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An Energy Proficient Load Balancing Routing Scheme for Wireless Sensor Networks to Maximize Their Lifespan in an Operational Environment

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ABSTRACT Owing to the limited resources of sensor nodes, we propose an efficient hybrid routing scheme using a dynamic cluster-based static routing protocol (DCBSRP), leveraging the ad hoc on-demand distance vector (AODV) routing protocol and low-energy adaptive clustering hierarchy (LEACH) protocol. In the proposed scheme, the cluster head (CH) nodes are formed dynamically for a fixed interval, whereas static routing is applied in the designated clusters by utilizing the AODV routing protocol. The static routing condition of the proposed scheme limits all connected nodes of the cluster for a defined interval of time (T) to share their collected information through a specific CH node. Once the time (T) interval is completed, all ordinary nodes connected with the specific CH are released and they are free to advertise their CH candidateship within the network. Likewise, the node receiving the maximum number of route replies (RREPs) is selected as the next CH node in the vicinity of deployed sensor nodes. However, with the DCBSRP protocol, the recently selected CH node does not advertise its candidateship for five consecutive cycles and acts as an ordinary node. The simulation result shows significant improvement in the lifetime and participation of ordinary nodes in the network until the end-stage of the network. In the proposed scheme, the participation of ordinary nodes in the network is 95.9 %, which not only balances load between participating nodes but also improves the network lifetime in the presence of field-proven schemes. Moreover, the simulation results show an out-performance of rival schemes in terms of communication cost, end to end delay, throughput, packet lost ratio, and energy consumption.

INDEX TERMS Wireless sensor networks, load balancing, WSNs lifespan, routing protocol, sensor nodes, wireless communication, sensor nodes energy,

I. INTRODUCTION

Wireless nodes are deployed in a targeted area and monitor the surrounding events according to their assigned tasks. Wireless nodes collect, process, and communicate information between the base station and a remote location [1]. Sensor nodes have limited resources, such as memory, processing, and onboard battery power, and the sizes and tasks of such nodes differ according to their functionality. Moreover, the cost of these tiny devices also varies according to their functionality and built-in power, processing, and sensing capabilities [2]. Wireless sensor networks (WSNs)

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are very important in the current era, due to its various applications in different fields such as healthcare, intelligent transportation systems, agriculture, and traffic etc, [3].

Load balancing of a wireless network is one of the most important aspects to be considered when developing or deploying such networks, [4], [5]. The homogeneous WSNs used mainly base station (BS) for load balancing in deployed networks. They used transmitting sensor node details such as residual energy, distance, time, etc. to control load across participating nodes and prolong their operating network existence. Moreover, if a BS is overloaded, the traffic is then shifted to a neighbor BS whose demand for traffic is relatively low [6]. Agrawal and Pandey proposed a fuzzy-based unequal cluster protocol to balance the energy consumption of a wireless network and prolong its lifespan [7]. Their proposed scheme uses a cluster formation in the network to manage the load balancing issue in the deployed area. The nodes with low energy levels are allowed to form a separate cluster in the network. In this way, the proposed scheme minimizes the energy consumption of the WSN and prolongs its lifetime. Moreover, the proposed model is effective at prolonging the network lifetime even when the formation of clusters with a specified condition increases the end-to-end delay and network overhead. Second, the formation of clusters from a long distance in the network increases the communication cost, which affects the overall network performance.

The improved gossiping protocol (IGP) scheme was used to extend the lifetime of a WSN while maintaining reliable communication [8]. However, with this scheme, the clustering algorithm with load balancing (CALB) was used as an extension to improve the network performance and lifetime. In addition, the ant colony taboo based energy balance routing protocol (ACTEBUC) was investigated for an improvement of the lifespan of a WSN [9]. With this scheme, the cluster head selection process was improved to minimize the energy consumption of the participating wireless nodes. The parameters considered for the cluster head node selection include the distance, energy, and density factor. To select the next cluster head node, the threshold values are set for the parameters mentioned above.

To resolve the load balancing issue in a WSN, a hybrid routing scheme using unequal clustering and the connected graph theory was proposed [10]. The proposed model was based on two functions. The first function in the scheme is a cluster head selection, in which the transmission power of the wireless nodes is used as a second function to implement the proposed model. However, during the process of cluster head selection, the numbers of votes of the specific wireless nodes and the transmission power were considered to implement the hybrid unequal clustering theory and connected graph theory routing protocol. In addition, a software-defined framework scheme for load balancing was proposed by Chen and Hao [11] to specifically investigate the offloading problem in a WSN. Moreover, the scheme also considers a communication delay problem and the energy consumption of the wireless nodes to enhance the network lifespan. The authors used the NP-hard paradigm in their scheme, which was further mixed with non-linear programming to resolve the off-loading problem occurring in a WSN.

The mobile edge computing (MEC) scheme was used to address the issue of load balancing in a WSN with the help of edge computing, as described in [12]. The objective of the MEC scheme is to control the wireless network energy consumption in terms of the computing and storage resources, such as the access points and cluster head/base stations. Furthermore, this scheme emphasizes the issue of latency and the computation cost of the network to minimize the energy consumption.

Wireless nodes have limited resources, such as memory, processing, and onboard battery, which require an efficient utilization for better results with optimal costs. Although some prominent studies on the load balancing of a WSN been conducted, most of the suggested techniques have their pros and cons. Therefore, an efficient routing protocol is proposed herein to resolve the issue of load balancing in a WSN. The proposed DCBSRP routing protocol addresses this issue of load balancing in a WSN with minimum communication and computational costs. Moreover, our proposed scheme surpasses the existing schemes for several performance metrics such as the end-to-end delay, throughput, and PLR. However, the load balancing of the DCBSRP routing protocol has also shown significant results based on an efficient cluster head node selection and implementation of static routing.

The rest of this article is organized as follows: Section 2 describes some related studies conducted in this area, and section 3 provides the problem statement and the aim of the proposed scheme. Section 4 details the proposed model of the DCBSRP routing protocol. Section 5 analyzes the results of the DCBSRP routing protocol, and finally, section 6 provides some concluding remarks.

II. LITERATURE REVIEW

Wireless networks have been in use for the last couple of decades, and have various applications in everyday life, including health-care, automation, agriculture, and transportation. The introduction section of the paper reviews some of the applications and deployment areas of these networks with their contribution. However, efficient utilization of these networks, minimizes it's implementation cost, and increases its productivity by accurate results. Therefore, the load balancing issue in wireless networks is the most attractive area for researchers when designing new techniques or modifying the existing schemes. In this section, some of the latest techniques of load balancing in a WSN are discussed along with their advantages and disadvantages.

Elkamel *et al.* [13] proposed an energy hole technique to resolve the load balancing issue in a WSN. Using this technique, they applied unequal clustering formation information to resolve the load balancing problem. As a limitation of this scheme, an equal cluster formation in a WSN environment is impossible. Therefore, the performance reliability of the proposed model will be affected within the operational environment, where a cluster formation has an unequal number of wireless nodes. In addition, an adaptive cycle control based opportunistic routing scheme for load balancing was proposed by Xiang *et al.* [14]. The objective of the proposed opportunistic routing scheme was to balance the workload among participating wireless nodes and prolong their lifetime. However, the complexity of the proposed model minimizes its uses in the real deployment of a WSN. A device-to-device (D2D) relaying scheme for load balancing in a wireless network was proposed by Jiang *et al.* [15]. In this scheme, a macro cell and macro user equipment (MUE) were used in combination to minimize the traffic overhead and prolong the network lifespan. As the limitation of a D2D relaying scheme, the adjustment of the additional equipment (macro cell & MUE) increases the network implementation and maintenance cost.

