Optimized Route-Discovery and Mobility-Aware Model: Guaranteeing Quality of Service Routing for Wireless Sensor Networks

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Abstract

Wireless Sensor Networks (WSNs) are the collection of sensor nodes founding the momentary network without the support of any orthodox centralized administration or infrastructure. In such a situation, it is mandatory for each sensor node to get support of another sensor nodes for advancing the packets to its desired destination node, particularly to the sink node or base station. Handling this situation, several quality of service (QoS) routing strategies have been introduced and focusing on the improvement of throughput and end-to-end delays in wireless sensor networks (WSNs). In such networks, data traffic can be poised into reliability-demanding data packets and time-sensitive data packets. In such situations, energy efficiency, node optimization, mobility of base station and load-balancing are of high significance. Thus, the trade-off in this paper is between network lifetime and ensuring the QoS provisioning.

This paper introduces optimized route-discovery and mobility-aware (ORM) model, which improves the QoS provisioning and prolonging the network lifetime. The ORM model involves the seven components; buffer allocation, distance measurement, signal to noise ratio, bandwidth management, residual energy and optimal path, received-signal strength indicator (RSSI), and moving base station. The goal of these components in ORM is to determine the next node with optimized resources, protecting the data loss, avoiding the congestion caused by buffer-overflow, identifying the node distance prior to route discovery that helps determine the location and distance when node is either movable or immobile. Furthermore, extending the network lifetime, load-balancing algorithm is introduced, which determines the optimized and braided paths. These paths avoid bottleneck and improves the in-order packet delivery, throughput, end-to-end delay, and prolongs the network life time.

To demonstrate the strength of the proposed approach, simulation is conducted using network simulator-2 (NS2) for validity of the work. . The performance of our model is compared to other QoS routing protocols. Simulation result demonstrates that our model surpasses the other routing QoS routing protocols in static and mobility scenarios.

Key words:

Wireless sensor networks, Quality of service, Routing, optimized path, braided paths, mobility.

1. Introduction

Wireless sensor networks (WSNs) comprises of the promising technology mounted for resolving several solutions, covering military, health, civilian, commercial and environmental applications [1],[2] ,[3],[4],[5],[6]. WSNs involve the large number of small and low-cost sensors, which are equipped with computation capabilities and wireless communication [7]. However, despite the benefits, WSNs are strictly limited due to energy limitations posed by the sensor nodes. The energy expenditure of wireless sensor networks depend on the data processing, environmental sensing and wireless communication. Hence, most of the QoS routing protocols aim mostly at the accomplishment of the energy preservation. Since some of the routing protocols designed for WSNs follow the attainment of energy efficiency, but practically are incompatible for QoS provision in WSNs[8]. Furthermore, network density, limited node power, severe bandwidth limitations, dynamicity of the topology and large scale deployments have raised many challenges in the management of WSNs. In addition, buffer overflow and noise have also posed several challenges including congestion, data loss, performance dilapidation and excess energy consumption. The limited memory space causes the buffer overflow and data packets start to drop. As a result, retransmission is required for the lost data packets[9]. Thus, an additional energy is consumed[10]. The buffer detection is largely open issue in WSNs due to limited computational capabilities and limited memory resources.

Furthermore, the routing protocols in WSNs should be designed with minimum communication overhead and low-processing convolution. The sensor nodes generally function in pervasive locations without user involvement. Thus, the routing should be done by using load-balancing scheme to take an adaptive decisions for balancing the load for each route with respect to external environment. Furthermore, the routing protocols must be performance-efficient and scalable[11].

Given the latest advances in wireless sensor networks, it is important to deploy the powerful load-balancing routing approaches to support for the applications such as security monitoring, battlefield intelligence, environmental tracking and emergency response[12]. These applications require multipath QoS routing protocol to create the tradeoff between energy consumption and QoS parameters prior to delivering the data to sink node[13]. The multi-path QoS

Manuscript received Fabruary 5, 2020
Manuscript revised Fabruary 20, 2020

routing protocols establishes multiple paths to balance the network traffic between source-node to destination-node. The main purpose of introducing the multi-path routing protocol is for fault tolerance, bandwidth aggregation, reducing the delay and load-balancing.

The sensor nodes handle the low data volume in low data rate applications. However, the multimedia-driven applications require to determine the status of a buffer prior to sending the data to the next hop because sensor nodes may heavily be loaded due to such applications, and buffer may start to overflow. In addition, buffer overflow invites the congestion that is not insignificant [15],[16],[17]. To handle the congestion, it is significant to determine the sufficient free buffer space prior to delivering the data packets to next hop nodes. There are several approaches available in literature for conventional networks. However, these approaches are too complicated to be introduced in resource constrained WSNs. Additionally, WSNs are varied by nature from wired network because node in WSN holds single queue that is connected with a single transmitter. Furthermore, noise and distance of nodes are also more important for discovery of the path for guaranteeing the QoS provisioning. The most of the approaches to discover the paths based on the residual energy of the node. These approaches are not workable in particular situations for example when sensor node is farther from sink node and even holds the high residual energy, but long distance and noise weaken the signal strength. As a result node does not receive all sent packets[18]. Efficient use of buffer and energy of sensor nodes are trade-off, which are highly desirable noise when designing the multi-path routing to guarantee the QoS provision for WSNs. We focus on the multi-path quality of service routing protocol for extending the network lifetime and improving the throughput, reducing the end-to-end delay and on-time packet delivery. The multi-path routing is based on optimized selection of disjoint and braided paths to achieve load balancing though splitting the network traffic on the primary path (optimized path) and braided paths (other alternative paths). Optimized node selection process improves the delivery of data reliability using received signal strength indicator and residual energy components. In order to transmit the data over optimized and braided paths, load-balancing algorithm is used to guarantee the load-balancing over the network traffic to avoid the congestion and improves the throughput and reduce latency. Furthermore the paper attempts to address the congestion and data overflow due to buffer limitations. We also detect the noise, improving the network lifetime using moving base station and determine the distance including the location of node that helps in the discovery of optimized path.

The remnants of the paper are organized as follow: In Section 2, we present an optimized route-discovery and mobility-aware (ORM) model. Section 3, describes the load-balancing algorithm. Section 4, presents simulation-setup and performance evaluation. Finally, section 5 concludes the paper.

2. Optimized Route-Discovery And Mobility-Aware Model

Guaranteeing the QoS routing in wireless sensor networks is highly challenging problem due to scarce properties of the sensor node. Our aim is to present the ORM model to improve the QoS provisioning and prolonging the network lifetime. Thus, we have introduced following components to achieve desired objectives.

- Residual Energy and Optimal Path
- Bandwidth Management
- Buffer Allocation
- Distance Measurement
- Signal-to-noise Ratio
- Received-Signal Strength Indicator
- Moving Base Station

A. Residual Energy and Optimal Path

Determining the optimum node discovery, each path between source node and destination node is defined as $P = (P_1, P_2, \ldots, P_n)$. Where, P_1 is the source node and P_n is the base station, which spans over $P_n - 2$ intermediate nodes between source and destination. Thus, residual energy of each intermediate node can be determined after creating the corresponding path and finishing the one event-detection cycle obtained as follows:

$$R_e = P + \sum_{I=1}^{n-1} E\,(P_i\,, P_{i+1}) \qquad (1)$$

where 'R_e' is the residual energy of each intermediate node on the path, and $E(P_i\,, P_{i+1})$ is the required energy for routing the message between two intermediate nodesP_i and P_{i+1}. Let us assume 'X' is the set of possible paths $X = x_1, x_2, x_3, \ldots, x_n$ between source node and destination. Therefore, optimistic path between two nodes can be determined as

$$x_k = \max\{(R_e):\ x_k \in X \qquad (2)$$

where $'x_k'$ is the optimum path between two nodes.

