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A STUDY ON ISSUES AND CHALLENGES TO ACHIEVE BETTER QOS IN WIRELESS SENSOR NETWORKS

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ABSTRACT

Wireless Sensor Networks (WSNs) are used in variety of fields which includes military, healthcare, environmental, biological, home and other commercial applications. The adoption of WSNs by specific applications that require complex operations, ranging from health care to industrial monitoring, has brought forward a new challenge of fulfilling the quality of service (QoS) requirements of these applications. However, providing QoS support is a challenging issue due to highly resource constrained nature of sensor nodes, unreliable wireless links,dynamic network topology and distributed architecture. We explore QoS challenges and perspectives for Wireless Sensor Networks, compare the current QoS research issues and classify the state of the art QoS-aware protocols to understand the properties and limitations of existing protocols.

KEYWORDS: Congesiton, QoS Challenges, QoS issues, QoS mechanisms, Routing, Wireless Sensor Networks

INTRODUCTION

Wireless Sensor Networks have low-power and low-cost sensor nodes that are communicating through a wireless radio interface. These sensor nodes are often battery powered and hence energy is a scarce resource. Wireless Sensor Networks consist of a large number of small scale sensor nodes that are capable of limited computation, wireless communication and sensing. Each sensor node acts like a router which inturn consists of a transducer, micro-computer, transceiver and power source [1].

These networks monitor and record conditions in various applications like temperature, pressure, wind speed, illumination intensity, voltages and chemical concentrations. The nodes in a sensor network collaborate to perform a common task like signal processing of collected sensor data. The transducer generates electrical signals based on the sensed physical quantities, the microcomputer processes and stores the sensor output. The transceiver receives instructions from a central computer and transmits data to that computer. These devices are equipped with a processor and wireless communication antenna and are powered with a battery. Some of the applications of sensor networks are: Video Surveillance, Traffic monitoring, Medical device monitoring, air traffic control, monitoring of weather conditions and so on.

Wireless Sensor Networks (WSNs) have been utilized in many applications like infrastructure and distributed data generation network due to their ubiquitous and flexible nature. A large number of WSN applications require real-time quality-of-service (QoS) [5]. Such QoS requirements usually depend on two common parameters: timing and reliability. The resource constraints of WSNs, limit the extent to which these requirements can be guaranteed.

Motivation

Emerging applications of Wireless Sensor Networks (WSNs) require real-time quality-of-service (QoS) to be provided by the network. Due to the nondeterministic impacts of the wireless channel and queuing mechanisms, probabilistic analysis of QoS is essential**.** QoS has been defined as a set of service requirements to be fulfilled during the transmission of packets from the source to the destination. In traditional data network, the QoS requirements in

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WSNs such as data accuracy, aggregation delay, coverage, fault tolerance and network lifetime etc. are application specific and they are different from traditional end-to-end QoS. The QoS protocols have to address various requirements like timeliness, reliability, energy consumption, bandwidth, delay, throughput, latency etc.

ISSUES IN WIRELESS SENSOR NETWORKS

The major issues that affect the design and performance of a Wireless Sensor Network are

- *Localization :* Sensor localization is a fundamental and crucial issue for network management and operation. In many of the real world applications, the sensors are deployed without knowing their positions in advance and also there is no supporting infrastructure available to locate and manage them once they are deployed.
- *Calibration:* Calibration is the process of adjusting the raw sensor readings obtained from the sensors into corrected values by comparing it with some standard values.
- *Quality of Service*: Quality of service is the level of service provided by the sensor networks to its users. Quality of Service (QoS) for sensor network is the optimum number of sensors sending information towards information collecting sinks.
- *Data aggregation*: During data gathering the sensor nodes periodically, sense the data from the surrounding environment, process it and transmit it to the base station .
- *Synchronization:* Clock synchronization is an important service in sensor networks. Time Synchronization in a sensor network aims to provide a common timescale for local clocks of nodes in the network. A global clock in a sensor system will help process and estimate the data correctly and predict future system behavior.

LITERATURE SURVEY

In recent years, there has been a growing interest in Wireless Sensor Networks (WSN). Recent advancements in the field of sensing, computing and communications have attracted researchers towards the field of WSNs. An overview of the basics of Wireless Sensor Networks, issues, challenges are discussed in [1-2]. Xiaoxia Huang et al., [3] utilize multiple paths between the source and sink pairs for QoS provisioning and have proposed a probabilistic model of link state for Wireless Sensor Networks. Based on this model, an approximation of local multipath routing algorithm is explored to provide QoS under multiple constraints, such as delay and reliability.

