Multilevel routing for data transmission in internet of things

Bhawna Ahlawat, Anil Sangwan
Department of Electronics and Communication Engineering, University Institute of Engineering and Technology (UIET), Maharshi Dayanand University Rohtak, Haryana, India

Article Info

Article history:

Received Dec 11, 2023
Revised Feb 29, 2024
Accepted Mar 16, 2024

Keywords:

Cluster head
Clustering
Data transmission
Internet of things
VGDRA

ABSTRACT

Internet of things (IoT) is the network in which sensor nodes sense information and transmit sensed information to sink. The small size and far deployment of SN results in causing problems related to higher energy utilization. Many techniques have been proposed in the last years to improve lifetime of the network. The already developed methods are the clustering techniques which are path optimization algorithms. The virtual grid-based dynamic routes adjustment (VGDRA) is the protocol which is already been proposed to increase network's duration. The VGDRA protocol improve life span but doesn't solve the issue of energy hole which affect network performance. This work aims to improvise the VGDRA algorithm to solve the power hole problem. The utilization of cache motes is done in the network and the sink will move energy to cache nodes for the data collection. MATLAB is executed to simulate the suggested model, and amount of dead motes, active ones and amount of packets, whose transmission is done to base station (BS).

Corresponding Author:

Bhawna Ahlawat
Department of Electronics and Communication Engineering
University Institute of Engineering and Technology (UIET), Maharshi Dayanand University Rohtak
124001 Rohtak Haryana, India
Email: bhawna.rs.ahlawat@mdurohtak.ac.in

1. INTRODUCTION

Internet of things (IoT) is a network which facilitates novel kinds of communication from individuals to objects, as well as between interconnected objects themselves. Each object or thing within the IoT network interacts with others and fulfills a specific role. In a future IoT network, each node autonomously acquires information, while humans verify the gathered data. IoT finds applications in various fields like transportation, healthcare, and smart environments [1], [2]. Figure 1 illustrates a typical IoT ecosystem setup.

RFID systems, WSNs, and radio-frequency identification sensor networks (RSNs) are vital network systems for enabling communication with IoT objects. In such networks, nodes are distributed within specific regions to collect necessary information such as temperature, motion, and physical changes. Because of finite transmission range of every mote, gathered information is forwarded to intermediate nodes. This process leads to the unintended energy consumption of intermediate nodes, resulting in high energy usage and network partitioning [3], [4]. Consequently, the energy efficacy of motes becomes a crucial aspect affecting network performance in distributed IoT networks.

Routing in WSNs poses significant challenges due to their unique characteristics, when it is differentiated from other wireless networks such as MANET or cellular ones. In a dynamic IoT environment, information between source and terminus is a crucial task. Traditional reactive routing protocols such as Ad hoc on demand distance vector (AODV) and dynamic source (DSR) prioritize finding the shortest path without considering node energy consumption. This can lead to repeated selection of certain nodes, reducing their lifespan and causing network partitioning. Additionally, these protocols utilize flooding algorithms that indiscriminately transmit RREQ packets to all neighboring motes [5], [6], resulting in excessive energy consumption. Limiting the broadcast of route request packets is necessary to prevent the depletion of mobile node batteries. Hierarchical or cluster-based routing, which assigns specific operations to CHs, is led to make the system more scalable and energy-effective and prolong the duration in WSNs.

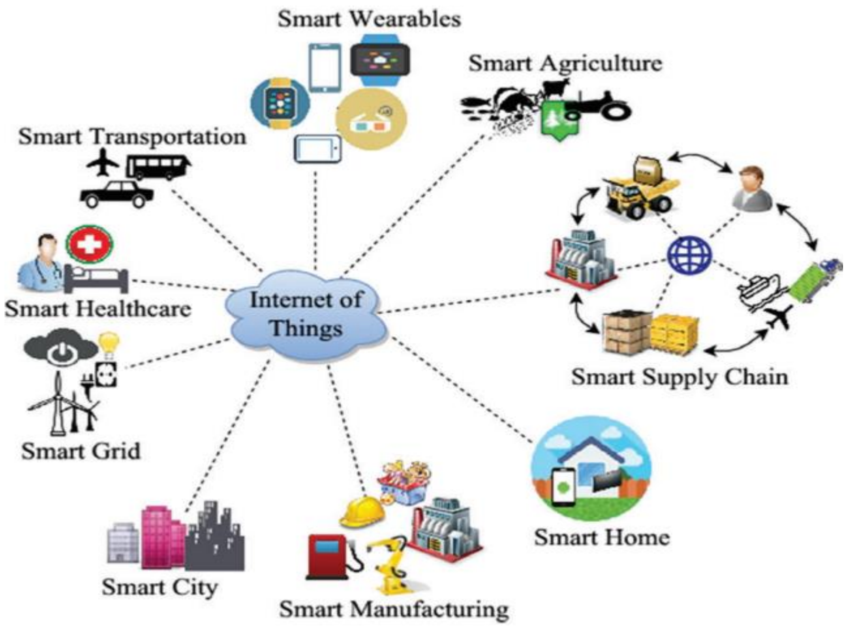

Figure 1. A typical IoT ecosystem setup

Clustered networks are formed by dividing nodes into clusters. Every cluster consists of a cluster head and several SNs. This clustering process establishes a dual-fold hierarchy, with CHs in the upper tier and sensor nodes in a lesser one. Figure 2 depicts the flow of data in a clustered network. Sensor motes are employed for transferring their data to the corresponding CHs, which then aggregate the data and relay them to a central BS, either in a direct way or via other CHs. The hierarchical structure of clustered WSNs enables to utilize restricted power of SNs effectively, thereby extending the overall network lifetime [7], [8].

