

A Virtual Projection-Based Incentive Routing Protocol for Mobile PFNs in Wireless Sensor Networks

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Abstract—The current Wireless Sensor Network (WSN) lacks the desired power owing to the non-availability of the power source. The challenge posed in the current scenario is conserving power for effective data transfer, which is seldom achieved. Added to this is the evolving technological innovations where the physical size of the Packet Forwarding Nodes (PFNs) is also reduced along with its power source, thereby reducing the power available to the system and making it inefficient. The existing methodology employed in monitoring the parameters used in Epidemic Algorithm (EA) and Incentive Compatible Routing Protocol (ICRP) protocols which are power guzzlers, the power available for data transfer is greatly reduced making the entire system inefficient. This paper attempts to mitigate the challenges posed by the EA & ICRP, the proposed protocol, “Incentive Routing Protocol with Virtual Projection (IRPVP)”, employs a Relay Sensing Node (RSN) which is designed to be distributed in a square cross-sectional area where each node acts as a unique Sensing Point (SP) monitoring each of the essential parameters like energy consumption, vibrant & non-vibrant SPN count, residual energy and routing overhead while still retaining power for data transfer since the RSN is connected to a dedicated power source. In IRPVP protocol, each packet of a node is subdivided into fragments that are designed to have fixed or variable lengths depending upon the application. Each of these packets is sent over multiple Packet Forwarding Nodes (PFNs) towards the data center. The selection of PFNs in the path is based on their trust levels like meeting probability, computation of residual energy, data weight, and security value. Special PFNs are placed in the network and are entrusted to deliver the packets to the data center without data loss during transmission. The result of the IRPVP protocol Vis-à-Vis the EA & ICRP protocol, backed by the simulation results proves that the IRPVP protocol is better in data handling and is more efficient.

Index Terms—Packet forwarding nodes, Epidemic algorithm, Incentive compatible routing protocol, wireless sensor networks.

I. INTRODUCTION

The miniature nature of PFNs has made the system increasingly popular and the exchange of packet data happens rapidly, due to this congestion occurs in the WSN. The regions are divided into sectors and each sector has distributed traffic. The congestion factor is computed for each neighboring sector and the lowest congestion factor

is selected. In Delay Insensitive Network Algorithm (DINA), the packets of length ‘L’ and data chunks of ‘M’ size are considered. Each data chunk will have an identifier, original data, and sequence number. These chunks are moved across multiple independent sectors with each sector having its unique identifier for communication. The PFNs within the transmission range will receive the control packet, then the acknowledgment will be sent to the initiator node. The node that has the lowest reply time is used as the next forward node. To avoid repeated use of the same PFNs, the transmission of packets is deferred. Security and energy consumption are the criteria being created during the initiation of packet transmission. In WSN, the initial SP energy level is four times higher than that of the SP that participated in the network's data transfer. The SP in the network has limited battery capacity. When the SP participates in the network, it loses its energy which depends on the factors like attenuation, amplification, and transmission range between the nodes. If the same SP repeatedly participates in the data transmission, then the SP becomes dead [1]-[4]. As the distance between the SPs increases, the energy consumption of the SP will be more. To overcome these issues a Relay Sensing Point (RSP) with continuous energy is used. It can be a renewable energy source that is continuously fed to the SP if the energy level drops to a threshold point. WSN is used for a wide range of use cases. The physical activity of constructor workers is detected with the help of the sensor node with the node having attributes namely cost, size, washing, and ergonomic volume. The worker's health is monitored with the help of dust detection and rays detection. The evolution of game theory has changed the burden of data packets in the network by balancing the network system [5].

The main goal is to design a system that allows the SP to lose energy at roughly a similar rate. The energy balancing is based on three-dimensional game theory which integrates numerous ways to make better selections while picking the forwarding node. The SPs are placed by balancing the energy and choosing the best forward path for communication. By calculation, the unit weight of data packets in the network and dividing the area into multiple paths can reduce the burden on the network during node-to-node communication. The area is selected based on the number of residual packets in the network, and then one of the SP is chosen to send the data packet. This energy

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harvesting strategy improves the lifetime ratio of the network [6]. Sensor SP (SSP) is spread throughout the area, each with its own set of characteristics, such as limited power, and short lifetime. The important constraint is to increase the network's lifespan ratio to increase network coverage. After computing the probability value, the scheduler is implemented in an optimum manner to distribute the packets with a small overhead ratio and greater coverage area. Social media, news, electronics, and location monitoring devices generate massive amounts of data. Data redundancy over multiple SPs is a new research challenge. In terms of the lifetime parameter, the estimated model is generated in a round-robin fashion. The network's lifetime can be extended by lowering the data and repeating request packets sent to SPs during the communication between the nodes in the network. This can drastically reduce the battery utilization among the nodes in the sensor network by introducing multi-hop transmission from source to destination in real-time [7].

As the battery of the SP becomes critically unhealthy, energy holes appear in the network. Conventional systems use either a static or mobile sink, where the system fails to incorporate the network weight balancing technique, thereby resulting in a shorter network lifetime. SPs must visit target sites and collect information about the nodes when the node information cycle is active in the network.

However, if the node is within the communication range, SSPs can send the data to its neighboring nodes successfully and thereby improving the network's lifespan ratio [8]. Network node paths can be minimized using a flexible design of the network so that the data can be collected by SSPs. To exponentially enhance the lifetime ratio of the network system, an intersection between the area of interest and the sensing area must be thoroughly investigated. The placement of the PFNs in the network will be initiated based on end region coordinates. The input PFNs count, x and y coordinates on the region are generated and PFNs have unique Ids starting from node 1 to the highest ID (Identification) of the node. The entire region is separated into multiple sectors using the density of packets in the network [9]. The selection of the region is based on the packets present in the sectors.

Conventional systems are more redundant due to various factors like the number of hops, energy consumption, alive (vibrant) & dead (non-vibrant) nodes among others. There was a need to revisit the existing system to further refine the same. The physical reduction of component size including batteries hardly sustains to fulfill the energy efficiency of the communication system. This research is aimed and innovated to mitigate the challenges faced where the overall efficiency of Wireless Sensor Network (WSN) is enhanced to reduce the time delay and data loss.