Jianwei et al., [4] have presented R3E, which can augment most existing reactive routing protocols in WSNs to provide reliable and energy-efficient packet delivery against the unreliable wireless links. It can effectively improve robustness, end-to-end energy efficiency and latency. Cheng et al., [5] have exploited the *Geographic Opportunistic Routing* (GOR) for multi constrained QoS provisioning in WSNs, which is more suitable than the multipath routing approach. Further, an *Efficient QoS-aware GOR* (EQGOR) algorithm is proposed for QoS provisioning in WSNs. EQGOR achieves a good balance between these multiple objectives and has very low time complexity.

In order to maintain better QoS under failure conditions, identifying and rectifying such faults are essential. Ravindra et al., [6] have proposed a method in which faulty sensor node is detected by measuring the round trip delay (RTD) time of discrete round trip paths and comparing them with threshold value. Yuli et al., [7] have proposed partial quality-of-service (QoS)-oriented relay selection scheme with a decode-and-forward (DF) relaying protocol, to reduce the feedback amount required for relay selection. The activated relay is the one with the maximum Signal-to-Noise power Ratio (SNR) in the second hop among those whose packet loss rates (PLRs) in the first hop achieve a predetermined QoS level.

Samina et al., [8] have developed a crosslayer techniques suitable for Wireless Sensor Networks (WSNs) that are capable of multichannel access. More specifically, energy and cross-layer aware routing schemes are proposed for multichannel access WSNs that account for radio, MAC contention and network constraints**.** Yunbo et al., [9] have developed a comprehensive cross-layer analysis framework, which employs a stochastic queueing model in realistic channel environments. This framework is generic and can be parameterized for a wide variety of MAC protocols and routing protocols which effects various network parameters like end-to-end delay. The developed framework can be used to guide the development of QoS-based scheduling and communication solutions for WSNs.

Fenye et al., [10] have proposed a hierarchical dynamic trust management protocol for cluster-based Wireless Sensor Networks, considering two aspects of trustworthiness, namely, social trust and QoS trust. A probabilistic model is developed for utilizing stochastic Petri nets techniques to analyze the protocol performance and validated subjective trust against objective trust obtained based on ground truth node status. Zheng et al., [11] have proposed COEQ protocol which can balance coding opportunities, energy and QoS in WSNs. It takes into account the potential coding opportunities, minimum energy, link delivery ratio and delay comprehensively to select an optimal path. Irfan et al., [13] presented a general overview of the state of art on cross-layer QoS approaches for delay and reliability critical applications.

Chen et al., [14] have developed an adaptive fault-tolerant QoS control (AFTQC) algorithm which incorporates path and source redundancy mechanisms to satisfy query QoS requirements while maximizing the lifetime of query-based sensor networks. Alwan H et al., [16] have proposed a mechanism for QoS routing with coding and selective encryption scheme for WSNs. This approach provides reliable and secure data transmission and can adapt to the resource constraints of WSNs. The original message is split into packets that are coded and selectively encrypted before being transmitted along different disjoint paths.

Mohammed et al., [17] have developed a mathematical model which uses Lagrangian relaxation mixed integer programming technique to define critical parameters and appropriate objective functions for controlling adaptive QoS constrained route discovery process. Performance trade-offs between QoS requirements and energy efficiency were simulated using the LINGO mathematical programming language. The proposed approach significantly improves the network lifetime, while reducing energy consumption and decreasing average end-to-end delays within the sensor network via optimised resource sharing in intermediate nodes.

Feng et al., [18] discusses the requirements, critical challenges and open research issues related to QoS management in WSNs. Sankarasubramaniam et al., [24] proposes a new reliable transport scheme Event to Sink Reliable Transport (ESRT) for WSNs. ESRT is a novel transport solution developed to achieve reliable event detection in WSN with minimum energy expenditure and their solution is based on a non-end-to-end concept. The solution includes a congestion control component that serves the dual purpose of achieving reliability, conserving energy and reliability of event detection that is controlled by the sink which has more power than sensors.

Javad et al., [20] discuss the Quality of Service (QoS) requirements in WSNs and present a survey of some of the QoS multi-parameters metrics in WSNs. Also, it gives the performance of 802.15.4, LEACH and CBRP protocol considering parameters. Hamid et al., [21] presents Effective Life time-Aware Routing in Wireless Sensor Networks. This method determines the network resource specifications such as the number of available nodes and their sensing spatial coverage. The sensing problem is addressed and analysed for various layers of the network. By using the solutions of various linear programming equations, normalized network lifetime can be calculated for various network environments.

