Hindawi
Wireless Communications and Mobile Computing
Volume 2019, Article ID 7502140, 12 pages
https://doi.org/10.1155/2019/7502140

Research Article

EEHRT: Energy Efficient Technique for Handling Redundant Traffic in Zone-Based Routing for Wireless Sensor Networks

Rab Nawaz Jadoon[1,2] **WuYang Zhou**[1] **Iftikhar Ahmed Khan,**[2] **Muhammad Amir Khan**[3] **and Waqas Jadoon**[2]

[1] *School of Information Science and Technology, University of Science and Technology of China, Hefei 230000, China*
[2] *Department of Computer Science, COMSATS University, Islamabad-Abbottabad Campus 22060, Pakistan*
[3] *Department of Electrical Engineering, COMSATS University, Islamabad-Abbottabad Campus 22060, Pakistan*

Correspondence should be addressed to WuYang Zhou; wyzhou@ustc.edu.cn

Received 11 February 2019; Accepted 9 April 2019; Published 6 May 2019

Guest Editor: Bojan Dimitrijevic

This paper presents an energy-efficient technique to handle redundant traffic (EEHRT) in the zone-based routing for wireless sensor networks. In this technique, multihop routing is performed based on the remaining energy of the nodes. Afterwards, it performs position-based routing without the need for the nodes to know their respective position. The main objective of this paper is to handle the redundant packets generated in zone-based routing using short beacon messages. Nodes of lower zones route the data of the higher zone to base station (BS) with a minimum number of hops and utilize only those nodes on the path which are energy efficient and located closer to BS. Moreover, the source node is acknowledged by the relaying node using a wireless broadcast advantage (WBA) without sending any special ACK packet to the sender, which reduces the control overhead in the routing process. The EEHRT technique improves the routing against RARZ by ensuring only one copy of the packet is propagated at each hop along the routing path to BS. Simulation results show that EEHRT achieved 28% improvement in energy efficiency, 10% and 25% improvements in data throughput against total and distinct packet reception at BS respectively, 35% increase in overall network lifetime, and 100% reduction in redundant packets generation and propagation in the network against RARZ routing.

1. Introduction

Wireless sensor networks are used to monitor the terrain either reachable or unreachable to human beings. A sensor node in the network can sense, process, and deliver data to its neighboring nodes or to the base station (BS), i.e., sink node either directly or in multihop fashion [1–4], etc. These types of networks are resource constraint in terms of memory, processing, bandwidth, and node residual battery (energy). After deployment, it is almost impossible in some cases in certain environments to charge or replace the battery upon depletion.

For physically remote and hostile environments, this is now a possibility through new emerging concept of sensor technology which monitors the physical phenomenon of interest. Sensor nodes are able to gather, manipulate, and transmit data to an ultimate destination with energy efficient data delivery techniques [5]. To extend the overall network lifetime of the nodes, the network should consume less energy for sensing, processing, and transceiving. Currently, researchers are working to develop efficient protocols which are lightweight, scalable, and energy efficient and does position-based routing without using any location service or GPS assumption.

In this paper, we have proposed a new protocol called EEHRT which handles the redundant packets generated especially when the next hop relaying node is not reachable to its neighboring node. The implementation condition is that this node is also contending to become the next hope node [6]. The next hop node is selected based on a timer which is a function of node residual energy and its closest location, i.e., zoneID.

According to RARZ, if a node has outstanding data to send, it first senses the channel. If the channel is available, then it broadcasts its data with its network ID (zoneID). All the nodes located in the same zone share the same zoneID, i.e., the network address. Nodes having lower zoneID will receive and schedule the packet for further relaying. Higher energy nodes having lower zoneID will become the potential next hop nodes. When the next hop node further relays the data, the nodes that hear that packet will kill their timer and drop the scheduled packet. The nodes that are not in the range of the relaying node will send the same packet again upon expiry of their timer, so multiple copies of the same packet are routed to BS, which ultimately degrade the overall network lifetime and throughput. This work aims to remove the probability of redundant packets generated in RARZ routing [6] and to enhance the overall throughput and network lifetime.

EEHRT is different from RARZ with the following points:

(i) EEHRT controls the redundant packets by introducing short beacon message in the routing algorithm.

(ii) EEHRT ensures distinct packet delivery at every hop on the path to BS.

(iii) The acknowledgment is handled in the EEHRT using WBA (wireless broadcast advantage) without considering a separate special ACK packet to the sender at each hop along the routing path.

When a node in the lower zone further relays this message, the same copy of the message is also received by the sender node using the benefit of a wireless broadcast. This technique is also called a wireless broadcast advantage (WBA). Once this message is correctly received by the source node, a short beacon message is exchanged to the next hop nodes by the sender node. The short message should have the following properties: (1) it should have message type 3 and (2) should have the same packet sequence number and zoneID. The short beacon message is targeted for those nodes who could not hear the relaying node packet. This packet is the same for which they are still waiting to transmit it, i.e., their timer not elapsed yet. Upon receiving this small beacon message, the nodes will delete the schedule packet and kill their timer. In this way only one copy of the data will be routed to the BS and sender is also acknowledged that its packet is relayed further.

The rest of the paper is organized as follows: related work and problem statement are described in Section 2 and Section 3, respectively. EEHRT technique is presented in detail in Section 4 and simulation results are presented in Section 5. The paper is concluded in Section 6.

2. Related Work

The researcher has contributed a lot to energy efficiency especially in sensor networks. Every routing protocol developed in the sensor networks considered energy efficiency because it overall affects the lifespan of the network. A lot of energy efficient routing techniques have been developed in the past for wireless sensor networks longevity. Despite all the routing categories in WSN, hierarchical routing techniques are considered more energy efficient and scalable as compared to rest of the techniques because only the aggregated data is transmitted through high-level energy nodes to BS [7] with few numbers of transmissions.

