QoS Provisioning issues in Wireless Multimedia Sensor Networks

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Abstract - **Increasing demand of imaging and video sensors in many applications of wireless sensor networks has led to the evolution of Wireless Multimedia Sensor Networks (WMSN). WMSN are wireless sensor networks that are able to retrieve multimedia content from the environment. WMSN applications require effective communication of event features in the form of multimedia such as audio, image, and video. The challenges faced in WMSN are same as Wireless Sensor Networks (WSN) but some additional challenges such as reliability, QoS, and high bandwidth demands, must be addressed as well. The main focus of research so far is on minimizing the energy consumption in WSNs, mechanisms to efficiently deliver application-level QoS, and to map these requirements to network-layer metrics such as latency and jitter, have not been primary concerns of research on sensor networks. Therefore, for fulfilling real- time requirements for multimedia delivery of data, new protocols need to be developed which not only ensure bounded response time but also strive to minimize energy consumption in data processing and communication. The QoS requirements in WMSN are quite different from traditional networks. In this paper we will discuss various QoS issues in network layer in WMSN and explain the reasons for the failure of traditional QoS models in WMSN. We review the work being carried out in provisioning QoS in WMSN followed by some open research issues.**

Keywords - Energy-Efficiency, Network Layer, QoS, Routing, Wireless Sensor Multimedia Networks, Wireless Sensor Networks.

I. INTRODUCTION

Wireless Sensor Networks (WSN) has recently been the focus of tremendous interest to the research community. WSN comprises of large number of low-cost, low-power sensor nodes, which communicate with each other, collaboratively working towards fulfilling application-specific objectives. The main aim of developing wireless sensor networks is collecting information from the remote and inhospitable areas and sending it to set of nodes called sink or base stations. The main application areas of sensor networks are Environment Monitoring, Seismic Detection, Health Monitoring, Military, etc [1].

Although wireless sensor networks have diverse application areas, the main constraint faced is enhancing the lifetime of sensor networks. Each sensor is equipped with limited battery power, which is difficult to replace or charge once the battery energy depletes. Therefore minimum utilization of energy is required to prolong the network lifetime. Research in sensor networks is mainly focused on minimizing energy usage [2][3].

With the rapid miniaturization and improvements in inexpensive CMOS cameras and microphones, a single sensor device can be equipped with audio and visual data collection capability. So a sensor network can now collect and store multimedia data, correlate them and even fuse multimedia data received from various sources, thereby leading to the evolution of Wireless Multimedia Sensor Networks (WMSN).

Wireless Multimedia Sensor Networks will not only enhance existing sensor network applications but also be able to deliver several new applications. Some of them are Multimedia Surveillance Networks, Controlling the vehicle traffic in highways, Health care personal area networks etc.

However, WMSN applications require certain performance guarantees such as end-to-end delay, jitter, minimum Bandwidth etc. For instance, transmission of imaging data in a disaster management setup requires careful handling in order to ensure that the end-to-end delay is within acceptable range and the images are received properly without any distortion. Such time-constrained applications have posed various QoS

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issues in wireless sensor networks [4]. Thus it has become necessary to develop protocols that are QoS based and also able to minimize energy so that network lifetime increases.

Provisioning QoS in wireless sensor networks is a very complex process. It requires QoS awareness at every layer of network architecture. In this paper we will be discussing the QoS issues in network layer.

The rest of the paper is organized as follows. Section II describes the challenges/ issues faced in provisioning of QoS in sensor networks followed by QoS requirements of Wireless Sensor Multimedia Networks in section III. In section IV, a brief review of QoS based routing protocols has been presented followed by conclusion & open research issues in section V.

II. QOS CHALLENGES/ ISSUES IN WIRELESS SENSOR NETWORKS

Wireless Sensor Networks differ from traditional wired Internet Infrastructures and Mobile Ad-Hoc Networks. The differences introduce unique issues or challenges for supporting QoS in wireless sensor networks. Approach for provisioning QoS in sensor networks is not fixed. It changes according to the application. Some of the major challenges/ issues that make provisioning QoS in sensor networks different from Traditional Networks are discussed below:

Severe Resource Constrained: Each sensor node is provided with low processing capability, low memory, limited transmission energy and limited battery power leading to the need for efficient utilization of resources.