This work is organized into five sections including the introduction section. The review of the literature is presented in Section II. The proposed incentive routing protocol with virtual projection is discussed in Section III. The simulation results of the proposed work are explained

in Section IV. Section V concludes the summary of the research work. Finally, Section VI discusses the future scope.

II. RELATED WORKS

The streaming of data is very important for civil and military-based systems in which the entire area is divided into multiple independent tiers to compute the lifetime ratio. The sensors used for sensing are classified into aggregators or forwarders so that packets are distributed across routes during packet forwarding. Different session flows are used for the transmission of data to improve the bit rates to increase the network life [10]. In the multi-route workflow, independent routes must be active so that the data can be distributed. Since more PFNs are involved, more energy loss occurs in the system. The aggregate or forwarder PFNs are based on the random selection where the possibility of a node becoming non-healthy. More amount of energy consumption occurs in the network leading to the creation of holes in the system [11]. The transmission range should be maintained within the range specified to avoid network holes. The next node selection should be completely based on geographic computation and the control of the number of packets sent. But, if only the positions are considered then there is a possibility of more holes getting created in the network. The monitoring of the sensitive area is important for better delay and QoS during data transmission [12]. The Efficient QoS aware geographic opportunistic routing (EQGOR) based method helps in picking the PFNs having the highest energy and low delay. This criterion helps in providing good support for sending packets toward the destination. The entire area is divided into multiple sub-areas with each area having a set of PFNs. The selection of nodes is done based on the computation of path loss and lifetime ratio. The routing protocol method is responsible for the selection of relay PFNs during faster path packet delivery [13]. The selection of the next node depends on hop count and the distance concerning the nodes. The lifetime ratio can be improved by turning ON or OFF the scheduling process, but the downside of this approach is the delay in packet delivery.

The SPNs (SP Networks) in the field of bioinformatics, environmental ecology, and transportation-associated applications required more retransmission of information due to drop packets. The energy consumption in the SP network is important to reduce the number of dead nodes in the network and this can be achieved by incorporating numerous multiple individual paths to decrease the overall energy dissipation and thereby improvising the consistency of the network. The energy consumption of the SP network goes below the threshold point, and the SP seems to be dead, to overcome this more SPs are to be replaced and it is not recommended in the WSN [14]. This can be achieved by the Energy Harvesting technique, so the system health can be improvised. In the real world, the system makes use of the Internet of Things (IoT), but still, there are limitations due to energy consumption by the

devices. The Energy Harvest technique reduces the coverage area and provides renewable energy for the system through external sources. The sensor points are arranged in an effective way for communication in a home network [15], [16].

For the betterment of the SP network, the duty cycle and communication power are adjusted along with data reduction. The regeneration token of the SP will use solar devices. For SPs, the routing protocol is changed according to the communication between the SPs to have a scheduled sleep interval in the network. This improves the overall performance by 29% when compared to fixed-point scheduling [17]-[19]. As the radiation of the SP is directed to another SP in a network that creates beamforming. In the improvement of the SP network, the power distribution is optimized on different layers namely link, routing, and MAC layer. In some cases, the sensing of water quality can be detected by having an SP that can be swapped between active and passive modes at regular intervals. The network of the path will have more SPs. The information in the path may be lost if one of the SPs is failed. These types of errors can be managed by using Low-Rank Parity Check Code (LRPC) while keeping the same decoding value in the system. When the information received is huge, the SP network values are changed according to energy consumption, memory size, and a few constraints of the SP network [20]-[22]. When the information present in the network triggers, the SPN visits the destination node and collects the data. Instead of collecting the data, the SPN transmits the data if the SP (SP) is within the communication network. The distance between the SPNs can be reduced and a design can be introduced into the system for flexible data transmission between the fixed SP and mobile SP. The lifetime ratio can be increased by significantly detecting the overlapping regions [23]-[25]. As each network has its specifications when it comes to communication between the regions using SPNs. By using the load balancing method, the network can be chosen and configured automatically by its parameters. The parameters can be automatically modified by using the genetic algorithms as and when needed. The payoff in the SP network is considered upon a cooperative game theory which is built on the interval-based payoff. The SPs are having the highest payoff are chosen for participation in the network. Different weights are assigned in the SPN, and the SPs are unaware of the energy level of the other SP. The transmission range of one SP to its neighboring SP determines the marginal energy levels in the network [26]-[28]. Individual SPs or the SPN as a whole are unaware of marginal energy levels during data transmission. In the wireless sensor network, the SPs are assigned with different energy weights which are not known to another SP. The energy level depends on the transmission range of the one SP to its neighboring SP. The individual SP energy level is known by SPs rather than each other in an SP network.

In the wireless sensor network, the balancing of energy levels is important during the transmission of information and this needs an efficient algorithm. The balancing can be

achieved by giving an equal opportunity to each SP network in the wireless sensor network [29]. By using the forward probability technique, energy balancing can be achieved by selecting the highest energy level SP in the network for forwarding the information during path formation.

The Epidemic Algorithm (EA) is developed on top of the Random Forest Algorithm (RFA). The efficiency of propagation can be improved by maintaining the list of nodes of the control packet in a selected route. First, the control header is cleared and the route section is updated with the nodes used in the path. From each of the nodes in the transmission range, the route is found between the initiator to the receiver node [30]. The timer is started as soon as the routing process is started and then the timer is stopped once a reply is obtained from the network is called a Delay Route. Average Time is obtained by dividing the Delay route parameter by the number of nodes. If there are N routers, the trust list can be defined as (TL1, TL2,TLN). From the list, the maximum value can be found as $\max(TL1, TL2, \dots, TLN)$ as TL max. The route which corresponds to Time Level (TL) max can be used to send the packets. The inputs for the Epidemic method are the initiator node, receiver node, range, and TL. The initiator PFN will send the request to other PFNs within the range, if a PFN is reachable then the receiver PFN sends the acknowledgment for the message, and the process is stopped otherwise the forward node is picked up based on the highest value of transmission count [31], [32]. If the value of Time to Live (TTL) is zero, then packets are dropped and the route is discarded.

