A Survey on Quality of Service Aware Energy Efficient Routing Protocols in MANETS

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Abstract: A Mobile Ad hoc Network (MANET) is a decentralized network and has no infrastructure. Here the mobile nodes form a dynamic network and communicates over wireless links. Due to its self-organizing ability and easy deployment, it is widely used in civil, military applications and rescue operations. With its increasing popularity, it is necessary to support real time and multimedia applications. These types of applications require and demands higher levels of Quality of Service (QoS) parameters like bandwidth, end-to-end delay, jitter and energy. Compared to other networks, providing QoS in MANETs is a challenging task because of the limited resource availability, dynamic network topology. A number of QoS routing protocols have been proposed over the years, but many QoS aware routing protocols did not addressed the feature of energy conservation. This paper presents the overview of several energy aware routing protocols developed for MANETs and addresses their efficiency in terms of providing QoS. A comparative study of the QoS energy aware routing protocols is done.

Keywords: Mobile Ad hoc Network (MANET), Quality of Service (QoS), Energy efficiency, Delay, Bandwidth, AODV, ESAR, QEPAR, DSR.

Introduction

A mobile ad hoc network (MANET) is a continuously self-configuring, autonomous, infrastructure-less network of mobile devices connected through wireless links. Each and every node in an ad-hoc network is free to move independently in any direction and will therefore changes its links to other nodes or devices frequently. MANETS are widely used in the situations like floods, warfare, rescue operations and other disasters where the infrastructure cannot be established. Here each node acts as host and also as a router. The mobile nodes can join or leave the network at anytime. Mobile node is characterized with less memory and power. The reliability and efficiency of a wireless link is often inferior when compared with wired link. The nodes will have identical features with similar responsibilities and capabilities. MANETS are also characterized with the Multi-hop radio relaying that is when a source and destination node for a message is out of the radio range, the MANETs establishes the connection through the multi-hop routing. Fig.1 shows an example of MANET.

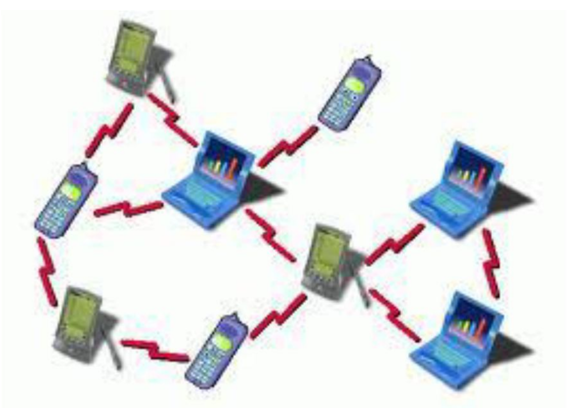

Figure 1. Mobile Ad hoc Network [5]

Energy aware routing reduces the overall energy consumption and thus increases the lifetime of the network. In MANETS, designing the routing protocols that conserve the energy has been a challenging task and also it is an active research area due to the free movement of nodes, dynamic topology and as the nodes will have limited battery energy [4]. Different approaches have been developed in conserving the energy and also in improving the lifetime of the network [6]. But the routing algorithms plays an important role in finding an energy efficient route because routing algorithm decides which node has to be selected for communication. Every node in the MANET depends on its battery power during the transmission of data packets. A particular node's energy drain depends on the data packet size sent through a particular node and also the transmission energy of the node.

There are number of routing protocols which have not considered the quality of service (QOS) parameters such as bandwidth, delay, throughput, jitter, packet delivery ratio, packet loss ratio, link stability, energy consumption etc. but with the development of adhoc network applications there is a need to consider the QoS parameters in routing protocols. For QoS Routing [2], it is not sufficient only to find a route from a source to the destination but also has to satisfy one or more QoS constraints. To guarantee these QOS constraints after a route was found, resource reservations on the participating nodes are made. Quality of service is more difficult to guarantee in ad hoc networks than in most other type of networks, because the wireless bandwidth is shared among adjacent nodes and the network topology changes as the nodes move. In the literature many researchers have proposed the QOS aware routing protocols but most of the QoS aware routing schemes are lack of providing the efficient energy conservation mechanisms. Many researchers have argued that in order to support QoS in MANETs all QoS aware routing schemes should be energy aware [1]. In this paper we study several energy aware routing protocols proposed for MANETs and discuss their QoS capabilities.

The rest of the paper is organized as follows: Section 2 presents the challenges in MANET. Section 3 briefly describes the Ad-hoc networks routing protocols. Section 4 briefly describes the QOS energy efficient routing protocols. The conclusion is given in Section 6.