Data- Centric: A large amount of data is generated and exchanged in sensor networks leading to redundancy. Though redundancy enhances reliability a lot of energy is wasted. Data Fusion or Aggregation Techniques can be employed to preserve energy but these techniques lead to increase in delay and reduced throughput thereby effecting QoS design.

Node Mobility: In sensor networks nodes as well as sink nodes frequently change their position which makes QoS provisioning complex.

Heterogeneous Traffic: Sensor network can be designed to collect different types of data. For example, a network can be designed to simultaneously monitor change in temperature, pressure or humidity of some location leading to different set of QoS parameters defined for each. Therefore, provisioning QoS in case of heterogeneous traffic can become quite complex.

Packet Criticality: In real-time environment it is required that critical or high-priority packets be given the preference over low-priority packet. The content of the packet may determine its criticality. QoS design must employ some packet differentiation mechanism so that critical packets are not ignored.

Scalability: Wireless Sensor Network consists of thousands of nodes. The QoS mechanism being designed be such that its performance does not degrades when the number of nodes increases or decreases.

III. QOS REQUIREMENTS IN WIRELESS SENSOR MULTIMEDIA NETWORKS

Every application has certain service requirements from the network. These requirements are called its expected Quality of Service (QoS) [5]. QoS in wireless sensor multimedia networks can be defined from three perspectives: timeliness, reliability & energy. By timeliness we mean delivery of data within some specified time interval i.e., QoS parameters measured are delay, jitter, throughput etc. Reliability means delivery of accurate data with minimum loss. QoS parameters are packet loss, accuracy & coverage. By coverage we mean number of sensor nodes required to get the full information about the area of interest. And accuracy is the measure of discrepancy between actual sensed data and data as received by the user. Energy as QoS metric means node that maintains desired energy level could be used to forward data.

The algorithms designed for provisioning QoS in wireless sensor networks can be single objective that is based on one parameter or it can be multiobjective that is based one more than one parameter. Optimizing multiple QoS parameters while preserving network resources is a complex problem.

IV. QOS ROUTING PROTOCOLS

Routing Protocols developed so far aims at efficient usage of energy in order to increase the network lifetime. Very few protocols are being developed which satisfies QoS parameters while routing data from node to sink. Some of them are described below:

Sequential Assignment Routing Protocol (SAR)[6]***:*** SAR is the first algorithm for WSN that includes the notation of QoS in its routing decisions. The objective of SAR algorithm is to make the network energy-efficient and fault tolerant. SAR uses multihop routing and maintains routing tables to record information about its neighbors. To create multiple paths from each node to sink, multiple trees are constructed, each rooted from one-hop neighbor of the sink. For path selection SAR takes into account the energy resource and QoS on each path and priority level of a packet. For each packet in network, SAR calculates weighted QoS metric, which is the product of the additive QoS metric and a weight coefficient associated with the priority level of that packet. Lower the average weighted QoS metric, higher the levels of QoS achieved. To handle failure within network, a handshaking process is used that enforces routing table consistency between the upstream and downstream neighbors on each path so that any local failure will automatically trigger a recomputation procedure locally. Simulation results shows that SAR has better performance than the minimum metric algorithm. The main disadvantage of this protocol is the overhead involved in maintaining tables and states at each node.

SPEED [7]***:*** *A stateless protocol for real-time communication in sensor networks:* SPEED is designed to support soft real-time communication service by maintaining desired delivery speed across the network so that end-to-end delay is minimized. Each node keeps information only about its immediate neighbors and utilizes geographic location information to make localized routing decisions and hence the protocol is called stateless, as it does not use routing tables resulting in minimal memory usage.

Stateless Non-deterministic Geographic Forwarding (SNGF) is the routing module responsible for choosing the next hop neighbor and it works with four other modules at the network layer to achieve desired delivery speed across sensor networks.

Neighbor beacon exchange module provides geographic location of the neighbors. Delay estimation module calculates delay at each node, which helps SNGF to select the node meeting speed requirements and also help to determine the occurrence of congestion. If a node meeting desired speed requirement couldn't be found, the relay ratio of the node is checked. The relay ratio is provided by Neighborhood Feedback Loop (NFL) module. Relay Ratio determines whether the packet is to be dropped or relayed. It is calculated by looking at the miss ratios of the neighbors of the node (the nodes which could not provide the desired speed) and is fed into the SNGF module, where a drop or relay action is taken. If the relay ratio is less than a randomly generated number between 0 and 1, the packet is dropped. Backpressure rerouting module is used to prevent voids i.e., when a node fails to find the next hop node or if congestion occurs, this module sends message back to the source nodes so that they can take new routes. Simulation shows SPEED performs better in terms of end-to-end delay ratio and miss ratio.

