

Comparative analysis of power aware routing protocols in mobile ad-hoc network

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Abstract

The Mobile Ad-Hoc network is a self-governing wireless network having dynamic topology and scattered mobile nodes. Limited power supply is the major challenge in wireless Ad-Hoc networks. Thus, for overall functioning of the ad-hoc network, efficient power conservation mechanism becomes the critical and most important component in ad-hoc network. Various power aware routing mechanism have been evolved to preserve energy, prolonging the life span of its nodes and thus of the network itself. Various other metrics for preserving energy also considered viz. selecting shortest path from source to destination, remaining battery power, fair distribution of traffic load among the nodes and minimizing the total transmission power with a view to increase the network life span and link stability. In this paper, various proposed protocols and recent energy conservation mechanisms are studied for mobile ad-hoc network. After analyzing the existing works it has been observed that there are still several areas where we can give more focus in the future.

Keywords: WSN; Ad-Hoc Network; Power Aware Routing Protocols.

1. Introduction

An ad-hoc network is self organized and dynamic network with wireless mobile nodes. These mobile nodes can dynamically and freely form a random and impermanent ad hoc network, thus granting devices and to impeccably connect mobile devices in areas with no preexisting infrastructure, for example, disaster recovery environments [2]. If the nodes belonging to a network are not within the direct transmission range with each other, the intermediate nodes can be used for receiving and forwarding the data packets within the network. MANETs are suitable for applications in the field of vehicular communications, exploration missions, military operations and disaster relief because they are easily deployable without using fixed infrastructure.

A vital issue for MANETs is that the nodes have limited battery, thus lengthen the battery life has become significant concern for the researchers. Various table driven and on-demand routing protocols have been developed and proposed during the past few years for ad-hoc networks. In a traditional routing algorithm energy of the nodes is not considered and the shortest path route is selected. These algorithms resulted in a rapid exhaustion of the battery power of the mobile devices which are used most heavily in the shortest path routes in the network [3]. Therefore energy of these nodes starts decreasing rapidly as they are overburdened and start dropping the packets, causing Retransmissions and wastage of energy. Hence such nodes exhaust their energy earlier than others and resulting in network to partition. The primary purpose of this paper is to study and compare various energy efficient routing protocols that include the remaining energy and fair load distribution as parameter to prolong the nodes battery lifetime, hence prolong the network connectivity. Many energy efficient routing mechanisms have been proposed that conserve energy of the nodes in MANETs. Various parameters for conserving energy viz. Minimum transmission power, shortest path, residual energy, min-

imum drain rate are some of the factors taken into account in order to develop the efficient energy aware protocol for ad-hoc networks. Other routing protocols also considers power consumption during transmission, reception, idle and sleep modes. Routing protocol are proposed which minimize the power consumption during the data transfer.

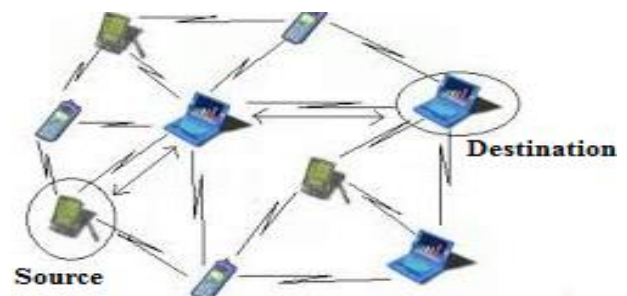


Fig. 1: Illustration of Ad-Hoc Network.

2. Classification of manet routing protocols

Mobile ad-hoc network protocol is classified into two categories: conventional routing protocols and energy aware protocols. The conventional routing protocols consist of reactive (On Demand) and proactive (Table Driven) protocols [5]. These routing protocols perform the activities like route discovery, route maintenance. Examples of conventional routing protocols are ODV, DSR, OLSR, TORA, and DSDV. They do not consider energy of individual node in the network. Whereas power aware routing protocols include various energy related parameters in order to develop the protocols which minimize the total power consumption on a particular route, considers residual energy of the node, minimize drain rate. The main objective of energy aware protocol is to prolong the network life span and increase the network performance.