B. Bandwidth Management

The optimal path requires reasonable bandwidth to transmit the packets; let us consider 'S' is the set of sensor nodes in the network as $S = \{S_1\,, S_2\,, S_3\,, S_n\}$. The initial energy of each node is set in the network prior to detecting the events. Thus, there are 'S' set of sensor nodes with initial energy $'I_e'$. For the randomized set of sensor nodes, transmission rate and bandwidth need to be defined. Thus, transmission rate $'S_{t\Delta}'$ of each sensor node is obtained as follows:

$$S_{t\Delta} = \frac{T_{p\Delta}}{t\Delta} \quad (3)$$

Where $'T_{p\Delta}'$: total number of transmitted data packets , and $'t\Delta'$: the time interval.
Therefore, the bandwidth for the sensor nodes can be determined as follows.

$$S_{b\Delta} = \frac{(P_{ack})^{x_k}}{t\Delta} \quad (4)$$

where '$S_{b\Delta}$': Bandwidth of sensor node, 'P_{ack}': acknowledged packets, and 'x': possible optimum path for sending the packets over the network.
Let us assume every directed connection between two nodes (s_1, s_2) on the optimum path $'x_k'$ is (P_1, P_2) where sensor node $s_1(s_2)$ is the initiating end of the connection, $[s_1 \in \{P_1, P_2, \dots, P_n\}, s_2 \in \{P_2, P_3, \dots, BS\}]$ is assigned a metric defined in terms of delay, bandwidth and transmission energy. Thus, the transmission energy for sending the data packet from one sensor node to another sensor node is associated with the link(s_1, s_2) (r), is the amplifier energy of sensor node s_1, which is the function of $r_{s_1 s_2}$, the distance between two sensor nodes s_1, s_2 and implicit propagation scheme. The corresponding delay for creating the connection between two sensor nodes (s_1, s_2) is specified by$'D_{s_2}'$, the average delay caused by the packets being transmitted to sensor node $'s_2'$, and available bandwidth between the two sensor nodes (s_1, s_2) corresponding to link is '$S_{b\Delta}$' that is minimum bandwidth. When routing is in the progress, the cost metric $C_{s_1 s_2}$ for two sensor nodes consist of combination of direct link between sensor nodes(s_1, s_2) create the delay and consumed transmission energy for each link between sensor nodes (s_1, s_2) in the network can be explained as follows:

$$C_{s_1 s_2} = \beta E_{a\Delta}\left(r_{s_1 s_2}\right) + (1-\beta) D_{s_2}, \forall link\ (s_1, s_2) \quad (5)$$

where $'E_{a\Delta}'$: Energy consumed for amplifying the signal, β: configurable parameter for transmission energy and delay metrics used for route selection.
The amplifier energy function can be determined as

$$r_{s_1 s_2} = \delta r_{s_1 s_2} * \omega \quad (6)$$

where 'δ' : Free space power amplification, 'ω': amplifying factor.
Therefore, if $r_{s_1 s_2} \le r_0, \omega = 2$ and $= \gamma$, then it is called as one-way amplification factor. On the hand, if $r_{s_1 s_2} \ge r_0, \omega = 4\ and\ \delta = \partial,$ then it is called as two-ray amplification factor. Thus, threshold distance can be determined as

$$r_0 = \sqrt{\frac{\gamma}{\partial}} \quad (7)$$

where γ: threshold value for one-way amplification factor, and ∂: threshold value for two-way amplification factor.

In the next step, we have to determine the minimum cost for link 'L_1' using optimum path 'x_k'. Thus, the total cost for creating the link between $s_1\ and\ s_2$ is $C_{s_1 s_2}$ that can be guaranteed using the delay '$D\Delta'$ and bandwidth requirements $'B\Delta$' for the connection.

$$Cx_k = \sum_{\forall (C_{s_1 s_2}) \in Q} C_{s_1 s_2} \quad (8)$$

where Cx_k: the cost for optimized path. Hence, the bandwidth for the path can be obtained as

$$B\Delta_{path} = \min\left(S_{b\Delta_{s_1 s_2}}\right) \ge B\Delta \quad \cong \forall\left(C_{s_1 s_2}\right) \in Q \quad (9)$$

Where '$S_{b\Delta_{s_1 s_2}}$': Bandwidth consumed for creating the path between sensors ($s_1\ and\ s_2$), and $B\Delta_{path}$: Assigned bandwidth for route.

$$D_{e\nabla} = f\left(\sum_{\forall (C_{s_1 s_2}) \in Q} C_{s_1 s_2}\right) \le D\Delta \quad (10)$$

where $'D_{e\nabla}'$: End-to-End delay for measuring an event and until receiving the information by base station. Based on (10), we deduce that '$D_{e\nabla}$' is the total delays for choosing the connection along the optimum path 'x_k'.

C. Buffer Allocation

Each sensor node $S = (S_1, S_2, S_3, S_n)$ measure the all traffic flows $'F(m,n)'$ passing from each link $L = (L_1, L_2, \dots, L_n)$, $\forall L_1, L_2, \dots, L_n \in L$. If $F_{nt}(m,n)$ is measurement done in the new time interval, and $P_k(P_{k1}, P_{k2}, P_{k3}, \dots, P_{kn})$ is the number of packets. Let us assume number of packets $P_k(P_{k1}, P_{k2}, P_{k3}, \dots, P_{kn})$ received by S_1 from sensor node S_2 over the link L_1 during the time interval $'t\Delta'$. Thus, size of buffer measured in new interval can be obtained as

$$F_{nt}(m,n) = \sum_{P_{k1} \in P_k} \frac{1}{S_1(P_k)} \quad (11)$$

Where' $S_1(P_k)'$: Already existing packets in the buffer of sensor node.
If sensor node $'S_1'$ is congested either due to bottleneck (heavy traffic) or full buffer, then buffer limit for each sensor nodes can be calculated as follows:

$$b\rho(S) = \frac{F(P_k)}{\rho(s) + \sum_{S_1 \in S} S_1\{F(P_k)\}} r(P_k) \quad (12)$$

Where '$b\rho$': Buffer limit, $'F(P_k)'$: The number of transmitted packets out of the buffer, '$r(P_k)$': The rate of packets transmitted in per second, '$\rho(s)$' : The source of the data , and' $S_1\{F(P_k)\}$: Buffer limit of 'S_1' sensor node.
The sensor node forwards the packets that can be measured locally, if $\rho(s)$=1 then 's' is the data source otherwise $\rho(s) = 0$. The sensor node 'S_1' advertise the buffer limit '$b\rho$' to the sensor node 'S_2' possibly by using

piggybacking in the acknowledgement packet. In response, the sensor node 'S_2' applies a rate limit (actual rate on path) '$B\Delta_{path}$' that is bounded by limit. If sensor node 'S_1' itself is data source, it will assign buffer to node 'S_2' as follows

$$b\rho(S_1) = \frac{1}{1 + \sum_{S_1 \in S} \quad S_1\{F(P_k)\}} r(P_k) \quad (13)$$

The neighbor node attempts to enforce a buffer rate limit, it may casue the congestion; if buffer capacity of the receiving node is full, then it administers rate limits. This process is applied for the data sources. Finally all the exaggerated data sources enable to adjust the packets rates based on allotted fair bandwidth. Note that only congested node administers the rate limit that is updated periodically.

