

GPS Aided Power efficient Dynamic Source Routing in MANETs

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Abstract: Mobile ad-hoc networks (MANETs) are multi-hop wireless communication networks formed dynamically on ad-hoc basis without fixed infrastructure and centralized administration. Successful communication between source and destination depends on quality of temporarily formed multi-hop link. Quality parameters for multi-hop link includes link life and link length. Aim of work presented in this paper is to improve link quality in terms of link life and link length. We have proposed GPS aided routing technique that finds shortest end to end path and adjusts transmission power of node based on calculated distance to next hop. Selection of shortest end to end path decreases end to end delay and average power consumption of node. To check suitability and efficiency of proposed routing technique we have modified well known Dynamic Source (DSR) routing protocol. We have done two modifications in DSR, first transmission power based on transmission distance and second, selection of route that has shortest distance to destination. Using NS3.25 simulation tool we demonstrate that there is approximately 29% saving in total energy consumption and average end to end delay is improved by 30% compared to conventional DSR during simulation time.

Keywords: GPS, DSR, MANETs, battery power, Haversine formula, end to end delay, control overhead, Energy consumption.

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I. INTRODUCTION

Fixed wireless local area networks (WLANs) can be extended to mobile WLANs. MANETs are such networks formed temporarily on ad-hoc basis without fixed infrastructure and centralized administration. As defined by IEEE 802.11 standards, the major difference between MANETs and WLAN is that MANETs are BSS (basic service set) without AP (Access Point) whereas WLANs are BSS with an AP. Applications of MANET includes remote military and emergency operations where it is required to form instantaneous network. In MANETs participating nodes acts as hop to forms multi-hop links between source and destination. Design and deployment of MANETs are challenging due to issues like routing, energy consumption, scalability, quality of services, available bandwidth, security etc. The limited battery power of the node is one of the important issues in MANETs. The battery power of node can be saved if we reduce extra transmissions in the form of control messages or by regulating transmission power per transmission based on criteria like distance. In following sections, the issue of routing, routing process, available routing protocols and possible improvement mechanism is discussed. Routing is challenging due to mobility of nodes in MANETs. The process of formation of end to end route and its maintenance is called routing. In MANETs, routing process is influenced by mobility, density and power limitations of nodes in a network. There are three categories of routing protocols for MANETs, reactive, proactive and hybrid. Reactive routing protocols also called on-demand routing protocols. Reactive routing protocols finds end to end route when source node has data packet for destination. Examples of important reactive routing protocols are AODV (Ad-hoc On-Demand distance Vector) routing, DSR (Dynamic Source) routing etc. Proactive routing protocols are those routing protocols which find end to end routes in advance. All nodes in a network maintains a routing table which consist ready to use routes to all other nodes in a network. Examples of important proactive routing protocols are DSDV (Destination Sequenced Distance Vector) routing, WRP (Wireless Routing Protocol), OLSR (Optimized Link State) routing etc. Hybrid routing protocol has characteristics of both reactive and proactive routing protocols. Examples of hybrid routing protocols are CEDAR, ZRP etc. Important issues related to routing in MANETs are node mobility, energy consumption, bandwidth, control overhead, node co-operation, hidden and exposed node problem etc.

II. RELATED WORK

In [1] author proposed dynamic source routing technique for ad hoc networks combined with network location awareness. Whenever node has a data packet for destination it computes graph G representing the current network topology from its location table. Then it locally applies a centralized algorithm for the

determination of a minimum cost path to the destination. Total cost represents the total number of intermediate hops to be traversed by a data packet to reach the destination. Author in [2] proposed a dynamic source routing discovery optimization protocol based on GPS system. Optimized protocol is based on GPS screening angle in which a node takes the forwarding decision based on the angle between the previous node, itself and the next node. This work shows GPS screening angle has the profound impact on reducing the number of route queries and therefore it reduces control overhead. In [3] author proposed LAR (Location- Aided Routing) protocol. LAR is developed from DSR which uses geographical location information like GPS to predict the location of node. The LAR protocols use location information to reduce the search space for the desired route. LAR divides network area into expected and request zones during the process of route formation. Limiting search space results in fewer route discovery messages which ultimately results in decreased control overhead. Author in [4] proposed new routing protocol called DREAM (Distance Routing Effect Algorithm for Mobility) based on the principle of distance effect. In this protocol, location tables update frequency is determined by the distance of the mobile nodes. Nodes maintain location table by flooding control packets consisting position and speed information of all neighbour nodes in the network. Whenever a node has data to send it computes the expected zone and forwarding zone in a circular shape similar to LAR. In [5] author proposed GPS assisted overhead reduction technique in which LAR is modified. This work focuses on the forwarding zone modification to overcome the misdirection flooding problem inspired by DREAM protocol.

