Minimum Battery Draining Rate Aware Optimized Link State Routing in Wireless Mesh Network

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Abstract

Wireless mesh network is a flexible, low cost and multi-purpose networking platform with wired infrastructure connected to the internet. In WMN nodes often have a limited battery supply to use for the sending and reception of transmissions. Routing protocols over WMN are an important issue and many proposals have been addressed to efficiently manage topology information, to offer network scalability and to prolong network lifetime. Optimized Link State Routing (OLSR) is a proactive type of routing which presents the advantage of finding a route between two nodes in the network in a very short time. It can consume lot of energy resources in selecting the Multi-point Relays (MPRs) and exchanging Topology Control information. To overcome this, we present a mechanisms for the OLSR routing protocol to improve its energy performance in Wireless Mesh Networks. We propose a Minimum Battery Draining Rate Aware (MDRA-OLSR) algorithm which utilizes the information collected by OLSR at every node in providing better network connectivity. We propose a modification in the MPR selection mechanism of OLSR protocol, based on the Willingness concept, in order to increase the network lifetime without losses of performance such as PDR, throughput etc. We consider both available energy and battery draining rate metric as a key criteria to select MPR in a set of MPRs. A comparison of an OLSR and MDRA-OLSR protocol is performed. The experiments are simulated using NS3 simulator by considering various situations such as changing speed of nodes, data rate and packet size by keeping the nodes position static and moving nodes dynamically. In this paper, we present the related works on utilization of energy as metric in routing, proposed model, simulation and discussions of the model in Wireless Mesh Networks.

Index Terms: Energy, Draining rate, OLSR, Routing, RV battery, Wireless Mesh Networks.

I. Introduction

Wireless Mesh Networks (WMN) is a type of wireless adhoc network defined under IEEE 802.11. IEEE 802.11s is a draft IEEE 802.11 amendment for mesh networking [11]. It defines the mechanism to interconnect an wireless devices to WLAN mesh network, which may be used for static topologies and adhoc networks. A wireless mesh network often has a more planned configuration, and may be deployed to provide dynamic and cost effective connectivity over a certain geographic area. It is often assumed that all nodes in a wireless mesh network are immobile, but this may not be the case. The mesh routers may be mobile, and be moved according to specific demands arising in the network [3], [4]. In the Fig. 1 dash and solid lines indicate wireless and wired links, respectively. This type of wireless mesh network (WMN) includes mesh routers forming an infrastructure for clients that connect to them. The mesh routers form a mesh of self-configuring, self-healing links among themselves. With gateway functionality, mesh routers can be connected to the Internet [15]. In WMN Energy-aware routing or battery-aware routing can be considered as a metric to decide route to relay traffic.

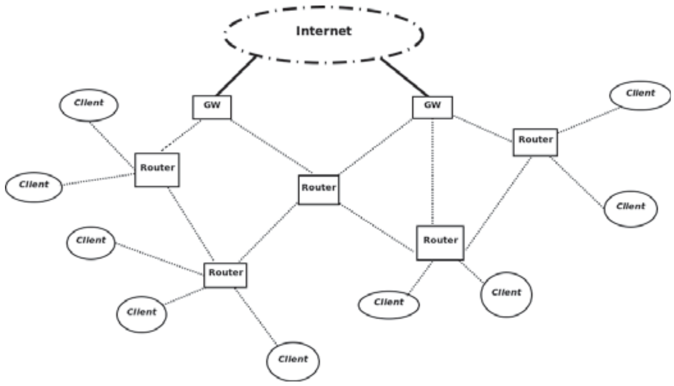

Fig. 1. Example of Mesh Network

In wireless mesh networks battery life of the node plays an important role because it is very difficult to recharge battery regularly. Hence, wireless mesh network nodes operate with finite battery capacity which is managed efficiently to increase reliability of individual nodes and lifetime of whole network. The lifetime can be increased by equally utilizing all nodes. This can be achieved by balancing individual nodes battery level. Since energy consumption is important factor in wireless devices and wireless network, there is a need to analyse energy consumption of each node. This can be achieved by adding energy as a metric for making decision on routing. OLSR routing process in wireless mesh network consumes energy at each node, hence there is a need to find the available energy and energy draining rate of the battery at every node and then select the MPR with minimum draining rate node to increase network life time. This metrics plays a major role in selecting MPR in a set of MPRs which leads to increase in network lifetime.

