Multipath based Energy Efficient (MEE) Routing Protocol for WMSNs

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ABSTRACT
WMSNs stands for Wireless Multimedia Sensor Networks in which various sensor nodes having the property of sensing scalar quantity like pressure, temperature, etc. and also to ubiquitously retrieve multimedia information like still images, video, sound etc. Due to the scarce resources like battery, processing capability, etc., application of WMSNs is constrained. WMSNs are supported with array of camera which gives multiple images of same scene of interest but individual transmission of these images consumes more energy resulting to less network lifetime. So there is always a trade-off between the image quality and energy consumed by the node. In this paper we have proposed a protocol, "Multipath based Energy Efficient (MEE) Routing, which transmits the image optimally to the sink wirelessly and also consumes less energy of the node.MEE uses the benefits of AOMDV to build the multiple paths first then they are scored using path conditions based on availability of resources such as buffer size, energy, expected transmission time, and packet loss along the paths. MEE is compared with non-energy efficient routing protocols which do not consider the average energy of nodes and overlapping and non-overlapping parts of the original images. Simulation is performed using ns-2.27 platform and results have demonstrated the effectiveness of MEE in terms of less delay in packet delivery, high throughput and less average energy consumed by the nodes compared to non-energy efficient routing protocol.

General Terms
Wireless Multimedia Sensor Network, Network Simulator, Heterogeneous, Sensors.

Keywords
Energy Efficient, Wireless Multimedia Sensor Network, Latency, Reliability, AOMDV protocol, Expected Transmission metric (ETX).

1. INTRODUCTION
Recent technological advances in electro-mechanical systems (MEMS) and development of small sized CMOS cameras have promoted to development of powerful sensor which have increase the capability of Wireless Sensor Network (WSN) in the sense to retrieve the video, still images, sound. This class of WSN is termed as Wireless Multimedia Sensor Networks(WMSNs).WMSNs are recently deployed for a class of real-time mission critical and monitoring applications, including search and rescue, security surveillance, traffic and environmental monitoring, wild animal tracking, disaster management, and patient monitoring [1].Most deployed WSNs measure physical phenomena like temperature, pressure, humidity, or location of objects. In general, most of those applications have low bandwidth demands, and are usually delay tolerant [2]. On the other hand, WMSNs, comprised of sensor devices equipped with audio and visual information collection modules, can have the ability to retrieve multimedia data, store or process data in real-time, correlate and fuse multimedia data originated from heterogeneous sources, and wirelessly transmit collected data to desired destinations [2]. Moreover, WMSNs are designed for those real-time applications which demand strict dead line low delay, high throughput, and reliability as well as those non-real time applications which require high or medium bandwidth, loss intolerance etc. However, achieving energy efficiency is the common challenge for both networks. A broad description and classification based on the survey of various Energy-Efficient Routing Techniques with QoS Assurances for Wireless Multimedia Sensor Networks is discussed in [1] with their merits and demerits. A single fixed camera or single moving pan-tilt-zoom (PTZ) camera usually installed in WMSN to retrieve the images have limited Field of View (FoV) or Field of Regard (FoR). This results in degradation of image quality at sink as individual transmission of image is not optimal due to the constraints of WMSN resources in terms of Energy, Bandwidth availability, Packet and buffer size, channel capacity. Hence energy efficient, optimal image transmission routing in WSN is a challenging task. Thus in proposed protocol MEE we adopt the multipath routing approach based on Ad-hoc On-demand Multipath Distance Vector Routing (AOMDV) and then to score the path based on various metrics like buffer size, energy, expected transmission time, and packet loss and to prioritized the image acquired from multiple cameras and send to the sink. The effectiveness of MEE is demonstrated using NS-2.27. The rest of the paper is organized as follows: Section 2 describes literature work based on Energy-aware Multipath routing is reviewed. In Section 3 we have discuss the environment and model used for proposed protocol. Section 4 describes the simulation parameters and discusses the results of proposed protocol. Finally in Section 5 we conclude our paper and discuss the possible future work.

