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A Review on Energy-Efficient Reliable Routing in Wireless Ad Hoc Networks

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Abstract: Ad-hoc networks are multi-hop wireless networks where all nodes in ad-hoc wireless network co-operatively maintain network connectivity. Three important requirements of ad hoc networks are the energy-efficiency, reliability, and prolonging network lifetime. There are various routing algorithms that consider the energy efficiency of nodes, reliability of links and the lifetime of networks. These algorithms are broadly classified into three categories. Firstly, those only consider the reliability of links to find more reliable routes. Secondly, those aim at finding energy-efficient routes. Thirdly, those try to prolong the network lifetime. In this paper, different energy efficient reliable routing protocols for wireless ad-hoc networks are compared based on the above mentioned categories.

Keywords: Ad-hoc Wireless Network, Routing, Energy-Efficiency, Reliability, Network Lifetime.

I. INTRODUCTION

A mobile ad hoc network (MANET) is defined as an autonomous system of mobile routers and their associated hosts connected by wireless links. A MANET is characterized by fast deployment, dynamic multi-hop topology, self-organization without typical infrastructure support etc. That's why Mobile ad-hoc networks are suitable in situations such as battlefields, where network connectivity is temporarily needed, or fixed infrastructures are unavailable, expensive, or infeasible to deploy. Wide deployment of MANET has not come yet due to many technical challenges like energy-efficiency, reliability, network life time etc, among which energy issue is a fundamental and most important one. Wireless devices are powered by small-sized batteries, whose replacement is very difficult or even impossible in some applications for example disaster relief operations. Power conservation in an ad hoc network is the process of determining the transmit power of each communication terminal such that a design objective like network lifetime, throughput, etc. can be satisfied.

To reducing energy cost of data communication in wireless ad hoc networks, Energy-Efficient routing is an effective mechanism. Generally, routes are discovered considering the energy consumed for end-to-end (E2E) packet traversal. But this should not result in finding less reliable routes and overusing a specific set of nodes in the network decreases the lifetime of the network. Energy-efficient routing in ad hoc networks is complete only with the consideration of reliability of links and residual energy of nodes. Considering the residual energy of nodes in routing can avoid nodes from being overused and can eventually lead to an increase in the operational lifetime of the network.

The rest of the paper is organized as follows: In Section II, present different categories of routing algorithms. In Section III, describes some protocols that are related to energy conservation and conclude in Section IV.

II. ROUTING ALGORITHMS

Various routing algorithms have been proposed during the last decades, that aiming at increasing energy-efficiency, reliability, and the lifetime of wireless ad hoc networks, that can be broadly classified into three categories in [14].

A. Algorithms that consider the reliability of links

The first category includes algorithms that only consider the reliability of links to find more reliable routes. This category algorithm is proposed in [10]. A High- Throughput Path Metric for Multi-Hop Wireless Routing is used to find reliable routes that consist of links requiring less number of retransmissions for lost packet recovery here introduces the notion of expected transmission count, that is represented as ETX. These reliable routes require less number of retransmissions so such routes may consume less energy but do not necessarily minimize the energy consumption for E2E packet traversal. This approach implicitly assumes that links either work well or don't work at all. The primary goal of the ETX design is to find paths with high throughput. Higher priority for reliability of routes may result in overusing some nodes. Some links more reliable than others, these links will frequently used to forward packets to achieve high throughput or to achieve the idea of less number of retransmissions. Nodes along these links will then fail quickly because

they have to forward many packets on behalf of other nodes.

B. *Algorithm that aim at finding energy-efficient routes*

This category includes algorithms that only aim at finding energy-efficient routes. The algorithms that come under this category do not consider the remaining battery energy of nodes to avoid overuse of nodes even though some of the algorithms address energy-efficiency and reliability together. But many routing algorithm have a major drawback, that is, they do not consider the actual energy consumption of nodes to discover energy-efficient routes. They only consider the output power of the power amplifier and also neglecting the energy consumed by processing elements of transmitters and receivers. The considered energy cost of a path by these algorithms is only a fraction of the actual energy cost of nodes for transmission along a path. This negatively affects energy-efficiency, reliability, and the operational lifetime of the network altogether.

