Performance Enhancement Of Optimized Link State Routing Protocol For Health Care Applications In Wireless Body Area Networks

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***Abstract*—Wireless Body Area Networks (WBAN) refers to the network of wearable sensor devices on a human body. The data gathered from the devices are sent to the server to take some action during an emergency. The collected data has to be successfully routed to reach the destination for an health care applications in WBAN. Hence selecting the routing protocol plays an important role in WBAN. Several researchers have proposed many routing protocols for WBAN. In this work, a novel proactive routing protocol called Energy Aware Power Save Mode Link State is proposed that modifies the existing Optimized Link State Routing protocol. The mathematical model is defined to select the best multi point relay node in a network that considers the power save mode state. The experiment is conducted using network simulator NS-3 and the result shows the substantial network performance metrics improvement in the proposed model compared to the existing.**

I. Introduction

In the sector of health care, Wireless Body Area Network (WBAN) has risen as a vital innovation which can give better strategies for continuous patient wellbeing observing at healing centers, remote areas and even at homes. WBAN incorporate communication between sensor nodes with possible evolving condition. Lately, WBAN has increased extraordinary intrigue and demonstrated a standout amongst the most investigated advancements by health care as a result of its essential part and extensive variety of use in clinical sciences. The three tier architecture of WBAN [19] is as shown in figure Fig. 1. It can be categorized at three distinct levels, to be specific: Tier-1 as Intra-BAN, Tier-2 as Inter-BAN and Tier-3 as Extra-BAN respectively. In Tier-1, the sensor nodes on the body gather information and sends it to the Gateway. In Tier-2, the Gateway processes the information and sends the data towards the destination node. In Tier-3, the packet received from the node is transmitted to the destination through Internet or other communication methods.

A. Routing in WBAN

WBAN comprises several sensor nodes connected to the body by forming Wireless Sensor Network (WSN). WSN alludes to a distributed network arrangement, comprising of scattered and independent sensor nodes. The sensor nodes comprises of a microcomputer, handset and power source. These nodes self-arrange themselves after the deployment and form a system, which is commonly involves a few to thousands

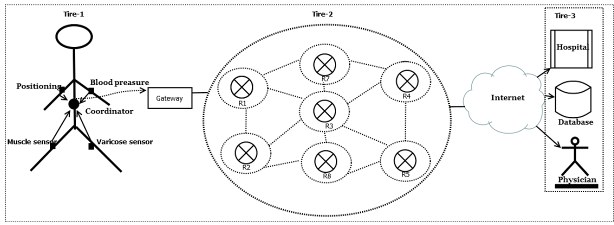


Fig. 1. Wireless Body Area Network Architecture

of such sensor nodes. After the network formation, sensor nodes sense, measure and collects data for further process [6]. Routing protocols are a set of protocols which can identify and maintain the routes in the network so that the data can be exchanged between the nodes efficiently. Hence, routing protocol plays a vital role in the wireless sensor networks for reliable communication between the sensor nodes. Figure Fig. 2 shows the classification of routing protocols in WBAN. The routing protocols are classified based on the challenges of Routing in WBAN. The protocols are characterized as Quality of services (QoS) aware, Cluster-based, Temperature-aware routing algorithms, Cross-layered and Postural movement.

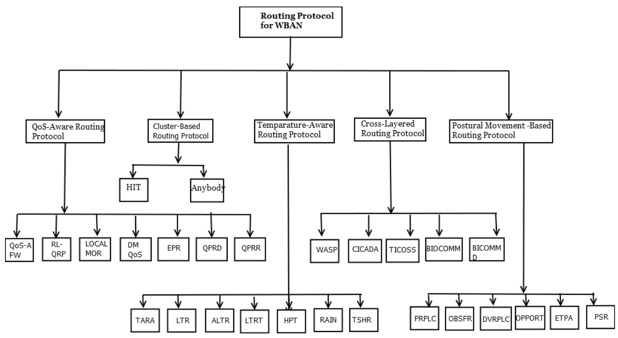


Fig. 2. WBAN Routing Protocols

As WBSNs deals with vital signs of the human body, data require are different for different quality of services. Patient data are divided into critical data like EEG, ECG etc., delay sensitive data like video streaming, reliability-sensitive data like vital signals monitoring respiration monitor, and PH monitor and ordinary data such as temperature, heartbeat, etc. The protocols to be used, must be aware of the different types of Qos required for different types of patients vital sign-related data. The energy aware peering routing protocol (EPR), QoS-aware peering routing protocol for delay sensitive data (QPRD) and QoS aware peering routing protocol for reliability sensitive data (QPRR) consumes less power as compared to any other protocols. Only few protocols are defined by considering energy consumption. QoS aware protocols is data-centric multi objective QoS-aware routing protocol (DMQoS) is the most used protocol as it can reduce the delay for delay sensitive information, and also, it can provide reliable routing for reliable-sensitive information. The remaining QoS-aware protocols are applied for a particular network, depending on QoS requirements and the data type.