Efficient load balancing and task scheduling in wireless networks increase their productivity in terms of achieving accurate results and prolonging the lifetime. Therefore, while developing a wireless network infrastructure, most researchers have focused on load balancing and task scheduling of the network to minimize network costs and increase the productivity. A collaborative multi-task data collection scheme was proposed by Ren *et al.* [16]. With this technique, a collaborative task scheduling and data reporter problem are resolved in a wireless network. Furthermore, the operational phenomena of this scheme consists of two functions, one of which can schedule/select system tasks, whereas the other increases the system productivity. However, the complex model of this scheme decreases its use in the real deployment of a WSN. Liu *et al.* [17] proposed a dynamic duty cycle (DDC) scheme to resolve the load balancing issue in wireless networks. The proposed scheme improves the end-to-end delay during the communication process. Moreover, the suggested DDC model uses two functions during the implementation phase to maintain network reliability. For the first function, DDC investigates the duty cycle, which affects the network delay. Likewise, for the second function, DDC prolongs the duty cycle of non-hotspot area nodes in the network, prolonging the network lifespan. In addition, a two-tier cooperative cache scheme for efficient query optimization in wireless networks was proposed by Zhou *et al.* [18]. The proposed model was effective for multiple supporting wireless network applications. Under ordinary conditions, the proposed model is too expensive to implement and maintain.

Furthermore, some researchers have used routing protocols to minimize the energy consumption of wireless nodes with a balanced load. Likewise, the double cluster head routing scheme for WSNs with a cluster-based formation was proposed by Wang *et al.* [19]. In this scheme, single- and multi-hop selection information were used by relaying nodes based on the residual energy to transmit data from the source node to the destination node. An energy efficient connected coverage (EECC) technique for load balancing in a WSN was also proposed by Roselin *et al.* [20]. This scheme uses information including the distance, connectivity, and residual energy to balance the energy consumption and prolong the network lifetime. Moreover, with the EECC approach, those nodes that do not contribute to the computation process will be used as relay nodes in the network. Limitations of the EECC model include its implementation complexity and relaying node segregation.

Arghavani *et al.* [21] proposed the optimal clustering in circular networks (OCCN) scheme to mitigate load balancing issues in a WSN and prolong the lifespan. The OCCN scheme is effective for circular wireless networks, and uses a cluster head node with a one-hop count communication. However, the limitation of the proposed OCCN model is its specific WSN environment deployment, which cannot always be achieved. In addition, a hierarchical multi-path routing (HMR) load balancing scheme for WSNs was proposed by Jadidoleslamy [22]. This protocol was specifically designed for cluster-based homogeneous wireless sensor networks. As the limitation of the proposed HMR protocol, it is suitable for a homogeneous one-hop count communication environment in the deployed WSNs. Moreover, WSNs are deployed in an unstructured environment, where one-hop communication with the cluster node is not always possible. In addition, an inter- and intra-cluster head based heuristic algorithm scheme for load balancing in a WSN was proposed by Yin *et al.* [23]. This proposed scheme has two steps for allocation of the task scheduling. During the inter-cluster head allocation phase, the task is allocated to various clusters for the sake of minimizing the energy consumption. In the intra-cluster phase, however, the workload is distributed among the sensor nodes to minimize the energy cost and network overhead. As a limitation of the proposed model, it is extremely hard to develop in a real environment owing to its complex infrastructure.

Yu *et al.* [24] proposed a distributed optimal on-line task allocation algorithm for energy efficiency and load balancing in wireless sensor networks. The proposed model uses computing, communication, sleeping, and sensing parameters of wireless nodes to manage network traffic. Although the proposed model is accurate for load balancing, its energy consumption is high owing to the complex calculation of the aforementioned parameters. In addition, a dynamic cell-based expansion scheme for load balancing in a WSN was proposed by Guo and Farrell. [25]. The proposed scheme uses the cell expansion idea to manage the network traffic in a deployed WSN. However, the area of a cell is extended or reduced according to the network traffic for better results. Moreover, a sustainable multipath routing protocol scheme for load balancing a WSN was proposed by Fu *et al.* [26]. In this proposed model, routing decisions are based on depth, residual energy, and the environment of the deployed WSN to minimize the energy consumption of the participating nodes. Finally, a multiple virtual machine-based tasked scheduling technique used to balance the energy consumption in a WSN was proposed by Singh *et al.* [27].

The time or duration required for the energy of the wireless nodes to be depleted is called the lifetime of a wireless nodes.

The onboard battery replacement of wireless nodes is not possible in most applications and deployment environments [28]. The energy balanced and lifetime extended routing protocol (EBLE) scheme was proposed by Wang *et al.* [29], to prolong the network lifetime of WSNs. They used residual energy of ordinary nodes to balance network traffic and maximize its lifespan. Wang *et al.* [30] proposed an adoptive routing protocol to resolve the load balancing issue in WSNs. They considered the point-to-point method in their scheme for a source node to build a route to the destination node and exchange information in the network. Feng *et al.* [31] proposed the software-defined wireless network (SDWN) scheme to address the issue of load balancing in WSNs through a centralized controller. Hamrioui and Lorenz [32] proposed the Load Balancing Algorithm for IoT devices, which is known as LBA-le routing protocol. The proposed scheme was specifically applied to IoT application in e-health-care to resolve the load balancing issue in deployed networks.

Singh and Pattanayak [33] used the analytical Study of Cluster-based Routing Protocol to extend the lifetime of WSNs. Moreover, they considered the sensor nodes dead rate by utilizing different routing protocols in their research to verify and compare the results. The genetic algorithm-based energy-efficient clustering and routing approach (GECR) for load balancing of WSNs was suggested by Wang *et al.* [34]. To resolve, the load balancing issue in WSNs an energy-efficient scalable routing algorithm (EESRA) was proposed by Elsmany *et al.* [35]. The three-layer hierarchy model was adopted in the proposed scheme to maximize the network lifetime. Singh *et al.* [36] used different photovoltaic cells to overcome the extra energy consumption of sensor nodes deployed in a harsh environment to collect and process information with extended lifespan. Kacimi *et al.* [37] used strategies based model in their research to resolve the load problem in WSNs and prolong the network lifetime. The energy-efficient Distributed Dynamic Diffusion routing algorithm (e3d) was proposed by Raicu *et al.* [38], to address the load balancing issue in WSNs. Chen *et al.* [39], proposed the receiver-oriented load-balancing and reliable routing (RLRR) scheme to resolve the load balancing issue in WSNs and extend network lifespan.

The compressive sensing-based (CS-based) and clustering strategy was used in combination by Wang and *et al.* [40], to resolve the load balancing in WSNs. Lin *et al.* [41], proposed the Game theory based Energy Efficient Clustering routing protocol (GEEC) model to address the load balancing issue in WSNs utilizing Cluster Head nodes. The power-aware task scheduling (PATS) scheme for cloud platform was proposed by Zhao *et al.* [42], to minimize energy consumption of deployed network. El Alami *et al.* [43], [44], suggested an enhanced cluster hierarchy (ECH) scheme to handle the load balancing problem in WSNs. In addition, the authors used neighboring nodes wake up, sleep time to optimize network life. The improved low-energy adaptive clustering hierarchy protocol was proposed by El Alami *et al.* [45], to resolve the load balancing issue in WSNs and prolong their lifetime in an operational network. The Energy-efficient fuzzy logic cluster head (EEFL-CH) routing scheme was proposed by El Alami and Najid [46], to address the load balancing issue in WSNs and extend network lifetime with better results. El Alami and Najid [47], proposed the Fuzzy Logic based Clustering Algorithm (CAFL) for WSNs to maximize their lifetime with balanced energy consumption.