In [2] have a technique that conserves battery power at nodes by intelligently powering off nodes that are not actively transmitting or receiving packets. In the case of Ad Hoc networks more importance to reduce the power consumption because networks are typically established in mission critical environments. Power is consumed when either node transmits or receives packets. PAMAS [2] protocol is the combination of the original MACA protocol and uses the idea of using a separate signaling channel. MACA uses a separate channel for the packet transmission and separate channel for signaling. And also PAMAS [2] assumes nodes have six states like Idle, AwaitCTS, Binary Exponential Back off, Await Packet, Receive Packet, and Transmit packet. RTS-CTS message passing is used for the communication. RTS is the Request To Send message and CTS is the Clear To Send message. In PAMAS, if n nodes present in a fully connected network then there are n-2 nodes shut themselves off. There are several conditions for powering off that are,

- One node have no packet to transmit then that turn off itself.
- At least one of the neighboring node transmitting and another is receiving then also that node turn off itself.

And most importantly the power off decision takes independently. Powering off has no effect in the behaviors like throughput and delay but the Longer power off state will affect the network throughput and delay.

PARO [11] is a Dynamic power controlled routing scheme, that helps to minimize the transmission power needed to forward packets between wireless devices in ad hoc networks. It uses a packet forwarding technique. One or more intermediate nodes called "redirectors" elects used to forward packets on behalf of source–destination pairs, it shorten the length of individual hops, also reducing the aggregate transmission power consumed by wireless devices. Reducing the transmission power may not significantly impact the device's operational lifetime. This PARO [11] is not designed to provide QoS, so the introduction of one or more redirectors will have a negative impact. PARO consumed less power in order to find power efficient routes due to its point-to-point on-demand design.

Paper [6] addresses energy-efficiency and reliability together. Energy-efficient routing algorithm proposed here is for the HBH system. In the case of route selection, considers both energy consumption of nodes and reliability of links. Generally refer this scheme as traditional minimum energy routing (TMER) scheme. The major drawback is that it neglects energy consumption of processing elements and the impact of HBH ACK.

The energy efficient algorithm proposed in [13], for the E2E system. It does not consider energy cost of processing elements of transceivers. Here present two centralized algorithms first one is the Basic Algorithm for Minimum Energy Routing (BAMER) and next is the General Algorithm for Minimum Energy Routing (GAMER). BAMER is the generalized extension of Dijkstra's shortest path algorithm and GAMER is the generalization of BAMER and it gives the minimum energy reliable communication and also used to find minimum energy paths in any network configuration. Here also present one distributed algorithm, DAMER (Distributed Algorithm for Minimum Energy Routing), it's a lightweight distributed routing protocol, and approximates the performance of the centralized algorithm and leads to significant performance improvement. It can be used for energy efficient routing in any network configuration. DAMER is also able to find minimum energy paths in the hop-by-hop model and effectively improves energy efficiency.

These algorithms do not consider the remaining battery energy of nodes. These algorithms uses shortest-path routing algorithm like Dijkstra's algorithm, which has been considered as an optimal solution but it does not provide an optimal solution it is a heuristic solution, and it can be an optimal solution only the number of retransmissions on each link is large enough to ensure complete reliability of links. Major drawbacks of these types of algorithms are,

- Do not consider the actual energy consumption of nodes.
- Only consider the transmission power of nodes.
- Neglecting the energy consumed by processing elements of transceivers.
- Considered energy cost of a path is only a fraction of the actual energy cost of nodes for transmission along a path.

- This negatively affects energy-efficiency, reliability, and the operational lifetime of the network altogether.
- Impact of acknowledgment packets on energy cost of routes in both HBH and E2E systems has been neglected.

C. Algorithms that try to prolong the network lifetime

These algorithms, however, do not address reliability and energy-efficiency so discovered routes by these algorithms may neither be energy-efficient nor be reliable. This can increase the overall energy consumption in the network. Thus, the network lifetime may even be reduced. These categories of algorithms are proposed in papers like Power-Aware Routing in Mobile Ad Hoc Networks.