Example of energy aware protocol are PR, MSR, PAR-DSR, OLSR-EA, PAAOMD.

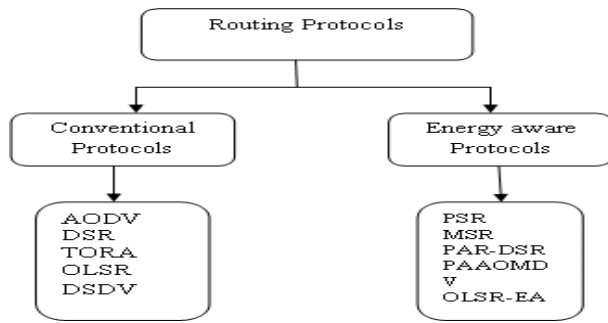


Fig. 2: Classification of Routing Protocols.

3. Energy aware protocols

PAR-DSR Algorithm

PAR-DSR is based on DSR and considers energy parameter while designing the protocol. The key purpose of this protocol is to enhance the network lifespan by balancing the traffic load amongst the participating nodes [10], [11]. PAR-DSR selects the node having more residual power, avoiding the low power nodes for packet transmission.

PAR-DSR protocol considerably reduces the power expenditure of terminals and increase the network lifetime. It has been analyzed PAR-DSR and DSR perform better if node mobility is low.

The cost function of PAR-DSR for any route at instant t can be defined as the sum of nodes all along the course, i.e.,

$$C(\pi, t) = \sum_{N_i \in \pi} C_i(t) \quad (1)$$

$C_i(t)$ is the cost of i^{th} node

$$C_i(t) = \frac{P_0}{SAR + \delta_i} \left[\frac{F_i}{R_i(t)} \right]^\alpha \quad (2)$$

Where SAR is Signal Attenuation Rate, R_i is the residual power of N_i at time t , F is the full-charge battery capacity of N_i , α is a positive weighting factor.

3.1. Minimum total transmission power routing

The Minimum Total Transmission Power Routing (MTPR) protocol utilize a simple energy metric which represents the total power expended for a route from source to destination.

The total power required for transmission from node i to j is the represented as the sum of power needed between each pair of node. It is represented as:

$$C(P) = \sum_{j=0}^{k-1} S(n_j, n_{j+1}) \quad (3)$$

The best path r_s is selected according to specified condition as follows:

$$C(r_s) = \min_{R_j \in r_s} C(P_j) \quad (4)$$

Where r_s represents all possible paths from n_0 to n_d .

3.2. Maximum survivability routing

Maximum Survivability Routing (MSR) intends to conserve the node's energy to extend the network connectivity by taking into consideration the remaining battery capacity [7]. The routing should be avoided through the nodes having lower residual power. Though the total power expenditure may increase because this technique can increase the distance or number of hops from source to destination.

The following cost function and utility function defined as:

$$U_i = U(T_i) = 1/T_i \quad (5)$$

$$C_R = f(u_i, I \in R) = \left(\sum_{i \in R} u_i^\beta \right)^{1/\beta} \quad (6)$$

Where $\beta \geq 1$.

To extend the network connectivity, route incur minimum cost is selected as:

$$R_{\text{selected}} = \arg \min_{R \in \Omega_{ij}} C_R = \arg \min \left(\sum_{i \in R} u_i^\beta \right)^{1/\beta} \quad (7)$$

3.3. MBA-OLSR (multipath battery aware OLSR)

MBA OLSR takes into account the remaining battery power as a parameter in the link cost function for route formation in the network [9]. Then multipath Dijkstra algorithm is used to find the best path between each pair of node based on residual energy.

