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Research Article

Buffer-overflow and Noise-handling Model: Guaranteeing Quality of Service Routing for Wireless Multimedia Sensor Networks

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Abstract

Wireless Sensor Networks (WSNs) are the collection of sensor nodes that form a momentary network without the support of any centralized administration or infrastructure. In such a situation, it is mandatory for each sensor node to obtain the support of other sensor nodes in order to advance the packet to its desired destination node, particularly to the sink node or base station. One significant challenge in designing the wireless multimedia sensor network is introducing an energy efficient routing protocol, which may transmit information despite limited resources. Another significant problem is determining the resources of the next hop node in advance. The routing protocols in existing literature mainly focus on prolonging the network lifetime. In this study, we introduce the buffer-overflow distance-aware and noise-handling (BODANH) model to guarantee the quality of service (QoS) for multipath routing over wireless multimedia sensor networks. The BODANH involves three components: Buffer allocation, distance measurement and signal-to-noise-ratio. This model prevents the loss of data and avoids the congestion caused by buffer-overflow, identifies the node distance prior to route discovery that helps determine the location and distance when node it is either movable or immobile. The performance of our model is compared to other QoS routing protocols. Simulation results demonstrate that our model surpasses the other routing QoS routing protocols in terms of throughput and the remaining live nodes in static and mobility scenarios.

Key words: Buffer overflow, routing, quality of service, signal-to-noise-ratio, wireless sensor networks

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INTRODUCTION

Due to the rapid advancement in emerging technologies particularly in micro electro-mechanical systems, small scale energy devices, low power integrated digital circuits, small scale energy supplies, microprocessors and low power radios have provided the platform for low cast, low energy and multifunctional wireless sensor nodes that can perceive and respond to deviations in physical phenomena[1]. Each sensor node is equipped with tiny microprocessor, radio transceiver, small battery and a set of transducers, which are used for obtaining information that redirect the vicissitudes in the surrounding environment. Wireless sensor networks involve a number of tiny sensor nodes that coordinate with each other to perform critical tasks (e.g., object tracking and environment monitoring, etc.) and deliver the collected data to the sink node or base station. The areas of wireless sensor network applications include healthcare, battlefield, surveillance, environmental monitoring, detection of fire etc.,[2,3]. However, network density, limited node power, severe bandwidth limitations, dynamicity of the topology and large-scale deployments have caused 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. Limited memory space causes buffer-overflow and data packets start to drop. As a result, retransmission is required for the lost data packets[4]. Thus, additional energy is consumed[5]. The recent advances of low cost and also miniature size cameras or microphones have led to the development of Wireless Multimedia Sensor Networks (WMSN) as a class of wireless sensor networks. The WMSN is a network of wirelessly interconnected sensor nodes that can capture images, video and audio data from the surrounding environment and send that to the sink. Wireless Multimedia Sensor Networks (WMSN) attracted the researchers attention because it enhanced the exiting WSN applications and enabled new applications such as multimedia surveillance sensor networks, traffic avoidance, enforcement and control systems and advanced health care delivery. In order to guarantee the successful transmission of the multimedia content, the routing protocols need to be energy efficient and quality of service (QoS) support[6]. Buffer detection is largely an open issue in WMSNs due to limited computational capabilities and limited memory resources.

The sensor nodes handle low data volume in low data rate applications[7]. However, multimedia-driven applications are required 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 the buffer may start to overflow. In addition, buffer-overflow invites the congestion that may cause a reduction in network efficiency[8-10]. To handle the congestion, it is important 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 WMSNs. Additionally, WMSNs vary in nature from wired network because nodes in WMSN hold a single queue that is connected with a single transmitter. Furthermore, the noise and distance of nodes are also more important for the discovery of the path for guaranteeing the QoS provisioning[6].

Most approaches used to discover paths are based on the residual energy of the node. These approaches are not suitable in particular situations for example when the sensor node is farther from the sink node and even holds the high residual energy, however, long distance and noise weaken the signal strength. As a result the node does not receive all sent packets[11,12]. Trade-offs are an efficient use of the buffer and energy of sensor nodes, which are highly desirable when designing multi-path routing that guarantees the QoS provision for WMSNs[13]. This study attempts to address the congestion and data overflow caused by buffer limitations. Furthermore, we detect the noise and determine the distance including the location of the node that helps in the discovery of an optimized path. The contribution involves the BODANH mathematical model that improves the throughput and extends the network life.