When the congestion state proceeds to sensor node 'S_1' then buffer rate limit is stopped. This situation can be happened by raising the buffer rate limits of sensor node 'S_1'. The Sensor node 'S_1' is capable to identify the situation of the congestion by detecting the fullness of the buffer, and when that situation happens. The sensor nodes fix the buffer rate limits to be $b\rho(S)$) and $b\rho(S_1)$, rather than over-setting them. As a result, a sensor node discontinues enforcing buffer rate limits once its congestion state is detached (buffer is deflated) and the data rates at which node accepts packets from the neighboring nodes are lesser than the buffer rate limits.

D. Distance Measurement

Based on the transmission rate '$S_{t\Delta}$' of each sensor node in the sensing area of the sensor network, the clustering process is initiated between clustering nodes and cluster head nodes for determining the optimistic path. This process involves the messaging that holds the information regarding the location of the sink node '$\aleph_s$' in wireless sensor networks. In addition, all the sensor nodes detect their locations '$\mathcal{D}\rho$' from sink node based on the Euclidian distance.

$$r(S_1) = \sqrt{\mathcal{D}\rho(\aleph_s) - \mathcal{D}\rho(S_1)^2} \quad (14)$$

Where '$r(S_1)$': Distance of sensor node from sink node, '$\mathcal{D}\rho(\aleph_s)$' : Location of sink node, $\mathcal{D}\rho(S_1)$: location of sensor node '(S_1)' after detecting the distance.

Our goal is to determine an optimized disjoint (primary) path and braided paths for data communication. Thus, the sensor node that possesses shortest distance '$r_\alpha(S_1)$' connects itself with disjoint path. Likewise, sensor node that has extended distance '$r_\beta(S_1)$' from the sink, which joins the braided path. Our approach is applied with lower and higher level of clusters in hierarchy. Let '$r(S_1)$' be the distance between source node and sink node and '$S_{t\Delta}$' be the transmission rate and '$E(S_1)$' be transmitted energy of sensor node that is proportional to the received signal strength. Thus, transmitted power '$P(S_1)$' of the node for each cycle can be obtained as

$$P(S_1) = r(S_1)\mu\sigma * S_{t\Delta} \quad (15)$$

where 'μ': constant value that is considered as the requirement of signal strength, and 'σ' : distance loss factor. In this contribution, we only assume ideal MAC and only interference is detected due to background that is set to be at the constant rate. Hence, the received signal strength deduces the signal to noise ratio. Thus, the energy consumption for sending one unit of data over the medium with distance '$r(S_1)$' can be obtained as

$$r(S_1)\mu\sigma = E(S_1) * \frac{1}{S_{t\Delta}}$$

$$r(S_1)\mu\sigma - E(S_1) * \frac{1}{S_{t\Delta}} = 0$$

$$r(S_1)\mu\sigma - \frac{E(S_1)}{S_{t\Delta}} = 0$$

$$r(S_1)\mu\sigma = \frac{E(S_1)}{S_{t\Delta}}$$

$$E(S_1) = r(S_1)\mu\sigma * S_{t\Delta} \quad (16)$$

In the wireless network, a major source of loss signal is attenuation. Fundamentally, the transmission data rate increases then communication range decreases. Thus, bit error rate is one of the important parameters that can be mapped into anticipated signal-to-noise ratio (SNR) explained in next section.

E. Signal-to-Noise-Ratio (SNR)

If data transmission rate increases, then error rate also increases. In this situation, transmitter 'T_x' requires higher SNR value to obtain same bit error rate at the receiver side. Thus, the relationship between SNR 'ŔΔ' and transmitter power 'T_{xp}' can be obtained as

$$\acute{R}\Delta = \frac{T_{Xp}}{N_p} \varphi \quad (17)$$

Where φ: channel attenuation, and N_p: Noise power. We can define noise power as follows:

$$N_p = N_d * T_{sr} \quad (18)$$

N_d: Noise power density, 'Δtx': Transmission rate, ə̡ : modulation pattern size, ∃Δ: Energy per bit , and T_{sr}: Transmission symbol rate can be obtained as

$$T_{sr} = \frac{\Delta tx}{ə̡} \quad (19)$$

Therefore, SNR is determined for background noise as

$$\acute{R}\Delta = \frac{\exists\Delta}{N_d} * ə̡ \quad (20)$$

F. Received-Signal Strength Indicator

The nodes estimate the distance based on relative angles. Thus, the signal strength is translated into distance. As a result, the existing techniques experience the problem due to noise interference, multi-path fading, and irregular signal propagation that highly affect the correctness of ranging estimate. To overcome these problems, we apply improved approach of determining the RSSI for optimized routing path. The localization accuracy can be endorsed to fulfill the requirements for optimization. We apply localization refinement, region partition and regular node placement. In RSSI, the distance between transmitter $'T_x'$ and receiver $'R_x'$ can be obtained by using long-normal shadowing approach described as:

$$R_p(r) = R_p(r_\circ) - 10nlog_\circ\left(\frac{r}{r_\circ}\right) + G^\circ \quad (21)$$

where $R_p(r)$: the received power, $R_p(r_\circ)$: received power of point, r : the distance between receiver and transmitter, $r_\circ$: reference distance, n : exponent factor for power loss, and G° :Gaussian random variable that is used for the change of the power when setting the distance. In practical, basic shadowing model is used for determining the distance based on RSSI.

$$R_p(r) = R_p(r_\circ) - 10nlog\left(\frac{r}{r_\circ}\right) \qquad (22)$$

We assume that reference distance is 1 meter, so can obtain resilient RSSI as follows:

$$RSSI = R_p(r) = \Delta\forall - 10nlogr \qquad (23)$$

where $\Delta\forall$: received signal strength. This RSSI-based localization covers mentioned limitations and also helps determine an optimize route.

G. Moving base station

In this section, we use moving base station to extend network lifetime. Let us prove whether this perception is definitely correct. We assume that the base station travels in such a fashion that it shows same frequency at every place of the network in the long run. We set initially the ideal position of base station for extending the network lifetime. The ideal position of the base station is center of the network from energy efficiency perspective. Let us assume that base station be at the $A(p_A, p_A)$ position and consider tiny area R that measures $(r_p \times r_q)$ and is centered on $(p \times q)$ as depicted in Figure 1. Based on Euclidean distance $r = \sqrt{(p - p_A)^2 + (q - q_A)^2}$ from the center of 'R' to 'A'. Thus, the optimized routing path 'p' from 'R' to 'A' is linearly used in distance 'r' due to applying other factors mentioned above. In resulting, the consumed energy for transmitting data from 'R' to 'A' is $E\gamma \times \forall dt$.
Where $\forall dt$: The amount of generated data within time 't', and $E\gamma$: The consumed energy for transferring the amount of data from 'R' to 'A'.