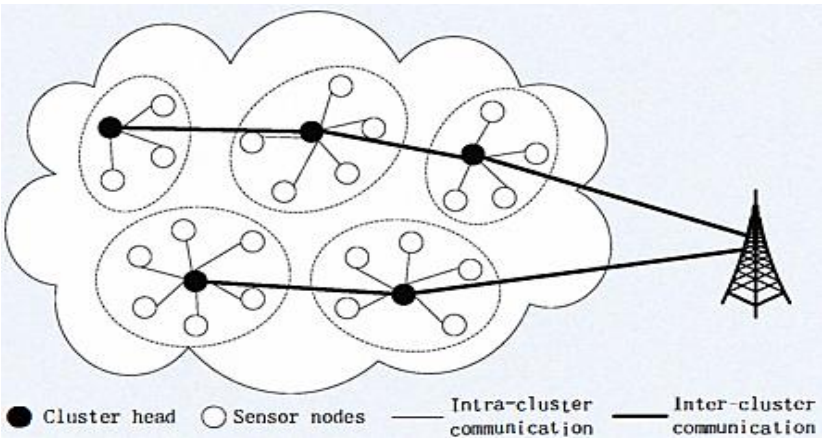

Figure 2. Architecture of cluster-based routing protocols

Classical routing algorithms are primarily focused on the selection of CHs and differ in their approaches to CH selection. The most widely recognized clustering protocol for homogeneous WSNs is LEACH. LEACH randomly assigns a set of CHs while frequently changing the remaining sensor nodes between CH and generic node roles. This approach aims to distribute energy consumption evenly across nodes to prolong network operation [9]. Numerous other protocols have been proposed in the literature that incorporate variations of the LEACH method, resulting in different performance levels. In addition, the VCH model is also an effective approach for mitigating energy utilization through a two-step process. VCH selects CH nodes based on their current power availability. Numerical results indicate that VCH is more effective than existing method concerning operational efficiency [10]. However, both mechanisms are formulated for homogeneous WSNs and exhibit limited performance when applied to HWSNs. Consequently, components from these mechanisms are integrated to develop novel routing algorithms specifically tailored for HWSNs.

Among such methods, syringe exchange program (SEP) [11] stands out as one of the most popular. SEP introduces 2 kinds of motes: advanced nodes and normal ones. The initial ones have a greater probability of becoming CHs compared to normal nodes. The protocol incorporates different threshold patterns based on node behavior. By effectively managing power of advanced motes and minimizing power consumption in normal nodes, SEP aims to extend the overall network lifetime. The mechanisms employed in SEP have been adopted in the development of several other approaches. An example is M-SEP [12]. It evaluates the power consumption of every mote in relation to the entire network for recognizing nodes of great capabilities which can be CHs. Motes having higher power levels are given a greater possibility of becoming CHs compared to nodes with lower energy levels. This integration significantly improves the network's lifespan and transmission rate.

Another protocol based on SEP is the prolong-stable election protocol. P-SEP determines the energy indecision of each node by modeling its behavior. This allows the protocol to avoid selecting nodes with energy levels below a threshold value. Only nodes surpassing this threshold have the possibility of becoming CHs. Similarly, the distributed energy-efficient clustering algorithm (DEEC) [13] employs a comparable mechanism to P-SEP as an effective clustering protocol for HWSNs. DEEC also utilizes a threshold limit for recognizing CHs. The energy level of SN determines duration, for which a sensor can function as a CH. DEEC operates on the premise that the nodes of greater power exhibit fine communication behaviors. In addition to conventional approaches, the architecture of clustering algorithms also explores the use of metaheuristic algorithms.

According to existing literature, metaheuristic approaches have demonstrated superior performance compared to traditional mechanisms and proved more robust and accurate. In context of clustering protocols, metaheuristic methods treat the problem as an optimization task, at which an objective function (OF) is formulated to assess the efficacy of a model. By leveraging the information taken from OF, nature-inspired algorithms explore diverse sensor outlines in search of the solution to maximize the network's lifetime [14]. Numerous clustering algorithms are developed based on optimization notions.

One notable example is energy centers examining using particle swarm optimization (EC-PSO). This approach initially determines CHs using a geometric approach and then employs the PSO method for selecting SN for being a cluster head. This approach also incorporates a mechanism to prevent selecting motes with least power. Another significant method is genetic-algorithm-based energy-efficient clustering (GAEEC). GAEEC utilizes a GA for selecting CHs based on a similarity parameter [15]. The OF GAEEC is to quantify the broadcasting cost of every mote in accordance with its energy level. At present, a routing algorithm utilizing GWO is put forward. The multiple-OFs are adopted for computing the goods of every SN. The OF values are considered for illustrating represent weights, which are adjusted based on the distance from other motes. This algorithm identifies a node configuration for diminishing the overall amount of weights [16]. Despite their promising results, nature-inspired approaches have a major drawback known as premature convergence. This defines the situation where a suboptimal node configuration is mistakenly identified as a good solution to deal with optimization issues.

The virtual grid-based dynamic routes adjustment (VGDRA) protocol is already been proposed to improve network's life span. This approach aims to split the entire network into clusters and select CH within cluster. This choice is done on the basis of power and distance. This approach is deployed to selects SN having higher power and lower distance to sink, as CH. The VGDRA protocol has disadvantage that it has energy hole problem which affects performance of the network. In the energy hole problem, the sensor nodes which are near to base station (BS) get dead and far nodes are unable to communicate with sink. This work is emphasized on enhancing VGDRA algorithm to solve energy hole problem in network. The extra cache nodes are executed that assist cluster head in transmitting information to cache nodes. The cache nodes will store information and BS move near to cache node and collect data.

This paper is organized as in section 2 literature survey is conducted and in section 3 proposed methodology is discussed in detail. In the fourth section, outcomes of the proposed model are developed and where results are compared with existing model. The conclusion and references are presented at the end of the paper.

2. LITERATURE REVIEW

Yarinezhad and Sabae [17] projected an innovative clustering technique called fixed-parameter tractable approximation clustering (FPTAC) for balancing the load of CHs in IoT. This method made use of a 1.2-approximation algorithm. Additionally, an energy efficient routing (EER), was proposed to move the data packets amid CHs and intended location. Therefore, the hot spot existence nearer to the BS was avoided by transmitting the data to BS on the optimal routes. The simulation findings demonstrated that the proposed technique is more feasible for networks of considerable size than the conventional approaches. In another work, Sankar *et al.* [18] investigated a novel energy-efficient cluster-based routing protocol (EECRP) that deployed an algorithm of CH selection and generating cluster, for tackling the issue of energy consumption. Initially, a swarm intelligence algorithm (SIA) known as sailfish optimization algorithm (SOA) was exploited for selecting CH. Subsequently, the Euclidean distance was considered for creating the cluster. According to experiments on NS2, the investigated protocol was applicable for prolonging the duration of network and mitigating the delays. A tree-based routing protocol was suggested by Yarinezhad and Azizi [19] which offered efficacy in energy consumption. This resulted in the reduction of EED in network. Two methods were used by this protocol. The first one was an energy-efficient and dependable improvement of the geographic routing algorithm. A structure based on trees was the second. To generate this method, the fewest control packets were used, and updating it was done with an effective scheme. Based on findings, the suggested protocol yielded lower energy consumption and delay, and higher duration of network and throughput.