Hierarchical protocols are also called cluster-based protocols. In cluster-based routing, the sensing region is divided into different regions called cluster, and each region has one designated cluster head (CH). CH gathers data from all its associated nodes and transmits the aggregated data to BS [8]. CH selection is an important mechanism which may be either distributed or centralized. In the centralized method, BS has the responsibility to setup clusters and CHs selection based on nodes remaining energy and location information [9–11] whereas, in distributed techniques, nodes organized themselves to form clusters without the control of a central authority. There are three types of clustering, static, dynamic, and hybrid.

In static clustering, once the clusters are formed, they will never be changed till the end of the network. In the case of dynamic clustering, there are two phases, setup, and steady-state phase. In the setup phase, each node sends its energy and location information to the BS. After getting this information from all the nodes in the network, BS will select the optimal number of clusters and CHs and intimate this information to all the nodes in the sensing region. At the end of the setup phase, the steady-state phase begins which is also called a data communication phase. In this phase, nodes send their data sensed data to designated CH and then CH is responsible for onward transmission to BS [5–8]. Hybrid techniques utilized both the mechanism of static and dynamic clustering at the same time.

A lot of energy efficient routing protocols have been developed in the recent past. LEACH (Low Energy Adaptive Clustering Hierarchy) [1] is a hierarchical protocol which sets a benchmark for the researchers to develop energy efficient techniques in cluster-based routing to prolong the network lifetime.

The work described in [12] is Power-Efficient Gathering in Sensor Information Systems (PEGASIS) called a chain-based protocol in which a chain of nodes having one leader is elected to send the data to BS. It outperforms LEACH in terms of an overall network lifetime.

Work described in [13] implemented a hybrid approach by incorporating data aggregation [7], energy awareness, and clustering into one algorithm. It greatly enhances the overall longevity of the network. After each round of communication new CHs is selected. Data is aggregated to achieve energy efficiency and long distances are handled using optimal multihop routing.

An energy and context-aware routing-based technique on clustering is presented in [10, 14] for the sensor networks. Based on routing protocols, a comprehensive comparison of sensor networks and MANET (mobile ad hoc networks) is presented in [15]. This qualitative comparison exposes new areas of research for developing new energy efficient routing protocols, especially for WSNs.

In normal clustering techniques, the arrangement of the nodes is fixed [7]. The new research implemented the clustering in an ad hoc fashion in [6, 11]. Work presented in [10] is a connected cluster architecture, where all nodes are like sensor nodes; CHs and gateways are treated in the same node of the network. The CH worked as a central control node, while the gateway node acts as a backbone to transmit the data to different users.

A similar network setup scheme is adopted as done in [6, 16], in which nodes are organized in a sensing region into equal size clusters. Cluster-based routing is used for prolonging the network lifetime. Authors claim that the network lifetime is extended by balancing the energy consumption among all the cluster heads in the network.

As sensor nodes are equipped built-in battery-powered and hence their lifespans are short, the researcher gave keen attention to these issues in almost every protocol developed at every layer of the protocol stack. To further enhance the network lifetime and conserve energy, a data query dissemination and gathering scheme is presented in [2]. In this work, the authors gave the concept of the parameterized query based on the user's profile to get the required data from the sensor nodes. The scheme is proven to be the most energy efficient as compared to the rest of the techniques of a similar domain.

A novel zone-based scheme is implemented in [16], which is energy-efficient and edge-based network apportioning technique, that organizes nodes into equal size clusters. It also proposed a cluster-based routing algorithm, called zone-based routing protocol (ZBRP), for prolonging network lifetime. BS divided the whole network into different equal size zones around the BS. Authors proved through simulation results that they equally balance the energy consumption among all the CHs in the network, hence extended the overall network lifetime.

A lot of work has also been investigated on energy-aware routing. A similar sort of work is done in [17], in which they utilize an energy-aware technique with static clustering called centralized control clustering (EACCC) to achieve energy efficiency and greater lifespan of the network along with network scalability as well. The performance of the EACCC is accessed through extensive analytical proofs and simulation and showed that EACCC is highly efficient in terms of balancing the energy consumption and prolonging network lifetime.

The work in [11] is based on hybrid clustering. According to this scheme, clusters are static and never changed up to 10 rounds. BS is responsible for the selection of next phase CHs. If the round number is less than 10, the current CH selects the new utmost energy level node as a CH and intimates its status to BS. After round number 10, all the nodes send their energy status and location information to the BS and BS will setup new clusters for the next time.

There are cases in which the environment is monitored periodically. In periodic monitoring applications, building protocols of such type are a challenging task. A handsome work to cater to such issues is done in [3], in which the authors worked in the two domains. The first is to make the protocol energy efficient and then provide a comprehensive mechanism for energy load balancing using distributed antenna theory.

An energy saving architecture for wireless sensor networks is presented in [18], in which biography-based optimization (BBO) is adapted which is a new paradigm to optimized complex problems. Optimal cluster head selection and routing are considered more complex problems in wireless sensor networks. Authors proposed BBO based cluster head selection algorithm having an efficient encoding scheme based on residual energy and distance as its metrics. Simulation results show that BERA (BBO based routing architecture) outperforms the existing routing architecture in terms of energy efficiency and communication overhead.

Along with energy efficiency, secure data communication is also needed during transmission either transmission from node to node or from node to BS. A virtual backbone is created for energy efficient intercluster routing. Signcryption technique is used for secure data transmission in the network. Energy efficient secure cluster-based routing is performed in [4] and compared with LEACH and hence showed that the proposed scheme can save 2720nJ/bit/m2 energy in one round of communication along with security than LEACH protocol.

For reliable data delivery of the packets to BS, authors handle the reliability issue by incorporating trust model in Cluster Algorithm for Sink Selection (CASS) scheme [19] to assure the reliability with the minimum overhead of maintenance to extend the overall network lifetime. Simulations results show that CASS with trust model greatly reduces the packet loss in the presence of unreliable nodes while extending the network lifetime by deploying multiple sinks.

