IOSR Journal of Computer Engineering (IOSR-JCE)
ISSN: 2278-0661, ISBN: 2278-8727, PP: 45-52
www.iosrjournals.org

Quality of Service in Wireless Sensor Networks: Issues and Challenges

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ABSTRACT: *Recent advances in wireless communications and electronics have enabled the development of low cost, low-power, multifunctional wireless sensor nodes that are small in size and communicate in short distances. The sensor networks can be used for various application areas (e.g., habitat monitoring, health, military applications etc). An efficient deployment of Wireless Sensor Network depends on successful implementation of Quality of Service (QoS) framework. The current state of the art of wireless sensor networks is captured in this article, where solutions are discussed under their related protocol stack layer sections. Various challenges in deployment of QoS framework is discussed in detail. This article also points out the open research issues and intends to focus on new interests and developments in this field.*

Keywords *- Sensor Network, WSN (Wireless Sensor Network), Sensor Management Protocol, Communication Architecture.*

I. INTRODUCTION

Sensor networks for the collection, fusion, and communication of environmental information are considered to have an outstanding potential for research and application [1].Basically, sensor networks are defined by the combination of miniaturized sensors with communication technology. Possible applications for sensor networks include the measurement of temperature/humidity, the collection of pollution data, the monitoring of weaknesses in building structures, and the detection of chemical agents, to name a few. A main advantage of distributed and collaborative measurements includes the non-obtrusiveness and the increased accuracy of the data collection. These applications demand for smart but cheap sensors, which operate self organized even under harsh environmental conditions [2-3].

Currently, sensor networks are considered to evolve towards so-called “smart dust” if technological advance permits such miniaturization. However, severe limits, for instance, in energy supply, costs, maintenance of once deployed sensor nodes and reliability of operation persist. These and other limits are especially important for the communication aspects of sensor networks as we show later. These tiny sensor nodes, which consist of sensing, data processing, and communicating components, leverage the idea of sensor networks. Sensor networks represent a significant improvement over traditional sensors. A sensor network is composed of a large number of sensor nodes that are densely deployed either inside the phenomenon or very close to it. The position of sensor nodes need not be engineered or predetermined. This allows random deployment in inaccessible terrains or disaster relief operations. On the other hand, this also means that sensor network protocols and algorithms must possess self-organizing capabilities. Another unique feature of sensor networks is the cooperative effort of sensor nodes. Sensor nodes are fitted with an onboard processor. Instead of sending the raw data to thenodes responsible for the fusion, they use their processing abilities to locally carry out simple computations and transmit only the required and partially processed data [4].

II. CHARACTERISTICS OF SENSOR NETWORK

Wireless Sensor network is one of the important and current topic of research in communication networks. Application goals often include adaptability and high sensing fidelity. The network should be fault tolerant, energy efficient, and low cost. As a consequence, one faces various trade-offs in designing sensor networks, some of which are also reflected in the design of the routing system[5].

The specific characteristics of sensor networks are:

• *Limited resources* (energy supply, bandwidth, power, memory size, etc.).

• *Restricted manageability* (unattended after deployment, hostile environments, self-configurability, etc.).

• *Large scale* (possibly millions of nodes, rapid deployment, geographical awareness, etc.).

• *Special requirements* (different communication patterns data centric vs. node centric, simplicity, fault tolerance, physical robustness, low cost, etc.).

• *Heterogeneity* (in application, in sensing, in computing, in communications, in connectivity, etc.).

• *Different quality metrics* (sensor fidelity, quality of information, dependability, etc.).

Compared to traditional networks, sensor networks exhibit fairly different characteristics and quality metrics. Because of the high integration of the sensor nodes and the very specific application goals, there is no one size fits all solution but the diversity in characteristics commands the routing mechanisms [6].

III. APPLICATIONS OF WIRELESS SENSOR NETWORKS

The above-described features ensure a wide range of applications for sensor networks. Some of the application areas are habitat monitoring, environment control, health, military, and home. In military, for example, the rapid deployment, self-organization, and fault tolerance characteristics of wireless sensor networks make them a very promising sensing technique for military command, control, communications, computing, intelligence, surveillance, reconnaissance, and targeting systems. In health, sensor nodes can also be deployed to monitor patients and assist disabled patients. Some other commercial applications include *managing inventory*, *monitoring product quality*, and *monitoring disaster areas*. Realization of these and other sensor network applications require wireless ad hoc networking techniques and Quality of Service (QoS) support. Although many protocols and algorithms have been proposed for traditional wireless ad hoc networks, they are not well suited to the unique features and application requirements of sensor networks. To illustrate this point, the differences between sensor networks and ad hoc networks are:

• The number of sensor nodes in a sensor network can be several orders of magnitude higher than the nodes in an ad hoc network.
• Sensor nodes are densely deployed.
• Sensor nodes are prone to failures.
• The topology of a sensor network changes very frequently.
• Sensor nodes mainly use a broadcast communication paradigm, whereas most ad hoc networks are based on point-to-point communications.
• Sensor nodes are limited in power, computational capacities, and memory.
• Sensor nodes may not have global *identification* (ID) because of the large amount of overhead and large number of sensors.