Firdous *et al.* [20] introduced a new power-efficient cluster-based routing (PECR) algorithm. The k-means clustering (KMC) model was utilized to cluster the data. This algorithm helped in arranging CHs and an main cluster head (MCH), selecting the precise path, establishing communication based on the EC framework, and relative location. The introduced algorithm was worked effectively for alleviating the traffic overhead and employing the energy assets. Moreover, this algorithm led to enhance the efficacy up to 44%. Rani and Malik [21] projected an innovative social relationship-based energy efficient routing SEER model for the opportunistic IoT. This protocol made routing decisions dependent on the nodes' buffer capacity, remaining energy, and forwarding viability degree. The degree to capture transmission feasibility, residual energy (RE) and residual buffer space of node were employed for selecting the process to transmit the data. The developed protocol had performed well with respect to MDP, HC, and overhead. Moreover, this protocol had generated a technique of awareness of power in mote and storage space, for preserving the power of node. An efficient permutation routing (EPR) method called NESEPRIN was suggested by Bomgni, *et al.* [22] for SH IoT. The capacity of memory varied depending on the object in this. This protocol was executed in 2 stages. First of all, a single channel was exploited to deal with the issue of permutation routing in a SH setting. The wake and sleep method was assisted in enhancing the efficacy of objects to preserve energy. The simulation results confirmed the supremacy of the designed method over the existing methods for tackling the permutation routing issue concerning energy saving in case of enormous amount of data to route.

Safaei, *et al.* [23] suggested a new routing parameter called strobe per packet ratio (SPR) for an energy-efficient cross-layer OF (ELITE). The MAC layer's radio duty cycling (RDC) policies led to the introduction of this parameter to specify the number of transmitted strobes per packet. The recommended protocol emphasized on selecting a route having lower strobe transmissions to its nodes. The findings demonstrated that the suggested approach proved effective in reducing the average number of strobes per packet by approximately 25% and improving the average energy consumption of an IoT node by around 39% in comparison with the traditional methods. An energy-efficient clustering algorithm (EECA) called decentralized connected resilient IoT clustering (DeCoRIC) was intended by Shivaraman [24]. This approach had resiliency against the network changes and ensured the connectivity. The protocol allowed to recognize the nodes for connectivity and generate the clusters having association among each other. Afterward, a robust and novel model was generated in a network which had any topological design. This algorithm was adaptable against node faults in a time-bound way. The experimental depicted that the intended algorithm offered 100% connectivity amongst all motes and enhanced the energy efficacy of nodes in the system in contrast to the traditional methods. In next work, Al-Sadoon *et al.* [25] presented a dual tier cluster-based routing (DTC-BR) protocol which led to split the network region into visual areas [25]. A CHM was utilized for selecting the suitable sensor node (SN) which was employed as CH. Additionally, virtual zones were put forward for covering the whole network area depending upon a dual-tier routing method. According to experiments, the presented protocol was useful for prolonging the duration of network up to 6% in contrast to dynamic directional routing (DDR) algorithm, up to 21% than MCCA, 25% than LEACH-MEEC, and 37% LEACH-M protocol.

Ramezanzadeh and Shokrzadeh [26] suggested a bee colony algorithm-based two-level hierarchical chain routing (PEG_ABC) protocol for mitigating delay to transmit data [26]. The primary task was to adjust RE of sensors, ED among SNs, and ED amid SNs and BS, to the fitness function of BCA so that the precise chain leader was selected. The experimental results demonstrated that the suggested algorithm had offered lower energy consumption, longer duration of network, higher packet delivery ratio (PDR), and least delay. Moreover, this algorithm was effective for computing the precise amount of clusters in hierarchical chain communication. A data-oriented RPL algorithm was projected by Wang *et al.* [27] for splitting the data during routing based on their content [27]. This algorithm was helped in mitigating the volume of duplicate data during its transmission, diminishing delay, preserving the restricted power of node, and prolonging the duration of network. The binary gray wolf optimization (BGWO) method was adopted to select the finest route with the objective of making the projected algorithm more effective. The fuzzy logic (FL) and BGWO (FL-BGWO) protocol was developed to generate this OF. On MATLAB 2022a and OMNET, the developed protocol was energy-efficient and yielded lower instability period up to 57% and least end-to-end delay (EED) in contrast to other methods. Han *et al.* [28] recommended an improved ant colony algorithm (IACA)-based routing algorithm for discovering the optimal routing method. This protocol was implemented for simulating the behavior of ants when they were searched for food, and optimizing factors while discovering the smallest path. In WSN, locations of motes were considered as the reference and ANs, and their integration was done with OF WSN RO. The experimental outcomes indicated the practicality of the developed algorithm and this algorithm outperformed the traditional methods concerning power usage, EED, amount of dead nodes, and throughput.

Priyanka *et al*. [29] introduced a region-based clustering and cluster-head election (REAN) algorithm for making the IoT networks more energy-effective in agriculture environment. The SRLC and RCHS algorithms were adopted for attaining the software and IoT application having energy-efficiency. The next focus was on creating and computing the techniques which were implemented for harvesting energy in real time. The experiments depicted that the introduced algorithm was useful for optimizing the energy usage of the IoT networks against existing schemes concerning power usage and EED. An RL intelligent adaptive trickle-timer (RLATT) protocol was constructed by Tan *et al.* [30] to optimize the routing in IoT awareness layer [30]. The triple-optimized trickle timer (TOTT) algorithm was implemented in this protocol. Contiki tool was executed for evaluating the constructed protocol against traditional methods. In experiments, the constructed protocol proved applicable in heterogeneous perception networks. Additionally, this protocol had offered higher PDR, convergence time and overall control cost ratio, and lower energy usage. A QL-based MAC protocol was established by Wu *et al.* [31] to adjust the length of the contention period adaptively in IoT networks when the ongoing traffic rate was considered [31]. The contention period's duration was modified in accordance with the flow of traffic rate using the reinforcement learning (RL) technique. This algorithm helped in revealing the novelty of established protocol. The method which lack of additional input information were tackled to be adaptable in environmental variations when the data was trained. The experimental results depicted the robustness of the established protocol with node contention. This protocol was performed well with respect to throughput, least EED, and reduced usage of power.

