QoS Aware Routing Protocol

for

Wireless Multimedia Sensor Networks

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QoS Aware Routing Protocol for Wireless Multimedia Sensor Networks

Thesis

Submitted in partial fulfillment of the requirements
for the degree of
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Guided By
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Undertaking for Originality of the Work

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Abstract

Wireless Sensor Networks (WSNs) have gained the research interest due to the significance of the field of applications and the advances in sensor technology. In areas where catastrophic events occur such as environmental disasters and battle fields, the network infrastructure is lost and there is a high demand to build a network in order to monitor the area and to help in rescue operations. An easy and fast way is to scatter scalar and video sensor nodes in an ad- hoc manner in the area of interest in order to establish a wireless multimedia sensor network (WMSN). Video sensor nodes provide better coverage of the area and enhance the interpretation of the monitored phenomenon.

The main challenges faced in WMSNs are Quality of Service (QoS) and energy constraints. Many routing protocols with various routing metrics have been developed for WSNs. However, limited research has been done on WMSN routing protocols and there is room for improvement in this area. Limited research has been done on routing protocol for WMSN deployed in ad-hoc manner that meets QoS requirements and at the same time considers energy efficiency for the purpose of increasing the lifetime of the network.In this thesis, a routing protocol is proposed for WMSN that is energy efficient and QoS-aware. This protocol is developed to improve the end-to-end delay, reliability and energy efficiency through discovering multiple paths from the source node to the sink node. The simulation results shows that proposed protocol improves the QoS parameters to transmit the multimedia contents.

Keywords: *Wireless Sensor Networks(WSNs), Wireless Multimedia Sensor Networks (WMSNs), Quality of Service(QoS), Quality of Experience (QoE).*

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- Malaram Kumhar

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Contents

List of Figures

List of Tables

Chapter 1

Introduction

Wireless Sensor Networks (WSNs) have attracted interest of researchers in recent years because of the significance of its applications in addition to the development and advances in sensor technology. Wireless sensor network is a consist of sensor nodes with limited power supply and transmission and computational capability. Due to the limited transmission and computational ability, and large number of sensor nodes, forwarding of data packets takes place in multi-hop data transmission. Therefore routing in wireless sensor networks has been an important area of research in the past few years.

The sensor nodes run on non-rechargeable batteries, so along with efficient routing the network should be energy efficient with efficient utilization of the resources and hence this is an important research concern. Advances in wireless technologies and evolution of low cost sensor nodes have led to introduction of low power wireless sensor networks. Due to multiple functions and ease of deployment of the sensor nodes it can be used in various applications such as target tracking, environment monitoring , health care, inventory control, energy management, surveillance systems.[1]

The main task of the sensor nodes in a network is to forward the collected information from the source to the sink for further operations, but the due to resource constraints, unreliable links between the sensor nodes in combination with the various application demands of different applications make it a difficult to design an efficient routing algorithm in wireless sensor networks.

Many routing protocols with various routing metrics have been developed for WSNs. However, limited research has been done on a routing protocol for WMSN deployed in ad-hoc manner that meets quality of service (QoS) parameters and at the same time considers energy efficiency and increasing the network lifetime.

This work focus on the WMSNs with video QoS and QoE support. The proposed QoS aware Routing protocol for WMSNs minimizes end-to-end delay and increases throughput. The protocol use hop distance link quality and residual energy of node to forward the data to the destination.

1.1 Motivation

In wireless communication media due to the resource constraint sensor nodes, reliable data delivery is a challenging task. If the route fails between source and sink, the routing protocol should be robust enough to recover from the failure. The existing QoS aware multipath routing protocols provides reliability against the cost of energy. The proposed work is motivated by the flaws of the existing QoS aware multipath routing protocols to make the network reliable and energy efficient.

1.2 Problem Statement

Given a Wireless Multimedia Sensor Networks (WMSNs) consists of n number of sensor nodes. Each sensor nodes works as a source or forwarding node. Let A and B are source and sink respectively. Our objective is to develop a QoS Aware Routing Protocol for or WMSN that is energy efficient and QoS-aware. This routing protocol finds the multiple path between source and sink to provide reliable and efficient data delivery from the source to the sink.

The performance of the protocol is evaluated based on performance metrics which includes QoS parameter: end-to-end delay, reliability and energy consumption and

QoE paramters: Peak Signal to Noise Ratio (PSNR), Structural Similarity (SSIM),Video Quality Metric (VQM) and MOS(Mean Opinion Score).

1.3 Applications of WMSN

The invention of low cost audio sensor and low power computational created many new applications, which enhance the existing WSNs capability. These can be classified as follows[1][2]:

1.3.1 Multimedia Surveillance Sensor Networks

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

1.3.2 Traffic Avoidance and Control Systems

This can be used for monitoring the traffic in big cities or on highways and deploy services which offer better traffic routing advice. Also, allow to find the available parking spaces and provide the automated parking advice to drivers.

1.3.3 Industrial Process Control

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

1.3.4 Environmental and Structural Monitoring

Many Video sensors can be used to continuously monitor the environment and also are used to monitor the structural health of bridges or other civil structures.

1.3.5 Advanced Health Care Delivery

Telemedicine sensor networks can be used to provide health care services. Patients will be carring the medical sensors and remote medical centers can easily monitor the condition of patients to provide medical facility in emergency situations.