The Optimized Link State Routing (OLSR) protocol is widely used by the researchers in the area of WBAN which is developed for mobile ad hoc networks. It operates as a table driven, proactive protocol, i.e exchanges topology information with other nodes of the network regularly. Each node selects a set of its neighbor nodes as Multi Point Relays (MPRs). In OLSR, only nodes, selected as such MPRs, are responsible for forwarding control traffic, intended for distribution into the entire network. MPRs provide an efficient mechanism for flooding control traffic by reducing the number of transmissions required. Nodes, selected as MPRs, also have a special responsibility when declaring link state information in the network. Indeed, the only requirement for OLSR to provide shortest path routes to all destinations is that MPR nodes declare link-state information for their MPR selectors. Additional available link-state information may be utilized, e.g. for redundancy. Nodes which have been selected as multipoint relays by some neighbor node(s) announce this information periodically in their control messages. Thereby a node announces to the network, that it has reachability to the nodes which have selected it as an MPR. In route calculation, the MPRs are used to form the route from a given node to any destination in the network. Furthermore, the protocol uses the MPRs to facilitate efficient flooding of control messages in the network. A node selects MPRs from among its one hop neighbors with symmetrical links. Therefore, selecting the route through MPRs automatically avoids the problems associated with data packet transfer over unidirectional links (such as the problem of not getting link-layer acknowledgments for data packets at each hop, for link layers employing this technique for unicast traffic). Energy Aware Power Save Mode (EAPSM) model is proposed by authors S.P. Shiva Prakash et.al [5] to improve Quality of Service (QOS) and minimize the power consumption rate of a node during data transmission. The PSM is scheduled based on energy constraints and transmission mode of a node. The model comprises of Energy consumption module, Transmission mode identifier and PSM scheduler module. The energy consumption module calculates the remaining energy of a node at a regular interval of time. The transmission mode identifier module identifies the nodes involvement in transmission such as receiving or transmitting or relaying packets. The calculated remaining energy and identified transmission mode is given as input to PSM scheduler. The scheduler compares the remaining energy of a node with the energy threshold required by the node to be involved in transmission. If the remaining energy of a node is greater than the minimum energy threshold required by node to be involved in transmission, the scheduler changes nodes current PSM state from light sleep mode to Active mode otherwise PSM of a node remains in Light Sleep mode. If the remaining energy of a node gets drained completely and reaches NULL or value 0, then scheduler changes the current PSM state of node to Deep Sleep mode. This method assures the successful delivery of packets and increases QoS of routing in WMN.

The rest of the paper is organized as follows: Section 2 discusses about the related works carried out by several authors. Section 3 describes the problem statements. Mathematical model for the proposed protocol is defined in section 4. Section 5 shows the steps involved in the proposed algorithm. The results are discussed in section 6 and section 7 discusses about the conclusion and future work.

II. Related Works

In this section the work carried out by several authors to improve the QoS for WBAN routing is discussed.

To improve the overall QoS performance of the network using link cost function, Authors Auqir A et.al. [2] have proposed an algorithm distance aware relaying energy efficient protocol (DARE). The algorithm consists of performance metric like Residual energy, PDR, number of packets sent to sink and compared to Mobility-supporting Adaptive Threshold-based Thermal-aware Energy-efficient Multi-hop ProTocol (M- ATTEMPT). To provide better QoS by selecting the best routing paths, authors Khan ZA et.al. [3] have proposed an algorithm QoS aware peering routing protocol for reliability sensitive data (QPRR). The algorithm consists of performance metric like Successful transmission rate, network traffic load, overall energy consumption and latency are compared with DMQos and NoRouting. Authors Nedal A et.al. [4] have proposed an algorithm called adaptive routing and bandwidth allocation protocol (ARBA) to enhance bandwidth utilization, routing in BAN and better network lifetime. Authors Javaid N et. al. [6] have proposed an algorithm relay based routing protocol for network lifetime maximization and end-to-end-delay (E2ED) minimization. The algorithm consists of performance metric like remaining energy, no. of dead nodes, no. of dropped packets and packet arrival rate. It is compared with single- hop, multi-hop and CH-rotate. To boost the network stability period and packet delivered to sink, authors Bangash J I et. al. [7] have proposed an algorithm called reliability aware routing (RAR). The algorithm consist of performance metric like Packet loss ratio, average PDR and average energy consumption. The algorithm is compared with relay nodes and TMQoS. To enhance the reliable delivery of emergency BAN data for indoor hospital communication and upgrade the LEEBA protocol by increasing throughput and decreasing delay, Sheth Mahammed Ovesh I and Sharma A K [8] have proposed an algorithm Modified LAEEBA: link aware and energy efficient scheme for BAN (MLEEBA). The algorithm consists of performance metric like PDR, end to end delay and throughput are compared with LEEBA. To extend network lifetime and to improve the network stability of WBAN, authors Cabacas R et.al. [9] have proposed an algorithm two-hop transmission scheme. The algorithm consists of performance metric like average residual energy, number of packets per priority level, total energy and number of dead nodes. It is compared with

