Energy-Efficient Reliable Video Routing in Wireless Multimedia Sensor Networks

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Abstract
Wireless multimedia sensor networks (WMSNs) can handle different traffic classes of multimedia content (video, audio streams and still images) as well as scalar data over the network. Use of general and efficient routing protocols for WMSNs is of crucial significance. Similar to other traditional networks, in WMSNs a noticeable proportion of energy is consumed due to communications. Many routing protocols have been proposed for WMSNs. The design of more efficient protocols in terms of energy awareness, video packet scheduling and QoS in terms of checkpoint arrangement still remains a challenge. This paper proposes the actuation of sensor on demand basis and routing protocol based on cost function which efficiently utilizes the network resources such as the intermediate nodes energy and load. Cost function is introduced to improve the route selection and control congestion. Simulation results, using the NS-2 simulator show that the proposed protocol prolongs the network lifetime, increase the throughput and reliability, decrease the network load.

Keywords
WMSNs, energy efficiency, reliability, Qos, video packet scheduling.

I. INTRODUCTION

Wireless multimedia sensor network (WMSNs) are a new and emerging type of sensor network [1]. The sensor nodes in WMSNs are equipped with cameras, microphones and other sensors producing multimedia content. During the survey of routing protocols, it is observed that routing protocols for WMSNs are found to be concentrated on communication between the nodes using single path.

Single path routing algorithms in wireless sensor networks (WSNs) focus on picking up an energy efficiency path from interconnect sensor nodes network, e.g. Directed Diffusion [2], Minimum Cost Forwarding [3]. They make sure data transmitted on optimized path and prolong the lifetime of the network. Besides energy efficiency, multipath routing take advantage of interconnect nodes network to reduce network load and enhance data throughphut and packet delivery ratio. Many multipath routing protocols have been proposed in the field of WSNs [4]. However, almost all the routing protocols in WSNs considered energy efficiency as the ultimate objective in order to maximize the whole network lifetime [5]. The transmission of video and image data requires both energy and QoS aware routing in order to ensure efficient usage of the sensors and effective access to the gathered measurements. In WMSNs, video sensors are used to enhance the capability of event description [6]. Video sensors can generate image and video streaming data, which with heavy load require higher transmitting capability. Since high transmit rate is required for multimedia packages, congestion in WMSNs is more prone to happen. So, congestion control is also of prime importance in WMSNs.

The problem of congestion control has been addressed in many works e.g. Priority Based Congestion Control Protocol [7], Queue Based Congestion Control Protocol with Priority Support [8]. They analyzed how to detect and control congestion but mainly on transport layer. For addressing multimedia packets transmitting congestion problem and assure energy efficiency and reliability an energy efficient reliable video routing protocol for WMSNs is proposed.

The paper is organized as follows. Section 2 introduces related works in this area; Section 3 presents the proposed solution. Some simulation results are presented in Section 4. Section 5 concludes the work.

II. RELATED WORK

Many routing protocols have been proposed in the field of WMSNs. However, the design of more efficient protocols still remains a challenge.

In [9] the authors determined closed form expressions for the required number of cluster heads and the required battery energy of the nodes for both single-hop and multi-hop modes. They proposed a hybrid communication mode which is a combination of single hop and multi-hop modes and which is more cost-effective than either of the two modes. They considered the overall design problem through a data aggregation model. Aimed at the problem of unbalanced energy consumption of cluster heads caused by inter-cluster communications in WSNs clustering routing

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protocols, a novel algorithm named Cluster Head Load Balanced Clustering (CHLBC) is presented work [10].

In [11] the author's proposed new algorithm called MPDT: Multipath Data Transfer protocol. It provides simultaneous multiple paths for communication between any two nodes and distributes the work among the nodes uniformly, prolonging the life of the WMSNs. It is observed that the packet drop reduces as the number of paths selected for the data transmission.

Routing techniques based on ant intelligence are inspired by the biological phenomenon that helps the ant in finding the shortest path among the explored routes and attracts more ants to reinforce the shortest path. Multimedia enables Improved Adaptive Routing (M-IAR) algorithm is based on ants cluster optimization algorithm [12]. M-IAR provided a shortest path of delay and delay jitter for transmission of multimedia data of single source node to single sink node.