1.4 Design Challenges in WMSNs

In order to design good applications for wireless micro-sensor networks, it is essential to understand factors important to the sensor network applications. The following is a combination of the various challenges in WSNs and WMSNs

- ***Resource constraints:***Energy, bandwidth, memory, buffer size, processing capabilities, achievable data rates, and limited transmission power.
- ***Dynamism 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.
- ***Energy balance:*** Balancing energy load between different nodes to prolong the life of the network.
- ***Power consumption:*** due to transmission, multimedia compression, packet processing, and mobility.
- ***Unbalanced traffic:***Traffic is directed mainly in WSN from a large number of sensor nodes to a small number of sink nodes.
- ***Data redundancy:*** One of the main characteristic of WSN is redundancy which is helpful in achieving reliability/robustness requirement. However, it also results in unnecessary power consumption and waste of bandwidth and data rate.

- ***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.
- ***Multiple sinks:*** Having multiple sinks results in having different network requirements.
- ***Multiple traffic types:*** This would introduce different QoS requirements such as delay and reliability requirements.
- ***Packet criticality:*** Different packets have different criticality and priority and should be treated differently. For example, type of video frame (I frame).
- ***Time constraints:*** Multimedia content have certain time constraints and delivery multimedia content after a certain deadline would be very critical.

1.5 Organization of Thesis

The remainder of this paper is organized as follows.

Chapter 2, provides the background and literature survey of existing QoS based Routing protocols in WMSNs.

Chapter 3, describe the proposed protocol with its operation.

Chapter 4, includes the simulation results of proposed protocol.

Chapter 5, provides the conclusions and future scope.

Chapter 2

Background and Literature Survey

2.1 Wireless Sensor Network

WSNs have gained the attention of many researchers especially with the various development and advances in sensor technology. WSN consists of a large number of sensor nodes that are densely deployed and are working together in order to track or monitor a phenomenon. Sensor nodes can collaboratively monitor physical or environmental conditions such as temperature, humidity, vibration, motion, pressure,sound etc. and they communicate with each other to transmit the sensed data to the user. Advances in sensor technology, digital electronics, and wireless communication, the development of sensor nodes has improved significantly. Therefore, sensor nodes are nowadays small-sized, low power, and low cost.

Sensor nodes have the following main components: a sensing unit, a processing unit, a transceiver unit, and a power unit. Additional units are added to the sensor node depending on the application such as a location finding system, a power generator, and a mobilizer. Traditional sensor nodes are operated mainly by one-way battery and when the battery runs out, these sensor nodes are discarded.

There are many challenges and constraints in WSN such as power consumption, network lifetime, short communication range, limited processing and storage, and quality of Service (QoS) provisioning. All traditional data networks have common QoS requirements and same end-to-end parameters while WSN has to consider and handle new QoS requirements.

There is a wide range of important applications for WSNs which includes military, environmental, health, home, and other commercial applications[3].

2.1.1 Wireless Sensor Network Routing Protocols

Many routing protocols with various routing metrics have been developed for WSNs [4],[5],[6],[7],[8],[9],[10]. 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, and tolerable end-to-end delay. Additionally, applications involving mul- timedia transmission should support Quality of Service (QoS) and Quality of Experience(QoE) to deliver video content with a level of tolerable video quality from the users perspective together with energy-efficiency and scalability. Those issues impose more constraints on the design of a routing protocol for WMSNs.[11]

2.1.2 Wireless Multimedia Sensor Network and Architecture

WMSN consists of wirelessly connected sensor nodes that are capable of storing, processing and retrieving different types of data such as video, audio, scalar data, and still images [1]. These sensor nodes are equipped with microphones and cameras to capture the audio and video information from the area of interest.

The availability of low cost hardware such as CMOS cameras and microphones has fostered research and development of WMSNs in the last few years. The use of MWSN not only enhances existing WSN applications such as tracking and monitoring but it also enables new applications such as military, civil, and health applications.

WMSN is considered one of the newest research areas and it has lots of room for improvement due to the various theoretical and practical challenges. Some of these challenges are high bandwidth requirements, high energy consumption, data processing and compressing techniques, variable channel capacity, multimedia in-networking processing, and cross-layer design [1].

The key challenge in developing a routing protocol for WMSNs is to optimize the energy consumption and the ability to meet QoS requirements[12]. In [1], multimedia traffic classes are classified based on application and QoS requirements taking into consideration the type of data, sensitivity to delay, and loss.

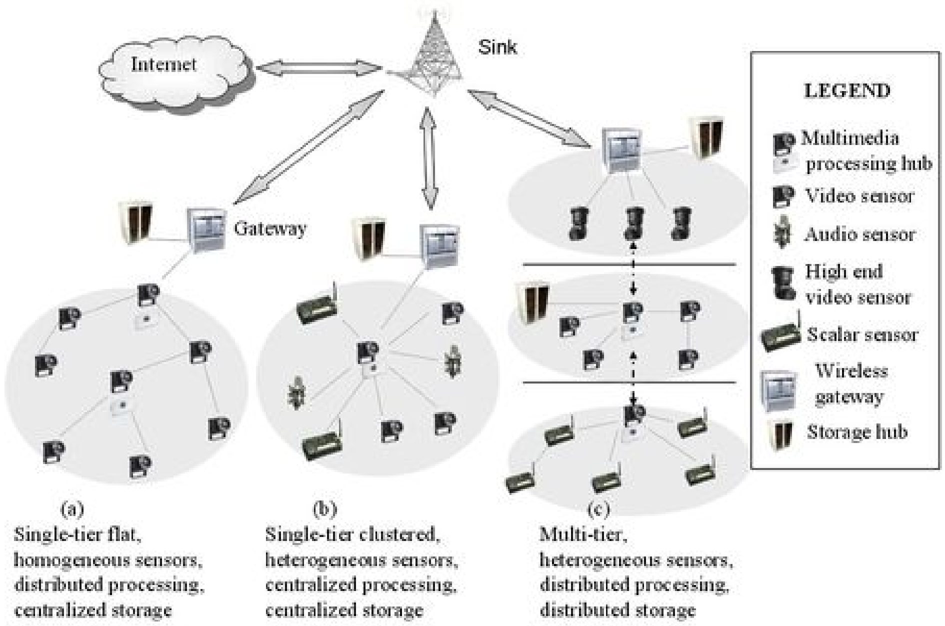

Figure 2.1: Reference architecture of a wireless multimedia sensor network[1]

Figure 2.1 shows the three different architectures of WMSNs[1]. The left of Figure 2.1 shows the single-tier flat architecture which is consist of sensor nodes with simillar sensing, computational and communication capability than the same video sensors. The nodes use either for basic multimedia information collection from area of interest or used as multimedia processing hub. The multimedia information is transferred in with multi hop transmission from the source nodes to sink node.

