CHAPTER 1

INTRODUCTION

1.1 Genesis of Wireless Sensor Networks

Wireless Sensor Networks (WSN) owe their genesis to the concept of ubiquitous computing which was proposed by Marc Weiser in his seminal paper [104] in 1991 and is today widely known as Pervasive Computing. Pervasive Computing represents the concept where technology is tightly integrated to all aspects of human life in a completely non-intrusive manner i.e. without the technology becoming the focus of attention. Pervasive computing envisions an intelligent and adaptive environment which continuously eases the interaction between the human being and his environment by sensing his actions and predicting his requirements from the environment around him, thus significantly enhancing the quality of interaction between the human being and the environment. It further envisions that this would be achieved by the presence of large number of tiny computing devices with sensing and radio communication capabilities, densely spread over the environment, gathering information about the environment, gathering information about the actions of the human subject and monitoring the interaction of the human subject with the environment. It also envisions that these computing devices would collaborate among themselves and be aware of the context while interpreting the data gathered by them to decide upon the subsequent action to be performed. Various types of context are defined in [2] including Social context, Location context, Motivational Context, Temporal Context etc.

Wireless Sensor Networks have emerged as an acceptable methodology for sensing events and acquire data generally spread over various locations in a geographic area [5] to satisfy the requirement mentioned in the implementation of Pervasive computing.

Wireless Sensor Networks consist of battery operated, inexpensive, small size computing devices with sensors and radio transceivers on board thus
having the capability to sense the events and communicate with each other [5]. The self-organizing sensor nodes would either communicate with each other to collaboratively establish the occurrence of an event in a distributed manner or simply pass on the sensed data to a centralized sink where the data would be evaluated and the occurrence of the event inferred. Using low cost, inexpensive and untethered wireless sensor nodes, for the purpose of sensing parameters and events over a region, has dramatically removed the constraints associated with traditional wired methodologies thus providing a paradigm shift in the approach towards the process of data acquisition. These nodes can be left unattended for long period of time and have the ability to self-organize to form a network and ensure delivery of sensed information or event to each other for collaborative sensing, besides sending the information to a centralized data warehouse.

A key difference between the usage of Wireless Sensor Networks and the traditional Data Acquisition Systems lies in the fact that the traditional systems focus on the accuracy of the sensed information at a specific point while in the case of Wireless Sensor Networks the focus is not on the degree of accuracy of the reading but more on what can be inferred, at a remote location, by using the bunch of readings obtained from various low cost, low reliability sensor nodes measuring similar data in a given region.

Figure 1.1: Diagram of a typical Wireless Sensor Network
Therefore having highly accurate and reliable sensors on-board the sensor nodes is not a key requirement in the Wireless Sensor nodes. This difference can be explained with the help of an example as follows.

If the requirement is to measure the rate of flow of water passing through a pipe for purpose of billing, then a single point reading made by a high accuracy sensor mounted on the pipe would be the correct methodology. However, if the requirement is to identify whether the soil in a large field is dry, slightly moist or very moist, then one high accuracy sensor would not suffice. Having a large number of high accuracy sensors could be a possible solution to this problem; however, the solution would be very expensive and probably give much higher accuracy than what is needed since the original requirement was to only identify regions with dry, slightly moist or very moist soil. The objective in this problem could be met with reasonable reliability by deploying large number of low cost, low accuracy sensor nodes spread over the region and infer the moistness of soil in the various parts of the field by studying the data obtained from these sensors. Thus utilizing Wireless Sensor Network in this problem could actually be a more reasonable and realistic solution [49], [76]. The solution could be upgraded by introducing Actuator Nodes in the network which could then control the amount of irrigation in specific regions based on the inferred information. However the requirements in that scenario will be more stringent [51]. The various constraints [6] faced by a typical Wireless Sensor Network include the following:

1. The Wireless Sensor Nodes are battery operated, have short-range radios on board along with low cost low accuracy sensors, are small sized and have low computing and memory resources. Thus these nodes are energy constrained, have low computational capability, low accuracy of sensing and are prone to hardware and communication failure.