2. RELATED WORK
Research shows that single path routing schemes are not suitable for supporting multimedia transmission in WSN as it will cause queuing delay and packet loss in restricted buffers at intermediate nodes and may cause congestion over network. Energy-aware multipath routing protocols are mostly heuristic protocols that pick up the next hop primarily

based on the remaining energy of neighboring nodes. Because sensor nodes have very limited amounts of energy, and in order to prolong the network lifetime, energy-aware approaches avoid choosing sensors with low energy in data forwarding. This presents network partition, because of early energy depletion of a part of sensors. Therefore, it is a good heuristic in balanced efficient routing protocols. Moreover, these protocols aim to balance the communication load based on the remaining energy of sensor nodes to balance energy consumption and provide data reliability using multiple paths. The protocols in this category construct the routes by broadcasting messages to whole network. The main purpose of message broadcasting is to collection formation of the neighboring nodes and to build the neighboring table. Each node contains a neighboring table which stores the significant information about the neighboring nodes including residual energy, hop distance, and signal strength. The neighboring table helps the node to decide the best next hop by using the attributes stored in the table. This scheme leads to a multiple path infrastructure, which is created from the nodes that satisfy the specific requirements. Energy-aware protocols use reactive routing, meaning that the path is created only when it is required. This reduces much of the communication overhead. Path maintenance is another major concern for every multipath routing protocol. In order to keep track of path performance or path failure, the destination node monitors the inter-arrival delay for each data packet. If the delay is above a predetermined threshold, the sink will assume that the path is broken [3]. There are many protocols available which effectively transmits the multimedia data to the sink depending on various distinct parameters. This protocols are widely explained in [3]. Table 1 summarizes Qualitative comparison of the performance of energy based multipath routing protocols [3] where;

LFT – Lifetime
LB – Load Balancing
PDR – Packet Delivery Rate
NoP– Number of Paths
RST – Route Set-up Time
TF – Amount of Traffic
PLen – Packet Length
Delay – Average Delay in delivering the packets
VG – Very Good
GD – Good
FR – Fair
Mid - Medium

In [4] the author proposes an effective algorithm, EEMR, to discover node-disjoint multiple paths between the source node and the destination node .Multiple paths are constructed by considering a link cost function, which takes both energy level and hop distance into account. The author also presents a load balancing algorithm, which helps to distribute the network traffic evenly on to the whole network .By using the link quantity as a performance metric the authors in [5]propose a multipath routing protocol, QoS and energy-aware multipath routing (QEMPR) for real-time application in WSNs. Each node in the network is assigned with a unique ID and also has a capability of calculating the packet receiving and packet sending probability using the link quality information. The multiple paths are discovered by message broadcasting and each node maintains a neighboring table which stores the information about the neighboring node such as remaining energy and transmission range. After constructing the paths, the packet will be transmitted based on the packet sequence number and number of hops it is away from the sink. This means the source will first transmit the packet with the lowest sequence number through the path with the lowest hop number. Then the packet sequence number and the hops associated with the path go higher and higher. In this way the sink will receive the packet consecutively. This approach helps to distribute the network traffic throughout the multiple paths, thus increasing network life time. In [6], the authors propose EEAMR which focuses on distributing the traffic based on the node's residual energy and received signal strength. For consistent resource utilization, more load is assigned to under-utilized paths and less load is assigned to over-utilized path. In order to save more energy, nodes which are not participating in the data transmission go into sleep mode .In another paper [7] authors propose a multipath routing protocol named Reliable and Energy Efficient multipath routing protocol (REEM) which constructs multiple paths from source to destination, considering node reliability and energy level. The path is constructed by a base station through message broadcasting and each receiving node will store the neighboring information in a table. Also, the path reliability is evaluated by the base station through a weighted and oriented graph, based on the neighbor information. For a large scale WSNs the authors in [8] propose a novel protocol named Multipath Routing with Multiple sink nodes (MRMS) to save energy. The main idea is to deploy multiple sink nodes and uses path cost metric to select the multiple paths. The path cost metric is determined based on the distance between two neighbor, and available energy at the node. In some scenarios the WSN is deployed in such an environment where the base station needs to query a certain portion of the network to collect the sensing information from the nodes. In [9] author propose an energy balancing multipath routing protocol (EBMR) which is based on client-server architecture with the base station processing the data received from the sensor nodes. The path construction is done by using message broadcasting from the base station.

