A Review of Sensor Networks: Challenges and Solution

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ABSTRACT-Sensor networks are dense wireless networks of small, low-cost sensors, which collect and disseminate environmental data. Wireless sensor networks facilitate monitoring and controlling of physical environments from remote locations with better accuracy. They have applications in a variety of fields such as environmental monitoring, military purposes and gathering sensing information in inhospitable locations. Sensor nodes have various energy and computational constraints because of their inexpensive nature and adhoc method of deployment. Considerable research has been focused on overcoming these deficiencies through more energy efficient routing, localization algorithms and system design. Researcher survey attempts to provide an overview of these issues as well as the solutions proposed in recent research literature.

KEYWORD- SINA, SQTL, Routing.

I. INTRODUCTION

Recent technological improvements have made the deployment of small, inexpensive, low-power, distributed devices, which are capable of local processing and wireless communication, a reality. Such nodes are called as sensor nodes. Each sensor node is capable of only a limited amount of processing. But when coordinated with the information from a large number of other nodes, they have the ability to measure a given physical environment in great detail. Thus, a sensor network can be described as a collection of sensor nodes which co-ordinate to perform some specific action. Unlike traditional networks, sensor networks depend on dense deployment and coordination to carry out their tasks [1].Previously, sensor networks consisted of a small number of sensor nodes that were wired to a central Processing Stations. However, nowadays, the focus is more on wireless, distributed, sensing nodes. But, why distributed, wireless sensing? [2] When the exact location of a particular phenomenon is unknown, distributed sensing allows for closer placement to the phenomenon than a single sensor would permit. Also, in many cases, multiple sensor nodes are required to overcome environmental obstacles like obstructions, line of sight constraints etc. In most cases, the environment to be monitored does not have an existing infrastructure for either energy or communication. It becomes imperative for sensor nodes to survive on small, finite sources of energy and communicate through a wireless communication channel.

Another requirement for sensor networks would be distributed processing capability. This is necessary for communication is a major consumer of energy. A centralized system would mean that some of the sensors would need to communicate over long distances that lead to even more energy depletion. Hence, it would be a good idea to process locally as much information as possible in order to minimize the total number of bits transmitted.

Applications of sensor networks:

Sensor networks have a variety of applications. Examples include environmental monitoring – which involves monitoring air soil and water, condition based maintenance, habitat monitoring (determining the plant and animal species population and behavior), seismic detection, military surveillance, inventory tracking, smart spaces etc. In fact, due to the pervasive nature of micro-sensors, sensor networks have the potential to revolutionize the very way we understand and construct complex physical system [3].

II. CHALLENGES

In spite of the diverse applications, sensor networks pose a number of unique technical challenges due to the following factors:

- **Adhoc deployment:** Most sensor nodes are deployed in regions which have no infrastructure at all. A typical way of deployment in a forest would be tossing the sensor nodes from an aero-plane. In such a situation, it is up to the nodes to identify its connectivity and distribution.
- **Unattended operation:** In most cases, once deployed, sensor networks have no human intervention. Hence the nodes themselves are responsible for reconfiguration in case of any changes.
- **Untethered:** The sensor nodes are not connected to any energy source. There is only a finite source of energy, which must be optimally used for processing and communication. An interesting fact is that communication dominates processing in energy consumption. Thus, in order to make optimal use of energy, communication should be minimized as much as possible.
- **Dynamic changes:** It is required that a sensor network system be adaptable to changing connectivity (for e.g., due to the addition of more nodes, failure of nodes etc.) as well as change environmental stimuli.

Thus, unlike traditional networks, where the focus is on maximizing channel throughput or minimizing node deployment, the major consideration in a sensor network is to extend the system lifetime as well as the system robustness [4].

III. SURVEY FOCUS

A number of papers propose solutions to one or more of the above problems. Researcher survey focuses on the suggested solutions in the following areas:

Energy Efficiency: Energy efficiency is a dominant consideration no matter what the problem is. This is because sensor nodes only have a small and finite source of energy. Many solutions, both hardware and software related, have been proposed to optimize energy usage.

