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Survey on QoS Aware Routing Protocols for Wireless Multimedia Sensor Networks

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Abstract: Wireless Multimedia Sensor Networks (WMSNs) has made it possible to send multimedia data on small sensing devices. The multimedia content in such networks increase the level of information collected from the monitored field, enlarging the range of coverage, and multi-view support. It is proved by researchers that the multi-tier network architecture is more beneficial than a single-tier in terms of energy-efficiency, scalability and reliability for multimedia data transmission. In this context, application like intrusion detection appears as a promising application of multi-tier WMSNs, where the lower tier can detect the intruder using scalar sensors, and the higher tier camera nodes will be woken up to send real time video sequences detected from the monitoring area. The multimedia data are quite different from the scalar data generated in Wireless Sensor Networks (WSNs), which demands real time delivery of data to target end to increase the Quality of Service (QoS). In this paper, the QoS aware routing protocols for WMSNs are surveyed with the performance issues and the design challenges of each protocol for WMSNs are discussed.
Keywords: Quality of Service (QoS), Wireless Sensor Networks (WSN), Wireless Multimedia Sensor Networks (WMSNs), Multi-tier architecture.

I. INTRODUCTION

Wireless multimedia sensor networks (WMSNs) has fascinated the researchers to gain the interest due to improvement in CMOS cameras and microphones. There many possibilities of capturing multimedia content for applications like traffic monitoring, telemedicine, intrusion detection and environment monitoring and military applications. Multimedia sensor networks is different from Sensor Networks due to various design constraints in WMSNs. Multimedia contents are delay sensitive, thus, the design of these networks is focused around reducing latency overhead at each layer and fast delivery of information to the destination. Further, these networks are very delicate to packet damages which result in delay and loss of contents in the received multimedia data i.e. image, video or audio data. In multimedia sensor networks, packets received after their given deadline, are considered to be lost and contribute to the overall distortion. In some applications like traffic and habitat monitoring, loss of some information can be tolerated but in other applications, such as, surveillance or battlefield monitoring, real-time delivery of multimedia content is very important. Delay and packet loss are very strictly correlated to each other, and it is necessary to guarantee real time delivery of each packet to the target.

Many routing protocols with various routing metrics have been developed for WSNs. However, very less research has been done on Wireless Multimedia Sensor Networks (WMSNs) routing protocols and there is need of improvement in this area. Moreover, multimedia delivery demands high bandwidth, real-time transmission, lower frame loss, tolerable end-to-end delay and jitter. Additionally, applications involving multimedia transmission should support Quality of Service (QoS).

The remainder of this paper is organized as follows:

Section 2 describes the applications which demands the existing WSN technology to be replaced by WMSN. Then in Section 3 describe the various architectures in WMSNs and the design constraints for designing routing protocols for WMSNs. In Section 4 we describe and discuss about existing QoS aware routing approaches in WMSNs along with comparisons shown in the table. In section 5 open problems and further possible research in WMSN are discussed. Finally section 6 concludes the paper.

II. APPLICATIONS OF WMSN

The invention of low power computational and low cost audio sensor created many new applications, which enhance the functionality if an existing WSNs. Some of those applications are classified as follows [9][10].

1. Multimedia Surveillance System

Surveillance sensor networks is used to improve the performance of existing systems to prevent crime. Multimedia data like image, video captured from cameras can be used to find the missing persons and identify criminals.

2. Traffic Avoidance and Control
This can be used to monitor the traffic in big cities or on highways which offer better traffic routing advice. Also, allow to find the available spaces for parking and guide the driver through automated parking system.

3. Health Care Delivery
Telemedicine sensor networks can be used to provide health care services. Patients will be carrying the medical sensors and remote medical centres can easily monitor the condition of patients to provide medical facility in emergency situations.

4. Environmental Monitoring
Multimedia sensors can be used to continuously monitor the environment and also are used to monitor the bridges or other civil structures.