The middle part of the Figure 2.1 shows the single-tier clustered architecture, composed of heterogeneous sensor nodes. The sensor nodes in the particular cluster collect scalar as well as multimedia information and sends it its cluster head. The processed information is then send to sink or storage device via the gateway. This architecture can address the wide range of application.

The right part of the Figure 2.1 shows the multi-tier architecture and this is comprised of three tiers. The first tier is consist of scalar nodes for doing simple tasks of collecting the scalar information from the environment. The middle tier consist of medium resolution video sensor nodes capable of collecting multimedia information from the surrounding. The final tier consist of vision sensor nodes for task such as object recognition and tracking. Every tier has a one central processing hub which is actually a video node with more computational and communication resources. The storage and the data processing can be performed in the distributed manner at individual tier. Such type of network better in term of scalability, reliability and better coverage in comparision with other architecture.

2.2 QoS aware Routing Protocols

The QoS aware routing protocols are best suitable for WMSN and many QoS based routing protcols proposed[13],[14],[15],[16],[17]. However,still there is a need of improvement in these protocols in order to meet the multimedia requirements and constraints. This section discuss existing QoS aware and real-time communication routing protcols in this field.

2.2.1 Sequential Assignment Routing Protocol(SAR)

The purpose of the 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 the sink, multiple trees are constructed, rooted from one-hop neighbor of the sink. For selecting the path, SAR takes into account the energy resource, the QoS of each path, and the priority of a 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 that is associated with the priority of that packet. The lower that the average weighted QoS metric is, the higher the QoS level will be.citemkk9[18]

To handle failures within the network, a handshaking process is used, which enforces routing table consistency between the upstream and downstream neighbors on each path so that any local failure will automatically trigger a re-computation procedure locally. Simulation results show that SAR has better performance than the minimum metric algorithm. The main disadvantage of this protocol is the overhead that is involved in maintaining the tables and states at each node.

2.2.2 Real-time Architecture and Protocol(RAP)

Chenyang Lu et al. develop real-time architecture and protocols (RAP) based on velocity [6]. RAP provides service differentiation in the timeliness domain by velocity-monotonic classification of packets. In order to facilitate, delivery of a high velocity packet before a low velocity one, velocity of the packet is calculated and its priority is set on the basis of packet deadline and destination, in the velocity-monotonic order. Figure 2.3 shows the architecture of RAP in which Sensing and control applications interact with RAP through a Query or Event Service APIs. A Query or Event Service layer send information of an area. Network stack including a transport-layer Location Addressed Protocol (LAP),a Velocity Monotonic (packet) Scheduling (VMS) layer, a Geographic Forwarding (GF) routing protocol and prioritized MAC provides the sensor based communication. It assumes that physical location is known to routing layer.

A router can find the location of the destination and forward the packet towards the destination. The Geographic Forwarding (GF) is highly scalable in terms of

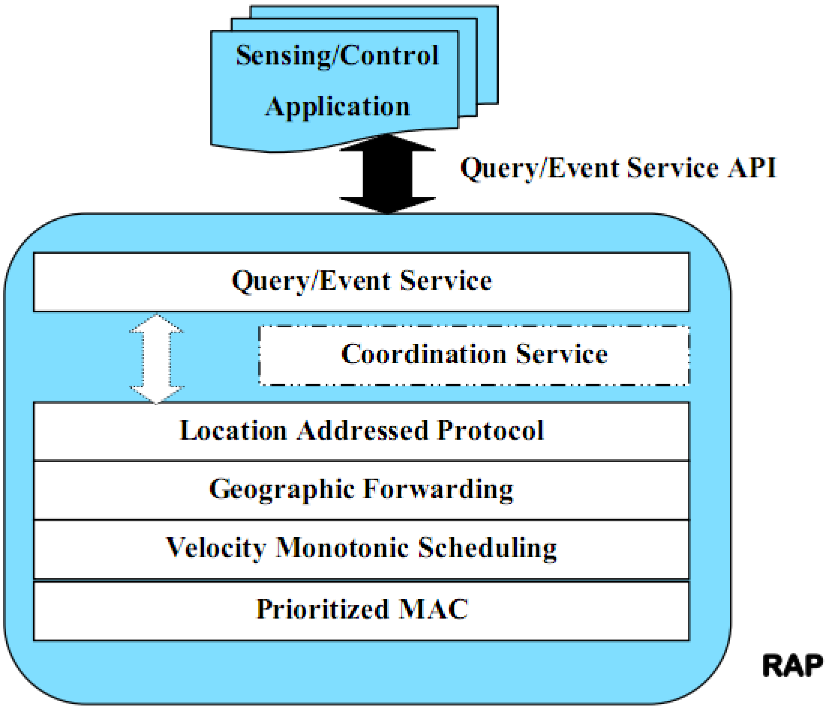

Figure 2.2: RAP communication architecture[6]

number of nodes, rate of change in network topology and diameter[32]. This protocol also supports a multiple priority scheduling of packets with support of a VMS, which assign the priority to the packets and schedule them on the basis speed required for the transmission.

