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A Survey of Multipath Routing protocols in Wireless Multimedia Sensor Networks

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Abstract: There has been a rapid development in the field of wireless sensor networks (WSN) in the recent years. The development is mainly due to the availability of small size sensor cameras and microphones The advances in microelectromechanical systems have promoted the progress of a powerful class of sensor-based distributed intelligent systems skilled of ubiquitously retrieving multimedia information, namely Wireless Multimedia Sensor Networks (WMSNs).So the WMSN is the current topic of research due to its applications in various fields. In order to improve the channel utilization rate, reduce transmission delay and balance the transmission load in WMSN multipath routing is a promising solution. Multipath routing helps to transfer data concurrently by reducing the delay and congestion in WMSN. In this paper, various protocols and schemes are being discussed on multipath routing strategy which will identify the areas of further development for WMSN.

Keywords: Wireless Sensor Networks (WSN), Wireless Multimedia Sensor Networks (WMSN), Multipath Routing.

1. INTRODUCTION

Wireless sensor networks(WSN) consists a significant number of interconnected sensor nodes(SNs) that have the potential to sense the physical environment attributes such as temperature, pressure, humidity, light and sound and simultaneously interact with each other over the wireless medium. The incorporation of the low power wireless networking with inexpensive hardware such as complementary metal-oxide semiconductor (CMOS) cameras and microphones is now enabling the development of distributed, networked systems that refer to as wireless multimedia sensor networks (WMSNs)[1].They are composed of smart sensor nodes that collect and route multimedia streams, still images, and scalar sensor data in real time and non-real time. In recent years many applications based on WMSNs have been developed for surveillance, advanced health care, smart homes, and environmental and industrial monitoring. Multimedia supervision faces new challenges in WSNs concerned with the provision of scalable quality of service (QOS) through the management of metrics, such as coverage, exposure, energy consumption, and application specific metrics. Routing strategies are key for meeting the different demands for network capacity provisioning and QoS guarantees in such networks. Many routing protocols with various routing metrics have been developed for WSNs. But only a few research on the routing protocols of wireless multimedia sensor networks (WMSNs) has been done.The multimedia content is different from the normal data especially in the size of the data. Thus the routing in WMSN requires special attention because the large data size reduces the efficiency of the data transmission the problem with the large size of the general sensor networks can be resolved by multipath routing in which the load is balanced among the available paths. The major contribution of this paper is the analysis of the various efficient multipath routing techniques for the transmission of multimedia content in WMSN. The routing techniques are studied and classified into energy aware routing and QoS aware routing techniques and geographical routing techniques [2].The rest of this paper is organized as follows section 2 presents the significant survey on various protocols and schemes in multipath WMSN section 3 concludes the paper with providing a glance on the issues of the multipath routing protocols.

2. LITERATURE SURVEY

Various multipath routing schemes are studied in this research work and are categorized into QoS aware routing, Energy aware routing protocols, and Geographical routing protocols.

He et al. [3] presented a real-time communication protocol called SPEED. SPEED is a stateless, localized algorithm with minimal control overhead so that the data delivery can be performed effectively. End-to-end soft real-time communication is achieved by maintaining a desired delivery speed across the sensor network through a novel combination of feedback control and non-deterministic geographic forwarding. SPEED provides efficient routing even where the resources of each node are scarce. The problem with this approach is that it uses more control packets and hence the energy consumption is high due to reduced packet speed.

Multi-Path and Multi-SPEED Routing Protocol (MMSPEED) for probabilistic QoS guarantee in wireless sensor networks has been proposed by Felemban et al. [4]. The QoS parameters-timeliness and reliability are considered for the effective routing of multimedia data. QoS can be satisfied by guaranteeing multiple packet delivery speed options and probabilistic multipath forwarding for timeliness and reliability. This routing approach enables global geographic routing packets by dynamic compensation method. The drawback with this approach is sub-optimal compatibility of the video data which also causes high power consumption for data delivery. The problem of compatibility can be overcome in MMSPEED aware with the embedded information of the multimedia packets as presented by Darabi et al. [5] for effective resource utilization. But still, high energy consumption problem has not been resolved. The problem of energy delay trade-off is also a serious concern.