direct transmission and TPDS.
To route data with minimum path-loss over the link in WBAN, authors Ahmed S et.al. [10] have proposed an algorithm Link-aware and energy efficient scheme for body area networks (LAEEBA). The algorithm consist of performance metric like stability period, residual energy, network lifetime, path-loss, delay spread and throughput are compared with SIM/PLE and M-ATTEMPT. Authors Ayatollahitafti V et.al. [11] have proposed an efficient next hop selection (ENSA-BAN) algorithm. The algorithm consist of performance metric like Energy consumption, packets forwarded, end-to-end delay, packet delivery ratio and compared with DMQoS. To forward the critical data packets with better reliability along with reduction in temperature rise of the in-body sensor nodes, authors Bangash JI et.al. [12] have proposed an algorithm critical data routing (CDR). Authors Javaid N et. al. [13] have proposed an algorithm relay based routing protocol for network lifetime maximization and end-to-end-delay minimization and Authors Ahmed S et. al. [14] have proposed an algorithm Cooperative link-aware and energy efficient protocol for WBAN (Co-LAEEBA) to select better routing path with minimum path-loss in cooperative links in WBAN. The algorithm consists of performance metric like Stability period, residual energy, path-loss and throughput are compared with LAEEBA, SIMPLE and M-ATTEMPT. Gupta S and Kaur P [15] have proposed threshold sensitive energy efficient sensor network protocol (TEEN) algorithm to monitor and record critical data of the patients body parameters. The algorithm consists of performance metric like energy consumption, false acceptance rate, false rejection rat and time served. To achieve better network lifetime for monitoring patients in multi-hop body area networks, authors Nedal A et.al. [16] have proposed an algorithm called adaptive routing and bandwidth allocation protocol (ARBA) to enhance bandwidth utilization and routing in BAN, better network lifetime. The algorithm consists of performance metric like Residual energy and throughput and compared with Optimal solution. To maximize the working lifetime of the network, authors Kumaria J and Prachia [17] have proposed an algorithm Energy efficient routing algorithm. The algorithm consists of performance metric like coverage distance, residual energy and communication count node criticality, Kaur HP and Goyal K [18] have proposed an algorithm Multi-hop protocol using cost function to boost the network performance and lifetime by optimum residual energy and distance. The algorithm consist of performance metric like Number of dead nodes, residual energy, data packets sent and received to sink and delay compared with Old energy aware multi-hop.

From the related work, it can be noticed that there is no significant model is available that selects the path considering battery status of node at an instance during data transmission. Hence there is a need to fill the gap to improve the QoS by proposing a model that considers all the parameter such as link state, battery and QoS support service.

III. Problem statement

In WBAN frequent usage of same node during routing results in energy degradation of nodes. Few works can be found in the literature in which the node selects the path based on energy resource and the link state. But in the reported work, it can be noticed that the energy threshold is fixed for all the nodes in the network. The need of framework to prioritize routing service with QoS requirement based on the user specification is the major challenge in the tier 3 layer of WBAN network for health care applications. Hence to improve the network performance, in this work, a novel model that triggers the power save mode (PSM) based on the energy constraints, link state and QoS using OLSR is proposed.

IV. Mathematical Model for the Proposed System

In this section, the mathematical model defined to select the MPR node that guarantees the performance improvement in the proposed model is defined.

A. Network model

Consider a network represented as graph $G(N, E)$ where N represents the number of nodes, E represents the set of links and $n_i(x_i, y_i) \in N$ represents the node i's location in the simulation field. The nodes are placed randomly within the simulation area. Each node is given a unique node id. Packet size of each node varies and data rate of each link is also chosen randomly. We consider a one and two hop wireless network where the nodes remains static. Since the nodes are installed with proactive routing protocol, the willingness metric of each node to participate in the routing process depends on the available energy and draining rate of the node battery status. The objective function must be,

$$MPR = PSM(A) \left\{ \begin{array}{c} Min(D_R) \\ Max(A_E) \end{array} \right\} \in R^* \quad (1)$$