Ahmed *et al.* [32] recommended an EEDAM relied on blockchain for aggregating data at the cluster level so that energy consumption was mitigated [32]. This method was helped to protect IoT networks from malevolent activities on the basis of blockchain technology (BT) and diminish data co-relation. The experiments proved that the recommended approach was worked effectively to alleviate the volume of data and secure IoT. Moreover, this approach offered availability to network, lower delay, least latency and higher scalability. A priority-based energy-efficient routing protocol (PEERP) was suggested by Soufiene *et al.* [33] for transmitting data in healthcare using the IoT. This protocol was emphasized on classifying health information into 2 kinds to assign priorities, such as emergency situation and vital health data. The initial one was a data of higher priority data whose transmission was required quickly. The latter one was a data required by physicians to monitor patients rapidly. The evaluation demonstrated that the presented technique was effective for mitigating power consumption of SNs and prolonging duration at higher PDR and making the network reliable. An EEGR algorithm Aravind *et al.* [34] was introduced relied on 6-fold-OF [34]. The FL model was adopted to select the finest path during EEG routing on the basis of QoS, trust, energy, distance, delay, and overhead. The harris hawk's optimization (HHO) was employed to optimize the data. The introduced algorithm was assisted in enhancing the accuracy as compared to traditional methods. The comparison of various techniques is described in Table 1 (see in Appendix).

3. DISCUSSION

The literature reviews reveal several innovative strategies for augmenting the efficiency and energy utilization of IoT, particularly in the context of cluster-based structures and routing algorithms. The emergence of the energy-efficient cluster-based routing protocol (EECRP) and FPTAC underscores the growing emphasis on optimizing cluster head selection and routing algorithms to minimize energy consumption [17], [20]. Additionally, noteworthy protocols like ELITE and NESEPRIN address issues related to radio duty cycle regulations and efficient permutation routing, showcasing a diverse range of methods aimed at addressing energy challenges [22], [24]. Furthermore, the significance of taking transmission feasibility, RE, and buffer capability into account while making routing decisions for the opportunistic IoT is highlighted by the development of SEER. Additionally, the paper examines decentralized connected resilient IoT clustering (DeCoRIC) and dual tier cluster-based routing (DTC-BR), exposing initiatives to improve network connection, scalability, and resilience [26], [28]. All of these evaluations highlight the necessity of flexible, low-power protocols to support IoT networks, taking into account different aspects such as communication techniques, routing, and clustering.

4. METHOD

Data is collected via selected cache nodes. Next the data is sent to the sink using the introduced approach, which is planned depending on the process of choosing the CH. The proposed methodology will also improve the network performance and reduce energy consumption thereby helping to extend the network lifetime.

4.1. Step 1: cluster head selection

The motes at random is the main goal of the clustered wireless sensor network (WSN) application. As a result of this process, CHs are produced, which causes a number of problems. As the issue of greater node energy consumption is present, the disability must be avoided for CH. Additionally, avoiding long-distance communication in the CH and putting the motes closer to them are the main points of attention. The CH refers to the nodes that the anticipated standards overlooked and are flawed (cluster head). Due to their circumstances, the nodes' presence in the network becomes difficult. These nodes cannot operate in distant regions. As a result, the nodes lose their effectiveness. The deployment of such motes as CHs is a result of the increase in intra-cluster power. As opposed to nodes that receive and send the data, authentic motes just consume a smaller amount. The system synchronizes the use of a broad spectrum. As a result, the motes need less battery power. When choosing the parent mote for each CH, the actions are divided and the yield is maximized. Using two value functions, each sensing node (SN) becomes more proficient. The node is chosen as CH as a result. The degree of the nodes is used to generate the functions, and the distance between the nodes and the sink is calculated using the average power of the nearby motes. To produce CH, the greatest number of motes possible are generated. To avoid expensive communications, the CH with a higher degree spreads out over a large number of motes. After reducing energy use, the network's lifespan is extended. The broadcast of a Hello message that includes identity is carried out during the first phase. The SS is taken into consideration while calculating the distance of the sink from each node. The transmission of the INTIAL-MSG across the entire network is the focus of the following step. This network includes the identity and the separation between each mote and sink. The primary objective is to calculate the distance between a node and its nearby nodes. The node uses the following computation method to compute the CH designated R_{CH} represented in (1):

$$R_{CH} = R_{min} * [1 + \left(\frac{d_{BS} - d_{BSmin}}{d_{BSmax} - d_{BSmin}}\right)] \tag{1}$$

this equation demonstrates the smallest size of the cluster with R_{min}, which serves as a protocol metric, d_{BSmin} representing distance from nearest mote to BS, and d_{BSmax} representing the distance amid farthest mote and BS. Each mote is quantified by the value function, which offers applicability to the node during its selection as CH. The detailed flowchart of the proposed model is shown in Figure 3.

4.2. Step 2: cache node selection

The energy clusters provide support for the established intra-cluster communication about efficient components like cluster. The process through which a node uses energy and establishes communication in the cluster is more expensive. It causes the intra-cluster energy to be maximized. The centrality is emphasized in this essay. The second power average is alleviated in cases where the distance from central cluster to recipient mote is smaller to reduce the energy of intra-cluster processes. The energy is negatively impacted by several things. Under difficult conditions, the standards that are offered choose the motes referred to as cache nodes. To choose any mote as a volunteer node, the accompanying equation is used to calculate the value of each step for every non-CH mote. Pay attention (2):

$$Access\ Time = H * T_C + (1 - H)(T_C - T_m) \tag{2}$$

H stands for the cache hit ratio, T_c represents the data search time, and T_m represents a memory access time. These CHs are in charge of sending the data that has been gathered to the sink.