MATERIALS AND METHODS

Buffer-overflow, distance aware and noise handling model: Guaranteeing the QoS routing in wireless multimedia sensor networks is a highly challenging problem due to limited properties of the sensor node. Our aim is to present the BODANH model in a manner that improves the throughput and prolongs the network lifetime. Thus, we focus on detecting the capacity of buffer prior to sending the data packets as well as determining the node distance and handling the noise. The BODANH model includes the following features:

- Buffer allocation
- Distance measurement
- Signal-to-noise ratio

Buffer allocation: Each sensor node S = (S_1, S_2, S_3, S_n) measures all traffic flows F_{nt} (m, n) passing through each link L = (L_1, L_2,..., L_n), $\forall L_1, L_2,..., L_n \in L$. Where, F_{nt} (m, n) is the measurement of the new time interval and P_k = (P_{k1}, P_{k2}, P_{k3},... P_{kn}) is the number of packets. Let us assume number of packets P_k = (P_{k1}, P_{k2}, P_{k3},... P_{kn}) received by S_1 from sensor node S_2 over the link L_1 during the time interval 'tΔ'. Thus, the size of buffer measured in new interval can be obtained as:

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

where, $S_1(P_k)$ is 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 the buffer limit for each sensor node can be calculated as follows:

$$b\rho(S) = \frac{F(P_k)}{\rho(s) + \sum_{S_1 \in S} S_1\{F(P_k)\}} r(P_k) \tag{2}$$

where, bρ is buffer limit, $F(P_k)$ is the No. of transmitted packets out of the buffer, $r(P_k)$ is the rate of packets transmitted in per second, ρ(s) is the source of the data and $S_1\{F(P_k)\}$ is the buffer limit of 'S_1' sensor node.

The sensor node forwards the packets that can be measured locally, if ρ(s) = 1 then 's' is the data source otherwise ρ(s) = 0. The sensor node 'S_1 advertises the buffer limit 'bρ' to the sensor node 'S_2' possibly by using piggybacking in the acknowledgment packet. In response, the sensor node 'S_2' applies a rate limit (actual rate on path) '$B\Delta_{path}$' that is bounded by a rate limit. If the sensor node 'S_1' itself is data source, it will assign the buffer to node 'S_2' as follows:

$$b\rho(S_1) = \frac{1}{1 + \sum_{S_1 \in S} S_1\{F(P_k)\}} r(P_k) \tag{3}$$

If the neighbor node attempts to enforce a buffer rate limit, it may casue congestion; if the buffer capacity of the receiving node is full, then it administers rate limits. This process is applied to the data sources. Finally, all the exaggerated data sources are able to adjust the packets rates based on the 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', the buffer rate limit is stopped. This situation can occur by raising the buffer rate limits of sensor node 'S_1'. The sensor node 'S_1' is capable of identifying the situation of the congestion by detecting the fullness of the buffer. When that situation happens, the sensor nodes fix the buffer rate limits to be bρ(S) and bρ(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 the node accepts packets from the neighboring nodes are lesser than the buffer rate limits.

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 optimal path. This process involves the messaging that holds the information regarding the location of the sink node $\aleph_s$ in wireless multimedia sensor networks. In addition, all the sensor nodes detect their locations D_ρ from the sink.

The base station sends the message inside the network, the nodes that receive the signal that start calculating the distance from the base station (sink). The process of calculating the distance is performed using Euclidian distance formula given in Eq. 4:

$$r(S_1) = \sqrt{D_\rho(\aleph s) - D_\rho(S_1)^2} \tag{4}$$

where, $r(S_1)$ is distance of sensor node from sink node, $D_\rho(\aleph s)$ is location of sink node, $D_\rho(S_1)$ is 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 the shortest distance '$r_\alpha(S_1)$' connects itself with the disjoint path. However, the sensor node that has extended distance '$r_\beta(S_1)$' from the sink, joins the braided path. This approach is applied with lower and higher levels clusters in hierarchy. Let '$r(S_1)$' be the distance between source node and sink node and 'Δt' 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 'ΔT_p' of the node for each cycle can be obtained as:

$$\Delta T_p = r(S_1)\ \mu\sigma \times \Delta t \tag{5}$$

where, μ is constant value that is considered as the requirement of signal strength and σ is 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 reduces 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:

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

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

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

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

$$E(S_1) = r(S_1)\mu\sigma \times \Delta t \tag{6}$$

In the wireless network, a major source of signal loss 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 the this study.