The Decentralized QoS-Aware Middleware for Checkpointing Arrangement in Mobile Grid (MoG) computing systems was proposed in [13]. The authors determined the globally optimal checkpoint arrangement to be NP-complete and so considered Reliability Driven (ReD) middleware, employing decentralized QoS-aware heuristics, to construct superior check pointing arrangements efficiently. ReD works to maximize the probability of check pointed data recovery during job execution, increasing the likelihood that a distributed application executed on the MoG, completes without sustaining an unrecoverable failure. It allows collaborative services to be offered practically and autonomously by the MoG.

The authors in [14] considered the design of more efficient protocols in terms of energy awareness, video packet scheduling and QoS in terms of check point arrangement. The proposed architecture Actuation Sensor Adaptive Routing With Checkpoint (ASARC) provides power aware, reliable routing and has low latency in delivering the sensing data from source or sink node to the destination node. ASARC provides actuation of sensor on demand basis and selection of path for communication between any two nodes such as sensor or relay node without video distortion**.**

Energy and Delay Aware Dynamic Source Routing (ED-DSR) efficiently utilizes the network resources such as the intermediate mobile nodes energy and load [15]. It ensures both timeliness and energy efficiency by avoiding low-power and overloaded intermediate mobile node. The route selection is done according to energy consumption and queue load of intermediate nodes. Cost function is defined based on residual energy, queue length, processing and transmission time of intermediate nodes. This protocol prolongs the network lifetime, increases the volume of packets delivered while meeting the data flows real-time constraints and shortens the end-to-end delay.

In existing WMSNs routing protocols, there is no actuation of the multimedia sensors in on demand basis, congestion control techniques are not used to select the least cost path to the base station and no checkpoint arrangement done for comparing the quality of the original sensed data.

III. PROPOSED SOLUTION

In this section an Energy Efficient Reliable Video Routing Protocol in WMSNs is proposed.

A. Multimedia Sensor Network Model

WSNs usually consist of sensors, a sink and a control center. In WMSNs, common sensors are mostly or totally replaced by multimedia sensors. Clustering technique is used to reduce energy consumption in proposed protocol. When triggered by the event happened in the monitoring environment, the source node collects multimedia information such as image and video of the object and then send the information to base station via cluster heads in a multi-hop way. The information will be transmitted to the base station at last as shown in Fig. 1.

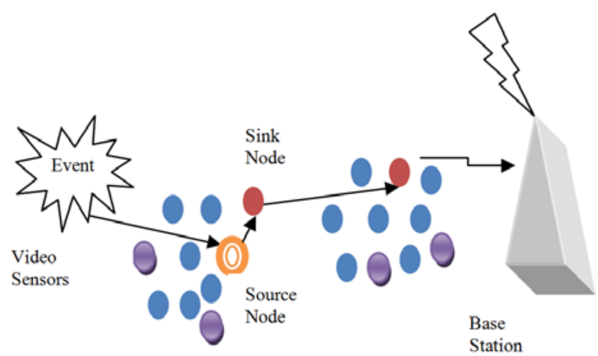

Fig.1. Model of a wireless multimedia sensor network.

B. Cluster Arrangement

In cluster arrangement, wireless sensor nodes (WSn) only are used as source node, relay or sink node to avoid more loading given to wirelesss multimedia sensor nodes (WMSn). WSn may be in sense mode and in relay mode. High power node is chosen to act in both the modes. Otherwise it acts in either of the modes. In sense mode it senses the data and in relay mode it acts merely as a relay route. In relay mode the node is called sink or relay node.

It acts in the relay mode when the request is given to it accordingly from the other nodes. The mode of the node is decided by the energy in the vicinity to act as sink or relay.

In the cluster arrangement the following assumptions are made:

- All the nodes are homogeneous with same battery power and architecture. .
- We assume that the network is noise and error free.
- Each node is aware of its location via some GPS system or by using some localization algorithm also each node has information about their neighbors.
- Each node also has information regarding its area coverage.

C. Actuation Algorithm

In actuation algorithm, only the nodes with highest residual energy are actuated. The actuated nodes are considered as the cluster heads through which the data is disseminated to other cluster heads.

D. Cost Function Based Multipath Routing

In cost function based multipath routing the route request, route reply, the route selection process and data dissemination are described as follows:

Route Request (RREQ): WMSn transmits RREQ to all next hop neighbors in the cluster Cg, which is the set of all one hop neighbors. The node can directly communicate with the nodes that are listed in the set without using relay nodes. The node receiving its data from WMSn is called source node, from this node that the data is transferred to all other nodes. On receiving the RREQ message the node responses with its ID by SenseNode ID (SNID), Senserelay ID (SRID), Sink ID (SID), depending upon the minimum, mediocre or maximum power of the node respectively. Sink ID (SID) is given priority for next hop from the source.

