TELKOMNIKA Indonesian Journal of Electrical Engineering
Vol. 12, No. 9, September 2014, pp. 6978 ~ 6983
DOI: 10.11591/telkomnika.v12i9.4767

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

Enyan Sun*, Chuanyun Wang, Feng Tian
School of Computer Science, Shenyang Aerospace University,
Shenyang, China (+86)02489723892
*Corresponding author, e-mail: sunenyan418418@163.com

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*

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

Received October 14, 2013; Revised Apr 29, 2014; Accepted June 1, 2014

networks, energy consumption is considered as the important factor. But GPSR doesn't consider the node' 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 can not 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 chooing the next-hop nodes.

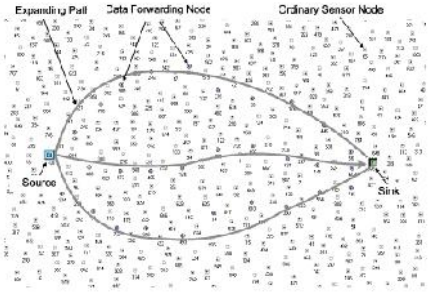

Figure 1. Multi-path Diagram by DGR

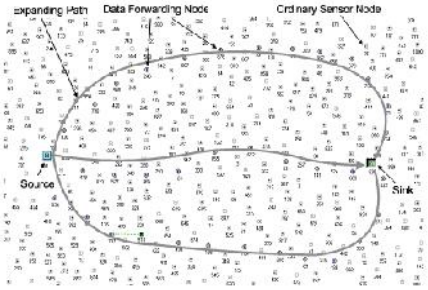

Figure 2. Multi-path Diagram by E-DGR

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 requirments 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 Procotols

Sun yan et al. [21] firstly applied an ant-colony optimation to routing protocols of wirless 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 perfamance of the algorithm.

CAO Xiao et al. [24] proposed ant colony based multi-path routing algorithm (ACMRA). ACMRA can find the paths which have 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 probalitiy 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 wirless 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 charateristics 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 machanism 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 vitual grid is small. It can increase the number of cluster heads near the sink. The radius r is calculated through Equation (1).

$$r = \begin{cases} \dfrac{R}{\sqrt{5}} & d_s > 2\sqrt{2/5}R \\ \dfrac{R}{2\sqrt{5}} & d_s \le 2\sqrt{2/5}R \end{cases} \quad (1)$$

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).

$$p = \frac{E_i}{di \bullet E_{sum}} \quad (2)$$

Where Ei is the residual energy of sensor node i and Esum is the sum of energy of sensor nodes within a virtual grid. di 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.

Luis Cobo et al. [32] proposed Ant-based routing for wireless multimedia sensor networks using multiple QoS metrics. The AntSensNet protocol conbines the clustering routing

protocol with the principles of ACO routing. It can support a power efficient multi-path video packet scheduling schme for minimum video distortion transmission. The cluster heads is selected by using T-ANT protocol. The backbone network is composes 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 decrease 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 multimeida sensor nodes and increase the throughout 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 geograhic 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 procotols, 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

[1] Akyildiz, Ian F, Tommaso Melodia, Kaushik R Chowdhury. A survey on wireless multimedia sensor networks. *Cmputer networks*. 2007; 51(4): 921-960.
[2] Soro, Stanislava, Wendi Heinzelman. A survey of visual sensor networks. *Advances in Multimedia.* 2009.
[3] Almalkawi, Islam T, Manel Guerrero Zapata, Jamal N Al-Karaki, Julian Morillo-Pozo. Wireless multimedia sensor networks: current trends and future directions. *Sensors* (Basel, Switzerland). 2010; 10(7): 6662-6717.
[4] Tsai, Jack, Tim Moors. *A review of multipath routing protocols: From wireless ad hoc to mesh networks*. In Proc. ACoRN early career researcher workshop on wireless multihop networking. 2006: 17-18.
[5] Jayashree A, GS Biradar, VD Mytri. Review of Multipath Routing Protocols in Wireless Multimedia Sensor Network–A Survey. *International Journal of Scientific & Engineering Research*. 2012; 3(7): 1-9.
[6] Zhou, Ling, Jian-Xin Wang. Research on routing protocol in wireless multimedia sensor networks. *Acta Electronica Sinica*. 2011; 39(1): 149-156.
[7] Karp, Brad, Hsiang-Tsung Kung. *GPSR: Greedy perimeter stateless routing for wireless networks*. In Proceedings of the 6th annual international conference on Mobile computing and networking, ACM. 2000: 243-254.
[8] Chen, Min, Victor Leung, Shiwen Mao, Yong Yuan. Directional geographical routing for real-time video communications in wireless sensor networks. *Computer Communications*. 2007; 30(17): 3368-3383.
[9] Chen, Min, Victor CM Leung, Lei Shu, Han–Chieh Chao. On multipath balancing and expanding for wireless multimedia sensor networks. *International Journal of Ad Hoc and Ubiquitous Computing*. 2012; 9(2): 95-103.