Leandro et al., [22] proposes Data Routing for In-Networking Aggregation (DRINA): A Lightweight and Reliable Routing Approach for In-Network Aggregation in Wireless Sensor Networks which reduces the energy consumption of various high density nodes. Data fusion and data aggregation methods can remove the redundancy in the data and can reduce the energy consumption and cost. Hence, reduced number of messages are used for setting up a routing tree, maximized number of overlapping routes, high aggregation rate, reliable data aggregation and transmission. The algorithm includes the Information Fusion-based Role Assignment (InFRA) and Shortest Path Tree (SPT) algorithms. These algorithms provide good performance in aggregation of data.

QOS CHALLENGES IN WSNS

Although WSNs offers a great deal of advantages and features which makes them preferred tools to monitor and control different environments, they suffer from limitations related to their hardware and communication features. Conventional wireless networks face traditional challenges when implementing QoS mechanisms. These challenges include time varying channels and unreliable wireless links. On the other hand, WSNs combine the challenges faced by conventional wireless network with a set of unique challenges due to the resource limited nature of the sensor devices. In this section

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we highlight and discuss some of these QoS challenges for WSNs which can be summarized as follows:

a**) Limited Resources:** WSNs suffer from limited resources which include limited energy availability, small bandwidth, low memory resources, limited processing capability and low transmission power. Any QoS mechanism implemented in a WSN needs to be careful about its energy consumption since sensor device are very much dependent on battery power and it may not be feasible to replace or recharge a sensor node battery due to the remote location of sensor nodes or the cost of replacing the batteries for hundreds or even thousands of nodes. Therefore, to design an efficient and practical QoS mechanism for a delay and reliability aware applications, computationally complex algorithms and protocols that require extensive communication overhead and considerable amount of memory should be avoided.

b) Traffic Asymmetry: Majority of the WSNs applications involve monitoring of an environment where traffic is mainly flowing from end sensor nodes to a sink node. The traffic from these end nodes to the sink could be transmitted in a periodic manner or aperiodic based on the monitoring application. This is also true for control applications where the flow is generally from sink to acuators. Thus, QoS mechanisms should consider traffic asymmetry or imbalanced flows especially in large WSNs where hundreds of nodes transmit to a handful number of sinks.

c) Dynamic Network Nature: Wireless networks in general and WSNs in particular are known to be highly dynamic in nature due to continuous topology changes and unreliable wireless links. A WSNs topology can change frequently due to node mobility, failure and addition of new nodes to the network. Wireless links are affected by the number of devices that share the same medium. In WSNs the link reliability can drop drastically when the number of device in a single Personal Area Network (PAN) increase abruptly (thousands of nodes) which makes the prediction of links failure very hard. Therefore, a QoS protocol should consider the unreliability of the wireless links and the dynamic network topology should not greatly increase the complexity of QoS support.

d) Redundant Data Transmission: Due to the distributed nature of WSNs where multiple sensor devices may report and transmit the same phenomena, data redundancy may take place especially in densely populated WSNs. In some situations, data redundancy may be desired to increase the system reliability. However, redundant data transmission may cause unnecessary power consumption. To solve this issue data aggregation or data fusion can be used to increase the reliability while maintaining acceptable power consumption levels. Data fusion and aggregation process can cause delays in packet delivery. This delay adds complexity and is an additional challenge to the QoS mechanism in WSNs. Therefore, a QoS mechanism should consider balancing between delay, redundancy and power consumption.

e) Scalability: Scalability is one of the major challenges that should be considered while designing an efficient QoS mechanism in WSNs. Most of the WSNs are composed of hundreds or thousands of sensor nodes. As the area of interest or requirements for the quality of observation increase, more sensor nodes need to be deployed. Therefore, designed QoS mechanism must scale well with highly dense or large scale networks.

f) Energy balancing: Energy efficiency is a key concern in WSNs protocol design. In some situations data packets may be routed in a shortest path to the destination to achieve the required QoS differentiation. This causes some sensor nodes to consume more power than other nodes in the PAN, this situation is especially true in a large network where the packet has to travel through multiple hops to reach the sink. The QoS mechanism should maintain a balance in the residual energy of each node along the path to the sink to maintain an acceptable power consumption level.

g) Multiple Sinks: Some WSN-based monitoring applications may require multiple sink nodes, especially in large and wide spread networks. For example: Consider a situation where multiple sinks located in different parts of the network and each sink gathers different information's from the sensor nodes. This multiple sink scenario imposes a challenge in implementing a QoS mechanism since it has to differentiate between different types of sinks and different traffic directions.