The topology control protocol based on learning automation (LBLATC) was suggested by Javad *et al.* [48], to prolong WSNs lifetime in an operational environment. The DLA (distributed learning automaton) scheme for improve quality of service (QoS) with balance energy consumption was proposed by Mostafaei. [49]. Mostafaei *et al.* [50], proposed an energy proficient algorithm by utilizing learning automata to maximize the lifetime of sensor nodes in a given area of interest. Sert *et al.* [51], used the modified clonal selection algorithm (CLONALG-M) to extend the network lifetime by utilizing fuzzy routing algorithms. Adil *et al.*, [52], proposed the Energy Gauge Node (EGN) scheme to resolve the load balancing issue in WSNs.

Therefore, designing an energy proficient communication framework for such networks is important to address their lifespan issue with better network results. Moreover, energy balancing in a wireless network is an attractive area for researchers working on the design of new techniques because the residual energy-based techniques used in WSN nodes not only increases the communication cost, it also affects the network performance in terms of extra calculations, processing power, and memory utilization. Therefore, this article also emphasizes resolving the issue of energy balancing in a WSN with minimal network costs and accurate results. The solution proposed in this article is a hybrid protocol, which is known as the DCBSRP routing protocol.

III. PROBLEM STATMENT

Owing to dynamic behavior, unstructured distribution, and scarce resources, wireless sensor networks are susceptible to different issues. Therefore, effective usage of sensor nodes in deployed WSNs increases network lifetime with greater efficiency. Studies have suggested that the various schemes available, however different, have constraints in their usage in a real deployment. The limitations identified in the literature includes the following:

1) The existing schemes have a complex residual energy calculation process, which generates network overhead.
2) They have a complex implementation process.
3) Most schemes in the literature are specific to the system or environment.
4) Some schemes are efficient against load balancing, but they have a limited throughput, high end-to-end delay, and a high packet loss ratio, which minimizes their use in the real world.

How to design an efficient load balancing infrastructure for a constraint-oriented network, which has the minimum communication and computational costs with an extended network lifetime?

Given a network topology containing (N) number of ordinary nodes, where an ordinary node is denoted by (C_i). Moreover, $C_i \in$ Network (C_N), which contains N number of sensor nodes in the deployed area. The i^{th} term in C_i is used to represent the i^{th} ordinary node such as $(C_i = 1, 2, 3 \ldots, N)$ to form clusters and process information in the network. However, each cluster has a defined region or area at the time of formation, where the whole region is defined as $CR = (C_{R1} \cup C_{R2} \cup C_{R3} \cup C_{R4}, \ldots, \cup C_{R(N)})$ for all sensor nodes, or where C_R in the problem statement simply represents the cluster region. C_i can form a cluster with all other nodes belonging to its region C_R and with itself when work as a cluster head (CH).

How efficiently the above mentioned network can be managed to prolong their lifespan with minimal resources and costs?

a: CONTRIBUTIONS OF OUR PROPOSED SCHEME

The related studies section contains various schemes to improve the lifetime of a deployed WSN, most of which have their own merits and demerits in terms of a complex implementation that are specific to the system or environment. Therefore, an efficient load balancing scheme is proposed in this article to resolve this issue in a WSN. The proposed scheme improves the lifetime of the deployed WSNs with better end-to-end delay, the minimum amount of communication cost, a high throughput, and the smallest packet loss ratio. Moreover, the steps adopted for implementation of the proposed scheme are as shown below:

1) All sensor nodes are interconnected.
2) We propose and implement a hybrid DCBSRP routing protocol.
3) We propose and illustrate dynamic CH selection for use in a network.
4) Static routing is achieved for a defined interval of time.
5) Our proposed scheme maintains load balancing and prolongs the lifespan of the network with minimal network communication and computational cost, the minimum packet lost ratio, minimum end-to-end delay, and high throughput.
6) We conducted simulations to compare the results of our proposed scheme with previous approaches.

However, the drawback of DCBSRP routing scheme is a complex implementation in the initial phase, but this is one time task for long term results.

IV. PROPOSED APPROACH

Wireless Sensor Networks (WSNs) can be described as a self-configured and infrastructure-free wireless network for monitoring physical or environmental factors, such as vibration, temperature, friction, sound, motion or contaminants, and for transmitting their data through the network to a main location or sink where data can be monitored and analyzed. However, sensor nodes have limited resources such as computing, memory, and onboard power etc, which require effective usage to boost network efficiency and lifespan. In fact, the wireless nodes operate in an operational network until their onboard power remains or the period over which the onboard power persists. Wireless node engagement cycle defined as the lifespan of sensor device in wireless networks. The onboard battery replacement of wireless nodes is not possible in most of its applications. Therefore, designing an energy proficient communication framework for these networks is very important. Load balancing in WSNs is still the most attractive area for the research community to work and design new techniques. To resolve the load balancing issue in WSNs, various existing techniques emphases on the cluster-based routing and residual energy of wireless nodes. However, the residual energy calculation in WSNs nodes not only increases communication cost, but it also affects network performance by means of extra calculation, processing power and memory utilization.

By keeping in view, the existing schemes of load balancing of WSNs, we proposed a hybrid DCBSRP routing protocol in this article. The DCBSRP routing protocol is designed from the composition of LEACH and AODV protocol. Moreover, while developing this hybrid scheme, we use the properties of both aforementioned protocols. However, the functionality of our DCBSRP routing protocol is completely different from both of the mentioned protocols. The DCBSRP routing protocol works as three functions scheme. The first function in the DCBSRP routing scheme is the selection of the cluster head node. Likewise, in the second function, the DCBSRP routing protocol applies static routing for the defined interval of time (T) against a formed cluster. Function three of the DCBSRP routing protocol is that to release connected nodes of a cluster after the defined interval of time (Static routing) and ignore the already selected cluster head node, as a cluster head candidate for five consecutive cycles in the cluster head selection process.

In our proposed model, the five-time ignorance or non-availability for CH candidate-ship allows the ordinary nodes to participate in the network until the end-stage. Moreover, this scheme allows every participating node to play the role of CH, which equalizes the energy consumption of participating nodes and extend the network lifetime. To elaborate on, the nodes that play the role CH did not advertise their CH candidate ship of CH for five consecutive cycles, which allows their vicinity nodes to play the role of CH. Therefore, in our proposed model maximum numbers of ordinary nodes get a chance to play the role of CH, which at end maximizes network lifetime in terms of participating nodes equal energy consumption and improves the defined metrics of communication with improved results.