The Protocol in [1] increases the life of nodes and networks. Power aware routing save overall energy consumption in the network and increases battery life. In this paper, explore the issue of increasing node and network life by using power-aware metrics for routing. Five metrics are present to ensure that node and network life are increased, that metrics are,

- Minimize energy consumed/packet
- Maximize time to network partition:- Need to maintain low delay and high throughput so optimizing this is difficult.
- Minimize variants in node power level:- Ensures all the nodes in the network remain up and running together for as long as possible.
- Minimize cost/packet:- Nodes will not be over used- increased their life.
- Minimize maximum node cost:- No way to implement this metric directly.

Common Characteristics of Algorithms that try to prolong the network lifetime are,

- By finding routes consisting of nodes with a higher level of battery energy.
- This does not address reliability and energy-efficiency.
- Discovered routes by these algorithms may neither be energy-efficient nor be reliable.
- Increase the overall energy consumption in the network.
- The network lifetime may even be reduced.

III. RELATED PROTOCOLS

Power conservation is the most important challenge in Mobile wireless ad-hoc networks. To conserve power so many techniques are present one is the power control technique second is the power-off mechanism and third one is the multi-channel mechanism.

A. Power control techniques

There are two important reasons for transmit power control. First one is the transmission at a high power may increase the interference to co-existing users and therefore degrade network throughput. One direct advantage of this increase is the enlarged overall traffic carrying capacity of the network [3]. Second one is the energy-efficient schemes that can impact battery life, consequently prolonging the lifetime of the network.

The most widely used MAC protocol in MANET is the IEEE 802.11 DCF (CSMA/CA+ RTS/CTS) mechanism. In 802.11, mobile nodes try to avoid collisions with carrier sensing before transmission. If the channel is busy, the node will defer transmission and goto back off state. In other case, the nodes will begin the RTS/CTS dialog process to capture the channel and then transmit the packets. The CSMA/CA scheme effectively decreases the amount of possible collisions. The RTS/CTS is also beneficial since it will reserve the channel spatially and temporarily. RTS/CTS exchange is also helpful in avoiding hidden terminal problem, But, this process severely limits available bandwidth.

A Power Control MAC (PCM) protocol is proposed in [7] that used to allow per packet selection of transmit power. In PCM, RTS/CTS packets are transmitted with a maximum power level, Pmax. But data packets, that are transmitted with a lower power level. During the DATA packet transmission PCM periodically increases the transmission power to Pmax to avoid a potential collision caused by the reduced carrier sensing zone. ACK packets are transmitted with the minimum required power to reach the source node. PCM effectively decreases the amount of possible collisions by periodically increasing the power level for data transmission,. This way, retransmission is avoided as much as possible, and correspondingly, the aim of energy savings is achieved. This shows that PCM [7] can achieve a throughput comparable to the IEEE 802.11 but with less energy consumption. The implementation of PCM is difficult because PCM requires a frequent increase and decrease in transmission power levels.

The Power Controlled Multiple Access (PCMA) Protocol [5] proposes a flexible bounded power collision suppression model and this allows variable transmit power levels on a per-packet basis. Similar with IEEE 802.11, PCMA utilizes RPTS/APTS handshake to determine the minimal transmission power required for successful packet reception. The difference lies in that PCMA introduces a second channel, the busy tone channel, this channel is used to implement the noise tolerance advertisement. Each active receiver will periodically send a busy tone to advertise the maximum additional noise power it can tolerate, during data transmission periods. Any potential transmitter must first sense the channel for busy tones to determine the upper bound of its transmit power for a minimum time period. Actually,

PCMA [5] utilizes the signal strength of a received busy tone message to bound the transmission power of neighboring nodes. This way, power control mechanism is realized and spatial reuse is achieved. By adapting the transmission ranges to be the minimum value required for successful reception on the receiver side, PCMA works effectively in energy conservation since it allows more concurrent data transmission compared with IEEE 802.11 standard. Different analysis results shows that PCMA [5] can improve the throughput performance by more than a factor of 2 compared to the IEEE 802.11 for highly dense networks. The throughput gain over 802.11 will continue to increase as the connectivity range is reduced. What's more, the power controlled transmission in PCMA helps increase channel efficiency at the same time preserving the collision avoidance property of multiple access protocols.

