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# Improving Energy Efficiency for EMRP Routing Protocol for Virtualization in Wireless Sensor Network

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**Abstract -** *Monitoring a remote environment using wireless sensor networks (WSN) in which hundreds or thousands of sensor nodes are interconnected became of great interest recently. WSN can be used in wide range of applications to capture, combine and analyze data for live environmental and physical phenomena. One of the widely used cluster-based routing algorithm is The New Energy Aware Mesh Routing Protocol (newEMRP). It is a multipath, robust, scalable, and energy efficient algorithm for data transmission between the Cluster Head (CH) and the Base Station (BS). The NewEMRP protocol is classified as one of the routing techniques that support virtualization in WSN [1][3]. In this paper, we propose a new scheme named Optimal, Adaptive and Energy driven Mesh Routing Protocol (OAEMRP). This new scheme gives an equal weight for the different routing protocol hyperparameters. Also the new scheme limits the choice of relay nodes in order to reduce the number of broadcasting messages during the selection process. This leads to the reduction of energy consumption of the entire network, also, achieves a better delivery rate and a better load balance compared to the state of the art in network virtualization routing techniques [4][8][9].*

*Our simulation results show that the new protocol, OAEMRP, achieves better node energy consumption and network lifetime. Also, a better data packet loss rate compared to the newEMRP protocol. We will analyze and evaluate a use case of virtualization in OMNET++ and compare with the state of the art of hierarchy cluster-based routing protocols. We will also inspect the capability of the network for collaboration and resource sharing between different virtual wireless sensor network (VSN)[14][9]. Our simulation results also show that OAEMRP protocol achieve better capability of network resource sharing than the newEMRP protocol.*

***Key Words***: **VSN, Efficient Network Resource Sharing, Multi-hop Transmission, Cluster Based**

## 1.INTRODUCTION

Improvement in wireless communications and electronics have enabled the development of sensor nodes capability, but still have some limitations such as communication ability, sensor computing power and energy restriction. The sensor nodes size are small and can communicate with other nodes over short distances due to limitation of the communication range. For the future Internet of Things (IoT) environment, a different dynamic type of network belonging to various WSN which can be controlled by different administrative bodies to perform a specific task.

Combining different Heterogeneous sensors nodes for network level virtualization (VSN), will give more scalability, flexibility, robustness and reliability for networks. There are many different pathways between every node that can be used in case of connectivity to a faulty node in the main pathway. [8][11][15]

In VSN the node power consumption and management of energy play critical roles. There are three basic ways a node consumes its energy: Sensing data, processing data, and data communication. In the data communication, a significant amount of energy consumed while data packets are being transmitted or received. A significant amount of energy can be saved by aggregating or eliminating redundant sensed data. Discarding this data eliminates the need to sending it saving energy which lead to increased network lifetime. Because of the difference in energy consumption in VSN compared to WSN, The VSN routing protocols are very challenging. It needs to be scalable, energy efficient, and robust. Large network that consist of thousands of sensor nodes with limited capability needs routing protocols that are self-reconfigurable. Such routing protocols will change the network topology and hierarchy in case of a node failure.

Routing protocols in network level virtualization can be classified into two types; flat and cluster-based routing protocols. In flat-based routing protocol all nodes have the same function and play the same role as the other nodes in the network based on the probability that a Cluster Head (CH) is selected and send aggregated data to Base station (BS). Cluster-based routing protocols separate nodes into clusters and the node with highest energy is selected as CH that will be in charge of sending the sensed data to the BS. The data from nodes that belong to respective cluster arrived by CH will be compressed then all aggregated data packet will be sent to the BS.

cluster-based routing protocols consist of two layers, one layer is responsible for CH selection and the other is responsible for transmitting data packets after being aggregated at CH to BS. Also, it can be a single hop or a multi hop hierarchy level cluster-based routing protocol. The time-driven and event-driven protocols are the most used approaches for hierarchical cluster-based routing protocols in virtualization of sensor network. In time driven approach, sensed data is periodically sent to the BS to provide information about the environment all the time. It forms fixed clusters in the initialization stage based on a probabilistic formula. In the event driven approach, sensed data is sent to the BS. Whenever an event is detected, the clusters are formed. Event driven protocols are efficient, energy efficient and has a longer network lifetime than time-driven protocols.