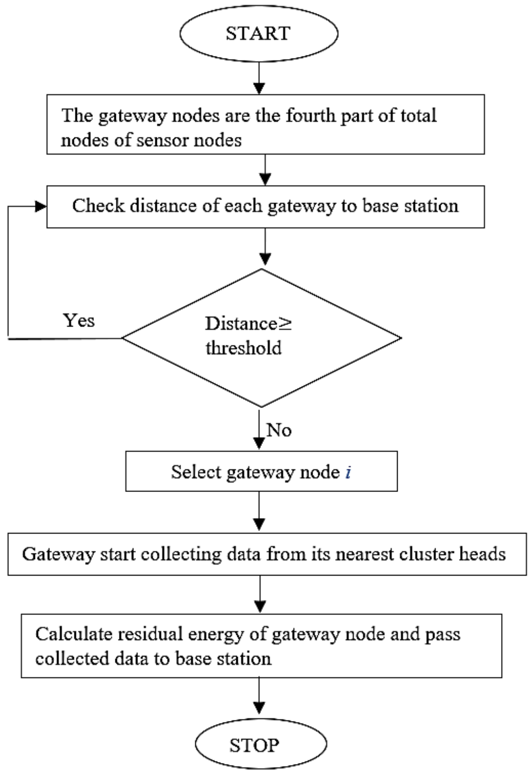

Figure 3. Proposed flowchart

5. RESULTS AND DISCUSSION

IoT is composed of numerous nodes and energy consumption is the major concern, various authors already proposed various schemes to improve network's lifetime. The clustering is a robust scheme that shows significant results towards improving lifetime of the network. This work focuses on enhancing VGDRA algorithm for prolonging the network's life span. The improved VGDRA approach focuses on implementing cache motes and BS which can collect data from the cache motes. The proposed model solves energy hole problem and results in expanding network's duration. MATLAB is a software, utilized to analyze the efficacy of the suggested cache-based WSNs. A comparative analysis is conducted on the suggested protocol against the existing fuzzy logic based WSNs. Diverse metrics, such as number of packets whose transmission is done to BS and amount of dead nodes, are considered to compute the suggested protocol. The simulations carried out in this work are displayed in Table 2.

Figure 4 illustrates the deployment of network on the basis of restricted amount of SNs. The clusters are formed and cluster heads are selected which are shown with the green color. The pink color is used to illustrate the cache motes and on the top there is BS. The clusters are transmitting information to cache nodes which are later passed to BS.

Figure 5 demonstrates that the number of dead node is analyzed amid suggested protocol and existing protocol. The sink in the existing protocol is dynamic. It moves from one location to another for gathering the data from CHs. The suggested protocol implements cache nodes and sink collects data from them. The number of dead nodes is alleviated after deploying the cache nodes in network. The detailed numeric values of the results are described in Tables 3-5.

Table 2. Simulation parameters

Paramete	Description	Value
A	Area of network	(200,250)
L-BS	BS location	(150,250)
N	Number of nodes in networl	100
$E_{initial}$	Initial energy of all nodes	0.5 joules
E_{space}	Free space energy model	50nj/bit
D_o	Threshold distance	87 meters
E_{DA}	Data aggregation energy	5 nj/bit/signal

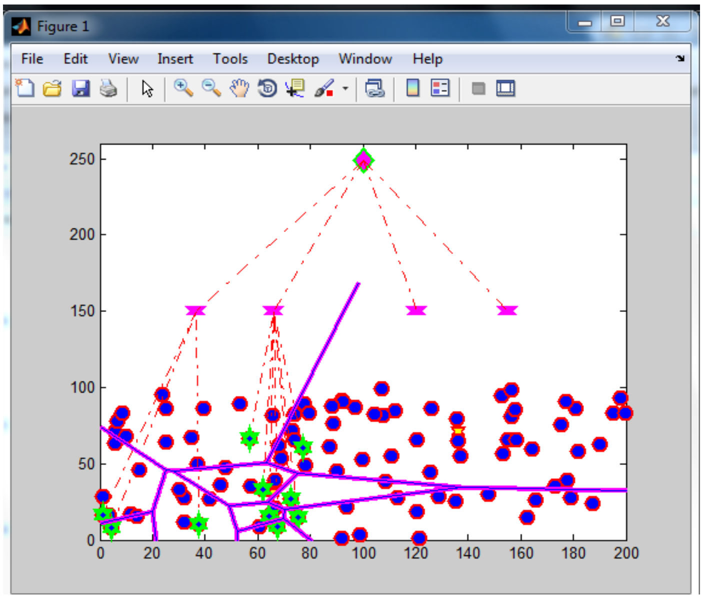

Figure 4. Network simulation model

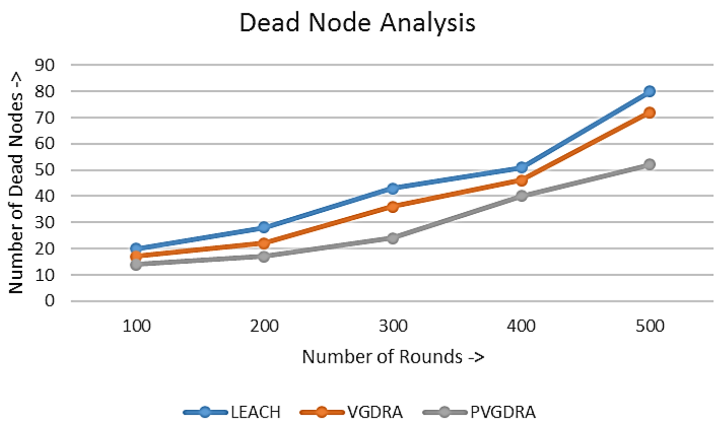

Figure 5. Number of dead nodes

Table 3. Dead node analysis

Number of rounds	LEACH	VGDRA	PVGDRA
100	20	17	14
200	28	22	17
300	43	36	24
400	51	46	40
500	80	72	52

Table 4. Alive node analysis

Number of rounds	LEACH	VGDRA	PVGDRA
100	80	83	86
200	72	78	83
300	57	64	76
400	49	54	60
500	20	28	48

Table 5. No. of packets transmitted analysis

Number of rounds	LEACH	VGDRA	PVGDRA
100	500	720	840
200	1,120	1,400	1,800
300	1,670	2,240	3,120
400	2,890	3,650	4,350
500	3,890	5,678	7,536

Figure 6 demonstrates the number of alive nodes in the network considering the number of rounds. The number of rounds is considered to maximize the number of alive nodes. The cache motes are exploited in the network to increase the alive nodes. The sink is utilized closer to these nodes for gathering the data. The results exhibit that the suggested protocol are compared with the existing ones.

Figure 7 depicted the comparison of the suggested protocol against the existing protocol. The suggested protocol is utilized to transmit the number of packets delivered to the BS. This protocol has potential for transmitting an enormous number of packets in comparison with the other. The number of dead nodes is mitigated in the network which results in transmitting a greater number of packets to the sink.