Incentive Compatible Routing Protocol (ICRP) will form the path and the degree of the path which is always 2. A profile is generated for each of the PFNs to maintain the meeting count of each PFN with other PFNs in the network. During the packet transmission, the sender PFN will find PFNs within the range and then picks a node based on the highest value of meet probability from the profile and starts to establish a connection between the sender and the receiver node [33]. At the SP energy level, the mechanism suppresses the selfishness of the SP behaviors which in turn reduces the repeated usage of SPs. It avoids the false quotation of malicious SP in the network. The energy mechanism in the network greatly reduces the delay and overhead of the network. Thereby reducing the latency and increasing the network lifetime. The opportunity algorithm considered has the mechanism to work on the energy level of the SPs to extend the lifetime of the network. It increases the survival rate of the SPs using an incentive routing protocol. The energy of each SP is considered in the network with a threshold point, the SPs which are below this threshold point is kept at idle mode whenever it is very much needed, and the SPs are allowed to participate in the network [34].

III. PROPOSED INCENTIVE ROUTING PROTOCOL WITH VIRTUAL PROJECTION (IRPVP)

Different parameters are considered for maintaining good network health namely meet ratio, remaining node

energy, and trust computation factors for the selection of replication node. Hence, the overall health and security of the network are increased. The following are the important highlights of the proposed work.

- a. Pick a node based on a measure of trust factor and the amount of energy remaining in the node.
- b. Make use of the on-demand selection of PFNs to form the complete path.
- c. When the PFNs in the route are non-healthy, then find an alternative set of PFNs so that the packets can be sent.

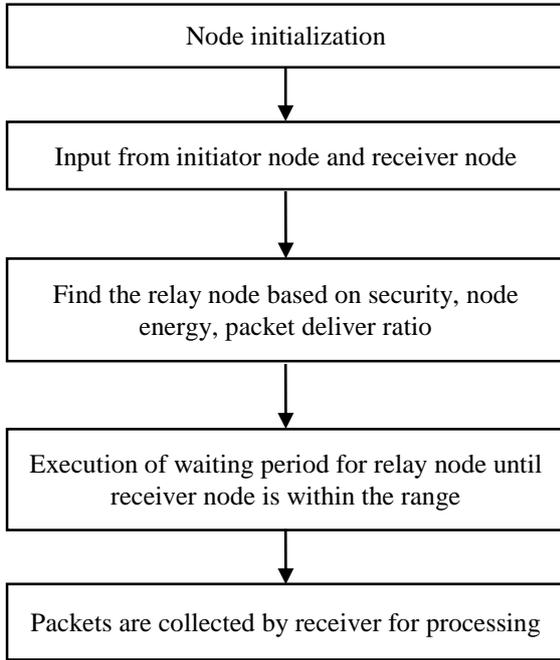


Fig. 1. Steps involved in the proposed Incentive Routing Protocol with Virtual Projection (IRPVP) method

Fig. 1 shows the steps involved in the IRPVP protocol, where the initiator node and the receiver nodes will be the input to the system. The first step is to find PFNs within the range and for each of the PFNs the selection criteria are executed, then a node is picked which has the maximum value of the selection criteria. The initiation node from the sender sends the packet to the relay node and then to the receiver node. During network setup, all the PFNs have the same amount of energy. The energy consumption will be computed for the link between the nodes is expressed as shown in Equation (1).

$$Ec(n1, n2) = 2 * Tx E + Gn E^{ef} \tag{1}$$

where,

TxE = Transmission Energy

GnE = Generation Energy

ef = Environmental factor

The new energy for a specific node can be defined as shown In Equation (2).

$$RE_n = EN_c - Ec(n1, n2) \tag{2}$$

where,

ENc = Energy of current node

$Ec(n1, n2)$ = Energy consumed between n1 and n2.

The profile can be created by making use of the repeat counter, node (n1), and node (n2). For each of the counting variables, the nodes are found within the range. The creation of a wireless sensor network depends on the source node, destination node, number of iterations, and number of input parameters. For each transmission and reception of data, the neighboring nodes are identified and the cover set for PFNs is found. The traversed list is stored and the non-traverse list is found to compute virtual network weight.

In the process to complete the virtual network weight, the following steps are considered.

- a. The initiator node will send the packets to nodes that are within the range.
- b. The packet is sent to all nodes within the range (Ns)
- c. The amount of acknowledgment received by the nodes is maintained (Na).
- d. The currency parameter for the first node is defined as $CP(N) = Na/Ns$.
- e. If a node has already participated in the current iteration, then it cannot be used again.
- f. Once the counter Cn is reached, the number of times the node is utilized in the network is also determined along with the weight of the network.
- g. During the process from step (a) to step (f), the counter at which each node meets every other node is determined and is termed as cutoff value (R). For each of the nodes which are within the transmission range, the R0 (count value) is copied for the next iterations. Therefore, the instants of the time can be defined as $\{t1, t2, \dots, tro\}$.

For each of the nodes, the following formula will be used to compute the Meet Ratio (MR), tro (end of transmission) as shown in Equation (3).

$$MR = \frac{\text{Number of time a node "i" meets}}{Ro} \tag{3}$$

The selection ratio for the node can be computed using Equation (4).

$$P = k \times \sum_{i=r+k}^{i-n} \left(\frac{1}{n} \times \frac{C_{i-r-1}^{k-1}}{C_{n-1}^{k-1}} \times \frac{r}{i-k} \right) \tag{4}$$

where, k= counter, n=number of PFNs, C = combination formula, r = cutoff threshold.

IV. SIMULATION RESULTS AND DISCUSSION

In this section, the PFNs are assigned with equal energy levels in the network with the following parameters as shown in Table I.