Hamid et al. [6] presented QoS-aware routing (QoS-R) protocol to support high data rate for wireless multimedia sensor networks. The proposed protocol is employed in the multi-channel multi-path foundation and hence the routing decision is made according to the dynamic adjustment of the required bandwidth and path length-based proportional delay differentiation for real-time data. The QoS-aware protocol ensures the bandwidth and the delay requirements for real-time data in a distributed manner. The throughput of the routing path is also improved by adjusting the service rate of real-time and non-real-time data. The drawback is that the approach requires frequent switching for selection of routes to reduce the switching delay.

The problem of reliable packet delivery has been resolved by using the EARQ [7] energy aware routing protocol for real-time large data transmission in sensor networks. In EARQ, a node determines the energy cost, delay, and reliability of a path to the sink node, based only on information from neighbouring nodes. Using the calculated information, the probability of selecting a path is estimated. Thus the effective routing can be achieved with less energy and cost but when more types of networks such as WLAN, Bluetooth, etc. are utilized with EARQ, the video data becomes less compatible due to inefficient load balancing. The problem can be resolved by using Load Balanced Hierarchical routing (LBHR) [8] algorithm.

The WMSN having the characteristics such as limited resources, variable channel capacity, dynamic links, and high data redundancy reduces the overall QoS. The utilization of the LBHR improves the QoS of routing by using the clustering techniques with minimum spanning tree and an improved ant colony optimization algorithm to find a primary path and some backup paths for large data routing. The major challenge is to maintain the success rate of transmission in all situations.

In order to maintain the success rate of transmission with QoS requirements, ant-based multi-QoS routing (AntSensNet) has been presented by Cobo et al. [9]. The approach builds a hierarchical network for selecting the suitable paths. The advantage of the approach is that it also uses an efficient multi-path video packet scheduling in order to get minimum video distortion transmission.

Another approach to ensure QoS in routing is the QoS NET proposed by Houngbadji et al. [10]. In QoS NET, a promising multipath QoS routing protocol based on a separation of the nodes into two sub-networks in which the first sub-network has specific nodes that are occasionally involved in routing decisions, while the second sub-network includes other nodes which fully take part in routing decisions. Thus efficient routing can be achieved with enhanced network lifetime

Sarisaray-Boluk et al.[11] also presented a QoS aware routing approach for underwater multimedia sensor network (QoS-R for UMSN) using different combinations of multipath transport, watermarking-based error concealment (EC), forward error correction (FEC), and adaptive retransmission mechanisms. This approach reduces the underwater channel impairments and mitigates packet losses due to node failures and intrinsic underwater acoustic channel characteristics. Though the approach is efficient, energy efficiency is not considered in this approach.

Kandris et al. [12] proposed a routing technique that is based on the QoS and also energy efficiency. The authors proposed PEMuR, a routing approach which includes the energy-aware hierarchical routing protocol with an intelligent video packet scheduling algorithm. PEMuR enables the selection of the most energy efficient routing paths and manages the network load

according to the energy remaining in the nodes. This reduces the useless data transmissions and hence the energy efficiency is improved. But the approach can be further improved by including bandwidth parameter

Xu et al. [13] presented bandwidth-power aware multipath routing which considers QoS, bandwidth and energy efficiency for selecting the routing paths. The approach defines bandwidth-power aware cooperative multi-path routing (BP-CMPR) problem and considers it as NP-hard which can be solved by a polynomial-time heuristic algorithm CMPR. Suurballe's method is employed in the approach to find k minimal-weight node-disjoint paths from source to destination on a weighted graph. Then, dynamic programming is used to implement relay assignment and power allocation. The approach also includes a distributed CMPR (DCMPR) for the effective power allocation and hence the BP-CMPR provides better routing than PEMuR

