A Survey on Multi-path Routing Protocols in Wireless Multimedia Sensor Networks

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Abstract

Single-path routing protocols cannot satisfy the need of Wireless multimedia Sensor networks, and Multi-path routing protocols have many advantages in wireless multimedia sensor networks. Recent years, some researchers have proposed many multi-path routing protocols. The paper introduces and outlines the different multi-path routing protocols in WMSNs and classifies them according to their characteristics. The future direction is pointed.

Keywords: wireless multimedia sensor networks, multi-path routing, geographic routing, ACO, QoS, clustering protocol

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1. Introduction

The rapid development of sensors, MEMS, embedded computing, inexpensive CMOS cameras and microphones has resulted in the advent of Wireless Multimedia Sensor Networks (WMSNs). WMSNs are networks of wirelessly interconnected sensor nodes equipped with multimedia devices, such as cameras and microphones, and capable to retrieve video and audio streams, still images, and scalar sensor data. WMSNs will not only enhance existing WSNs applications, but also they will produce some new applications such as multimedia surveillance, environmental monitoring, smart homes and etc. [1-3].

WMSNs have also new characteristics and challenges. The nature of multimedia data needs the high bandwidth, the short end-to-end delay and the low frame loss rate etc. Moreover, there are many resource constraints in WMSNs involving limited energy, memory space, processing capability. WMSNs produce a huge amount of data, and the transmission of these data in a single path cannot satisfy the need of some applications. Multi-path routing transmission is to set up multiple paths between the source node and the sink. These data may be transmitted parallelly through multiple paths or different paths according to different priorities. It benefits QoS, balances energy consumption and extends the network lifetime. It also produces redundant paths and increases reliability. Multi-path transmission can increase transmission capability and reduce end-to-end delay [4-6]. Multi-path routing protocols have become the hotspot of research in WMSNs.

The following classifies and introduces multi-path routing protocols in wireless multimedia sensor networks. Due to the relation between these protocols, the classification is not strict.

2. Research Method

2.1. Geographic Routing Protocol

Geographic routing protocol is the routing protocol which knows the sensor nodes’ position and looks for multiple paths between the source sensor node and the sink.

GPSR [7] is early geographic routing protocol for wireless networks. GPSR makes greedy forwarding decisions using one-hop neighbors’ information. GPSR doesn’t maintain network topology information and routing cost is small. But GPSR is not designed for wireless sensor networks and GPSR have some shortcomings when applying in wireless sensor network and wireless multimedia sensor network. Because of constraint resources of wireless sensor
networks, energy consumption is considered as the important factor. But GPSR doesn't consider the node's energy consumption and the network lifetime. GPSR chooses the best path to transmit the data every time and the nodes in these paths are too frequently used to be alive. These early dead nodes can lead to the partition of the network, and further it will lead the failure of network communication.

DGR [8] is an improved version of GPSR. DGR considers the characteristics that the real-time video streaming is transmitted in wireless sensor networks. DGR can construct a number of multiple disjointed paths between video nodes and the sink. The multiple paths in DGR facilitate load balancing, bandwidth aggregation, and fast packet delivery. DGR can acquire lower delay, longer network lifetime and better video quality than GPSR.

DGR achieves multi-path expanding around the source nodes, but multi-path balancing around the sink cannot be realized successfully. The symmetric paths will form a heart-like shape. The multiple disjointed paths will converge to a close proximity to each other when approaching to the sink node. Thus, there is still a lot of contention between the paths when close to the sink.

To alleviate the contention between paths close to the sink, E-DGR [9] divides the path construction into expanding phase, parallel phase and converging phase. The detection algorithm for path construction and the deviation angle adjustment algorithm are introduced to set up multiple disjointed paths. E-DGR can achieve spatially distributing multiple paths evenly in the proximity of the sink. The longer lifetime can be achieved due to the feature of path balancing round the sink. However, the length of the some built paths using DGR and E-DGR is added obviously due to multi-path expanding round the source nodes and the sink. The transmission in these paths need more end-to-end delay. DGR and E-DGR do not consider the residual energy of nodes when choosing the next-hop nodes.

Lei Shu et al. [10-12] proposed Two Phase Geographical Greedy Forwarding (TPGF) for exploring multiple optimized node-disjoint transmission paths. It is based upon geographic position information to build routing paths. It can find a path which meets requirements per execution and can be executed repeatedly to find more node-disjoint routing paths. In greedy forwarding phase, the current node chooses the neighbor node which is the nearest from the sink as the next hop node. The chosen next hop node may be farther than the current node from the sink. The advantage of TPGF is that source node can transmit data to the sink through least hops. TPGF routing algorithm provides better solution for hole-passing in wireless sensor networks than GPSR and can find the routing paths if paths exists in networks.