TABLE I: EXPERIMENTAL SETUP OF THE PROPOSED PFN'S

Name of parameter	Assigned value
Number of PFNs	100
First-time energy	3000 J

Transmission energy	5 J
Generation energy	10 J
Environment factor	0.5
Time level	4
Counter	25
Initiator node	12
Receiver node	52

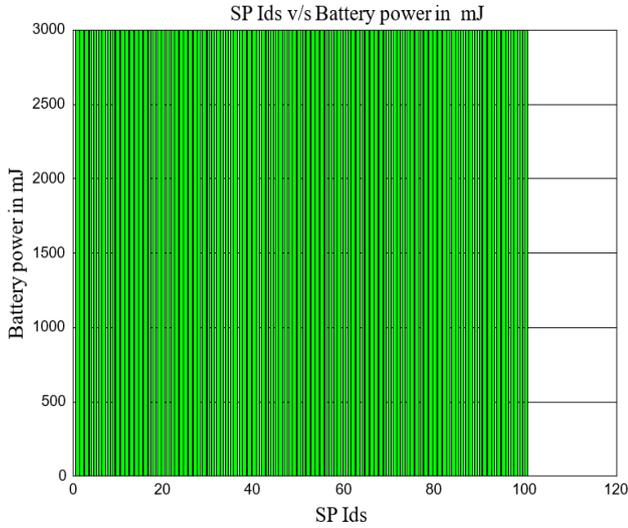


Fig. 2. SP Ids versus battery power of PFNs

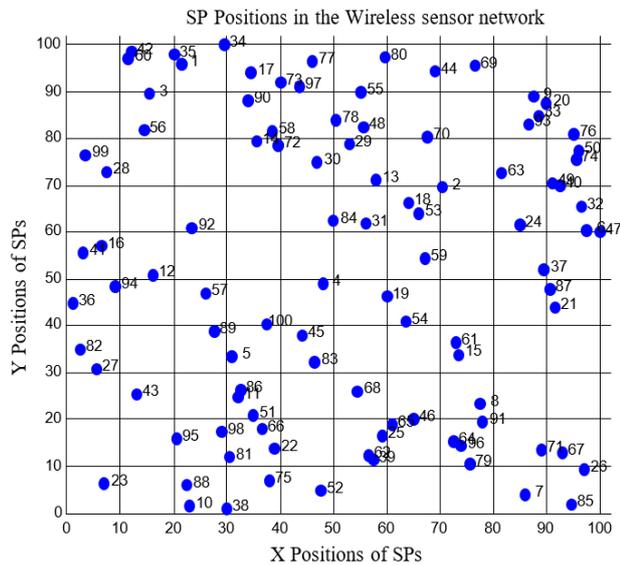


Fig. 3. SP positions in the proposed PFNs

Fig. 2 shows the first energy for PFNs has been assigned the same amount of energy to all the nodes in the network with a value of 3000 J. The PFNs are spread randomly in an area of 100* 100 m with each PFN having a location with a value of (Xp, Yp). Fig. 3 shows that PFN12 is present at the location (10,12) and the PFN94 has the location (72,94) and the remaining 98 PFNs have represented at their locations.

Fig. 4 shows the meeting time ratio of PFNs where the PFN45 is having a value of 102 which indicates that PFN45 has met the receiving PFN52 102 times. PFN1 has met PFN52 78 times and similar is the process for all other 98 PFNs in the network.

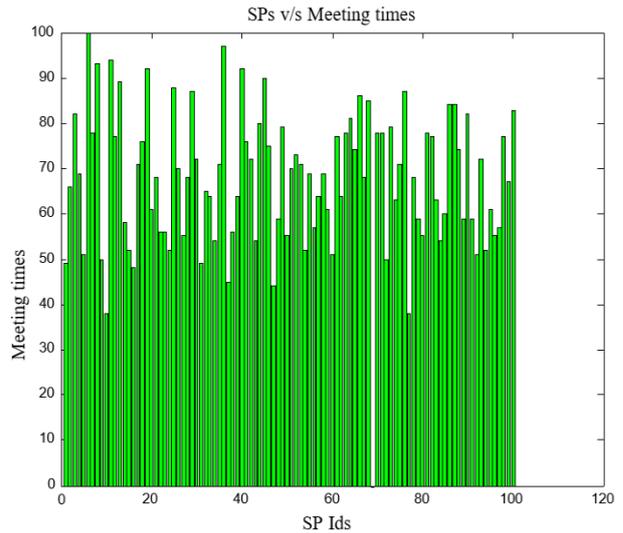


Fig. 4. SP versus meet time ratio of PFNs

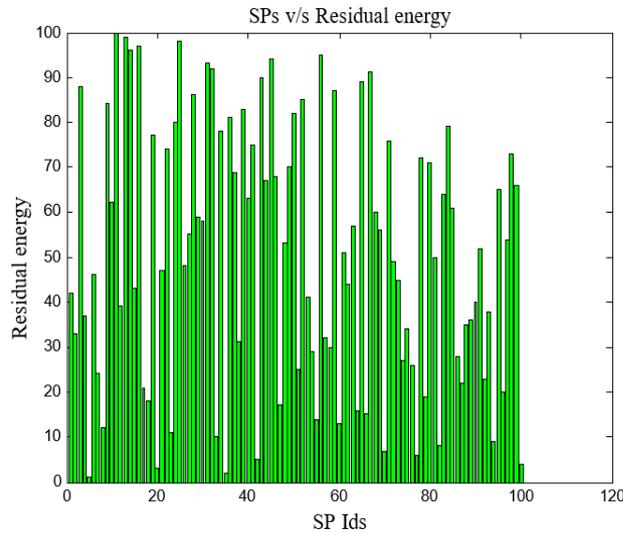


Fig. 5. SP versus the residual energy of PFNs

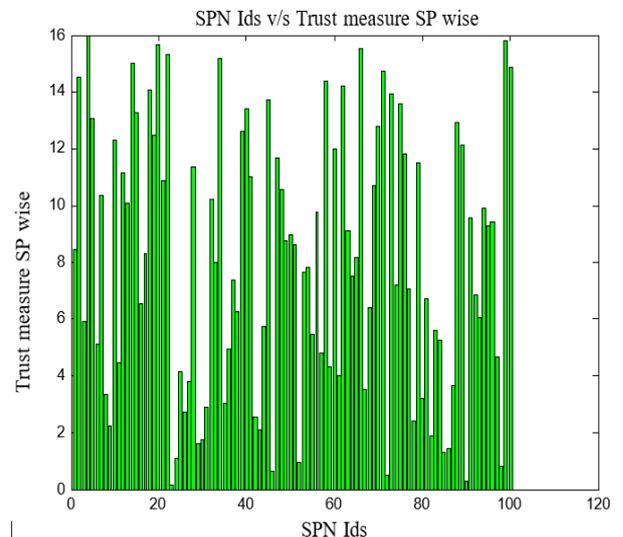


Fig. 6. SPN Ids versus trust ratio measure of PFNs

Fig. 5 shows the energy computation for PFNs and the energy of PFN1 is 50, PFN18 has an energy of 98. Fig. 6

shows the security level of each of the PFNs in the network. PFN1 has a trust level of 8, and PFN100 has a trust level of 15.