5. Industrial Process Control
Multimedia content such as video, image can be used for industrial process control. In automated manufacturing processes, WMSNs help the system to make it simple and add flexibility for visual inspections and automated services.

III. WMSN ARCHITECTURE AND DESIGN CHALLENGES

A. ARCHITECTURE OF WMSN
This section describes the network architectures for WMSN. The network architecture of WMSN is shown in Fig. 1 and can be classified into three categories depending on the kind of targeting application [10].

The left part of Figure 1 shows the single-tier flat architecture which is consist of sensor nodes with similar sensing, communication and computational capability than the same video sensors. The middle part of the Figure 1 shows the single-tier clustered architecture, with heterogeneous sensor nodes. This architecture can address the wide range of application.

The right part of the Figure 1 shows the multi-tier architecture and this is comprised of three tiers. The first tier is consist of scalar nodes, middle tier consist of medium resolution video sensor nodes and the final tier consist of visual sensor nodes for recognizing and tracking the object.

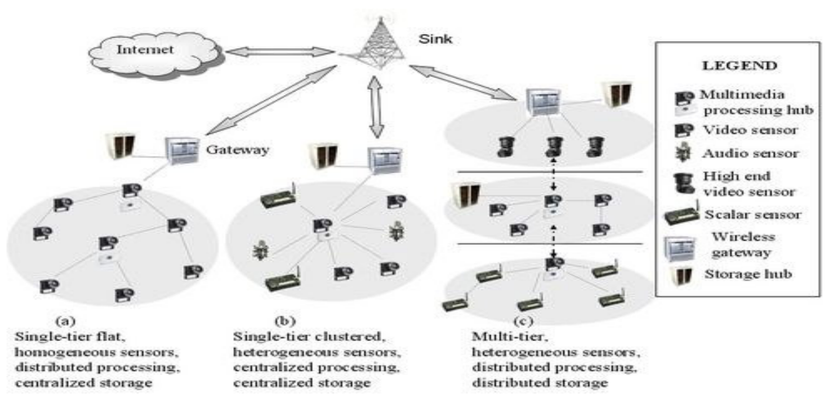

Fig. 1. Architecture of a wireless multimedia sensor network [9]

B. DESIGN CHALLENGES
In order to design good applications for wireless sensor networks, it is required to understand factors which are important and affect the design of sensor network applications. The following is a combination of the various design challenges in WMSNs[18]:

Energy balance: Balance the energy load between different nodes to increase the life of the network.

Power consumption: Due to various multimedia transmissions and compression, packet processing, and also due to mobility.

Multiple traffic classes: This would impose the different QoS parameters such as reliability and delay requirements.

Resource constraints: Bandwidth, energy, memory, processing capabilities, buffer size, data rates, and limited transmission power to transmit the data.

Dynamisms of Network: due to node failures, wireless link failures, and node mobility. This necessitates dynamic routing where the routing algorithm dynamically checks the routes either periodically or on demand before transmission.

Scalability: Scaling up or down the network by changing the number of nodes should not affect the performance and the required QoS of the network.

Packet criticality: Different packets have different priority and criticality and should be processed differently. For example, in video I frame should be processed first than P and B frame.

Time constraints: Multimedia content have certain time constraints and delivery multimedia content after a certain deadline would be very critical.

Unbalanced traffic: Traffic is directed mainly in WSN from a large number of sensor nodes to a small number of sink nodes.

Data redundancy: This is helpful in achieving reliability requirement. However, it also results in unnecessary power consumption and waste of data rate and bandwidth.

IV. QoS AWARE ROUTING PROTOCOLS FOR WMSN

The network layer is an important layer to provide QoS for multimedia application because it is responsible for providing energy efficient path that meets QoS requirements.[2]

The QoS-aware routing protocols are to be the most suitable protocols for WMSN. Many QoS aware routing protocols have been proposed for WMSN. However, still lots of improvement is needed in these protocols in order to meet the multimedia requirements. This section discusses the various routing protocols proposed for WMSN along with features and limitations of each protocol.