2. Since the nodes may be deployed in areas where they are exposed to harsh vagaries of the environment including exposure to extreme temperatures, humidity and other such physical factors, the probability of a node failure is high.

3. The wireless medium itself is prone to irregular and unpredictable behaviour because of issues like interference and channel fading.
4. Moreover since the same medium is being used for communication by all the nodes in a network, the probability of loss of information because of packet loss and network congestion is high.

The standard methods adopted by Wireless Sensor Networks to get over these constraints are as follows:

- Redundancy is introduced in the network by deploying significantly larger number of sensor nodes than what are actually needed for sensing and eventual reliable estimation and re-construction of the sensed event at the sink. This is done to counter the issue of node failure and packet loss during communication since with a larger number of nodes participating, the probability of sufficient number of nodes remaining un-affected by the node and communication failure for reliable re-construction and estimation of the event sensed in the region of deployment is high.

- The adverse impact on the Network life-time because of energy constraint on the nodes is offset to an extent by making the nodes go into low power sleep mode when not sensing, thus conserving battery life. Mechanism is also introduced to ensure even loading of the nodes in a network so that the overall network life time improves.

1.2 Evolution of Wireless Sensor & Actuator Networks

Over time the Wireless Sensor Networks have evolved into Wireless Sensor & Actuator Networks (WSAN) [6] which consists of special nodes called Actuator nodes besides the typical Wireless Sensor Nodes. The Wireless Sensor Nodes perform the task of gathering information about the environment in which they are deployed. Additionally special nodes called Actuator nodes are also introduced into the network and have the ability to actuate upon some control elements that have an impact on the environment in which the sensor nodes are deployed. Actuator Nodes are not energy constrained, have higher computational and memory capabilities, better communication capabilities and are able to actuate upon some controllable element. With the introduction of Actuator Nodes into the network the following two network architecture, as shown in Figure 1.2, are generally observed [6]:

1. Centralized Decision Making (Semi-Automated)
2. Distributed Decision Making (Automated)

![Figure 1.2: a) Centralized Decision Making Architecture b) Distributed Decision Making Architecture](image)

In the case of Centralized decision making approach, the sensor nodes pass on the sensed information to a centralized sink where the decision on the control action to be taken by the multiple actuators is decided based on the gathered information. This information is subsequently passed on to the actuators for implementation by the actuators. In the case of distributed Decision making approach, the sensor nodes send the gathered information to specific actuators, who then communicate and collaborate among themselves to take decision about the specific control action to be performed by each one of them. The second approach is more in tune with the actual definition of Wireless Sensor Networks where the issue of collaborative deduction of an event and the response to it is highlighted. Wireless Sensor & Actuator Networks are expected to significantly accelerate the acceptability of Wireless Data Acquisition & Control systems in applications which are non-real time and do not employ very complex control action.

However, with the evolution of Wireless Sensor & Actuator Networks additional constraints [9],[63] have been thrust upon the reliability of the data acquisition process of the network since the decisions taken for control of actuating action depend upon the data acquired by the sensor network. These are:

- Since the Actuator Node/s are required to take a decision on implementation of the control action, based on the estimation or re-construction of the event
relying on information delivered by the sensor Nodes, it is imperative that the control action is time coherent with the circumstances of the environment. This means that the delay between the time an event is sensed by the deployed nodes and the time when the action is taken by the actuators must be as less as feasible to ensure that the control action is not delayed.

• Thus an additional constraint is placed on the Network Latency Time ($T_{NLT}$) which becomes critical in the case of WSAN i.e. the time lag between detection of event by a sensor node and the time the same is reported at the sink /actuator, $T_{NLT}$, must be less than the desired Actuation Latency Time of the application.