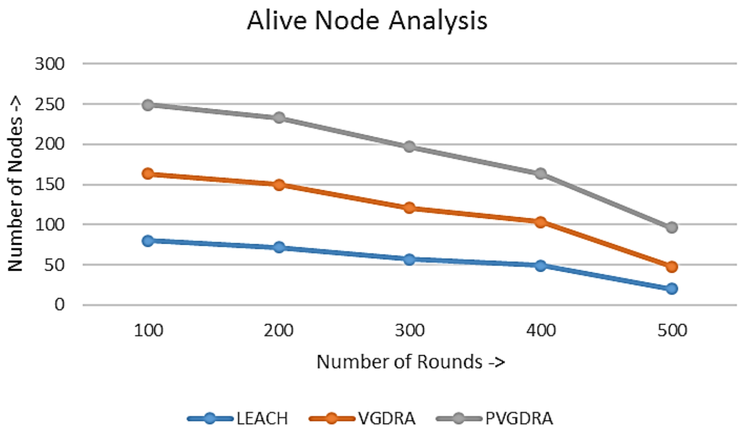

Figure 6. Number of alive nodes

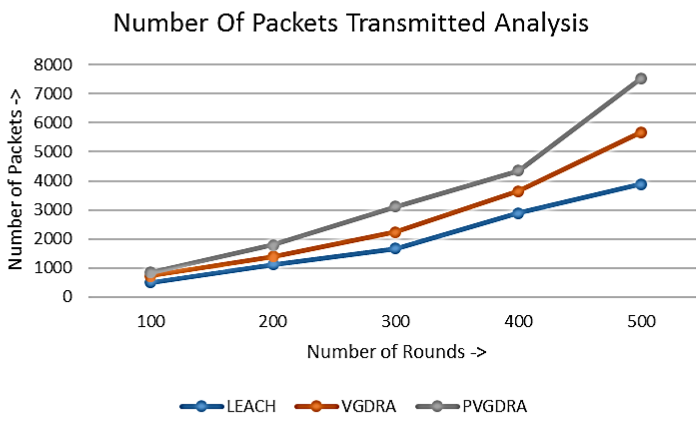

Figure 7. No. of packets transmitted

6. CONCLUSION

WSNs encounter energy consumption challenges due to the widespread usage and compact size of SNs. IoT proves beneficial in military applications, including object tracking, traffic management, and survival rate monitoring. The VGDRA represents an energy-efficient routing technique that has the potential to prolong the lifespan of IoT devices. This research project deploys cache nodes in the network and proposes an upgraded VGDRA protocol. The BS later gathered the data that the cluster heads had sent to the cache nodes. The evaluation of the improved VGDRA model in contrast to the original VGDRA protocol reveals an approximate 15% enhancement in metrics such as the number of dead motes, living motes, and amount of packets transmission within the network. The upgraded VGDRA protocol demonstrates significantly superior performance, particularly concerning extending the duration. The improved VGDRA algorithm is not yet tested under the impact of various types of security attacks. To bolster network security even further, additional enhancements can be implemented in the VGDRA protocol.

APPENDIX

Table 1. The comparison of existing work

Author	Year	Technique used	Parameters	Results	Limitations
Yarinezhad *et al.* [17]	2021	FPTAC	Duration of network, energy consumption	The simulation results exhibited the practicality of the projected algorithm over the traditional methods for large-scale networks.	The major limitation was that an approximation technique was adopted in this work.
Sankar *et al.* [18]	2020	EECRP	Delay, lifespan of network	According to experiments, the investigated protocol was applicable for prolonging the duration of network and mitigating the delays.	The efficiency of this protocol was mitigated in real time scenario.
Yarinezhad *et al.* [19]	2021	A tree-based routing protocol	Energy consumption, delay, duration of network and throughput	Based on findings, the presented approach yielded lower energy consumption and delay, and higher duration of network and throughput.	This protocol performed poorly on some domains in which several MSs were available.
Firdous *et al* [20].	2022	PECR algorithm	Overhead, PDR, energy utilization, life span of network	The introduced algorithm worked effectively while alleviating the traffic overhead and employing the energy assets.	This approach made the deployment of only one MCH and sink
Rani *et al.* [21]	2022	SEER	MDP, AHC and overhead	This protocol had generated a technique of alertness about power in mote and storage space, for preserving the power of node when a conditional choice was made for transmitting the data to a nearby node or not.	The computation of this protocol was not possible on real mobility traces.
Ramezanzadeh *et al.* [22]	2024	PEG_ABC protocol	Energy consumption, cost, duration of network, delay	The experimental results demonstrated that the suggested algorithm had offered lower energy consumption, longer duration of network, higher packet delivery ratio (PDR), and least delay.	The energy usage was increased when the sufficient amount of clusters was not selected precisely.
Wang, *et al.* [27]	2023	FL-BGWO algorithm	Instability period, duration of network, energy consumption, and end-to-end delay (EED)	According to experiments on MATLAB 2022a and OMNET, the developed protocol was energy-efficient and yielded lower instability period up to 57% and least EED than other methods.	This algorithm was not able to discover an exact association among the content, and recognize the similar information.

Table 1. The comparison of existing work (*continue*)

Author	Year	Technique used	Parameters	Results	Limitations
Han *et al*. [30]	2023	An improved ant colony algorithm (IACA)- based routing protocol	Power usage, EED amount of dead motes, and throughput	Experimental outcomes indicated the practicality of the developed algorithm in IoT that led to enhance the way to develop digital economy and create smart cities.	The major drawback was that the network topology was varied, and higher energy consumption was found to transmit data.
Priyanka *et al*. [23]	2023	Region-based clustering and cluster-head election (REAN) algorithm	Energy consumption, delay	The experiments depicted that the introduced algorithm was useful for optimizing the energy consumption of the IoT networks in comparison with the existing methods concerning energy usage and delay.	This system was lack of more factors and inapplicable in complex applications.
Tan *et al*. [30]	2023	RLATT protocol	PDR, energy usage, convergence time, and CCR	The constructed protocol proved applicable in heterogeneous networks and effective for augmenting the routing efficacy	The major drawback was that this protocol was computed only on emulator. Further, it was inapplicable in real time scenario.
Wu *et al*. [31]	2021	A QL-based MAC protocol	Throughput, EED, and EC	The experimental results depicted the robustness of the established protocol with node contention. This protocol was performed well in comparison with the traditional methods with respect to throughput, least EED, and less power usage.	This protocol consumed higher cost.
Ahmed *et al.* [32]	2022	EEDAM based on blockchain	Delay, energy consumption, latency and scalability	The experiments proved that the recommended approach was worked effectively to alleviate the volume of data and secure IoT. Moreover, this approach offered availability to network, lower delay, least latency and higher scalability.	The approach was not cost-effective.
Soufiene *et al*. [33]	2020	PEERP	Energy consumption and PDR	Based on simulations, the presented approach was effective for mitigating power consumption of SNs and prolonging the duration of network at higher PDR.	The computing complexity of this protocol was higher.
K. Aravind, *et al*. [34]	2024	Energy-efficient geographic (EEG) routing algorithm	QoS, trust, energy, distance, delay, and overhead	The introduced algorithm was assisted in enhancing the accuracy as compared to traditional methods.	The temperature and time were not considered in this approach.