Localization: In most of the cases, sensor nodes are deployed in an ad hoc manner. It is up to the nodes to identify themselves in some spatial coordinate system. This problem is referred to as localization.

Routing: Communication costs play a great role in deciding the routing technique to be used. Traditional routing schemes are no longer useful since energy considerations demand that only essential minimal routing be done. Besides the above topics, we will also look at some proposed sensor network systems. We also have a quick look at some of the simulators available today for simulating sensor networks.

IV. ARCHITECTURE

To have a general idea of the kind of architectures and operating systems which are suitable for sensor networks, we give an example of each[5]. Proposes a middleware architecture called SINA (Sensor Information Networking Architecture). The architecture has the following components.

Hierarchical clustering: The sensor nodes are organized into a hierarchy, based on their power levels and proximity. A cluster head is elected to perform various functions; with the abilityto re-initiation should the cluster head veil.

Attribute-based naming: The sensor nodes are named based on their attributes. For example, consider a system which is used to measure temperature at a particular location. Then, the name [type=temperature, location=N-E, temperature=103] refers to all the sensors located at the northeast quadrant with a temperature reading of 103F. Thus, they can reply when a query like "which area has a temperature more than 100F" is posed. Such a scheme works because the nodes are by themselves neither unique nor dependable. So, applications access a particular data element by naming it directly. This approach has another advantage in that it eliminates the need for maintaining mapping/directory services, which is an extra overhead.

Most sensor data are associated with the physical context of the phenomena being sensed. Hence spatial coordinates are a natural way to name data. This makes localization - determination of the position of the node in some coordinate system - an important problem.

The SINA architecture proposes Sensor Query and Tasking language (SQTL) as the programming interface between sensor applications and SINA middleware. The SQTL defines three events: receive, query and expire. An SQTL message consisting of a script should be interpreted and executed by any node in the network. The authors have described some sample applications like co-coordinated vehicle tracking which can be carried out using the nodes built using the SINA architecture.

TinyOS [6] is a component-based operating system that is specially designed for sensor networks. [7] Describes an active message communication model using TinyOS which can be used as a building block for carrying out higher level networking capabilities.

V. ENERGY EFFICIENCY

Energy consumption is the most important factor to determine the life of a sensor network because usually sensor nodes are driven by battery and have very low energy resources. This makes energy optimization more complicated in sensor networks because it involved not only reduction of energy consumption but also prolonging the life of the network as much as possible. This can be done by having an energy awareness in every aspect of design and operation. This ensures that energy awareness is also incorporated into groups of communicating sensor nodes and the entire network and not only in the individual nodes.

A sensor node usually consists of four sub-systems [8]:

- A **computing** subsystem: It consists of a microprocessor (microcontroller unit, MCU) which is responsible for the control of the sensors and execution of communication protocols. MCU's usually operate under various operating modes for power management purposes. But shuttling between these operating modes involves consumption of power, so the energy consumption levels of the various modes should be considered while looking at the battery lifetime of each node.
- A **communication** subsystem: It consists of a short range radio which is used to communicate with neighboring nodes and the outside world. Radios can operate under the Transmit, Receive, Idle and Sleep modes. It is important to completely shut down the radio rather than put it in the Idle mode when it is not transmitted or receiving because of the high power consumed in this mode
- A **sensing** subsystem: It consists of a group of sensors and actuators and links the node to the outside world. Energy consumption can be reduced by using low power components and saving power at the cost of performance which is not required.
- A **power supply** subsystem: It consists of a battery which supplies power to the node. It should be seen that the amount of power drawn from a battery is checked because if high current is drawn from a battery for a long time, the battery will die even though it could have gone on for a longer time. Usually the rated current capacity of a battery being used for a sensor node is lesser than the minimum energy consumption required leading to the lower battery lifetimes. The lifetime of a battery can be increased by reducing the current drastically or even turning it off often.