The cluster head (CH) formation phenomena of our proposed scheme are the same as the LEACH protocol, where several clusters are formed against designated cluster head (CH) nodes. However, in our proposed model they are bound for a defined interval of time to share their collected information utilizing selected CH in static routing formation. The participating ordinary nodes of the deployed network in the initial phase (off-line phase) broadcast a route request (RREQ) message in the presence of DCBSRP routing protocol to acknowledge their existence and communication request in the network. In response, they receive a route reply (RREP) packet form neighbors nodes, which contains the suggested path information of responding nodes for communication in the network. Similarly, the nodes in the network, which receive the maximum number of RREP replies for the next-hop count or shortest path from neighboring nodes in the close vicinity are selected as cluster head (CH) nodes such as LEACH protocol. In the presence of our proposed DCBSRP routing protocol, the selected CH nodes act as CH for designated clusters for the defined interval of time. Once, the CH node process completes, the DCBSRP routing protocol binds all the ordinary nodes connected with a specified CH by applying the static routing configuration. The static routing of DCBSRP routing protocol enables ordinary nodes of the network to share their collected information through concerned CH in a unicast fashion. However, the CH nodes continually work for a defined interval of time (according to DCBSRP routing protocol static configuration). Once the defined interval of DCBSRP routing protocol expires (static routing), all the ordinary nodes connected with CH nodes are released.

Similarly, once the defined interval of time for a CH node expires all connected nodes are released and now they are allowed to select new CH node or advertise their CH candidate-ship information in the close vicinity of designated WSNs. Likewise, in the initial phase, the participating nodes of the network generate the RREQ packet in the network, and all ordinary nodes in the close vicinity respond with the RREP packet. The nodes that receive the maximum number of RREP(s) are selected as CH nodes with small cluster formation, but in this phase, the node that currently performed the duty of cluster head did not advertise their CH candidate-ship. Similarly, this process continues for five consecutive cycles for a recently selected CH node. However, this node participates in the network as an ordinary node to collect information according to their task and process it through the concerned CH node. The detail overview of DCBSRP routing protocol is shown in figure 1. The brief overview of DCBSRP routing protocol is shown in figure 1. The green node shown in the figure 1 represent the cluster nodes, which were selected dynamically through DCBSRP routing protocol. The nodes connected with CH node, show the formation of clusters in DCBSRP routing protocol. However, as stated earlier in the article, the cluster head node is selected on the basis of most request from neighbors nodes for shortest path or next hop count toward the destination node. Likewise, once the cluster is formed among the participated nodes, the DCBSRP protocol apply the static routing configuration to bind all the connected nodes with concerned cluster head for define interval of time.

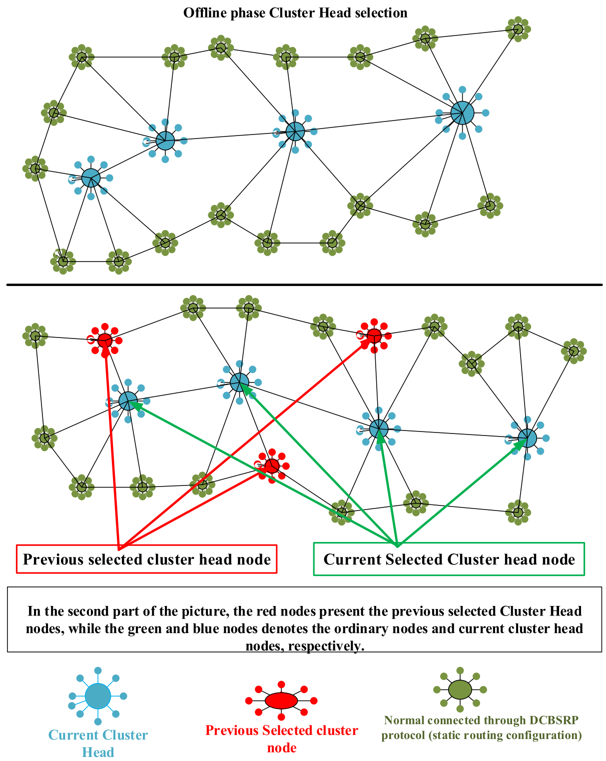

FIGURE 1. Brief over of DCBSRP routing protocol, how cluster head selection took place.

A. FUNCTION 1 & 2 CLUSTER HEAD SELECTION IN OFF LINE PHASE

In this phase, all the participating wireless nodes generate a RREQ packet to acknowledge their presence in the network. Once, the RREQ packet is received by other participating ordinary nodes, they respond with a RREP message, which contains hop count or shortest path information of the responding node. Those nodes that receives the most number of RREQ messages are considered as cluster head nodes, which form small clusters in the deployed network. After the declaration of CH node, the DCBSRP routing protocol applies static routing configuration to the connected nodes, which bound connected nodes of a specific CH to share their collected data via this CH in the network. The selected cluster head node process the collected information of the connected nodes in the network for a defined interval of time. However, in the meanwhile, none of the nodes (connected with the cluster formation) are allowed to advertise their CH candidate-ship or shortest path information in the network. Moreover, all the connected nodes share their information through the concerned CH node in a unicast fashion. The defined interval of time in the DCBSRP routing protocol minimizes the energy consumption of an individual wireless node leveraging unicast communication and every node CH candidateship selection. Once the DCBSRP routing protocol defined interval of time expires, then all the connected nodes with the cluster head are released. Now, they are allowed to advertise their candidate-ship of CH, except the one node that played the role of CH in the previous five intervals.

1) CLUSTER HEAD (CH) FORMATION DCBSRP ROUTING PROTOCOL

Let assume a wireless network topology, which is deployed in a rectangle area (M) with N number of wireless nodes in the region CR. The ordinary wireless nodes participating in the network have an equal amount of energy in the initial phase. Furthermore, assume that every participating node has self-power control while communicating in the network concerning distance parameters. The energy model adopted for our proposed DCBSRP routing protocol during the formation of the cluster is as follows. A wireless node $C_i \in C_N$ broadcast a l-bit message over a distance ((des)-meters). The energy consumes during transmission is E_{TX} (l, des), where l is the length of message in bits and (des) represents the destination distance over which the message can be transmitted.

$$E_{TX}(l, des) = l(E_c + \varepsilon_\lambda des^2), \quad if\ des < \alpha$$
$$E_{TX}(l, des) = l(E_c + \varepsilon_m des^4), \quad if\ des \geq \alpha \tag{1}$$

In equation 1 E_c represents the consumed energy of C_i node in [j/ bits] per transmission in the network, where ε_f & ε_m represents the Friss factor of transmission in [j/bits/meter] and of a signal is denoted by (λ). The free space model is denoted by $\alpha = \sqrt{\varepsilon_\lambda / \varepsilon_m}$.

Moreover, the energy consumed during the reception of a message is shown in equation 2.

$$E_{TR}(l) = l(E_c) \tag{2}$$

In equation, 2 E_{TR} denotes the consumed energy of an ordinary node during reception of message of length (l). When a wireless node (C_i) listens to the transmission channel for time t(sec.), then the energy consumed during this process is considered as t(El) per unit time [j/sec], whose value is constant to maintain simplicity in the proposed model. The time is divided into (x) rounds for our proposed model, where x = 0, 1, 2, 3, 4, 5, ...n. The CH nodes formed dynamically in each round with an exception of k, whose value is taken as free calculated for the system.

