Energy Efficient, Power Aware Routing Algorithm for Sensor Network

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Abstract—**With the advance of wireless communication technology, small size and high performance computing and communication devices like commercial laptops and personal computers are increasingly used in convention centers, conferences and electronic classrooms. In wireless ad-hoc networks, a collection of nodes with wireless communications and networking capability communicate with each other without the aid of any centralized administrator. The nodes are powered by batteries with limited energy reservoir. It becomes difficult to recharge or replace the batteries of the nodes hence energy conservation is essential. An energy efficient routing protocol balances node energy utilization to reduce energy consumption and increase the life of nodes thus increasing the network lifetime, reducing the routing delay and increasing the reliability of the packets reaching the destination. Wireless networks do not have any fixed communication infrastructure. For an active connection the end host as well as the intermediate nodes can be mobile. Therefore routes are subject to frequent disconnection. In such an environment it is important to minimize disruptions caused by changing topology for applications using voice and video. Power Aware Routing enables the nodes to detect misbehavior like deviation from regular routing and forwarding by observing the status of the node. By exploiting non-random behaviors for the mobility patterns that mobile user exhibit, state of network topology can be predicted and perform route reconstruction proactively in a timely manner. In this paper we propose an Energy Efficient-Power Aware routing algorithm where we have integrated energy efficiency with power awareness parameters for routing of packets.**

Index Terms—**energy efficient, power aware, sensor, network.**

I. Introduction

The history of wireless networks started in the 1970s and the interest has been growing ever since. The tremendous growth of personal computers and the handy usage of mobile computers necessitate the need to share the information. The great popularity of Internet services make more people enjoy and depends on the networking applications. However, the Internet is not always available and reliable, and hence it cannot satisfy people's demand for communication at anytime and anywhere. Mobile Ad hoc Network (MANET) is a wireless network without any fixed infrastructure or centralized control; it contains mobile nodes that are connected dynamically in an arbitrary manner. Based on infrastructure, the wireless networks broadly classified into two types, first type infrastructure networks contains base-stations. The second type is called Mobile Ad hoc Networks enable users to communicate without any physical infrastructure regardless of their geographical location.

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Recent advances in wireless technology have helped the users to equip portable computers, like notebook computers and personal digital assistants with wireless interfaces for networked communication, thus making mobile ad hoc networks as a self organizing and rapidly deployable network in which neither a wired backbone nor a centralized control exists. The network nodes communicate in a multi hop fashion with one another over wireless channels. The ad hoc network is adaptable to the highly dynamic topology resulted from the mobility of network nodes and the changing propagation conditions.

A. Applications of Mobile Ad Hoc Networks

The following are some well-known applications [3] of MANET.

Military

- Automated battlefield
- Special operations
- Homeland defense

Civilian

- Disaster Recovery
- Law enforcement
- Search and rescue in remote areas
- Environment monitoring (sensors)
- Space/planet exploration

Commercial

- Sport events, festivals, conventions
- Patient monitoring
- Ad hoc collaborative computing (Bluetooth)
- Sensors on cars
- Vehicle to Vehicle communications
- Video games at amusement parks, etc

B. Multipath Routing in MANET

The routing is the most active research field in the MANET. The routing protocols designed for wired networks are not suitable for wireless networks due to the node mobility issues in wireless networks. The different protocols are proposed to deal with routing problem in the MANET. These routing protocols can be classified into two main categories: Table driven routing protocols and on demand routing protocols [1].

Developing routing protocols for MANETs has been an extensive research area during the past few years. In particular, energy efficient routing is the most important design criteria for MANETs since mobile nodes will be powered by batteries with limited capacity.

Multipath routing appears to be a promising technique for ad hoc routing protocols. Providing multiple routes is beneficial in network communications, particularly in MANETs, where routes become obsolete frequently because of mobility and poor wireless link quality [4]. The source and intermediate nodes can use these routes as primary and backup routes. Alternatively, traffic can be distributed among multiple routes to enhance transmission reliability, provide load balancing, and secure data transmission. The multipath routing effectively reduces the frequency of route discovery therefore the latency for discovering another route is reduced when currently used route is broken. Multiple paths can be useful in improving the effective bandwidth of communication, responding to congestion and heavy traffic, and increasing delivery reliability.