1.3 Modes of Data Acquisition

The prime purpose of deployment of a WSN is to gather information about the environment in which it is deployed and then pass on the collected information to the sink which may be located remotely. The collected information is then assessed to estimate or re-construct the events occurring in the deployment area. The deployed nodes generally scan and collect information periodically but will send the gathered information to the sink depending upon the mode of Data Acquisition that could be one of the following [4]:

1. **Periodic Data Acquisition:** In this mode the nodes will not only collect the information periodically but will also transmit the collected information periodically to the sink. The frequency of data sampling would generally be much higher than the rate at which the collected information is transmitted to the sink. This is because the energy spent by the node on sensing and computing is generally significantly less than the energy spent in transmitting the information, although there are certain applications where the reverse has been found to be true [35].

2. **Event Based Data Acquisition:** In this mode, the deployed nodes may scan and collect information periodically; however, they will transmit the information only when a specific pre-defined event occurs. The network life in this mode tends to be significantly higher as compared to Periodic Data Acquisition mode since the nodes will not transmit periodically thus saving
considerable amount of energy. This mode is not suitable for applications where periodic updates about the event area are needed e.g. habitat monitoring.

3. **Query Based Data Acquisition:** In this mode, the deployed nodes may scan and collect information periodically; however, they will transmit the information only when specifically queried about the information. In this mode the sink will initiate a query which will be propagated throughout the network, also called interest propagation. Only those nodes which fulfil the criterion of the query will send the information available with them. One of the critical aspects of this mode is that the query needs to be propagated to all nodes in minimum amount of time and with consumption of least amount of energy.

4. **Hybrid Data Acquisition:** This mode is a combination of the above mentioned modes. Different sections of the deployed nodes may be using one or more of the above mentioned data acquisition modes.

Generally speaking, the Event based data acquisition mechanism will use the least amount of energy followed by query based and then subsequently periodic data acquisition.

### 1.4 Reliable Data Acquisition

The concept of reliability of data acquisition has been defined in different contexts as discovered during the literature survey [16], [48]. The traditional definition of reliability of a system, as mentioned in the theory of reliability [82], is as below:

\[
\text{Reliability}(t) = e^{-\lambda t} = e^{-t/m}
\]  

(1)

where \( \lambda \) is the failure rate, \( m \) is MTBF.

This definition indicates that for a given system under observation, if the failure rate is constant, then the reliability of the system will reduce with time in an exponential manner. Here the constant failure rate means the average failure rate observed over a period of time. The traditional definition is valid in context of a Wireless Sensor Network even though Wireless Sensor Network is a virtual entity composed of widely distributed physical sub-entities called Sensor Nodes. These nodes are not physically joined to each other, however, they are able to communicate and share information among themselves to collaboratively perform the
task of sensing or detecting in the environment where they are deployed and thus act as a system. In a Wireless Sensor Network this definition of reliability can be observed in different contexts as mentioned below (Figure 1.3):

1. **In context of physical failure of nodes:** If the rate of failure of nodes in a Wireless Sensor Network is constant, due to physical damage or draining out of the battery, then the reliability of the network to perform the assigned task of collecting information or detecting events, in the environment of deployment, will decline exponentially with time. The validity of this statement is easily verified since it is clear that as the nodes in a network die, the ability of the network to acquire information about the environment, in which it is deployed, drops significantly since the number of sensing points reduce and the probability of missing out on the detection of an event increases. Thus the **Reliability of Coverage (or Sensing)** will reduce exponentially as more nodes keep on failing on a regular basis.

2. **In context of failure of nodes to communicate:** The medium of communication in a WSN is highly un-predictive and its characteristics and behaviour change constantly. This has an obvious impact on the ability of the nodes to communicate with each other and share the information collected, which is an issue at the core of the existence of the Wireless Sensor Network. As more and more nodes fail to communicate with each other, the ability of the network to pass on the acquired information to the sink reduces thus. This lack of ability to pass on the information collected by the nodes to the sink is reflected in a parameter called Packet Delivery Ratio [95] which is measured as:

   \[
   \text{Packet Delivery Ratio} = \frac{\text{Total Number of Packets received at Sink}}{\text{Total number of Packets sent by the nodes}}
   \]  

   As the Packet Delivery Ratio of a Wireless Sensor Network drops constantly, the **Reliability of Delivery** of sensed information degrades exponentially.