Let assume that the desired number of CH nodes is p = k/N for ($0 \leq p \leq 1$), when in the offline phase there in no CH node. The round of time in the proposed model is denoted by [.]. In the DCBSRP protocol, ($1/P$) consecutive rounds establish the group of round (GOR). Now let assume that $G(x)$ is the set of C_i nodes that have no cluster or CH node within the GOR in the current round (x). In the current round (x), $C_i = C_1, C_2, C_3, C_4 \ldots\ldots\ldots.., C_N$, Likewise C_i advertise itself for the candidate-ship of CH node with a probability:

$$T_{C_i,x} = \frac{P}{(1 - P(mod[\frac{1}{p}] \times x))},$$
$$Otherwise,\ it\ is\ 0. \quad For,\ C_i \in G(x) \tag{3}$$

In the proposed model every step is to start with a start-up phase, which is further categorized in two sub-phases. However, these phases operate successively during the per-defined interval of time period T_1 and T_2 for our proposed model. In phase I of the proposed model, CH nodes are selected using the dynamic procedure of equation 3, where each node $C_i \in C_N$ wants to be selected as CH node, they broadcast the RREQ message in the network, which contains node ID and other necessary information with carrier sense multiple access (CSMA) as media access control (MAC) protocol. The C_i broadcasted message is a two-tuple message, which contains C_i node ID and necessary information as scattering code to mitigate inter-cluster intervention. Similarly, all participating ordinary nodes of the network simultaneously enters phase II, where the ordinary nodes choose the close vicinity CH and go to sleep mode for time (t). The ordinary nodes wake up at a dynamic interval of time and send their join request RREP to close vicinity CH by means of CSMA relevant information.

Once the communication infrastructure establishes (set-up phase) in our proposed model. Then the CH(s) simultaneously broadcast time division multiple access (TDMA) scheduling packets with the scattering codes to initiate the communication process and process the ordinary nodes collected data in the network for further processing such as aggregation and connectivity to the edge node. The utmost time interval set for the an unvarying condition phase is defined by T_3. Moreover, note that in our proposed model RREQ packet is broadcasted with a preset energy consumption analogous to a distance of $\sqrt{2.1M}$ [meters]. To elaborate on the the distance range for an ordinary node is set about $\sqrt{2.1M}$ [meters] to broadcast a RREQ packet in the network. For further details refer to equation 1 of the document. The graphical representation of this phase is shown in figure 2. The brief overview of cluster formation and connectivity of DCBSRP routing protocol is shown in figure 2. Let's assume that a node C_i advertises their RREQ message for the candidate-ship of CH. The nodes $C_i \in C_N$ respond with RREP packets. The C_i node receives maximum number of RREP from C_N nodes and selected as CH. The C_i node, which is now selected as CH apply DCBSRP routing protocol configuration. The DCBSRP routing protocol static routing configuration bind all connected nodes $\in C_N$ for a defined interval of time (T). In time (T) interval, all nodes $\in C_N$ process their information through selected CH in the network. The nodes $\in C_N$ collect information according to their assigned task and unicast it to the CH for further processing, as shown in figure 2. The unicast message transmission of C_i nodes $\in C_N$ minimizes their energy consumption because every time they did not generates RREQ packets for the shortest path selection in the network to transmit their collected information. Additionally, this also minimizes the chance of malicious node to participate in the network, because the static routing configuration of DCBSRP routing protocol ignores RREQ message after the formation of the clusters.

Moreover, to elaborate on the concept of figure 2. The green nodes shown in the figure are ordinary nodes $\in C_N$, which are connected with CH as shown in blue color. The DCBSRP routing protocol after the formation of the cluster applies the static routing configuration of our proposed protocol. The static wireless connectivity of CH and C_i nodes $\in C_N$

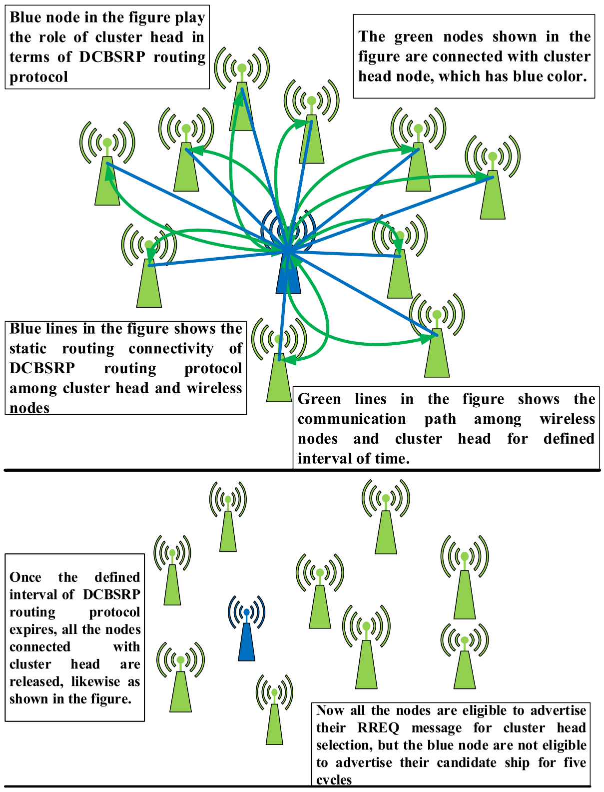

FIGURE 2. Brief over of DCBSRP routing protocol, where CH formation is set up and after that communication took place.

Algorithm 1 Cluster Head Node Selection in off Line Phase: Through DCBSRP Routing Protocol

Require: Cluster Head (CH) to allow traffic among connected nodes through DCBSRP protocol static functionality.
Ensure: Static routing of DCBSRP protocol for time (t).

C_i initiate the RREQ
Ordinary nodes $\in C_N$ Receives $\longmapsto C_i$ RREQ
C_N nodes responds $\leftarrow$ *RREP*
  Ordinary nodes $\in C_N$ receives $\leftarrow C_i$ RREP
  C_i receives max No. of RREP $\leftarrow$ Selected as CH
  DCBSRP applies $\leftarrow$ Static routing for time (t) for selected CH
    for (i = 0; i = 4; i++)
    If
    i = 4 **then**
    for CH $C_i \leftarrow$ DCBSRP release static routing
  end if
  $C_i \leftarrow$ Is now act as ordinary node
return The next CH candidate information of C_i nodes $\in C_N$.

is shown with the blue lines in the figure 2. The green lines show the communication channel among CH and participating nodes, which $\in C_N$. Once, the DCBSRP routing protocol static time interval completes, the *CH* release all connected nodes $\in C_N$. The formation of participation nodes after release as shown in the lower portion of figure 2. Now all the participating nodes are allowed to advertise their candidateship for the next CH selection, except the blue node, which has recently played the role of *CH*. The restriction condition for the blue node of figure 2 continues until five new CH nodes play the role of CH. After five CH selection, the blue node will be eligible to advertise their candidate ship of CH node in the network.

Algorithm 1 of the paper illustrates the operation of function 1 of DCBSRP protocol. A Sensor node $C_i \in C_N$ initiates the RREQ message in the network. All the ordinary nodes $\in C_N$ in close vicinity receives C_i RREQ and respond with the RREP message. Let C_i receives the maximum number of RREPs form close vicinity nodes and selected as CH nodes. Now C_i nodes work as a CH for time (t) with static routing implementation. Once, the time (t) interval expires the C_i node that currently performing the duty of CH node releases all connected ordinary nodes. Now the released nodes are free to advertise their CH candidate-ship or select new CH node in the network.