Challenges in MANETS

Since the MANETs have limited resources and several unique characteristics compared to other wired networks, it faces lots of challenges while providing QOS and efficient routing [3]. The major challenges faced by this architecture can be broadly classified as follows:

Dynamic topology: All nodes in the ad-hoc network are free to move randomly and freely, thus the network changes dynamically and changes rapidly at unpredictable times. It may consist of unidirectional as well as bidirectional links. Thus the QoS provisioning or the routing techniques designed for the static networks may evidence its inefficiency in the dynamic topology networks where nodes have imprecise information about the network state.

Device discovery: In order to select the optimal route automatically, newly moved in nodes has to be identified and all the information about those new nodes has to be updated dynamically.

Routing Overhead: As the nodes in the network moves randomly, the routes formed between the source and destination changes very frequently. So, some dry routes will be formed which leads to the routing overhead which is not necessary.

Limited bandwidth: Wireless links will continue to have lower capacity compared to wired networks.

Limited Power Resources: As the nodes are portable, charging is not possible. Therefore all the nodes in the network are integrated with the limited battery power. QoS aware routing should consider the energy level of a node because each node acts a router and overuse of a particular node may lead to shutting down of the node.

Security threats: Generally mobile wireless networks are more susceptible to security threats than the fixed and wired networks. So providing security for the data packets is quite a challenging task.

Ad-hoc Networks Routing Protocols

The routing protocols are the set of rules or standards to be followed while selecting the routes or paths in the network to send the data traffic. Routing in MANETS has been a difficult task due to the free movement of the nodes in the network. The routing protocols may be classified into three types: proactive or table-driven protocols, reactive or on-demand protocols and hybrid protocols. Based on the capability of the network the protocols are selected.

Proactive Protocols

In proactive routing protocols, each node in the network maintains the routing information about the complete network topology and updates the routing tables periodically even if they have to communicate or no need to communicate. Each node broadcast the messages to all the nodes in the network when there is any change in the network status. Therefore the communication between the source and destination nodes takes place with minimal delay. But these protocols have the disadvantage of the additional control overhead cost to update the routing table periodically. This may leads to the degradation of the overall throughput. The examples of this type of protocols are Distance vector (DV) protocol, Destination Sequenced Distance Vector (DSDV) protocol, Wireless Routing Protocol (WRP), Fisheye State Routing (FSR) protocol and Optimized Link State Routing (OLSR) protocol.

Reactive Protocols

These protocols are on-demand routing protocols. The reactive routing protocols are intended to maintain the routing information about the active routes only. Here, each node in a network discovers or maintains a route based on the demand. It floods the control message by the global broadcast while discovering a route and when the route is discovered then the bandwidth is used for the data transmission. As compared to the proactive routing protocols, the reactive protocols consume less bandwidth and have reduced control overhead. These protocols have one more advantage that, if a node in the selected route fails it quickly reconstructs the network. But the time delay is more compared to proactive routing protocols. Dynamic Source Routing (DSR) protocol, Ad-hoc On Demand Distance Vector routing (AODV), Temporally Ordered Routing Algorithm (TORA) and Associativity Based Routing (ABR) protocols are some of the examples of the reactive routing protocol [2].

Hybrid Protocols

Hybrid protocol is a combination of both proactive and reactive protocols. It is featured with the advantages of both proactive and reactive protocols. An example of hybrid protocol is Zone Routing Protocol (ZRP). The ZRP protocol first selects the route as per the proactive basis and serves the demand of the nodes as per the reactive basis. The ZRP is designed and developed to overcome the control overhead problem which occur in proactive protocols and the problem of low latency which occur in reactive routing protocol.

QOS Energy Efficient Routing Protocols

In literature, there are several energy aware routing protocols which try to conserve energy in an ad hoc environment using different techniques. Most of the routing protocols conserve energy during the node’s active state i.e., when a node is transmitting or receiving data. The transmission power required to transmit a packet consumes significant energy [7]. Various energy aware routing protocols develop efficient transmission mechanisms where a node is able to dynamically adjust its transmission power instead of transmitting at full power always. Most of the routing protocols consider the residual energy levels of nodes while forwarding packets and using the techniques based on the estimation of energy status of the node and transmission power control mechanism prove efficient in terms of energy conservation. But, only several protocols provide QOS support. As MANETs becomes more popular and used for multimedia applications, it is very much essential to provide QoS support along with efficient energy conservation. In this paper, some energy efficient protocols which also consider the QoS parameters like delay, bandwidth and packet loss etc. for MANETS are mentioned.