[10] Shu, Lei, ZhangBing Zhou, Manfred Hauswirth, Danh Le Phuoc, Peng Yu, Lin Zhang. *Transmitting streaming data in wireless multimedia sensor networks with holes.* In Proceedings of the 6th international conference on Mobile and ubiquitous multimedia. ACM. 2007; 24-33.
[11] Shu, Lei, Yan Zhang, Zhangbing Zhou, Manfred Hauswirth, Zhiwen Yu, Gearoid Hynes. Transmitting and gathering streaming data in wireless multimedia sensor networks within expected network lifetime. *Mobile Networks and Applications.* 2008; 13(3-4): 306-322.
[12] Shu, Lei, Yan Zhang, Laurence T Yang, Yu Wang, Manfred Hauswirth, Naixue Xiong. TPGF: geographic routing in wireless multimedia sensor networks. *Telecommunication Systems.* 2008'; 44(1-2): 79-95.
[13] Zhang, Lin, Manfred Hauswirth, Lei Shu, Zhangbing Zhou, Vinny Reynolds, Guangjie Han. *Multi-priority multi-path selection for video streaming in wireless multimedia sensor networks*. In Ubiquitous Intelligence and Computing. Springer Berlin Heidelberg. 2008: 439-452.
[14] YANG Tao, WANG Xiaoming, ZHANG Jun, WU Sanbin. Energy-aware multipath routing for wireless multimedia sensor networks. *Computer Engineering and applications*. 2011; 47(17): 95-98.
[15] Wu, Sanbin, Xiaoming Wang, Tao Yang. Improved GPSR model and simulation analysis. *Jisuanji Gongcheng yu Yingyong (Computer Engineering and Applications*). 2011; 47(8): 100-104.
[16] Wu, San-Bin, Qiang Liu, Cheng-Bo Li, Xiao-Ming Wang. Based on energy balance routing algorithm for wireless sensor networks. *Application Research of Computers.* 2012; 4: 075.
[17] Sutagundar AV, SS Manvi, Kirankumar B. Balavalad. "Energy efficient multipath routing protocol for WMSNs*. International Journal of Computer and Electrical Engineering.* 2010; 2(3): 503-510.
[18] Medjiah, Samir, Toufik Ahmed, Francine Krief. *GEAMS: a geographic energy-aware multipath stream-based routing protocol for WMSNs. In* Information Infrastructure Symposium, 2009. GIIS'09. Global, IEEE. 2009; 1-8.
[19] Medjiah, Samir, Toufik Ahmed, Francine Krief. *AGEM: adaptive greedy-compass energy-aware multipath routing protocol for WMSNs.* In Consumer Communications and Networking Conference (CCNC), 2010 7th IEEE. 2010; 1-10.
[20] Medjiah, Samir, Toufik Ahmed, Abolghasem Hamid Asgari. Streaming multimedia over WMSNs: an online multipath routing protocol*. International Journal of Sensor Networks.* 2012; 11(1): 10-21.
[21] Sun Yan, Hua-Dong Ma, Liang Liu. An ant-colony optimization based service aware routing algorithm for multimedia sensor networks. *Acta Electronica Sinica*. 2007; 35(4): 705-711.
[22] XIE, Hui, Xiao-ping WU, Yong-yu ZHANG, Wei LIAO. QoS routing protocol based on ACO in wireless multimedia sensor network. *Journal of Naval University of Engineering*. 2009; 21(6): 15-19.
[23] Ke Zongwu, Chen Niansheng. An ant colony routing algorithm for wireless multimedia sensor networks. *Journal of Computer Research and Development*. 2010; 47: 156-161.
[24] Cao, Xiao, Ru-Chuan Wang, Hai-Ping Huang, Li-Juan Sun, Fu Xiao. Multi-path routing algorithm for video stream in wireless multimedia sensor networks. *Ruanjian Xuebao/Journal of Software*. 2012; 23(1): 108-121.
[25] DENG Da, ZHOU Ji-liu, LIN Feng. Research into WMSN Routing algorithm Based on Ant Colony Optimization. *Transactions of Beijing Institute of Technology*. 2011; 31(4): 456-460.
[26] SUN Yan, MA Hua dong. The QoS Guarantee Problem for Wireless Multimedia Sensor Networks. *ACTA ELECTRONICA SINICA*. 2008; 36(7): 1412-1420.
[27] Ke Zongwu, Li Layuan, Chen Niansheng. A QoS Routing Game Model for Wireless Multimedia Sensor Network. *Journal of Wuhan University of Technology*. 2009; 33(2): 295-298.
[28] Dong Wushi, Ke Zongwu, Chen Niansheng. QoS Routing Algorithm for Wireless Multimedia Sensor Networks. *Journal of Wuhan University of Technology*. 2009; 33(4): 783-786.
[29] Sha Chao, Li-Juan Sun, Ru-Chuan Wang, Hai-Ping Huang. Multi-path transmission strategy and congestion control scheme for multimedia sensor networks. *Journal of China Institute of Communications.* 2010; 31(11): 147-157.
[30] Li Fang-Min, Yi-Lin Fang, Heng Li, Xin-Hua Liu. QoS differentiated service routing for wireless multimedia sensor networks. *Dianzi Xuebao (Acta Electronica Sinica)*. 2010; 38(10): 2322-2328.
[31] Qin Shao-Hua, Jian Cao, Jia-Ning Ye, Yong-Ping Huang. Real-time Clustering Routing Protocol for Multimedia Sensor Networks. *Computer Engineering*. 2010; 36(17): 129-131.
[32] Cobo, Luis, Alejandro Quintero, Samuel Pierre. Ant-based routing for wireless multimedia sensor networks using multiple QoS metrics. *Computer networks*. 2010; 54(17): 2991-3010.
[33] WANG Yan-mei, QIN Shao-hua, CAO Jian, YE Jia-ning. Real-time Routing Protocol of Cross-layer Optimization in Multimedia Sensor Networks. *Computer Engineering*. 2009; 35(22); 106-108.
[34] ZHANG Zhuo, FAN Xinnan, ZHANG Xuewu, LI Qingwu. A Cross- Layer Optimization for Wireless Multi-Media Sensor Network Based on Service-Driver. *Chinese Journal of Sensors and Actuators*. 2012; 25(12): 1743-1747.
[35] TANG Zi-long, Liang-lun CHENG. A new geographic routing for mobile sink in wireless multimedia sensor networks. *Transducer and Microsystem Technologies*. 2011; 30(3): 28-31.