Route Reply (RREP): When a destination node receives an RREQ, it returns back a RREP packet to the source node. When an RREP packet is being sent back to the source node, each intermediate sensor node will stamp its current status in the RREP packet. Finally, at the source node, the routing agent collects the RREP. This status information is shown in Table. 1, in which *i* is the index for the sensor nodes.

Information Fields	**Contents**
d_i	Distance of this node provided by the physical layer
L^i_{queue}	Current length of queue, provided by network layer
E^i_{remain}	Current remaining energy of this node, provided by the physical layer

Table.1. Information fields of RREP.

The cost of each available route is calculated according to the following equation:

$$C = \Sigma M_{i=1} (\alpha \times C^i_{energy} + \beta \times C^i_{queue}). \quad (1)$$

Where C is the cost of the route and C^i_{energy}, C^i_{queue} are the costs of node *i* considering the energy and queue length respectively. α, β are the factors which normalize C^i_{energy}, C^i_{queue}. C^i_{energy} is calculated as follows:

$$C^i_{energy} = \frac{di}{Ei\ remain} . \quad (2)$$

C^i_{energy} is a function depending of the distance and remaining energy of node *i*, d_i is the distance of the node provided by the physical layer and E^i_{remain} is the current remaining energy of the node provided by the physical layer. More remaining energy and shorter distance indicate less C^i_{energy}. C^i_{queue} is given below:

$$C^i_{queue} = \log(1 + L^i queue) . \quad (3)$$

Where L^i_{queue} is the queue length at node *i*. If there are more packets in the queues along the route, the transmission will inevitably suffer a longer delay. C^i_{queue} increases rapidly with L^i_{queue}.

Route Selection: The proposed protocol waits for a certain period of time to collect RREP packets from the destination node along various routes. Later the source node selects the one based on minimum value of cost function (C). The cost function reflects the requested QoS features such as remaining energy and queue load of intermediate sensor nodes. The cost function is calculated from the current status information of the intermediate sensor node.

Data Dissemination: After the route selection, in the data transmission phase the source node is selected based on the residual energy in the node. The data is encoded into frame source coding to ensure the reliability of data .The Reed Solomon (RS) encoder is used because the complexity of code generation is less, hence the energy consumption is less which is primary concern for developing the algorithm in WMSNs.

E. Video Packet Scheduling

In the source wireless sensor node (SWSn) each frame is coded into a number of video packets according to the size. Source Sensor node decides which video packets will be optimally dropped in order to reduce its current transmission rate. A combination of one or more video packets may be omitted prior to the video transmission. Dropping video packet imposes a distortion that affects not only the current frame but all the correlated frames. By using checkpoint arrangement in the source sensor the optimum pattern of packets/frames are dropped.

F. Checkpoint Arrangement

For robust check pointing and recovery to support execution, minimizing execution rewind, and recovery rollback delay penalties are required. Sense of Grid (SoG) scheduler make decisions on selectively submitting job portions to node having superior check pointing arrangements in order to ensure successful completion by providing highly reliable check pointing, which increases the probability of successful recovery, minimizing rollback delay. Checkpointing saves intermediate data and machine states periodically to reliable storage during the course of data transformation.

IV. SIMULATION RESULTS

A. Simulation Setup

The proposed protocol is simulated over NS-2 v2.34 [16]. The network size is 500 × 500 m^2 with 150 nodes at first instance. Each node is equipped with an IEEE 802.11 for the MAC layer as shown in Table.2, which lists the parameters used in our simulation.

Parameters	Values
Network Area	500 ×500 sq m
Number of Nodes	150
Clusters Formed	15
Packet Size	512 B
Initial Energy	50 Joules
Mac Layer	IEEE 802.11
Radio Model	Two Ray Ground Model
Radio Range	40 m
IFQ Length	50 Packets

Table.2. Simulation parameters.

B. Performance Metrics

Four important performance metrics are evaluated. They are used to compare the performance of routing protocols in simulation:

- *Routing overhead:* The ratio between the average numbers of data events relayed by a data forwarder for every distinct event delivered to the sink.
- The *energy consumption* measures the average energy dissipated to transmit a data packet from source to sink.
- The *packet delivery ratio (%)* is the number of packets generated by the source to the number of packets received by the sink node.
- *Throughput:* It is the average rate of successful message delivery over a communication channel.