The rest of the paper is organized as follows: Section II unfolds the related work carried out. Section III presents the proposed model, section IV discusses about the design, section V describes about algorithms, section VI shows the experimental results and discussions. Conclusion and future work is given in section VII.

II. Related works

A WMN typically consists of networks of access points, which are connected through a wireless backbone. Research focus has been diverted in finding ways to minimise the power consumption of these networks. The Optimized Link State Routing protocol (OLSR) is a proactive routing protocol based on the shortest path algorithm [9], [2], [1], [10].

In recent years a number of power-aware metrics have been proposed at the network layer. Authors of [13] describes a Multipath OLSR in which the path with the intermediate nodes containing the higher energies is considered to be the best path among the multiple paths between a given pair of source node and a destination node OLSR always uses the shortest hop route which leads to congestion. Authors of [5] have showed that the well recovered nodes have to be given the higher priority in order to achieve the prolonged network lifetime. The authors have also shown that being aware of the battery status and by prioritizing the nodes, the network lifetime can be increased remarkably. Authors of [6] describes an approach to increase the life time of the network by efficiently utilizing the node energy according to a energy parameter in OLSR routing protocol. To enhance the energy performance of the network Authors of [8] have modified OLSR in the aspect of MPR selection mechanism. Authors of [14] proposed a power-aware dual tree based multicast routing protocol which emphasizes on achieving the load balance of data transmission. Authors of [12] addressed an issue by introducing an energy based OLSR named RE-OLSR, in which to select MPR nodes, the residual energy level of each node has to be taken into account. Authors of [7] proposed a Link Management Scheme which aids in detecting the link breakages thus improving the overall performance of the network. Management scheme proposed is based on the signal strength, which indicates the link quality. The algorithm combines the concept of OLSR to use Hello packets for link management.

Most of the work carried out considers only link state as a parameter to OLSR routing in WMN, which may result in network failure. In WMNs, battery energy at the nodes is a very limited resource that needs to be utilized efficiently. The failure of some node's operation can greatly reduce performance of the network and even affect the basic availability of the network. Since OLSR is a proactive routing type and it considers only link state as a metric to select MPR, we consider two more metric called energy draining rate and available energy to select MPR in existing OLSR routing. We have used Network Simulator NS3 as a simulating tool to simulate our proposed model.

III. Proposed model

A. MDRA-OLSR model

In existing OLSR, only link state of a node is considered as criteria to select MPR node which is used to forward packet. This may result in poor packet delivery rate. To avoid this problem we propose an MDRA-OLSR algorithm which considers available energy and battery draining rate to select MPR. Fig. 2 shows propose model in which both Available energy of node and Drain rate of node is considered while selecting MPR node. In classical OLSR, every node declares a default willingness value by considering only link state whereas in MDRA-OLSR , each node declares its willingness value by calculating its own energy status. Willingness is based on battery status as well as the predicted life time which in turn is based on the energy drain rate of the node. Available energy and minimum draining rate are used as energy aware metric for forwarding the data packet among the MPR neighbours set.