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

B. Proposed model

To achieve the objective, A novel Energy Aware Power Save Mode Link State (EAPSMLS) routing protocol is proposed in QoS-aware routing service framework which switches between power save modes depending on the status of battery among the nodes before partaking in link state routing. The proposed routing model is referred to the process that takes accessible outstanding energy and energy draining rate of a node into consideration to make decisions on relaying traffic in WBAN. It consist of three units namely Path choosing, Mode selector and Energy evaluator. The proposed OLSR routing protocol incorporating power saving mode(PSM) consisting of three models namely: Energy consumption, PSM scheduler and Multi Point Relay (MPR) selection. It allows discovering and maintaining the optimal routes in accordance with a predefined metric, provided that every node has a process to find the cost of link to every individual neighbor metric. To propagate the metric information among nodes, a metric field is used. Only a subset of nodes called MPR is used in the network in the process of ooding that controls the message exchange frequencies in accordance with sheye scopes. Multi point relay selection in OLSR is as shown in figure Fig. 3.

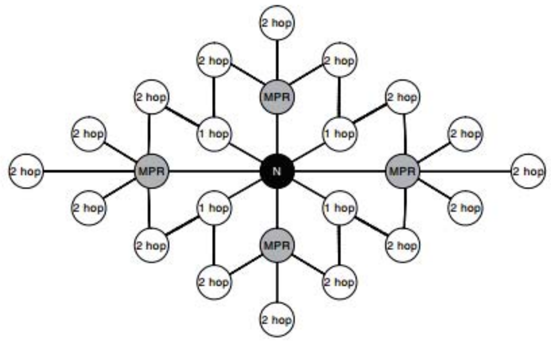


Fig. 3. MPR selection in OLSR

The energy consumption (E_c) of each node varies from $E = \{0, E_{max}\}$ and it is calculated by using,

$$E_c = I * V * t_p \tag{2}$$

where I = current, V = Voltage of the battery used and t_p = time taken to transmit packet. The transmission time t_p, is the amount of time from the beginning until the end of a message transmission.

Considering packet size ps and data rate dr of a node, the existing energy consumption equation is modified and equation (2) is rewritten and expressed as,

$$E_c^{'} = \frac{I * V * t_p * P_s}{D_r} \tag{3}$$

Also it has been known that during transmission of packets nodes have different roles such as transmitter, relay and receiver. Hence considering the transmission mode of a node, a model is defined in which energy consumed to transmit E_c^{Tr} and receive E_c^{Rc} packet from node n_i to node n_j can be calculated using 3 where $I * V$ is substituted with the power of transmitting antenna (P_t).
For the relay mode of a node, the energy consumed ($E_{c_{(i,j,k)}}^{Rel}$) to transmit packet from node n_i to node n_k via node n_j is given by,

$$E_{c_{(i,j,k)}}^{Rel} = E_c^{Tr} + E_c^{Rc} \tag{4}$$

Hence, The total energy consumed by a node which is involved in the transmission of packet is given by,

$$E_c^{total} = E_c^{T_r} + E_c^{R_c} + E_{c_{(i,j,k)}}^{Rel} \tag{5}$$

If E_{init} is the initial energy of a node, then the remaining energy E_{rem} can be calculated using (5) as,

$$E_{rem} = E_{init} - E_c^{total} \tag{6}$$

Further the draining rate (D_r) of a node is given by,

$$\begin{aligned} D_r &\leftarrow \frac{1}{\triangle t} \int_{t_1}^{t_2} E_c^{total}(t).dt \\ \implies D_r &\leftarrow \frac{1}{\triangle t} \int_{t_1}^{t_2} ({E_c^{total}}_{(t-1)} - {E_c^{total}}_t) \end{aligned} \tag{7}$$

Using the equation to schedule PSM proposed by [5], the PSM scheduler takes into consideration of the available energy(AE) and the transmission modes(TM) of the nodes to change the power save mode of the nodes. It is given by,

$$PSM(node) = \left\{ \begin{array}{ll} \text{A} & \forall n(TM = 1, AE = 1) \\ \text{LS} & \forall n(TM = 0, AE = 1) \\ \text{DS} & \forall n(TM = 1/0, AE = 0) \end{array} \right\} \tag{8}$$

where TM is the transmission mode for node and is determined using

$$TM = \begin{cases} 1, & n \in \{T_X, R_X, R_{EL}\} \\ 0, & \text{otherwise} \end{cases} \tag{9}$$

where packets are arriving at the rate of λ in the time interval t and AE is the available remaining energy and is determined as,

$$AE = \frac{({E_c^{total}}_I) - ({E_c^{total}}_U)}{D_r} \tag{10}$$

where D_r, $({E_c^{total}}_I)$ and $({E_c^{total}}_U)$ represents the draining rate, initial available energy and energy consumed after involving in the transmission respectively.

To select MPR, Let u be the reference node, $N(u)$ be the set of 1-hop neighbours of u and $N_2(u)$ be the set of 2-hop neighbours of u. For a node to be an MPR the following conditions must be satisfied as defined in equations 11, 12 and 13.