II. Related Work

In recent focus to develop a routing protocol which reduces the energy consumption of communication subsystem and increases the life of nodes, that energy efficient routing decision is more important than simple shortest path routing. Power aware routing suggests the use of different energy aware metrics when determining a routing path. Several strategies are commonly employed for power aware routing in WSNs. Minimizing the energy consumed for each message. This parameter might unnecessarily overload some nodes causing them to die prematurely. Minimizing the variance of the power level of each node in the network. This is based on the scenario that it is useless to have battery power remaining at some nodes while others exhaust their battery, since all nodes are equally important in the network. Minimizing the cost per packet ratio of each of the node in the network. In this approach, different costs can be assigned to different links, for example, incorporating the discharge curve of the battery, and thus postponing the moment of network partition. Minimizing the maximum energy drain of any node in the network.. The basis of this approach is that the network utility is first noticed when the first node exhausts its battery in the network, and thus it is necessary to minimize the battery consumption at this first node.

In order to make the system work with the best efficiency, the least bit error rate, the shortest delay and the best stability, we proposed an improved routing algorithm named Ant Colony Routing Algorithm based on Neural Networking for the AMR system [11]. The Minimum Total Transmission Power Routing (MTPR)[12] was initially developed to minimize the total transmission power consumption of nodes participating in the acquired route. These protocols build multiple routes based on demand but they did not consider the power aware metrics. The Min-Max Battery Cost Routing (MMBCR) [10] considers the remaining power of nodes as the metric for acquiring routes in order to prolong the lifetime of network. The Multipath Power Sensitive Routing (MPSR)[9] shows how an efficient heuristic based multipath technique can improve the mean time to node failure and maintain the variance in the power of all the nodes as low as possible.

III. Routing in Wireless Sensor Networks

A routing protocol is a protocol that specifies how routers communicate with each other, disseminating information that enables them to select and the implementation of a routing algorithm in software or hardware. A wireless sensor network (WSN) consists of spatially distributed autonomous sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants. Wireless sensor networks are formed by small devices communicating over wireless links without using a fixed networked infrastructure. Routing in WSNs is very challenging due to the inherent characteristics that distinguish these networks from other wireless networks like mobile ad hoc networks or cellular networks. The effect of power aware routing algorithms on the lifetime of multihop wireless sensor networks (WSNs). The energy efficient protocol shutdown the candidate nodes who are not the leader in the data forwarding process to save and improve the network performance. According to IEEE specification of the network interface card (NIC) with 2Mbps. The energy consumption varies from 240mA at receiving mode and 280mA in the transmitting mode using 0.5V energy. Thus, when calculating the energy consumed to transmit a packet *p* the current, voltage and the time taken to transmit the packet *p* are considered. The energy consumption of overhearing the data transmission may be assumed as equivalent to energy consumption of receiving of the packet. The routing algorithm used for reducing congestion in wireless sensor networks normally constitutes a wireless ad-hoc network, meaning that each sensor supports a multi-hop routing algorithm. Congestion in network will lead many problems such as: it can lead to indiscriminate dropping of data. Some packets of high priority might be dropped while others of less priority are transmitted .Congestion can cause an increase in energy consumption as links become saturated. The existing protocols are discussed here. The AODV routing protocol is a reactive routing protocol; therefore, routes are determined only when required. Hello messages may be used to detect and monitor links to neighbors. If Hello messages are used, each active node periodically broadcasts a Hello message that all its neighbors receive. Because nodes periodically send Hello messages, if a node fails to receive several Hello messages from a neighbor, a link break is detected When a source has data to transmit to an unknown destination, it broadcasts a Route Request (RREQ) for that destination. At each intermediate node, when a RREQ is received a route to the source is created. If the receiving node has not received this RREQ before, is not the destination and does not have a current route to the destination, it rebroadcasts the RREQ. If the receiving node is the destination or has a current route to the destination, it generates a Route Reply (RREP). The RREP is unicast in a hop-by-hop fashion to the source. Control messages are route request route reply and Hello message. Dynamic Source Routing (DSR) also belongs to the class of reactive protocols and allows nodes to dynamically discover a route across multiple network hops to any destination. Source routing means that each packet in its header carries the complete ordered list of nodes through which the packet must pass. DSR uses no periodic routing messages (e.g. no router advertisements), thereby reducing network bandwidth overhead, conserving battery power and avoiding large routing updates throughout the ad-hoc network [1]. Instead DSR relies on support from the MAC layer (the MAC layer should inform the routing protocol about link failures). The two basic modes of operation in DSR are route discovery and route maintenance. DSR uses a route cache that stores all possible information extracted from the source route contained in a data packet. The purpose of a sensor network is to monitor and report events in a particular area.