RAP differentiates between its services by the deadline destinations field of packets . It computes the required transmission velocity of data packets in advance and assigns priority to different packets and then make the queue of data packets at nodes to wait for the service. Packets having higher priority will get the service first. Each queue accepts reports of velocities within a certain range.[19]

It adjusts the back-off and waiting times at MAC layer based on the priority of the report being transmitted, so that report with higher priority has more probability of accessing the channel. Although it distinguishes among different services and data packets with higher priority get services first, it cannot guarantee end-to-end real-time data transmission. Its real-time transmission mechanism also cannot be set dynamically to fulfill the different real-time requirements.

2.2.3 Energy-Aware QoS Routing Protocol(EQSR)

EQSR[10] is an energy-aware QoS routing protocol that finds a least cost and energy efficient path and guarantees certain end-to-end delay. Figure 2.3, 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 2.3, 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 Dijkstras algorithm to find a list of least cost paths and chooses the path which meets the desired requirements.

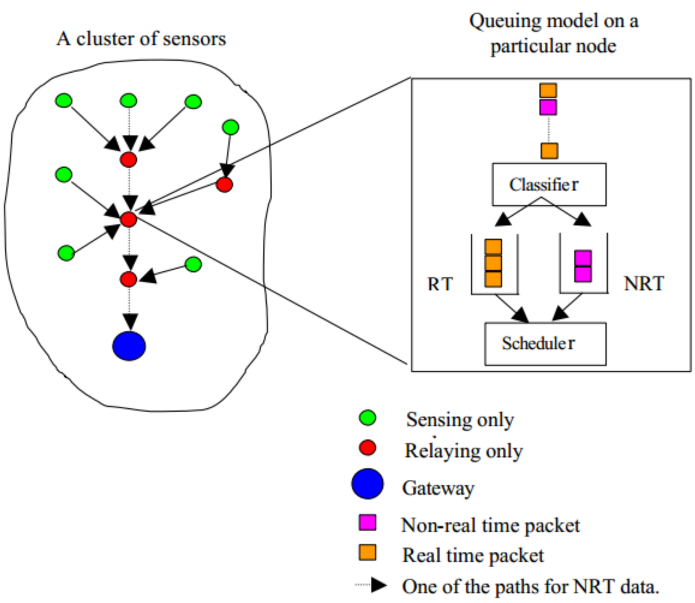

Figure 2.3: Energy-aware QoS routing protocol[7]

Energy-aware QoS routing protocol has an excellent performance 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.

2.2.4 Stateless Protocol for Real-Time Communication Protocol (SPEED)

SPEED [7] 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.[5]

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 as shown in Figure 2.4 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 it is not possible to find a node with desired speed requirement, then the relay ratio of the node is checked. The relay ratio is provided by the Neighborhood Feedback Loop (NFL) module to determines whether the packet is to be relayed or dropped. Relay ratio is calculated by the miss ratios of the neighbors of the node and is send back to the SNGF module, where a relay or drop action is taken. If the relay ratio is not between 0 and 1, which is randomly generated, then the packet is dropped. The backpressure rerouting module prevents the voids ot 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 to take new routes.

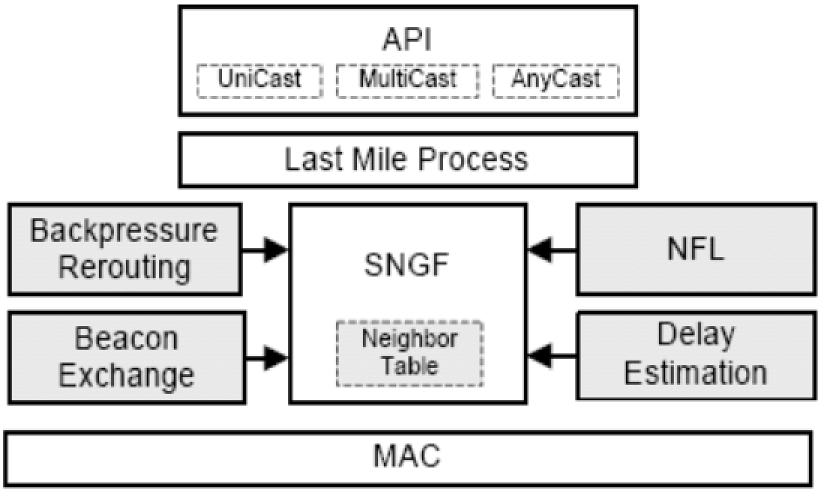

Figure 2.4: SPEED Protcol[7]

SPEED protocol's performance is good in terms of the 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.

2.2.5 Multi-Path and Multi-SPEED routing protocol (MM-SPEED)

MMSPEED is an extension to SPEED protocol and it is proposed in [20]. 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 packets reliability and timeliness requirement, packet will be processed with a certain QoS level and certain delivery speed.[5],[20]

MMSPEED protocol provides the following services which other protocols are not able to provide:

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

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

2.2.6 Real-time Power-Aware Routing protocol(RPAR)

Real-time Power-Aware Routing protocol (RPAR)[8] varies from the existing ones in many ways:

- It is the only protocol that uses the power control and real-time routing for supporting energy-efficient and real-time communication.
- It control the trade-off between energy utilization and communication delay by specifying packet deadlines.
- It utilizes a novel neighbourhood management mechanism that is more efficient than the periodic beacons scheme adopted by SPEED and MMSPEED.
- It uses dynamic transmission power adjustment and routing decision to minimize the miss ratios. The transmission power has a large impact on the delivery ratio as it improves wireless link quality and reduce the number of transmissions to deliver a packet.