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 the same bit error rate at the receiver side.

Thus, the relationship between SNR '$\dot{R}\Delta$' and transmitter power 'T_{xp}' can be obtained as:

$$\acute{R}\Delta = \frac{T_{xp}}{N_p}\varphi \tag{7}$$

where, φ is channel attenuation and N_p is noise power. We can define noise power as follows:

$$N_p = N_d \times T_{sr} \tag{8}$$

where, N_d is noise power density, Δtx is transmission rate, ঌ is modulation pattern size, ∃Δ is energy per bit and T_{sr} is transmission symbol rate can be obtained as:

$$T_{SR} = \frac{\Delta tx}{\text{ঌ}} \tag{9}$$

Therefore, SNR is determined for background noise as:

$$\acute{R}\Delta = \frac{\exists\Delta}{N_d} \times \text{ঌ} \tag{10}$$

RESULTS AND DISCUSSION

In order to examine the performance of buffer-overflow the distance-aware and noise-handling models, the wireless multimedia sensor network was created to cover the area of 600×600 m. The performance of BODANH is compared with other QoS routing protocols: Mobicast[14], QoS and energy aware multi-path routing algorithm (QEMPAR)[15] and Cluster-based QoS aware routing protocol (CQARP)[16]. The network topology considered the following metrics:

- A dynamic sink is set
- Each node is initially assigned to uniform energy
- Each node senses the field at the different rates and is responsible for transmitting the data to the sink node or base station
- The sensor nodes are 10-60% mobiles
- Each sensor node involves the homogenous capabilities with the 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 in 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[17] simulator-2. The scenario consists of 400 homogenous sensor nodes with initial energy 4 J. The base station is located at point (0, 1100). The packets size is 256 bytes. Initial energy of node is 4.5 J. The rest of parameters are explained in Table 1.

Based on simulation, we are interested in the following metrics:

- Throughput with stationary nodes
- Throughput with and different nodes
- Remaining alive nodes (lifetime) with mobility in days

Throughput with stationary nodes: Throughput is an average-mean of successfully delivered data packets. It was observe that once simulation time increases then throughput performance starts dropping but BODANH is not highly affected as compared to other routing protocols; QEMPAR, Mobicast and CQARP.

After completion of simulation time, BODANH reduces only 2 kb sec^{-1} throughput while other competing protocols reduce from 12.5-17.75 kb sec^{-1}. Based on the obtained result, we prove that our model is effective when nodes are stationary. Figure 1 shows the throughput with stationary nodes.

Table 1: Simulation parameters and its corresponding values

Parameters	Values
Size of network	600×600 m^2
Number of nodes	500
Queue-capacity	25 packets
Number of frames	350 frames
Distance from the base station to the center of WSN	1100 m
Mobility model	Random way mobility model
Maximum No. of retransmissions allowed	03
Initial energy of node	4.5 J
Size of packets	256 bytes
Data rate	250 kb sec^{-1}
Sensing range of node	40 m
Simulation time	9 min
Average simulation run	10
Frame rate	40 fps
Reliability	0.8, 0.9
Reporting rate	1 packet sec^{-1}
Base station location	0, 500
Transmitter power	12 mW
Receiver power	13 mW
Mobility (%)	10, 20, 40 and 60%
Buffer threshold	1024 bytes

Throughput with different mobility ratios: The mobility affects throughput performance. The throughput performance of the network reduces when the ratio of mobile sensor nodes (mobility of nodes) start to increase. We show in Fig. 2 that mobility affects the performance of all competing protocols; however, the throughput of BODANH is still higher than other QEMPAR, mobicast and CQARP routing protocols. In fact, higher mobility ratio causes lower packet delivery ratio. We also observe that a drop in transmission of the packets causes the retransmission of the packets. As a result, additional energy is consumed for sending the lost packets.