The major limitations of SPEED protocol are that it does not employ any packet differentiation mechanism. It gives same preference to both real-time & non-real time packets. It is not scalable as it maintains a desired speed for each packet and if the parameter is changed than protocol performance degrades.

Energy-aware QoS routing protocol [8]***:*** This protocol finds least-cost, delay-constrained path for real time data based on node's energy reserve, transmission energy, error rate and other communication parameters. Moreover, the throughput of non real-time traffic is maximized. This protocol ensures guaranteed bandwidth through the duration of connection while providing the use of most energy efficient path. The protocol consists of two steps. The first step consists of calculating candidate paths in ascending order of least costs using an extended version of Dijkstra's algorithm without considering end-to-end delay. In second step, it is checked which path fulfills the end-to-end QoS constraints and the one that provides maximum throughput is selected. Simulation results have shown that the proposed protocol consistently performs well with respect to QoS and energy metrics.

MMSPEED: *Multi-path and Multi-speed Routing Protocol* [9]*:* MMSPEED protocol is an extension of SPEED protocol designed to provide probabilistic QoS differentiation with respect to timeliness and reliability domains. For timely delivery of packets, MMSPEED provides multiple delivery speed options for each incoming packets. Each incoming packet according to its speed class is placed into appropriate queues. The packets in the highest speed queue are served in FCFS basis, followed by the next highest speed queue and so on. The priotrization of packet is done with the MAC layer support. Service differentiation in reliability domain is achieved by calculating the reaching probability of each packet and then forwarding the packets through multiple paths whose progress speed is higher than the speed threshold. These decisions are made locally at each node without global network state information and end-to-end path setup, thus MMSPEED protocol is scalable and adaptable to large networks. Only limitation of the protocol is that the energy metric is not taken into consideration.

V. CONCLUSION & OPEN RESEARCH ISSUES

Designing QoS based routing protocols is an emerging research area in wireless sensor networks. In this paper we have listed different QoS metrics & challenges involved in implementing QoS in routing protocols. Also we have presented a brief overview of some recently designed QoS based routing protocols. Table 1 summarizes the various QoS based routing protocols that have been covered in this paper.

QoS based routing protocols developed so far aims at minimizing end-to-end delay only. Other parameters such as jitter, throughput etc is not being considered while selecting the path. So to design routing protocols that takes into account other QoS parameters depending on different applications is an open research issue.

QoS routing protocols designed so far does not take into account energy metric while making routing decisions. There exists a tradeoff between delay and energy efficiency. It is therefore required to design protocols that take into account this tradeoff while choosing best path from source to sink.

TABLE 1. Comparison of QoS Routing Protocols

	SAR	**SPEED**	**Energy-Aware QoS Routing Protocol**	**MMSPEED**
QoS metric	End-to-End Delay	End-to-End Delay	End-to-End Delay	Delay and Reliability
Compared with	Minimum Metric Algorithm	AODV, DSR, GF	None	SPEED
Energy-Aware	Limited	No	Limited	No
Location-aware	No	Yes	No	Yes
Scalability	No	No	Limited	Yes
Node Mobility	Limited	No	No	Yes
Data-Delivery Model	Not Query based	Query-Based	Not Query-Based	Query- based
Data Aggregation	No	No	No	No
Service Differentiation	Limited	No	Yes	Yes

While designing routing protocols sensor nodes are assumed to be stationary. But many applications such as tracking intruder movement require both sensor nodes and sink to be mobile. So another open research is to develop QoS routing protocols that takes node mobility into account.

Wireless sensor networks are data-centric in nature. Similar data is sensed by more than one node at the same time. A lot of protocols have been developed that employ data aggregation techniques [10] [11]. It will be interesting to introduce QoS parameters in these algorithms and then study their behavior. The combination of real-time data & data aggregation techniques makes the problem complex and an open research issue.

Sink uses Internet to communicate with the user or other networks. The QoS requirements of traditional networks and wireless sensor networks are very different. So further research is necessary for handling differences between them and to maintain QoS requirements in such situation.

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