Routing is considered the most energy consumptive process in sensor networks. Improving the routing in sensor networks researcher has contributed a lot to minimize the overhead of unwanted packets in the network. In [20], state free geographic forwarding protocol is proposed which is a cross-layer designed for minimizing the energy consumption. All the protocols developed in the past under SGF utilized Distributed Coordination Function MAC protocol of 802.11 for routing because it deals well with the hidden terminal problem using four-way handshaking. This creates an overhead in terms of end to end delay and energy consumption in the network. To handle these issues, a directional compact Geographic Forwarding (DCGF) protocol [20] is proposed which mitigated the overhead incurred in four-way handshaking in multihop networks. It uses a smart antenna and QoS aware data aggregation approach to handle the broadcast data received and multiple unicast traffic, respectively.

Despite all these efforts, there is still the requirement in contributing to energy efficiency and to increase the overall network lifetime of the sensor networks. All the protocols discussed above use a lot of control information along with actual data sensing and transmission, but our focus is to develop a protocol which has low control overhead to make the routing energy efficient, lightweight, and reliable [6]. Moreover controlling the unwanted traffic in the network increases the network lifetime.

2.1. A Brief Overview of RARZ Routing. In our early study presented in [6], the routing strategy is more energy efficient but, in some specific scenario, it generated redundant packets in the network which ultimately waste some scarce resources and affect the overall throughput and network lifetime. The routing strategies that were used in [6] is as follows.

RARZ works in three phases: network setup and configuration phase, the next hop node selection phase, and data communication phase. The network configuration or setup phase splits the whole sensing region into different concentric static rings around the BS. For ring formation, the BS broadcasts messages with various transmission powers to the sensing field. Each message from the BS contains a ring ID and each node, upon first time receiving the message, will set its ring ID to the one contained in the message received. For covering the whole sensing field, the BS progressively broadcasts messages with various communication ranges comprising different ring IDs. Each node, upon receiving a ring i message from BS, recognizes that the latter belongs to ring i unless they have already set a ring with lower ring ID. All the nodes in a particular ring have the same ring ID (i.e., network address). At the end of this phase, the route discovery process is formulated that nodes belonging to the smallest ring will relay the packet to the BS and any other node in the same ring and nodes located in the higher ring will discard the packets.

The main work done in RARZ protocol is the next hope selection phase. According to RARZ, the next hop node is also called a relaying node that is selected on the fly without considering any prior information available in the network. Selection is purely done based on its residual energy and the zone in which it is located. A node having high energy and lower zone ID has the highest probability to become the next ultimate relaying node. Only the lower zone nodes can carry the data of the higher zones to BS. Same and higher zone nodes will delete the packet after receiving at the MAC layer. The node whose timer expired first will become the potential next hope node. Once the relaying node sends the data further, the nodes located in its radio range will cancel their timer and delete the packet for which they have already running timer. In RARZ the timer is a function of node residual energy and node current location Z_ID, i.e., zoneID,

$$Timer = \alpha * Z\_ID + \beta \left[\frac{\eta}{\mu} \right] \tag{1}$$

α and β are weighted values against node current location and its residual energy, respectively. The values of α and β are the tuning parameters set in simulations according to Table 1 for efficient and normalized setup of data routing. The parameter η is the initial energy level and μ is the current energy level of a node at any particular time. As residual energy appears in the denominator, the higher the node current energy level is, the lower the time value will be and vice versa. The timer returns values in a millisecond. In (1) Z_ID (zoneID) played an important role in routing because some of the nodes are immediate to next ring, so that node should be selected as a next hop node. This is because one hop will be reduced and the average energy consumption in the system will also be minimized.

Figure 1 shows the graphical demonstration of the RARZ routing scheme. Three nodes (B, C, and D) are in zone 3 and are directly in the radio range of A. Once the node A broadcast its data, nodes in zone 3 will setup their timer as per (1). Node B's timer expired first because its energy level is high as compared to node D and C. When node B further relays the packet, neighboring node of B (i.e., C, D, E, and F) will also receive that message and nodes C and D will kill their timer and delete the packet for which they have currently running timer for the same packet sent by B.

Node E and F from zone 2 will now start their timer after getting the message from node B as they both are located in zone 2. Node F will become the next potential hop node due to its high energy as compared to E, so it further relays the packet. Through this way, the packet is routed to BS without any reactive mechanism in the routing procedure. On the path, only those nodes are selected which are energy efficient and located near to BS.

3. Problem Statement

In [6], whenever a node acts as a relaying node, there are some nodes that could not hear the data of the relaying node. The nodes that could not hear the relaying node packet will also relay the same packet further upon their timer expiration. This will create redundant packets in the network, i.e., multiple copies of the same packet are transmitted in the network, hence degrading the network resources and affecting overall network lifetime.

Figure 2 shows how the duplicate packets are generated in the network in RARZ routing [6]. Upon receiving the data from node A in zone 4, node B and C in zone 3 schedule their timer according to (1) and become the next potential hope node to route the received packet to BS. According to the scenario presented, the timer of node B will be expired first. When node B further relays the packet, node C could not hear that packet, so upon timer expiration of node C, it will also relay the same packet that is already sent by node B. In this way the duplicate packet is routed to BS resulting in degrading network lifetime.

4. EEHRT (Energy Efficient Technique for Handling Redundant Traffic) in Zone-Based Routing

EEHRT tackles the above scenario as follows. When node A sends its data, it adds the packet ID and zone ID in its buffer called "sent queue". When node B becomes the next hop node and relays the received packet after updating its zoneID to 3, node A will also get the packet sent by node B with zoneID 3. Afterward, A will compare the received packet ID and its zone ID to its sent queue values. This is an intimation for node A that the packet is successfully sent by a node from the lower zone. After that, it will send a small beacon message immediately in its vicinity so that the nodes with active timers who could not hear the packet sent by B due to out of the radio range of B could kill their timers and drop the scheduled packet. After sending the short beacon

Table 1: Simulation setup.