Dai et al. [14] proposed a correlation-aware QoS routing algorithm (CAQR) to efficiently deliver visual information under QoS constraints by exploiting the correlation of visual information observed by different camera sensors. The approach provides better load balancing along with reduced network congestion based on the correlation of the data so that the need for retransmissions can be reduced with reduced sensors energy consumption. The use of optimization QoS routing framework further reduces the energy consumption under delay and reliability constraints. The problem with this approach is that the correlation of the visual information requires efficient compression techniques for efficient video data routing.

To satisfy the QoS, the parameters like delay, reliability, and energy efficiency have to be considered. Potential based Real-Time Routing (PRTR) protocol is proposed by Xu et al. [15] for efficient routing with reduced delay and reduced congestion. PRTR provides better routing without choosing a point to point communication and thus improves the maintenance of the selected routes. Sung-Lee et al. [16] presented an energy efficient QoS aware routing (EE-QoSR) technique for the transmission of multimedia content. The approach is sensitive to the changes in delay and reliability even at the stages of the resource efficiency. The technique reduces the control messages and instead utilizes the broadcast message from the sink for reducing energy consumption during routing.

The Greedy Perimeter State Routing (GPSR) [17] approach uses the locations of the nodes to provide routing in a greedy manner. GPSR uses the geographical locations of the nodes discovered using the positioning systems like GPS or Galileo. Using the location of the destination node, the GPSR forms the route for data delivery in a greedy manner by selecting the nearest node in the route to the destination. When there is no available node for greedy forwarding or presence of voids, the perimeter formation uses the right-hand rule to forward the data packets. Though GPSR approach provides better routing, the approach suffers from the inability to eliminate the edge without obstacles. GPSR takes other nodes into consideration only when the energy of the nearest neighbour nodes is used up and it forms energy hole. This problem reduces the ability to forward packets especially multimedia content

To overcome the problem that faces in the position connectivity graph, Leong et al. [18] presented protocols called Path Vector Exchange Protocol (PVEX) and Oblivious Path Vector Face Routing (OPVFR) for effective local face detection. Using the face detection, Greedy Path Vector Face Routing (GPVFR) is proposed to provide better routing performance in terms of both path stretch and hop stretch by determining available local face information even without identifying the face information or limited routing state. The only problem with this approach is that the energy consumption is high because of the mapping of face locations.

To overcome the problems in GPSR and GPVFR, the Directional Geographical Routing (DGR) [19] has been introduced. DGR constructs a number of multiple disjointed paths for a video sensor node to transmit parallel FEC-protected real-time video streams in multiple paths so that the video streams can be forwarded efficiently. DGR reduces the route coupling problems and has many advantages such as less delay, longer network lifetime, and better received video quality. DGR can also be extended for the green vehicular networks for environmental friendly data aggregation [20]. But the drawback is that the approach does not support multiple active video sources due to the limited bandwidth which is a result of high received video quality. Similarly, DGR suffers from the energy bottleneck problem due to the multi-path forwarding

GOAFR plus [21] is an efficient geographical routing technique to overcome the detection of local face problems. The approach has been currently utilized extensively in MANETs which can be extended to sensor networks with effective selection of the boundary circle the adaptive boundary circle selection without any local information of the face neighbours. Thus the routing can be improved without unnecessary expansion of the boundary circle and hence reduces the calculation cost. Though the forwarding cost is less, the drawback in the approach is the inability to adapt to the multiple active video sources.

Geographic Energy-Aware Multipath Stream-based (GEAMS) routing protocol is presented by Medjiah et al. [22] for the effective forwarding of the multimedia content without global knowledge to reduce the high energy consumption problem. GEAMS routing decisions are made online, at each forwarding node without requiring the global topology knowledge and

maintenance. GEAMS uses smart greedy forwarding and walking back forwarding for efficient routing. The problem with this approach is that it cannot offer adaptive path selection for the next hop node selection which may reduce the routing efficiency.