$isIsolated(node) = 1$ if its second hop neighbour has only one link.

$$isIsolated(N_2(u)) = \left\{ \begin{array}{ll} 1 & degree(N_2(u)) = 1 \\ 0 & degree(N_2(u)) = 0 \end{array} \right\} \tag{12}$$

and

$$maxReachability(N(u)) = \left\{ \begin{array}{ll} 1 & max(degree(N_2(u))) = 1 \\ 0 & \text{otherwise} \end{array} \right\} \tag{13}$$

V. Algorithms

In this section the algorithms for the proposed model is presented. The variables and its description used to define the steps are shown in Table I.

TABLE I. PARAMETERS

Variable	Description
u	reference node
N(u)	1-hop neighbor of u
N_2(u)	2-hop neighbor of node u
state(u)	PSM state of of a node u
A	Active state of a node
LS	Light Sleep state of a node
DS	Deep Sleep state of a node
S	Nodes in the selected region

Algorithm 1 shows the steps involved in selecting MPR. To select the node as a MPR, it must be at one hop distance from the reference node(MPR selector node), must be in active state, the one hop neighbors must also be in active state and it must be such that its one hop neighbor is either isolated or its reachability is a maximum among all candidate nodes. In

$$MPR(u) = \begin{cases} 1 & PSM(N(u) = A, PSM(N_2(u) = A, \&isIsolated(N_2(u)) = 1 \parallel maxReachability(N(u) = 1)) \\ 0 & PSM(N(u) = LS/DS \parallel PSM(N(u)) = A, PSM(N_2(u)) = LS/DS) \end{cases} \quad (11)$$

this algorithm, multi point relay is checked taking power save mode in to account. Initially the available energy of the node is checked to set the PSM state for the node. In this, current node checks for the first hop and second hop neighbor node. If the node is in active mode and has the second hop neighbor, node has maximum reachability of one or degree of node is ONE, then it is considered as MPR set node. If node is not in active mode or node is isolated, then node is treated as light sleep mode or in deep sleep mode with respect to the energy of the node.

Algorithm 1 MPR Test

```
function MPRTEST
    AVAILABLEENERGY(u,N(u),N2(u))
    PSM(u,N(u),N2(u))
    if (state(N(u)) = A) then
        if (Exists(N2(u))) then
            if (stateN2(u)) = A then
                if (isIsolated(N2(u))) then
                    MPR' ∈ MPR(u)
                else
                    if (maxReachability(N(u))) then
                        MPR' ∈ MPR(u)
                    end if
                end if
                if (state(N2(u)) = LS || || state(N2(u) = DS) then
                    MPR' ∉ MPR(u)
                end if
            end if
        end if
    else
        if (state(N(u)) = LS || || state(N(u)) = DS) then
            MPR' ∉ MPR(u)
        end if
    end if
end function
```

Consider a subset of the above topology of the nodes with the given source and destination. The algorithm to select the MPRs en route the destination is as follows is presented in algorithm 2.

In algorithm 2 MPR from source to destination is selected. If the reference is destination node then return it as MPR. If the node has some energy, then the node is in active mode and it has second hop neighbor, is isolated, max reach-ability of the node is one or the degree of the node is one. Then this node has taken into the set of MPR. If node is not in active mode then that node has to be treated as in light sleep mode or in deep sleep mode with respect to the energy of the node respectively. This algorithm checks for the MPR until all reference nodes are covered.

Algorithm 2 MPR Selection for a given source and destination

```
function FINDMPR(source,reference,destination)
    if N(reference)=destination then
        return MPRsource;
    end if
    ∀u ∈ N(reference)
    if ( thenexists(N(u)))
        AVAILABLEENERGY(u,N(u),N2(u))
        PSM(u,N(u),N2(u))
        if (state(u) = A) then
            if state(N(u)=A) then
                if (isIsolated(N(u)) then
                    u ∈ MPR(ref)
                else
                    if (maxReachability(N(u))) then
                        u ∈ MPR(u)
                    end if
                end if
            else
                if (state(N(u)) = LS || || state(N(u) = DS) then
                    u ∉ MPR(u)
                end if
            end if
        end if
    else
        if (state(u) = LS || || state(u) = DS) then
            u ∉ MPR(u)
        end if
    until all N2(reference) are covered
    FINDMPR(source,MPR(reference),destination)
    end if
end function
```

VI. RESULTS AND DISCUSSION

The experiment conducted and the results obtained is discussed in this section.