REFERENCES

[1] J. C. R. Kumar, D. V. Kumar, B. M. Arunsi, D. Baskar, and M. A. Majid, "Energy-efficient adaptive clustering and routing protocol for expanding the life cycle of the iot-based wireless sensor network," *Proceedings - 6th International Conference on Computing Methodologies and Communication, ICCMC 2022*, pp. 328–336, 2022, doi: 10.1109/ICCMC53470.2022.9753809.

[2] S. Umar, N. L. Reddy, T. B. Yadesa, T. D. Deressa, and E. Fikadu, "Allocating and routing resources in an iot network with an efficient hybrid optimization approach," *Proceedings - International Conference on Applied Artificial Intelligence and Computing, ICAAIC 2022*, pp. 1580–1589, 2022, doi: 10.1109/ICAAIC53929.2022.9792945.

[3] A. Shahraki, A. Taherkordi, O. Haugen, and F. Eliassen, "A survey and future directions on clustering: from WSNs to IoT and Modern Networking Paradigms," *IEEE Transactions on Network and Service Management*, vol. 18, no. 2, pp. 2242–2274, 2021, doi: 10.1109/TNSM.2020.3035315.

[4] V. Vimal *et al.*, "Clustering isolated nodes to enhance network's life time of WSNs for IoT applications," *IEEE Systems Journal*, vol. 15, no. 4, pp. 5654–5663, 2021, doi: 10.1109/JSYST.2021.3103696.

[5] G. Kaur, P. Chanak, and M. Bhattacharya, "Energy-efficient intelligent routing scheme for IoT-enabled WSNs," *IEEE Internet of Things Journal*, vol. 8, no. 14, pp. 11440–11449, 2021, doi: 10.1109/JIOT.2021.3051768.

[6] A. Rodríguez, C. Del-Valle-Soto, and R. Velázquez, "Energy-efficient clustering routing protocol for wireless sensor networks based on yellow saddle goatfish algorithm," *Mathematics*, vol. 8, no. 9, 2020, doi: 10.3390/math8091515.

[7] O. O. Ogundile, M. B. Balogun, O. E. Ijiga, and E. O. Falayi, "Energy-balanced and energy-efficient clustering routing protocol for wireless sensor networks," *IET Communications*, vol. 13, no. 10, pp. 1449–1457, 2019, doi: 10.1049/iet-com.2018.6163.

[8] T. M. Behera, S. K. Mohapatra, P. Mukjerjee, and H. K. Sahoo, "Work-in-progress: DEEC-VD: A Hybrid Energy Utilization Cluster-Based Routing Protocol for WSN for Application in IoT," *Proceedings - 2017 International Conference on Information Technology, ICIT 2017*, pp. 97–100, 2018, doi: 10.1109/ICIT.2017.42.

[9] R. Dogra, S. Rani, H. Babbar, and D. Krah, "Energy-Efficient Routing Protocol for Next-Generation Application in the Internet of Things and Wireless Sensor Networks," *Wireless Communications and Mobile Computing*, vol. 2022, 2022, doi: 10.1155/2022/8006751.

[10] M. Micheletti, L. Mostarda, and A. Piermarteri, "Rotating energy efficient clustering for heterogeneous devices (REECHD)," *Proceedings - International Conference on Advanced Information Networking and Applications, AINA*, vol. 2018-May, pp. 213–220, 2018, doi: 10.1109/AINA.2018.00042.

[11] A. S. Nandan, S. Singh, R. Kumar, and N. Kumar, "An optimized genetic algorithm for cluster head election based on movable sinks and adjustable sensing ranges in IoT-based HWSNs," *IEEE Internet of Things Journal*, vol. 9, no. 7, pp. 5027–5039, 2022, doi: 10.1109/JIOT.2021.3107295.

[12] J. T. Thirukrishna, S. Karthik, and V. P. Arunachalam, "Revamp energy efficiency in homogeneous wireless sensor networks using optimized radio energy algorithm (OREA) and power-aware distance source routing protocol," *future generation computer systems*, vol. 81, pp. 331–339, 2018, doi: 10.1016/j.future.2017.11.042.

[13] V. Nivedhitha, A. G. Saminathan, and P. Thirumurugan, "DMEERP: a dynamic multi-hop energy efficient routing protocol for WSN," *Microprocessors and Microsystems*, vol. 79, 2020, doi: 10.1016/j.micpro.2020.103291.

[14] C. Iwendi, P. K. R. Maddikunta, T. R. Gadekallu, K. Lakshmanna, A. K. Bashir, and M. J. Piran, "A metaheuristic optimization approach for energy efficiency in the IoT networks," *Software - Practice and Experience*, vol. 51, no. 12, pp. 2558–2571, 2021, doi: 10.1002/spe.2797.

[15] Y. Fathy and P. Barnaghi, "Quality-Based and Energy-Efficient Data Communication for the Internet of Things Networks," *IEEE Internet of Things Journal*, vol. 6, no. 6, pp. 10318–10331, 2019, doi: 10.1109/JIOT.2019.2938101.

[16] M. Elappila, S. Chinara, and D. R. Parhi, "Survivable Path Routing in WSN for IoT applications," *Pervasive and Mobile Computing*, vol. 43, pp. 49–63, 2018, doi: 10.1016/j.pmcj.2017.11.004.

