Energy Efficient Performance of Routing Protocols in Mobile Networks

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Abstract—Transporting data in a mobile network is a vital job. For transporting data, planned mode and non planned mode are used. The planned mode requires data to be transferred from fixed hosts to a mobile unit before a disconnection occurs. For transmission this mode needs that a disconnection protocol know which data will be used in the near future. The planned mode is more suitable for expected disconnection, while the second mode i.e. unplanned mode is suitable for unpredictable disconnection. Due to lack of infrastructure and the broadcast nature of the network, security is a moresensitive issue in MANETs than any other networks. Researchers have proposed a variety of store-carry-forward routing schemes/protocols. In these protocols, algorithms are developed in such a way that node's battery consumption should be reduced. A node stores a message and carries it for certain duration until a communication opportunity arises. Local forwarding decisions are independently made using utility functions, and multiple copies of the same message are propagated in parallel to increase the delivery probability. This paper takes a look after how the performance of these protocols can be improved.

Keywords*—Manet, protocols, energy efficient*

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I.INTRODUCTION

A query processing in mobile environment is quite different than the transactions in the centralized or distributed environment. The mobile query processing splits their computations into sets of operations of which some operations get execute on a mobile host while others get executed on stationary host. Disconnection is the main problem of mobilecomputing. To overcome this transaction shares their states and partial results with other transactions [1].As the mobile hosts move from one cell to another, the location information, the states of query processing, states of accessed data objects also move.For better performance, the queryprocessing architectures should tackle the limitations of mobile computing like limited battery life, low bandwidth, disconnections and reduced storage capacity. An ad hoc network consists of a collection of mobile nodes formed by means of multi-hop wireless communication. There is no use of any existing network infrastructure in MANETs[2]. In mobile ad hoc networks, nodes communicate with each other by means of broadcast radio signals. Broadcast is a unique case of multicast, wherein all nodes in the network get the broadcasted message. Multicasting is a communication process in which the transmission of packets (message) isinitiated by a single user and the message is received by one or more end users of the network. Multicasting in wired and wireless networks has been advantageous and used as a essential technology in many applications such as audio/video conferencing, corporate communications, collaborative and groupware applications, distance learning, stock quotes, distribution of software, news etc [3].Under multicast communications, a single stream of data can be shared with multiple recipients and data is only duplicated when required [4].

In order to get full advantage of the lifetime of nodes, traffic should be routed in a way that energy consumption is minimized. In recent years researchers are working on reduction of energy consumption and various energy efficient routing protocols have been proposed.

II. CATEGORIZATION OF ROUTING PROTOCOLS

A routing protocol is needed whenever a packet needs to be transmitted to a destination via number of nodes. Numerous routing protocols have been proposed for such kind of Adhoc networks. These protocols find a route for packet delivery and deliver packet to the correct destination.

Basically, routing protocols can be broadly classified into three types asA) table -driven (or) proactive routing protocol,B) on-demand (or) reactive routing protocol C) hybrid routing protocol[5].

A) Table-Driven (or) Proactive routing protocols: every node maintains the network topology information in the form of routing tables by periodically exchanging routing information.

B) On-Demand (or) Reactive routing protocols:instead of maintaining the network topology information.They obtain the necessary path by using a connection establishment process.

C) Hybrid routing protocol combine the best features of the above two categories.

Apart from these categorization researchers have studied the variety of protocols which are efficient in terms of energy consumption.

III.EXISTING ROUTING PROTOCOLS

A. Energy-Efficient Location Aided Routing (EELAR)

EELAR Protocol stands for Energy Efficient Location Aided Routing [6]. It is developed on the basis ofthe Location Aided Routing (LAR) [7]. EELAR protocol limits the area of discovering a new route to asmaller zone thus makes significant reduction in the energyconsumption of the mobile node batteries. EELAR uses a reference wireless base station and divides the network's circular area centered at the base station into six equal sub-areas. During route discovery, control packets are flooded to only the sub-area of the destination mobile node.The base station maintainsa position table to store locations of the mobile nodes. Using the NS-2 Simulations [8] it is seen that EELAR protocol makes an improvement in control packetoverhead and delivery ratio compared to AODV, LAR [9], and DSR [10][11] protocols.