A. Simulation Setup

The simulation was setup for the proposed model by creating 50 mesh nodes in the simulation area using NS3. Initially a mesh network is created with few nodes where each node is installed with OLSR and RV battery model. In the proposed protocol all the nodes are equipped with PSM functions. The available energy and energy draining rate functions were called to compute available energy and draining rate and it is given as an input criteria to change its PSM leading 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. IP address was assigned to every node's device interface and was set with the OLSR algorithm. 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 equations 5 and 7 respectively. The congestion management techniques are considered as suggested by authors E. Dashkova and A. Gurtov [1]. The source and destination nodes have been selected from the 50 available nodes randomly. UDP traffic is used between nodes. The parameters are set to OLSR algorithm as shown in Table II.

TABLE II. SIMULATION PARAMETERS

Parameters	Values
Simulation Time	1000s
Area	300 X 1500
No. of Nodes	10,20,30,40,50
Packet Size	256,512 bytes
Data Rate	1, 2, 3, 4 Mbps
No. of Packets	500
Traffic Sources	12
Traffic Type	CBR
Start of Traffic	30s
End of Traffic	380
Initial Energy	10 J
Initial PSM Mode	Light Sleep
Initial Transmission Mode	0
Transmission Power	I=330 mA, V=5V
Reception Power	I=230 mA, V=5V

The result obtained for the proposed model are compared with existing system.

Figure Fig. 4 shows the comparison of PDR of the network at 256 KB and 2 mbps, 256 KB and 4 mbps, 512 KB and 2 mbps and 512 KB and 4 mbps for both existing and proposed model. We can notice that in existing approach, due to link breakage the PDR is quite low as against energy degradation, compared to the proposed model. The PDR of the model which is proposed is 100%. This is achieved because of significance of the metrics which is used in the proposed model.

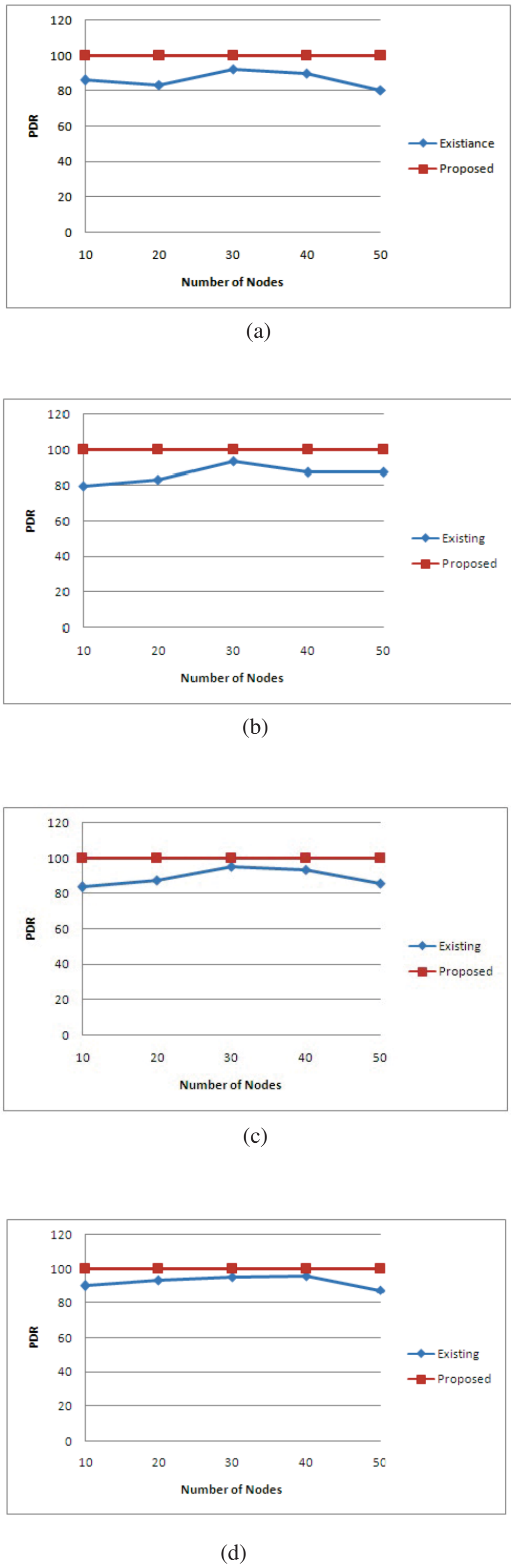


Fig. 4. PDR variation in proposed Vs existing model (a) at 256 KB and 2 mbps (b) at 256 KB and 4 mbps (c) at 512 KB and 2 mbps (d) at 512 KB and 4 mbps

