive redundant count metrics. This analysis underscores the performance impact of the strategies presented. Additionally, sensor node distribution strategies presented demonstrate the flexibility and validate the platform. Further, Chapter 5 provides 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 degree of freedom (DOF) with respect to scalability in wireless sensor networks. In this chapter, we derive a novel approach for the chi-squared distribution when the underlying correlated data dissemination protocol has strong influence on wireless sensor networks. We have evaluated the DOF with respect to scalability to derive the joint resultant. Moreover sense count, transmit count and receive redundant count sensor node operations are also evaluated.

Finally, simulation analysis has been carried out to prove the validity of our proposal. However, chi-distribution for wireless sensor node seems intractable with the DOF when varied with the specific number of nodes in the scenario.

Finally, Chapter 6 summarizes the thesis and concludes with a prediction of future technology trends.