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A New Algorithm for High Power Node Multicasting in Wireless Sensor Networks

R. SANTHANA KRISHNAN[1], E. GOLDEN JULIE[2], Y. HAROLD ROBINSON[3], LE HOANG SON[4,5], RAGHVENDRA KUMAR[6], MOHAMED ABDEL-BASSET[7], AND PHAM HUY THONG[8,9]

[1]Department of Electronics and Communication Engineering, SCAD College of Engineering and Technology, Tirunelveli 627414, India
[2]Department of Computer Science and Engineering, Anna University Regional Campus, Tirunelveli 627414, India
[3]Department of Computer Science and Engineering, SCAD College of Engineering and Technology, Tirunelveli 627414, India
[4]VNU Information Technology Institute, Vietnam National University, Hanoi 01000, Vietnam
[5]College of Electronics and Information Engineering, Sejong University, Seoul 100083, South Korea
[6]Computer Science and Engineering Department, LNCT College, Bhopal 462021, India
[7]Department of Operations Research, Faculty of Computers and Informatics, Zagazig University, Sharqiyah 44519, Egypt
[8]Division of Data Science, Ton Duc Thang University, Ho Chi Minh City 700000, Vietnam
[9]Faculty of Information Technology, Ton Duc Thang University, Ho Chi Minh City 700000, Vietnam

Corresponding author: Pham Huy Thong (phamhuythong@tdtu.edu.vn)

ABSTRACT Multicast routing protocols normally depend upon the standard establishment of a multicast tree that needs maintenance of state information by individual nodes. In the case of dynamic networks with burst traffic, between the bursts of data, a long period of silence is expected. The multicast state preservation appends a huge amount of transmission and memory overload. This is no longer suitable for any applications. Therefore, this paper proposes a stateless high power node multicasting method utilizing a group of sink node data, which are implanted in packet headers, to facilitate recipients to fix the finest technique to send data packets in the multicast traffic. In order to eliminate expensive state information of the neighbor table, the HPN multicast protocol utilizes the awareness of the exact positions of sensor nodes. This protocol will be preferably appropriate for multicasting in active networks. The simulation results confirm that HPN multicast affords elevated success rates and little delay exclusive of the trouble of state information.

INDEX TERMS WSN, multicast, high power node, success rate, delay.

I. INTRODUCTION

Wireless Sensor Networks (WSNs) consist of sensor nodes that are proficient of supervising and quantifying physical or ecological conditions over an extended period [1], [2]. These sensor nodes correspond to an excess of minimum communication area in spite of transferring captured data with the help of several hops to recipient nodes [3]. WSNs have been assembled for numerous output circumstances such as traffic monitoring, environment observing, target following, war zone reconnaissance and security applications [4]. In these applications, sensor hubs need to send a similar message to compound recipient nodes. These applications can get assistance from multicast broadcasting and diminish utilization of applications in WSNs. Consequently; it is significant to **design proficient multicast routing protocols** to sustain these sensor networks [5]. The Multicast routing methods are used to increase the performance of the network by various metrics like throughput ratio, bandwidth, and utilization of the network channels [6], [7]. These protocols can be categorized into Mesh topology, Tree topology and Hybrid Topology [8]. These topology controls are forming the network routing using the concept of multicast routing [9], Multicast tree-based routing [10]. The **limitations of the existing works** are that they use the concept of multicast communication but they must aware of the adjacent nodes. Few existing works contain the multicast algorithm which relies ultimately on the routing table and multicast tree maintenance.

In this paper, we **propose a stateless High Power Node (HPN) based Multicast protocol**. The key points of HPN multicasting are to enlarge the network lifetime by increasing the total number of successful delivering of messages. If the message is failed to deliver, it will be a complex problem. In this method, data packets are delivered to the destination through high power nodes when the distance exceeds the feasible distance. The Multicast Routing in Wireless Sensor Network is fully based on the location of the node and the attributes of GPS to find the distance between

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the adjacent nodes. The navigation of the GPS device will trace the routing of the network and discover that any failure in the network and ascertain the network routing paths. The primary objective for monitoring the Wireless Sensor Network is to gather the data about the states of the node, battery communication level, topology of the network, bandwidth, link availability, communication range. The management of Wireless Sensor Network can execute a lot of control task, energy management, network performance monitoring, network traffic organization and fault tolerance methodology.

Here, the packet routing, dividing of packets into numerous routes and every node depend exclusively on locality data of recipient nodes. HPN Multicast contains a packet header which includes a list of the multicast members' locations. This can avoid the transparency of constructing and preserving multicast routes because of all essential data for delivering the packet in the network. In addition to that, the transmission mechanism is engaged which does not necessitate any state data. No adjacent table preservation is essential in this method which makes HPN Multicast need the slightest information, and it is thus perfectly pertinent for active networks.