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

The drawback of the protocol is that it shows degraded performance in handling large hole and sudden congestion and also, the neighbor discovery is a potential problem to the real-time performance because it takes more time.

2.2.7 Directional Geographical Routing protocol(DGR)

Directional Geographical Routing protocol[9] addresses the issue of real-time video streaming with two constrained bandwidth and energy. It forms an application based number of multiple disjointed paths for a VN(Video-sensor Node) to send parallel FEC-protected H.26L real-time video streams over a bandwidth-limited, unreliable networking environment. H.26L is a kind of video-coding standard which separates the video server design into two separate layers: a video coding layer that is responsible for efficiently representing the video content, and a network adaptation layer that combines the coded data in an appropriate manner based on the network it is being transmitted.

Multiple paths are used to support the multiple transmission instead of single-path based on shortest path which quickly drain the energy of the nodes of some path which will reduce the network life. It spreads the paths in all directions in the proximity of the source and sink nodes, which implies that packets along some paths are likely to be forwarded to a neighbor farther to the sink than the node itself. DGR performance is good in terms of delay, network lifetime and received video quality. It improves the average video PSNR by up to 3dB compared to a other geographic routing protocols[9].

DGR assumes that the video nodes take turns to send video streams to the sink, i.e., at a time only one of the video node is actively sending video data to the sink.

This assumption is unreasonable, hence DGR can't be deployed in the networks with large scaled sensor nodes.

Table I: Routing Protocols in WSNs and WMSNs

Routing protocol	Architecture	Data Aggregation	Location awareness	Multipath capability	Energy consumption	Scalability	Quality of Service(QoS) support
SPIN	Flat	Yes	No	No	Limited	Limited	No
DD	Flat	Yes	No	No	Limited	Limited	No
RR	Flat	Yes	No	No	Low	Good	No
LEACH	Hierarchical	Yes	No	No	High	Good	No
PEGASIS	Hierarchical	No	No	No	High	Good	No
TEEN	Hierarchical	Yes	No	No	High	Good	No
APTEEN	Hierarchical	Yes	No	No	High	Good	No
MECN	Location	Yes	Yes	No	Low	Good	No
SMECN	Location	Yes	Yes	No	Low	Good	No
GAF	Location	No	Yes	No	Limited	Good	No
GEAR	Location	No	Yes	No	Limited	Limited	No
SAR	Flat	Yes	No	Yes	High	Limited	Yes
SPEED	Flat	No	No	No	High	Limited	Yes
MMSPEED	Flat	No	No	Yes	High	Limited	Yes
RAP	Flat	Yes	Yes	No	High	Good	No
RPAR	Flat	Yes	Yes	No	Low	Good	No
DGR	Flat	No	Yes	Yes	Limited	Limited	No

2.2.8 Observations

Based on the literature survey I have come up with the following obervations about the existing routing 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 is a large number of nodes, is the huge overhead caused by maintaining tables at each sensor node.

RAP although differentiates among different services and data packets with higher priority get services first,but it cannot guarantee end-to-end real time transmission of packets. Its real-time transmission mechanism also cannot be adjusted dynamically to satisfy different real-time requirements.

Energy-Aware QoS Routing Protocol has an 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 requires different priority classes for different real-time operations.

SPEED performs good in terms of the end-to end delay ratio 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, the energy metric is not considered.

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 every node without information about the network state and end-to-end path formation. The only limitation of this protocol is that the energy metric is not taken in to consideration.

RPAR has the forwarding policy and neighbourhood management of which significantly reduce the energy uses with desired real-time delivery. However, the response time of the neighbour discovery is an issue for the real-time performance. Also, the transmission of packet at a high power level has a side effect of decreasing throughput due to increased interference and channel contention.

DGR uses the multipath routing to increase source-to-sink bandwidth and to achieve better load balancing. In combination with packet-level FEC coding, it simultaneously achieves reliability, energy efficiency and timely delivery of packet to support real-time video service over WMSNs. DGR assume that at a time only one video node is actively send video data to sink which is unreasonable. Therefore it cannot be deployed in large scaled sensor networks.

Table II: Routing Protocols comparision

Routing Protocol	Performance metrics	Packet prioritization	Reliability	Hole By-passing	Location Awareness
SAR	Energy Consumption and weighted QoS metric	Yes(based on packet deadline)	No	No	Yes
RAP	End-to-End deadline miss ratio	Yes(based on packet deadline and velocity)	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
SPEED	End-to-End delay, Dead line miss ratio	Yes(based on dealine and distance to sink)	No	Yes(back-pressure routing)	Yes
MMSPEED	Average end to end delay, Overhead, Reliability	Yes(based on speed value)	Yes(multipath forwarding)	No	Yes
RPAR	Energy Consumption, Dead line miss ratio	Yes(based on required velocity)	No	No	Yes
DGR	Average end-to-end packet delay, Reliability,PSNR	No	Yes(multipath routing)	No	Yes

Based on the Table I and Table II and literature survey it is concluded that there are few WSN routing protocols that considered Quality of Service for multimedia and real time applications in terms of delay reliability constraints as well as finding energy efficient paths. In other words there is a need to find QoS based energy-aware routing protocols.