B. FUNCTION 3 OF DCBSRP ROUTING PROTOCOL

In the operational phase, when the sensor nodes collect, store, process and transmit information from the deployed infrastructure to the destination node. The DCBSRP routing protocol works like other network routing protocols, where its use its build-in configuration parameters to select CH node for defined interval of time, where static routing is implemented. Moreover, to elaborate on the concept of DCBSRP routing protocol in this phase. Once the first phase of the time interval is completed and the CH(s) releases all bind/connected nodes. Then the next CH node selection process is started. In this process, all the nodes participate, just like offline phase and broadcast a RREQ message in the network. All the participating nodes $C_i \in C_N$, where $C_i = C_1, C_2, C_3 \ldots\ldots\ldots C_N$, responds with a RREP message. The node in $C_i = C_1, C_2, C_3 \ldots\ldots\ldots C_N$, which receives the most number of RREP(s) for shortest path or CH to process the information of neighbor nodes to the destination node, they are selected as CH(s).

Keeping in view, the restriction condition of DCBSRP routing protocol. The nodes that currently perform the duty of CH did not advertise their candidate-ship for CH (as like by advertising their shortest path information). The previously selected CH nodes respond with RREP message to the RREQ message of candidate CH node, which advertise shortest path for destination node and participate in CH node selection process in the close vicinity. However, the node which receives the most number of RREP(s) against its advertised RREQ message is selected as CH. Likewise, off-line phase or the first phase nodes, which $\in C_N$ receives most RREPs messages from neighbor nodes are selected as next cluster head node (CH). Once, the next CH node is selected, the DCBSRP routing protocol applies the static routing configuration, which bind all the connected nodes (cluster nodes) with CH for defined interval of time. Likewise, all the connected nodes

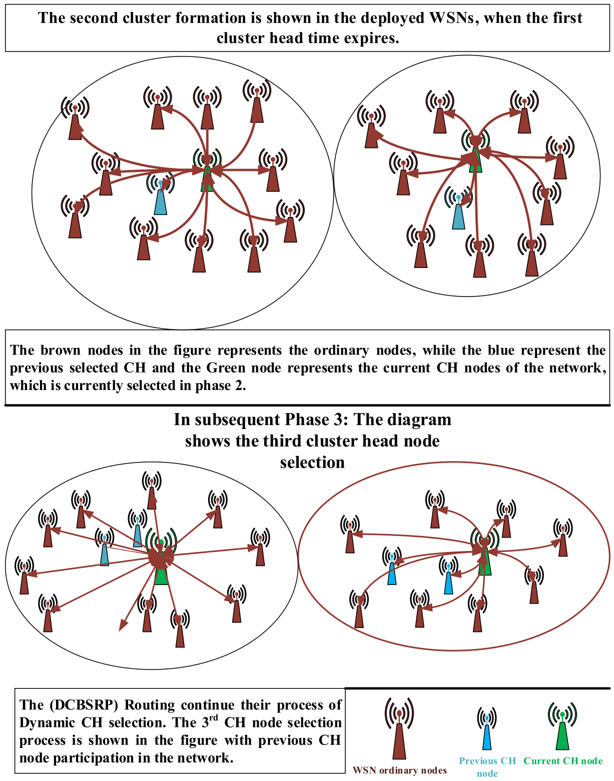

FIGURE 3. Current CH node and Previous CH nodes are shown in this diagram.

in the cluster formation, collect, store and process their information through concerned CH for defined interval of time.

Once, the five cycles of previous selected CH node completes, its eligibility criteria is revised in our scheme. The DCBSRP routing protocol reverts their configuration and they are now eligible for CH node candidate-ship as like other participating node to advertise their candidate-ship. Likewise, the process of the CH node candidate-ship continues throughout the entire lifetime of the network. The CH node candidate-ship for defined interval of time not only minimize energy consumption through static routing, but it also enables the participating nodes to share their information with minimum end-to-end delay and minimum packet loss ratio in the network. Furthermore, the DCBSRP routing protocol allows every participating nodes to play the role of cluster head, because of their five cycles restriction, after selection of CH node. Therefore, the DCBSRP routing protocol allows each node to play the role of CH, which balance the energy consumption of all participating nodes in the deployed WSN. Moreover, the DCBSRP routing protocol ensures survival of participating nodes in the network until the final stage of the network. In this way the DCBSRP routing protocol balance the energy consumption of the WSN and prolongs their lifespan. Figure 3 of the paper represent the next CH node selection.

Figure 3 describes a brief overview of the subsequent CH selection process. The brown nodes in the figure 3 represents the ordinary nodes, while the blue nodes shows the previous selected CH nodes and green nodes shows the current CH(s). Moreover, the brown lines in the figure shows static routing connectivity or static communication channels. The ordinary nodes and CH node uses these channels for collected information exchange. Let's assume that, the current CH node complete their time interval (T) and released all the connected nodes. Once, the CH releases the connected nodes which $\in C_N$ nodes. Then, all the nodes broadcast a RREQ message to advertise their candidate-ship of CH. Upon reception of broadcasted RREQ message, all the nodes $\in C_N$ in close proximity responds with a RREP message. The node C_i receives the maximum number of RREP messages in their vicinity. The C_i node is selected as CH node, which is shown by green color in figure 3.

Similarly, the CH node, which is the part of ordinary nodes $\in C_N$ nodes. The DCBSRP routing protocol applies the static routing configuration on the connected nodes and bind all nodes $\in C_N$ with CH by means of static routing for time (T) interval. Once, the time interval expires the nodes $\in C_N$ are released. The two blue nodes shown in the lower part of the figure represent the CH(s), which have recently perform the duty of CH node. The blue nodes only establish communication with CH by means of unicast transmission, which enable it to share their collected information with minimum energy consumption. Furthermore, these nodes advertise their CH candidate-ship until they work as ordinary node for five consecutive cycles with other CH. The restriction is same for all nodes, that plays the role of CH.

The dynamic cluster head selection and static routing of our DCBSRP model minimizes energy consumption of ordinary nodes by means of unicast communication. Moreover, the DCBSRP routing protocol allows each participating node of the network to play the role of CH. Once, a node C_i play the role of a CH, then it is not eligible for the CH in the next five cycles of CH selection. Likewise, the previous selected CH node participate in the network as an ordinary node, which balance its energy consumption with other nodes of the network. The formation of small cluster for a defined interval of time in wireless infrastructure, not only balance the energy consumption, but it also maintains the load balancing environment in the deployed WSN. Moreover, the performance of WSNs was also improves by means of minimum communication cost, minimum end-to-end delay, packet loss ratio and high throughput. Consequently, the network lifespan is improved by means of energy consumption of the participating nodes to survives until the final stage of the network.

C. DCBSRP ENERGY CONSUMPTION MODEL

In this subsection, we propose the average energy consumption model for our proposed scheme to analysis results at the simulation environment. The average energy consumption of ordinary nodes is ($E_{c_{(C_i)}}$), and for CH nodes with distance (d) from the edge node is $E_{C_{CH}}(d_{C_i})$, in each round of static routing configuration for a specific CH. Now let assume that a sensor node (C_i) collects data and transmits it to the concerned CH. The transmitted packets of (C_i) contains the node ID, source and destination information etc,. with scattering factor (h).

The length of the advertised packet in our proposed model is denoted by L_{adv}, where adv symbolizes the advertised packet. Similarly, L_{TDMA} represents the TDMA scheduling packets in the network, while L_{join} denotes the length of joint packets and L_{data} symbolizes the data signal length. The mentioned information should be in [bits] for our proposed scheme. The energy consumed by a CH node during aggregation of data is denoted by $E_{c_{DA}}$ in [J/bit per signal]. E_{MAC} [J] symbolizes the energy consumption of C_i node during CSMA processing.