A. Sequential Assignment Routing (SAR)

Sequential Assignment Routing (SAR) [11][12] is the first routing protocol which consider the QoS and energy for sensor networks. The main objective of the SAR is to make the network energy-efficient and fault tolerant. SAR uses multihop routing and routing tables to store the information about its neighbors. To form the multiple paths from each node to the sink, multiple trees are constructed, and all these paths will be rooted from one-hop neighbor of the sink. To select the appropriate path, it takes into account the energy resource, the QoS on each path, and the priority level of an each packet. For each packet in a network, SAR calculates the weighted QoS metric, which is the product of the additive QoS metric and a weight coefficient which is associated with the priority level of that packet. The lower that the average weighted QoS metric is, the higher the QoS level will be. It handles the failures within network, by a handshaking process, which enforces routing table consistency between the upstream and downstream neighbors on each path.

The limitation of this protocol is that the overhead to maintain the tables and storing the information about the status of each sensor node most importantly when the number of nodes are more in the network.

B. Energy-aware and QoS-based protocol (EQSR)

EQSR [7] is an energy-aware and QoS-based protocol that finds a least cost and energy efficient path and guarantees certain end-to-end delay. Figure 2, shows the differentiated traffic classifier with best effort and real-time queues. It supports both types of traffic using a queuing model shown in the Figure 2, that permit sharing of service between both types of traffic. The scheduler ensures that best-effort traffic should not reduce resources that are required for real-time traffic. This protocol is based on a multipath approach that uses enhanced version of Dijkstra's algorithm to find a list of least cost paths and chooses the path which meets the desired requirements.

The performance EQSR is good in terms of QoS and energy metrics. But, it only considers one real-time priority class which is only suitable for a single real-time application and for multiple applications because it requires several priority classes for different real-time traffic.

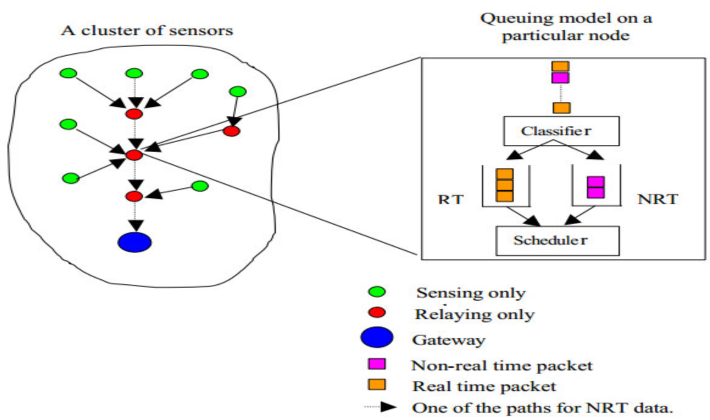

Fig 2. Queuing model for Energy-aware QoS routing protocol [7]

C. A Stateless Protocol for Real-Time Communication in Sensor Networks (SPEED)

SPEED [4] is a QoS routing protocol for WSNs that provides soft real-time end-to-end guarantees. It maintains the desired delivery speed across the network so that the end-to-end delay is minimized. Each node keeps information only about its immediate neighbors and geographic location information is used to make localized routing decisions. So, the protocol is called "stateless," as it does not use routing tables, which result 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 4 other modules i.e. Beacon Exchange, Delay Estimation, Backpressure Rerouting, and Neighborhood Feedback loop at the network layer to achieve the desired delivery speed across the sensor networks. The neighbor beacon exchange module provides the geographic location of the neighbors. The delay estimation module calculates the delay in each node and helps the SNGF to select the node meeting speed requirements and also to determine the occurrence of congestion. If a node meeting desired speed requirement can't be found, the relay ratio of that node is checked. The relay ratio is provided by the Neighborhood Feedback Loop (NFL) module to determine whether the packet is to be relayed or dropped The backpressure rerouting module is used to prevent voids at holes i.e., when a node fails to find the next hop node or if congestion occurs, it sends the message back to the source nodes so that they can take new routes.