Serial #	Type	Parameters	Values
1	Network	Sensing region	$600 \times 600\ m^2$
		Node initial energy	3000 mJ/battery (Random 2.8J ~ 3J)
		Deployment	Random
		Number of Zones	10
		Node Transmission Range	100m
		Distance between zones	50m
2	Application	Data Packet	100 bytes
		Broadcast packet	25 bytes
		Packet header	25 bytes
		Beacon packet	15 bytes
		Carrier frequency	$2.4\ e^{+}\ 9$
		NAV	8 bits
		Zone ID	4 bits
		Node ID	4 bits
		MAC protocol	CSMA/CA (DCF)
3	Timer values	t_g (Guard time)	50 μs
		t_l (Listening time)	500 μs
		t_b (Back-off time)	500 μs
		(α, β)	(0.003, 0.001)

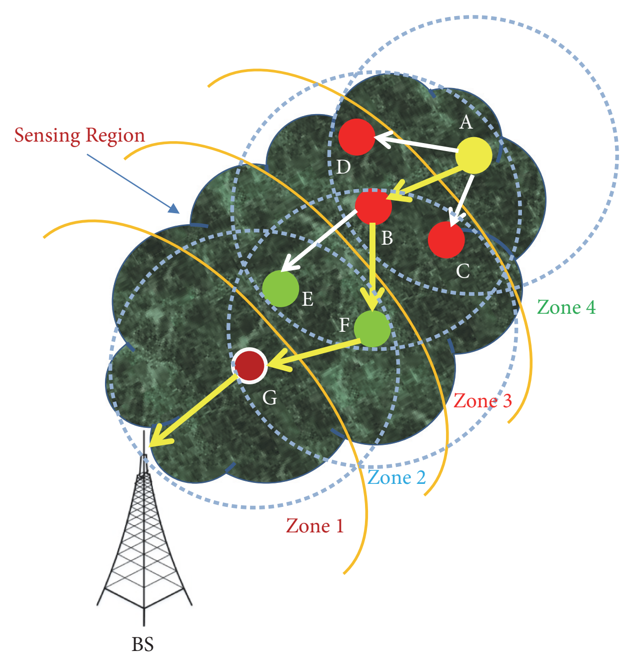

Figure 1: The selection of next hop node.

message by node A, it then clears its buffer. In this way, the sent packet acknowledgment is also received. Furthermore, confirmation is sent to those nodes that are located outside the radio range of the relaying node to kill their timers and delete the packets for further relaying. Through this way, the RARZ routing is improved by eliminating the probability of the duplicate packets generated in the network.

4.1. Network Model. We have assumed the same network configuration as used in [6, 9] with the following assumptions:

(1) All nodes are static w.r.t their position, i.e., immobile.

(2) BS position is flexible and can be setup either inside or outside the sensing region.

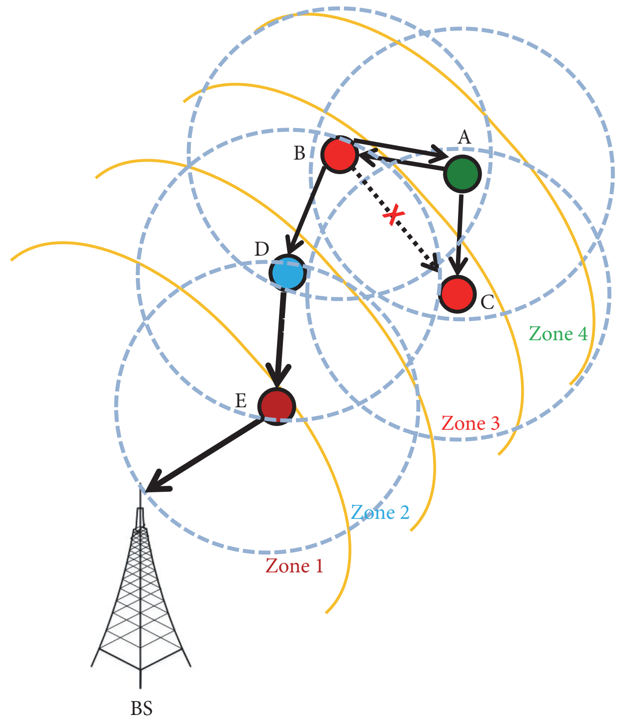

FIGURE 2: Redundant packet generation scenario.

(3) In a specified timeslot, each node can send its data to BS.

(4) All the nodes in the network are homogenous in nature with limited battery.

(5) The data sampling rate is fixed.

4.2. EEHRT Algorithmic Description. See Algorithm 1.

4.3. Message Types. We have defined different type of messages in our protocol. Detail and parameter value's description is presented in Figure 3.

4.4. How EEHRT Works? In EEHRT a node may not always be in listening state. A node may listen till it detects an event or has data of other nodes to relay it to BS. Moreover, for power saving, NAV (Network Allocation Vector) based virtual channel sensing technique is used for medium sensing and channel reservation for the current duration of the data transmission. The virtual carrier-sensing is a logical concept which does not let nodes sense the channel physically at the air interface to conserve node battery. The NAV field specifies the transmission time required for the frame, in which time the medium will be busy.

In EEHRT the receiver node is not predetermined, which contrasts with 802.11 standards. Hence, there is an additional random backoff time t_b required to ensure that potential relaying nodes in the lower zone will not collide upon their timer expiration.

In EEHRT, we give a random ID to each node in the network. Every time a node sends or relays the data, it will choose a newly generated ID as an originator ID, but the message sequence number remains the same. This greatly reduces the chance of sensor nodes in the locality choosing same identifiers and then steadily colliding.

Whenever a node has outstanding data to transmit, the node attempts to find an ultimate next hop node located in the lower zone or immediate to next zone having high energy, which could relay its data. This is in contrast with IEEE 802.11 where a node attempts to transmit to a node as decided beforehand by the routing algorithm. In EEHRT source node does not need to discover the neighbors for data transmission. Among the ultimate neighbors of the sender, one node is selected on the fly as a next hop node that is energy efficient and located closer to BS as compared to rest of the neighbors without any prior routing, energy and location information. We used the same routing strategy as used in [6] except some changes to handle the duplicate message created in RARZ routing. This is the main change done in our protocol to make the routing lightweight (i.e., less routing control overhead). This is done based on location and energy efficiency routing in which nodes do not need to know their respective position as well as any prior information for neighbor or route discovery mechanism.

