

## An Effective Location-Based Power Conservation Scheme for Mobile Ad Hoc Networks

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**Abstract: Problem statement:** One of the major issues in current reactive routing protocols for Mobile Ad Hoc Networks (MANETs) is the high bandwidth and power consumptions during the routing process. In this study, we proposed and evaluated the performance of an efficient Location-Based Power Conservation (LBPC) scheme for MANETs. **Approach:** In this scheme, the transmitting node utilized the location-information of the first-hop neighbors to adjust its radio transmission range according to one of the following criteria: Farthest first-hop neighbor, average distance of the first-hop neighbors and a random distance between the nearest and the farthest first-hop neighbors. **Results:** A number of simulation were carried-out to evaluate the power conservation ratio that can be achieved for two route discovery algorithms, namely, pure flooding and Location-Aided Routing Scheme 1 (LAR-1) algorithms. **Conclusion:** The simulation results demonstrated that the scheme can provide power conservation ratios between 10-50% without adding any extra overheads or complexity to the routing algorithm.

**Key words:** MANETs, dynamic routing protocols, route discover, flooding optimization algorithms, LAR-1 algorithm, wireless power consumption

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### INTRODUCTION

A MANET is defined as a collection of low power, wireless, mobile nodes forming a temporary network without the aid of any established infrastructure or centralized administration<sup>[1-3]</sup>. In MANETs, a node usually consumes its power in wireless communication (in other words, message passing), message processing and other operation missions. It has been realized that the power consumed in message passing is orders of magnitude higher than what is consumed in other tasks; therefore, minimizing it is a vital requirement to extend the lifetime of the battery-powered nodes. Nodes are communicating with each other for two main objectives; these are: route establishment and data forwarding using certain routing protocols<sup>[3-5]</sup>.

The most widely used routing protocols in MANETs are known as reactive routing protocols, such as Dynamic Source Routing (DSR)<sup>[6]</sup>, Ad Hoc On Demand Distance Vector (AODV)<sup>[7]</sup>, Zone Routing Protocol (ZRP)<sup>[8]</sup> and Location-Aided Routing (LAR)<sup>[9]</sup>. Reactive protocols mainly consist of two phases: route discovery and route maintenance<sup>[10]</sup>. The cost of information exchange (in terms of bandwidth

and power consumption) during route discovery is higher than the cost of point-to-point data forwarding<sup>[5]</sup>.

A number of optimization algorithms have been developed to minimize bandwidth and power consumption during route discovery, such as: location-based<sup>[9]</sup>, probabilistic<sup>[11]</sup>, multipoint relaying<sup>[11]</sup>, counter-based<sup>[12]</sup>, distance-based<sup>[9]</sup>, cluster-based schemes<sup>[13]</sup>. All algorithms are based on reducing the number of Retransmissions for the Route Request (RREQ) messages, so that the bandwidth is saved and contention, duplicate reception and node power consumption are reduced. These advantages may cost some reduction in the network reachability.

In this study, we propose and evaluate the performance of Location-Based Power Conservation (LBPC) scheme that can be used to reduce power consumption in MANETs. The scheme makes use of location-information to reduce power consumption, where it is assumed that each node within the network is always aware of the location of all other nodes within the network. With the significant advancement in Global Positioning System (GPS) technology and the drop in its costs, the nodes location may be provided by using a built-in GPS<sup>[9]</sup>.

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In this scheme, the node utilizes the location-information available on the first-hop neighbors to adjust its radio transmission range to cover an area up to: Farthest first-hop neighbor, average distance of the first-hop neighbors, or a random distance between the nearest- and farthest first-hop neighbors.

In this study, the power conservation ratios for two flooding algorithms, namely, pure flooding<sup>[1-3]</sup> and LAR-1<sup>[9]</sup> algorithms, are evaluated. For the two algorithms, the effect of a number of network parameters, such as: node density, node mobility, node maximum radio transmission range, on the power conservation ratio, number of retransmission, average duplicate reception and reachability, are investigated using the MANET simulator (MANSim)<sup>[14,15]</sup>.

The simulation results demonstrated that the scheme can provide power conservation ratios that vary from 10-50% depending on the network parameters and the adjustment criteria. However, adjusting the radio transmission range to be equivalent to the average distance of the first-hop neighbors provides higher power conservation ratio, but it also slightly affects other network parameters.

**Related work:** A lot of work has been done to minimize power consumption in Ad Hoc networks and Wireless Sensor Networks (WSNs), where in such networks nodes are either fixed or has a very limited mobility. Therefore, they experience a very limited topology or route variations and most of the communication power consumption is exhausted for data communications. While in a MANET, due to the high nodes speeds, the network usually suffers from continuous topology and route variations, thereafter, nodes consume more power for route establishment. Reducing power consumption has been addressed through the adjustment of the node radio transmission range, which is done through different aspects till now.