B. Online Max-Min Routing Protocol (OMM)

The Online Max-Min (OMM) power-aware routing protocol [12] is used in wirelessad-hoc networks spread over large geographical areas. The primary data OMM protocol requires is the power level information of all nodes and the power cost between twoneighboring nodes. Using this information OMM makes a routing decision that minimizes power consumptionand maximizes the minimal residual powerin the nodes of the network. OMM makes the use of Dijkstraalgorithm to find the path that minimizes the power consumption (Pmin). By analyzing the power efficient paths with some tolerance, it selects the best path that optimizes the minimal residual powerin the node by iterativeedge removals using Dijkstra algorithm. The area is divided into a small number of zones. A routing path formulated of a global path from zone to zone and a local path within the zone. Zone-based hierarchical routing mechanismis very usefulto improve the scalability. The extended OMM protocol enables a node to estimate the power level of each zone. It computes a path across zones, and computes the best path within each zone.

C. Power-aware Routing (PAR) Protocol

During the route establishment process, Power-aware routing (PAR) protocol maximizes the network lifetime and minimizes the powerconsumption by selecting lesscongested and more stable route. It is used to transfer real-time as well as non real-time traffic[13]. For providing energy efficient routes PAR focuses on 3 parameters: Accumulated energy of a path, Status of battery lifetime and type of data to be transferred. By focusing on traffic level of the path, battery status of the path and type of request fromuser side PAR selects less congested and morestable routes for data delivery. It can provide different routes for different type of data transferand increases the network lifetime. Simulation results shows that PAR performs more efficiently than similar protocols[14] such as DSR and AODV Although, PAR can causeincreased latency during data transfer for discovering routes that can last for a long time andencounter significant power saving.

D. Minimum Energy Routing (MER) Protocol

Minimum Energy Routing (MER) is the routing of a data-packet on a routethat consumes the minimum amount of energy to get the packet to the destination. It requires the knowledge of the cost of a link in terms of the energy expanded to transfer and receive data packet over the link successfully. It maintains the energy to discover routes and the energy lostto maintain routes [15]. MER poses higher routing overhead and lower total energy.

E.Conditional Max-Min Battery Capacity Routing (CMMBCR) Protocol

The Conditional Max-Min battery capacity routing (CMMBCR) [16] protocol makes the use of threshold to maximize the lifetime of each node by utilizing the battery properly. If there are number ofnodes having larger battery energy remained than the threshold in some possible routes then the min-powerroute among those routes will be chosen [14]. If battery capacity of nodes in all possible routes is low than the threshold, the max-min route is chosen. If all nodes in all possible routes have sufficient battery capacity greater threshold then Conditional Max-Min Battery Capacity Routing protocol selects the shortest path. If the battery capacity of some nodes goes below a predefined threshold then suchroutes which go through these nodes will be avoided. By adjusting the value of the threshold[17], one can maximize the time of node battery failure and thus the lifetime of nodes in the network can be extended.

F. Lifetime-aware Multicast Tree (LMT) Protocol

The Lifetime-aware multicast tree routing algorithm [18] maximizes the ad hoc network lifetimeby finding routes that minimize the variance of the remaining energies of the nodes in thenetwork. LMT assumes that the energyrequired to transmit a packet is directly proportional to the forwarding distance. Simulation results demonstrate the effectiveness of LMT over a wide range of simulated scenarios with respect to a number of different metrics (i.e., twodefinitions of the network lifetime, the root mean square value of remaining energy, the packetdelivery ratio, and the energy consumption per transmitted packet) in comparison to a variety ofexisting multicast routing algorithms and Least-cost Path Tree (LPT) [19][20].