Thus, the total energy consumption can be determined as

$$E_{tot} = \iint_i^\pi E\gamma \times \forall dt \; dxdy \qquad (25)$$

It is clear that ideal position of base station can cause the minimizing the total energy, which can be described as follows:

$$\iint_{-Z}^{Z}(\sqrt{(Z^2 - q^2)}\left[\sqrt{(p - p_A)^2 + (q - q_A)^2}\right]dxdy$$

$$\frac{1}{2}\pi Z^2(2{p_A}^2 + 2{q_A}^2 + Z^2) \qquad (26)$$

If it gets the minimum value $p_A = q_A = 0$, then the base station will be placed at the center of the network.
We do model the mobility behavior of base station.
Let us consider an energy consumption of a random node 'k', which is at the distance 'r' from the center of the network, with respect to the position 'p' of moving base station 'A'. As depicted in Figure 5. We assume that sensor node 'k' is charged with a load forwarding capacity from a small sector
Δs. Once the base station stays at 'A' on segment 'X'. As, 'X' and 'Y' are intersections of line kA , X and Δs, which are centered on the line 'kA' with an angle $'\theta'$. Here, θ is decreasing function of |kA|. For simplification, we use an average value 0.01 for θ, which can be estimated for the positions $\Delta s1$ and $\Delta s2$ between 'A' and 'k'. To make further calculation, we also assume that A is positioned in another sector γs centered on line 'kX' with an angle
$\theta 1$. When $\theta 1 \leftarrow 0$, it goes back to the position where 'A' is on the segment 'kX'. Hence, base station 'A' can move everywhere in the network depicted in Figure 1. Thus, an average load of base station can be calculated as follows when sending the data to the moving base station.

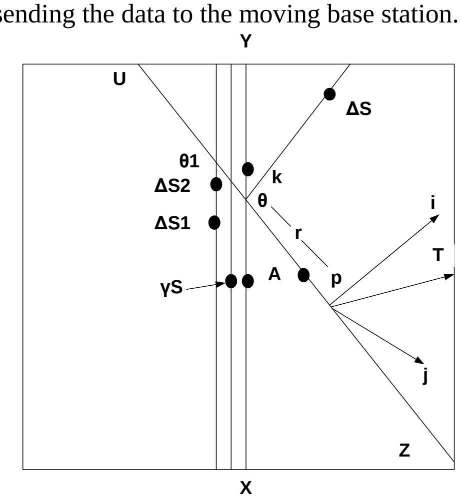

Fig. 1 Showing the position of moving base station and arbitrary node

$$\sum_{\beta=0}^{2\pi}(\beta \times \frac{(T^2 - r^2)^2\theta\mu\lambda\Delta s1}{4\pi T^2} \qquad (27)$$

where μ : Node density, $\Delta s1$: position of node, λ : Frequency of the node, r: Distance of the node from the center of the network & T: End point of the network.

3. Load Balancing

To balance the load over the network, the traffic is routed through multiple routes. With equal load balancing, network traffic is utilized efficiently. We use dynamic load-balancing approach for all paths from source to destination. The bandwidth is distributed over these paths according to the traffic load. The paths consist of optimized and braided paths. Optimized path is the primary path that is allotted more bandwidth and braided paths are alternate paths to balance to traffic depicted in Figure 2. The bandwidth is reserved for each route based on optimized load balancing (OLB) algorithm. Let us assume that expected load $'\text{ᶕ}'$ on optimized and braided paths need to be updated. This is the reason that original $'\text{ᶕ}'$ is distributed on the all candidate paths and their respective values are updated as follows

$$\text{ᶕ} = \text{ᶕ} - \forall(\vartheta,\varpi)\Phi + \Phi_{\text{Ѧ}} \quad \forall \in R_{\Phi}$$
$$\text{ᶕ} = \text{ᶕ} - \forall(\vartheta,\varpi)\Phi + (K - \acute{K}) \quad \forall \in R_{\Phi 1}$$
$$\text{ᶕ} = \text{ᶕ} - \forall(\vartheta,\varpi)\Phi \quad \forall \notin (R_{\Phi} \cup R_{\Phi 1}) \qquad (28)$$

where $'\vartheta'$: source, and $'\varpi'$: distination. We deduct the bandwidth-demand value $'\forall(\vartheta,\varpi)\Phi'$ that is passed through each link. Each link creates optimized $'R'_{\Phi}$ and braided paths $'R'_{\Phi 1}$ over the network. Optimized path $'R'_{\Phi}$ is the primary route. The tangible reservation is$'\Phi'_{\text{Ѧ}}$. In case of reserved bandwidth for optimized load balancing, $\Phi_{\text{Ѧ}} = \Phi$ for all the links $L_1 \in R_{\Phi}$. From other perspective, in case of reserved bandwidth-delay for OLB, we divide an end-to-end delay into different each-link delay limitations. As a result, each link along the optimized and braided paths has the different reserved bandwidth$'\Phi_{\text{Ѧ}}'$.
Thus, $\Phi_{\text{Ѧ}} \geq \Phi$. For the links along a braided path $'R_{\Phi 1}'$, the $\left(K - \acute{K}\right)$ in both cases ranges between 1 and $'\Phi_{\text{Ѧ}}'$ based on the shared bandwidth on the links $'L_1'$. K: Initial energy of link and $\acute{K}$: residual energy of link, which are calculated before and after reserving the bandwidth for paths of network. The expected load $'\text{ᶕ}'$ for each path is updated over each link. In the end, having setup the all possible routes, the most utilized links will get highest value.

Algorithm 1: Determining the optimized and braided path for end-to-end bound delay $'\beth'$and bandwidth of Φ.

1. Input: Optimized specification $(\vartheta, \varpi, \Phi, \beth)$
2. Expected load of each link ᶕ , residual energy of link $\acute{K}$, and total energy Σ
3. Set ϑ of T candidate pair of braided pairs (M_1, M_2)
4. Output: optimized path R_{Φ} and braided path $R_{\Phi 1}$
5. While all links L_1 do
6. $t_{\Delta} = \frac{\text{ᶕ}}{K}$
7. *end while*
8. $O_{min} = infinity$; O_{min}: (Rest of links except optimized and braided links)
9. while each braided pairs (M,N) ∈ ϑ that meets the requirements of $(\beth, \Phi)$ do
10. Divide $\beth$ individually along the braided pairs $M_1$and M_2
11. Recalculate the residual energy of link $\acute{K}$
12. Recalculate the link costs $t_{\Delta} = \frac{\text{ᶕ}}{K}$
13. Recalculate the network metric N_m
14. If $N_m < O_{min}$ then
15. $O_{min} = N_m$; R_{Φ} =M_1 ; $R_{\Phi 1} = M_2$
16. *endif*
17. End while
18. If $O_{min} > \delta$; δ: value of braided link
19. Reject O_{min}
20. else
21. Choose R_{Φ} , $R_{\Phi 1}$ as optimized and braided links for routing.
22. end if

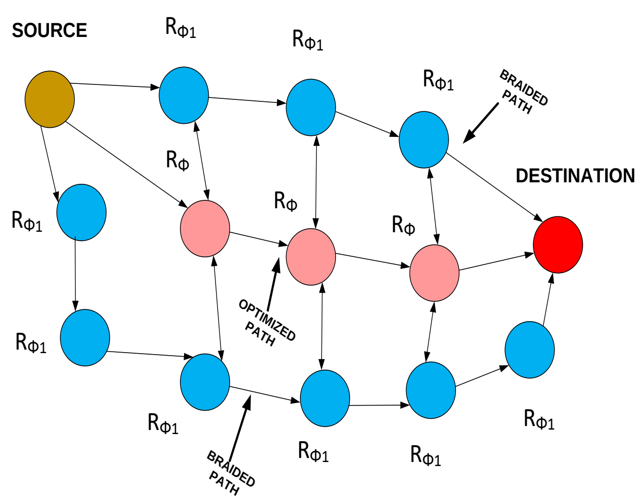

Fig. 2 Optimized route discovery process using load-balancing approach

4. Simulation Setup and Performance Analysis

In order to demonstrate the performance of optimized route-discovery and mobility-aware model and load-balancing algorithm, the wireless sensor network was constituted that covers the area of 600 m x 600 m. The performance of our approach is compared with other QoS routing protocols: Mobicast[16], QoS and Energy Aware Multi-Path Routing Algorithm (QEMPAR)[17] and Cluster-based QoS aware routing protocol (CQARP)[18], Multi-Path and Multi-SPEED (MMSPEED) Protocol [19], Multimedia Geographic Routing (MGR)[20] and Sequential Assignment Routing (SAR)[21].The network considers the following toplogy.