In paper [4] Salwa Othmen et al. proposed the power and delay aware multi-path routing protocol (PDMRP) for MANETS, which aims to find more number of stable paths from source to destination node concerning the remaining life time of the battery and also to find and select the multi-paths which have minimum hop-count and highest residual energy. These selected multi-paths satisfy the requirements of the QoS, in terms of bandwidth and the delay. This protocol is applied in MANETS by a source to discover the optimal routes to the destination. When some problem occurs in the primary or active route, the source keeps on sending the packets to destination by switching quickly to a secondary route i.e., the backup paths. This protocol shows better performance than the power awareness based Stable Path Routing Protocol and the Modified Adhoc On-Demand Distance Vector (MAODV) routing protocols in terms of the end-to-end delay, throughput and the loss rate. The PDMRP reduces the end-to-end delay as it takes the number of hops when selecting the primary path. It also pays a positive impact on the throughput and packet loss as it considers battery life of nodes and chooses a stable path and as it can rapidly uses the secondary paths when a node or link breaks.

In paper [8] P. Bergamo et al. proposed an energy efficient routing protocol called flexible Distributed Power Control Mechanism (DPC) for MANETS. The main source of energy consumption is the transmission power and this protocol uses the transmission power as the link cost metric for route selection as well as discovery processes. Flexible DPC mechanism determines the required transmit power levels to reach the destination through the next hop neighbors from the source. The DPC is featured with the power control capabilities by which the network interference and energy consumption during the multi-hop operations can be minimized. Due to the estimated power control capability, the DPC mechanism can maintain the network connectivity always. DPC mechanism provides highly reliable link stability also it spends low energy per packet. At the same time DPC mechanism has a negative impact on delay, bandwidth, and throughput.

In paper [9] F. De Rango et al. proposed an optimization routing mechanism for MANET called the location based Link Stability and Energy Aware Routing (LAER) protocol. This protocol aims to increase the link stability and to minimize the energy consumption of the mobile nodes, when selecting paths for the individual transmissions. For data forwarding, this LAER uses a greedy scheme. As the greedy scheme requires only neighborhood and the destination node knowledge the packet forwarding in LAER gives high scalability. The authors have given more priority for energy and link stability metrics. This protocol is designed to select the routes based on minimizing the energy consumption and maximizing the link stability. Link stability is one of the metric which is directly related to the delay. Therefore for the applications requiring reduced delay more emphasis is given to link stability metric. In order to save energy consumption per packet, LAER considers the residual energy levels of the nodes while forwarding packets. But the main drawback of LAER is that the mobility has a negative effect on the link stability metric.

In paper [10] Mandeep Kaur Gulati et al. proposed an energy efficient routing protocol called the Stable Energy efficient QoS based Congestion and Delay aware Routing (SEQCDR) Protocol for wireless mobile Adhoc networks, which mainly aims to avoid the origination of the unstable routes and also to avoid congested nodes to form new routes. In order to increase the system performance the SEQCDR consider the multiple metrics like signal strength, drain rate, queue length and the delay. By applying the load balancing mechanism effectively at every node, it finds the stable path in between source and the destination on basis of the strength of the received signal. This SEQCDR is an on-demand routing protocol and it works under two mechanisms called the Route Discovery and the Route maintenance. To avoid the link-breaks the SEQCDR incorporates the local route repair mechanism of the AODV protocol, which can find the other alternate path present in the nearby neighboring node. If the alternate path is not present each node sends a route error (RERR) message to different nodes having the required links in their routing tables. After getting the RERR packet source node originates the discovery of new route or to find the alternate path for the routing. This protocol gives a better performance than the AODV with reference to the throughput, packet delivery ratio, average end-to-end delay and the routing overhead.

In paper [11] T.A. Ramrekha et al. proposed an energy efficient protocol called the flexible Energy Efficient (E2) mechanism. This protocol considers the energy required to transmit and receive a packet as the cost metric. It uses the residual energy levels of the nodes efficiently to reduce the degree of failure of nodes. The E2 mechanism discovers multiple routes from source to destination. Also this mechanism can use any proactive routing schemes like DSDV, WRP, CGSR etc. or reactive routing schemes like DSR, AODV, TORA, EPAR etc. in order to select an energy efficient and optimized route from that set of multiple routes with more residual energy and with minimum hop count and with the highest residual energy. As this mechanism is capable of identifying and leaving paths with maximum hop count, it can prove itself to be more energy efficient. But it has a negative impact on the network life time.