Ingelrest *et al.*<sup>[16]</sup> investigated the problem of minimum energy broadcasting in Ad Hoc networks. Two localized broadcasting protocols were presented, based on derived "target" radius, these are: (i) the target radius Local Minimum Spanning Tree (LMST) Broadcast Oriented Protocol (TR-LBOP). It computes the minimal radius needed for connectivity and increases it up to the target one after applying a neighbor elimination scheme on a reduced subset of direct neighbors. (ii) The Target Radius and Dominating Sets-Based (TRDS) protocol, each node first considers only neighbors whose distance is not greater than the target radius; and neighbors in a localized connected topological structure such as Relative Neighborhood Graph (RNG) or LMST.

Jan Blumenthal *et al.*<sup>[17]</sup> investigated that the autonomous localization of nodes in WSNs is essential to minimize the complex self-organization task consequently and to enhance network lifetime. A method to measure the distance using the minimal transmission power between a transmitting node and a receiving node was proposed. They showed that the determined distance was very precise and has a low variance. Dongjin *et al.*<sup>[18]</sup> investigated the impact of variable transmission power on link quality and proposed variable power link quality control techniques to enhance the performance of data delivery in WSNs.

Pan *et al.*<sup>[19]</sup> considered a two-tiered WSN consisting of sensor clusters deployed around strategic locations and Base-Station (BSs) whose locations are relatively flexible. Within a sensor cluster, there are many Small Sensor Nodes (SNs) that capture, encode and transmit relevant information to the designated area and there is at least one Application Node (AN) that receives raw data from these SNs, creates a comprehensive local-view and forwards the composite bit-stream toward a BS. They focused on the Topology Control (TC) process for ANs and BSs, which constitute the upper tier of a two-tiered WSN. They proposed approaches to maximize the topological network lifetime of the WSN, by arranging BS location and inter-a relaying optimally. They evaluated the performance of TC and proved that its efficiency is as a vital process to maximize the lifetime of WSNs.

Lui and Li<sup>[20]</sup> considered the problem of TC in a network of heterogeneous wireless devices with different maximum transmission ranges, where asymmetric wireless links are not uncommon. For such environment, they presented a distributed TC algorithm to calculate the per-node minimum transmission power, so that (1) reachability between any two nodes is guaranteed to be the same as in the initial topology: And (2) nodal transmission power is minimized to cover the least number of surrounding nodes. Their simulation results demonstrated the correctness and effectiveness of the proposed algorithm.

Zarifzadeh *et al.*<sup>[21]</sup> redefined the problem of TC regarding both transmission range and traffic load parameters. They mathematically formulated a mixed integer linear programming problem to find optimal solutions. Then, they introduced polynomial-time heuristic algorithms to practically solve the problem. During construction of network topology, they deliberately took into account the impact of the employed routing method on load of individual nodes. They showed the advantages of their proposed algorithms through simulations.

**Wireless communication power consumption model:**

Wireless communication power consumption depends on two factors, these are: the radio transmission range and data transmission rate. For a node transmitting a bit-stream at a rate of  $b$  bps over a distance  $r$  m, the minimal transmitter power consumption  $E_t$ , for free-space radio communication, is given by:

$$E_t(b, r) = (\alpha_1 + \alpha_2 r^2) b \tag{1}$$

Where:

- $\alpha_1$  = The power consumed in the transmitter electronic circuit for message processing, which is the distance-independent power consumption term
- $\alpha_2$  = The power consumed in message passing, which is the distance-dependent power consumption term

Equation 1 is applicable even with a more complicated model (e.g., including multi-path fading and geographical shadowing effects), as long as the distance related power consumption can be isolated empirically.

For a node to receive a bit-stream at a rate of  $b$  bps from other node, the power consumed in the receiver circuit is given by:

$$E_r(b) = \beta b \tag{2}$$

Thus, the total power consumed by a node to bypass and forward a bit-stream at a rate  $b$  bps over a distance  $r$  m, is given by:

$$E(b, r) = [(\alpha_1 + \alpha_2 r^2) + \beta] b \tag{3}$$

In a MANET that consists of  $N$  nodes, the route discovery using, for example, pure flooding involves  $n$  transmissions and  $m$  receptions. Thus, the power consumed in message passing and processing ( $E_f$ ) is expressed as:

$$E_f = n E_t(b, r) + m E_r(b) \tag{4}$$

Substituting Eq. 1 and 2 into Eq. 4 yields:

$$E_f = n (\alpha_1 + \alpha_2 r^2) b + m \beta b \tag{5}$$

It is clear from the above equation that the total power consumption during route discovery depends on four parameters, these are: Number of retransmissions ( $n$ ), number of receptions ( $m$ ), data transmission rate ( $b$ ) and transmission distance ( $r$ ). However, due to the fact that the power consumption in message processing is very small as compared to the power consumption in message passing, then Eq. 5 can be simplified to:

$$E_f = \alpha_2 n b r^2 \tag{6}$$

**The proposed LBPC scheme:** In what follows, we present a description of the proposed LBPC scheme. It makes use of location information to reduce power consumption during route discovery in MANETs. In this scheme, it is assumed that each node is aware of the location of all other nodes within the network and the nodes location that is used may be provided by a built-in GPS<sup>[9]</sup>. The LBPC scheme can be summarized as follows:

Each node searches for all first-hop neighbors:

- Calculate the Euclid distance ( $r$ ) between the node and all other nodes within the network
- Compare  $r$  with the maximum radio transmission range ( $R_{max}$ ) of the node. If  $r \leq R_{max}$ , then this node is a first-hop neighbor, otherwise it is not

Adjust the radio transmission Range ( $R$ ) according to one of the following criteria:

- Maximum distance ( $r_{max}$ ), which means the transmission will reach the farthest first-hop neighbor, i.e., set  $R = r_{max}$
- Average distance ( $r_{avg}$ ) and its associated standard deviation ( $\sigma$ ), i.e., set  $R = r_{avg} \pm \sigma$ . However, in this work we use  $R = r_{avg}$
- Random distance ( $r_{ran}$ ) lies between the nearest and farthest nodes, which is calculated as:  $r_{ran} = r_{min} + (r_{max} - r_{min})\xi$ , where  $r_{min}$  and  $r_{max}$  are the distances of the nearest and farthest nodes, respectively and  $\xi$  is a random number between zero and one ( $0 \leq \xi < 1$ ), i.e., set  $R = r_{ran}$

The criterion that is used for adjusting the transmission range may affect other network parameters, such as the number of retransmission, average duplicate reception, reachability<sup>[22]</sup>. However, it can be seen that none of these parameters will be affected if  $R = r_{max}$ . The efficiency of the proposed scheme is defined in terms of a power conservation ratio ( $P_c$ ), which is calculated as:

$$P_c = \left( 1 - \frac{\hat{n}R^2}{\bar{n}R_{max}^2} \right) \times 100 \tag{7}$$

Where:

- $\hat{n}$  and  $\bar{n}$  = The number of retransmission with and without implementing the power conservation scheme, respectively

R and  $R_{max}$  = The adjusted and maximum radio transmission range, respectively

In a MANET that uses LAR algorithm, each node is already aware of the location of other nodes within the network. Therefore, this scheme can be implemented in such networks with absolutely no added overheads. In a network that uses other routing algorithms and in order to minimize communication overheads, nodes can be configured to exchange its location with their first-hop neighbors only.

**RESULTS**

In order to evaluate and analyze the performance of the LBPC scheme, three scenarios were simulated using MANSim<sup>[15]</sup>. These scenarios evaluate the effects of a number of input network parameters, such as: node density ( $n_d$ ), node mobility (u) and node maximum radio transmission range ( $R_{max}$ ), respectively. The

performance is evaluated in terms of  $P_c$ , number of Retransmission (RET), Average Duplicate Reception (ADR) and Reachability (RCH), for the three radio transmission range adjustment criterion (e.g., maximum, farthest, average).

In this study, the simulations were carried-out for two route discovery algorithms: pure flooding and LAR-1. The input parameters for these three scenarios are shown in Table 1. The simulation results are shown in Table 2-4.

Table 1: Input parameters for the three scenarios

Parameters	Scenario # 1	Scenario # 2	Scenario # 3
Node distribution	Random	Random	Random
Network area	600×600 m	600×600 m	600×600 m
Number of nodes (n)	50, 75, 100 nodes	100 nodes	100 nodes
Transmission radius ( $R_{max}$ )	100 m	100 m	100, 125, 150 m
Average node speed (u)	2 m sec <sup>-1</sup>	2, 4 and 6 m sec <sup>-1</sup>	2 m sec <sup>-1</sup>
Simulation time ( $T_{sim}$ )	1200, 600 and 300 sec for 50, 75 and 100 nodes, respectively		
Pause time ( $\tau$ )	$\tau = (0.75 \times R_{max}) u^{-1}$		