[17] R. Yarinezhad and M. Sabaei, "An optimal cluster-based routing algorithm for lifetime maximization of internet of things," *Journal of Parallel and Distributed Computing*, vol. 156, pp. 7–24, 2021, doi: 10.1016/j.jpdc.2021.05.005.

[18] S. Sankar, S. Ramasubbareddy, F. Chen, and A. H. Gandomi, "Energy-efficient cluster-based routing protocol in internet of things using swarm intelligence," *2020 IEEE Symposium Series on Computational Intelligence, SSCI 2020*, pp. 219–224, 2020, doi: 10.1109/SSCI47803.2020.9308609.

[19] R. Yarinezhad and S. Azizi, "An energy-efficient routing protocol for the internet of things networks based on geographical location and link quality," *Computer Networks*, vol. 193, 2021, doi: 10.1016/j.comnet.2021.108116.

[20] S. Firdous, N. Bibi, M. Wahid, and S. Alhazmi, "Efficient clustering based routing for energy management in wireless sensor network-assisted internet of things," *Electronics (Switzerland)*, vol. 11, no. 23, 2022, doi: 10.3390/electronics11233922.

[21] Rani and A. Malik, "A social relationship-based energy efficient routing scheme for opportunistic internet of things," *ICT Express*, vol. 9, no. 4, pp. 697–705, 2023, doi: 10.1016/j.icte.2022.10.002.

[22] A. B. Bomgni, M. L. F. Sindjoung, D. K. Tchibonsou, M. Velempini, and J. F. Myoupo, "NESEPRIN: a new scheme for energy-efficient permutation routing in IoT networks," *Computer Networks*, vol. 214, 2022, doi: 10.1016/j.comnet.2022.109162.

[23] B. Safaei, A. M. H. Monazzah, and A. Ejlali, "ELITE: an elaborated cross-layer RPL objective function to achieve energy efficiency in internet-of-things devices," *IEEE Internet of Things Journal*, vol. 8, no. 2, pp. 1169–1182, 2021, doi: 10.1109/JIOT.2020.3011968.

[24] N. Shivaraman, S. Ramanathan, S. Shanker, A. Easwaran, and S. Steinhorst, "DeCoRIC: decentralized connected resilient iot clustering," in *Proceedings - International Conference on Computer Communications and Networks, ICCCN*, 2020, vol. 2020-Augus, doi: 10.1109/ICCCN49398.2020.9209755.

[25] M. E. Al-Sadoon, A. Jedidi, and H. Al-Raweshidy, "Dual-tier cluster-based routing in mobile wireless sensor network for IoT application," *IEEE Access*, vol. 11, pp. 4079–4094, 2023, doi: 10.1109/ACCESS.2023.3235200.

[26] F. Ramezanzadeh and H. Shokrzadeh, "Efficient routing method for IoT networks using bee colony and hierarchical chain clustering algorithm," *e-Prime - Advances in Electrical Engineering, Electronics and Energy*, vol. 7, 2024, doi: 10.1016/j.prime.2024.100424.

[27] Z. Wang, Z. Jin, Z. Yang, W. Zhao, and M. Trik, "Increasing efficiency for routing in internet of things using binary gray wolf optimization and fuzzy logic," *Journal of King Saud University - Computer and Information Sciences*, vol. 35, no. 9, 2023, doi: 10.1016/j.jksuci.2023.101732.

[28] H. Han, J. Tang, and Z. Jing, "Wireless sensor network routing optimization based on improved ant colony algorithm in the Internet of Things," *Heliyon*, vol. 10, no. 1, 2024, doi: 10.1016/j.heliyon.2023.e23577.

[29] B. H. D. D. Priyanka, P. Udayaraju, C. S. Koppireddy, and A. Neethika, "Developing a region-based energy-efficient IoT agriculture network using region- based clustering and shortest path routing for making sustainable agriculture environment," *Measurement: Sensors*, vol. 27, 2023, doi: 10.1016/j.measen.2023.100734.

[30] H. Tan, T. Ye, S. ur Rehman, O. ur Rehman, S. Tu, and J. Ahmad, "A novel routing optimization strategy based on reinforcement learning in perception layer networks," *Computer Networks*, vol. 237, 2023, doi: 10.1016/j.comnet.2023.110105.

[31] C. M. Wu, Y. C. Kao, K. F. Chang, C. T. Tsai, and C. C. Hou, "A Q-learning-based adaptive MAC protocol for internet of things networks," *IEEE Access*, vol. 9, pp. 128905–128918, 2021, doi: 10.1109/ACCESS.2021.3103718.

[32] A. Ahmed, S. Abdullah, M. Bukhsh, I. Ahmad, and Z. Mushtaq, "An energy-efficient data aggregation mechanism for IoT secured by blockchain," *IEEE Access*, vol. 10, pp. 11404–11419, 2022, doi: 10.1109/ACCESS.2022.3146295.

[33] B. O. Soufiene, A. A. Bahattab, A. Trad, and H. Youssef, "PeerP: an priority-based energy-efficient routing protocol for reliable data transmission in healthcare using the iot," in *procedia computer science*, 2020, vol. 175, pp. 373–378, doi: 10.1016/j.procs.2020.07.053.
[34] K. Aravind and P. K. R. Maddikunta, "Optimized fuzzy logic based energy-efficient geographical data routing in internet of things," *IEEE Access*, vol. 12, pp. 18913–18930, 2024, doi: 10.1109/ACCESS.2024.3354174.

BIOGRAPHIES OF AUTHORS

Bhawna Ahlawat is a Research Scholar at Maharshi Dayanand University, Rohtak, Haryana. She has done her Bachelor's and Master's degree in Electronics and Communication Engineering from Maharshi Dayanand University, Rohtak, Haryana, INDIA. She is currently pursuing her Ph.D. from the same university. Her research areas are IoT, WSN, and Clustering. She can be contacted by email: bhawna.rs.ahlawat@mdurohtak.ac.in.

Dr. Anil Sangwan is an Associate Professor at Maharshi Dayanand University. Rohtak, Haryana. He received his Bachelor's degree in Electronics and Communication Engineering and Master's degree in Electrical Instrumentation and Control Engineering from Maharshi Dayanand University, Rohtak, Haryana, INDIA. He received his Ph.D. degree from Maharshi Dayanand University, Rohtak, Haryana, INDIA. He has published around 30 research papers in national and international journals and conferences. He can be contacted at email: anilsangwan.uiet@mdurohtak.ac.in.