In [6], the author proposed a method to measure a distance using the minimal transmission power between a transmitting node and a receiving node distance. In this method sensor nodes knowing their own position (beacons) transmit their position with a stepwise increasing transmission power in range from minimum to maximum value. Target node may not be able to receive message for a value, then sensor node increases the value of transmission power in stepwise manner. When target node receives message, it stores the transmission power as distance. The sensor node saves only the smallest sufficient transmission power, messages with higher transmission powers are discarded. Author has demonstrated that the determined distance is very precise and has a low variance. A distributed position-based network protocol optimized for minimum energy consumption in mobile wireless networks that support peer-to-peer communications is proposed in [7]. Author illustrates that a simple local optimization scheme executed at each node guarantees strong connectivity of the entire network and attains the global minimum energy solution for stationary networks. [8] focuses on method to determine the transmission power level of each link to minimize energy consumption in a wireless ad hoc network based on node density. It determines the transmission power for a link based on the levels that maximize the asymptotic spectrum efficiency while maintaining the energy consumption per bit of the link below a threshold. In [9] author proposes transmission power optimization algorithm-based distance to neighbour. Transmission node and neighbour node exchanges range and distance information by means of management. It is based on free space model and two-way propagation model which measures node density and calculates the optimal transmission power. In [10] author proposes Variable Transmission Power Control (VTPC) to minimize the rate of energy consumption. Received signal strength is used to determine distance and location of a node in a network.

III. BASIC OPERATION OF DSR

DSR uses source routing to send data packet from source to destination [11]. In the source routing sender has complete end to end routes to all possible destinations in a network. These routes are stored in route cache of a node. Node updates route cache information during data exchanges and route discovery process. Whenever source has a data packet to send, it puts complete end to end route to be followed into header of the packet. Route information in packet header consists next to next hop (to whom data packet to be forwarded) information. Intermediate nodes forward data packet to the destination as per route available in a packet header. If there is no route to the destination in route cache of source node then source node initiates route discovery process using globally flooding route request (RREQ) packet. Upon receiving RREQ, receiving node sends route reply (RREP) to source node if it is the destination or has a route to the destination. In the case of route break, the source node is notified by sending route error (RERR) packet by the intermediate node beyond which route is broken. Source node updates its route cache and avoids this route for further communications. Fresh route discovery process is initiated for a new route to the destination if required.

IV. POWER CONSUMPTION MODEL

Wireless channel between transmitter and receiver can be modelled by several key parameters. Value of these parameters depends on environment and geographical conditions of the area. Three types of fading occur [12], path loss, large scale shadowing and small scale fading. Large scale shadowing occurs due to variations over large areas. Small scale fading causes great variation within a half wavelength. Modern wireless communication receivers are designed with diversity reception to combat small-scale variations such as RAKE receiver. In [7] author showed that a minimum power network design that addresses the increase in transmit power to handle large-scale variations is fundamentally the same as a design that considers only the path loss.

Therefore, to find minimum transmission power over given distance we considered only path loss component. Propagation characteristics varies over frequency bands and requires different prediction models. For free space model in [12] and using transmission scheme given in [13]. The simplest approach to calculate path loss and finally optimal value of transmitted power is using Friss power transmission formula given by equation,

$$P_{rj} = \frac{P_{ti} G_t G_r \lambda^2}{(4\pi d_{i,j})^2} \quad (1)$$

Where, P_{rj} is received power (at node j) which is function of distance ($d_{i,j}$) between two node i and j , P_{ti} is power transmitted (from node i), λ is the wavelength of the signal, G_t , G_r are transmitter and receiver antenna gain respectively. Path loss ($P_{li,j}$) is ratio of P_{ti} and P_{rj} , for free space model it is given by,

$$P_{li,j} = \frac{P_{ti}}{P_{rj}} = \frac{G_t G_r \lambda^2}{(4\pi d_{i,j})^2 M_l N_f} \quad (2)$$

The outage probability of transmission (as in Nakagami - m fading model) is given by,

$$O_{i,j} \simeq \frac{1}{\Gamma(m+1)} \left(\frac{mN\beta}{P_{ti,j} P_{li,j}} \right)^m \quad (3)$$