The node that has data to send or relay the received packet on its timer expiration waits for a guard time t_g before attempting to transmit its data. Upon t_g expiration or freeing event of the channel, the node further waits for time t_l (listening time) before transmitting. The guard time t_g is used to ensure that the channel status should be either busy or idle. The additional random listening time t_l is to ensure that nodes do not transmit at the same time to avoid a collision

```
Begin
Set MsgSeqNo ⟵ 0
Set SzoneID ⟵ -1
Set SMsgType ⟵ -1
For each node's Schedule MSG
Set MsgType ⟵ 0
   If Msg ⟵ OwnMsg then
    Set MsgType ⟵ 1
    Waits for a guard time t_g    // After the guard time expires or when the channel becomes free, then
    Waits for a random listening time t_l   // Wait for time t_l before the actual transmission
    BroadCast Msg
    Add zoneID, MsgSeqNo and MsgType into buffer
   End if
   If MsgType ⟵ 1 or 2 and Node ⟵ BS then
    Set RecvPCKT ⟵ RecvPCKT + 1
    Drop Msg
   Else
    If MsgScheduled == RcvMsgSeqNo then
     If Recv_zoneID < SzoneID and MsgType > = SMsgtype  //SMsgType is the buffered value of MsgType
     and SzoneID is buffered/stored zoneID
     Set SeqNo ⟵ MsgRcvSeqNo
     Set zoneID ⟵ SzoneID
     Set MsgType ⟵ 3
     BroadCast Beacon        //Broadcast Beacon message
     CANCEL Event
     Drop Msg
     Reset buffer to initial value
    Else
     If RcvPCKT_ zoneID < = ZoneID then
      Drop Msg
     Else
      Schedule Msg for relaying by adding its own zoneID
      Set MsgType ⟵ 2
     End if
    End if
   If zoneID==RecvZoneID and SeqNo==MsgRcvSeqNo and MsgType == 3
    Kill timer
    Drop Msg
           Reset the buffer
    End if
End while
End
```

Algorithm 1: Pseudocode for EEHRT routing strategy.

which increases the data losses and greatly affects the network throughput.

The next hop node avoids contention with other potential next hop nodes in its vicinity by immediately choosing a random backoff time t_b and listening to the channel for sending a packet with the same sequence number. After that, it relays the received packet further with its own zoneID and with a message type 2. This again is in contrast with 802.11 where there is only one receiver node determined by the routing algorithm. This does not need any contention between potential receiver nodes. However, in EEHRT multiple receivers in the lower zones contend to become the ultimate potential next hop node. The EEHRT mechanism is based on random access and based closely to 802.11. In waiting period t_l, if next hop node hears the same packet with the same sequence number with the correct zoneID and message type from another next hop node or beacon from the source node, it will immediately kill its timer, delete the schedule packet, and immediately go back into the listener state.

If the message is received successfully by another node with a lower zoneID (which we call the next hop nodes), then one of the receiving nodes in the lower zone relays the received packet once its timer expired. The source node will also hear that packet because it is in the vicinity of the relaying node. The source node upon receiving the message with the same sequence number and lower zoneID will know that a node in the lower zone has relayed its data further. This is an acknowledgment (ACK) for the sender node. This is not a special ACK message but a copy of the lower zone

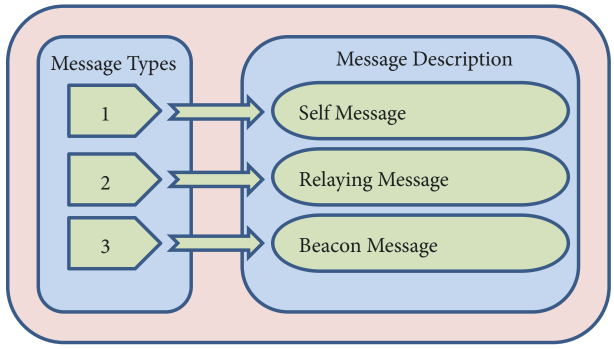

Figure 3: Messages types defined in the simulation.

node relayed message which is received by the sender node using the benefit of the wireless broadcast. This technique is also called wireless broadcast advantage (WBA). Once this message is correctly received by the source node, a short beacon message with message type 3 with the same packet sequence number and zoneID is quickly exchanged among the next hop nodes by the sender node. This message is for those nodes who could not hear the relaying node packet. This is the same packet for which they are still waiting to transmit it, i.e., their timer not elapsed yet. Upon receiving this small beacon message, they will kill their timer and delete the schedule packet and again go back to the listening state. In this way, the only one copy of the data at each hop along the routing path will be transmitted to the BS.

In EEHRT, once the sender node could not receive or hear its packet from the lower zone node, this means that there is no node in its vicinity (i.e., in lower zone) to further relays its data. If it could not hear an ACK from the lower zone, it will no more participate in the communication process and will be considered dead. In our simulation setup, we have not observed any situation where there is an isolation of a region in the network at the time of node deployment, i.e., the network topology is assumed completely dense in the proposed technique. There is no need of the rebroadcast packets as per the routing scheme used in EEHRT. When the sender did not receive the same packet from the lower zone node, this situation may happen especially when the network is almost near to depletion stage, i.e., when most of the nodes may deplete their energy, create holes, and make the network sparse. This may occur only once when the last rounds of communications in the network are in progress.

4.5. EEHRT Routing Illustration. The EEHRT routing process is illustrated graphically in Figure 4.

(a) Node S broadcasts its packet once the channel becomes free. Nodes in zone 2 will receive the packet and schedule it according to (1).

(b) Nodes in zone 2 will receive the packet and scheduled it according to (1).

(c) Node A will become the potential next hop node according to (1). When node A further relays the packet, node S will receive the packet, but node B will not receive it because it is out of the radio range of node A.

(d) After getting the packet from node A, node S will immediately broadcast a short beacon message with same packet ID and its own zone ID with MsgType 3.