Medjiah et al. in another paper [23] proposed an online multipath routing protocol to be used along with geographical routing to overcome the problem of GEAMS in WMSNs. The proposed technique is called as Adaptive Greedy-compass Energy-aware Multipath (AGEM) routing which considers both node energy constraints and QoS needs of audio and video streams for the selection of paths. The greedy forwarding of GPSR is utilized with forwarding decision approach considering the factors such as the residual energy at the node, the number of hops visited by the packet before it arrives at this node, the distance between the node and its neighbours, and the history of the packets forwarded belonging to the same stream. But still, AGEM depends on beacon exchange for neighborhood state maintenance which reduces the overall efficiency

Shu et al. [24] presented the Two-Phase geographic Greedy Forwarding (TPGF) routing algorithm for reducing the energy consumption. TPGF performs two phases for finding one shortest path per execution and can be executed repeatedly to find more on-demand shortest node-disjoint routing paths. In the first phase, the possible paths are selected while in the second phase, the optimization of paths is performed for finding the routing path with the least number of hops. TPGF supports hole-bypassing, the shortest path transmission, and multipath transmission and at the same time improves the energy efficiency. But the approach has a minor drawback in geographical forwarding phase which is not good as in previous research techniques

Geographic Energy-Aware non-interfering Multipath (GEAM) has been proposed by Li et al. [25] for effective multipath routing of multimedia transmission in WSN. GEAM divides the whole network topology into many districts and forwards data through these districts without interfering with each other resulting in interference-free transmissions. The approach adaptively manages the load in each district based on the remaining energy status of the nodes and hence maintains the performance of the routing even when the topology changes rapidly. To send a packet, GEAM will assign the packet with district boundary and send it through the district by the greedy algorithm to the sink. The use of district adjustment for selection of paths with fewer hops will also reduce the energy-hole problem. But the use of many source-sink pairs may reduce the overall efficiency.

Pair-wise directional geographical routing (PWDGR) strategy is proposed by Wang et al. [26]to solve the problems present in the existing scenarios like GPSR, GOAFR, DGR, TPGF and GEAM. In PWDGR, first, the source node can send the data to the pair-wise node around the sink node in accordance with the certain algorithm and then it will send the data to the sink node. These pair-wise nodes are equally selected in 360 scopes around the sink according to a certain algorithm. Therefore, it can effectively relieve the serious energy burden around the Sink and also make a balance between energy consumption and end-to-end delay. PWDGR uses GPSR routing scheme to forward packets from pair-wise hop node to sink node.

The above schemes have been briefly summarized in the below table with their working mechanism, advantages, and disadvantages. So it becomes easy to understand the various schemes by simply following the table. It also provides an outlook for other people to work on those domains which are still left unnoticed.

Table 1: Comparison of various multipath energy aware, QoS-aware and geographical routing techniques.

Sr.No	Scheme	Technique used	Advantage	Disadvantage
1	SPEED	SNGF algorithm back pressure re-routing last mile processing	Maintained packet delivery speed reduces congestion problems	Packet delivery speed cannot be increased Consumption is increased
2	EED	MMSP-Multipath forwarding Virtual isolation among the speed layers Dynamic compensation of local decisions	Desir-able scalability and adaptability is achieved Reliability and timeliness is efficiently guaranteed	Energy-delay trade-off problem occurs High energy consumption
3	QoS-R	QoS-aware Packet Scheduling Dynamic Bandwidth Adjustment	Maximized throughput Reduced end-to-end delay	High switching delay Multiple priorities not supported
4	EARQ	Queuing model k-least path algorithm	High reliability with tolerable delay	Requires complete topology knowledge