Fig. 7 shows the number of neighbors on one side and the other side contains the count of neighbors. For instance, PFN1 has the value of 2 nodes, and PFN5 has a set of 25 pins.

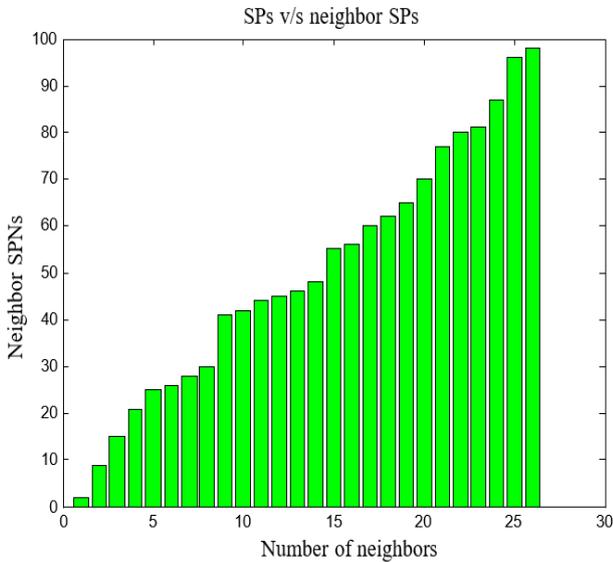


Fig. 7. Distance between the neighboring PFNs

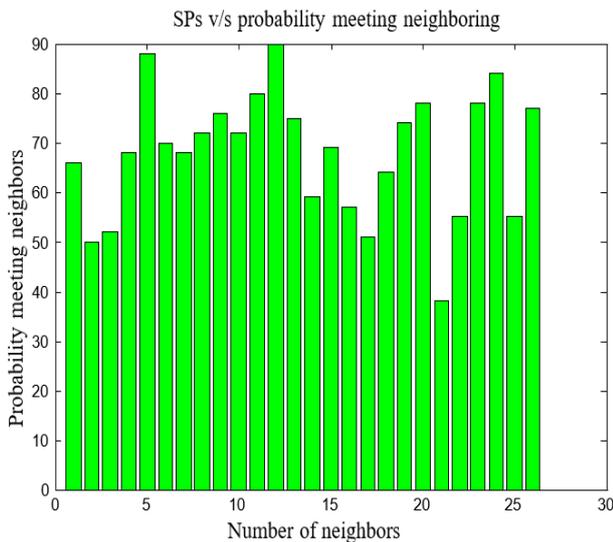


Fig. 8. Meeting ratio of neighboring PFNs

Fig. 8 shows the meeting ratio for PFNs. The number of PFN ranges is on one side and the count of the number of times the PFN meets the receiving node is on the other side. PFN1 meets the receiving PFN around 68 times, PFN2 meets the receiving PFN around 48 times, and the same process is repeated for the remaining range nodes is also determined. Fig. 9 shows the security factor for the range of PFNs. In the figure, the security factor is on the other axis. PFN1 has a security factor of 0.4. PFN6 has a security factor of 2.3.

Fig. 10 shows the selection criteria where the highest value of the selection criteria for the SPNs are SPN9,

SPN10, SPN11, SPN17, SPN19, and SPN23. Fig. 11 shows the communication between SPN23 and SPN28 where SPN28 is the relay SPN. SPN23 is the source and SPN28 is the destination in the first iteration. Fig. 12 shows the communication between SPN69 and SPN28, where the connection was established after a certain period.