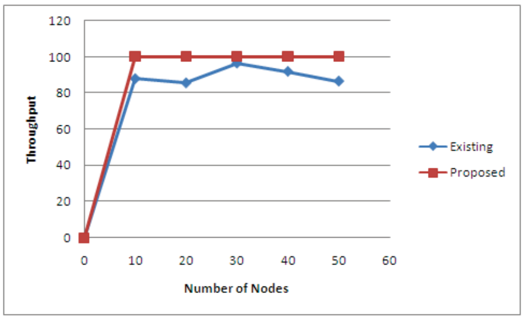
Figure Fig. 5 shows the throughput comparison result obtained at 256 KB and 2 mbps, 256 KB and 4 mbps, 512 KB and 2 mbps and 512 KB and 4 mbps for both existing and proposed model. It can be notice that the results of proposed model exhibits high throughput compared to existing model. 100% throughput is achieved in the proposed model is due to the impact of the methods we have introduced in selecting best MPR for a specific testing scenario with minimal nodes.

Figure Fig. 6 shows comparison of delay. The time which is required by a packet to reach the destination is taken in to account. The graph depicts the delay for existing as against proposed model at 256 KB and 2 mbps, 256 KB and 4 mbps, 512 KB and 2 mbps and 512 KB and 4 mbps for both existing and proposed model. In both the cases when compared to existing system, delay is reduced in model proposed.

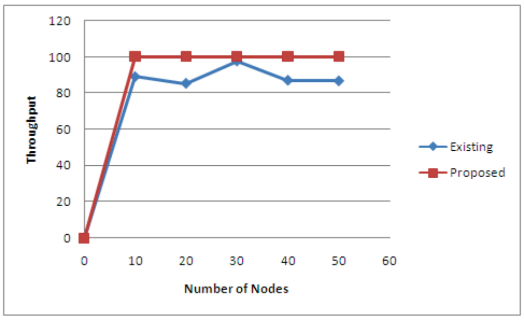
Figure Fig. 7 shows the comparison of jitter variations in delay. It shows that jitter occurrence in the model at 256 KB and 2 mbps, 256 KB and 4 mbps, 512 KB and 2 mbps and 512 KB and 4 mbps for both existing and proposed model. It can be observe as, the jitter is reduced in the proposed model as compared to the existing model. This is achieved due the metrics used in proposed model.

VII. CONCLUSION AND FUTURE WORK

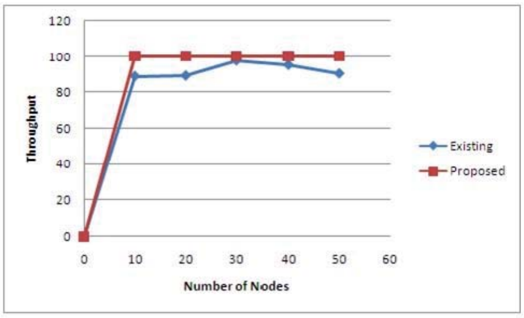
In this work, a novel routing protocol is proposed that helps in transmitting sensitive data successfully to the destination



(a)



(b)



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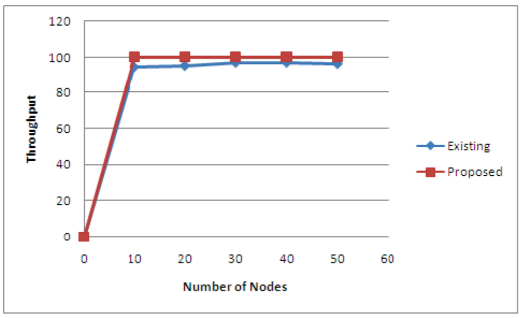
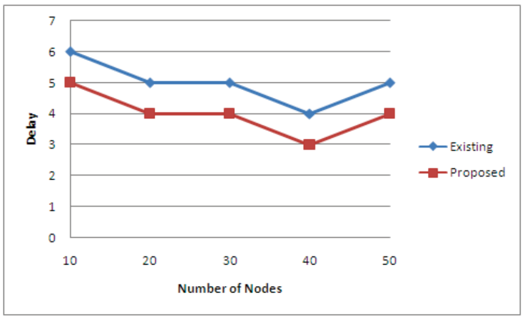
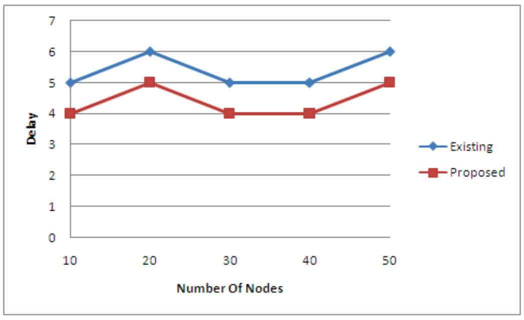


(d)