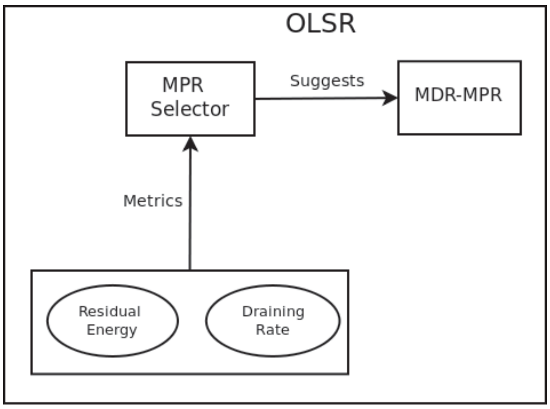

Fig. 2. Proposed model

B. Energy model

Consider a single node n in a set of N nodes $n_i \in \{N\}$ Where i is the number of nodes. We have $n_{ij} \in \{N\}$ where ij is the traffic from $i \to j$.
Considering movements of nodes with a velocity V, that is $n_{ij} \in V$
we have V_i is $((x_i - x_{i-1})/(t_i - t_{i-1}))$ where V is the velocity of node i at t_i time.

We know that, The energy consumed to transmit packet p is

$$E(p) = I * V * t_p joules \tag{1}$$

where I is current, V is voltage and t_p is the time taken to transmit packet p.

If we consider a generic route $R_d = n_0, n_1, n_2......n_d$ where n_0 is the source node and n_d is the destination and $T(n_i, n_j)$ denotes the energy consumed while transmitting over the Hop (n_i, n_j). The total transmission power of the route is calculated as

$$p(R_d) = \sum_{i=0}^{d-1} T(n_i, n_{i+1}) \tag{2}$$

In MDRA-OLSR the willingness of the node can be defined as

$$W_{mn} = \begin{cases} f(k) & 1 < k < 4 \\ m & 1 < m < 25 \\ n & 1 < n < 25 \end{cases}$$

Where k value suggests the willingness of node equal to 1, 2, 3 and 4 as low, mid, default and high respectively, m and n are the number of nodes and

$$f(k) =^{Min(D_R)}_{Max(A_E)} \left\{ \; R(k) \; \right\} \in R^* \tag{3}$$

where R^* is the set of all possible routes from node.

The MPR node is selected based on the available energy and energy draining rate at each node. According to (3) the node with minimum draining rate and maximum available energy must be selected as MPR in a set of routes of a network which ensures the increase in network lifetime and packet delivery.

IV. Design

A. MDRA-OLSR: MPR selection

Fig. 3 shows the modified OLSR where MPR selection takes place based on the nodes available energy and battery draining capacity. In clasical OLSR, the willingness of a node is determined by link state. Only link state can not assure the packet delivery and increase the network lifetime. Hence the proposed model considers both available energy and battery draining capacity of node to set the willingness of a node to forward the packet in a topology control message. This will reduce the overhead during the flooding mechanism of a two hop neighbours.