QOS REQUIREMENTS IN WSNS

The QoS protocols have to address various requirements like timeliness, reliability, energy consumption, bandwidth, delay, throughput, latency etc.

- *Reliability:* The transmission reliability is an important index of QoS, calculated to measure the probability of transmission failures and can be expressed in terms of data.

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- *Energy Consumption:* It is a measure of the energy required for data transmission, from any sensor node to the sink on a single path.
- *Bandwidth:* It is a measure of information carrying capacity of a network.
- *Delay Metric:* Delay is a measure of time elapsed from the departure of a data packet from the source node to the destination node.
- *Throughput :* It is defined as the time average of the number of bits that can be transmitted by each node to its destination.
- *Timeliness :* Timeliness refers to the occurrence of events at suitable instants of time. It evaluates the punctuality of the event.

Mechanisms to Achieve QoS in WSNs

In this section, we describe the existing mechanisms that have been proposed in the literature, which allow WSNs to achieve QoS.

(i*) Topology Management:* Most of the energy that is expended by a node is through transmission and sensing. To minimize the amount of energy that is consumed by a sensor node in the network, the nodes can be put to sleep mode when they are not required to sense or transmit data to their nearby nodes. Topology management can be used to achieve this dual goal of coordinating the sleep schedules of all the nodes, such that data can still be transmitted efficiently to the sink. This can be achieved by exploiting the high nodal density and high spatial correlation of the sensed data. As such, topology management helps to increase energy efficiency and increase network lifetime at the expense of higher latency, because nodes that are required for the data forwarding process may be in sleep mode during the transmission.[21]

(ii*) Localization:* Localization provides an alternative mechanism of finding the physical locations of the sensor nodes in the network instead of making use of GPS, which is costly and infeasible indoors. It usually involves two phases : (i) ranging, which is the distance estimation of the node from the sink or other nodes in the network using techniques such as signal strength, angle-of-arrival(AoA) etc and (ii) iterative multilateration, which makes use of the range measurements from the previous phase to estimate a new location. Hence, localization increases spatial accuracy, at the cost of higher overheads (and transmissions) which reduces energy efficiency.

(iii*) Controlled Mobility:* One of the main causes of performance deterioration in Wireless Sensor Networks is node mobility (due to influence from the environment) and random deployment of nodes (due to the denseness which nodes are usually deployed). As such, the resulting network topology is usually not optimized for the protocols which are designed for the network. To incorporate QoS in the sensor network, controlled mobility using mobile nodes or Unmanned Autonomous Vehicles (UAVs) can be used to deploy sensor nodes more efficiently to enhance connectivity and/or coverage.

(iv*) Data Aggregation and/or Fusion:* In data aggregation, data which is coming from different sources en route into a single data packet. This helps to reduce redundancy caused by spatial correlation of the sensed data and minimize the number of transmissions required to forward the information back to the sink. However, as data processing is required at some (or all) of the sensor nodes then aggregating data could potentially result in higher latency, which should be taken into consideration when designing data aggregation algorithm for use in wireless sensor networks. In data fussion data of different modalities such as pressure, salinity and temperature are combined before data is transmitted.

(v*) Network Topology:* Conventional Wireless Sensor Networks have a single centralized sink that is usually placed in a corner of the network and all the source nodes have to send data to the sink in a predominantly unilateral direction. Hence sensor nodes that are near the sink have to perform more data forwarding and packet transmissions, which leads to two undesired behaviors: (i) increased contention and collisions near the sink; and (ii) nodes that are near the sink will drain up their energy faster, which results in shorter network lifetime.

(vi*) Cross-Layer Designs:* Although traditional networking paradigms promote the usage of a multi-layered protocol stack in which different layers have minimal impact on each other, where optimal performance is not achived. Cross layer designs such as that proposed by Chen et al., [14] help to improve network performance by sharing information across the different layers at the cost of eliminating the interdependency between adjacent layers.

vii*) Security:* Security in sensor networks is an important factor as performance and low energy consumption in many applications. Security in a sensor network is very challenging as WSN is not only being deployed in battlefield applications but also for surveillance, building monitoring, burglar alarms and in critical systems such as airports and hospitals.

viii) *Synchronization:* Time Synchronization in a sensor network aims to provide a common timescale for local clocks of nodes in the network. A global

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clock in a sensor system will help to process and analyze the data correctly and predict future system behavior. Some applications that require global clock synchronization are environment monitoring, navigation guidance, vehicle tracking etc[25].