Many researchers are currently engaged in developing schemes that fulfill these requirements [6,7]. A survey of protocols and algorithms proposed with current research issues in this emerging field for sensor networks is presented. An investigation into pertaining design constraints and outline the use of certain tools to meet the design objectives is also presented next.

IV. COMMUNICATION ARCHITECTURE

The wireless sensor nodes are usually scattered in a *sensor field.* Each of these scattered and route data back to the *sink*. Data are routed back to the sink by a multihop infrastructure less architecture through the sink as shown in Fig. 1

The sink may communicate with the *task manager node* via Internet or satellite. The design of sensor network as described by Fig. 1 is influenced by many factors, including *fault tolerance*, *scalability*, *production costs*, *operating transmission media*, and *power consumption*. *environment*, *sensor network topology*, *etc.*

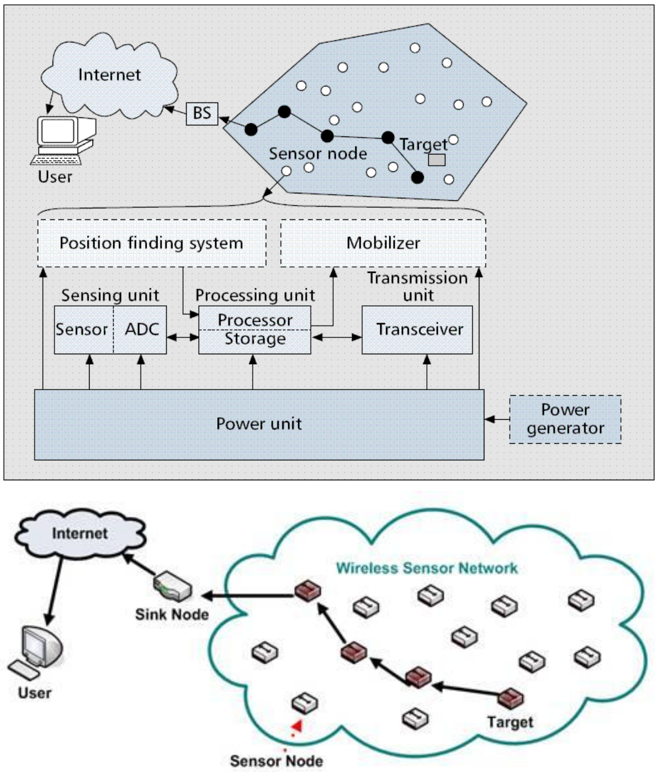

Figure 1 : A basic architecture of Wireless Sensor Network.

V. PROTOCOL STACK

1. The Physical Layer

The physical layer is responsible for frequency selection, carrier frequency generation, signal detection, modulation, and data encryption. Thus far, the 915 MHz industrial, scientific, and medical (ISM) band has been widely suggested for sensor networks. Frequency generation and signal detection have more to do with the underlying hardware and transceiver design.

2. The Data Link Layer

The data link layer is responsible for the multiplexing of data streams, data frame detection, and medium access and error control. It ensures reliable point-to-point and point-to-multipoint connections in a communication network.

3. Medium Access Control

The MAC protocol in a wireless multihop self-organizing sensor network must achieve two goals. The first is the creation of the network infrastructure. Since thousands of sensor nodes are densely scattered in a sensor field, the MAC scheme must establish communication links for data transfer. This forms the basic infrastructure needed for wireless communication hop by hop and gives the sensor network self-organizing ability. The second objective is to fairly and efficiently share communication.

Error Control

Another important function of the data link layer is the error control of transmission data.

Two important modes of error control in communication networks are forward error correction (FEC) and automatic repeat request (ARQ). The usefulness of ARQ in multihop sensor network environments is limited by the additional retransmission energy cost and overhead [7,8].

4. Network Layer

Sensor nodes are scattered densely in a field either close to or inside the phenomenon, as shown in Fig. 1. As discussed in the first section, special multihop wireless routing protocols between the sensor nodes and the sink node are needed. Traditional ad hoc routing techniques do not usually fit the requirements of the sensor networks due to the reasons explained earlier. The networking layer of sensor networks is usually designed according to the following principles:

• Power efficiency is always an important consideration.

• Sensor networks are mostly data-centric.