Fixing $O_{i,j}$ at packet loss limit $O_{*i,j}$, the optimal transmission power between two nodes (i and j) is given as follows,

$$P_{ti,j} = \frac{mN\beta}{P_{li,j} \sqrt[m]{\Gamma(m+1) O_{*i,j}}} \quad (4)$$

Where, d = distance, $G_t = G_r$ = Transmitter and receiver antenna gain, λ = Wavelength, P_t = Transmitted power, P_r = Received power, m = Nakagami- m dist, parameter (related to fading), M_l = Link Margin, N_f = Noise figure, B = System bandwidth, N_0 = Noise density, N = Noise power spectral density (= $N_0 B$), $\beta = 24-1$ (Threshold below which outage occurs), 4 = System spectral density.

Total Energy consumed per bit during transmission is given by,

$$E_b = \frac{P_{ti,j} + P_{TX} + P_{RX}}{R_b} \quad (5)$$

Where, P_A is power consumed by amplifier, P_{TX} and P_{RX} are power consumed by transmitter and receiver circuitry. R_b is bit rate. Using advanced technology P_A , P_{TX} and P_{RX} can be minimized effectively.

V. GPS AIDED DSR

As mentioned earlier, GPS aided DSR is basically optimized DSR with following additional features,

- All nodes exchanges GPS information using hello packets during network initialization phase.
- Route cache of all nodes in a network is modified to store GPS information of all active nodes in a network.
- GPS information is updated during data exchange, route discovery process.
- Need to construct complete end to end route in data packet header at the source node is omitted.
- Now, packet header has GPS locations of destination node. • Controlled flooding is used during route discovery process.
- Variable transmission power is used depending upon transmission range between two nodes.

If node has data to transmit, it searches route cache for GPS location of the destination. If GPS location of the destination node is not available in its route cache, source node initiates route discovery process. In case GPS location of destination is available, the end to end communication follows process explained in the following section. Haversine formula is used to find the minimum distance between two nodes along with variable power transmission is explained in the following section.

A. Haversine Formula

Haversine formula [19][21] is used to calculate the distance between two nodes. It is an important equation in navigation to calculate distance on earth. Ignoring ellipsoidal effects, if GPS locations of two points (let $i = 1,2,3..$ (up to number of neighbors) and $j =$ destination node) on earth are available then shortest distance ($d_{i,j}$) between these/respective two points on surface of earth is calculated as,

$$d_{i,j} = R \cdot c \quad (6)$$

Where, $a = \sin^2(\Delta\Phi_{ij}/2) \cdot \cos\phi_i \cdot \cos\phi_j \cdot \sin^2(\Delta\lambda_{ij}/2)$, $c = 2 \cdot \text{atan2}(\sqrt{a}, \sqrt{1-a})$, $\Delta\Phi_{ij} = \phi_i - \phi_j$, $\Delta\lambda_{ij} = \lambda_i - \lambda_j$, Φ_i and λ_i = Latitude and Longitude of "i", Φ_j and λ_j = Latitude and Longitude of "j", R = Earth Radius (Mean Radius=6371km).

B. Relative Speed

Whenever there is need to find route, relative speed and direction of neighbor node is taken in to account to avoid frequent route breaks. RREQ is forwards are avoided if next node is moving in opposite direction or moving away. Since all nodes keeps track of neighbors, relative speed is measured using GPS locations obtained. Relative speed between two nodes is given by Equation (7),

$$RS_{i,j} = |N_i(t) - N_j(t)| \quad (7)$$

Where, $N_i(t)$ and $N_j(t)$ are speed of node “i” and “j” respectively.

C. Route formation

Whenever source node (i) has data to send to destination node, it looks for route entry to destination in its route cache. If source node has GPS location of destination in its route cache, then it follows *algorithm 1* otherwise it starts route discovery process as explained in algorithm 2. Here it is to be noted that each node keeps update of GPS location of all nodes in its transmission range. Upon reception of RREQ intermediate node follows the steps given in *algorithm 3*.

Algorithm 1: When node has GPS location of destination node.

- 1) Calculate distances from neighbor to destination node.
- 2) Compare these distances to find out minimum reachable distance to destination node.
- 3) Calculate minimum power transmission value to reach the neighbor having minimum reachable distance to destination node.
- 4) Send data packet to neighbor having minimum distance to destination with calculated value of transmission power.