IV. Power Management In MANET

Power management is a technique to reduce the energy consumed in the wireless interface of battery-powered mobile devices. The design of optimal power management policies needs to explicitly account for the diverse performance requirements posed by different application scenarios such as latency, throughput and other performance metrics.

Power management techniques have been studied extensively in the context of CPU, memory and disk management in the past. The main idea is to switch devices to the low-power state in periods of inactivity. As compared with traditional techniques in operating systems, power management in communication devices requires distributed coordination between two and more than those communicating entities, as all the entities have to be in the active mode for a successful communication. When the arrival pattern of communication events is not known a priori, communication over the same wireless channel is required to inform a remote sleeping node to wake up for packets destined for it. This makes power management seemingly simpler. For example, if node A has packets destined for node B while node B is in the low power state, node A has to wait till node B becomes active before it transmits any packet. On the other hand, when node B is in the low-power state, it has no idea that node A has packets destined for it. Therefore, energy saving and performance inherently contradict each other in power managed wireless networks. A naive design that minimizes the energy consumption may render the network non-operational. This paper proposes a plan to present an analytical characterization of energy consumption, delay and loss rate of power management policies as a function of the Traffic load, buffer size and protocol specific parameters. By proposing a theoretical model to analyze the time-out driven policies based on a variation of M/G/1/K queuing system with multiple vacations.

A power management policy in wireless networks is invoked to make the following decisions: i) which set of nodes should perform power management, ii) when a power-managed node switches to the low power state and iii) when a power-managed node switches from the low-power state to the active state.

A good power-saving topology management scheme for wireless ad hoc networks should have the following characteristics:

- It should allow as many nodes as possible to turn their radio receivers off most of the time because even an idle radio in receive mode can consume almost as much energy as an active transmitter.
- It should forward packet between source and destination with minimally more delay than if all nodes were awake.
- This implies that enough nodes must stay awake to form a connected backbone.
- The algorithm for picking this backbone should be distributed, requiring each node to make a local decision [6].

The approaches so far discussed focus on different metrics of energy efficiency. A common characteristic of these metrics is that they can lead to a disconnected network with a high residual power: once the critical nodes of the network have exhausted their batteries, the network is essentially dead For a practical sensing application, the network can be considered to have stopped working when it fails to deliver the sensed readings from a bulk of the sensors, and the important metric is the time when this occurs. Therefore use the network life time becomes one of the main performance measures.

V. Proposed Power Management, Energy Aware With Low Overhead And Topology Scheme

Minimizing energy consumption is the important challenge in mobile networking. Wireless network interface is often a device’s single largest power consumer. Since the network interface may often be idle, turning the node off when not in use could save a considerable amount of power. In practice. However, this approach is not straightforward. A node must arrange to turn itself on not just to send packets, but also to receive packets addressed to it and to participate in any higher level routing and control protocols. The requirement of cooperation between power saving and routing protocols is particularly acute in the case of multihop ad hoc wireless networks, where nodes must forward packets to each other.

A node must switch its state from time to time between being a agent node and being a member. A node becomes a gateway, if its agent node chooses it as a gateway to route the packets between nodes. It has to switch its state to undecided, if it looses contact with its agent node due to mobility.