• Data aggregation is useful only when it does not hinder the collaborative effort of the sensor nodes.

• An ideal sensor network has attribute-based addressing and location awareness.

5. Transport Layer

The need for a transport layer is pointed out in the literature [4]. This layer is especially needed when the system is planned to be accessed through the Internet or other external networks. However, to the best of our knowledge there has been no attempt thus far to propose a scheme or discuss the issues related to the transport layer of a sensor network in literature [8].

6. Application Layer

To the best of our knowledge, although many application areas for sensor networks are defined and proposed, potential application layer protocols for sensor networks remain a largely unexplored region. In this survey, we examine three possible application layer protocols: Sensor Management Protocol (SMP), Task Assignment and Data Advertisement Protocol (TADAP), and Sensor Query and Data Dissemination Protocol (SQDDP), needed for sensor networks based on the proposed schemes related to the other layers and sensor network application areas. All of these application layer protocols are open research issues.

Sensor Management Protocol

Designing an application layer management protocol has several advantages. Sensor networks have many different application areas, and accessing them through networks such as the Internet is aimed at in some current projects [6]. An application layer management protocol makes the hardware and software of the lower layers.

Task assignment and Data advertisement Protocol.. Another important operation in the sensor networks is interest dissemination. Users send their interest to a sensor node, a subset of the nodes, or the whole network.

This interest may be about a certain attribute of the phenomenon or a triggering event. Another approach is the advertisement of available data in which the sensor nodes advertise the available data to the users, and the users query the data in which they are interested. An application layer protocol that provides the user software with efficient interfaces for interest dissemination is useful for lower-layer operations, such as routing, explained in an earlier section [9,10].

VI. QOS REQUIREMENTS IN WSN

The QoS requirements in conventional data networks and WSN is different in many aspects because of their characteristics and interaction with physical environment.The various QoS requirements are depited in Figure 2. This imposes challenges in achieving desired QoS. Some of these issues and challenges are given below:

1. Energy Efficient Protocol Design : Sensor nodes are employed in remote locations with limited power capacity. Replacement of power sources is not easily possible. When the energy level of a node decreases, it may stop functioning and the communication between node and base station ceases. A situation may arise when some nodes may not be able to communicate with each other. This situation is also called as network partitioning, where some part of the network is detached from remaining part of network. If partitioning is bigger in size and last for long time, the entire WSN may become useless. Under this situation, it becomes a primary requirement for QoS that WSN design should have energy efficient protocols.

2. Scalability: This is one of the important issue in design of WSN for fulfilling QoS requirements. Since a network is spread over a large geographic area, the protocol should be scalable in terms of coverage and density of sensor nodes.

3. Self Configuration : Conditions like node failures, link failures, mobility of nodes, node state transition impose and additional requirement on nodes and protocol design which must be self configuring and self maintaining in nature. This dynamic nature of Sensor Network increases the complexity of QoS support.

4. Unbalanced Traffic : The flow of traffic in sensor network is highly unbalanced. Most of the traffic flow is from thousands of sensor nodes to the sink node and less traffic from sink node to sensor nodes. QoS mechanisms should be designed for such unbalanced and continuously changing traffic loads.

5. Redundancy in Data Transmission : A bulk amount of data is transmitted from sensor nodes which is many times redundant in nature and not useful. Some mechanism is necessary either in sensor nodes or protocol for data aggression or data fusion. Redundant data transmission consumes resources like bandwidth, buffer space and processing capabilities. Mechanism to support QoS should avoid data redundancy.

6. Energy Management: A sensor node consists of a sensing unit, a processing unit, a transceiver and a power unit. All these components are assembled in a small unit which has limitations of low processing power, low transmission rates and a limited power source. The unbalanced load on processing power and transmission of data will result in unbalanced energy requirements. The energy load must be evenly distributed among all sensor nodes for their best performance and long life of sensor network. QoS provisioning mechanism must incorporate these energy management factors into account.

7. Heterogeneous Traffic : The sensors for different sensing applications have different features in terms of data transmission rates, processing of data and energy requirements. The mix traffic of sensors monitoring pressure, humidity, temperature etc. have different traffic characteristics which must be taken into account while providing QoS support to WSN.