- The Dynamic and static sinks are set farther from the sensing field.
- Each node is initially assigned the uniform energy.
- Each node senses the field at the different rates and responsible to transmit the data to sink node or base station.
- The sensor nodes are 10% to 60% mobiles.
- Each sensor node involves the homogenous capabilities with same communication capacity and computing resources.
- The location of sensor nodes is determined in advance.

The aforesaid network topology is suitable for several applications WSNs, such as home monitoring, reconnaissance, biomedical applications, airport surveillance, fire detection, home automation, agriculture and animal monitoring. The real application of this introduced model is used for airport surveillance where the sensor nodes are either static or mobile. , which are used for monitoring the travelers and staff members. The simulation was conducted by using network simulator-2[25]. The scenario consists of 400 homogenous sensor nodes with initial energy 4.5 joules. The base station is located at point (0, 1100). The packets size is 256 bytes. Initial energy of node is set 4.5 joules. The rest of parameters are explained in table 1.

Table 1: Simulation parameters and its corresponding values

PARAMTERS	VALUE
Size of network	600 × 600 square meters
Number of nodes	500
Queue-Capacity	25 Packets
Number of frames	350 frames
Distance from the base station to the center of WSN	1100 meter
Mobility Model	Random way mobility model
Maximum number of retransmissions allowed	03
Initial energy of node	4.5 joules
Size of Packets	256 bytes
Data Rate	250 kilobytes/second
Sensing Range of node	40 meters
Simulation time	9 minutes
Average Simulation Run	10
Frame rate	40 fps
Reliability	[0.8, 0.9]
Reporting rate	1 packet/s
Base station location	(0,500)
Transmitter Power	12 mW
Receiver Power	13 mW
Mobility %	10%, 20%, 40% and 60%
Buffer threshold	1024 Bytes

A. Throughput with stationary nodes

Throughput is an average-mean of successfully delivered data packets. Figure 3 shows the throughput performance of the model based on stationary nodes. We observe that once simulation time increases then throughput performance starts dropping, but ORM is not highly affected as compared with other routing protocols; QEMPAR, Mobicast and CQARP. After completion of simulation time, ORM reduces only 2Kb/sec throughput while other competing protocols reduce from 12.5 to 17.75 Kb/sec. Based on the obtained result, we prove that our model is effective when nodes are stationary.

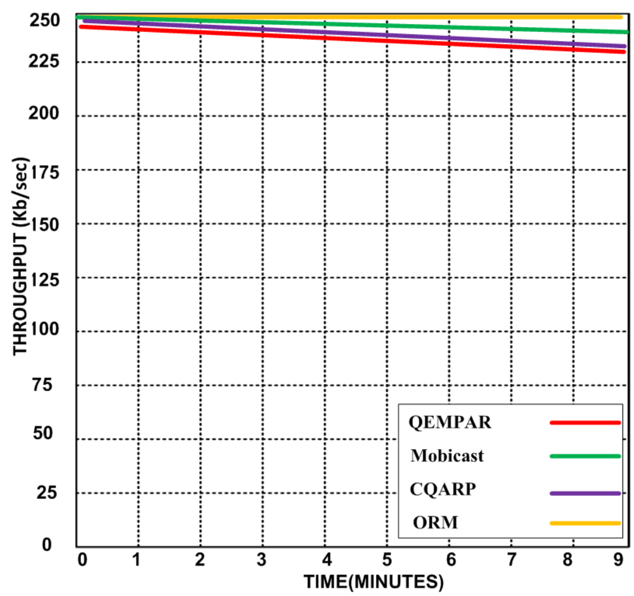

Fig. 3 Throughput with static nodes

B. Throughput with different mobility ratios

The mobility affects the throughput performance. The throughput performance of network reduces when ratio of mobile sensor nodes (mobility of nodes) start to increase. We show in Figures 3-7 that mobility affects the performance of all competing protocols, but throughput of ORM is still higher than other QEMPAR, Mobicast and

CQARP routing protocols. In fact, the higher mobility ratio causes the lower packet delivery ratio. We also observe that drop in transmission of the packets causes of retransmission of the packets. As a result, additional energy is consumed for sending the lost packets. Throughput performance with different mobile sensor ratios and reduction in percentage are given in Table 2 and Table 3 respectively.