The main aim of proposed routing is to increase the life time of network with low overhead while achieving many desired features of routing protocol of MANET. It selects the optimal paths using power aware metric and optimizes the power consumption, overhead and bandwidth. It supports reliability by providing node-disjoint paths and it provides the stability (increasing mean life time of the nodes) by distributing the burden of routing and congestion control.

It consists of the following four main mechanisms

- Route selection
- Route Discovery
- Maximization of Network lifetime and

Congestion control

• Route Maintenance

A. Route selection

The route selection is to select the optimal paths to prolong network's life time. It is based on cost function The main objective of cost function is to give more weight (or) cost to node with less energy to prolong its life time. Let $f_i(c_i^t)$ be the battery capacity (residual energy) of a node n_i at time t. The cost of node n_i is equal to value of battery cost function, which in turns inversely propositional to residual energy of the node n_i i.e. $f_i(c_i^t) = 1/c_i^t$ We describe the following cost function

$$f_i(c_i^t) = \rho_i x \left[\frac{F_i}{c_i^t} \right] x W_i$$

B. Route Discovery

The route selection is based on route discovery. We choose the Dynamic Source Routing (DSR)[9] protocol as a candidate protocol and make modifications to enable the discovery of energy aware node disjoint paths.

1) Modifications of control packets

We modify the format of Route Request (RREQ) packet and Route Reply RREP) packet of the DSR. The RREQ of the DSR is extended as RREQ of the ENDMR adding with two extra fields, one is cost field and another is max-cost

Field is shown in the following fig. It contains type field, source address field, destination field, unique identification number field, hop field, max-cost field, cost (cumulative cost) field and path field.

T	S A	I D	D A	TT L	Hop	Max cost	Cost	Path

Fields of RREQ Packet

Type (T) field: It indicates the type of packet .SA (Source Address) field: It carries the source address of node. ID field: unique identification number generated by source to identify the packet. DA (Destination Address) field: It carries the destination address of node. Time To Live (TTL) field: It is used to limit the life time of packet, initially, by default it contains zero. Hop field: It carries the hop count; the value of hop count is incremented by one for each node through which packet passes. Initially, by default this field contains zero value. Max-Cost field: When packet passes through a node, if its cost is greater than max-cost of packet, then this field is updated by the node by copying its cost other wise this field is not disturbed. Initially by default this field contains zero value. Cost field: It carries the cumulative cost; when packet passes through a node; its cost is added to this field. Initially, by default this field contains zero value. Path field: It carries the path accumulations, when packet passes through a node; its address is appended at end of this field. The Route Reply packet (RREP) of the DSR is extended as RREP of the ENDMR adding with cost field.

2) Modifications at source node

In the DSR, when a source node wants to send data to a destination, it looks up its route cache to determine if it already contains a route to the destination. If it finds that an unexpired route to the destination exists, then it uses this route to send the data. But if the source node does not have such a route, then it initiates the route discovery process by broadcasting a route request (RREQ) packet. In the ENDMR, the functions of the source node similar, but source node maintains energy aware node disjoint multipath to a destination and it chooses the optimal path to send the data.

3) Modifications at intermediate node

In the DSR, when an intermediate node receives a RREQ packet, it checks whether its own address is already listed in the route record of received RREQ packet. If its address is not found, then it appends its address to the route record of received RREQ and it is broadcasted to all its neighbors. Other wise the received RREQ packet will be dropped. Later if an intermediate node receives duplicate RREQ packets(whose Source address and ID are same as Source address and ID of currently received RREQ) from other paths, then those duplicate RREQ packets will be dropped. The pair (Source address, ID) is used to distinguish the packets.

4) Modifications at Destination node

In the DSR, when the destination receives the RREQ packet, its address is appended to it and it generates the route reply by inserting path. In DSR, destination sends single route reply. Later duplicate RREQ packets will be dropped and it doesn't send any reply. Where as in the ENDMR, when the destination generates several replies and sends them to the source. Finally all multiple RREQ (Route requests) packets will be reached to the destination, then destination appends its address and adds total cost to each route request, now each route request contains a path from source to destination. In the conventional on demand multipath outing protocols, the source node computes optimal path(s) from multiple paths that were supplied by the destination in the route reply. But here we have introduced new concept, the computation of optimal paths is assigned to the destination instead of the source to reduce to reduce the overhead. The following four cases the overhead increases for sending multiple paths through replies.