HPN Multicast is a recipient-related protocol, where the communication's adjacent node is determined by prospective data recipients in a disseminated approach. The HPN Multicast method does not need routing tables which facilitates the latest spatial-temporal neighborhood applications. This is a key asset, particularly for active networks. In HPN Multicast, recipients participate for the channel-based on their probable involvement in the direction of packet delivering, stimulated by the active mechanism for WSNs [11]. Nodes are having a high amount of energy and unbreakable links and all the nodes that help to send the data packet to the recipient node will transfer data to the next node. In HPN Multicast, the key point of a virtual node for delivering data packets to the recipient multicast members with the help of adjacent nodes. In addition, we also calculate the distances between a source node and various multicast members. Using this information, we fix a particular threshold limit called **feasible transmission range.** Transmission of packets to the multicast members will be decided via the threshold value. The proposed method is experimentally validated.

The remainder is as follows. Review of literature is given in Section 2 while Section 3 depicts the proposed method. Experiments are shown in Section 4 accompanied with conclusions and future works in the last section.

II. RELATED WORKS

The related multicast routing methodologies for WSNs and MANETs join multicast nodes via a tree. They depend on network tables at transitional nodes for multicast construction [12]. Multicast methods generate an optimum path from a single source to multiple destinations with geographical routing [13]. Whenever multicast trees are involved in many-to-many network communications, they are attached to optimization problems [14].

MAC Layer Multicast [15] provides the maximum threshold related methods to optimize the accessible bandwidth's utilization factor. Mobicast related forwarding zone assortment method [16] employs the dynamic selection of zone based on various traffic situations. Whenever the node reached the destination location, the zone forwarding location can be increased. The important drawbacks of the Mobicast are it can choose the topology randomly and the complexity of the method is also increased [17]. The Low Energy and Low latency-based protocol-based multicast routing [18] was implemented for routing.

Position Based Multicast (PBM) [19] creates the subsequent adjacent nodes within the active node to all the recipient nodes and determines a value of packet division. PBM uses the idea of multicast and data of adjacent nodes. Routing method for Low power networks [20] provides the explicit requirements and metrics. It builds a Directed Acyclic Graph to improve the root-sibling connection within the dissimilar routings. It creates the multipoint communication to reduce the traffic overhead within the network.

Multicast method for Low power networks [21] is known as the dribble multicast for generating multicast forwarding technique for lossy networks. Each node in the WSN receives all the multicast packets to deliver all the other adjacent nodes. EMGR [22] employs an energy-related multicast tree, which is created by the group of recipients and the initial node based on the parameter of energy more precede, to straight multicast data packet delivery. It sequentially picks neighboring nodes to the power-optimized position as the next node delivers for power preservation. CNSMR [23] employs the multicast routing protocol to increase the bandwidth, the utilization of the channels and improved throughput ratio. The core network modelling is implemented to reduce the routing overhead. LEMR [24] employs the multicast multichannel routing protocol which is used to reduce the interference problem by increasing the throughput and decreasing the delay. DCME-MR [25] proposes the concept of reducing the Minimum-Energy Multicasting problem and also reduces the NP-hard problems.

The **drawbacks of the existing works** are whenever data packets are circulated within the entire communication area; a large amount of communication overhead is established if the routing overhead is increased. Furthermore, the intervallic rebroadcasting of data packets will increase the routing overhead. The buffer of every packet needs a large amount of memory, and it reduces the multicast packets overall efficiency. Several timers are needed to guzzle the energy. Data packets increase the processing overhead as a result.

In the HPN Multicast method, the multicast members' locations are identified using GPS. If the position data is predefined, multicast routing is feasible based exclusively on position data exclusive of construction of an exterior tree construction. HPN Multicast supplementary reduces the requirement of significant information, and only the position of the nodes is required. This shows the **novelty of the proposed method** against the related ones.