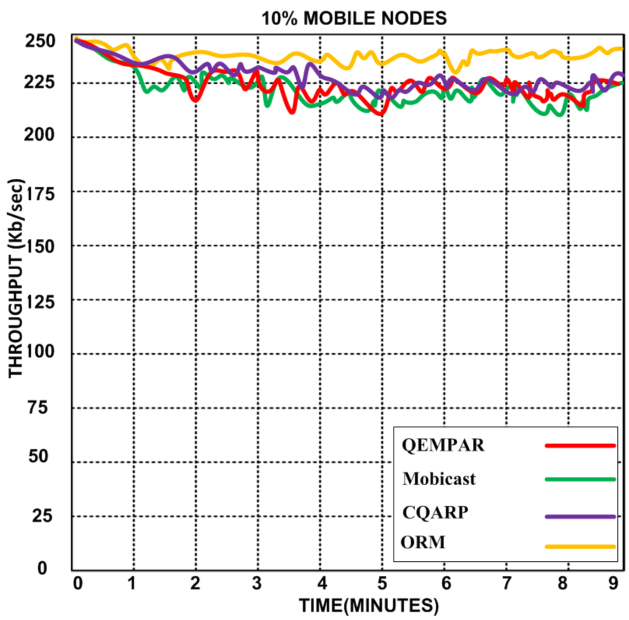

Fig. 4 Throughput with 10% mobile nodes

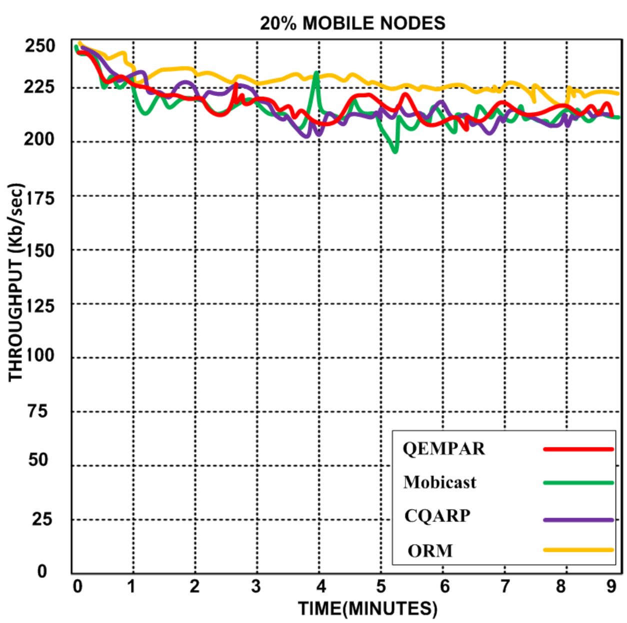

Fig. 5 Throughput with 20% mobile nodes

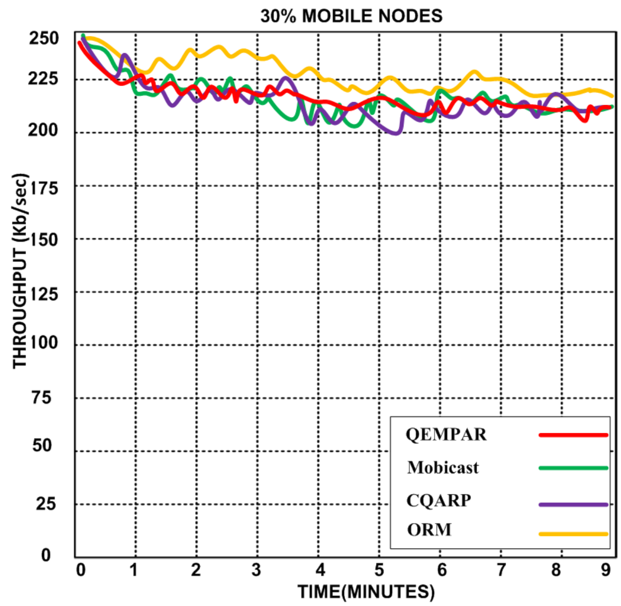

Fig. 6 Throughput with 30% mobile nodes

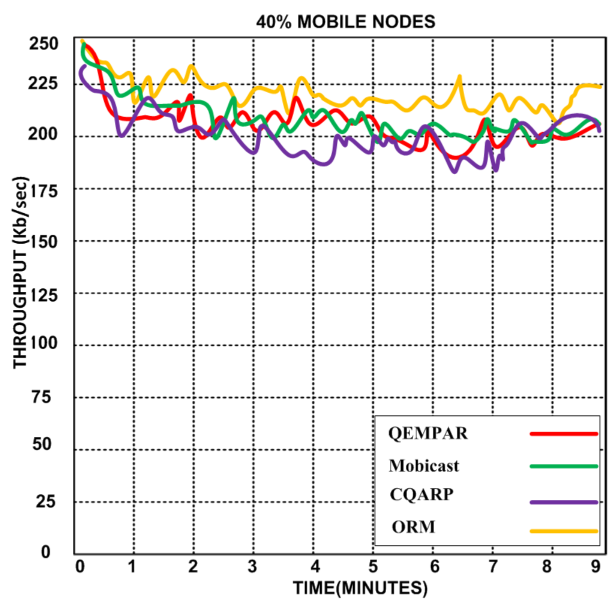

Fig. 7 Throughput with 40% mobile nodes

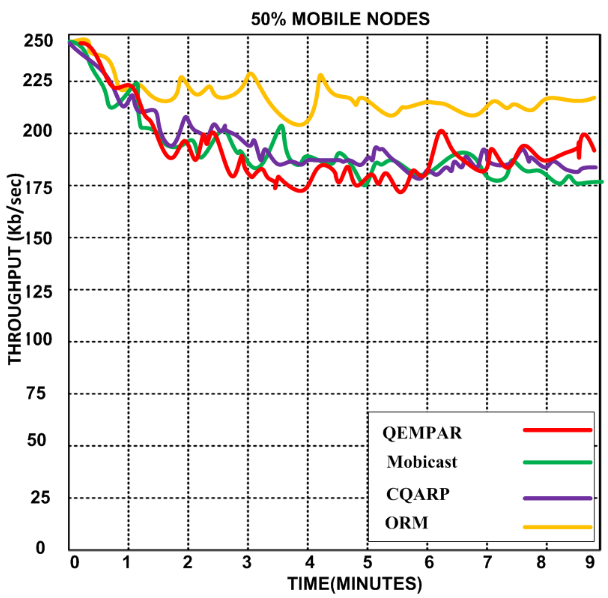

Fig. 8 Throughput with 50% mobile nodes

Table 2: Throughput performance of protocols with different mobility ratios (mobile sensor nodes)

Name of protocol	10% Mobile sensor node	20% Mobile sensor node	30% Mobile sensor node	40% Mobile sensor node	50% Mobile sensor node
QEMPAR	217.4 Kb/Sec	212.9 Kb/Sec	211 Kb/Sec	201.3 Kb/Sec	178.2 Kb/Sec
Mobicast	219 Kb/Sec	209 Kb/Sec	207.9 Kb/Sec	202.1 Kb/Sec	190.2 Kb/Sec
CQARP	227 Kb/Sec	213 Kb/Sec	212.5 Kb/Sec	198.5 Kb/Sec	191.6 Kb/Sec
ORM	245 Kb/Sec	227 Kb/Sec	224 Kb/Sec	215 Kb/Sec	209 Kb/Sec

Table 3: Reduction of throughput performance in percentage % with different mobility ratios (mobile sensor nodes)

Name of protocol	Reduction with 10% Mobile sensor node	Reduction with 20% Mobile sensor node	Reduction with 30% Mobile sensor node	Reduction with 40% Mobile sensor node	Reduction with 50% Mobile sensor node
QEMPAR	13.04%	14.84%	15.6%	19.48%	28.72%
Mobicast	12.4%	16.4%	16.84%	19.16%	23.92%
CQARP	9.2%	14.8%	15%	20.6%	23.36%
ORM	2%	9.2%	10.4%	14%	16.4%

Based on the simulation results, we have demonstrated that competing protocols QEMPAR, Mobicast and CQARP are highly affected with 10% mobile sensors, but 20%, 30%, 40% and 50% mobile sensor nodes slightly reduce the throughput except QEMPAR that also highly drops the throughput with 50% mobile sensor nodes; whereas our proposed model ORM is affected with 20% mobile sensor nodes, but even performs better with other percentage of mobile sensor nodes. However, the overall performance of ORM is acceptable.

C. Remaining alive nodes with stationary nodes

We describe the number of remaining alive nodes in Figure 8 after performing some simulation rounds (Environment sensing rounds) using stationary nodes. We observe that once simulation rounds increase then an energy of nodes depletes. As a result, the nodes start to die. ORM outperforms QEMPAR, Mobicast and CQARP. At the end of 135 simulation rounds, ORM has remaining 483 alive nodes whereas other protocols have remaining 450 alive nodes. Simulation results demonstrate that ORM loses 3.4% nodes, but competing protocols lose 10% nodes.

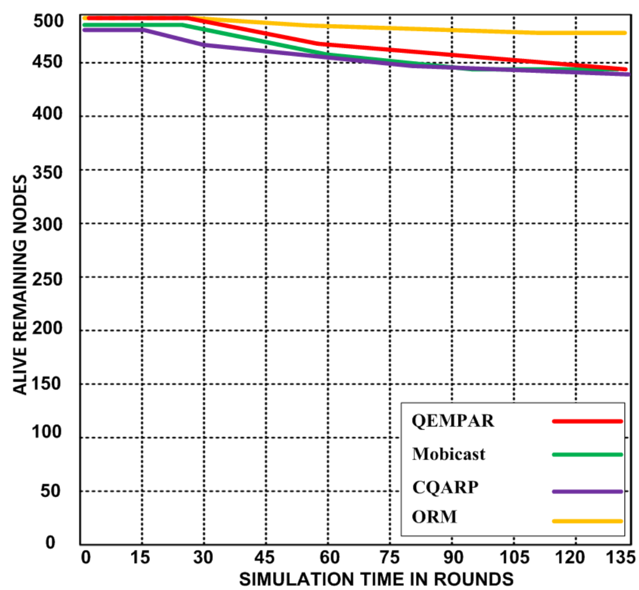

Fig. 9 Alive remaining node VS sensing routs with static nodes

D. Remaining alive nodes with mobility

The mobility affects the performance of the network, but performance can be improved using effective model. In Figure 9-13, we show the behavior of network in presence of our proposed ORM and other competing QEMPAR, Mobicast and CQARP routing models. We use 10%, 20%, 30%, 40% and 50% mobile sensor nodes and measure how many nodes survive after completion of sensing rounds. We observe that with increase of mobile sensor nodes, the network starts to lose the nodes that situation gets worse with higher number of mobile sensor nodes. All the participating protocols are affected. However, ORM outperforms to other competing routing protocols. We demonstrate that ORM improves the network lifetime despite of mobile sensor nodes. The number of remaining alive nodes and percentage of the lost nodes are illustrated in Table 4 and Table 5 respectively.