3. **In context of lack of security of data communication among nodes:** As the nodes are using the wireless medium for communication among them, the information transmitted by them in an open medium leaves the possibility of the transmitted information being intercepted by unauthorised
or rouge nodes which may ingratiate themselves into the network. This could have an adverse impact on the performance of the network as the information could be misused. Further these rogue nodes may start feeding false information to the nodes or may even take control of the nodes within the network. If more and more nodes in the WSN get compromised then the Reliability of Secure Data Exchange in the network will degrade exponentially.

As can be seen, the definition of reliability could have different connotation in a Wireless Sensor Network.

Another important parameter defined in the traditional theory of reliability is Availability [82] of the system which is defined as:

\[
\text{Availability} = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}} \tag{3}
\]

where MTBF is Mean Time Between Failures and MTTR is Mean Time To Repair.

![Figure 1.3 Categorization & Definition of Reliability](image)

This parameter, also called Operational Availability, is an indicator of the overall reliability of the system as it indicates the probability that the system will be available to perform the assigned task at any given time.

In context of Wireless Sensor Networks, availability may be seen in context with the service that the WSN is expected to provide i.e. sensing
information or detecting a specific event and then ensuring that the information gathered is successfully passed on to the sink where subsequent action pertaining to the gathered information can be taken. If the WSN is unable to provide satisfactorily the task of gathering and passing on the information then the network could be called as being un-available or it could be stated that the Availability of the network is low.

The non-availability of a network can be primarily because of the fact that large number of sensor nodes comprising the network may have failed due to physical failure or draining out of their battery [5]. Thus a network with long **Network Lifetime** would have higher Availability as compared to a network with low network life-time. The non-availability of the network could also be attributed to lack of ability of the WSN to deliver satisfactorily the service that it is expected to provide [5]. Thus, if a Wireless Sensor Network is able to provide Reliable and satisfactory service, despite failure of some sensor nodes, the availability of the Wireless Sensor Network will be high. Within the Wireless Sensor Network, on a micro-level, Availability could also be construed as the availability of a neighbour of a sensor node for forwarding the information gathered towards the sink.

Specific form of reliability required may change from application to application [65]. Since the primary reason for deploying a Wireless Sensor Network is to sense information or detect event within the deployment zone remotely and then be able to pass on this information to the sink for estimation and reconstruction at the sink therefore from the perspective of the Sink **Reliability of Data Acquisition** become an important parameter which encompasses the various definitions of reliability and availability associated with a Wireless Sensor Network. From the perspective of the Sink, **Reliable Data Acquisition** could be defined as the ability of the Wireless Sensor Network to ensure delivery of sufficient amount of the gathered information, by the deployed sensor nodes to the sink, for it to be able to faithfully and successfully re-construct the event sensed and detected by the nodes. This will further include the availability of the data acquisition service being provided by the network for as long as possible without compromising on the ability of the centralized sink to faithfully re-construct the event sensed by it. Reliability also includes the ability of the network to be tolerant to faults, within a limit, without comprising on the basic issue as mentioned above.
There are a few issues which are different in the case of a WSAN and which have an impact on the definition of Reliable Data Acquisition. In the case of a Wireless Sensor & Actuator Network the possibility of Distributed Decision making also exists which requires that the data sensed by the deployed nodes should be sent to the closest Actuator rather than a centralized sink, therefore mechanism for this to happen reliably must exist.

Further in the case of a WSAN there is a time constraint on the Network Latency Time ($T_{NLT}$) i.e the time difference between the sensing of information by the deployed node and the time at which the sensed information is received at the Centralized sink or the Actuator [ , ]. This time constraint, although application specific, exists to ensure that the action taken by the actuators is in coherence with the sensing done by the deployed nodes and the control action is not erratic and un-stable.