Fig. 9. SP versus security factor of PFNs

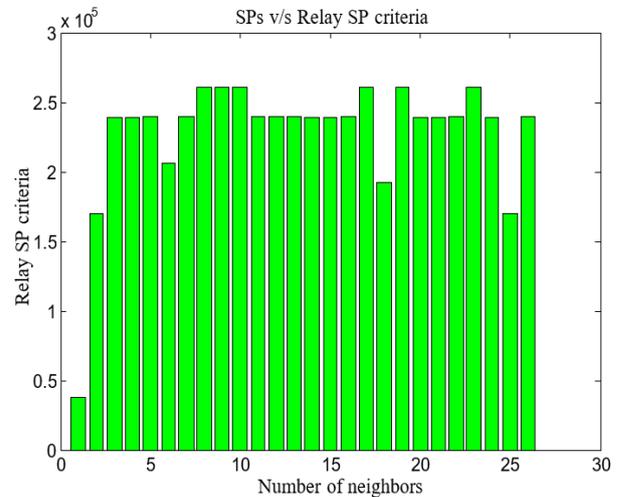


Fig. 10. SP versus relay SP selection criteria

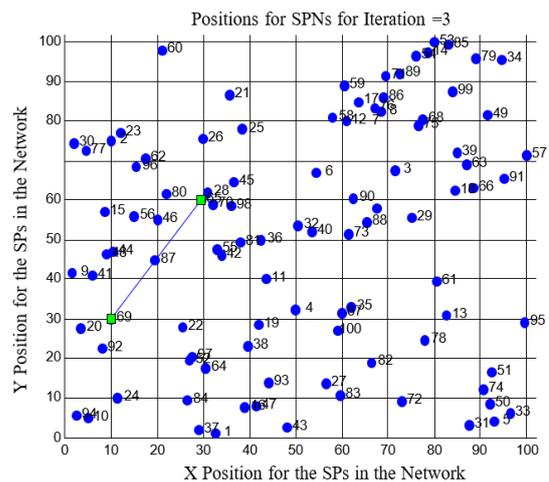


Fig. 11. Position of SPNs in a wireless sensor network for iteration 1

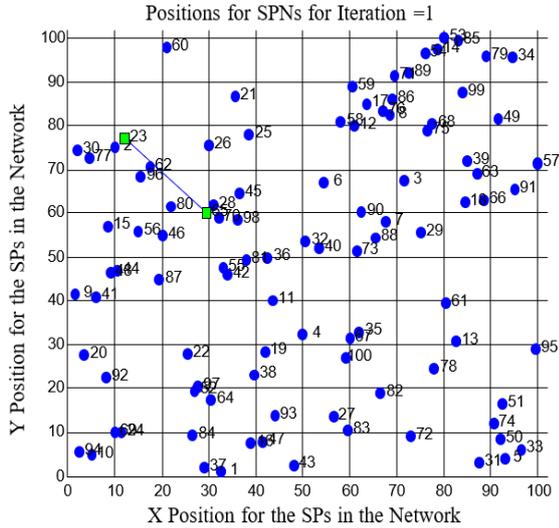


Fig. 12. Position of SPNs in a wireless sensor network for iteration 3

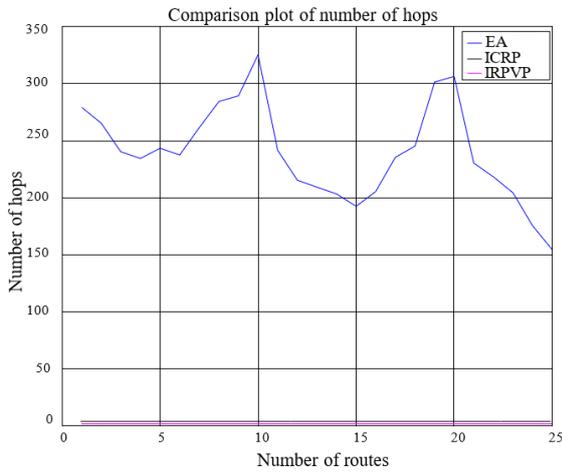


Fig. 13. Comparison plot of the number of hops count versus the number of routes

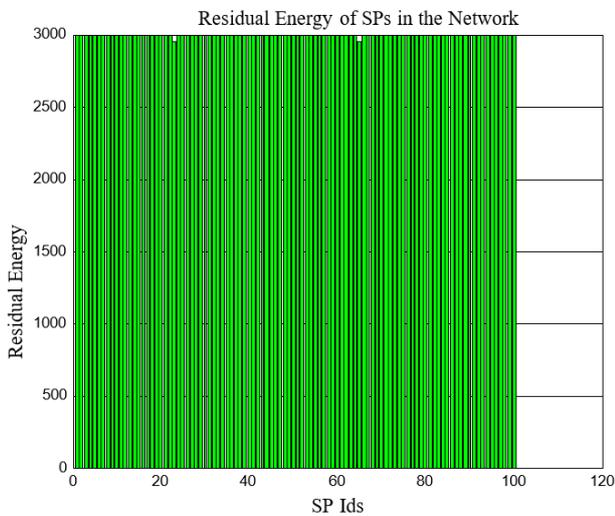


Fig. 14. Residual energy of SPs in the network

Fig. 13 shows that IRPVP has the least number of hops compared to ICRP and EA. The number of hops required for successful information transmission from any source to any destination is only three in IRPVP. This is because of introducing the relay SP in the network. These relay SP

help in the transmission of information from source to destination in a smoother way than the regular SP to SP transmission which in turn reduces the overall residual energy of the network system.

Fig. 14 shows the SPNs remaining energy whereas only two SPNs will have remaining energy while other SPNs have the same amount of energy.



Fig. 15. Comparison plot of route versus energy consumption

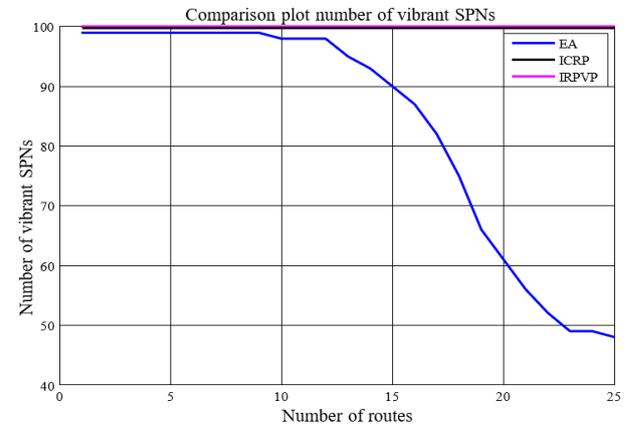


Fig. 16. Comparison plot of vibrant count SPNs versus the number of routes

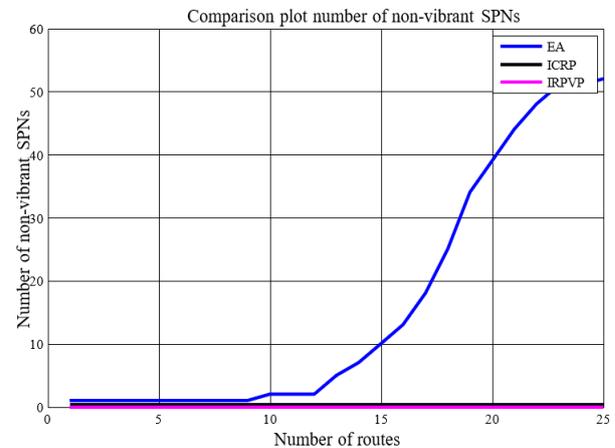


Fig. 17. Comparison plot of non-vibrant SPNs versus the number of routes

Fig. 15 shows the energy consumption of the system where the proposed method will have the lowest energy consumption as compared to ICRP and EA. Fig. 16 shows

the vibrant (alive nodes) SPNs where the proposed IRPVP and ICRP will have all 100 SPNs as vibrant and EA has 99 SPNs as vibrant. Fig. 17 shows the non-vibrant (dead nodes) SPNs where the proposed IRPVP and ICRP have 100 SPNs and the EA has one non-vibrant SPN. Fig. 18 shows the residual energy of SPNs wherein the proposed IRPVP method has the highest residual energy SPNs followed by ICRP and EA. The residual energy will decrease as the number of iterations increases. Fig. 19 shows the overhead ratio of the proposed method (IRPVP) will have lower routing overhead as compared to EA and ICRP.