Table 2: Results for scenario #1: Investigate the effect of the node density ( $n_d$ )

n	RET		ADR		RCH		$P_c$	
	$R_{max}/R_{far}$	$R_{avg}$	$R_{max}/R_{far}$	$R_{avg}$	$R_{max}/R_{far}$	$R_{avg}$	$R_{far}$	$R_{ave}$
<b>Pure flooding</b>								
50	0.605	0.585	3.477	3.136	0.620	0.598	25.8	40.0
75	0.793	0.861	7.267	6.456	0.806	0.875	17.6	20.4
100	0.929	0.900	10.789	9.513	0.939	0.911	13.6	26.2
<b>LAR-1</b>								
50	0.129	0.093	0.274	0.158	0.475	0.305	22.5	51.3
75	0.142	0.125	0.405	0.272	0.615	0.530	16.5	35.3
100	0.167	0.162	0.622	0.549	0.819	0.737	11.7	26.0

Table 3: Results for scenario #2: Investigate the effect of the node mobility or node speed (u)

u	RET		ADR		RCH		$P_c$	
	$R_{max}/R_{far}$	$R_{avg}$	$R_{max}/R_{far}$	$R_{avg}$	$R_{max}/R_{far}$	$R_{avg}$	$R_{far}$	$R_{ave}$
<b>Pure flooding</b>								
2	0.929	0.900	10.789	9.513	0.939	0.911	13.6	26.2
4	0.901	0.903	9.305	8.305	0.911	0.915	14.3	24.1
6	0.911	0.896	8.692	7.778	0.921	0.908	14.4	26.0
<b>LAR-1</b>								
2	0.167	0.162	0.622	0.549	0.819	0.737	11.7	26.0
4	0.157	0.143	0.490	0.427	0.762	0.640	13.0	31.6
6	0.154	0.137	0.445	0.367	0.743	0.611	13.0	33.3

Table 4: Results for scenario #3: Investigate the effect of the node transmission range ( $R_{max}$ )

$R_{max}$	RET		ADR		RCH		$P_c$	
	$R_{max}/R_{far}$	$R_{avg}$	$R_{max}/R_{far}$	$R_{avg}$	$R_{max}/R_{far}$	$R_{avg}$	$R_{far}$	$R_{ave}$
<b>Pure flooding</b>								
100	0.929	0.900	10.789	9.513	0.939	0.911	13.6	26.2
125	0.987	0.977	11.033	9.320	0.997	0.987	10.8	24.0
150	0.990	0.990	15.111	12.280	1.000	1.000	8.7	23.3
<b>LAR-1</b>								
100	0.167	0.162	0.622	0.549	0.819	0.737	11.7	26.0
125	0.166	0.158	0.575	0.497	0.835	0.746	10.5	26.6
150	0.184	0.182	0.761	0.623	0.917	0.876	6.8	24.2

## DISCUSSION

The results show that the LBPC scheme provides a  $P_c$  that varies between 10 to 50% depending on the input network parameters. For similar parameters, adjusting node radio transmission range to cover a distance equivalent to the average distances of the first-hop neighbors yields higher  $P_c$  than adjusting the transmission range to reach farthest first-hop neighbor, but at the same time it affects RET, ADR and RCH. In what follows the results obtained for each scenario are summarized and briefly discussed.

The results for scenario #1 are shown in Table 2. It shows that as node density increases from 50-100 nodes,  $P_c$  is decreased, for both pure flooding and LAR-1 algorithms. Also, it can be realized that pure flooding provides higher  $P_c$  than LAR-1 for equivalent node density.

For scenario # 2, the results in Table 3 show that the node mobility has insignificant effect on  $P_c$  for both algorithms. For Scenario # 3,  $P_c$  decreases as  $R_{max}$  is increased from 100-150 m, for both algorithms and all other parameters are remained unchanged. This is because the number of retransmissions is increased and nodes consume more power during these retransmissions than what they save by radio transmission range adjustment.

## CONCLUSION

This study presents an efficient Location-Based Power Conservation (LBPC) scheme for MANETs. The scheme utilizes the location information of the node first-hop neighbors to adjust the radio transmission range of the transmitting node to cover (i) an area up to the farthest first-hop neighbor, (ii) an area at a radius equivalent to the average distance the first-hop neighbors and (iii) an area up to a random distance between the nearest and the farthest first-hop neighbors.

Three scenarios have been simulated to evaluate the power conservation ratios for two route discovery algorithms: pure flooding and LAR-1. The simulations show that a power conservation ratio of 10-50% can be achieved depending on the network environment and the simulation time. This is considered as a very encouraging result as it can be achieved without added overheads or complexity. However, the results obtained demonstrate that the power conservation is reduced as node density increases and all other network parameters are remained unchanged. The same is for increasing radio transmission range. While increasing node mobility has little effect on the power conservation ratio.

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