A Survey on Multipath Routing Protocol for Wireless Sensor Networks Based on Infrastructure

Yongxian Jin, Hong Zhu
(College of Mathematics, Physics and Information Engineering, Zhejiang Normal University, Jinhua Zhejiang 321004, China)

Abstract: With the development of science and technology of the times, the wireless sensor network has been inextricably linked with people's lives, the traditional ad hoc network has been insufficient to meet the needs of people in all aspects. Among them, the quality of the wireless sensor network routing technology plays a vital role to achieve the success of using the applications. In this paper, some infrastructure based multipath routing technologies for wireless sensor network are studied deeply, and they are divided into three categories: energy-aware multipath routing protocol, hierarchy based multipath routing protocol and ant based multipath routing protocol. The current typical multipath routing protocols are classified, analyzed and compared, and some new ideas for future research work are proposed.
Keywords: wireless sensor networks; infrastructure based multipath routing technology; multipath routing protocol

Introduction

There are two main types of wireless sensor network routing technology, single path and multiple paths. Single path routing algorithm is simple and has good expansibility, but it’s the biggest drawback is its poor fault tolerance and it is prone to be attacked maliciously. Once the path nodes get failed due to a variety of reasons, it cannot transmit the packet to the destination node, which reduces the reliability of data transmission greatly, especially the resources are very limited in the wireless sensor network. In contrast, multipath routing technology can solve the problem possibly.

The nature of multipath routing protocols is constructing multiple alternate paths in wireless sensor networks, in case of that the optimal path failure caused the data cannot be successfully transmitted to the destination node. It cannot only greatly improve the reliability of the data, it also has made good improvements in the aspect of security and load balancing. Moreover, single path routing protocol may cause the path node energy running out quickly because it uses an optimal path for data transmission repeatedly, but multiple paths routing protocol can prolong the life of the whole network and enhance the network performance by distributing the load evenly.

Multipath routing protocols can be divided into three subclasses, multipath routing protocols based on infrastructure, multipath routing protocols based on non-infrastructure and multipath routing protocols based on coding. This paper studies the multipath routing protocols based on infrastructure. This protocol can be subdivided into the following three categories, energy-aware multipath routing protocol, hierarchy based multipath routing protocol and ant based multipath routing protocol. This paper makes a detailed analysis and comparison about these three kinds of protocols and puts forward a new train of thought for the future research work.

1 Energy awareness multipath routing

1.1 AEMRP-LB

AEMRP-LB（An Adaptive Energy-aware Multi-path Routing Protocol with Load Balance）[3] is provided on the base of DD(directed diffusion)[4]. Due to the DD transmitting the data by using the low-energy consumption paths frequently, which can cause the excessive consumption of the node energy and network partition. Above all, it may shorten the life of the network. AEMRP-LB is an adaptive energy awareness and load balancing of multipath routing protocol. Its advantage is that it can prolong the network lifetime efficiently.

The protocol provides two different mechanisms, single pair of source-sink node and multiple pairs of source-sink nodes. The analysis is as follow:

(1) single pair of source-sink node: In this mechanism, only one pair of the source and sink node. The protocol establishes multiple disjoint paths by weighing the hops between the nodes and the sink node and the residual energy of the nodes. It uses a weighted communication scheduling algorithm to distribute the traffic flow evenly in the network.

The sink node uses the direction angle to send messages to adjacent nodes in the right direction. The messages contain initialization information of the nodes. Direction Angle is defined in order to avoid energy dissipation caused by broadcasting. The meaning is to try to make the sink node forward messages in the direction of the source node. Then, the first relay node which receives the messages attach the residual energy to it and then continues forwarding messages in the right direction, but if the residual energy is less than the original value in the table, the message table will not be updated. The multiple paths cannot be formed until all the message tables arrived at the source node. Each node in the path will be shown in the form of name and residual energy. The source node selects the preferred path and backup path according to the hop and residual energy of each node in the path.