G.Localized Energy-aware Routing (LEAR) Protocol

The LEAR[21] protocol directly controls the energy consumption. It balances the energy consumption among all participating mobile nodes.[22], [13] The LEAR protocol is based on DSR[23], where the route discovery requires flooding of route-request messages. When a routing path is

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searched, each mobile node relies on local information of *remaining battery level* to decide whether or not to participate in the selection process of a routing path. An energy-starving node can conserve its battery power by not forwarding data packets on behalf of others. Decision-making process in LEAR is distributed to all relevant nodes, and the destination node does not need wait or block itself in order to find the most energy efficient path.Upon receiving a route-request message, each mobile node has the choice to determine whether or not to accept and forward the route-request message depending on its remaining battery power (Er).When it is higher than a threshold value (Thr), the route-request message is forwarded; otherwise, themessage is dropped. The destination will receive a route-request message only when all intermediatenodes along the route have good battery levels. Thus, the first arriving message is considered to followan energy-efficient path which is short in comparison.If any of the intermediate nodes along every possible path drops route-request message, the source will not receive a single reply message even though one exists.

H. Power-aware Multiple Access (PAMAS) Protocol

PAMAS [24] uses a new routing cost model todiscourage the use of nodes running on low battery power. PAMAS turns off radios when the nodes are not in use. Results show that the lifetime of the network isimproved significantly. There is a slight negative effect on packet delivery fraction and delay,except at high traffic scenarios, where both actually improve due to reduced congestionRouting load, however at low traffic scenarios, it is consistently high. PAMAS illustrates significant benefits at high traffic and low mobility scenarios. It is implemented on the AODV protocol. The poweraware protocol works only in the routinglayer and is used to exploit only routing-specific information [25].

I. Geographic Adaptive Fidelity (GAF) Protocol

GAF protocol [26], [27] is used for extending the lifetime of self-configuring systems by exploitingredundancy to conserve energy while maintaining application fidelity.

In MANETs each node uses location information based on GPS to associate itself with a “virtual grid”. GAF protocol identifies theunnecessary nodes with respect to routing and turns them off without sacrificing the routing fidelity. In GAF, nodes are in one of three states: sleeping, discoveringand active. Originally, a node is in the discoverystate and exchanges discovery messages to find other nodes.The active node remains active to handle routing for predefined time duration. When there is a high mobility scenario, sleepingnodes wake up earlier to take over the role of an active node, where the sleeping time Tsis calculated based on the estimated time. Thus, these nodes switch between on and off to ensure that one master node in each grid stays awake to route packet. A node becomes activeif it does not hear any other discovery message for a specified time Td. If more than one node is in the discovery state, one with the longest expected lifetime becomes active. Thus node energy is conserved in GAF.

J. Protocol for Unified Multicast through Announcements (PUMA)

In PUMA [13] there is no need of any pre-assigned core and unicast routing protocol for its operation. It uses simple multicast announcement signaling to create and maintain the core, the multicast routing structure. In PUMA the receiver chooses a core as the point of contact between the group nodes and non-members of thegroup.Multicast announcement is nothing but a single control message that is used in PUMAfor all its functions. It gives the details about sequence number,group ID, core ID, distance to the core and parent details. The multicast receivers connect the core through the shortest path between the core and the individual receiver.For every three seconds the coretransmitsmulticast announcements periodically. If the multicast announcement is already received then the core specified is taken as its core. In PUMA, the multicast packets move hop by hop, until they reach the mesh members. When the data packets reach the mesh, they are flooded within the mesh. Packet ID cache is used to detect and discard the duplicate packets. It is observed that even though the node mobility, number of senders, multicast group size or traffic load is changed the control overhead of PUMA is almost constant [4].