In order to make local awareness about residual energy a TLV (type-length-value) field is added for residual energy information. Depending on the residual battery energy the following cost function is defined for estimating link cost between two nodes.

$$RB_{ij} = \frac{RB_i}{RB_i + MRB} + \frac{RB_j}{RB_j + MRB} \quad (8)$$

$$\text{Link Cost}_{ij} = 1 + k * \frac{1}{e^{RB_{ij}}} \quad (9)$$

Where MRB RB_i and RB_j are the remaining energy of the nodes i and j , MRB is the maximum remaining battery capacity, and RB_{ij} is the ratio of residual battery energy of both nodes i and j . K is the weight factor.

3.4. Min-max battery cost routing

MTPR protocol has reduced the entire power expenditure over a route. If a node is participating in several paths from source to destination, then energy of that node will deplete rapidly, thus it will cause network to partition [4]. Major drawback of MTPR protocol is that it does not take into account the remaining energy of individual node in the network. MMBCR protocol prolong the network lifetime by estimating remaining energy of the node more precisely.

The presently available power of node n_i at time t is $C_i(t)$. The cost function for node n_i is represented as $F_i(t)$. If the nodes capacity is less than some threshold value, then that node will not forward the data. The cost function of MMBCR is

$$F_i = \frac{1}{C_i(t)} \quad (10)$$

The cost incurred for a route MMBCR is represented as

$$P(r_j) = \max_{n_i \in r_j} F_i \quad (11)$$

The best route with higher residual energy id represented as

$$P_{\text{best}} = \min_{r_j \in r^*} P(r_j) \quad (12)$$

Where r^* is the all available routes having higher value of residual energy on that route. Hence MMBCR protocol helps in enhancing the network lifetime, but total power expenditure on the chosen route is not assured to be minimal.

3.5. Conditional max-min battery capacity routing (CMBCR)

CMBCR algorithm has combined two approaches of MTPR and MMBCR protocols. MTPR protocol selects the path which consume least energy from source to sink node while ignoring residual energy of nodes. Whereas MMBCR protocols makes energy

consumption of the node quite fair, ignoring the minimum power consumption on the selected route. CMMBCR combined the two, the path selected by CMMBCR will have minimum energy consumption and residual energy on this will be more than the threshold value Y . Cost incurred for selecting a path using CMMBCR protocol at any instant t as [6]

$$P_j(t) = \min_{v_n \in r_j} C_i(t) \quad (13)$$

CMMBCR protocol select the route which consume minimum power and all the node on that route having residual capacity greater than Y . Otherwise, select the path P_j with maximum battery capacity.

3.6. MDR (minimum drain rate)

Minimum Drain Rate protocol computes the lifetime of a node with currently available residual energy and traffic going through that node [1]. The cost function for MDR can be defined as :

$$C_i = \frac{RP_i}{DR_i} \quad (14)$$

Where RP_i is the residual power and DR_i is the drain rate of the i^{th} node, C_i will compute how long the node will be active in the network with current traffic. Drain rate is the rate at which energy is depleted and calculated from previous and recent values of DR .

$$DR = \alpha * DR_{old} + (1 - \alpha) * DR_{current} \quad (15)$$

Where $DR_{current}$ and DR_{old} signify the currently and previous calculated values of drain rate.

The route r_p with maximum lifetime is calculated by the smallest cost C_i on that route is given as follows:

$$L_p = \min_{v_n \in r_p} C_i \quad (16)$$

From the set of all available alternative routes r^* MDR selects route r_0 , from source to destination that have the uppermost highest lifetime value as:

$$R_0 = r_p = \max_{v_n \in r^*} L_i \quad (17)$$

3.7. Local energy aware AODV

LEA-AODV protocol is the advanced version of conventional AODV protocol which takes into account the remaining energy of participating devices in the network. The major intention of LEA-AODV is to fair distribution of the traffic during communication among wireless devices [5]. The nodes depend on the information given by neighboring nodes about the remaining energy and to make a decision whether to participate in the communication or not. Nodes having low energy can deny further forwarding the data packets in order to remain alive in the network. The threshold power is calculated as follows:

$$Avg_power = \frac{\sum_{i=1}^n n_power_i}{n} \quad (18)$$

Where n is total number of nodes in the network and n_power is the available power. If the nodes falls below this average power level. Then that node discards further packet forwarding. The nodes will calculates its power level as follows and keep this information in the packet header.

$$Power_level = \frac{Current_energy}{initial_energy} \quad (19)$$

LEA-AODV is designed to prolong the battery life of terminals by maintaining the network connectivity and hence lead to the increased network lifetime.