SPEED protocol perform well in achieving end-to-end delay ratio and the miss ratio. The main limitations of the SPEED protocol is that it does not provide any packet differentiation service. It gives the same preference to both real time and non-real time packets. Also it is not scalable, as it maintains a desired speed for each packet, so the performance of SPEED degrades, if the parameter are changed.

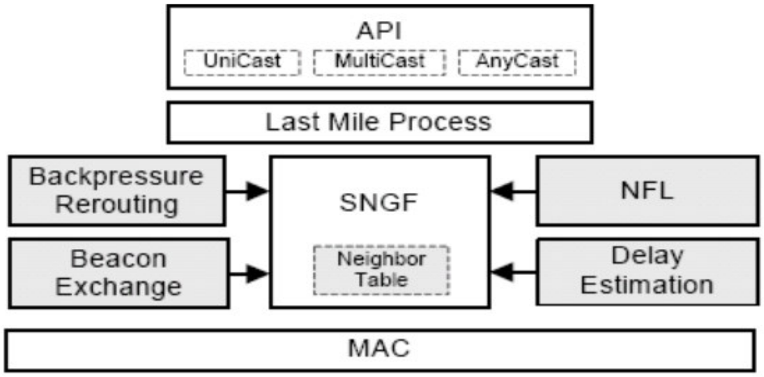

Fig. 3. SPEED Protocol [4]

D. Multi-Path and Multi-SPEED Routing Protocol (MMSPEED)

Multi-Path and Multi-SPEED routing protocol is an extension to SPEED protocol and it is proposed in [14]. MMSPEED is a novel cross-layer routing protocol that provides services to packets based on the packet priority and uses multipath approach to achieve a reliable transmission besides QoS provisioning. Packets are differentiated based on two QoS domains: reliability and timeliness. Based on the packet's reliability and timeliness requirement, packet will be processed with a certain QoS level and certain delivery speed [13][14]. MMSPEED protocol provides the following services which other protocols are not able to provide:

- Localized packet delivery without information about of the network topology.
- Minimizing less reliable and unbounded transmissions over wireless links.
- Service differentiation and guarantee in both reliability and timeliness domains.

Enhancement to 802.11e MAC protocol is required to implement MMSPEED QoS mechanism such as prioritization based on Differentiated Inter-Frame Spacing (DIFS). Based on the speed value, packet will be mapped to a certain MAC priority class. MMSPEED has many advantages, it provides QoS differentiation in both reliability and timeliness domains. The limitation of this protocol is that, it does not handle the trade-off between delay and energy, also it does not handle network layer aggregation.

E. Real-time Power-Aware Routing (RPAR)

Real-time Power-Aware Routing protocol (RPAR) [5][15] support energy efficient and real-time communication in wireless sensor network. It is different from the other existing protocols in many ways:

- It uses the power control and real-time routing for supporting energy-efficient and real-time communication.
- It better control the trade-off between energy uses and communication delay by giving deadline to each packet.
- The novel neighbourhood management mechanism used by this is more efficient than the periodic beacons scheme adopted by protocols such as SPEED and MMSPEED.
- It minimize the miss ratios by using dynamic transmission power adjustment and routing decision.

The forwarding mechanism and neighborhood management of this protocol both together significantly reduce the energy consumption with required real-time guarantee. It also better handles the properties of WMSNs i.e. limited bandwidth and memory.

This shows the degraded performance in handling sudden congestion and large holes. Also the neighbor discovery process takes more time which in turns increase the overall time to transmit the data to the sink node.