Remaining alive nodes with stationary nodes: We describe the number of remaining live nodes in Fig. 3 after performing some simulation rounds (Environment sensing rounds) using stationary nodes. We observe that once simulation rounds increase then the energy of the nodes depletes. As a result, the nodes start to die.

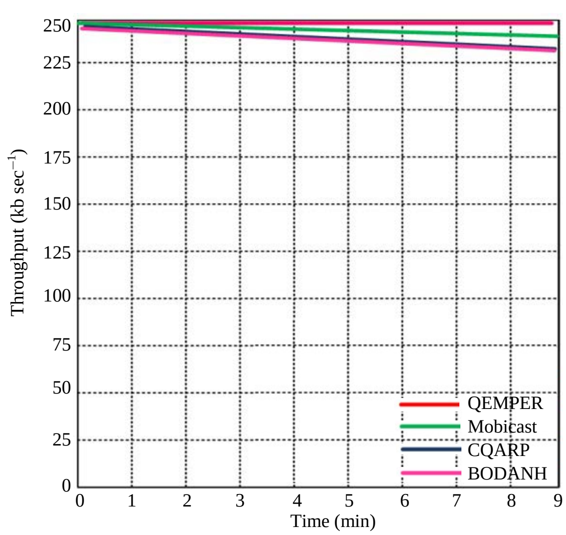

Fig. 1: Throughput with stationary nodes

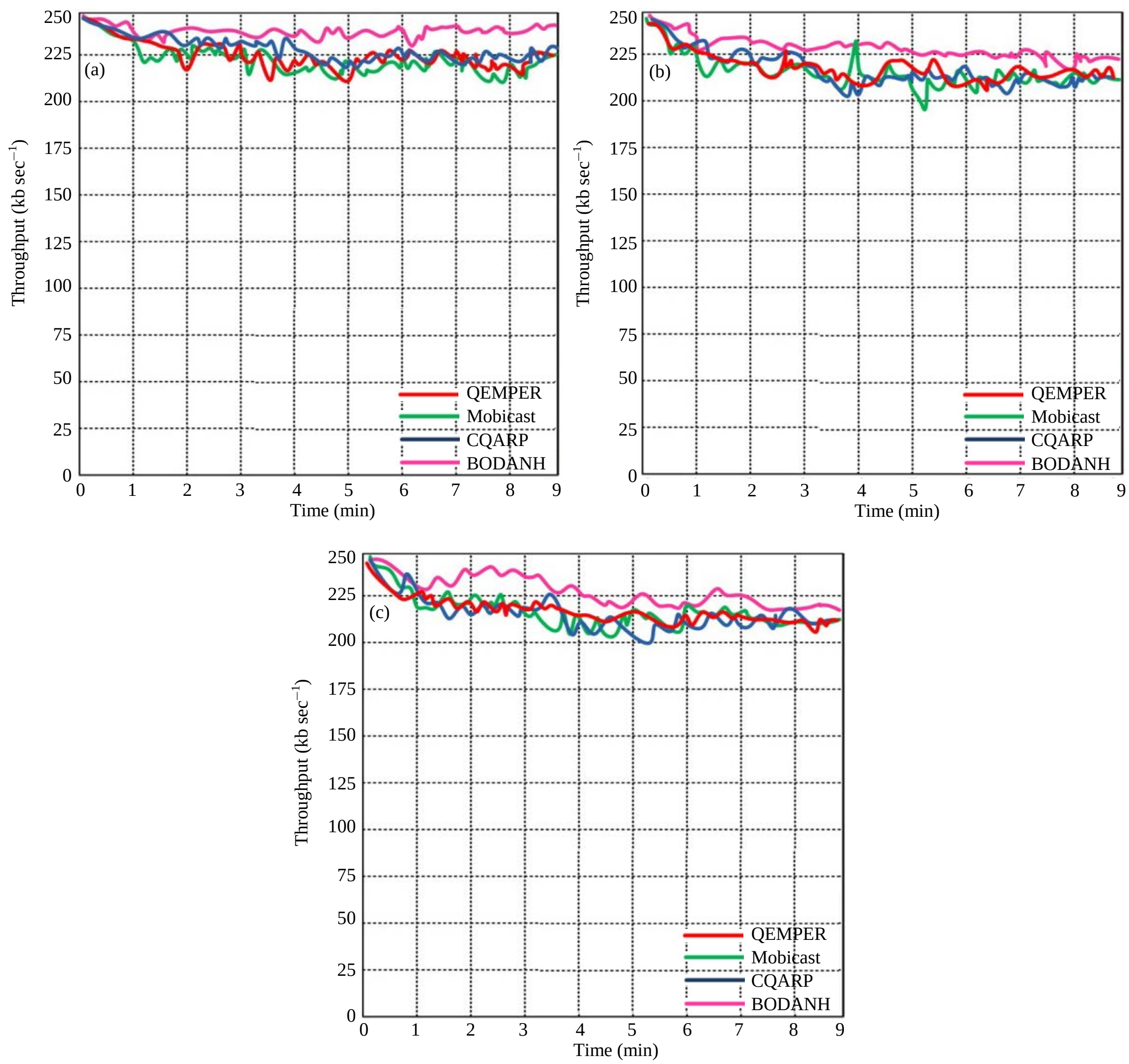

Fig. 2(a-c): (a) Throughput with (a) 10%, (b) 20% and (c) 30% mobile nodes

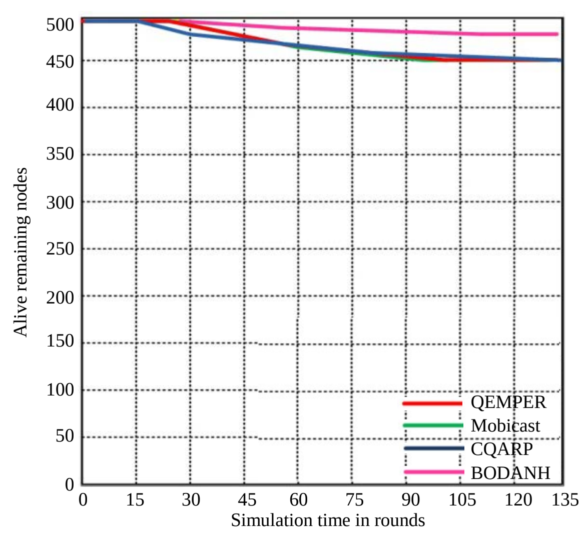

Fig. 3: Alive remaining node vs sensing routes with static nodes

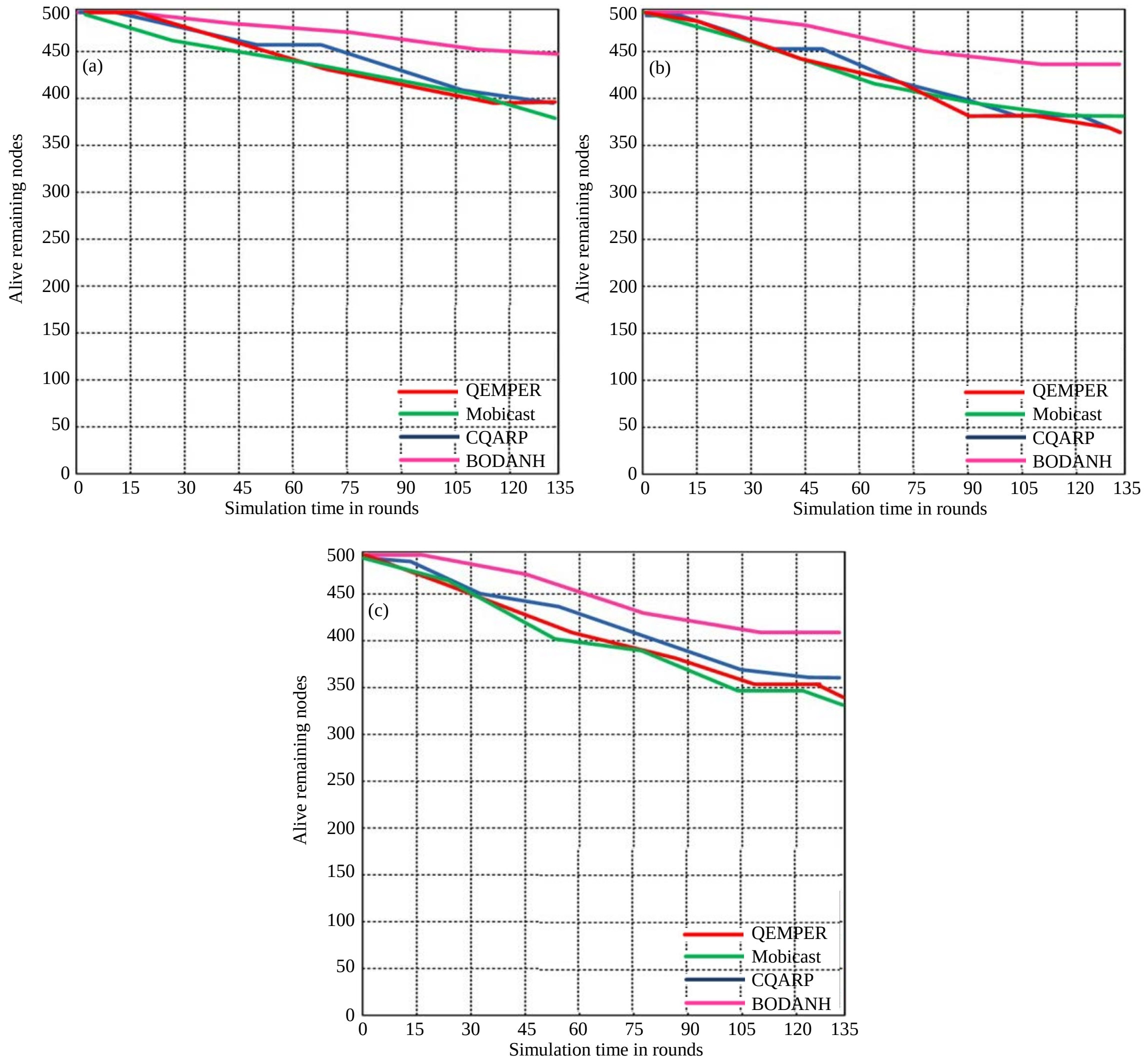

Fig. 4(a-c): Alive remaining node vs sensing routes with (a) 10%, (b) 20% and (c) 30% mobile sensor nodes

The BODANH outperforms QEMPAR, mobicast and CQARP. At the end of 135 simulation rounds, BODANH has remaining 483 alive nodes whereas other protocols have remaining 450 alive nodes. Simulation results demonstrate that BODANH loses 3.4% nodes but competing protocols lose 10% nodes.