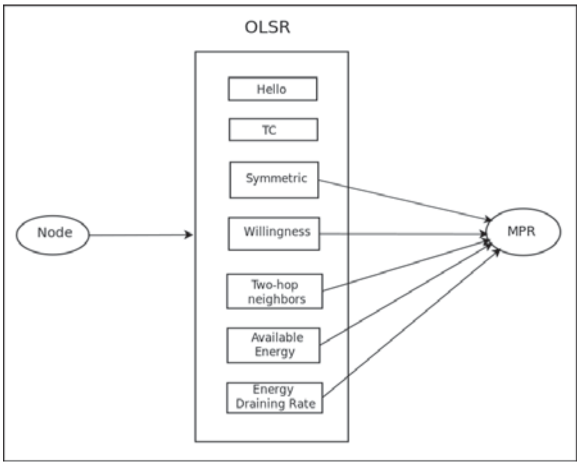

Fig. 3. MDRA-OLSR MPR selection

B. MDRA-OLSR: MPR selection process model

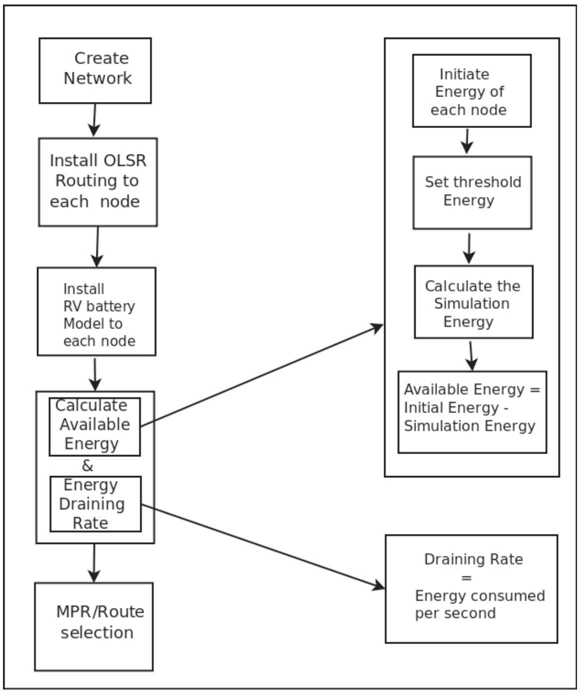

Fig. 4. MDRA-OLSR process model

Fig. 4 shows the process model of MDRA-OLSR. Initially a mesh network is created with few nodes where each node is installed with OLSR routing and RV battery model. The available energy and energy draining rate functions were called to compute available energy and draining rate, then it is given as an input criteria to select the MPR node. The available energy is calculated by subtracting the simulation energy and the initial energy. The draining rate is calculated by the energy consumed per simulation time. Each node is set with initial energy and threshold energy.

V. Algorithm

In this section we discus about the algorithms used to select the MPR node by calculating the available energy and the energy draining rate.

Algorithm 1 Select MPR

Require: $A_E = 10 \vee D_R = 0$
Ensure: $A_E \geq= 3 \vee D_R \leq 3$
  if $(A_E >= 7 \&\& D_R <= 3)$ **then**
    willingness == high
  else if $((A_E > 5 \&\& A_E < 7) \&\& (D_R < 5 \&\& D_R > 3))$ **then**
    willingness == mid
  else if $((A_E > 3 \&\& A_E < 5) \&\& (D_R < 7 \&\& D_R > 5))$ **then**
    willingness == default
  else
    willingness == low
  end if

Algorithm 1 shows the conditions needed to set the willingness parameter of MDRA-OLSR. The willingness could be assigned with 4 different values known as low, default, mid, and high where high is set to ALWAYS and low is set to NEVER of an willingness parameter of OLSR. If available energy is more and and the draining rate is less than willingness is set to high or ALWAYS. If available energy is less and draining rate is high the willingness is set to low or NEVER.

Algorithm 2 Calculate Available Energy

Require: $I_E = 10 \vee C_E = 0$
Ensure: $A_E \geq 3$
  $E_{i+1} = E_i + V * (t_{i+1} t_i) * I_i$
  $A_E = I_E - C_E$

The algorithm 2 shows the function used to calculate the available energy which is defined by RV battery model.

VI. Experimentation and result analysis

The experiment is conducted by using NS3 network simulator. The behaviour of model is observed by changing positions of nodes such as keeping nodes static and moving nodes randomly. We discuss the simulation setup and discuss the results in this section.

A. Simulation setup

The simulation was setup for the proposed model by creating 5X5 mesh dynamically moving around the specific area in wireless mesh network using NS3. IP address was assigned to every node's device interface and was set with the OLSR routing algorithm to whole network. The RV battery model available in NS3 simulation tool is installed to all the nodes. The available energy and draining rate is calculated using the equation (3) The source and destination nodes have been selected from the 25 available nodes randomly. Each node is

TABLE I
SIMULATION PARAMETERS

Parameters	Values
Area	300 X 1500
Nodes	25
Nodes speed	40 m/s
Simulation Time	400s
Traffic Sources	12
Traffic Type	CBR
Packet Size	512 bytes
Start of Traffic	30s
End of Traffic	380
Transmission Power	1.4 W
Reception Power	1.0 W
Idle Power	0.0 W
Initial Energy	10 J
Energy threshold	3 J

connected via UDP. The following parameters are set to OLSR routing algorithm as shown in Table I.