K.Predictive Energy-efficient Multicast Algorithm (PEMA)

In case of large scale MANETs there is a main problem of scalability issue regarding the large number of nodes and its overhead. Predictive Energy-efficient Multicast Algorithm (PEMA) [28] exploits statistical properties of the network to solve these problems instead of relying on route details or network topology. The running time of PEMA does not depend on network size. Even though the MANETs consist of 1000 or more nodes, PEMA primarily depends on the multicast group size. This makes PEMA fast enough. Simulation results show that PEMA protocol is very efficient in significant energy savings as compared to other existing protocols. It also attains good packetdelivery ratio in mobile environments. Since it is totally independent of its network size also the routing decision does notrely on the information about network topology or route details, PEMA appears to be extremely fast because of its running time [13].

IV. COMPARATIVE ANALYSIS

The different energy metrics to determine efficiency of protocols are [4]

- Control Packet overhead
- energy consumption/cost required per packet
- End to end delay
- time to network partition/Node expiration time
- packet delivery ratio
- Maximum node cost.

When some particular mobile nodes are unfairly burdened to support many packet-relaying functions, they consume more battery energy and stop running earlier than other nodes. Thus to maximize the network lifetime is the important goal of an energy efficient routing. For the energy efficient routing in MANETs protocols have to balance energy consumption that keeps a certain node from being overloaded and ensures longer network lifetime. By distributing network traffic, network energy consumption can be reduced. A comparative analysis of different energy efficient protocols is done as follows.

Protocol	Control Packet overhead	Energy consumption per packet	End to end delay	Node expiration time	Packet delivery ratio
EELAR	reduced.	Reduced	reduced	Increasing	Improved
OMM	reduced	reduced	reduced	Optimal node lifetime	Improved
PAR	Improved	Minimized	reduced	Maximizes n/w lifetime	Improved
MER	High routing overhead	Maintains overall energy of N/W	----	Stabilizes	Degrades in high mobility scenario
CMMBCR	Chooses appropriate algo. to reduce overhead	Chooses suitable route to utilize node energy properly	Maintained	maximize the time of node battery failure	maintained
LMT	Minimized	energy reqd. to transmit a packet is directly proportional to the forwarding distance	reduced	Minimized	Better
LEAR	Maintained	Balances the energy consumption among all participating mobile nodes.	reduced	Balanced	optimized
PAMAS	significant benefits at high traffic and low mobility scenarios	Lifetime of network is improved significantly	negative effect on delay	discourage the use of nodes running on low battery	efficient
GAF	Maintained	40%-60% less energy	maintains a constant level of routing fidelity	N/W lifetime increased	Increased
PUMA	Constant	Constant	Maintained	minimized	Highest
PEMA	Maintained	Significantly less	Very small	reduced	Good

V. PERFORMANCE EVALUATION

The main target of choosing energy efficient protocols is to determine energy efficient routing path to transmit data. Performance evaluation of the studied protocols as follows

The protocol EELAR reduces the energy consumption of themobile node batteries significantly. It is achieved by limiting the areaof discovering a new route to a smaller zone. EELAR reduces the control packet overhead as compared to AODV, DSR and LAR. In EELAR, the network's circular area centered at thebase station is divided into six equal subareas.During route discovery, instead offlooding control packets to the wholenetwork area, they are flooded to only thesub-area of the destination mobile node.The base station stores locations of themobile nodes in a position table. Thus EELAR protocol makes animprovement in control packet overhead and delivery ratio.

OMM It is mainly used to support applications where the message sequence is not known. The protocol optimizes the lifetime of the network as well as the lifetime of individual nodes by maximizing the minimal residual power. It helps to prevent the occurrence of overloaded nodes. Without knowing the data generation rate, the OMM protocol maximizes the lifetime of the network. The metrics developed shows that OMM had a good empirical competitive ratio to the optimal online algorithm [12] that knows the message sequence and the max-min achieves over 80% of the optimal node lifetime [13].