Therefore, in context of a Wireless Sensor & Actuator Network, Reliable Data acquisition refers to the ability of the Wireless Sensor & Actuator Network to ensure delivery of sufficient amount of the gathered information, by the deployed sensor nodes, in a *time-bound and coherent manner* to the centralized sink for it to be able to faithfully and successfully re-construct the event and take necessary action in time. *Coherent manner* indicates that the sequence of delivery of data at the sink / actuator is in the same sequence as which the data is generated at the sensor nodes i.e. the sequence in which the nodes detect the occurrence of the event. Reliability further includes the availability of the data acquisition service being provided by the network for as long as possible without compromising on the ability of the centralized sink to faithfully re-construct the event sensed by it. Reliability also includes the ability of the network to be tolerant to faults, within a limit, without compromising on the basic issue as mentioned above.

The efforts of a Wireless Sensor & Actuator Network to attain a high degree of reliability are marred by the constraints mentioned in 1.1 & 1.2 above.

1.5 State of the Art

Various approaches have been proposed to improve the reliability of data acquisition [45, 57, 70, 72] by focusing on one or more of the reliability definitions as mentioned.
in 1.4 above. A detailed literature survey is available in Chapter 2, however, a brief categorization of the various methodologies developed is provided below.

Table 1.1 : State of the Art

<table>
<thead>
<tr>
<th>Approach</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fault Tolerant</td>
<td>The objective in this approach is for the Sensor Network to continue its operation with as high reliability as is feasible under the given fault condition in the network. The fault conditions could vary from temporary loss of communication between a set of nodes, to permanent loss of a node because of damage or end of battery life of the node. The focus of design of algorithm tends to be on ensuring detection of event and then delivery of sensed information by the deployed nodes to the centralized sink despite the fault condition. Some algorithms also focus on detection of fault condition itself and then managing it. Majority of these solutions propose algorithms with the ability to dynamically find alternate network paths in case a given network becomes un-usable because of a fault condition. Many algorithms present methodology where the data sensed is transferred on multiple paths simultaneously to begin with thus ensuring delivery of information at sink despite some path becoming useless because of node failure. These methods compute reliability for multiple paths depending upon status of nodes and send data on most reliable path or broadcast data on multiple routes with probabilistic approach for success. Some algorithms use Centralized or distributed approach to fault detection based on historic data or location-awareness. However, these set of methods tend to be highly memory &amp; computational intensive thus putting significant load on the nodes and increasing the computational delays and reduction in life of</td>
</tr>
<tr>
<td>Maximising Packet Delivery Ratio</td>
<td>The objective in this approach is to maximize the packet delivery ratio of the network thus ensuring that all information sensed by the deployed nodes reaches the sink. The focus of design of algorithms is on ensuring that the packet origination from a deployed node is not dropped at any stage and if it does drop then some alternate methodology is available for recovery of the same. Multiple approaches including exploiting spatial and temporal redundancies, hop-by-hop recovery, end-to-end reliability, tree based optimization of routing path, multipath [joint or disjoint] approach, quick fetching of lost packets from neighbours are used. Concept of handshaking is also used in some cases using RTS/CTS or NACK as handshaking confirms success of transaction. These approaches focus on ensuring the delivery of information sensed by the deployed nodes to the centralized sink, however, a time-constraint is not generally defined for these cases. Besides high control overheads are observed because of the effort involved in ensuring packet delivery. Algorithms are available for many-to-one and many-to-few approach for data aggregation. However, the reliability here is at a cost of end to end delay time.</td>
</tr>
<tr>
<td>QoS Aware Methodology</td>
<td>The focus in this approach is on using one or multiple QoS parameters for making decisions regarding the actions to be taken by the nodes in context of delivery of sensed information. In particular, the focus is on satisfying certain QoS metrics (delay, energy, bandwidth) when delivering data to the base station. Some QoS aware mechanisms are topology aware or geographically aware. Shortest path with least energy being used is the criterion generally used which may be applied at local (node level) or network wide level. Some algorithms use the end-to-end</td>
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</table>
delay constraints as a part of the performance metric but the network overheads tend to be high and the delay may not meet the application criterion in many cases. Generally prescribed for many-to-one collection of data and are not suited for many-to-few criterion applicable in Multi-Actuator distributed scenario.