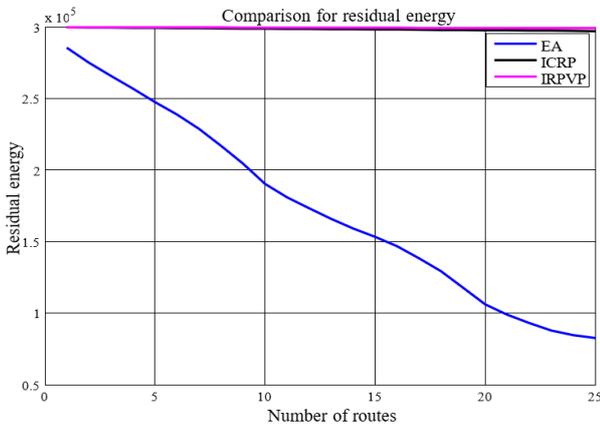


Fig. 18. Comparison plot of residual energy for SPNs versus the number of routes

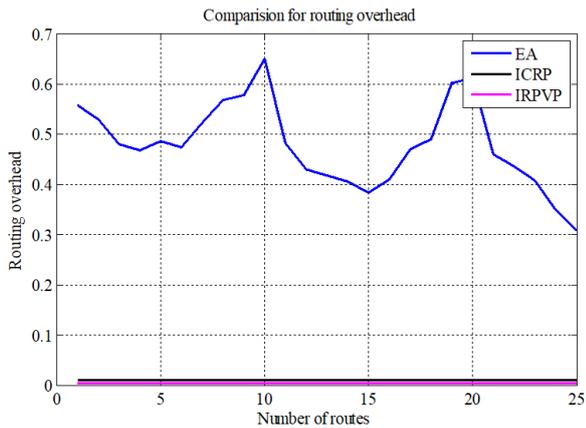


Fig. 19. Routing overhead ratio of SPNs versus the number of routes

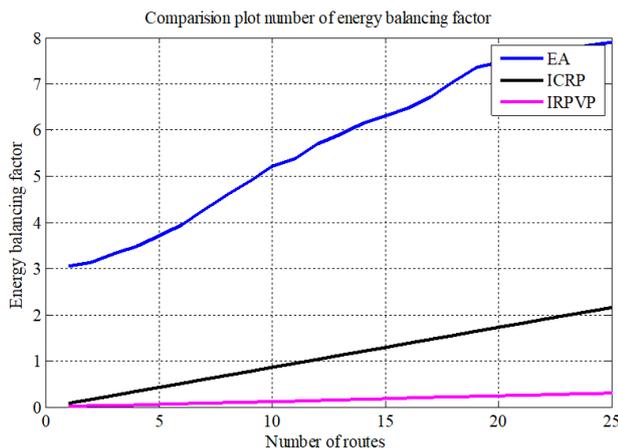


Fig. 20. Comparison plot of an energy balancing factor in SPNs

Fig. 20 shows the energy balancing factor comparison of the proposed IRPVP method. The IRPVP has a stable energy balance as compared to EA and ICRP.

V. CONCLUSION

The proposed IRPVP is improvised by utilizing PFN which is chosen based on its weight level as against random selection in the conventional method resulting in more energy loss and leading to non-vibrant SPNs. This method will select the next Sensing Point (SP) based on multiple characteristics like residual energy, meeting probability including the next SPNs weight level to improve the delay, vibrant SPNs count, and the energy balancing factor which has better performance. The performance of IRPVP is mainly enhanced as the packets are moved from the initiator to the receiver by relay SPNs reducing the hops, thus reducing time delay and avoiding data loss. In the conventional method, i.e., EA and ICRP, the path is formed between initiator SPN and receiver SPN with its neighboring SPNs increasing the hops which may also carry noise along with unsecured data. However, ICRP is restricted to a shorter path only, as against its reliability. The only challenge faced by this method proposed in this paper is the requirement of dedicated 4 relay nodes for every 100 nodes to monitor the health of the other nodes.

VI. FUTURE SCOPE

The incentive routing protocol with virtual projection can be extended with special relay nodes (SRN) having continuous power sources to further reduce the power utilization of the neighboring nodes.

CONFLICT OF INTEREST

The author states that there is no conflict of interest.

AUTHOR CONTRIBUTIONS

All authors perceived the research on Incentive Routing Protocol with Virtual Projections. Niranjana developed the model and Dr. Manoj Priyantham M supervised and validated the results. All the authors contributed to rendering the results and writing the research paper. All authors have approved the final version.