Remaining alive nodes with mobility: The mobility affects the performance of the network but performance can be improved using an effective model. In Fig. 4, we show the behavior of the network in our proposed BODANH and other competing QEMPAR, mobicast and CQARP routing models.

It was 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 the increase of mobile sensor nodes, the network starts to lose the nodes. This situation gets worse with higher number of mobile sensor nodes. All the participating protocols are affected. However, BODANH outperforms to other competing routing protocols. We demonstrate that BODANH improves the network lifetime despite of mobile sensor nodes.

CONCLUSION

This study introduces a buffer-overflow distance-aware and noise-handling model to guarantee the QoS provisioning for wireless multimedia sensor networks. This BODANH model creates a reliable discovery route based on buffer allocation, distance measurement and signal-to-noise-ratio. These features of model reduce congestion, improve the throughput and extend the network lifetime. Tradeoff is between mobility and network lifetime and throughput. The performance of

BODANH has been compared with other routing protocols, which are QEMPAR, Mobicast and CQARP in terms of throughput and number of remaining live nodes. To validate the effectiveness of a model, we have used ns2 to simulate an airport surveillance system. Based on the simulated results, BODANH outperforms the other participating routing protocols. The BODANH obtains 11.4% throughput and 6.8-19.6% network lifetime in the static and mobility scenarios. The outcome validates that the BODANH model is a better choice for improving the network lifetime and guaranteeing QoS provision. In future, the BODANH model will be extended by incorporating more features in order to validate other QoS metrics.

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