EMRP[8], OPEAS[7], ARPEES[10], OEDSR[13], HPEQ[12], newEMRP[9] are event-driven cluster based hierarchical routing protocols. In these protocols, clusters are formed upon the detection of an event. After the clusters formation, data would be transmitted. ARPEES, OEDSR, HPEQ do not guarantee link reliability for data transmission to BS. If a link dies due to insufficient energy, a loss of data may happen mainly because there is no backup path available for transmission. EMPR, newEMPR protocols consist of three stages: initializing stage, cluster formation stage, and data transmission. At the first stage, the relay path that consist of a Relay Node (RN) and a Back Node (BN) is chosen based on the maximum value of the link cost function $F_{RN}$. Each time the CH searches its relay path, it sends a Req_RELAY message to all nodes within its range. All the candidate nodes must reply with a ACK_ RELAY message that contains node location to BS, Node ID, and node residual energy to its neighbors. This process continues to repeat until a path to the BS is reached.

In a large network with thousands of nodes, the optimal route path will have many hops in order to reach the BS. Such large number of hops leads to huge number of messages (Req_RELAY & Ack_RELAY) being transmitted in order to discover the path. In this paper, we propose a new routing protocol named: Optimal, Adaptive and Energy driven Mesh Routing protocol (OAEMRP). The protocol aims to reduce the number of broadcasting message during the relay node and backup node selection process. Using the proposed protocol would lead to energy consumption reduction of the entire network as well as a lower rate of data packets loss compared to recent routing protocols including EMRP, newEMRP and other protocols of the same category. Our simulation results shows that the proposed protocol OAEMRP could achieve a better energy consumption, a better lifetime, and a better packet loss rate than both the EMRP and the newEMRP protocols.

The remainder of the paper is organized as follows: section II related work section III present our new OAEMRP protocol in details section IV presents the performance evaluation of the proposal and the last section concludes the result and give possible future direction.

## 2. Related work

Many researchers in recent years focused on developing routing protocols to be used in WSN. Such routing protocols can be classified into two main categories; node level and network level protocols. Each of them can further classified into one of the following sub-categories : query-driven, time-driven , and event-driven protocols. SPIN, TTDD, and direct diffusion are examples of query-driven protocols. Leach, TEEN, APTEEN, and PEGASIS are examples of time-driven protocols. And finally, ARPEES, EMRP, newEMRP, HPEQ, and OEDSR are examples of event-driven protocols. The baseline used in this paper, newEMRP, is a cluster-based hierarchy multi-hop event-driven routing protocol.

The newEMRP consists of three stages: initializing stage, cluster formation stage, and data transmission stage[2][5][6]. In the first stage, initialization of the Relay path towards the BS from each node in the network. This can be achieved by selecting the optimal path which consist of a RN and a BN based on a link cost function where the node residual energy is the main parameter. At the second stage, whenever an event is detected in the network, a cluster will be created with all nodes nearby this event becoming active. The EMRP protocol will choose a cluster head out of the active nodes upon sensing an event. The CH will setup a time-slot scheduler called TDMA for all non-CH and cluster member nodes. This scheduler will specify when to send sensed data to the CH by assigning a time slot to each node in order to avoid collision during data transmission. The CH will receive data from all nodes, then it will aggregate all the data to form a frame ready for transmission to the BS.

The data transmission is the final stage. At this stage of the EMRP protocol[8], the CH uses the relay nodes, assigned at the initialization stage, to route data to the BS. Each of the nodes has two alternative relay paths and dynamically switch between these two paths based on a defined switch level to route data to the BS. The newEMRP[9] protocol does not use stored energy level of RN and BN from initialization stage. To achieve a better accuracy. A stored energy level will only be accurate when the RN and BN are not involved in any data transmission of other events. In the newEMRP, the CH queries the energy levels of the RN and BN using control message. By keeping up-to-date and accurate energy levels, the switching strategy will work efficiently.