Table 1.Qualitative comparison of the performance of above multipath routing protocols.

Name of Protocol	LFT	LB	PDR	NoP	RST	TF	PLen	Delay
EEMR	VG	GD	GD	Low	Mid	Low	Low	Low
QEMPR	GD	GD	GD	Low	Mid	Low	Mid	Low
EEAMR	VG	FR	GD	Low	Mid	Low	Low	Low
REEM	FR	GD	GD	Low	High	Mid	Mid	Low
MRMS	VG	GD	VG	Low	High	Low	Low	Low
EBMR	FR	FR	FR	Low	Mid	Mid	Low	Low

In [10], authors described AOMDV which shares several characteristics of AODV. The core of the AOMDV protocol lies in ensuring that multiple paths discovered are loop-free and disjoint, and in efficiently finding such paths using a flood-based route discovery. In [11], authors proposed a collaborative transmission scheme for image sensors to utilize inter-sensor correlations to decide transmission patterns based on transmission path diversities, which achieves minimal energy consumption, balanced sensor lifetime and required image quality. This optimization scheme not only allows each image sensor to transmit optimal fractions of the overlapped images through appropriate transmission paths in energy-efficient way, but also provides unequal protection on the overlap image regions through path selections and resource allocations to achieve good transmission image quality. In [12], authors proposed an effective approach where the data redundancy among correlated image sensors can be considerably reduced. The communication overhead for data exchange is relatively small to exploit the correlations in the proposed approach. Furthermore, it is investigated and considered both source sensor image transmission schemes and routing patterns together in WSN assuming that image sensors are installed in various locations of a large size sensor network to monitor or track objects. These sensed images may overlap with each other. The sensors have limited capability and resource to process the images; therefore, images have to be sent to base station (sink) for more sophisticated processing. To save energy, it would be important for each source sensor to send its own Non-overlapping region (NOVR) and not to send the overlapping region. As the base station may be far away from the image sensor, the images then have to be transmitted by multiple hops through relay sensors to the base station. It requires an effective image transmission pattern, to handle large-size image data. Further this uses MLRR routing scheme achieving energy efficiency and longer network lifetime, based on residual energy level at each of the nodes rates are determined at each of the node. It will choose the next hop node in next level whose rate is same as that of its, so that lower transmission rate is assigned to nodes which have less residual energy. In [13] protocol named "Energy Efficient Prioritized Multipath QoS Routing (EEPMQR)" author have calculated overlapping and non overlapping region of the images captured, and path score is calculated based on buffer size, and energy and also prioritized region scheduling is done to avoid the redundancies.

3. Proposed Protocol

WMSNs are supported with array of camera which gives multiple images of same scene of interest but individual transmission of these images consumes more energy resulting to less network lifetime. So there is always a trade-off between the image quality and energy consumed by the node. In this paper we have proposed a protocol, "Multipath based Energy Efficient (MEE) Routing, which transmits the image optimally to the sink wirelessly and also consumes less energy of the node.

3.1 Working Technique

The proposed protocol "Multipath based Energy Efficient (MEE) Routing", which transmits the image optimally to the sink wirelessly and also consumes less energy of the node, uses multipath based approach to transmit image over WMSN. The image sensors are installed in various locations of a large size sensor network to monitor a scene of interest or track objects. Initially multiple paths are build from source node to sink node considering the features of AOMDV [10]. Source node can be an aggregation node also called as Cluster Head if clustering is used that collects the data from the multiple image sensors. These sensed images may overlap with each other and have some regions in common (overlapped, OVR) and some are not (non-overlapping, NOVR). The captured image of scene of interest is separated into OVR and NOVR region of original image. OVR of the images have the redundant information and hence can be transmitted only once to reduce energy consumption and also is the important region because the two original images can only be recovered by the reliable reception of this OVR at the sink. Further the use prioritized region scheduling, reduce energy consumption and thus increase the lifetime of the network. When the correlated images among cameras considered, after classification of image into OVR and NOVR not all the packets in all the regions have the same effect on the image quality, so it is better to give priority to packets belonging to OVR because these packets are most important to reconstruct the images as they carry information of both the images and loss of such packet degrades the picture quality and hence a most reliable path is searched among the multi-paths to send the OVR packets. The data is scheduled for transmission through multiple paths according to the path scores. Multiple path scores are calculated by considering the, minimum residual energy, and minimum buffer size. Node failure condition if occurred is also taken care in MEE to find alternate path. The data is transmitted through highest path score paths. The optimal scheme provides high throughput, low packet loss and less delay in packet delivery.