Chapter 3

Proposed QoS Aware Routing Protocol

In this section the operation and algorithm of proposed routing protocol, is discussed. It is a reactive and multipath routing protocol.The proposed routing protocol is designed to provide timeliness and reliability in data delievery to the destination. It uses the localion based packet routing without setting end-to-end path between source and sink node. In sensor networks, information in a packet is more highly associated with the geographic area where the event is occured than with a particular sensor node. Each sensor node is assumed to be aware of its geographical location using GPS [21]. Thus, all the node is knows the location its neighbors within its radio range and their locations. Each node can locally make a routing decision to progress the packet towards the final destinations. If each node relays the packet to a neighbor that is closer to the destination, the packet can be succussfully delivered to the destination without knowledge of global topology. Here the goal of this protocol is to provide guaranteed packet delivery to the destination in both timeliness and reliability domains while preserving the energy comsumption as low as possible and also the quality of the video to transmitted.

3.1 Effect of frame loss on quality of video

As the compressed video is composed of three types of frames i.e. I, P and B. The frame sequence that depends on an I-frame is called Group of Pictures (GOP). A GOP length of 30 frames meaning is that the GOP starts with an I-frame, followed by 29 P or B frames.

The main issue is that the loss of an I-frame will affect the other B or P frames of the same GOP. Hence, the errors will be propagated by other frames until a new I-frame reaches the receiver in a GOP. In case of loss of a P-frame, the error will be propagated by the remaining P and B frames in a GOP. In case of loss of a B-frame, the error will not be propagated, because the B-frames are not used as a reference for other frames[11].

The loss of I-frames causes more distortion in the output video at the destination than the loss of P and B frames from the user point of view. Also, the loss of P-frames at the starting of a GOP causes more video distortion than at the end of a GOP.

3.2 Operation of the Protocol

Assume that network is densely deployed and there are multiple paths exist between source s and sink d The path consists of a set of nodes to deliver data from source node(s) to sink node(d). When a node wants to send packet towards sink node, finds the weight for each neighbour node,which is defined as by(equation 1). The weight(W) will be calculated based on the metrics as hop distance,link quality and energy remaining at that node. Based on the weight value and the type of frame(I,P and B) it send the packet to next node. Each intermidiate node the path repaet the above process until packet reach to sink node.

$$W_j = w1 * (\frac{D_{sd}+1}{D_{jd}+1} - 0.5) + w2 * (\frac{LQI_j}{LQI_max}) + w3 * (\frac{E_j^r}{E_j^i}) \quad \text{......................................(1)}$$

Suppose there are total N neighbours of source node s then total paths from node s to destination or sink d will be N. Node where event has ocurred will find the weight W for all the neighbours weight will be calculated by above equation. The node will be consodered as the most reliable node which has the maximum value of weight(W). This process will be repeated by all the other neighbour nodes untill the packet reached to the destination(sink) node.

Algorithm: QoS Aware Routing

s is source node where the event has occured;
d is destination node
N is the set of neighboring nodes of forwarding node;
j is the neighbor node of forwarding node;
w1, w2 and **w3** are weighted values;
E_i is the initial energy of the node;
E_r is the remaining energy of the node;
FrameType is the type of incoming frame;

repeat for each incoming frame
 for each neighbor j in N **do**
  Find the weight W_j of neighbor node j as;
  $W_j = w1 * (\frac{D_{sd}+1}{D_{jd}+1} - 0.5) + w2 * (\frac{LQI_j}{LQI_max}) + w3 * (\frac{E_j^r}{E_j^i})$
 end for
Sort all the weight values in to descending order
if FrameType == I **then**
 Send the frame to node with weight W_1
end if
if FrameType == P **then**
 Send the frame to node with weight W_2
end if
if FrameType == B **then**
 Send the frame to node with weight W_3
end if
until (j!=sink)

Where D_{sd} denotes hop distance from node source node s to sink node d, D_{jd} is hop distance between node j and sink d, LQI_j is link quality value of node j, LQI_{max} is maximum link quality value, E_j^i is an initial energy level of node j, E_j^r is remaining energy level of node j. W_j is the weight value of node j, ranging from 0 to 1.

Chapter 4

Simulation and Results

4.1 Simulation Parameters

Table I: Simulation Parameters

Parameter	Value
Field size	100x100
Number of Nodes	30 to 60
Simualtion Time	200s
Topology	Uniform
MAC layer	TunableMAC
Initial Energy of nodes	18,720 J
Radio Model	CC2420
Video sequence	Hall
Video Encoding	H.264
Format	CIF(352x288)
Format rate	30fps

In oder to measure the performance of proposed routing protocol simulation is done in Castalia simulator[22] and also used the Mobile MultiMedia Wireless Sensor Network (M3WSN) OMNeT++ framework [23]. Castalia is a simulator for Wireless Sensor Networks (WSN), Body Area Networks (BAN) and generally networks of low-power embedded devices. It is based on the OMNeT++[24] platform and can be used to test protocols in realistic wireless channel and radio models, with a realistic node behavior especially relating to access of the radio. Also Castalia evaluate different platform characteristics for specific applications, since it is highly parametric, and can simulate a wide range of platforms.The programming language that it support is C++.

4.2 Performance Metrics

The proposed protocol for the multimedia data like image or video transmitted in the wireless network is compared with the existing routing protocols on the basis of QoS and QoE performance metrics.

The QoS parameters includes end to end dealy reliability and energy consumed by the nodes. QoE metrics are used to access the quality of multimedia services from the user point of view[25], which includes Peak Signal to Noise Ratio (PSNR), Structural Similarity (SSIM), Video Quality Metric (VQM) and Mean Option Score (MOS)

PSNR: It is a basic but important metric to measure the quality of the video received by the user. The value of PSNR is expressed in dB (decibels). A video with average PSNR of at least 30dB will be considered as the good quality video.

SSIM:The SSIM is used to measure the structural distortion of the video, with a better correlation with the users subjective impression and the values between 0 and 1. The closer the value to 1, will be considered as the good quality video.