Algorithm 2: When GPS location is not available.

- 1) Send RREQ to all neighbors with one hop count.
- 2) Wait for RREP equal to one hop count.
- 3) If counter expires, increase hop and send again to all neighbors.
- 4) Wait for RREP until set hop count expires. 5) Increase hop count and repeat process until RREP is received.

Algorithm 3: When RREQ received at intermediate node.

- 1) Check duplication of RREQ, if ok follow step 2 else discard RREQ.
- 2) Look for GPS location of destination node specified in RREQ from route cache.
- 3) If it has GPS location of destination node send RREP consisting GPS location of destination to source node.
- 4) If GPS location is not available, check hop count.
- 5) If hop count alive, forward RREQ to all neighbors else remain silent.

Example 1: As shown in Figure 1, let node i is source node and node j is destination node. Say if node i has data to send then it looks that neighbor among node k, n and o who is nearer to node j using Haversine formula and GPS locations of respective nodes. Node i finds node o has minimum distance to node j. Now node i calculates the value of minimum transmission power to reach node o and transmit the data packet to node o using calculated value of transmission power. Node o will follow same process and transmit the data packet to node m. The process continuous until data packet reach to node j.

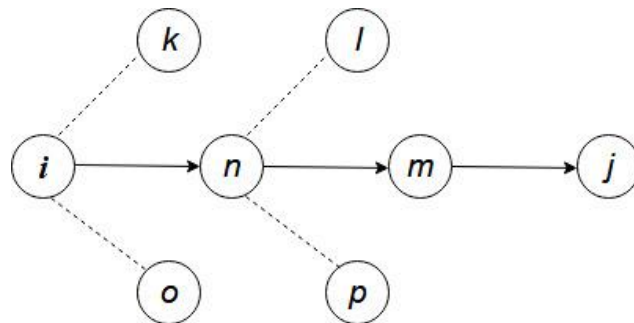


Figure 1: Route formation process

VI. PERFORMANCE METRICS

To measure suitability of proposed technique different packet level metrics are used. Performance metrics used are Energy consumption, End to End Delay and Normalized routing load.

End to End Delay (EED) is average time taken by packets to reach destination in seconds. EED is calculated by taking simulation time difference between transmission (tt) and reception (rt) of packet.

$$EED = \frac{tt}{rt} \quad (8)$$

Normalized Routing Load (NRL) is defined as the number of routing (control) packets transmitted per data packet sent to the destination. NRL is ratio of routing packets (rp) and data packets transmitted.

$$NRL = \frac{rP}{pt} \tag{9}$$

Energy Consumption in terms of energy per bit is calculated using equation (5). Considering current advancement in IC technology, the energy loss within internal circuitry of transmitter and receiver is assumed to be zero.

VII. RESULT ANALYSIS

Set of simulations are performed for increasing number of nodes with fixed transmission power and constant speed of nodes. Different sets of nodes are used wise 10, 20, 30, 40, 50, and 100. The simulation time is 100 seconds for each set of parameters listed in table 1.

Fig.2 gives comparison of energy consumption. Overall GPS aided DSR performs 30% better than conventional DSR. For nodes less than 30, average of total energy consumption in joule is 41 and 21 and for nodes greater than 30 the values are 420 and 299 for conventional DSR and GPS aided DSR respectively. Results shows energy consumption is decreased by 29% using variable power transmission strategy. From Fig.3 we can compare end to end delay performance of proposed optimization and conventional DSR. It is average time taken by packets to reach destination in seconds and calculated from simulation time difference between transmission and reception of particular packet. The effect of shortest path can be seen from graph in the form of E2E delay. Average value for GPS aided DSR is 0.60 ms and for DSR is 0.86ms. Less end to end delay also confirms selection of shortest end to end route. For low node density, large value of end to end delay is because few nodes are available to form the route. Control flooding and route maintenance at local level limits the generation of routing packets. Large number of control packets consumes battery power and bandwidth which ultimately reduces routing efficiency. As we can see from Fig. 4, average control packets per data packet transmitted. GPS aided DSR transmits 1.4 control packets per data packet, whereas traditional DSR transmits 11 control packets for 5 data packets. GPS aided DSR avoids global flooding during route discovery process and uses route maintenance at local level. It is to be noted that as number of hops increases in a route, control packets also increases.