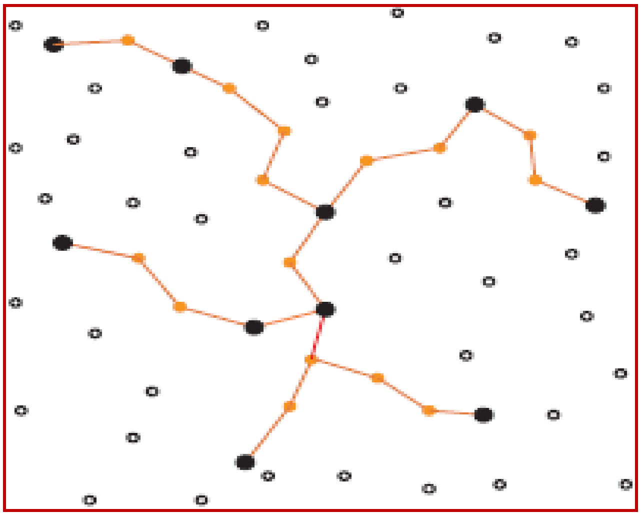

FIGURE 1. Network formation.

III. PROPOSED WORK

A. NETWORK FORMATION

It is measured that every sensor node is deployed in a 2-dimensional location and all the nodes are placed in a separate location. The two-way communication links are established within all nodes. The locations of nodes are captured using the GPS system. The sensor nodes are communicated with data packets and sensor nodes have the next hop information for communication. The source node must contain the distance parameter for communication. Figure **1** demonstrates the formation of Wireless Sensor Networks. The entire sensor nodes are divided into 3 regions x, y and z. Each region consists of multiple nodes. In order to compute the distance between the node in x region and the node in other regions may be calculated using a difference between the summations of the distance of two different regions. The distance between the node from $Node_x$ and $Node_z$ using $Node_y$ is computed using Eq. (1).

$$distance\,(Node_x, Node_z) = \sum_{i=1}^{n} distance(Node_{x_i} - Node_{y_i}) - \sum_{j=1}^{m} distance(Node_{y_j} - Node_{z_j}). \quad (1)$$

We generate the 2-dimensional coordination model shown in Figure **2**. Let the initial node is the origin node, X and Y axis are the corresponding node to the quadrangle boundary. The entire WSN is separated into $\frac{1}{\sqrt{n}}$. The transmission range is calculated using Eq. (2).

$$T_{range} = \sqrt{\frac{2}{\varepsilon}}\sqrt{\frac{\log x}{x}}. \quad (2)$$

In this coordination model, the feasible transmission range is computed using the Eq. (3).

$$\sum_{i=1}^{z} c\frac{1}{\sqrt{z}}\sqrt{a\int_{0}^{S} f\,(y)\,dy} \leq c\sqrt{a}\int_{o}^{y\in[0,1]^2} f\,(y)\,dy. \quad (3)$$

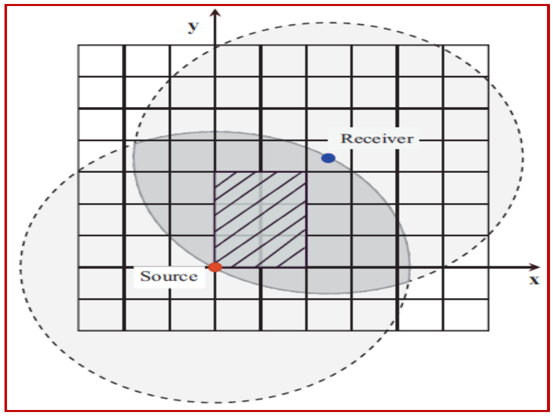

FIGURE 2. Network 2-dimensional coordination model.

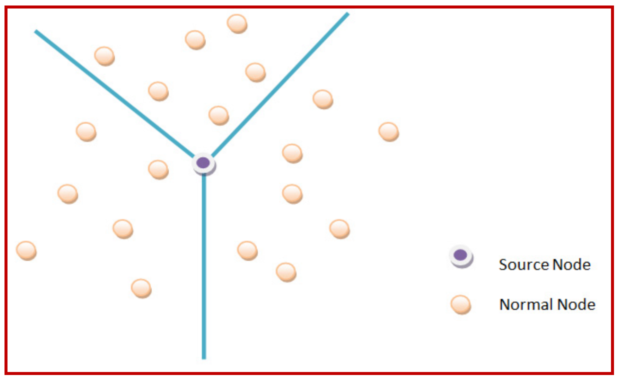

FIGURE 3. Separating the position into three 120^0 parts.

Expected Length is computed using Eq. (4).

$$E_{length} \leq c\sqrt{a}\int_{o}^{y\in[0,1]^2} f\,(y)\,dy. \quad (4)$$

B. FORMING OF MULTICAST REGIONS

There are 2 basic possible ways to create a multicast region by dividing the space which consist of sensor nodes as follows.

i. Dividing the space into four quadrants (Splitting using 90 degree) and
ii. Dividing the space into three 120-degree pieces.