			in packet data delivery	Load balancing is not efficient
5	LBHR	Clustering algorithm Ant colony optimization Minimum spanning tree algorithm	Prolonged Network Lifetime Guaranteed QoS in transmission of data	Transmission success rate varies with the situations
6	AntSensNet	Ant Colony Optimization QoS Routing	Better QoS for multiple types of WMSN services Reduced consumption of constraint resources	Node mobility reduces the network lifetime
7	QoSNET	Switching QoS routing Resolution mapping	Improved network lifetime based on QoS constraints Reduced end-to-end delay	Packet error problem occurs
8	QoS-R for UMSN	Forward error correction coding, Watermarking based ECalgori-thm, Disjoint multipath image transmission, Retransmission-based hop by hop error recovery	Mitigates packet loss due to node failures Achieve desired quality of transmitted image with cont-rolled pixel error in the packets	Energy efficiency, network model parameters are not considered
9	PEMuR	Energy efficient hierarchical routing, video packet scheduling	Efficient utiliza-tion of limited available band-width by selective dropping of less significant packets	Bandwidth is not considered
10	BP-CMPR	Cooperative communication Distributed BP-CMPR	Better power consumption Optimal solution for bandwidth power aware cooperative multi-path routing problem	High delay
11	CAQR	Video In-Network Compression, Correlation-aware internode differential coding scheme and correlation aware load balancing	Minimized network traffic with better congestion control Minimized energy consumption subject to delay and reliability constraints	Need for separate compression schemes
12	PRTR	Maximum force rule, delay bound analysis	Minimizes delay for real-time traffic Better congestion control	Expensive to implement

13	EE-QoS-R	Routing table construction algorithm	Minimizes the routing control messages and reduces energy consumption Low congestion	Transmission in all directions may increase the energy consumption
14	GPSR	Greedy forwarding Perimeter forwarding	Improves forwarding efficiency even in void regions through perimeter forward-ing	Unable to eliminate the edge nodes without obstacles Energy hole problem
15	GPVFR	Greedy forwarding, PVEX, OPVFR	Improved data forwarding with limited routing state	High energy consumption
16	DGR	Forward error correction, deviation angle adjustment	Reduced route coupling problem Less delay, longer network lifetime, and better received video quality	Does not support multiple active video sources Energy Bottleneck problem
17	GOAFR plus	Boundary circle decision, greedy forwarding, Face routing	Improved route discovery without unnecessary Expansion of boundary circles	Does not support multiple active sources
18	GEAMS	Smart greedy forwarding, walking back forwarding	Reduces overall energy consumption	Low routine office--agency due to non-adaptive path selection
19	AGEM	Smart greedy forwarding, walking back forwarding	Im-proves routing with considering node energy constraints and QoS needs of audio and video stream	Depends on beacon exchange for neighborhood state maintenance
20	TPGF	Geographical routing, path optimization	Selection of optimal routes with hole by passing	Geographic routing phase is less efficient
21	GEAM	District adjustment and hole avoidance	Better routing with interference free transmissions	Many source-sink pairs scenario reduces routing performance
22	PWDGR	Directional Geographical routing, GPSR	Reduces energy hole problem Effective energy balance-ing in the nodes nearest to sink	Use of GPSR for routing from pairwise nodes to sink increases the energy consumption

CONCLUSION

In this research, the multipath routing techniques namely QoS aware, Energy aware and geographical routing protocols for wireless multimedia sensor networks are studied for the efficient transmission of multimedia content. Multipath routing is a promising technique for achieving reliability, load balancing, high aggregate bandwidth, a minimum end to end delay, minimum energy consumption and high throughput. Multipath routing protocols ensure that the Quality of Service (QoS) demand of the applications is met and that energy efficiency is addressed. Multipath routing can reduce the need for route updates, balance the traffic load and increase the data transfer rate in a WSN, improving the utilization of the limited energy of sensor nodes. We have listed the benefits of using Multipath schemes in routing and described the various classes of Multipath routing. We also provided various other proposals of Multipath routing discussed in the literature.

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