To calculate remaining energy of each node, we consider only communication energy rather than considering the algorithm running on it. Initially basic energy source was connected to every node in the network. RV battery model's Energy supply was attached to each node and was set with initial energy. Later, device energy model class was connected to the Basic energy class. The remaining energy and total energy consumed were calculated using the basic energy class. The energy draining rate is calculated by sending remaining energy and time as the parameter to each node. The current and previous remaining energy and simulation time has been computed. The MPR selection was done based on considering the factors such as remaining energy and draining rate.

B. Results and discussion of energy consumption behaviour of the node

1) Draining rate variation by changing packet size: Fig. 5 shows the draining rate variations of a node over a period of simulation time. The experiment is conducted by keeping nodes position static and changing packet size with 512 Kb and 1024 Kb respectively, also varying nodes position dynamically and changing packet size with 512 Kb and Kb bytes respectively. We can notice that as the packet size increases the draining rate increases in both static and dynamic situation.

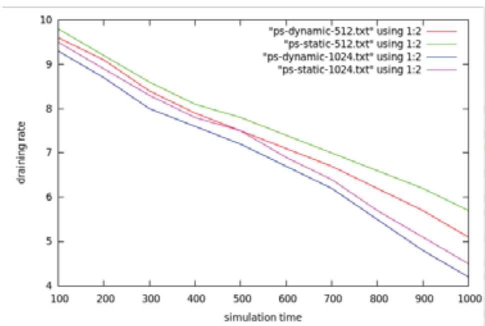

Fig. 5. Draining rate changing packet size in static and dynamic

2) Draining rate variation by changing data rate: Fig. 6 shows the draining rate variations of a node over a period of simulation time. The experiment is conducted by keeping nodes position static and changing the data rates on nodes 40 and 80 kbps respectively, also varying nodes position dynamically and changing data rates on nodes 40 and 80 kbps respectively We can notice that as the data rate increases the draining rate increases in both static and dynamic situation.

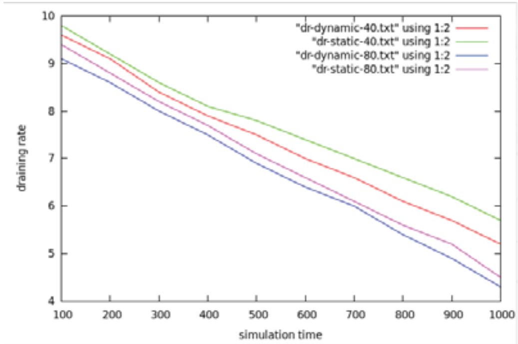

Fig. 6. Draining rate varying data rate

3) Draining rate variation by changing nodes distance: Fig. 7 shows the draining rate variations of a node over a period of simulation time. The experiment is conducted by keeping nodes position static and changing the distance between the nodes 120 and 240 respectively, also varying nodes position dynamically and changing distance between the nodes 120 and 240 respectively. We can notice that as the distance increases the draining rate increases in both static and dynamic situation.