Whenever a sensor node obtains a multicast packet, it separates the network into multicast regions (dividing the space into four quadrants or dividing the space into three 120-degree pieces). Further, it generates a replica packet and sends it to all regions which have one or more multicast members. Dividing the network into multicast regions in shown in Figure **3** and Figure **4**.

Dividing space into three 120-degree pieces resembles a Steiner tree approach in which every node has three branches. To separate space into 120-degree regions, angle to each destination node must be calculated. Calculation of angle depends up on trigonometric calculations. This additionally requires floating point operations. Most of the CPUs in existing sensor nodes do not support floating point calculations owing to the demand for low cost and low power. Moreover, multicast regions must be reevaluated in each hop of

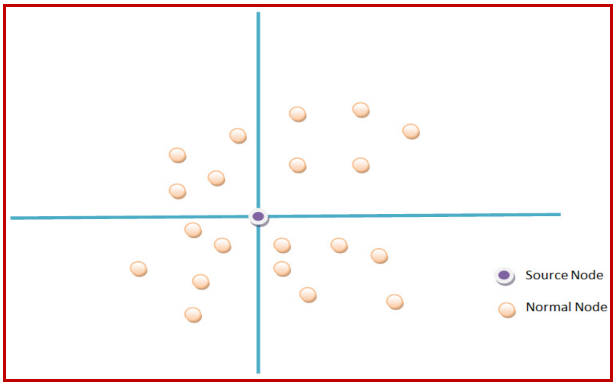

FIGURE 4. Separating the position into four quadrants.

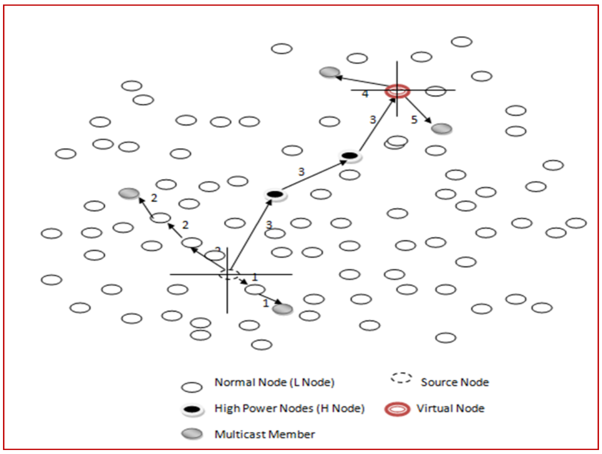

FIGURE 5. Multicast packet forwarding example.

packet delivery. This will generate a needless burden on sensor nodes and hence this method is therefore unacceptable. In 4 quadrants approach the multicast region calculation only needs two comparisons (X and Y axes) for all multicast member and it is found to be extremely fast.

C. ILLUSTRATION OF MULTICAST PACKET FORWARDING

Figure **5** demonstrates the Multicast Packet Forwarding Example. Here, an example is taken into account for explaining packet forwarding. Source node firstly checks the multicast members' positions in the multicast region. The Multicast region is considered as R. It is divided in to 4 quadrants r1 (North West), r2 (North East), r3 (South East) and r4 (South West). Here, 1 multicast member is in North West region (r1), 2 multicast members are at North East region (r2), 1 multicast member is in South East region (r3) and no multicast members are found in South West region (r4). Only 3 regions r1, r2 and r3 has multicast members. Hence only 3 duplication packets must only be done. Region r4 does not have any multicast nodes and consequently, no duplication of a packet is required for that part. For regions r1 and r3, only one multicast member is found. Hence, for those two multicast members, the distance between the beginning node and the multicast member node is calculated.

If the calculated distance value is less than the feasible transmission range, the transmission of a packet is done with the help of normal nodes (low power nodes). Similarly, if the calculated distance value is greater than the feasible transmission range, the transmission of packet is done with the help of high power nodes. Consider the region r2 which contains 2 multicast members in that region, the virtual node is selected in such a way that the virtual node should be at a mean distance from both multicast member nodes. After selection of the virtual node, the source node transmits the duplicated packet to the virtual node though normal nodes or high power nodes after calculating the distance within the beginning node and virtual node.

In northeast region the destination node is found to be closer to the source node. Hence it transmits the packet through normal nodes. Whereas in the northwest region; the distance between the source node and the virtual node is greater than the feasible distance. Hence, it chooses High Power Nodes (HPN) for data transmission.

D. IMPLEMENTATION OF HPN (HIGH POWER NODE)

In WSNs, there are two types of nodes.

- *H* nodes: The nodes have superior power and a huge communication area.
- *N* nodes: The nodes have the minimized power with tiny communication area.