The number of C_i nodes connected in a cluster are denote ψ, which is random in nature with a probability expectation of E[ψ] = N/k. To keep on our proposed model simple, in the first case we consider the probability expectation E[ψ] to develop our algorithm. Let assume a CH node, which is at a distance (d_{C_i}) from edge node. The energy consumption for a CH node in a round is given by.

$$E_{cCH} \times (d_{C_i}) = E_{TX}(C_i, hL_{data}) + E_0 \tag{4}$$

$$\begin{aligned} E_0 = &E_{TX}\ (hL_{data}, \sqrt{2.1M}) \\ &+ E_{MAC} + (T_1 + T_2 + T_3) \times E_l \\ &+ E_{TX}(hL_{TDMA}, \sqrt{2.1M}) \\ &+ (E[\psi] - 1) + E_R(hL_{join}) \\ &+ E[\psi]l_{data} \times E_{DA} \\ &+ (E[\psi] - 1)E_R(hL_{data}) \end{aligned} \tag{5}$$

Now in the next step, we calculate the average energy consumption of ordinary nodes ($E_{c_{(C_i)}}$) in the same round of cluster formation (where static routing of DCBSRP protocol is working). Herein we assume that each cluster engages a (M^2/k) area on an average consideration. In our case, we have considered the engaged vicinity of a cluster as a circle shape with the radius of R = M/$\sqrt{k \times \pi}$.

However, our assumption of circle consideration might not be accurate in the real deployment of WSNs, but we considered it for simplicity in the simulation environment. Moreover, the objective of this assumption is to measure the energy consumption of the ordinary nodes and the CH node in a defined interval of time (t).

Suppose, we have a cluster of nodes in the network, where all the ordinary nodes are connected in a circular shape with a radius (R). The distance from the center of the CH node to the ordinary nodes is symbolized by a random variable (r). So, the probability function ($f(r)$) of a random variable (r) can be find through, f(r) = 2r/ R.

When a ordinary node broadcasts a message, which contains $L_{data} - bits$ with concerned CH, it consumes energy during transmission. The energy consumed by ordinary nodes during transmission is symbolized by $E_{TX}(r, hL_{data})$, where (r) in the equation represents the randomness values.

Moreover, the expected energy consumed during transmission from ordinary node to CH node is denoted by $E_c[E_{TX}](r, hL_{data})$. Similarly, $E_c[E_{TX}](r, hL_{data})$ is calculated by the following equation. (if the value of R < δ).

$$E_c[E_{TX}](r, hL_{data}) = hL_{data}(\int_0^R \varepsilon f(r)(fr^2) \times dr) \tag{6}$$

$$E_c[E_{TX}](r, hL_{data}) = hL_{data}(\varepsilon f(R^2)/2) + E_e \tag{7}$$

Similarly, if the value of R $\geq \delta$, then.

$$\begin{aligned} E_c[E_{TX}](r, hL_{data}) = hL_{data}(\int_\delta^R \varepsilon_m r^4 f(r) \times dr \\ + \int_0^\delta \varepsilon f r^2 f(r) \times dr + E_e \end{aligned} \tag{8}$$

Likewise,

$$\begin{aligned} E_c[E_{TX}](r, hL_{data}) = hL_{data}(\varepsilon_m/3(R_4 - \delta^6/R_2) \\ + (\varepsilon f \delta^4/2R^2) + E_e \end{aligned} \tag{9}$$

Now the energy consumption (E_c) of ordinary node can be calculated for defined interval of time as follows.

$$\begin{aligned} E_{c_{(C_i)}} = E_{TX}(hL_{join}, \sqrt{2.1M}) + KE_R(L_{ADV}) \\ + E_R(hL_{TDMA}) + T_2E_l + E[E_{TX}(r, hL_{data})] \end{aligned} \tag{10}$$

So the ordinary nodes energy can be calculated through 11.

$$\begin{aligned} E_{c_{(C_i)}} = &E_{TX}(hL_{join}, \sqrt{2.1M}) + E_e(KL_{ADV} \\ &+ hL_{TDMA} + hL_{data}) + hL_{data}(E_e \\ &+ \varepsilon_m/3(b_4 - \delta^6/b_2)) + \varepsilon f a^4/2R^2 + T_2E_l \end{aligned} \tag{11}$$

Herein a and b in equation 11 denotes the minimum and maximum values of (R, δ). We have notice in our proposed model that different f(r) can be used to design other distribution of nodes or placement of nodes.

D. DISTANCE PARAMETERS THRESHOLD VALUE SET IN DCBSRP ROUTING PROTOCOL FOR CH SELECTION

Our proposed model uses the threshold value of distance parameters while forming clusters in the network. The probability of a C_i node to be selected as CH node depends on distance with the edge node and RREP from C_i node $\in C_N$ in close vicinity.

Let assume that the edge node is at a distance of δ[meters] from CH node. The CH node consumes energy, while communicating with edge node.

Therefore, let assume that d_{C_i} be the distance between CH node and edge node in the network.

So now we have given d_{C_i}, k, M, and N to find the optimal distribution of C_i nodes with CH by differential percentage as P_{C_i}, where P_{C_i} is the distance between CH and edge node.

Here, the value of d_{C_i} for our proposed model is fixed as p = k/N. Similarly, the estimated value for total CH nodes is as k.

$$\sum_{C_i=1}^{N} P_{C_i} = k. \tag{12}$$

Now assumed the C_i and C_j nodes of the network. The C_i and C_j nodes have turn of CH node with the probability of P_{C_i} and P_{c_j}, respectively.

The expected energy consumption equation for mentioned supposition is as follows:

$$E_{c(CH)}\ node(d_{c_i})(1+P_{C_i}) \times E_{c(C_i)} = P_{c_j} \times E_{c(CH)}(d_{cj}) + (1-P_{cj}) \times E_{c(C_i)} \quad (13)$$

Similarly,

$$P_{C_i} = P_{cj}(\frac{(E_{c(CH)}(d_{cj}) - E_{c(C_i)}}{E_{c(CH)}(d_{cj} - E_{c(C_i)}}) \quad (14)$$

Let $C_1 = P_1(E_{c(CH)}(d_{c1})) - (E_{c(C_i)})$ and $\psi_{C_i} \equiv 1/(E_{c(CH)}(d_{C_i}) - (E_{c(C_i)})$. Then, we have $P_{C_i} = C_1\ \psi_{C_i}$. To use Equation 12. Then, $C_i =$ k/ $\sum_{cj=1}^{N} \psi_{cj}$. So, P_{C_i} can be calculated as follows:

$$P_{C_i} = k(\frac{\psi_{C_i}}{\sum_{cj=1}^{N} \psi_{cj}}) \quad (15)$$

Equation 15 provides P_{C_i} with equal energy consumption. Subsequently, the network will have a distinguished group (GOR) for each C_i node $\in C_{n-1}$, as maintained by P_{C_i}. In this case, C_i nodes have their GOR as follows: r $= 0, 1, 2, 3, \ldots, [1/P_{C_i}] -1$. Following the equation of GOR. Then, in consecutive steps the GOR should be r $= [1/P_{C_i} -1], [1/P_{C_i} -1]\ 1, 2 \ldots, 2[1/P_{C_i} -1]$ and so on.

Let us assume that G_{C_i} will be the round (x) indicator in our proposed model to verify whether a C_i node performs the duty of a CH node during five rounds. The value of G_{C_i} (x) $=$ 0 if the node has conducted the duty of a CH and is now participating in the network as an ordinary node. Similarly, the value of G_{C_i} (x) $=$ 1 if the C_i node is a CH node in the current round.