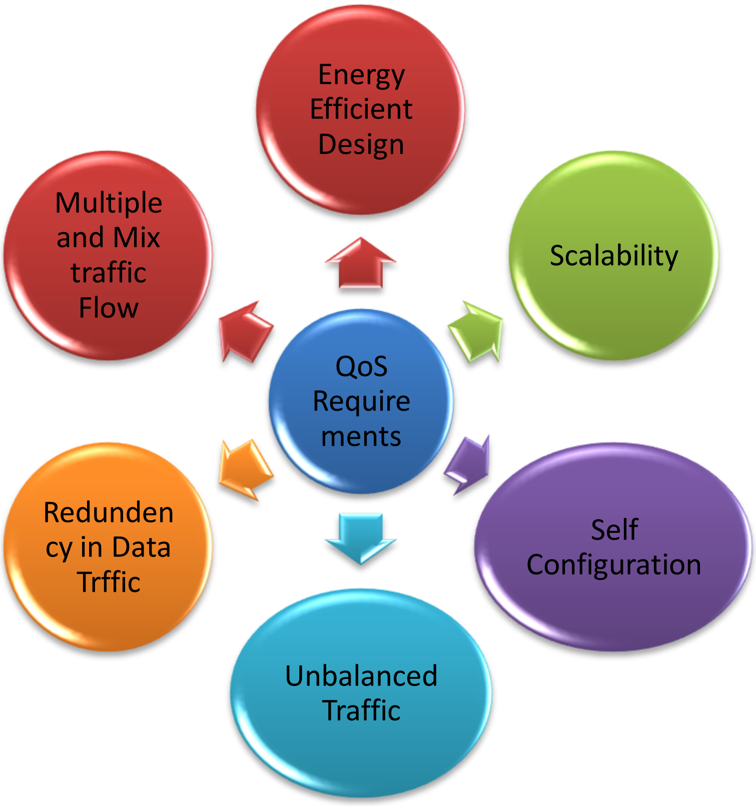

Figure 2 : Various Requirements of QoS for WSN.

VII. RESEARCH ISSUES IN ACHIEVING QOS

The QoS support as provided in traditional data networks such as Asynchronous Transfer Mode or Internet models such as Interserv or Diffserv are not applicable in WSN because traditional network provide over provisioning of resources or policing mechanisms. Because one of the important constraints in WSN along with bandwidth utilization is critical energy management at sensor nodes. Unnecessary energy consumption is to be eliminated in WSN. Issues and challenges discussed in above section such as scalability, data redundancy, self configuration nature, link failure and limited resources imposes challenges in designing QoS framework for WSN [10]. The open research issues for achieving QoS is depicted in Figure 3.Following research issues and QoS framework requirements are identified considering these challenges.

1.Simple QoS Models: The complexity of traditional models be eliminated while maintaining operational simplicity. Cross layer design may be useful in this case.

2.Hardware Constraints and mix traffic : The criteria for service differentiation be clearly defined. Some of the parameters are traffic type, mix of traffic models, sensor types, content of data or application types. Clearly, the traffic classes must be limited because of limited memory and processing capabilities. Many data flows are not feasible in a given node. One of the objective is to obtain desired QoS and maximum utilization of resources including energy available.

3.Model considering data redundancy and delay: Data Redundency is major issue in WSN protocol design. Data Fusion and Fragmentation can be used which introduces additional delay. This may deteriorate performance. A proper mechanism to reduce delay and minimizing data redundancy is one of the requirement for achieving QoS.

4.Protocol Design considereing QoS requirements: Some of the important design issues in data dissemination protocols are : data fusion, data aggregation, traffic classification and priority of traffic flows, energy management and network dynamics including unbalanced load. The protocols designed for WSN must be QoS centric i.e. all QoS requirement issues must be incorporated in protocol design [9.10].

5.Service Differentation : The services provided by WSN are mainly non end-to-end services rather than end to end services as provided in traditional data networks. Traditional services such as best effort service, guaranteed and differentiated services may not be feasibele in context of WSN. Newservice clases satisfying QoS requirements is important design issue in WoS framework.

6.QoS Control Mechanism: In spite of centralized QoS control, a distributed QoS control mechanism is needed. Sensor nodes transmit excessive and bulk duplicate data or data with less importance to sink node. Some distributed mechanism or intelligence in sensor node network will ensure the required information is transmitted in network. Thereby, reducing burden on centralized control mechanism.

Figure 3 : Various Research Issues in WSN.

VIII. CONCLUSION

The flexibility, fault tolerance, high sensing fidelity, low cost, and rapid deployment characteristics of wireless sensor networks create many new and exciting application areas and challenges in remote sensing. In the future, this wide range of application areas will make wireless sensor networks an integral part of our lives. However, realization of sensor networks needs to satisfy the constraints introduced by factors such as fault tolerance, scalability, cost, hardware limitations, topology change, network dynamics, and power management. One of the important constraints is QoS support for various challenging issues of WSN. Since these constraints are highly stringent and specific for sensor networks, new wireless ad hoc networking techniques are required. Many researchers are currently engaged in developing the technologies needed for different layers of the sensor networks protocol stack, Along with the current research projects, we encourage more insight into the challenges is QoS support and intend to motivate a search for solutions to the open research issues described in this research paper.

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