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REFERENCES

- [1] K. Xie, L. Wang, X. Wang, G. Xie, and J. Wen, "Low cost and high accuracy data gathering in WSNS with matrix completion," *IEEE Transactions on Mobile Computing*, vol. 17, no. 7, pp. 1595-1608, 2018.
- [2] N. Lodha, P. Rewagad, and Y. Pawar, "Simulation of MTMS using TSSE and minimum energy consumption using DVS for WSN ad hoc network," in *Proc. Fourth International Conference on Communication Systems and Network Technologies*, 2014.
- [3] P. K. Sharma, Y. Jeong, and J. H. Park, "EH-HL: Effective communication model by integrated EH-WSN and Hybrid Lifi/WIFI for IoT," *IEEE Internet of Things Journal*, vol. 5, no. 3, pp. 1719-1726, 2018.
- [4] N. Shwetha, N. Gangadhar, L. Niranjana, and Shivaputra, "A retraction Note to: A cluster-based distributed cooperative spectrum sensing techniques in Cognitive Radio," *Innovative Data Communication Technologies and Application*, 2021.
- [5] A. Bagheri, A. Ebrahimzadeh, and M. Najimi, "Game-theory-based lifetime maximization of multi-channel cooperative spectrum sensing in wireless sensor networks," *Wireless Networks*, vol. 26, no. 6, pp. 4705-4721, 2020.
- [6] S. Perez, J. A. Fuentas, and M. Coupechoux, "ODMAC++: An IoT communication manager based on energy harvesting prediction," in *Proc. IEEE 28th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications*, 2017.
- [7] M. Koussaifi, C. Habib, and A. Makhoul, "Real-time stress evaluation using wireless body sensor networks," *Wireless Days (WD)*, 2018.
- [8] J. Zhong, Z. Huang, L. Feng, W. Du, and Y. Li, "A hyper-heuristic framework for lifetime maximization in wireless sensor networks with a mobile sink," *IEEE/CAA J. Autom. Sinica*, vol. 7, no. 1, pp. 223-236, Jan. 2020.
- [9] M. Jamshidi, E. Zangeneh, M. Esnaashari, A. M. Darwesh, and M. R. Meybodi, "A novel model of Sybil attack in cluster-based wireless sensor networks and propose a distributed algorithm to defend it," *Wireless Personal Communications*, vol. 105, no. 1, pp. 145-173, 2018.
- [10] A. R. Suhas and M. M. Priyatham, "Lifetime and energy efficiency improvement techniques for hierarchical networks," *International Journal of Engineering and Advanced Technology*, vol. 9, no. 1S6, pp. 62-72, 2019.
- [11] M. J. Al-Amery and M. H. Ghadban, "An energy consumption minimization approach in wireless sensor networks," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 22, no. 3, p. 1485, 2021.
- [12] T. Le, "Multi-hop routing under short contact in delay tolerant networks," *Computer Communications*, p. 165, pp. 1-8, 2020.
- [13] G. Yang and H. Liang, "A wireless paging network with load-balancing equal opportunity routing in high-rise building construction," *International Journal of Distributed Sensor Networks*, vol. 14, no. 10, 2018.
- [14] A. Soundarya and V. Santhi, "An efficient algorithm for coverage hole detection and healing in wireless sensor networks," in *Proc. 1st International Conference on Electronics, Materials Engineering and Nano-Technology (IEMENTech)*, 2017.
- [15] G. Martinez and C. Zhou, "Maximum lifetime SMDP routing for energy-harvesting wireless sensor networks," in *Proc. IEEE 84th Vehicular Technology Conference(VTC-Fall)*, 2016.
- [16] G. Jackson, S. Ciocoiu, and J. A. McCann, "Solar energy harvesting optimization for wireless sensor networks," in *Proc. GLOBECOM 2017 - 2017 IEEE Global Communications Conference*, 2017.
- [17] A. R. Suhas and M. M. Priyatham, "Heal nodes specification improvement using modified chef method for group based detection point network," *International Journal of Pervasive Computing and Communications*, 2021.
- [18] M. Benaddy, B. E. Habil, M. E. Ouali, O. E. Meslouhi, and S. Krit, "A multipath routing algorithm for wireless sensor networks under distance and energy consumption constraints for reliable data transmission," in *Proc. International Conference on Engineering&MIS (ICEMIS)*, 2017.
- [19] X. Deng, B. Wang, W. Liu, and L. T. Yang, "Sensor scheduling for multi-modal confident information coverage in sensor networks," *IEEE Transactions on Parallel and Distributed Systems*, vol. 26, no. 3, pp. 902-913, 2015.
- [20] F. Alavi, K. Cumanan, Z. Ding, and A. G. Burr, "Beamforming techniques for nonorthogonal multiple access in 5G cellular networks," *IEEE Transactions on Vehicular Technology*, vol. 67, no. 10, pp. 9474-9487, 2018.
- [21] N. Lodha, P. Rewagad, and Y. Pawar, "Simulation of MTMS using TSSE and minimum energy consumption using DVS for WSN Ad Hoc Network," in *Proc. Fourth International Conference on Communication Systems and Network Technologies*, 2014.
- [22] M. Sangeetha and A. Sabari, "Prolonging network lifetime and optimizing energy consumption using swarm optimization in mobile wireless sensor networks," *Sensor Review*, vol. 38, no. 4, pp. 534-541, 2018.
- [23] J. Roselin, P. Latha, and S. Benitta, "Maximizing the wireless sensor networks lifetime through energy-efficient connected coverage," *Ad Hoc Networks*, vol. 62, pp. 1-10, 2017.
- [24] A. A. A. Asmael and B. Al-Nedawe, "Energy-efficient WSN using hybrid modification PEGASIS with ant lion optimization," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 23, no. 1, p. 273, 2021.
- [25] L., N., & Priyatham, M. (2019). An energy-efficient and lifetime ratio improvement method based on energy balancing. *International Journal of Engineering and Advanced Technology*, 9(1S6), 52-61. <https://doi.org/10.35940/ijeat.a1012.1291s619>.

- [26] W. Hsien-Chung, "Interval-Valued cores and interval-valued dominance cores of cooperative games endowed with interval-valued payoffs," *Mathematics*, vol. 6, no. 11, p. 255, 2022.
- [27] L. Niranjan and M. M. Priyatham, "Lifetime ratio improvement technique using special fixed SPs in wireless sensor network," *International Journal of Pervasive Computing and Communications*, 2021.
- [28] J. Akerberg, M. Gidlund, T. Lennvall, K. Landerns, and M. Björkman, "Design challenges and objectives in industrial wireless sensor networks," *Industrial Wireless Sensor Networks*, pp. 79-99, 2017.
- [29] O. Singh and V. Rishiwal, "Scalable energy-efficient routing mechanism prolonging network lifetime in wireless sensor networks," *International Journal of Systems, Control and Communications*, vol. 11, no. 2, p. 161, 2020.
- [30] S. Chai, Z. Wang, B. Zhang, L. Cui, and R. Chai, "Energy-balanced routing protocols for wireless sensor networks," *Wireless Networks*, pp. 19-68, 2020.
- [31] M. A. Khan and S. Hussain, "Energy-efficient direction-based topology control algorithm for WSN," *Wireless Sensor Network*, vol. 12, no. 3, pp. 37-47, 2020.
- [32] C. Naik and P. D. Shetty, "FLAG: fuzzy logic augmented game theoretic hybrid hierarchical clustering algorithm for wireless sensor networks," *Telecommunication Systems: Modelling, Analysis, Design and Management*, Springer, vol. 79, no. 4, pp. 559-571, April 2022.
- [33] Y. Cai, Y. Fan, and D. Wen, "An incentive-compatible routing protocol for two-hop delay-tolerant networks," *IEEE Transactions on Vehicular Technology*, vol. 65, no. 1, pp. 266-277, 2016.
- [34] L. Li, H. Wang, Z. Liu, and H. Ye, "Gir: An opportunistic network routing algorithm based on game theory," *IEEE Access*, vol. 8, pp. 201158-201172, 2020.

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