In paper [12] Shivashankar et al. proposed a source based Efficient Power- Aware Quality of service (QoS) reactive Routing protocol (QEPAR). In order to make the QEPAR protocol energy efficient, it is implemented on the existing DSR (Dynamic Source Routing) protocol with the QOS metrics such as bandwidth and residual battery power. Here the authors observed the energy consumed in Transmit mode, Receive mode and the Idle mode in comparison with the DSR and DSDV(Destination Sequenced Distance Vector). In all the modes QEPAR consumed very less power compared to the DSR and DSDV. Also this QEPAR outperforms the DSDV and DSR in different aspects such as minimum average end to end delay, increase in the lifetime of the network. QEPAR achieved a packet delivery ratio of 86% while the DSR and DSDV gives a PDR of 72% and 56% respectively. QEPAR performs effectively and efficiently in the traffic loads. To reduce the delay and the search time, in QEPAR the weak nodes will be replaced by the efficient nodes.

In paper [13] S. Lim et al. proposed a communication mechanism for MANETS called the Randomcast mechanism. This mechanism is designed to overhear the message and the forwarding mechanism balances the energy savings as well as the network performance. Due to the overhearing and forwarding mechanisms, it reduces the excessive energy spent due to the unnecessary overhearing in the network and the unconditional forwarding of the broadcast packets. In this mechanism, each and every node specifies their levels of overhearing and then it minimizes the redundant rebroadcasts for the broadcast packet due to which it can reduce the packet loss and also it can increase the network lifetime. As this Randomcast mechanism reduces the forwarding of more number of control packets, it places a positive impact on the channel capacity/bandwidth and on the link stability. This scheme places a negative impact on the end-to-end delay and the network lifetime due to the reduced overhearing of the messages.

In paper [14] Almetwally Mostafa et al. proposed a leader replacement protocol which aims to reduce the energy consumption. In MANETs, a Leader or authoritative control node is assigned as an organizer in order to preserve the data consistency. As the mobile nodes in MANET have a limited amount of battery power the leader or authoritative control node may tend to fail at any point of time. As soon as this leader node fails another new leader should be elected in order to maintain data consistency and the data availability. The replacement of the leader node in this approach employs a notable communication overhead and also it consumes large amount of energy i.e., it consumes around 70% of the total available battery power. In this paper the authors designed an approach to reduce the communication overhead on the nodes in order to reduce the energy consumption. In this novel approach when the leader node's battery power goes down and reaches the minimum threshold level or before a leader fails, the early precaution will be taken by replacing this exhausted leader with a new and healthy leader node. Here the rate of battery's power consumption is observed at leader node regularly so that an early replacement of that leader node is performed before the battery power goes off. Hence the leadership is given to the new leader node in presence of the exhausted or old node.

In paper [15] J. Zhu et al. proposed a model and protocol for energy efficient routing over MANETS which is called as Progressive Energy Efficient Routing (PEER) protocol. This protocol has the ability to adaptively adjust the routing path to improve performance. During route discovery phase the PEER protocol reduces the energy consumption. In route discovery phase the PEER follows 2 steps. The first step is that it estimates the shortest paths with a minimum number of hops. Then as step2, it selects the most energy efficient shortest path from the shortest path set which is estimated in step1. Here the total power necessary to successfully transmit and receive a packet is taken for consideration. To prevent the excessive energy consumption due to the extra signaling messages, the route maintenance process does not use any additional periodic messages. The PEER protocol has a positive impact on the Bandwidth/channel, performance, energy consumption and end to end delay.

Conclusion

The dynamic nature of the mobile ad-hoc network consumes lot of power and the energy as compared to fixed or wired network. Therefore, energy consumption is one of the important issues in MANETs. Also with the widespread use of MANETs, providing the QoS is very important in order meet the user requirements. In this paper, a number of energy efficient routing protocols along with their effects on various QoS metrics like delay, packet loss ratio, bandwidth, network lifetime etc. The strengths and the drawbacks of some protocols have been mentioned so as to investigate the future areas of the research. This study also exhibits that the energy aware routing protocols increases the overall lifetime of the network but some QOS metrics like bandwidth and delay suffer due to the increased hop count and extravagant distribution of packets which indicates the lifetime of a node. This study also indicates that there are a number of challenges to be addressed and solved in order to design the QoS routing protocols. Some of those challenges are: reliability, reducing the control overhead, resource reservation, route maintenance, power consumption, security etc. Therefore there is a need to design and develop the new QoS aware routing protocols which can address the above issues and provides a significant reduction in delay and the bandwidth.

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