VQM:The VQM metric measures the "perception damage" the video experienced by the user, with the Human Visual System (HVS) characteristics, including different metric factors such as noise,color distortion and distortion blocks and blurring. VQM obtain the value between 0 and 5, closer the value to 0, means a better video quality.

MOS:This is the most popular subjective metric is called Mean Option Score (MOS). The quality level of a video (or audio) sequence based on MOS model is rated on a scale of 1 to 5, where 5 is the best possible score and 1 is the bad score.

4.3 QoS Metrics

4.3.1 Average End-to-End Delay

The average end-to-end delay is the time required to send multimedia data successfully from source node to the sink node. Figure 4.1 shows the average end to end delay for

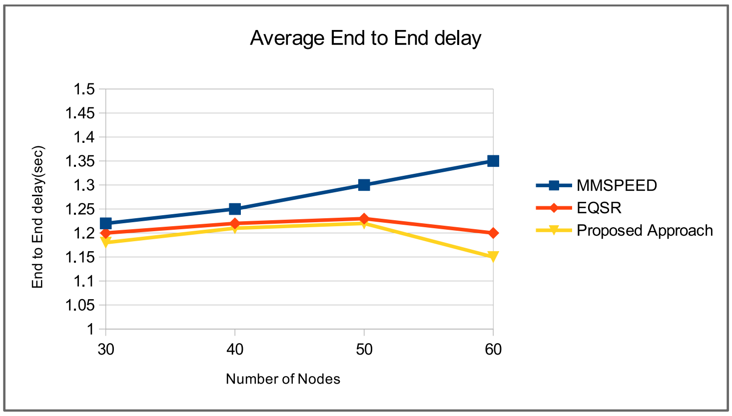

Figure 4.1: Average end to end delay

MMSPEED,EQSR and proposed protocol. It can be seen that proposed protocol has the better average end to end delay than MMSPEED and EQSR routing protocols.

4.3.2 Packet Delivery Ratio(PDR)

The average delivery ratio is the number of data packets received by the sink node to data packets generated by the source node shown in Equation 2.
PDR= Total Number of Packet received/Total Number of Packet sent ....(2)

Figure 4.2 shows that proposed protocol outperforms the other protocols in terms of average packet delivery ratio. This optimization is because it combines the link quality and the remaining amount of energy parameters with each other for selecting the forwarding node.

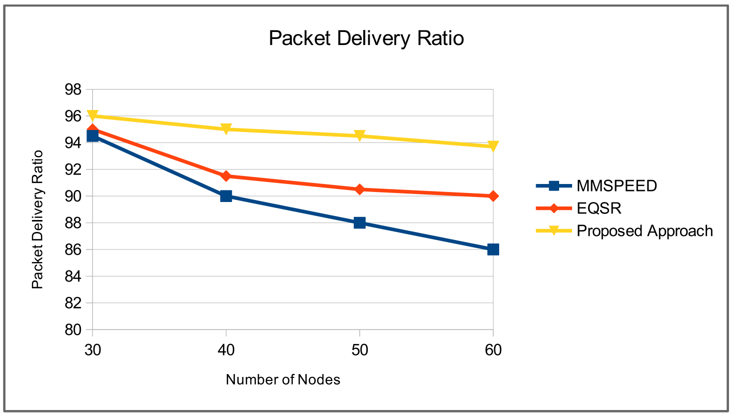

Figure 4.2: Packet Delivery Ratio

4.3.3 Average Energy Consumption

The average energy consumption is the average of the energy consumed by the nodes involve in data packets transfer from source node to the sink node. Figure 4.3 shows

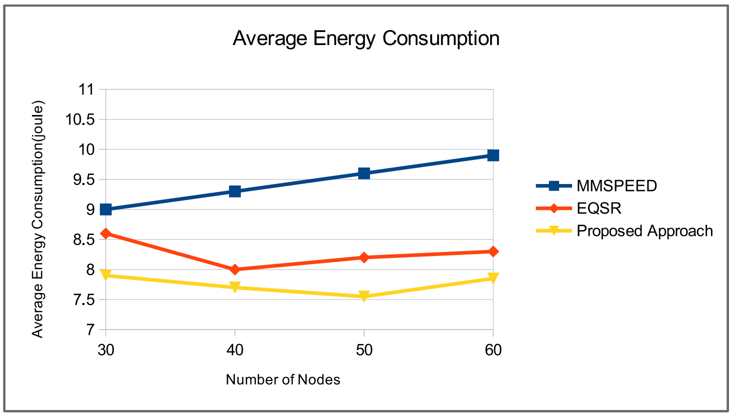

Figure 4.3: Average Energy Consumption

the results for energy consumption in three protocols. In the proposed protocol, energy consumption for sending packet form source to sink node is optimize as it consider the remaining and initial energy of the neighbor node to choose as next transmitting node.

4.4 QoE Metrics

4.4.1 Peak Signal to Noise Ratio (PSNR)

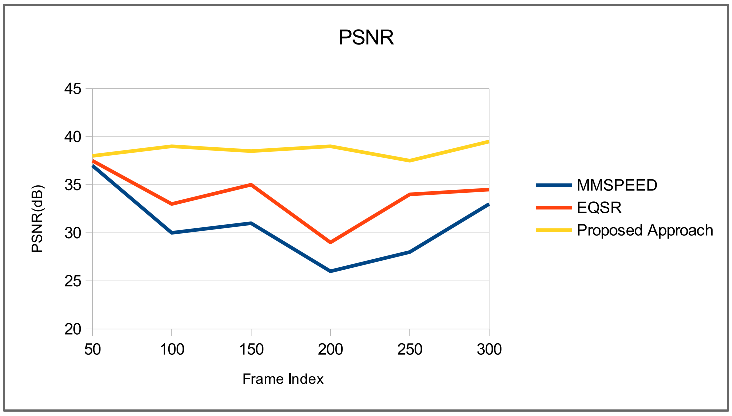

Figure 4.4: PSNR with respect to Frame Index

Figure 4.4 showing the video quality measurement using the PSNR metric. The graphs shows that PSNR value of proposed protocol higher as compared to MMSPEED and EQSR which indicate that the quality of received video is better in comparision with existing ones.