<table>
<thead>
<tr>
<th>Location or Topology Aware Approach [7], [47]</th>
<th>This approach utilizes the knowledge about the location of the nodes to deliver the information sensed through the shortest, least congested path. Geographic knowledge also enables the nodes to be scheduled for sleep patterns since the path for forwarding the information packets can be ascertained in terms of geographic location of nodes. However, location knowledge of nodes is generally not easily available or prevalent and actually ascertaining the same is highly energy intensive.</th>
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<tbody>
<tr>
<td>Swarm Intelligence based Approach [22],[29],[74],[103]</td>
<td>This approach uses the Swarm Intelligence techniques like ant colony Optimization, Foraging Bee hive, for arriving at optimized decisions for reliable communication. Suitable for distributed problem solving approach, however, tend to have communication and energy overheads.</td>
</tr>
<tr>
<td>Query Dissemination [54], [68]</td>
<td>The objective is to ensure guaranteed delivery of a query sourced by the sink to the nodes. Approaches include flooding, selective dissemination.</td>
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</table>
1.6 Researcher’s Contribution

The researcher’s contribution is illustrated by the diagram given in Figure 1.4 below and is summarized as follows:

This thesis presents a novel Reliable Data Acquisition methodology using Wireless Sensor & Actuator Networks which meets the criterion of reliability as mentioned earlier. The proposed methodology includes the following:

**Event Based Data Acquisition**
Algorithm for Reliable Transfer of Acquired Information by a Set of Nodes detecting an event

**Periodic Data Acquisition**
Algorithm for Reliable Transfer of Acquired Information by a set of Nodes detecting information periodically

**Query Based Data Acquisition**
Algorithm for Reliable dissemination of query/interest into the Network
Algorithm for Reliable Transfer of Acquired Information by a Set of Nodes based on the query

**Reliable Data Acquisition at Sink for Event Re-construction & Deciding Subsequent Control Strategy**

**Reliable Data Acquisition at Actuators for Event Re-construction & Deciding Subsequent Control Strategy**

**Increased Reliability of Estimation & re-construction of Event or Inference at Sink**

**Time Constraint on Network Latency**

**Fault tolerance against temporary loss of communication between set of nodes or permanent failure of nodes**

**Low Computational delays & memory utilization**

**Increased Network Lifetime**

**Figure 1.4: Illustration indicates the Researcher’s Contribution**
1. A new methodology for categorisation of deployed nodes into Layers has been developed to reduce latency of network
   - A Distance Based Multi-Layer Assignment Methodology (DBMLAM) has been developed to physically categorise the randomly deployed nodes into Layers.
   - Use of LQI / RSSI based methodology to perform the task of categorisation of nodes into Layers
   - Two variants of the methodology have been developed which work for Centralized Decision Making approach with Single Sink & Distributed Decision Making approach with Multiple Actuators.

2. A non-traditional definition of Neighbouring Nodes termed as Layer Based Neighbours (LBN) has been arrived at and methodology has been developed for finding various categories of neighbours for each deployed nodes
   - Neighbouring Nodes have been defined in context of Downstream, Upstream, adjacent & Layer Bypass category
   - The methodology ensures that each node is aware of its local topology in all possible directions.
   - The methodology allows for an upper bound on the number of neighbouring nodes at each node in each layer
   - Two variants of the methodology have been developed which work for Centralized Decision Making approach with Single Sink & Distributed Decision Making approach with Multiple Actuators.