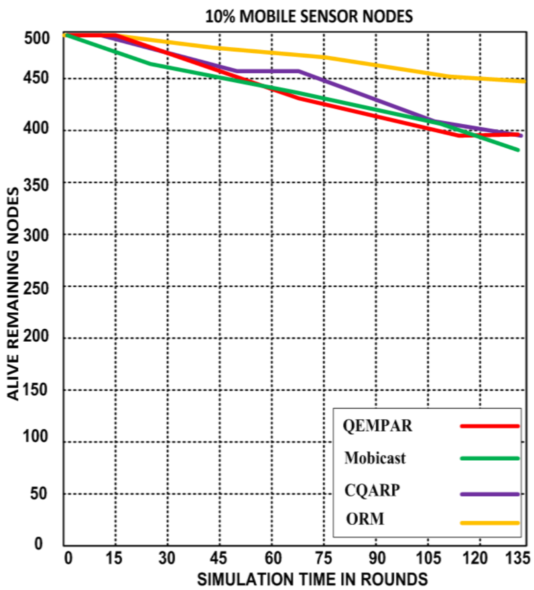

Fig. 10 Alive remaining node VS sensing routs with 10% mobile sensor nodes

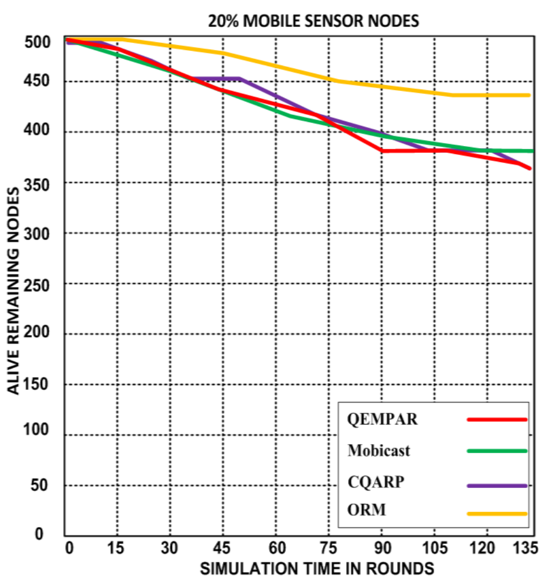

Fig. 11 Alive remaining node VS sensing routs with 20% mobile sensor nodes

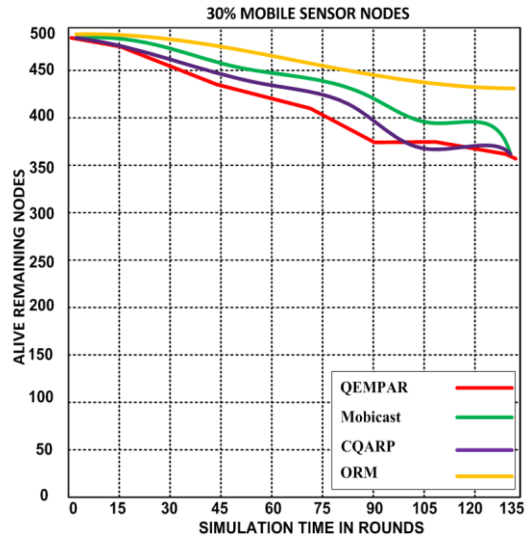

Fig. 12 Alive remaining node VS sensing routs with 30% mobile sensor nodes

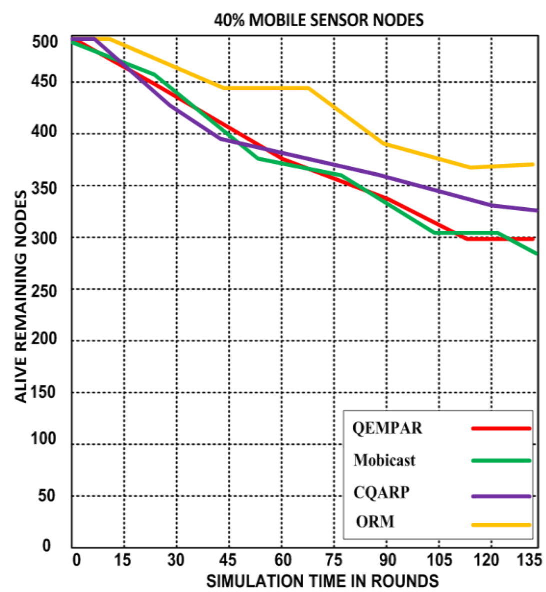

Fig. 13 Alive remaining node VS sensing routs with 40% mobile sensor nodes

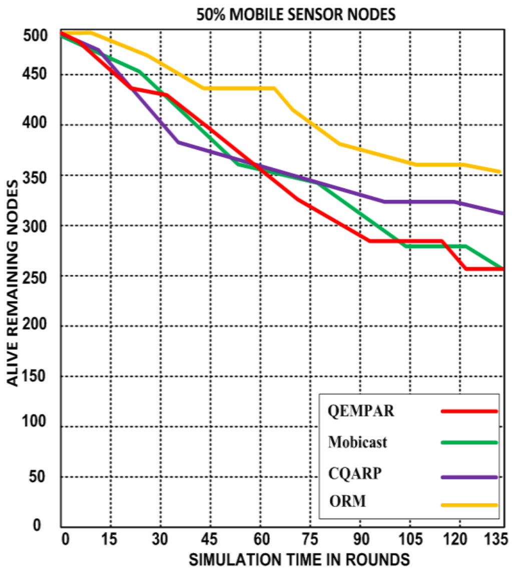

Fig. 14 Alive remaining node VS sensing routs with 50% mobile sensor nodes

Table 4: Number of Remaining alive nodes with different mobility ratios (mobile sensor nodes) after 135 sensing rounds

Name of protocol	Alive nodes with 10% Mobile sensor node	Alive nodes with 20% Mobile sensor node	Alive nodes with 30% Mobile sensor node	Alive nodes with 40% Mobile sensor node	Alive nodes with 50% Mobile sensor node
QEMPAR	399	375	348	300	255
Mobicast	378	362	339	291	255
CQARP	400	363	358	337	319
ORM	450	439	415	374	353

Table 5: Percentage % of died nodes with different mobility ratios (mobile sensor nodes)

Name of protocol	Percentage % of died nodes with 10% Mobile sensor nodes	Percentage % of died nodes with 20% Mobile sensor nodes	Percentage % of died nodes with 30% Mobile sensor nodes	Percentage % of died nodes with 40% Mobile sensor nodes	Percentage % of died nodes with 50% Mobile sensor nodes
QEMPAR	20.2%	25%	30.4%	40%	49%
Mobicast	24.4%	27.6%	32.2%	41.8%	49%
CQARP	20%	27.4%	28.4%	32.6%	36.2%
ORM	10%	12.2%	17%	25.2%	29.4%

Based on the simulation results, we validated that competing protocols QEMPAR and Mobicast lose their more nodes with 10% and 50% mobile sensors, but CQARP is affected with 10% and 20% mobile sensor nodes; whereas ORM is affected with 40%. However, network can survive more with ORM model at different mobile sensor nodes.