Lin Zhang et al. [13] proposed a Multi-priority Multi-path Selection scheme (MPMPS). MPMPS is an improved version of TPGF. Not every path found by TPGF may be suitable for transmitting video. For example, a long routing path with long end to end transmission delay can not satisfy the time constraint of video. Image and audio streams play different roles in different applications. Higher priority should be given more important stream. MPMPS can support multiple priorities and choose the maximum number of paths for video transmission. However, when looking for a path, TPGF and MPMPS do not consider nodes' residual energy. The nodes in the optimal paths will be dead too early because these nodes are used frequently to transmit too much data. The nodes in the networks unevenly consume its energy, which leads to shorten the whole network lifetime.
Considering that node's residual energy is not uniform, EACM [14] computes the residual energy difference between the current node and the next hop node when choosing the next hop node. EACM can balance the residual energy difference of nodes and adjust the aggregation degree of multiple paths to balance the energy consumption and reduce the transmission delay.

To ensure QoS requirements in routing discovery, WU san-bin et al. proposed IGPSR [15]. IGPSR algorithm divides the forward region into different segments according to the residual energy of the neighboring node and adopts probability mechanism to select the next hop node in the segment of chosen forward region. IGPSR algorithm work more effectively than GPSR in balancing the energy consumption and the network lifetime. IGPSR-2 [16] is an improved version of IGPSR. IGPSR-2 divided forward direction region evenly into four parts according to area and chose the region with minimal energy variance as the routing select region. IGPSR-2 can acquire better performance than IGPSR. However, IGPSR and IGPSR-2 are only suitable for wireless sensor networks and do not consider the characteristics of wireless multimedia sensor networks.

A.V. Sutangundar et al. [17] proposed Energy Efficient Multi-path Routing Protocol for WMSNs. When choosing multiple paths between the source and the sink, it considers nodes' residual energy and received signal strength. It allocates more loads to under-utilized paths and less loads to over-committed paths, so all available paths can be evenly utilized. And it extends the system lifetime.

Samir Medjiah et al. proposed AGEM [18-20] which is suitable for transmitting multimedia streaming over WMSNs. AGEM routing decisions are made online and each node does not need to know global topology knowledge. AGEM exploits the multi-path capabilities to make load balancing among nodes. When choosing the next hop nodes, AGEM considers the residual energy of neighbour nodes, the distance of the neighbour to the sink and the data rate of the link. Compared to GPSR, AGEM can acquire better performance in the distribution of the residual energy across the network and average end-to-end delay. However, simulation experiments can not show the result about the network lifetime using AGEM. When choosing the next hop nodes, AGEM gives scores to its neighbour nodes. But AGEM can not consider the importance of different data packets of multimedia streaming, which will degrade the quality of multimedia streaming.

2.2. Ant Colony-based Routing Protocols

Sun yan et al. [21] firstly applied an ant-colony optimization to routing protocols of wireless multimedia sensor networks. The basic services of WMSNs is divided into event alarm, information query and stream query and abstracts a QoS routing model. An Ant-colony optimization based on Service Aware Routing protocol (ASAR) is proposed in the paper. The ASAR choosed the suitable three paths to satisfy the demand of three service.

XIE Hui et al. [22] proposed QoS routing protocol based on ACO in wireless multimedia sensor network. AntWMSN was proposed considering the link bandwidth, delay, packet loss. The protocol looks for the best routing path under the conditions of multi-constrained QoS.

Ke Zongwu et al. proposed an ant colony routing algorithm for wireless multimedia sensor networks [23]. Assume that each sensor node know its position information and the position information of the sink. In the beginning of the algorithm, a forward ant chooses the sensor nodes which are near from the sink as the next-hop. It can improve the performance of the algorithm.

CAO Xiao et al. [24] proposed ant colony based multi-path routing algorithm (ACMRA). ACMRA can find the paths with different priorities. On the basis of the importance of video data, ACMRA chooses different paths. ACMRA can enhance video transmission performance and extend the network lifetime. But multiple paths which ACMRA can set up are based upon many iterations, the cost is too high.

DENG Da et al. [25] proposed Research into WMSN Routing algorithm Based on Ant Colony Optimization. One node calculates the probability to choose the next-hop send package. The probability mainly depends on the frequency of paths used and the cost of paths.

2.3. QoS Routing Protocol

Due to the characteristics of wireless multimedia sensor networks such as different media, great data amount, complex task, QoS guarantee is important. QoS-based routing
protocol is to look for paths between the source node and the sink to meet QoS demands. QoS includes bandwidth, delay, jitter, loss rate, throughout [26].

Ke Zongwu et al. [27] proposed A QoS Routing Game Model for Wireless Multimedia Sensor Network. They proposed a model of routing game for wireless multimedia sensor network and the cost function of paths. The algorithm can find optimal paths between source nodes and the sink through the game theory.