Figure **5** demonstrates the HPN where H Nodes are high power nodes which cover a huge communication area. Whereas N nodes are normal nodes which have low power and hence the communication area is also reduced. In this paper, we calculate the feasible transmission range between the source node and multicast members node. If the distance is found to be less than the calculated feasible transmission range, normal nodes (N Nodes) are used for transmitting the packet; otherwise, high power nodes (H- nodes) are used.

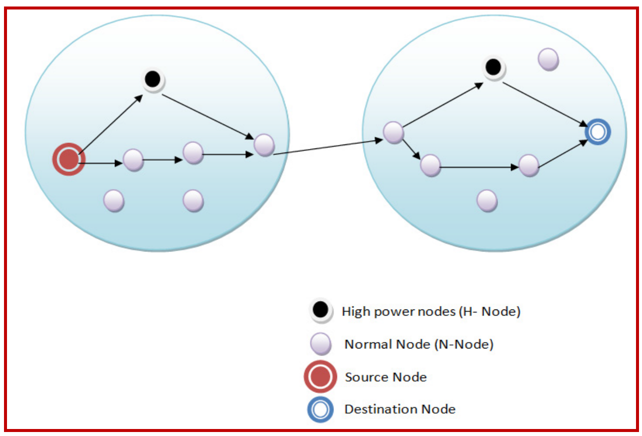

FIGURE 6. Implementation of HPN (High Power Node).

In Figure **6**, when we use N-nodes (normal nodes) to transmit the packet from source node (denoted as red circle) to destination node (denoted as blue circle), it requires 7 hops, whereas when we use H-nodes (High Power Nodes),

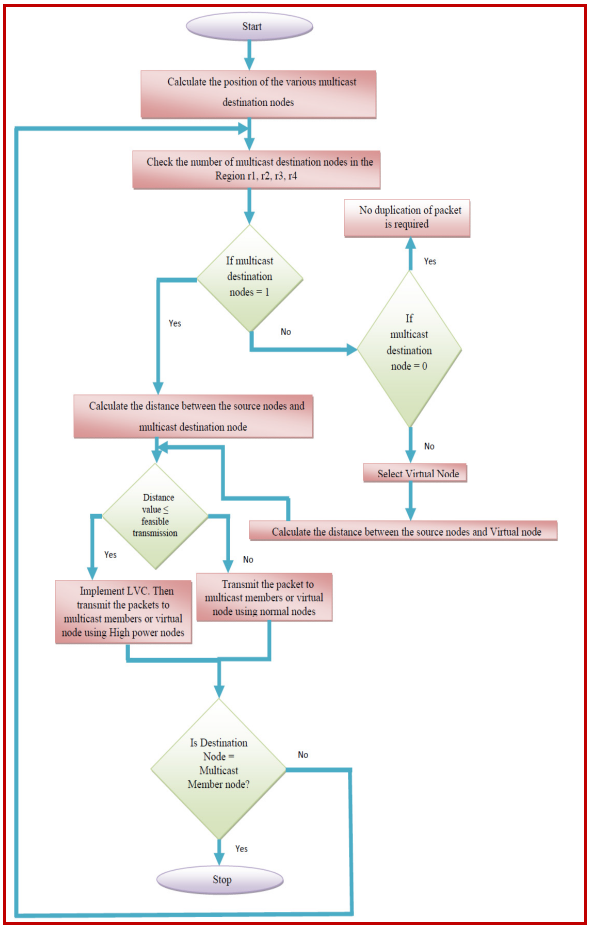

FIGURE 7. Flowchart for implementing the HPN multicast method.

it requires only 5 hops to transmit the packet between source node and destination node.

E. STEPS IN IMPLEMENTING THE HPN MULTICAST METHOD

Step 1: Identify various multicast destination nodes.

Step 2: Calculate the position of various multicast destination nodes and distance between the source nodes and various multicast destination nodes using GPS.

Step 3: Use multicast region concept to transmit the packets.

Step 4: Implement HPN: If the distance within the initial nodes and recipient multicast node is below the feasible transmission range value, we use normal nodes to transfer packets to multicast destinations. Similarly, if the distance within the initial nodes and recipient multicast node is above the feasible transmission range value, the high power nodes for transmission of the packets are used.

Step 5: If there are extra multicast elements in a particular part, we select a virtual node which would be at a mean distance between all the multicast elements in that part.

Step 6: Then repeat from step1 to step 5

The flowchart detail is demonstrated in Figure 7.