QoS Based Routing Protocols in Wireless Sensor Network

Many protocols based on improving the efficiency of various QoS parameters have been designed so far. Sequential Assignment Routing (SAR) is the first protocol that includes a notion of QoS for sensor networks. Assuming multiple paths to the sink node, each sensor uses SAR algorithm for path selection. It takes into account the energy and QoS factors on each path and the priority level of a packet and accordingly creates trees rooted at one-hop neighbors of the sink. SPEED provides real-time end-to-end QoS. This protocol requires each node to maintain information about its neighbors and uses location-based routing to find the paths. Multi-Path Multi-Speed Protocol is an extension of SPEED providing multipath multispeed of packets across the network. The protocol spans over network layer and Medium Access Control (MAC) layer which provides QoS support interms of reliability and timeliness.

An *Efficient Geographic Opportunistic Routing GOR* (EGOR) algorithm for QoS provisioning in WSNs achieves good balance between these multiple objective and is specifically tailored for WSNs considering the resource limitation of sensor devices. In MultiConstrained MultiPath(MCMP) algorithm a probabilistic modeling of link state for Wireless Sensor Networks is proposed. Based on this model, an approximation of local multipath routing algorithm is explored to provide QoS under multiple constraints, such as delay and reliability. Directed Alternative Spanning Tree (DAST) considers three important QoS parameters namely energy efficiency, network communication traffic and failure tolerance. In this protocol a directed tree-based model is constructed to make data transmission more efficient. A Markov based communication state predicting mechanism is used to choose reasonable parent and packet transmission to double-parent is submitted with alternative algorithm. Various nodes in the network are prioritized and this is used to decide different functions of nodes in WSNs. In GORMA(Group Optimal Retransmission Medium Access Protocol), retransmission with required QoS is designed and evaluated.

QoS Based Congestion Protocols in Wireless Sensor Network

Priority based Congestion Control Protocol (PCCP) is an upstream congestion control protocol in WSN which measures congestion degree as the ratio of packet inter-arrival time to the packet service time. It is designed in a way that the data packets have a guaranteed weighted fairness so that sink can get different throughput from the sensor nodes but in a weighted manner. PCCP is intended to improve energy-efficient and support traditional QoS in terms of latency, throughput and packet loss ratio. Congestion control for Multiclass Traffic (COMUT) is a framework that consists of a distributed and scalable congestion control mechanism. that is based on self-organisation of networks into clusters. Each cluster is equipped with a sensor that autonomously monitors congestion within its scope.

COMPARISON OF PERFORMANCE OF VARIOUS QOS PROTOCOLS

Author	Algorithm/protocol	Concept	Performance
Jianwei et al., [4]	Reliable Reactive Routing Enhancement for Wireless Sensor Networks (R3E)	routing protocols for energy-efficient packet delivery against the unreliable wireless links	Improve robustness, end-to-end energy efficiency and latency.
Zheng et al., [11]	COEQ	Balancing coding opportunities,energy and QoS is analyzed	Improves throughput and saves energy.
Chen et al., [14]	Adaptive Fault-Tolerant QoS control (AFTQC)	Incorporates path and source redundancy mechanisms to satisfy query QoS requireme	Maximizies the network lifetime.

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Mohammed et al., [17]	Lagrangian relaxation mixed integer programming technique	Performance trade-offs between QoS requirements and energy efficiency were simulated	Significantly Improves The network lifetime, while reducing energy consumption and decreasing average end -to-end delays.
Peng Ji et al., [20]	Directed Alternative Spanning Tree (DAST)	In this protocol a directed tree-based model is constructed to make data transmission more efficient.	Improves Important QoS para meters namely energy efficiency, network communi cation traffic and failure tolerance.
Leandro et al., [22]	Data Routing for In-Networking Aggregation (DRINA)	Redundant data is aggregated Shortest path is established between the source and the sink	High and reliable data aggregation Maximum number of overlapping routes.
Akyidiz et al., [24]	Event to Sink Reliable Transport (ESRT)	Configures the network to an optimal operating point with required realiability	reliable event detection in WSNs with minimum energy expenditure.

CONCLUSIONS

Due to the miniature structure and availability of limited resources has attracted researchers to improve and provide better QoS. The performance of WSNs can be improved by considered layered or cross layer approach, Routing protocols, MAC protocols and data processing stratergies.

In this paper, we have studied and analyzed few of the QoS issues,requirements,challenges and exisisting protocols in a wireless Sensor Networks. Which provides an insite in the design and development of new QoS protocol. Finally, the perspective metrices, parameters & requirements of QoS protocols of the existing protocols are compared.

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