A Dynamic Channel Assignment with Power Control (DCA-PC) is proposed in [9]. Similar with PCMA [5], this power control protocol uses one control channel to transmit all the control packets (RTS, CTS, RES etc). The important difference is that multiple data channels are assigned on demand basis. In DCA- PC, the pair of source and destination nodes uses a RTS/CTS dialogue to decide which channel to grab and which power level to utilize for data transmission. To reserve the data channel a RES message is used. Then data packets and ACK packets are transmitted on the reserved data channel by using the assigned power level. In DCA-PC [9], all the control packets are transmitted with a maximal power level in order to warn the neighboring nodes of the communication. This is the first protocol to realize the mechanisms of power control and multi- channel medium access together in MAC protocols of MANETs.

The Power Controlled Dual Channel (PCDC) Medium Access Protocol [12] also uses two channels like PCMA [5], one is the control channel and other is the data channel. However, PCDC is the first to utilize the inter-layer dependence between the MAC and network layers to provide an efficient and comprehensive power control scheme. This idea is based on the observation that the transmission power has direct impact not only on the floor reserved for the next transmission but also on the selection of the next hop node. Hence, the interaction between the MAC and network layers can help for an effective power control scheme.

B. Power off mechanism

In typical wireless systems, receivers have to be powered on at all time to detect any possible signals that target them. More energy is consumed in idle state than in sleep state.

An energy-efficient MAC protocol for wireless sensor networks, called S-MAC is introduces in [8]. Different from PAMAS [2], S-MAC utilize the scheme of periodic listen and sleep to reduce the energy consumption done by avoiding idle listening. However, here need synchronization among neighboring hosts. And the latency is increased since a sender must wait for the receiver to wake up before transmission. But to form virtual clusters of nodes on the same sleep schedule S-MAC uses synchronization. This method coordinates nodes to minimize additional latency. S-MAC uses the in-channel signaling to put the nodes in sleep mode when its neighboring node is in transmission this is an another difference from PAMAS. The in-channel signaling helps to decrease the overhearing problem and avoids the use of additional channel resource. Comparative study with 802.11, S-MAC [8] reduces the energy consumption by up to 50% for heavy traffic; and much more energy is saved for light traffic.

C. Multi-channel mechanism

The main function of MAC layer protocols is to control and coordinate the multiple accesses of wireless terminals to share the communication medium, while at the same time maintain high network utilization. Most of the MAC protocols assumes that there is only one channel shared among different mobile nodes in ad hoc networks. Thus the essential design goal is to avoid hidden terminal and exposed terminal problems and at the same time increase the channel utilization.

An ad hoc network built on multi channel scheme can be considered as a system composed of one control channel, together with one or more data channels. In other words, the overall bandwidth is divided into one control channel and n data channels.

In [4] introduces a Dynamic Channel Assignment (DCA) protocol that assigns channels dynamically in an on-demand style. This protocol exploits one control channel to resolve contentions on data channels and assign data channels to mobile hosts. For data transmission multiple data channels are available. In the case of this protocol, all data channels are equivalent with the same bandwidth. Each host has two half-duplex transceivers, thus it can listen on the control channel and its data channel simultaneously. Channels are used here with little control message overhead. Analysis results shows that DCA suffers less collision and corruption compared with a simple 802.11-like multi channel protocol. The introduction of the control channel and multi data channel helps to decrease unwanted power consumption.

IV **CONCLUSION**

The dynamic, fast deployable ad hoc networks have many promising applications such as e-conference, emergency services, home networking, etc., more and more attention are focused on wireless ad hoc network research, especially on energy-aware mechanisms. Here presented an in-depth study of energy-aware routing in wireless ad- hoc networks. It is very important to study how to decrease the power consumption at the same time also need to study how fully-utilizes the bandwidth resource.

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