PAR focuses mainly on 3parameters Accumulated energy of a path, Status of battery lifetime and Type of data to be transferred. By selecting less congested and more stable route, during the source todestination route establishment process, PAR maximizes the network lifetime andminimizes the power consumption.PAR can provide different routes for different type of data transfer and ultimately increases the network lifetime. Simulation results showsthat PAR outperforms similar protocols

such as DSR and AODV with respects todifferent energy-related performance metrics even in high mobility scenarios.

Minimum Energy Routing (MER) protocol requires the knowledge of the cost of a link in terms of the energy, so that it can discover a route that consumes the minimum amount of energy to get the packet to the destination. Although it maintains the energy to discover routes and the energy lost to maintain routesMER poses higher routing overhead and lower total energy.As the mobility increases, the minimum energy routing protocol's performance degrades but still it yields noticeable reductions in energy as compared to performance of minimum hop routing protocol.

CMMBCR relies on the residual battery capacity of nodes. It considers both the total transmissionenergy consumption of routes and the remaining power ofnodes. CMMBCR selects a route on the basis of battery capacity utilized by the nodes so that total energy consumption of the network can be minimized.

Local Energy-Aware Routing (LEAR) [21] typically optimizes the query processing transactions so that energy consumption can get balanced. It avoids the blocking and route cache problems by minimizing routing delay. LEAR balances energy consumption based only on local information. LEAR does not affect other layers of communication protocols while integrating into existing ad hoc routing algorithms. NS2 Simulation shows that energy usage is better distributed with the LEAR algorithm as much as 35% better compared to the DSR algorithm[22]. LEAR establishes balanced energy consumption in a realistic environment taking into account routing algorithms, mobility and radio propagation models [23], [13].

GAF maintains a constant level of routing fidelity by identifying nodes that are equivalent from a routing perspective. It turns off unnecessary nodes. Nodes that source or sink data remain on and intermediate nodes monitor and balance energy use. GAF is independent of the underlying ad hoc routing protocol. The Ns2 simulations for performance of GAF show that it can consume 40% to 60%

less energy than other ad hoc routing protocol. Network lifetime increases proportionally to node density [13].

PUMA [25] uses simple multicast announcement signaling to choose a core for the group for its operation. As compared to ODMRP and MAODV, PUMA provides the lowest and a very tight bound for the control overhead. It is observed that even though the node mobility, number of senders, multicast group size or traffic load is changed the control overhead of PUMA is almost constant. PUMA provides the highest packet delivery ratio [13]. The mesh constructed by PUMA provides redundancy to the region containing receivers, thus reducing unnecessary transmissions of multicast data packets. PUMA protocol is totally independent of the existence of any specific pre-assigned unicast protocol.

VI.CONCLUSION

A mobile ad hoc network (MANET) is an infra-structure-less network of autonomous mobile nodes. Each node communicates directly with the nodes within its wireless range or indirectly with other nodes ina network. In order to utilize the node energy in reliable manner within a MANET, anefficient routing protocol is required to discover routes between mobile nodes. This paper shows the survey of a number of energy efficient multicast routingprotocols in order to make efficient use of nodes.Each protocol is different in terms of its goal with differentassumptions and employs variety of mechanisms to achieve the goal. According to this survey, all the above protocols have different strengths and drawbacks. A multicast protocol cannot satisfy allthe requirements. EELAR, OMM, PAR works better in terms of packet delivery as well as minimum delay while minimizing the total energy consumption of the network.MER poses higher routing overhead and lower total energy. The performance of CMMBCR depends on the selection of appropriate algorithm. LEAR, LMT and GAF optimize the packet delivery by maintaining the energy consumption of the network. PAMAS illustrates significant benefits at high traffic and low mobility scenariosdue to reduced congestion Routing load.PEMA and PUMA works efficiently in terms of delivery ratio and network delay.One routing protocol cannot be a solution for all energy efficientissues that are faced in MANETs.Each protocol is designed to providethe maximum possible requirements according to certain required scenarios. In future modified algorithms by merging the features of the energy efficient protocols can provide support for secure communication, minimize storage and resource consumption, ensure optimal paths and minimize network load.

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