F. ALGORITHM 1 HPN- MULTICAST SEND

The algorithm explains how a packet is sent from the beginning node to recipient multicast node.

```
Gather reliable info M from group table
for node m in reliable info M do
for communication area x in 4 parts R do
if m ϵ x then
        Include m as x.info
end if
end for
end for
for x ϵ R do
if x.info<> 0 then
Replicate a data_packetpt
        Include HPN_Multicast_header (T T L,
check_sum, x.info) to pt
Send to next node
end if
end for
```

G. ALGORITHM 2 HPN- MULTICAST RECEIVE

The algorithm explains about how a node reacts when a packet is received from previous node.

```
Compute check_sum.
Remove data_packet if there is Format_error
Gather Recipient Info S
for every node s in recipient list S do
if current_packet = s then
Replicate the packet
Remove s from Info S
end if
end for
if TTL in packet_header == Empty then
Remove all data_packet
end if
for communication area x in 4 parts R do
if s ϵ x then
Include de into x.Info
end if
end for
for d ϵ R do
if x.Info is <> 0 then
Replicate a data_packetpt
Include HPN_Multicast (T T L − 1, check_sum,
x.Info) to pt
Send to next node
end if
end for
```

H. ALGORITHM 3 HPN- MULTICAST ROUTING

The algorithm explains about the concept of HPN-Multicast Routing.

HPN-Multicast Routing (Node n)
For every n nodes in the Wireless Sensor Network
  Compute the position of the multicast destination nodes
  Check whether the amount of multicast destination nodes in the communication range
If the multicast destination nodes are found in the communication range then
  compute the distance between the initial node to the recipient node
End If
If the distance is less than the transmission feasible range then
  perform HPN Routing
else
  transmit the data packets to the members of the multicast
End if
If the multicast member node is the destination node then
  Stop the entire HPN-Multicast Routing process
End if
End For

TABLE 1. Parameters.

Metrics	Assessments
Node distribution	random
network scenario	850 m x 1050 m
Data message	CBR traffic
Network Simulation	50 simulation per second
Bandwidth	5.0 Mb/s
Mobility speed	0 to 10 m/s
starting energy	5.2 J
traffic type	dynamic
physical layer	PHY 802.11c
battery power	linear
transmission area range	290 m
node compactness	22.7
standard hop-count	6.3

IV. PERFORMANCE EVALUATION

The simulation of the WSN is implemented using Network Simulator 2. The network is simulated with limited number of nodes from 100 to 900. The parameters of simulation are displayed in Table **1**. The Simulation Results compared the Proposed Work HPN Multicast with CNSMR [23], EMGR [22], LEMR [24] and DCME-MR [25].

A. EFFICIENCY

Figure **8** shows the comparison graph for Efficiency for all the Methods. Efficiency is calculated based on the lifetime of the network and processing power of the sensor nodes. The performance of efficiency of WSN nodes are compared to the related works. The efficiency of the proposed work is improved from all the related multicast routing methods such as CNSMR, EMGR, LEMA, DCME-MR. The successful rate is the key factor for improving the efficiency for the routing of the data packets in the WSN. The efficiency is improved when the packet drop ratio is small and produces the alternative routes whenever the link failure happens.

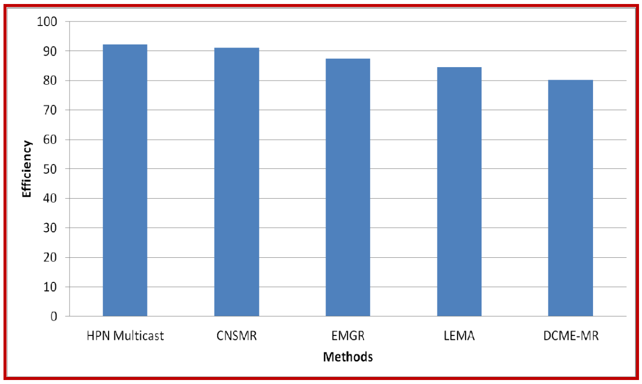

FIGURE 8. Comparison graph for efficiency for all the methods.

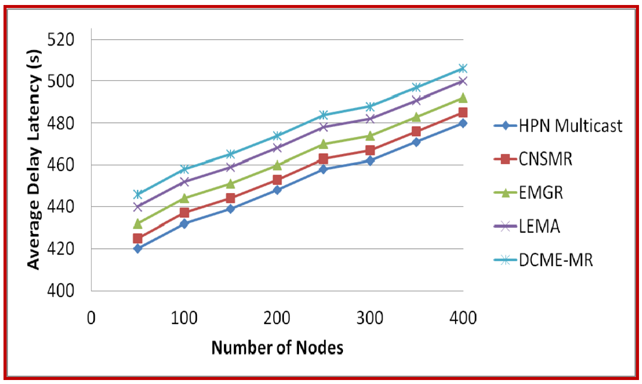

FIGURE 9. Comparison graph for number of nodes v/s average delay latency.