(2) multiple pairs of source-sink nodes: In this mechanism, there are more than one source and sink node in pairs forming multiple paths. In this way, it must exist some sharing nodes in the path. To use these sharing nodes reasonably and effectively, AEMRP-LB can adaptively adjust the residual energy of the sharing nodes in order to prolong the network life. It constructs multiple paths by the same way as the single pair of source-sink node. If the path contains a relay node, it will be selected as the preferred path. In addition, if the backup path also contains the relay nodes, the backup path will be discarded in order to save energy.

In general, the data transmission capacity of AEMRP-LB depends on the minimum residual energy of nodes. The protocol evenly balances load and prolongs the life of nodes. However, it has some disadvantages. It needs to calculate the direction angle and establish multiple paths between source nodes and sink node, which will cause high beginning communication delay. Direction angle is put forward, which has advantages and disadvantages at the same time. Even though the advantages outweigh the disadvantages, we still need to improve this aspect in the later study and develop a more effective way to find the routing.

1.2 IMEA

IMEA (improved multi-path routing protocol with energy-aware based on AOMDV)[5]is an improved protocol based on AOMDV(on-demand multi-path distance vector routing in ad hoc networks)[6]. AOMDV is applied to the traditional Ad hoc network, but its data reliability is poor and the network lifetime is too short in the WSNs which have limited resources. Therefore, IMEA improves for it in these two aspects.

IMEA is an on-demand driven routing. When the event occurs in the coverage area of the wireless

sensor network, the source node needs to transmit information to destination node. The protocol finds routing in the form of broadcasting messages. Source node usually broadcasts a RREQ packet to the entire network, namely the routing request message. The serial number of the message determines whether the message can be forwarded continuously. After the destination node receives the first RREQ, it will start the timer and keep the RREQ packet into the cache. Once the timer is turned off, the destination node starts to reply and send the RREP message, namely routing reply message. When the RREP arrived at the source node, it can successfully establish the paths. Finally, it selects an optimal path in the multiple paths according to the residual energy of nodes and the hop count between the nodes and the sink node. However, the optimal path is likely to be destroyed and cannot continue to transmit data due to various natural or man-made factors. Therefore, we need to choose a suboptimal path to continue transmitting the data, which ensures the reliability of data transmission. Of course, it is better to choose a suboptimal routing that shares the least number of nodes with the original optimal routing.

Compared with AOMDV in wireless sensor network (WSN), it improves the reliability of data transmission and prolongs the network life effectively. But its energy efficiency is not much improved, even is worse than the energy efficiency of classic protocols in the case of network cycle . In addition, the protocol does not consider the security of data transmission.

1.3 QEMPR

QEMPR (QoS and energy-aware multipath routing)[7] is a protocol that considers the link number as the performance index of routing protocol. It not only has the energy awareness mechanism, but it also provides the security mechanism. After the events trigger, routings are established by broadcasting messages. Each node in wireless sensor network has a unique ID number, and it can compute the probability of receiving and sending data packets through the link quality information. Each node stores a neighboring table, which contains some basic information of neighboring nodes, such as the residual energy, transmission range, hop count and so on.

After the path is constructed, it transmits the packets according to the serial number of the packet and its distance to the sink node. That is to say, the source node will transmit the packet with the minimum serial number and the minimum hop firstly. Then, it will transmit the packets with the increase of the serial number and hop till all data packets transmission completed. So, sink node can receive packets continuously, which can distribute the network traffic evenly and achieve the load balancing.

In QEMPR, end-to-end delay is shortened and energy consumption is reduced. Also, it can provide better service quality. However, it has extra overhead because it spread messages by broadcasting. What's more, it will consume much energy and greatly increase the network traffic if it transmits the same data on different paths.

2 Multipath routing protocols based on hierarchical

2.1 N-to-1

N-to-1 (An efficient n-to-1 multipath routing protocol)[8] just has one time to find the routing. In the process of finding routings, the base station broadcasts the update messages periodically. The node which is the first one to receive the update messages will set the sending node as the parent node. The base station will stop broadcasting when it receives the returned data packets. In this approach, base station is considered as the root node of the spanning tree.