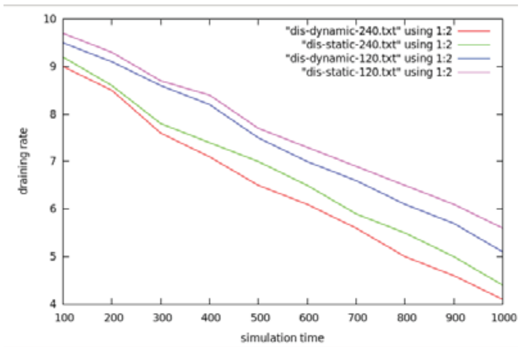

Fig. 7. Draining rate changing nodes distance in static and dynamic

4) Packet delivery ratio of both OLSR and MDRA-OLSR in static nodes: Fig. 8 shows the variation in packet delivery ratio of conventional OLSR and MDRA-OLSR in static environment. We can notice that the packet delivery ratio is consistent in MDRA-OLSR compared to conventional OLSR where the packet dropping rate is high at some instant.

5) Packet delivery ratio of both OLSR and MDRA-OLSR in dynamic nodes: Fig. 9 shows the variation in packet delivery ratio of conventional OLSR and MDRA-OLSR in dynamic environment. We can notice that the packet delivery ratio is consistent in MDRA-OLSR compared to conventional OLSR where the packet dropping rate is high at some instant.

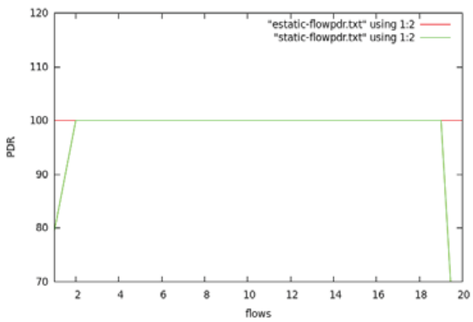

Fig. 8. PDR keeping nodes static

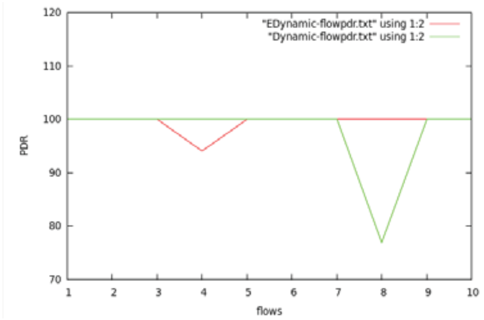

Fig. 9. PDR keeping nodes dynamic

C. Algorithms comparison

Table II shows the comparison of existing OLSR algorithm and proposed MDRA-OLSR algorithm.

TABLE II
OLSR AND MDRA-OLSR COMPARISON

Techniques	MPR selection	Description
OLSR	MPR selection based on link state	Finds the optimal link state to reach destination, Packet delivery Ratio is lower
MDRA-OLSR	MPR selection based on both Available Energy and Nodes draining Rate	Maintain same energy level in all nodes over networks , Packet delivery Ratio is higher

Several studies have been conducted on energy consumption behaviour of the nodes by varying different sources at every node. The MPR is selected based on the Available energy and energy draining rate criteria. We can notice that MDRA-OLSR algorithm increases the lifetime of the network by initially estimating the energy draining rate of each node and selecting the MPR with less energy draining rate and more available energy of node. This ensures that the network lifetime increases compared to the existing OLSR routing algorithm.

VII. CONCLUSION AND FUTURE WORK

Most of the research carried out till date are considered the residual energy as a metric to select the MPR in an OLSR routing in wireless mesh network. The proposed algorithm consider both the available energy and the draining rate of a node as a metric to identify the MPR in OLSR. The Experimental results shows that these two metrics will help in the increase of network life time and also increases the packet delivery ratio, throughput in both static and dynamic environment. The results have been compared with the conventional OLSR.

Present work considers only the battery draining rate and available energy to select MPR in OLSR. We can notice that there is a change in PDR and throughput when the nodes are moving dynamically. Also the speed of the node result in changing of battery status/energy consumption. Hence there is a need to consider the nodes mobility and its speed to assure high PDR rate. Wireless mesh network has a power safe mode which changes nodes status from awake to sleep or deep sleep modes. So our future work concentrate on implementing power safe modes of wireless mesh network in OLSR routing.

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