(e) As node B is in the radio range of S, once it hears the beacon from the node S, it will cancel its timer and remove the packet from its buffer

Through this way, the redundant packets generated in the network are handled and only one copy of each packet is routed to BS. This technique totally removes the redundant packets from the network and ensures reliable data delivery in the network without any extra control overhead using WBA technique.

5. Simulation and Results

5.1. Energy Model. We have used the same energy consumption model in EEHRT as used in [1, 6, 7, 9, 14].

5.2. Simulation Setup. EEHRT scheme is implemented and evaluated in OMNET++, INET simulation Framework. Simulation parameters and their values are defined in Table 1.

Following parameters are defined in the simulation to assess the performance of the EEHRT routing scheme:

(a) Measuring duplicate packets reception at BS.

(b) Measuring unique packets reception at BS.

(c) Calculating network lifetime (i.e., no. of nodes alive over time).

(d) Average energy consumption in the system over time.

(e) Throughput (no. of messages successfully received at BS)

Figure 5 shows a total number of packets successfully received at BS in both RARZ and EEHRT. It is clearly depicted from the results that EEHRT outperforms RARZ in terms of the total number of messages received at BS and also it removes the probability of the duplicated packets creation in the network.

As EEHRT completely removed the redundant packets generation in the network, only a single copy of each packet is

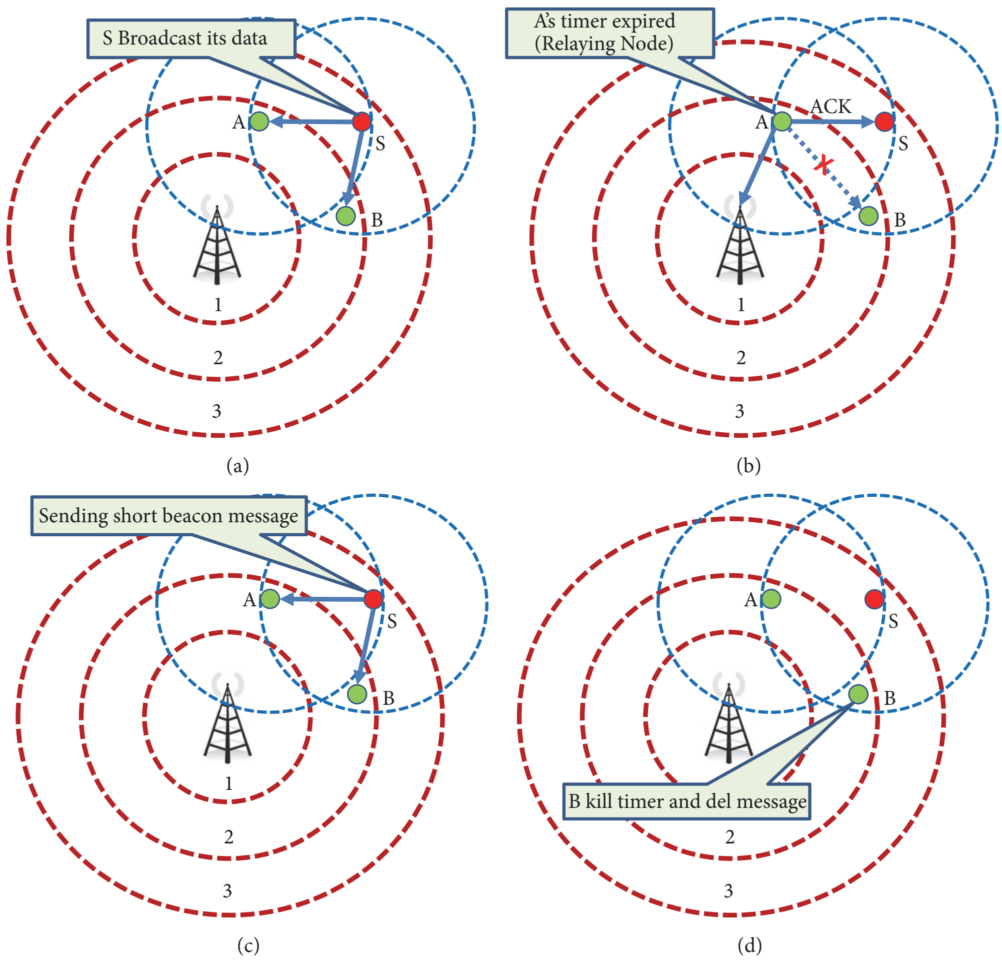

Figure 4: EEHRT working mechanism.

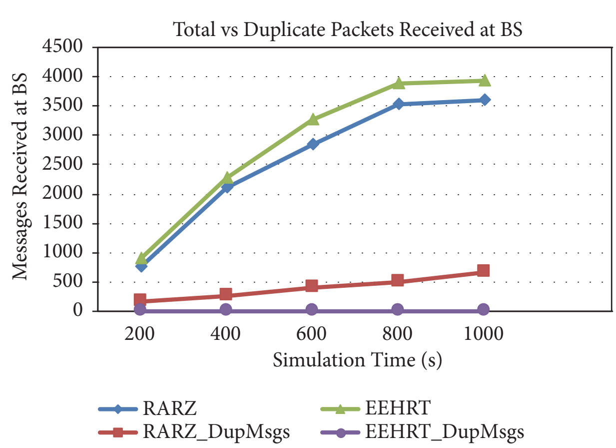

Figure 5: Total versus duplicate packet reception at BS.

received at BS. As shown in Figure 6, it is clearly seen that the total number of successfully received packets at BS is equal against the unique packets' reception at BS over time; hence, EEHRT outperforms RARZ in terms of distinct messages received at BS.