3.2 Energy Model

The energy model used for communication is same as [15]. The model gives the formulae to calculate the various parameter of energy of sensor node, which are as follows :

- The consumed energy for transmission of a n-bit message is given by,

$$E_T = (n \times E_{elect}) + (n \times E_{amp} \times r^2)$$

where;
E_T – Energy consumed for transmission
n – No. of bits of messages
E_{elect}– Energy consumed in the nodes electronic apparatus
E_{amp} – Energy requirements for the signal amplification
r – Distance between the transmitting and receiving node.

- To receive a n-bit message, a sensor consumes the energy is given by;

$$E_R = n \times E_{elec}$$

- Residual energy of each node is computed based on;

$$E_{res} = E_0 - E_R - E_T$$

where;
E_0 – Initial energy of the node
E_R – Energy consumption for receiving n-byte
E_T – Energy consumption for transmitting n-byte

- The count of available buffer space of each node is computed based on;

$$ABS = BS - j$$

where;
j – Counter that shows the number of packets in each intermediate node buffer.
BS – Buffer size is maximum capacity of the buffer to store the packets.

3.2.1Path score calculation:

Path score calculation is done in the same manner as done in [13] but instead of , we have consider Expected Transmission Count Metric (ETX). The ETX [16] of a link is calculated using the forward and reverse delivery ratios of the link. A sender will retransmit any data packet that is not successfully acknowledged. Because each attempt to transmit a packet can be considered a Bernoulli trial, the expected number of transmissions for a link is approximated as:

$$ETX = 1/(d_f \times d_r)$$

where;
d_f-Forward delivery ratio i.e. the measured probability that a data packet successfully arrives at the recipient.

d_r- Reverse delivery ratio i.e. the probability that the ACK packet is successfully received by the data sender, given that the data packet was received successfully.
(d_f × d_r) - The probability that a data transmission is successfully received and acknowledged.

3.3 Algorithm

In the proposed protocol, "Multipath based Energy Efficient (MEE) Routing protocol", we assume that each sensor node take care of OVR and NOVR of images captured from same scene of interest so that less redundant information is transmitted and further reduces the energy consumption of base-station.
Step 1. Sensor node randomly selects the images of scene of interest from the array of sensors deployed. Then it calculates OVR and NOVR of the images selected.

Step 2. Then the path discovery is done. Source node finds the multiple paths towards the sink based on AOMDV routing protocol. Once the path is build then they are scored based on [13, 16] and then the paths having higher scores are sorted and stored in valid path lists.

Step 3.Prioritized region scheduling is performed i.e. OVR is send over highest scorer path and then NOVR of images is send over comparatively lower scorer paths.

Step 4. Thus at the sink the image is reconstructed.

4. SIMLATION AND RESULT

In this section we present and discuss about the simulation environment and results obtained showing the effectiveness of MEE over non-energy efficient routing protocol. The proposed scheme is implemented i.e. simulated using ns-2.27.

4.1 Simulation Model

The platform used for simulation purpose and to show the effectiveness of MEE protocol is Network Simulator i.e. ns-2.27. *ns*is a discrete event simulator targeted at networking research. Ns provides substantial support for simulation of TCP, routing, and multicast protocols over wired and wireless (local and satellite) networks [14]. *ns*is an object oriented simulator, written in C++, with an OTcl interpreter as a frontend. The simulator supports a class hierarchy in C++ also called the compiled hierarchy in this document), and a similar class hierarchy within the OTcl interpreter (also called the interpreted hierarchy in this document). It provides the most complete support of communication protocol models, among non commercial packages. NS 2.27 supports Energy Model and gives better understanding of simulation environment.