The final stage of the newEMRP protocol can be summarized as the following steps: First, the frame is formed by the CH after receiving all the data from all non-CH nodes. CH will gather, aggregate and pack the processed sensed data into a frame called DATA_to_BS. In the second step, CH updates the stored energy level of RN and BN by sending control message directly to RN and BN querying their current energy level. Third, CH starts to send the data frame DATA_to_BS to its relay node RN1. Fourth, when RN1 receive DATA_to_BS frame RN1, it calculates the total energy cost for both receiving one DATA_to_BS frame from the CH plus relaying this frame to RN2 using the radio model(1):

$$
\begin{aligned}
Etotal\,(k,d) &= ETX(k,d) + ERx(k) \qquad (1)\\
&= KEelec + KEFSd2 + KEelec\\
&= 2kEelec + kEfsd2
\end{aligned}
$$

Equation (1) where Eelec is the power requirement on the electronics devices for transmitting and receive data, Efs is the transmission amplification energy, K is message bit length parameter, d is the transmission distance. RN1 sends back to CH a RELAY_Energy message containing the energy cost Etotal(k,d) and its current residual energy ERN1. The CH saves the Etotal(k,d) in its parameter ERE and update ERN1 if needed. Fifth, after having all the three parameters: energy residual of RN1, ERN1 and BN1EBN1 as well as the estimated energy for sending data to RN1:ERE, CH sends the DATA_to_BS_Frame to RN. Also, the CH updates parameter ERN1 corresponding to the residual energy of RN1 each time a DATA_to_BS frame is transmitted on the relay path using the below equation(2):

$$ERN1 = ERN1 - ERE \quad (2)$$

The sixth step happens concurrently with step 5. Before transmitting DATA_to_BS frame, the CH needs to check the following two conditions: First, if both ERN1 and EBN1 fall below a predefined critical level, it means that both RN& BN don't have enough energy in order to continue to send data. So, the CH will broadcast a Req_Relay message again to find new RN& BN. The second condition is If (EBN1-ERN1) less than a predefined switch level, RN1 will become a new BN and BN will become a new RN. Seventh, in the next hop , the current hop RN serves as the CH of the next hop. This CH uses the same method to relay data to the next RN, BN. RN and BN can switch dynamically. This process is repeated until the data frames arrive at the BS.

## 3. OAEMRP Routing Protocol

Optimal, adaptive and energy driven mesh routing protocol (OAEMRP) protocol process consists of two stages: first stage, a cluster created and the selection of CH is done. The second stage, the selection of the relay path is don creating a route to BS. When event occurs in the network, all node nearby this event become active. Req_ Cluster message will be broadcasted by these nodes. The node with maximum cost function sets itself as the CH. The CH stores all the nodes' ID and create a TDMA scheduler. The scheduler assigns a transmission time slot for each node that needs to send sensed data. This scheduled transmission will help to avoid data collision. After that, The CH broadcasts a Req_Relay message to all the nodes in the cluster. All non-CH nodes responds by brodcasting to its neighbors packets that contain node-ID, residual energy and location relative to BS. All the nodes use this information to choose a relay node and a back node based on the maximum weighted sum of the balanced factors function $F_{RN}$ (3).

$$F_{RN}(j)=norm\{Cos\alpha_j\}+norm\{E_{res}(j)\}+norm\{d(CH,j)/d(j,BS)\} \quad (3)$$

$$\forall_j \max F_{RN}(j) : j \in Y \&\& 0 <= Cos\ \alpha_j =< 90$$

Where Max $F_{RN}(j)$ represents the relay nodes, $E_{res}(j)$ is the normalized value for residual energy and available energy of node j, d(CH,j) is the distance from CH to a candidate node j, d(j,BS) is the distance from candidate node j to the base station, $\alpha_j$ is the angle value created by the edges connecting BS, CH and node j, Y represents a set of candidates for evaluating the relay path within the radio range. In the initialization stage, nodes who receive Request_Relay messages would respond with an ACK_relay message back to the CH.

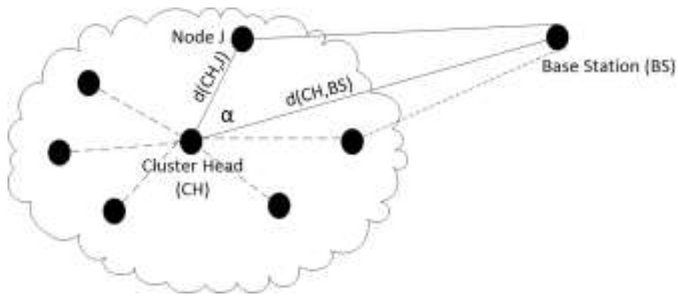


**Fig -1 :** Relay nodes selection

The total number of messages of this type has been reduced because only the nodes that has the value of Cos $\alpha_j$ (4) greater than 0 and less than 90 need to reply by sending Ack_relay message to CH. Where $\alpha_j$ is the angle between Node j, Cluster Head and Base station. Also, in this stage the weighted sum of balanced factors function is used to balance the three factors (energy, distance and angle) value for choose the relay path.