B. NUMBER OF NODES v/s AVERAGE DELAY LATENCY

Figure **9** demonstrates the comparison graph for Number of nodes v/s Average delay latency. The average delay latency is computed by the quantity of period is needed to broadcast the data packet from one node to the recipient nodes. Whenever the multicast group is higher than the delay latency minimizes. The main nodes can save the alternative path information and supply to minimize the delay latency. Simulation results proved that the proposed method has 4.81% reduced compared to that of DCME-MR, 3.81% reduced compared to LMEA, 2.88% reduced compared to EMGR and 0.96%

reduced compared to CNSMR in terms of average delay latency.

C. NUMBER OF NODES v/s PACKET DELIVERY RATIO

Figure **10** shows the comparison of Number of nodes v/s Packet delivery ratio. The WSN routing based on multicast methods are diverged from packet delivery ratio. Whenever the density of the node enlarges, the proposed method delivers the data forwarding methodology to reduce the transmission delay and improves the packet delivery ratio. The simulation results proved that the proposed method have 1.01% increment in packet delivery ratio with respect to CNSMR, 2.6% increment in packet delivery ratio with respect to EMGR, 3% increment in packet delivery ratio with respect to LEMA and 3.1% increment in packet delivery ratio with respect to DCME-MR.

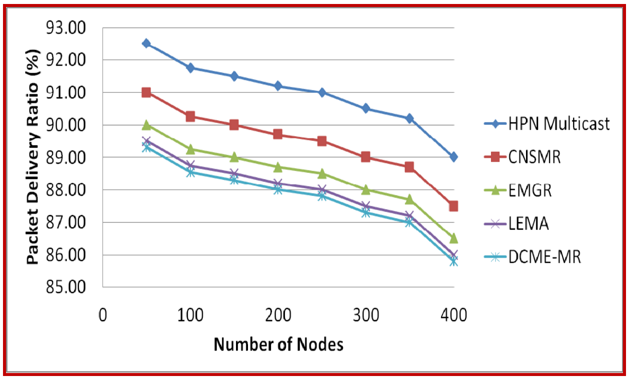

FIGURE 10. Comparison graph for number of nodes v/s packet delivery ratio.

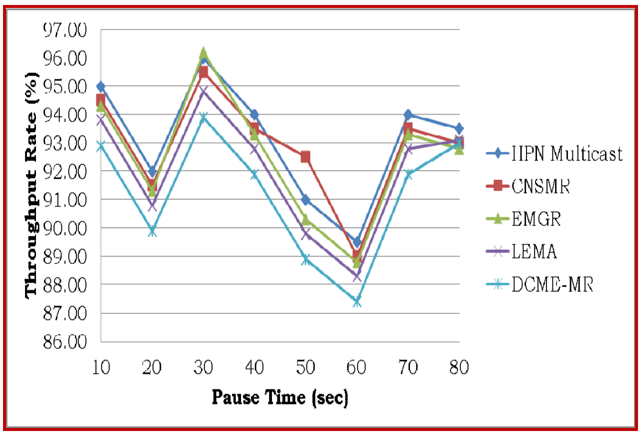

FIGURE 11. Comparison graph for pause time v/s throughput ratio.

D. PAUSE TIME v/s THROUGHPUT RATIO

Figure **11** shows the pause time v/s Throughput ratio. In disseminated network surroundings, the throughput ratio is computed by using the whole amount of data packets are broadcasted in the recipient node in a multicast time period. The simulation results indicated that the proposed method has 0.3% increment in pause time vs throughput ratio compared to CNSMR, 0.5% increment in pause time vs throughput ratio compared to EMGR, 1% increment in pause time vs throughput ratio compared to LEMA and .75% increment in pause time vs. throughput ratio compared to DCME-MR.

V. CONCLUSIONS

A stateless High Power Node multicast (HPN Multicast) protocol has been developed with a number of multicast members (sinks) focus to the receivers to fasten the packet delivery to the multicast destinations. In order to eliminate the costly state maintenance of tree/neighbor table, HPN Multicast protocol uses the information about the physical locations of the nodes. HPN multicast protocol is suitable for multicasting in dynamic networks. The experimental results confirm that HPN Multicast routing gives elevated success rates and reduced delay.