4.2 Simulation Environment

For simulation purpose of the proposed protocol, "Multipath based Energy-Efficient (MEE) Routing", we assume that the sensor nodes are stationary for lifetime. The network topology scheme is as shown in the figure 1 where, Number of sensor nodes = 25 are uniformly distributed over an area of 1400 x 1400 m^2. addition, we assume that each sensor is able to compute its residual energy, available buffer size. The source sensor senses the image and stores in it, then the OVR and NOVR of the original image is calculated. This avoids data redundancy on multiple paths achieving load balance on the network. Quality scalable source encoders such as JPEG 2000 [17] can be used which offer flexibility in choosing the size of the information bit stream to be transmitted. In [18], authors proposed a system for JPEG-2000 with multiple descriptions coding of image and video data, image transmission over WSNs that minimizes energy consumption which is based on encoding the information bit stream using assumption while satisfying QoS guarantees. The input image is encoded using standard JPEG format. Both gray scale image and color images can be used. Although a JPEG file can be encoded in various ways, most commonly it is done with JFIF encoding .

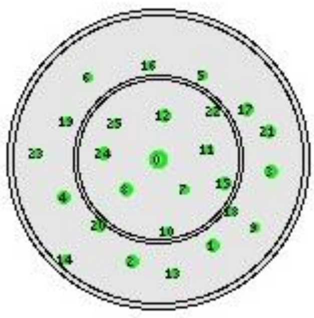

Figure 1: Network Topology

4.3 Simulation Parameters

The simulation scenario is set up according to the parameters mentioned in Table 2 and 3.

Table 2: Node configuration parameters

Simulation Area	1400X1400
Model	Energy
Sensor initial Energy	10 J
Transmitting Power	0.6
Receiving Power	0.3
Transmission Range	50m
No Of Mobile Nodes	25

Table 3: Energy Model

Radio Propagation Model	Two Ray Ground Model
Antenna Model	Omni Antenna
Network Interface Type	Phy/Wireless Phy
MAC Type	802.11
Routing Type	AOMDV
Interface Queue Type	Queue/Drop Tail/PriQueue
Buffer Size of IFq	5

4.4 Simulation Scenario

In this section Figure 2, 3 and 4 describes the working of the proposed protocol, "Multipath based Energy-Efficient (MEE) Routing" based on the parameters mentioned in section 4.3

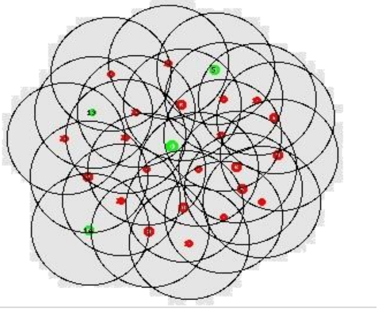

Figure 2 : Multipath Routing

Figure 2 shows the scenario of multipath build and source and destination is fixed based on energy of the nodes. Here, the green nodes represent the active state whose energy is more than pre-determined and red nodes represents energy level of it is degraded.