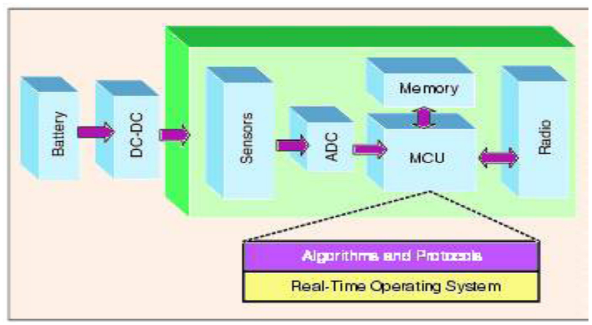

Figure 1. System architecture of a typical wireless sensor node

The power consumed by the sensor nodes can be reduced by developing design methodologies and architectures which help in energy aware design of sensor networks. The lifetime of a sensor network can be increased significantly if the operating system, the application layer and the network protocols are designed to be *energy aware*. Power management in radios is very important because radio communication consumes a lot of energy during operation of the system. Another aspect of sensor nodes is that a sensor node also acts a router and a majority of the packets which the sensor receives are meant to be forwarded. Intelligent radio hardware that helps in identifying and redirecting packets which need to be forwarded and in the process reduce the computing overhead because the packets are no longer processed in the intermediate nodes.

Traffic can also be distributed in such a way as to maximize the life of the network. A path should not be used continuously to forward packets regardless of how much energy is saved because this depletes the energy of the nodes on this path and there is a breach

in the connectivity of the network. It is better that the load of the traffic be distributed more uniformly throughout the network.
It is important that the users be updated on the health of a sensor network because this would serve as a warning of a failure and aid in the deployment of additional sensors. Younggang Zhao *et al*. [9] Propose a mechanism which collects a residual energy scan(**eScan**) of the network which is an aggregated picture of the energy levels in the different regions of the sensor network. They also propose to use incremental updates to scans so that when the state of a node changes, it does not have to send its entire scan again thereby saving energy.

VI. LOCALIZATION

In sensor networks, nodes are deployed into an unplanned infrastructure where there is no *a priori* knowledge of location. The problem of estimating spatial-coordinates of the node are referred to as localization. An immediate solution which comes to mind is GPS [10] or the Global Positioning System. However, there are some strong factors against the usage of GPS. For one, GPS can work only outdoors. Secondly, GPS receivers are expensive and not suitable in the construction of small cheap sensor nodes. A third factor is that it cannot work in the presence of any obstruction like dense foliage etc. Thus, sensor nodes would need to have other means of establishing their positions and organizing themselves into a coordinate system without relying on an existing infrastructure.

Most of the proposed localization techniques today, depend on recursive Trilalteration/multi-alteration techniques [11]. One way of considering sensor networks is taking the network to be organized as a hierarchy with the nodes in the upper level being more complex and already knowing their location through some technique (say, through GPS). These nodes then act as beacons by transmitting their position periodically. The nodes which have not yet inferred their position, listen to broadcasts from these beacons and use the information from beacons with low message loss to calculate its own position. A simple technique would be to calculate its position as the centroid of all the locations it has obtained. This is called as proximity based localization. It is quite possible that all nodes do not have access to the beacons. In this case, the nodes which have obtained their position through proximity based localization themselves act as beacons to the other nodes. This process is called iterative multi-lateration. As can be guessed, iterative multi-lateration leads to accumulation of localization error.

Since most of the localization algorithms use some form of trilateration, a brief overview of trilateration based on[12], is given. Consider a person A, who wants to determine his position in 2-D space. Suppose A knows that he is 10kms from a point x. Then he can determine that he is anywhere on the circle of radius 10kms around the point x. Now, if A also knows that he is 20 kms from a point y, A can deduce that he is on either one of the two intersecting points of the circle of radius 10km around x and the circle of radius 20km around point y. Suppose A also has additional information that he is 15km from a point z. Now he knows at which of the two intersecting points he is one because only one of them will intersect with the third circle also. This is shown in figure 2 [12] below. Let x be Boise, y be Minneapolis and z be Tucson.