Table 1: Simulation Parameters

Parameter	Value/Type
Number of Nodes	10, 20, 30, 40, 50, 100
Total Simulation Time	100 seconds
Data Packet Length	64 Bytes
Data Rate	2048 bps
Network Area	300 x 1500 m
Propagation Delay Model	Constant Speed
Physical Standard	IEEE 802.11b
Transmit Power	10 dBm
Variable Node Speed	20 ms
Pause Time	0 ms

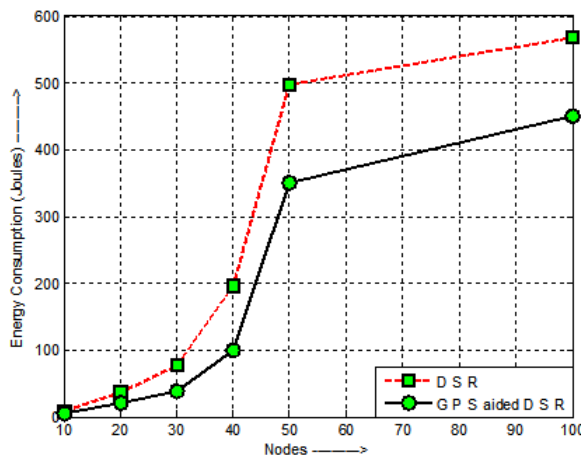


Figure 2: Energy Consumption (Joules) v/s increasing nodes

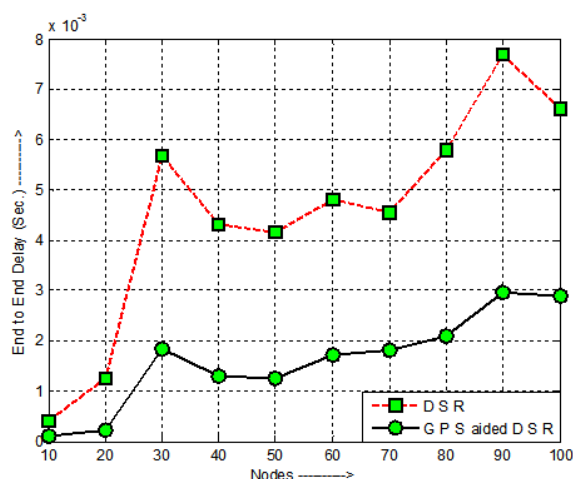


Figure 3: End to End Delay (mSec) v/s increasing nodes

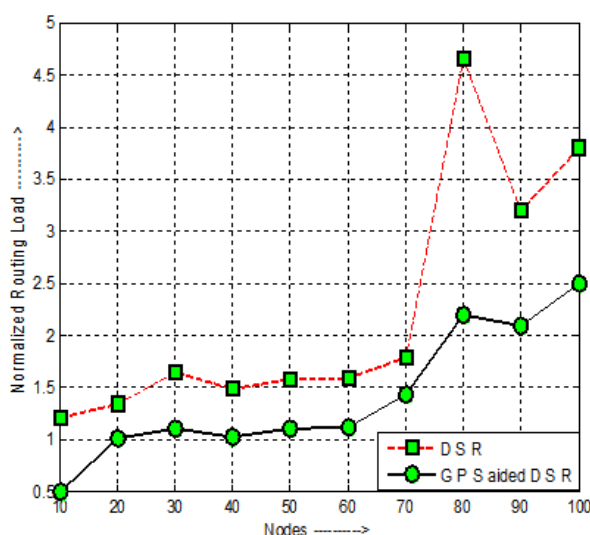


Figure 4: Normalized Routing Load v/s increasing nodes

VIII. CONCLUSION

From result analysis it is clear that GPS aided routing mechanism can perform better compared to conventional methods. End to end delay analysis confirms that GPS aided DSR succeed to find shortest end to end routes in terms of length and number of hops. Node calculate transmission power based on distance to next node in a route while sending packet. Selection of route with minimum number of hops reduces number of transmissions which ultimately reduces average energy consumption. Route discovery in proposed method uses controlled flooding to reduce transmission of control packets as we can see from normalized routing load analysis. The process of route maintenance is handled at node level which results in fast mending of broken routes. From result analysis we can say that GPS aided dynamic source routing is very effective and efficient and it outperforms conventional DSR. Use of GPS increases hardware and processing complexity, but this is no more issue with availability of low-cost advance hardware with fast processing power. In future, GPS aided technique can be extended to more sophisticated and efficient routing protocols. Mobility parameters can be considered enhance performance of proposed routing technique.

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