Future studies will investigate parallel methods and advanced optimization methods [26]–[34] to boost up the designed protocol in this research.

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R. SANTHANA KRISHNAN has the total teaching experience of 10 years. He is currently an Assistant Professor with the Department of ECE, SCAD College of Engineering and Technology, Tirunelveli. He has published several papers in international journals. He has presented many papers in national and international conferences in the IOT, mobile computing, and network security.

E. GOLDEN JULIE received the B.E. degree in computer science and engineering and the M.E. degree in computer science and engineering from Anna University, Chennai, in 2005 and 2008, respectively, and the Ph.D. degree from Anna University, Chennai. She is currently an Assistant Professor with the Regional Centre, Anna University, Tirunelveli, India. She has published many research papers in various fields. Her research interests include wireless sensor adhoc networks and image processing. She is a member of ISTE.

Y. HAROLD ROBINSON has the total teaching experience of 11 years. He is currently an Associate Professor with the Department of CSE, SCAD College of Engineering and Technology, Tirunelveli. He published several research papers in international journals. He has presented many papers in national and international conferences in network security, mobile computing, and cloud computing. His research interests include wireless networks, mobile computing, and wireless sensor networks.

LE HOANG SON received the Ph.D. degree in mathematics–informatics from the VNU University of Science, Vietnam National University (VNU), in 2013. He has been promoted to Associate Professor in information technology, since 2017. He was a Senior Researcher and the Vice Director with the Center for High Performance Computing, VNU University of Science, VNU, from 2007 to 2018. Since 2018, he has been the Head of the Department of Multimedia and Virtual Reality, VNU Information Technology Institute, VNU. He serves as an Editorial Board of *Applied Soft Computing* (ASOC, in SCIE), the *International Journal of Ambient Computing and Intelligence* (IJACI, in SCOPUS), and *Journal of Computer Science and Cybernetics* (JCC) (Vietnam). He is an Associate Editor of the *Journal of Intelligent & Fuzzy Systems* (JIFS, in SCIE), the IEEE Access (in SCIE), *Neutrosophic Sets and Systems* (NSS), *Research and Development on Information and Communication Technology* (RD-ICT) (Vietnam), *VNU Journal of Science: Computer Science and Communication Engineering* (JCSCE), and *Frontiers in Artificial Intelligence*.

RAGHVENDRA KUMAR received the B.Tech. degree in computer science and engineering from SRM University, Chennai, India, the M.Tech. degree in computer science and engineering from KIIT University, Bhubaneswar, India, and the Ph.D. degree in computer science and engineering from Jodhpur National University, Jodhpur, India. He is currently an Assistant Professor with the Computer Science and Engineering Department, L.N.C.T Group of College Jabalpur, India. He has published 86 research papers in international/national journal and conferences, including IEEE, Springer, and ACM as well as serve as a Session Chair, Co-Chair, Technical Program Committee members in many international and national conferences and serve as a Guest Editor in many special issues from reputed journals (Indexed By: Scopus, ESCI). He has authored 12 computer science books in field of data mining, robotics, graph theory, and turing machine by IGI Global Publication, USA, IOS Press Netherland, Lambert Publication, Scholar Press, Kataria Publication, Narosa, Edupedia Publication, S. Chand Publication, and Laxmi Publication. His research interests include computer networks, data mining, cloud computing, secure multiparty computations, theory of computer science, and design of algorithms. He also received Best Paper Award in the IEEE Conference 2013 and the Young Achiever Award-2016 by IEAE Association for his research work in the field of distributed database.

MOHAMED ABDEL-BASSET received the B.Sc., M.Sc., and Ph.D. degrees in information systems and technology from the Faculty of Computers and Informatics, Zagazig University, Egypt. He has published more than 150 articles in international journals and conference proceedings. His current research interests include optimization, operations research, data mining, computational intelligence, applied statistics, decision support systems, robust optimization, engineering optimization, multi-objective optimization, swarm intelligence, evolutionary algorithms, and artificial neural networks. He is working on the application of multi-objective and robust meta-heuristic optimization techniques. He is also an/a Editor/Reviewer in different international journals and conferences. He holds the Program Chair in many conferences in the fields of decision making analysis, big data, optimization, complexity, and the Internet of Things, as well as editorial collaboration in some journals of high impact.

PHAM HUY THONG is currently pursuing the Ph.D. degree with the VNU University of Science, VNU. He is currently a part-time Researcher with the Division of Data Science, Ton Duc Thang University, Vietnam. His research interests include data mining, soft computing, fuzzy computing, geographic information systems, and molecular dynamics simulation.