The protocol uses the spanning tree algorithm to improve the data reliability and has a good effect on maintaining the routing. However, there are some defects in the aspect of load balance. Broadcasting messages may cause extra overhead too. In the future study, we can combine it with encoding and further improve the network performance.

2.2 ALBCH

ALBCH (adaptive load balancing clustering hierarchy)[9] and LRP-EPCA(layered routing protocol based on the energy priority clustering algorithm)[12] are all improved protocols based on LEACH[10] and PEGASIS[11][13]. LEACH mainly selects the cluster head nodes randomly. Each node can share the network load so that we can effectively improve the energy efficiency and prolong the network life. But LEACH chooses single hop pattern and this will cause unnecessary energy consumption. PEGASIS is the improvement of LEACH. It uses the greedy algorithm to connect nodes in a network into chains, which makes each node need to communicate with the nearest neighbor node around it. This way can prolong the network lifetime effectively. Moreover, every node has a data fusion, which reduces the network redundancy. The problems are that the delay of data transmission is long and energy consumption is high because of the chain communication. Therefore, it is not suitable for practical application. Finally, LEACH and PEGASIS are only applicable to homogeneous network in general, it is not the dominant in the heterogeneous network.

ALBCH makes some improvements for the disadvantages of LEACH and PEGASIS. First of all, in the process of the election of cluster head, the protocol considers the residual energy of nodes. The threshold formula is improved, so that energy consumption can be reduced in the heterogeneous network. It greatly enhances the scalability and plays a positive role in maintaining the network. Secondly, it improves PEGASIS greedy algorithm and proposes a distance threshold method.

In the process of the election of cluster head, LRP-EPCA not only considers the residual energy , but also the average energy. The average energy is the average energy in the node in the cluster. In the process of data transmission, it combines single hop with multihop to transmit data. By balancing the residual energy and the average energy, it achieves the effect of load balancing.

Above all, ALBCH can save node energy and prolong the network life effectively. It also has good scalability, which can optimize the network in homogeneous and heterogeneous network. It is very beneficial to the real-time applications. LRP-EPCA achieves the load balancing and prolong the network life cycle. It is suitable for large-scale network. It has good real-time performance like ALBCH. These two protocols have the same problems that lack of security mechanism, or not perfect. We still need to further improve them in the future in order to improve the security of data transmission.

3 Multipath routing protocols based on ant colony algorithm

3.1 EEABR

EEABR (Energy Efficient Ant-Based Routing)[14] is a kind of effective energy saving routing based on ant colony, which belongs to a kind of hierarchical routing. The protocol is a promotion scheme based on ant colony routing protocol. In the process of finding routing, each node in the wireless sensor network (WSN) periodically sends an "ant package" with fixed size. It is also a news package. Each news packet carries some related information about the node has been visited,

such as the prior node, the forwarding node, the identification of the news package, a timeout value etc. This also means that relay nodes have the specific records of the receiving news packet. When a node receives the news package, it will check its routing table and identify the information. If the information is not consistent, it will restart the timer and forward the news message to other nodes. Once the destination node receives the package, it will set up routing and update the news package automatically.

This way achieves load balancing and reduces energy consumption. But there is an exsiting problem that it lacks of QoS and causes a delay in the process of data transmission which causes unnecessary overhead. So it remains to be improved in terms of security and real time .

3.2 EBAB

EBAB (Energy Balanced Ant Based Routing Protocol)[16] is a routing protocol based on geographic location. Its primary purpose is to save energy and prolong network lifetime. Routing algorithm is divided into inter-Cluster and intra-Cluster. The following analyze the inter-Cluster algorithm. The cluster head selection depends on the strength of the node relative to the base station. Once a cluster head node is selected, it sends the message to nodes in its own area and invite the node to join into the cluster. If a node receives more than one invitation, it will consider some factors such as energy of the transmission etc. Finally, it makes a final choice to join one of the clusters. Then, the node will send an ACK message package to agree to join the cluster. In the process of data transmission, all nodes open the receivers. Cluster head nodes will inform all the nodes the information about TDMA time slot which is the only parameter in the process.