4.4.2 Structural Similarity (SSIM)

Figure 4.5 shows the video quality by using the SSIM metric. The SSIM value for the proposed protocol is higher as compared to SSIM value for the MMSPEED and EQSR, means the quality of received video is better than the existing QoS aware routing protocols.

4.4.3 Video Quality Metric (VQM)

Figure 4.6 shows the video quality measurement using the VQM metric. The graph shows that the performance of proposed protocol is better in comparision to MMSPEED and EQSR as the VQM value is higher than MMSPEED and EQSR.

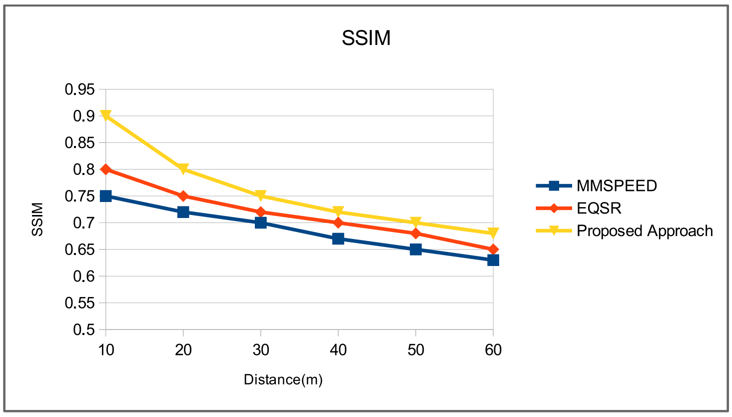

Figure 4.5: Distance from the source node to Sink

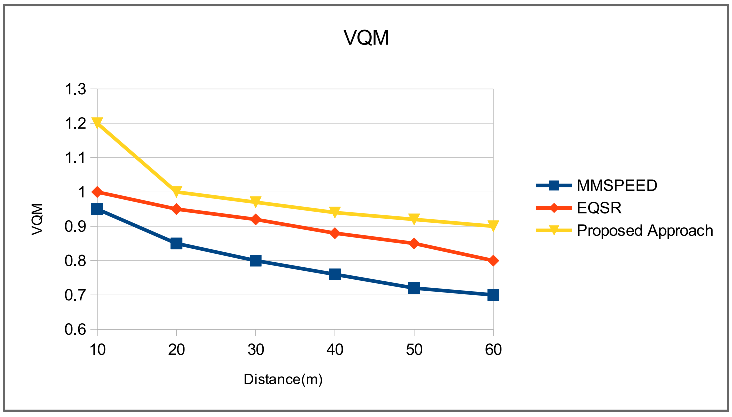

Figure 4.6: Distance from the source node to Sink

4.4.4 Mean Option Score (MOS)

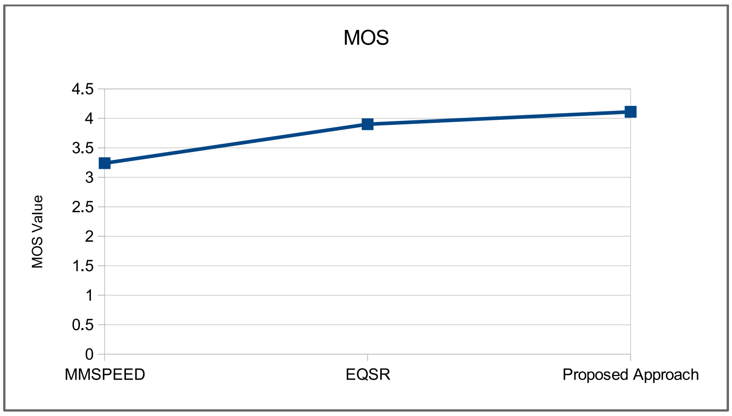

Figure 4.7: Mean Opinion Score

Figure 4.7 shows the video quality by using the MOS metric. In the graphs MOS value for the proposed protocol is more than 4 which is higher than the MOS values of existing QoS based routing protocols MMSPEED and EQSR.

Chapter 5

Conclusions and Future Scope

5.1 Conclusions

The main objective of this thesis is to design QoS aware routing protcol for multimedia transmission, while achieving energy-efficiency. Most of the applications in wireless sensor networks requires service differentiated QoS routing protocols depending on forwarding packet types. The proposed QoS aware routing protocols is a reliable and real-time protocol for multimedia data sensor network. The proposed protocol provides end-to-end delay delivery of multimedia data by meeting both reliability and timeliness requirement. Simulation results shows that the protocol finds the better path for real-time data with certain end-to-end delay, packet delivery ratio and minimum energy consumption as compared to existing QoS based protocols MMSPEED and EQSR for the multimedia transmissions. Also the quality of the video transmitted is evaluated using QoE parameters PSNR, SSIM, VQM and MOS. The simulation results shows that the quality of the received video is better as compared to existing QoS aware routing protcols.

5.2 Future Scope

The proposed protocol can be extend in future to develop the optimal routing in WMSNs where sensor nodes are mobile and their location can change with time. Also sensor nodes with different capabilities in terms of transmission range, energy level and computation capabilities can be used for the multimedia transmission in wireless sensor networks.

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