As in EEHRT, one short beacon message is introduced in the RARZ algorithm which eliminated the chance of duplicate packets creation in the network. All the redundant packets are removed in the proposed technique which greatly increases the overall network lifetime. Figure 7 shows a

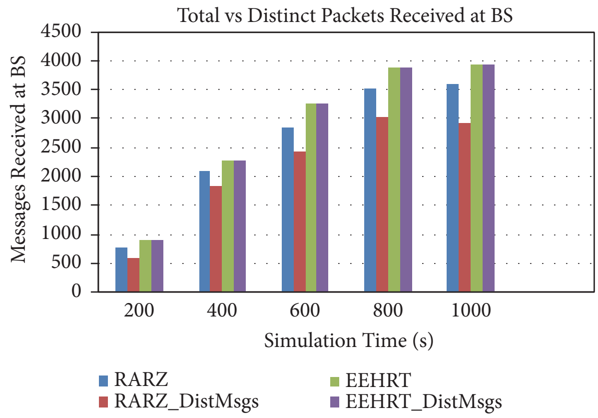

FIGURE 6: Total versus distinct/unique packet reception at BS.

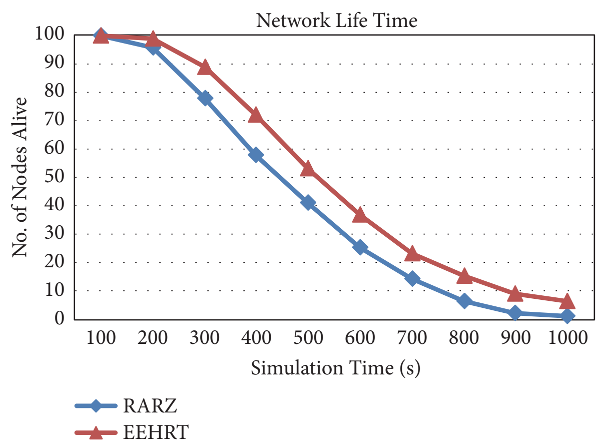

FIGURE 7: No. of nodes alive over time.

tremendous average improvement of 35% in EEHRT against RARZ routing in terms of overall network lifetime. This is because EEHRT, instead of sending multiple copies of the same packet, ensures a distinct copy of each packet received at BS.

The average energy consumption in the system is shown in Figure 8. As mentioned earlier that redundant packets greatly affect the overall network lifetime and other scarce resources like average consumption in the system over time. EEHRT extends the network lifetime by decreasing the energy consumed against the redundant packet's creation and their processing in the network because redundant packets are unwanted traffic which greatly influences the node battery lifetime. As shown in Figure 8, EEHRT outperforms RARZ routing by an improvement of overall 28% of energy efficiency in the network.

The number of data packets successfully received at BS is shown in Figure 9. As per the previous results evaluation, it is generally seen that redundant packets and extra control overhead of ACK packets greatly decrease the overall network lifetime and throughput. As in EEHRT, we removed the concept of duplicate packets creation and their processing the network. This greatly affects the overall throughput of the network. Figure 9 clearly shows that EEHRT performs better against RARZ when the total number of messages received at BS is high. An improvement in throughput is seen in a simulation which is 10% high against RARZ routing and 25% improvements against RARZ in unique packet reception at BS.

6. Conclusion

A novel data delivery technique called EEHRT for wireless sensor networks is proposed in this work. It divides the network into static zones by eliminating the control overhead and hence extends the network lifetime. The proposed protocol is a stateless protocol which is completely tableless and nonposition based. Energy efficient nodes in the network are used for data relaying purpose. This results in even distribution of energy consumption and avoids depletion of node's energy in a path. It also ensures distinct data copies of the messages received at the BS by removing the concept of duplicate packets generation in the network. Duplicate packet generation greatly affects the overall network lifetime and data throughput. Moreover, it handles acknowledgment without sending any special ACK packet to the sender by using wireless broadcast advantage (WBA), which significantly reduces the control overhead in the routing process.

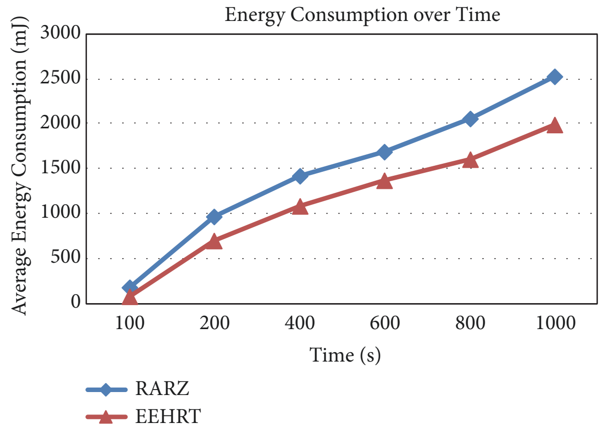

Figure 8: Average energy consumption over time.

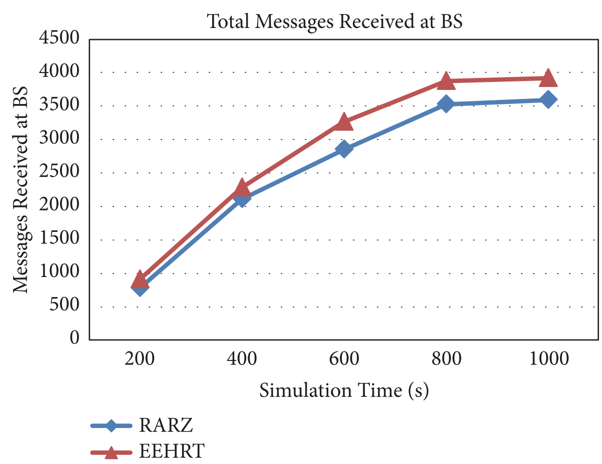

Figure 9: Network throughput.

The energy efficiency and ease of deployment make EEHRT a reliable data delivery protocol for wireless sensor networks. Simulation results show that EEHRT achieved 28% improvement in energy efficiency, 35% increase in overall network lifetime, 10% and 25% improvements in data throughput against total and distinct packet reception at BS respectively, and 100% reduction in redundant packets generation and propagation in the network against the RARZ routing.