Dong Wushi et al. [28] proposed QoS Routing Algorithm for Wireless Multimedia Sensor Networks. This paper gave QoS routing problem model with multiple QoS constraints, which include the delay, delay jitter and bandwidth. They proposed a QoS routing algorithm which is based on genetic algorithm. Genetic algorithm operation includes coding, building fitness function, selection, crossing, variation.

Sha Chao et al. [29] proposed Multi-path transmission strategy and congestion control scheme for multimedia sensor networks. Before sending actual sensing data, the algorithm firstly sends metadata packets which describe sensing data and look for multiple paths. By considering the transmission time, residual energy as well as transmission rate of the wireless links, three classes of paths are established with the help of metadata packets. The main path is the first selected path in which these sensing data are sent from the source node to the sink. The sub-path is used to transmit control messages. The backup path services as the alternate path of the main path. Network congestion rate is reduced as well by adjusting time intervals of sampling.

There are many types of data in wireless multimedia sensor networks, which have different quality of service requirements. This paper [30] proposes an angle-based differentiated services routing algorithm. Sense nodes in this new algorithm select appropriate transmitting region which is classified by its deviate angel for different types of date streams. Sensor nodes choose the appropriate paths which are based on local neighbor information such as neighboring node position, single-hop communication cost and residual energy.

2.4. Clustering Routing Protocol

Clustering routing protocol is the traditional protocol in wireless sensor networks. Considering the characteristics of wireless multimedia sensor networks, some people proposed the improved version of clustering routing protocol.

Qin Shao-Hua et al. [31] proposed Cluster-Based Real-time routing Protocol (CBRP). CBRP considers geographic forwarding mechanism and uneven virtual grid-based clustering routing protocol. CBRP divides the monitoring area into the different size virtual grid. When the virtual grid is near from the sink, the size of the vitudal grid is small. It can increase the number of cluster heads near the sink. The radius r is calculated through Equation (1).

\[
\begin{cases}
    R & \text{if } d_s > 2\sqrt{\frac{2\sqrt{5}}{5}} R \\
    \frac{R}{2\sqrt{5}} & \text{if } d_s \leq 2\sqrt{\frac{2\sqrt{5}}{5}} R 
\end{cases}
\]  

(1)

Where R is the communication radius of sensor nodes and ds is the distance between the centre of the virtual grid and the sink.

Within each virtual grid, one cluster head is selected according Equation (2).

\[
p = \frac{E_i}{d_i \cdot E_{\text{sum}}} 
\]  

(2)

Where \( E_i \) is the residual energy of sensor node i and \( E_{\text{sum}} \) is the sum of energy of sensor nodes within a virtual grid. \( d_i \) is the distance between the sensor node and the centre of virtual grid. The sensor node whose p is the most is selected as a cluster head.

The backbone network which is composed of cluster heads is used to transmit data. According to the real need, the backbone can dynamically adjust the data transmission rate.

protocol with the principles of ACO routing. It can support a power efficient multi-path video packet scheduling scheme for minimum video distortion transmission. The cluster heads is selected by using T-ANT protocol. The backbone network is composed of Cluster heads. Using ACO, the optimal multiple paths can be found in the backbone network.

2.5. Cross Layer Routing Protocol

WANG Yan-mei et al. [33] proposed a cross-layer optimization based routing protocol for Real-Time Energy-Balance (RTEB). RTEB uses a collaborative design of MAC and Network layer. When RTEB chooses the next-hop among the path, RTEB considers the residual energy of sensor nodes and reliability to balance the energy consumption and decrease the retransmission times. RTEB decreases the cost of control messages by using BACK message of MAC layer.

ZHANG Zhuo et al. [34] propose A Cross-Layer Optimization for Wireless Multi-Media Sensor Network Based on Service-Driver. A Cross-layer optimization strategy is based on service-driver and self-feedback mechanism. The approach automatically optimizes each layer parameters of network protocol according to the principle of QoS level of multimedia application, and feeds back optimized parameters to the appropriate network protocol layer to achieve network resources optimization under QoS.

2.6. Support the Mobile Sink

The mobile sink can balance the energy consumption of sensor nodes in wireless multimedia sensor nodes and increase the throughput of the entire network. Furthermore, it can extend the network lifetime. TANG Zi-long et al. [35] proposed A new geographic routing for mobile sink in wireless multimedia sensor networks. The network adds the anchor nodes and the mobile sink communicate with the anchor nodes. The source node sends the data to the anchor nodes using geographic routing protocol.

3. Conclusion

Multi-path routing protocols have some advantages and become the research hotspot in wireless multimedia sensor networks. This paper introduces different multi-path routing protocols which include Geographic routing protocols, Ant colony-based routing protocols, QoS routing protocols, Clustering routing protocols, cross layer routing protocols and the routing protocol which supports the mobile sink. The new routing protocol which combines the above several routing technologies will be brilliant in the future.

References