$$COS\ \alpha_j = d(CH,j)^2 + d(CH,BS)^2 - d(j,BS)^2/2d(j,BS)d(CH,BS) \quad (4)$$

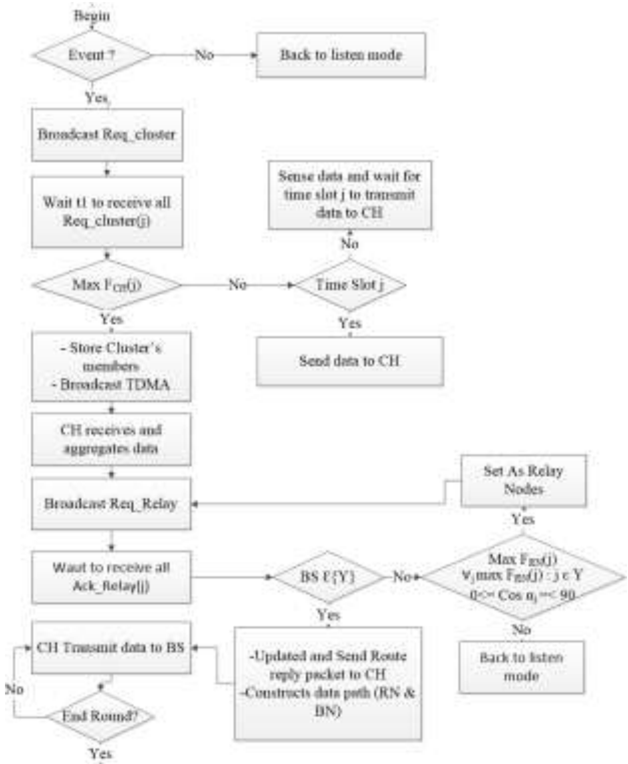


**Fig -2 :** Flow chart of OAEMRP routing protocol

After this stage, we end up with a mesh hierarchy network topology with each node having two links. One link to its relay node (RN) and the other link to its backup node (BN). Each node stores node ID, residual energy, and the locations of these two nodes. The nodes with the maximum value of the the weighted sum are selected as RN& BN. OAEMRP uses the weighted sum of balanced factors function to generate the cost of the path from CH to the BS passing by the relay path of node j. the flow chart in figure 2 illustrates the two stage of OAEMRP routing protocol.

## 4. performance evaluation

The OAEMRP protocol was implemented in the OMNET++ simulator [14]. OMNET++ is a network simulation tool that can be used to simulate discrete event systems in communication network application. Also it is a component based open-source with open-architecture simulation environment. It has a strong GUI and an embeddable simulation kernel. We ran our simulation with two square fields of size 150 by 150 and 300 by 300. The BS is located at coordinates (75,150) with the origin at the top left corner. we used the network and radio model with all the parameters setup during our simulation are shown in table 1. The newEMRP protocol has been implemented in the same simulator and its simulation results are included for comparison to the proposed protocol. Each simulation scenario will be terminates when all the sensor nodes that are within transmission range to the BS are dead. In other words, the simulation will be terminates when all the links to BS are broken and the data transmission is not possible anymore.

**Table -1:** Simulation Parameters

| # | Parameters | Values |
|---|---|---|
| 1 | Initial energy of nodes | 1 joule |
| 2 | Data packet size | 500 bytes |
| 3 | Broadcast packet size | 25 bytes |
| 4 | Transmission & receiving energy (Eelec) | 50 nJ/bit |
| 5 | Free space transmitter amplifier energy (E fs) | 10 pJ/bit/m2 |
| 6 | Multipath fading transmitter amplifier energy (E mp) | 0.0013 pJ/bit/m4 |
| 7 | Data aggregation energy (E DA) | 5 nJ |
| 8 | Type of distribution | Random |
| 9 | Number of nodes | 50,100,150 |
| 10 | Simulation area size | 150m*150m<br>300m*300m |
| 11 | Transmission Range | 150m |
| 12 | Sensing range | 70m |
| 13 | Switch level | 0.5 nJ |

Simulation: we have performed analytical simulation to evaluate and compare the performance of OAEMRP, the proposed protocol, and the newEMRP protocols using the following network performance metrics:

a. Stability period: it is the time before the death of the first node (FND). This is the period for which the network is considered stable. when the energy of any node reaches 0.005J it is marked as a dead node. In our simulation, as shown in table 2, the stability period of OAEMRP is increased by 37.9% compared to the newEMRP. The stability period is measured as the ratio between the first node dies (FND) period to the number of events created during the simulation. The main purpose of the weighted sum of balanced function is to chosse the relay path as well as deciding on the switching between the RN & BN based on the current residual energy of each node.