Whereas traditional AODV protocol does not consider power but optimizes the best path based on lowest delay

Table 1: Comparative Analysis of Power Aware Routing Protocols

Routing Protocols	Cost Function	Primary Objective	Node energy Status	Scalability	Transmission Delays
PAR-DSR	$C_i(t) = \frac{P_0}{SAR + \delta_i} \left[\frac{F_i}{L_i(t)} \right]^\alpha$	Finding the route which required minimum total power consumption	No	Medium size ad-hoc network	Low
MTTPR	$C(r_0) = \min_{R_j \in r_p} C(R_j)$ $C_R = f(u_i, i \in R) = (\sum_{i \in R} u_i^\beta)^{1/\beta}$	Selects a path having minimum energy consumption	No	Medium size ad-hoc network	Low
MSR	$R_{selected} = \arg \min_{R \in \Omega_{ij}} C_R = \arg \min (\sum_{i \in R} u_i^\beta)^{1/\beta}$	This routing chooses the route with the maximum residual battery capacity of all nodes on the path.	Residual battery power	Large scale ad-hoc network	Medium
MBA-OLSR	$RB_{ij} = \frac{RB_i}{RB_i + MRB} + \frac{RB_j}{RB_j + MRB}$ $LinkCost_{ij} = 1 + k * \frac{1}{e^{RB_{ij}}}$ $F_i = \frac{1}{C_i(t)}$	Selects a route with minimum value of link cost between two nodes based on their residual battery's energy.	Residual battery power	Medium size ad-hoc network	High
MMBCR	$P(r_j) = \max_{v_n \in r_j} F_i$ $P_{best} = \min_{r_j \in r^*} P(r_j)$	Selects the route with maximum residual energy of nodes on that route	Residual battery power	Medium size ad-hoc network	Medium
CMMBCR	$P_j(t) = \min_{v_n \in r_j} C_i(t)$ $C_i = \frac{RBP_i}{DR_i}$	Combined MTTPR and MMBCR. Selects a route with minimum energy consumption and highest residual power of nodes on that route.	Residual battery power	Large scale ad-hoc network	High
MDR	$DR = \alpha * DR_{old} + (1 - \alpha) * DR_{current}$ $L_p = \min_{v_n \in r_p} C_i$ $r_M = r_p = \max_{v_n \in r^*} L_i$	Selects a route r_M by maximizing the network lifetime L_p which is induced by the least value of cost function C_i over the route p .	Residual battery power	Large scale ad-hoc network	High
LEA-AODV	$Power_level = \frac{Current_energy}{initial_energy}$ $Avg_power = \frac{\sum_{i=1}^n n_power_i}{n}$	Uses local information about battery remaining power. Selects the best route having residual power more than the threshold.	Residual battery power	Medium size ad-hoc network	Medium

4. Conclusion

In this paper various power aware algorithms have been studied for conserving energy of terminals to increase the network lifetime. Designing power aware routing protocols is a challenging and critical task, because energy is the limited resource in wireless networks. Two approaches for power conservation have been discussed in the literature. First is by computing residual energy of nodes and then design a routing mechanism which efficiently uses the residual power to increase the network lifetime. Secondly, protocols for minimum power required to transmit a packet from source to sink node are studied. Routing protocols are then proposed various mechanisms to optimize the total transmission energy from source to sink node. Further more research is needed towards designing a routing protocol which takes into account various other factors viz. temperature, ageing ,charge cycle, link stability etc in order to have the accurate estimation of remaining energy and enhance the link stability.

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