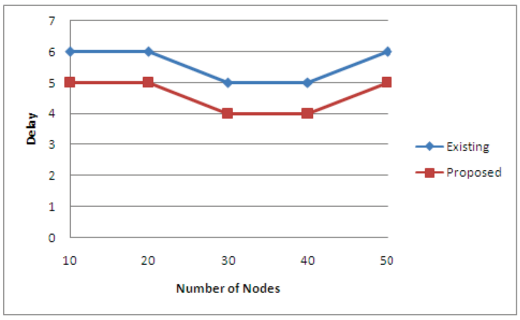
Fig. 5. Throughput variation in proposed Vs existing model (a) at 256 KB and 2 mbps (b) at 256 KB and 4 mbps (c) at 512 KB and 2 mbps (d) at 512 KB and 4 mbps



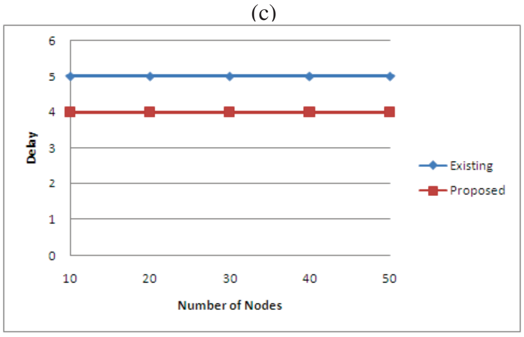
(a)



(b)

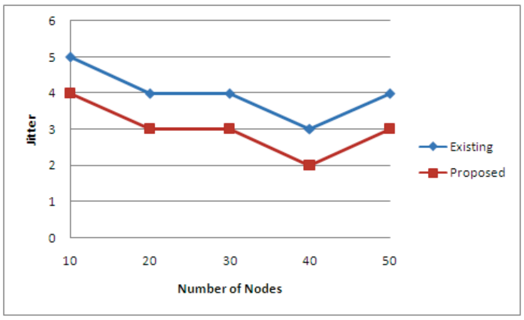


(c)

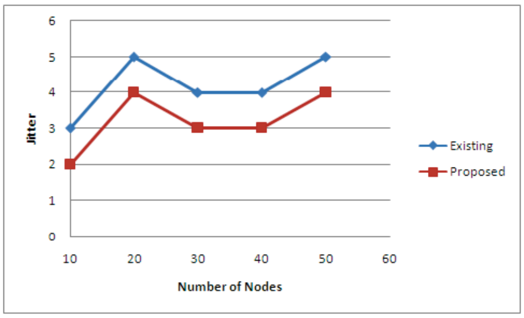


(d)

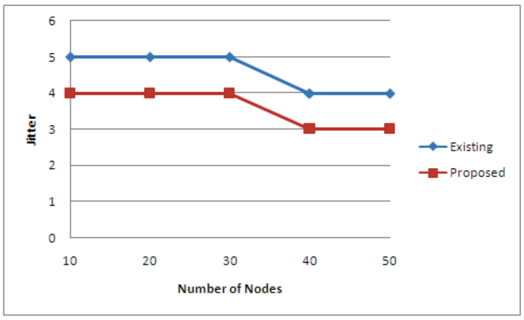
Fig. 6. Delay variation in proposed Vs existing model (a) at 256 KB and 2 mbps (b) at 256 KB and 4 mbps (c) at 512 KB and 2 mbps (d) at 512 KB and 4 mbps



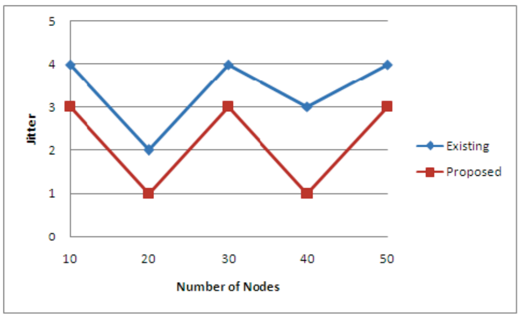
(a)



(b)



(c)



(d)

Fig. 7. Jitter variation in proposed Vs existing model (a) at 256 KB and 2 mbps (b) at 256 KB and 4 mbps (c) at 512 KB and 2 mbps (d) at 512 KB and 4 mbps

by considering PSM state of a node. Incorporating power save mode into the OLSR protocol considerably reduces the number of packets getting dropped due to energy deficiency. A network without power conservation mechanism consumes the battery power of nodes continuously resulting in a faster rate of node deaths. On the other hand, a sleep mode gives a small rest intervals to a node resulting in longer life time of the network. The amount of buffer space required to store packets of a sleep node depends is on load on the network. Sleep mode however incurs longer end-to-end delays for packets of sleeping nodes. This increase in end to end delay is proportional to sleep duration. The result shows the substantial amount of improvement the performance metrics of the network using our proposed model. The nodes remains static in the proposed work and the mobility of the nodes can be considered as future work.

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