E. Average delivery rate

One of the important metrics in investigating the routing protocols is an average delivery ratio. In Figure14, node failure probability and an average delivery ratio are depicted. ORM outperforms other routing protocols: MMSPEED, MGR and SAR. The average delivery ratio decreases by node failure, but node failure highly affects other participant routing protocols as compared with ORM. The reason of the better performance of ORM is to include the load-balancing algorithm and optimized node processing approach based on several factors including residual energy and optimal path bandwidth management, buffer allocation, distance measurement, signal-to-noise ratio, received-signal strength Indicator and moving base station. The performance of ORM reduces maximum to 18% by node failure, but other MMSPEED, SAR and MGR reduce the performance maximum up to 40%.

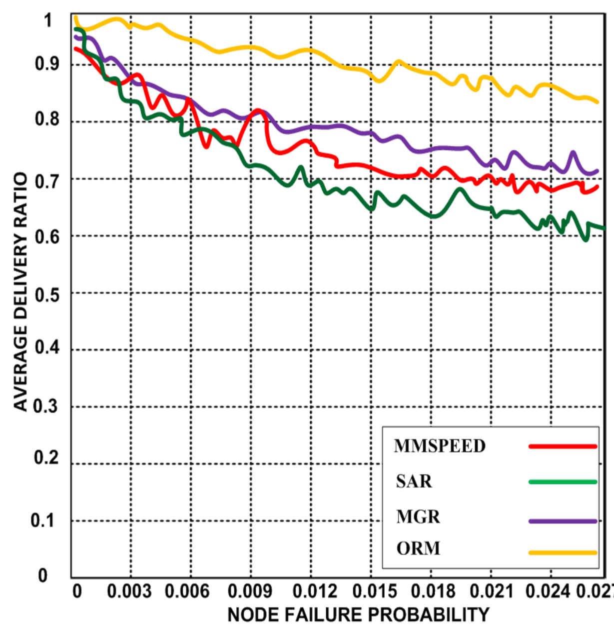

Figure. 15 Average delivery rate on variable node failure probability

F. Average energy consumption

Figure 15 shows the result of energy consumption based on node failure probability. We note that ORM outperforms MMSPEED, SAR and MGR. The energy consumption is also not highly affected due to QoS provisioning (throughput and delay). Hence, trade-off reducing the energy consumption and improving QoS provisioning is proved that reduce the expenditure. The maximum an average energy consumption for ORM on 0.027 node failure probability is 0.037 joule/packet as compared with other protocols that range from0.052 to 0.063 Joule/packet. The result demonstrates that ORM consumes almost half of energy as compared with MMSPEED, SAR, and MGR due to node failure probability.

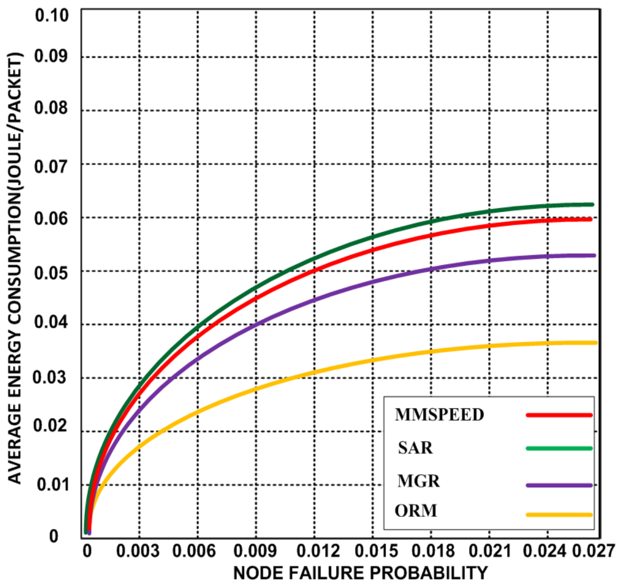

Fig. 16 Average energy consumption VS node failure probability

G. End-to-end delay

End-to-end delay is another significant parameter for investigating the QoS based routing protocols. The packet end-to-end delay increases as time interval increases depicted in Figure 16. In this experiment, we use variable size of packet arrival rate at the sender side. We measure an end-to-end delay for both non-real time and real time data traffic. Based on the results, we validate that ORM outperforms to other participating routing protocols. The maximum end-to-end delay at the end of simulation for ORM is 0.047 second that is almost 50% lesser than other routing protocols.

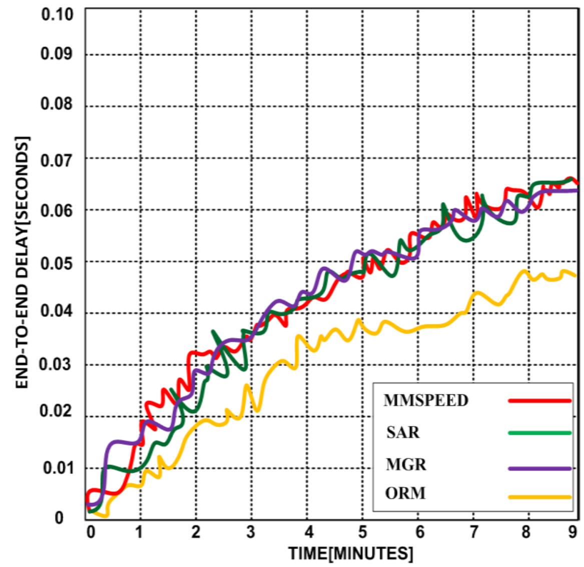

Figure 17. End-to-end delay at different time interval

H. Lifetime

The main goal is to improve the lifetime of WSN that is trade-off between energy consumption and network lifetime. We use variable network topology size to determine the lifetime of network illustrated in Figure 17. In the experiment, we have proved that lifetime of network is improved using ORM. In addition, we have also determined that increase in network size also improves the lifetime of network. The overall performance of ONSP is better than all competing routing protocols at variable network size. ORM improves the network lifetime approximately 37.5% that is much better outcome.

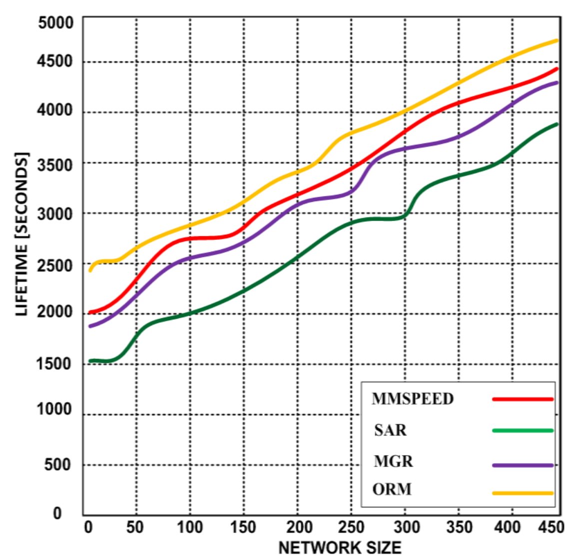

Fig. 17 Lifetime of network at varying network topologies

5. Conclusion

In this paper, we have introduced optimized route-discovery and mobility-aware model for improving the quality of service provisioning based on multi-path routing for wireless sensor networks. This approach is designed particularly for real-time and non-real time traffic. Our approach uses the multi-path paradigm based on optimized and braided paths for improving the network life. This approach uses optimized node process model for determining the improved node that helps for route discovery.

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