Data Availability

No data were used to support this study. We have conducted the simulations to evaluate the performance of EEHRT and RARZ protocol. However any query about the research conducted in this paper is highly appreciated and can be asked from the principal author (Rab Nawaz Jadoon) upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

Acknowledgments

We are thankful to CAS-TWAS for supporting this work (CAS-TWAS No. 45, 2016). Also special thanks are due to COMSATS University, Islamabad (Abbottabad Campus), and School of Information Science and Technology, USTC Hefei, China, which fully supported us by providing all key resources during the implementation and all afterward phases of this project. We would also like to personally thank Prof. WuYang Zhou and Dr. Iftikhar Ahmed Khan because of their continuous encouragement and massive support both academically and socially during this project. This work is sponsored by Key Program of National Natural Science Foundation of China (Grant No. 61631018).

References

[1] W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, “Energy-efficient communication protocol for wireless microsensor networks,” in *Proceedings of the 33rd Annual Hawaii International Conference on System Siences (HICSS ’00)*, p. 10, IEEE, January 2000.

[2] M. Guerroumi and A.-S. K. Pathan, "Hybrid data dissemination protocol (HDDP) for wireless sensor networks," *Wireless Networks*, vol. 24, no. 5, pp. 1739–1754, 2018.

[3] R. E. Mohamed, W. R. Ghanem, A. T. Khalil, M. Elhoseny, M. Sajjad, and M. A. Mohamed, "Energy efficient collaborative proactive routing protocol for Wireless Sensor Network," *Computer Networks*, vol. 142, pp. 154–167, 2018.

[4] T. Maitra, S. Barman, and D. Giri, "Cluster-based energy-efficient secure routing in wireless sensor networks," in *Information Technology and Applied Mathematics*, vol. 699 of *Advances in Intelligent Systems and Computing*, pp. 23–40, Springer, Singapore, 2019.

[5] B. Bhushan and G. Sahoo, "Routing protocols in wireless sensor networks," in *Computational Intelligence in Sensor Networks*, vol. 776 of *Studies in Computational Intelligence*, pp. 215–248, Springer, Berlin, Germany, 2019.

[6] R. N. Jadoon, W. Zhou, W. Jadoon, and I. A. Khan, "RARZ: ring-zone based routing protocol for wireless sensor networks," *Applied Sciences (Switzerland)*, vol. 8, no. 7, article no. 1023, 2018.

[7] W. B. Heinzelman, A. P. Chandrakasan, and H. Balakrishnan, "An application-specific protocol architecture for wireless microsensor networks," *IEEE Transactions on Wireless Communications*, vol. 1, no. 4, pp. 660–670, 2002.

[8] J. N. Al-Karaki and A. E. Kamal, "Routing techniques in wireless sensor networks: a survey," *IEEE Wireless Communications Magazine*, vol. 11, no. 6, pp. 6–28, 2004.

[9] R. Nawaz, S. A. Hussain, S. A. Abid, and J. Shafi, "Beaconless multihop routing protocol for wireless sensor networks," in *Proceedings of the 2011 IEEE 3rd International Conference on Communication Software and Networks, ICCSN 2011*, pp. 721–725, IEEE, May 2011.

[10] D. J. Baker, A. Ephremides, and J. A. Flynn, "The design and simulation of a mobile radio network with distributed control," *IEEE Journal on Selected Areas in Communications*, vol. 2, no. 1, pp. 226–237, 2003.

[11] F. Bajaber and I. Awan, "Dynamic/Static Clustering Protocol for Wireless Sensor Network," in *Proceedings of the 2008 Second UKSIM European Symposium on Computer Modeling and Simulation (EMS)*, pp. 524–529, IEEE, Liverpool, UK, September 2008.

[12] S. Lindsey and C. S. Raghavendra, "PEGASIS: power-efficient gathering in sensor information systems," in *Proceedings of the IEEE Aerospace Conference*, vol. 3, pp. 1125–1130, IEEE, Big Sky, Mont, USA, March 2002.

[13] M. Hempel, H. Sharif, and P. Raviraj, "HEAR-SN: A new hierarchical energy-aware routing protocol for sensor networks," in *Proceedings of the 38th Annual Hawaii International Conference on System Sciences*, p. 324, IEEE, January 2005.

[14] W. Heinzelman, A. Sinha, A. Wang, and A. Chandrakasan, "Energy-scalable algorithms and protocols for wireless microsensor networks," in *Proceedings of the 2000 International Conference on Acoustics, Speech and Signal Processing*, pp. 3722–3725, IEEE, Istanbul, Turkey, 2000.

[15] A. Dwivedi, S. Kushwaha, and O. Vyas, "Performance of Routing Protocols for Mobile Adhoc and wireless sensor networks: A Comparative study," *International Journal of Recent Trends in Engineering*, vol. 2, no. 4, p. 101, 2009.

[16] M. V. Kumaramangalam, K. Adiyapatham, and C. Kandasamy, "Zone-based routing protocol for wireless sensor networks," *International Scholarly Research Notices*, vol. 2014, Article ID 798934, 9 pages, 2014.

[17] N. Al-Humidi and G. V. Chowdhary, "Energy-aware approach for routing protocol by using centralized control clustering algorithm in wireless sensor networks," in *Computing, Communication and Signal Processing*, vol. 810 of *Advances in Intelligent Systems and Computing*, pp. 261–274, Springer, Singapore, 2019.

[18] P. Lalwani, H. Banka, and C. Kumar, "BERA: a biogeography-based energy saving routing architecture for wireless sensor networks," *Soft Computing*, vol. 22, no. 5, pp. 1651–1667, 2018.

[19] V. Junapudi and S. K. Udgata, "Extended lifetime and reliable data transmission in wireless sensor networks with multiple sinks," in *Smart Intelligent Computing and Applications*, vol. 105 of *Smart Innovation, Systems and Technologies*, pp. 91–100, Springer, Singapore, 2019.

[20] I. A. Umar, Z. M. Hanapi, A. Sali, and Z. A. Zulkarnain, "Towards overhead mitigation in state-free geographic forwarding protocols for wireless sensor networks," *Wireless Networks*, pp. 1–14, 2018.