EBAB improves the data reliability and achieves the effective energy saving. But it is poorer than the former in the aspect of load balancing. And its security and real time have no obvious improvement. These problems are all major challenges for future research.

3.3 ABMR

ABMR (ant-based multipath routing algorithm)[17] is an optimization algorithm proposed for solving the problem of energy equilibrium. Using ant colony algorithm in the process of finding routing, nodes will release pheromones, just like ants releasing a substance in the body in order to guide the similar when they are searching for food. Compared with the traditional way to update the pheromone in accumulated methods, ABMR makes effective improvement. The nodes do not only blindly accumulate pheromones, but they also weigh the surplus energy and the distance to sink node, which will make the traffic evenly distributed throughout the network and reduce the congestion and delay to prolong the network lifetime.

In short, ABMR improved the energy efficiency and the success rate of data transmission. It has good real-time performance too. The spread of ant packages will lead to some extra overhead, but the overall overhead is relatively less, so the effect can be ignored.

4 Comparison of the protocols

Multipath routing effectively improves the poor data reliability of single path routing. It also has a significant advantage in energy saving, load balancing, etc. The following Table 1 are the comparison of multipath routing protocols based on infrastructure, such as AEMRP-LB、IMEA、QEMPR、N-to-1、ALBCH、LRP-EPCA、EE-ABR、EBAB、ABMR.

Table 1 the comparison of multipath routing protocols based on infrastructure

Name	Classification	Data reliability	Load balancing	Energy efficiency	Network life	Time delay	Topology adaptive	Security
AEMRP-LB	Energy awareness	good	good	good	good	general	good	general
IMEA	Energy awareness	good	good	general	good	short	general	general
QEMPR	Energy awareness	good	good	good	good	short	general	good
N-to-1	Hierarchical	general	general	good	good	general	general	good
ALBCH	Hierarchical	good	good	good	good	short	good	general
LRP-EPCA	Hierarchical	good	good	good	good	short	good	general
EE-ABR	ant colony algorithm	good	good	good	good	long	general	poor
EBAB	ant colony algorithm	good	general	good	good	general	general	general
ABMR	ant colony algorithm	good	good	good	good	short	general	general

Advantages of the above protocols are very obvious. We want to discuss some disadvantages of them respectively. Energy awareness routing protocols select the next hop node according to the remaining energy of adjacent nodes, which can easily lead to network partition. Moreover, it will cause additional costs to spread news by broadcast. These protocols are also susceptible to get malicious attacks. Routing protocols based on hierarchical often don't consider using the optimal path to transmit data, so we can integrate some heuristic methods to achieve better performance in the future. The applicability of routing protocols based on ant colony algorithm is very strong. They are more applied for the dynamic topology, but their operating speed is slow which reduces the efficiency of finding routing.

Compared with multipath routing protocols based on infrastructure, multipath routing protocols based on non-infrastructure and multipath routing protocols based on coding [18] have their own special advantages. Multipath routing protocols based on non-infrastructure keep forwarding the data packets to find routings. They don't need the routing maintenance because the relay nodes forward packets. Multipath routing protocols based on coding has high security because the packet is transmitted in the form of encoding. They can be decoded only after the packets arrive at the destination node, so the data during transmission cannot be eavesdropping. This approach is much better than others.

5 Conclusions

WSNs still has a lot of challenges because of its limited resources, the variability of topological structure and so on. For a long time, they are all important indicators to improve WSNs, such as data reliability, network security, energy efficiency. The protocols mentioned in this paper have some breakthrough in these three aspects. However, the scalability and security in the existing protocols are not perfect enough. Many protocols rarely think about security. Therefore, security

mechanisms of protocols need further improvement. In addition, it is also important to improve the adaptability of routing that can meet the needs of diverse applications. Aimed at the limitation of the routing protocols, we can consider cross-layer cooperation, for example, combining with a MAC layer protocol, which maybe achieve better results. To sum up, we need to make a further research and innovation for WSNs.

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