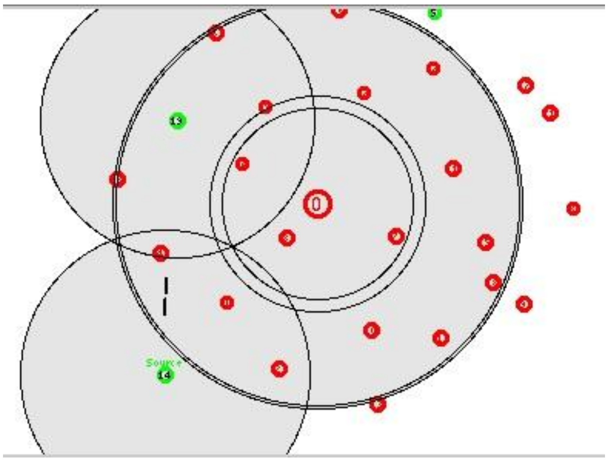

Figure 3 : Packet delivery statefrom Source to intermediate node

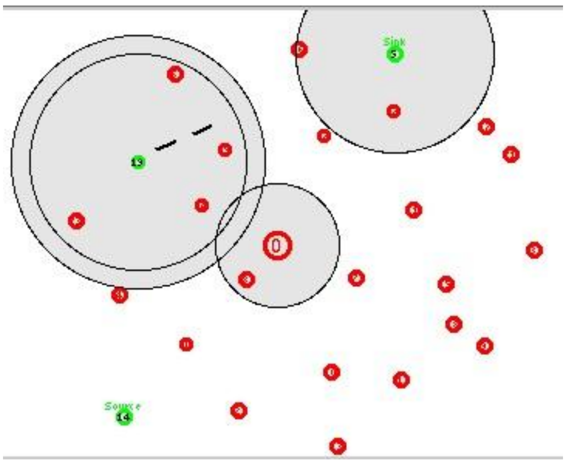

Figure 4 : Packet delivery from Intermediate node to Sink

4.5 Result Analysis

In this section the performance and effectiveness of the proposed optimal energy efficient routing "Multipath based Energy-Efficient (MEE) Routing" protocol in wireless multimedia sensor network is compared with non-optimal energy-efficient routing scheme in terms of Average delay in Figure 5, Throughput in Figure 6 and Average energy consumption in Figure 7.

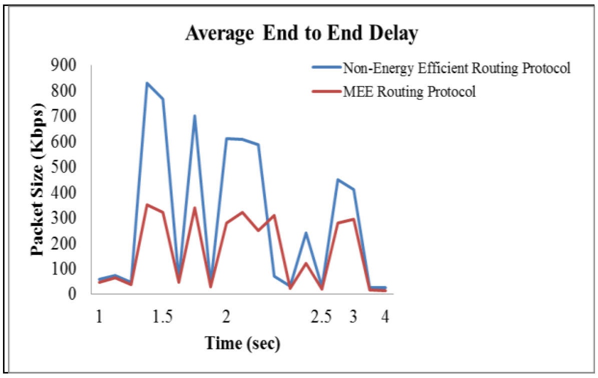

Figure 5 : Average End to End Delay

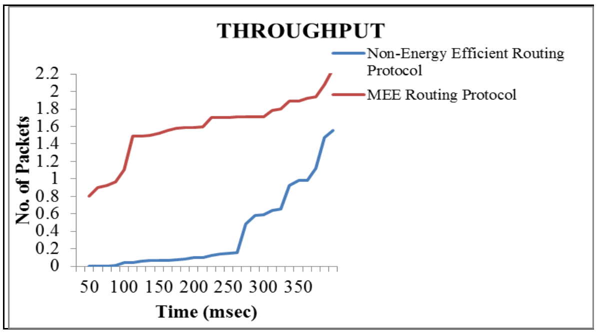

Figure 6 : Throughput

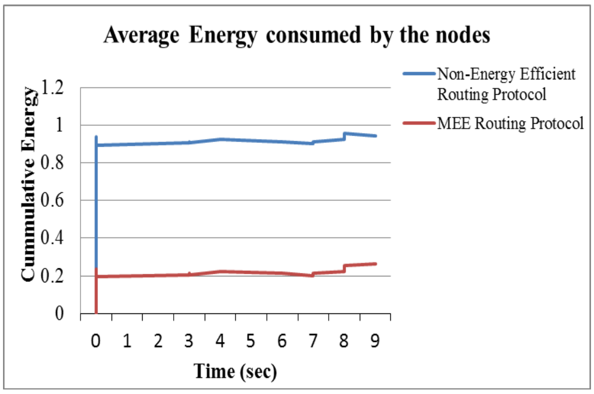

Figure 7 : Average consumption of energy

5. CONCLUSION

When designing protocol architectures for wireless multimedia sensor networks, it is important to consider and the severe energy constraints of the nodes. As found in literature, there is always a trade-off between large size image with high quality and energy consumption of the nodes. To overcome this problem, we design a MEE protocol which makes use of multipath routing taking the advantages posed by AOMDV and prioritized region scheduling. The proposed protocol is compared with non-optimal energy efficient transmission scheme. Results from our experiments show that MEE provides the high performance needed under the tight constraints of the wireless channel.

As a future work, more optimal routing protocol can be used to build the multipath.

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