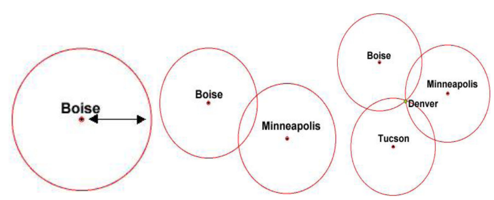

Figure 2. Principle of trilateration in 2-D space

Thus, trilateration is a geometric principle which allows us to find a location if its distance from other already-known locations are known. The same principle extends to three-dimensional space. In this case, spheres instead of circles are used and

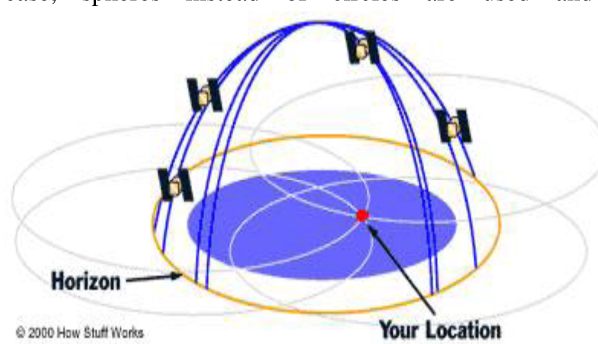

Figure 3: Principle of trilateration in 3-D space as used in GPS.

four spheres would be needed. This is the principle used in GPS also. Figure 3 [12] demonstrates trilateration in 3-D space as used in GPS.

When a localization technique using beacons is used, an important question would be 'how many initial beacons deploy'. Too many beacons would result in self-interference among the beacons while too less number of beacons would mean that many of the nodes would have to depend on iterative multi-lateration. Many papers research techniques to solve this problem. An associated problem would be to decide the total number of sensor nodes required in a given area. That is, determining the network density. [11] Defines network density as:

$$\mu (R) = (N \cdot \pi \cdot R2) / A$$

Where, N is the number of nodes in a region of area A whose nominal range is given by R. Beyond a critical value λ, addition of extra nodes does not provide additional sensing nor coverage fidelity. Hence techniques would be required to decide optimum deployment.

VII. ROUTING

Conventional routing protocols have several limitations when being used in sensor networks due to the energy constrained nature of these networks. These protocols essentially follow the flooding technique in which a node stores the data item it receives and then sends copies of the data item to all its neighbors. There are two main deficiencies of this approach [13].

Implosion: If a node is a common neighbor to nodes holding the same data item, then it will get multiple copies of the same data item. Therefore, the protocol wastes resources sending the data item and receiving it.

Resource management: In conventional flooding, nodes are not resource-aware. They continue with their activities regardless of the energy available to them at a given time.

The routing protocols designed for sensor networks should be able to overcome both these deficiencies or/and look at newer ways of conserving energy increasing the life of the network in the process. Ad-hoc routing protocols are also unsuitable for sensor networks because they try to eliminate the high cost of table updates when there is high mobility of nodes in the network. But unlike ad-hoc networks, sensor networks are not highly mobile. Routing protocols can be divided into proactive and reactiveprotocols. Proactive protocols attempt at maintaining consistent updated routing information between all the nodes by maintaining one or more routing tables. In reactive protocols, the routes are only created when they are needed. The routing can be either source-initiated or destination-initiated.

VIII. CONCLUSION

Sensor Networks hold a lot of promise in applications where gathering sensing information in remote locations is required. It is an evolving field, which offers scope for a lot of research. Their energy-constrained nature necessitates us to look at more energy efficient design and operation. We have done a survey of the various issues in sensor networks like energy efficiency, routing and localization. Further work is the various schemes proposed for these issues and have given brief descriptions of these schemes.

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