Table 1: Routing Protocols comparison

Routing Protocol	**Performance metrics**	**Packet prioritization**	**Reliability**	**Hole Bypassing**	**Location Awareness**
SAR	Energy Consumption and weighted QoS metric	Yes(based on packet deadline)	No	No	Yes
EQSR	End-to-end delay and Energy Consumption	Yes(based on class of packet , real-time and best effort traffic)	Yes(multipath forwarding)	No	No
RPAR	Energy Consumption, Deadline miss ratio	Yes(based on required velocity)	No	No	Yes
SPEED	End-to-End delay, Dead line miss ratio	Yes(based on deadline and distance to sink)	No	Yes(backpres-sure routing)	Yes
MMSPEED	Average end to end delay, Overhead, Reliability	Yes(based on speed value)	Yes(multipath forwarding)	No	Yes

OBSERVATIONS

Based on the survey of QoS aware routing protocols following observations are made about these protocols:

- **SAR** takes routing decision based on energy resources, QoS for each path, and the priority level of traffic. It uses a table-driven multipath approach in order to achieve energy efficiency and fault tolerance. The main limitation, especially when there are a large number of nodes is, the huge overhead caused by maintaining tables at each sensor node.

- **EQSR** has better performance in terms of QoS and energy metrics. But, it only considers one real-time priority class which is only appropriate for a single real-time application and it is not suitable for multiple applications because different applications require different priority classes for different real-time operations.

- **SPEED** protocol performs well in improving the end-to-end delay and the miss ratio. It also provides congestion avoidance if the network is congested. In SPEED the load is evenly distributed through the SNGF, so the total transmission energy is less. The major limitations of the SPEED protocol are that it does not employ any packet differentiation mechanism and also, SPEED does not consider in making any routing decision, thus making it less informed about energy consumption.

- **MMSPEED** provides services to packets based on the packet priority and uses multi-path approach to achieve a reliable transmission along with QoS. Packets are delivered based on local knowledge at each node without information about the global network state and end-to-end path setup. The only limitation of this protocol is that the energy metric is not considered in performance measurement.

- **RPAR** has the forwarding policy and neighbourhood management of which significantly reduce the energy uses with required real-time data delivery. However, the response time of the neighbour discovery process is still a problem to the real-time guarantee. Also, the transmission of packet at a high power level decrease the throughput due to increased contention and interference in the channel.

V. RESEARCH DIRECTIONS

There are many research made in the recent years in routing protocols in WMSNs, still there are many open problems which need to be solved. In this section, open problems are discussed for further research in this area.

Mobility: Most of the existing routing protocols in current literature for WMSN do not take mobility into consideration. Mobility of sensors and sinks is also possible for real time delivery. So, to support multimedia in WSNs can be an interesting area for future research.

Energy efficiency: Energy efficiency plays an important role in designing a routing protocols for WMSNs. But the QoS guarantee must also have an equal importance. So, there is always a trade-off between energy efficiency and reliability. Balancing QoS and energy efficiency trade-off and find the optimal solution is a good research area in this field.

Multiple sources and sinks: Most of the routing protocols designed for WMSNs to send data from single source to single sink. A network can have the multiple sources and multiple sinks to get the information about event occurred at a particular location. Developing routing protocols for applications with multiple sink and source can be considered as a new research area.

Secure routing: Currently most of the routing protocols focus on optimizing application based parameter of the sensor networks, and do not take security into consideration. But in WMSNs we transmit multimedia data with detailed information about an event so the leakage of information can create problem. So, for sending data in secure is another research area WMSNs.

Multi-constrained QoS: Real-time delay transmission is the main QoS requirement in most of the QoS aware routing protocols in WMSNs. However, various reliability constraint also needs to be considered. So, designing a protocol which can provide the multi-constrained QoS guarantee is the another area of research.

V. CONCLUSION

In WMSNs wide range of real time applications to do research on the routing protocols. The goal of routing protocols in WMSNs is to provide good QoS along with efficient energy consumption. In this paper, we had presented the survey on WMSNs architectures, design challenges and the QoS-aware routing protocols for WMSNs with their advantages and performance issues. Finally, the open issues and detailed comparison of QoS based routing protocols SAR, EQSR, SPEED, MMSEED, RPAR and DGR based on the characteristics like performance metrics, packet prioritization. reliability, hole bypassing and location awareness is also presented. At the end research findings are given to do the more research in unexplored areas in WMSNs.

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