C. Results and Discussions

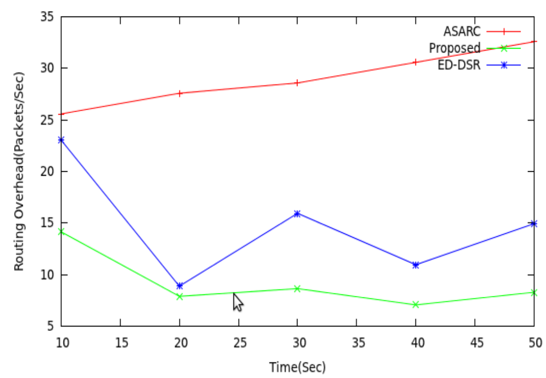

Fig.1 Routing Overhead

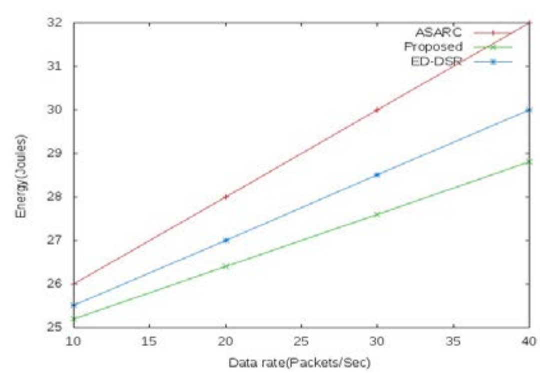

Fig.2 Energy Consumption

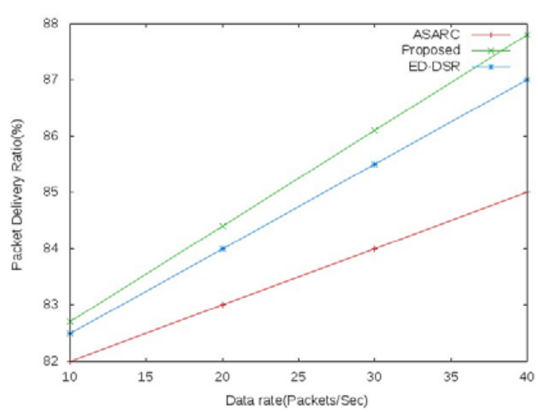

Fig.3 Packet Delivery Ratio

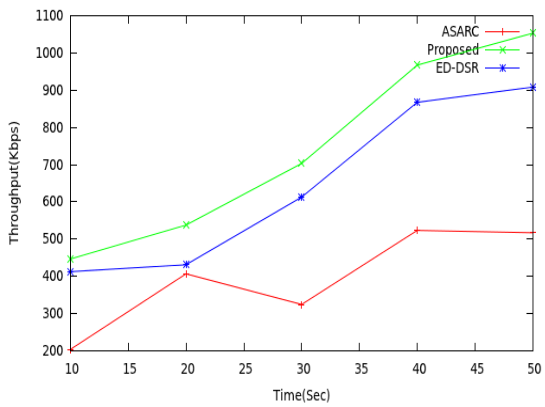

Fig.4 Throughput

The simulation was carried out by comparing the proposed protocol Energy efficient reliable video routing with Actuation sensor adaptive routing with checkpoint arrangement (ASARC) and Energy and delay aware dynamic source routing (ED-DSR).

Fig.1 shows the routing overhead. By using the cost function based routing and checkpoint arrangement the optimum number of packets are dropped. It provides the least cost path for transmission of multimedia data and decrease the network load.

Fig. 2 shows the results for the energy consumption. From the figure, it is observed that there is less energy consumption by the proposed protocol. As the network load increases the energy consumption also increases.

Fig. 3 shows the packet delivery ratio. Proposed protocol has higher delivery rate than ASARC and ED-DSR because proposed protocol disperse packets into least cost paths and with checkpoint arrangement reduce collision of packets.

Fig 4 shows the throughput. It is noticed that with the increase in traffic load, proposed protocol outperforms ASARC and ED-DSR because proposed protocol selects a path with high residual energy and lightly loaded nodes.

V. CONCLUSION

This paper analyzes the energy and the reliability problem in routing transmissions based on wireless multimedia sensor network. By means of actuating the sensors on demand basis, the energy is greatly saved. In the process of QoS routing selection, a cost function based multipath routing which considers residual energy and queue length of each intermediate node is used to calculate cost. The quality of the image is compared by arranging checkpoint at intermediate nodes. An energy efficient reliable video routing is achieved. It can be enhanced by using poison model for finding the route among more than 500 nodes.

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