- Increasing of multiple number of paths
- Increasing of length of a path or increasing of lengths of paths
- Increasing of distance between the source and the destination
- all above

C. Maximization of network lifetime and congestion control

If battery capacity of node reaches less i.e zero then node will die.

To maximize the lifetime of network, each node maintains minimum energy level, it is also called threshold or cut-off value. Threshold is always greater than one. During the transmission of data, each node checks whether its energy reaches to threshold or not. If its energy reaches to threshold then node sends a choke packet to the source node in reverse path shown in fig 1.

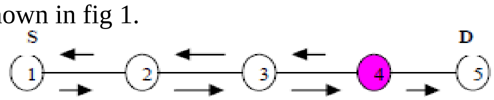

Figure 1

After receiving the choke packets, the source node stops the data transmission on selected path and it uses the alternate path if available otherwise it initiates discovery process to continue the data transmission. This choke packet can also be used for congestion control, during the transmission of data if any node is congested then it sends the choke packet to the source node. After receiving choke packet, the source node stops the data transmission selected path and it uses the alternate path if available otherwise it initiate discovery process to continue the data transmission. Here choke packet is used for dual purpose; one purpose is for increasing life time of the network, another purpose for congestion control.

1) Route Maintenance

Node which discovers the link breakage between two nodes sends a Route Error (RERR) packet. The source uses an alternate valid route, if not; it initiates a route discovery process

2) Simulation

The integrated energy and power aware protocol significantly reduces the total number of route request packets, this result in an increased packet delivery ratio, decreasing end-to-end delays for the data packets, lower control overhead, fewer collisions of packets, supporting reliability and decreasing power consumption. Each route request carries the cumulative cost, so very little bit overhead is increased to carry the cumulative cost but it is negligible. In the fig. 2 red line indicates the existing system and the blue indicates the proposed system.

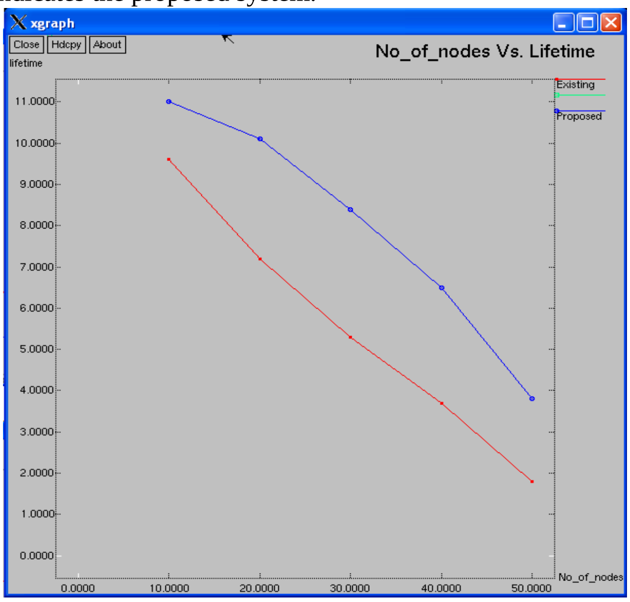

Figure 2. Number of node Vs Life time

VI. Conclusion

The Energy Efficient, Power Aware Routing protocol significantly reduces the total number of route request packets, this result in an increased packet delivery ratio, decreasing end- to-end delays for the data packets, lower control overhead, fewer collisions of packets, supporting reliability and decreasing power consumption. Each route request carries the cumulative cost, so very little bit overhead is increased to carry the cumulative cost but it is negligible

In this paper we discussed the need to make routing protocols energy efficient and power-aware. We proposed a methodology of routing protocol for misbehaving network with a power management scheme protocol, and to improve routing protocol performance by using mobility prediction. The protocol used here enables nodes to detect misbehavior by observing the status of the nodes.

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