3. A data acquisition mechanism has been developed termed Layer Based Time Constrained Reliable Data Acquisition Mechanism (LTCRDM) for acquisition of data from deployed nodes to a Centralized Sink or Multiple Actuators.
   - The methodology makes use of the Distance Based Multi-Layer Assignment Methodology (DBMLAM) and the Layer Based Neighbors Methodology (LBNM) mentioned above to facilitate forwarding of information sensed by the deployed nodes towards a Centralized Sink
A Table based approach has been developed for selection of neighbors based on a priority function and the concept of Swarm Intelligence has been utilized for strengthening the choice of priority neighbor.

Time Constrained hand-shaking has been utilized to ensure reliability of data delivery as well as ensuring that the time-constraint on the Network Latency is met

Two variants of the methodology have been developed. One approach work for the Centralized Decision Making approach with Single Sink termed as LTCRDM-C and another approach for the Distributed Decision Making approach with Multiple Actuators termed as LTCRDM-D

The mechanism ensures that sufficient amount of the information gathered by the deployed sensor nodes regarding a sensed event is reported to the centralized sink / Actuator for acceptable estimation or re-construction of the event detected, within the time-constraint fixed by the control action to be taken by the Actuator nodes.

The methodology results in delivery of the sensed information by the deployed nodes within the time-constraint placed on the Network Latency Time (T_NLT) of the sensor network which is defined as time between sensing of information by the nodes and the time of delivery of information at Sink/Actuators.

The methodology results in delivery of sensed information by the deployed nodes in a coherent manner

The mechanism is fault tolerant to an extent as it has the ability to be tolerant to temporary communication faults, within a limit, without compromising on the ability of the centralized sink / Actuators to faithfully re-construct the event sensed by it.

The mechanism provides the above mentioned services while offering significant network life with acceptable reliability

The methodology supports the three modes of Data Acquisition viz

a. Periodic Data Acquisition
b. Event Based Data Acquisition
4. **A new methodology has been developed for efficient and quick dissemination of query originating from a Sink into the network of deployed nodes**

- The methodology is based on the Distance Based Multi-Layer Assignment Methodology (DBMLAM) described earlier.
- Methodology ensures dissemination of query originating from the Sink to each node in a short time with reasonable reliability.
- Each query originating from the Sink is identified by a unique identification number.
- All nodes do not participate in the dissemination of query thus flooding is averted however, limited duplication of query does exist.

### 1.7 Organization of Thesis

This thesis is divided into seven chapters.

**Chapter 1** is devoted to introduction.

**Chapter 2** contains literature review and overview of various algorithms and mechanism for improving reliability of data acquisition in WSN’s.

**Chapter 3** presents the motivation behind the work presented in the thesis besides the objectives of the proposed mechanism. The concept of measurement of Reliability of Data Acquisition is also introduced which helps in refining the objectives.

**Chapter 4** presents the concept of Layer Based Time Constrained Reliable Data Acquisition Mechanism (LTCRDM) and the design for the same for single hop and multi-hop Wireless Sensor & Actuator Networks with Centralized Decision mechanism.

**Chapter 5** presents the concept of Layer Based Time Constrained Reliable Data Acquisition Mechanism (LTCRDM) and the design for the same for single hop and multi-hop Wireless Sensor & Actuator Networks with Distributed Decision mechanism.
Chapter 6 presents Mechanism for infusing query into a single or multi-hop network divided into layers which form the basis of LTCDRM.

Chapter 7 concludes the work and talks about the future work in this direction.

1.8 Chapter Summary

In this chapter the origin of Wireless Sensor Networks has been traced and its close linkage to concepts of Pervasive Computing & Ubiquitous Computing has been presented. Characteristics and constraints that apply to Wireless Sensor Networks have also been shown. The evolution of Wireless Sensor & Actuators has then been discussed along with information about the standard configurations and additional constraints that apply to it. The concept of reliability has also been traced to its traditional definition and then the application of the concept of reliability, in context with Wireless Sensor Networks, has also been presented. The state of the art in this field has also been presented briefly followed with the information about the contribution of this thesis.