**Table -2:** Stability Period

| Protocols | Avg. # of event | Avg. First Node Dies | FND Ratio |
|---|---|---|---|
| OAEMRP | 8085 | 5887 | 0.72818 |
| newEMRP | 35606 | 12398 | 0.34820 |

b. Network lifetime: it is defined as the time before all the nodes are died which leads to disabling the data transmission. This period is the duration for which the networks remains functional. The network lifetime for OAEMRP was found to be better than newEMRP with 25.04%. The big difference can be explained by the lower power consumption profile of the OAEMRP compared to newEMRP. The OAEMRP consumes less energy because of the limited participation of non-cluster nodes in each event due compared to newEMRP. This could be achieved by balancing the three factors of the cost function (energy, distance and angle) as shown in below figure 3.

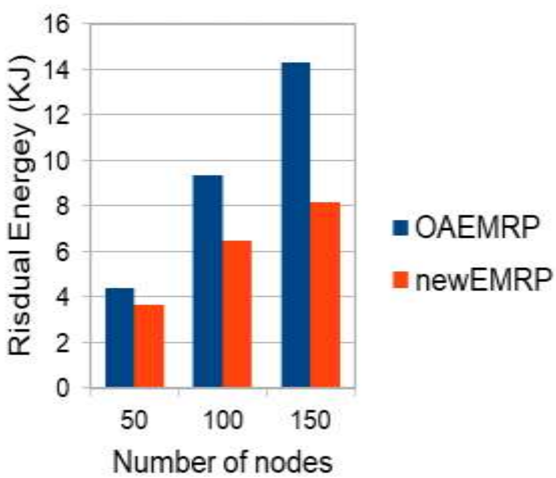


**Fig -3 :** Total Residual Energy

c. Energy consumption: the total amount of energy dissipated during data transmission from the cluster member nodes to the cluster head node during the lifetime of the sensor network. The result of this simulation shows that the residual energy of OAEMRP is more than newEMRP which means the OAEMRP is better than newEMRP in terms of energy consumption. This could be done by reducing the number of sent messages to CH by non-cluster nodes as shown in Table 3.

**Table -3:** Ratio for All Node Died

| Protocols | Avg. # of event | Avg. All Node Dies | AND Ratio |
|---|---|---|---|
| OAEMRP | 8085 | 8191 | 0.98709 |
| newEMRP | 35607 | 35700 | 0.99739 |

d. Total packets received at the cluster head node: it's the count of all the packets that received by CH from all non-CH nodes during the network lifetime. The number of messages in the case of OAEMRP is less than the newEMRP because of exclusion of nodes that has $\alpha_j$ more than 90 or less than 0 from replaying to CH Acknowledge messages. Also nodes with residual energy less than (0.005Joule) will be marked as failed nodes. So, the number of messages will be less and the nodes will save more energy. As shown below in table 4, the ratio of message failure of OAEMRP is better when compared to newEMRP by 2.4%.

**Table -4:** Message Rate Delivery

| Protocol | Total # of message | Failure messages | Ratio of message failure |
|---|---|---|---|
| OAEMRP | 9699 | 822 | 0.967907 |
| newEMRP | 164067 | 4820 | 0.992082 |

## 5. Conclusion

In this paper, we proposed a new hierarchical cluster based event driven routing protocol for Virtual wireless sensor network that is based on the EMRP protocol. In the proposed protocol, we used a new weighted sum of a balanced factors function for the choice of relay path for data transmission from CH to BS. The weighted sum of balanced factors function balances between three factors: Energy, angle, distance. The use of this new function lead to reduction in the number of broadcasting messages from non-cluster nodes to CH. These new characteristics of the proposed protocol caused better performance in terms of energy efficiency, network lifetime, load balance, data rate delivery, and better packet loss rate. The entire network lifetime prolonged by the improvement in consumption of nodes energy. The mentioned properties of the OAEMRP protocol leads to better network resource sharing by increasing the capacity to relay more messages over other VSN compared to the newEMRP protocol in case of virtualization of WSN.

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