We now propose a new threshold mechanism for CH selection according to our proposed model with a probability (P_{C_i}) in round (x) as follows:

$$T_{C_i} \times (x) = \frac{P_{C_i}}{1 - P_{C_i} \times ((x) \times mod[\frac{1}{P_{C_i}}])} \quad (16)$$

Note that, at the beginning of G_{C_i}, (x) is set to 1, which ensures that each C_i node $\in C_N$ is a CH candidate in GOR rounds $[1/P_{C_i}]$.

E. COMPLEXITY OF DCBSRP PROTOCOL

The evaluation of time complexity for an algorithm is a very important aspect to be considered in terms of reliability, applicability, scalability, and robustness. The time complexity of DCBSRP protocol is O(p + t), where the length of the packet is symbolized by p and time interval for the specified packet is denoted with t in the given case. Moreover, the time complexity of DCBSRP routing scheme is impractical in an operational network, because the ordinary nodes share information through concerned CH node, where the traditional protocols first initiates the RREQ packet in the network to verify or chose the next-hop count for information exchange in the network. Consequently, the worst-case time complexity for the proposed DCBSRP routing scheme is O(P n) + O(t), where n denotes a constant value for half-length of the packet (p).

TABLE 1. DSBSRP routing protocol parameter setup used in implementation phase.

Name of the Parameter	Value of the parameters
Wireless nodes	100, 200, 400, 800, 1200
Network topology	Random deployment
Simulation Environment	1500 x 800 [Meters]
Simulation tool/Environment	OMNeT ++
Transmission interval of nodes	13 μSec
Consumed E during transmission	78.6 mW
E consumption in normal state	1.3 mW
Consumed E during reception	44.6 mW
Residual energy E_r of a node	E_i - E_c
E consumption in sleep mode	0.75 μW
Static routing time interval	3 mints
Initial energy of nodes E_i	53,000 mAh
Transmission range	120 M
Channel bandwidth	10 Mbps
Network traffic type	UDP and CBR
Cluster formation	dynamically
Communication	unicast/broadcast
CH selection	dynamically
Packet size	128 Bytes

V. EXPERIMENT RESULTS

In this section, a detailed description of the extraction results is presented to verify and elaborate on the performance of the proposed model against field-proven schemes. The simulation results of the proposed model were compared based on the communication cost, computation cost, energy consumption of ordinary nodes, lifetime of the deployed WSNs, latency, packet loss ratio, and throughput. Moreover, existing studies have taken into account an evaluation of the performance metrics of our DCBSRP routing protocol, including the dynamic duty cycle (DDC) scheme [17], energy efficient connected coverage scheme [20], optimal clustering in circular networks scheme (OCCN) [21], and distributed optimal on-line task allocation algorithm [23]. The metrics of the above results were evaluated during the simulation for our proposed DCBSRP routing protocol and the competitor schemes.

A. IMPLEMENTATION AND ENVIRONMENTAL SETUP FOR PROPOSED MODEL

The proposed algorithm of DCBSRP was implanted into the OMNet ++ simulation tool, which is an open-source simulation platform for resource-limited networks. Initially, a random deployment of wireless nodes is adopted in network topological order with the consideration of the resource limitation of wireless nodes. However, during the implementation phase of the DSBSRP routing scheme, the interference parameters were kept constant throughout the entire network infrastructure. The different parameters used in the simulation setup of the proposed model are shown in 1. To verify the accuracy of the results of the DSBSRP routing protocol,

TABLE 2. Computational cost analysis of DSBSRP routing protocol & rival schemes.

Scheme name	Ordinary node side	Next Hop involved	Edge node/CH	Total Cost
Liu, et al, [17]	$4T_{XOR} + 3T_M + 4T_A$	$5T_{XOR} + 4T_M + 4T_A$	$5T_{XOR} + 4T_M + 4T_A$	$14T_{XOR} + 11T_M + 12T_A$
Roselin, et al, [20]	$3T_{XOR} + 4T_M + 3T_A$	$3T_{XOR} + 4T_M + 3T_A$	$5T_{XOR} + 5T_M + 4T_A$	$11T_{XOR} + 13T_M + 10T_A$
Arghavani, et al, [21]	$3T_{XOR} + 3T_M + 3T_A$	-	$3T_{XOR} + 3T_M + 2T_A$	$6T_{XOR} + 6T_M + 5T_A$
Yin, et al, [23]	$5T_{XOR} + 5T_M + 4T_A$	$3T_{XOR} + 3T_M + 3T_A$	$3T_{XOR} + 3T_M + 3T_A$	$11T_{XOR} + 11T_M + 10T_A$
Our scheme	$4T_{XOR} + 4T_M + 3T_A$	$2T_{XOR} + 2T_M + 2T_A$	$2T_{XOR} + 1T_M + 1T_A$	$8T_{XOR} + 7T_M + 6T_A$

standard battery power was used because we are working with the load balancing and lifetime of wireless networks.

B. COMPUTATIONAL COST

During the development phase of a wireless network infrastructure, the limited resources of the wireless nodes should be considered. Therefore, designing new protocols or modifying existing protocols to improve the load balancing of deployed WSNs with the aim of prolonging their lifetime and maintaining high-performance reliability metrics is extremely beneficial for a resource-limited network. The protocols having the lowest computational cost are given preference over computationally expensive protocols if they do not compromise the reliability of the network performance. A detailed comparative analysis of the proposed scheme and competitor schemes in terms of their computational cost is shown in 2. In Table 2, T_{XOR} represents the exclusive OR operation, and T_M describes the time required to process the message packets, whereas T_A represents the time during which communication is established among ordinary nodes or the CH. The computation cost calculation starts from an ordinary wireless node and subsequently moves to the hop count and CH. The proposed DSBSRP scheme is more suitable for wireless networks because it has the lowest computational cost over field-proven schemes. In Table 2, the computational cost of our scheme and the costs of the rival schemes are shown. The results indicate that the computational cost of our scheme is quite low in comparison to all other considered schemes, except for Arghavani *et al.*'s [21] approach. However, Arghavani *et al.*'s [21] scheme is limited to cluster or circular wireless networks, which minimize its use in a real deployment, as described in the literature.

C. COMMUNICATION COST

The communication costs of our scheme and the existing schemes are compared, and only those messages necessary for the communication process, including offline and online operational phases of the network, are assumed. A communication session was generated in our scheme, and the necessary messages used to compute the communication cost, in comparison with the existing schemes, were applied. It can be seen in Table 3, that our proposed scheme has the minimum communication cost in comparison to the existing schemes. A detailed analysis of the communication cost is shown in Table 3.

D. ENERGY EFFICIENCY OF DCBSRP ROUTING PROTOCOL

Our proposed hybrid DCBSRP routing protocol extends the network lifespan by constructing dynamic cluster head nodes in the network for defined interval of time. Once the cluster head is selected for the particular time (T), the DCBSRP routing protocol uses a static routing configuration, which enables the ordinary nodes of the network to communicate their collected data in a unicast fashion. The unicast communication of ordinary nodes saves energy owing to a direct connectivity with the CH. Therefore, the DCBSRP routing protocol prolongs the network lifespan with minimum network overhead, as shown in the simulation results. Moreover, the results are also displayed for an individual ordinary node participating in the network because our scheme focuses on the individual node participation. In a sense, each participating node is given an opportunity to perform the duty of a CH and operate as an ordinary node in the network. How long an individual node can survive in the network during the operational time of the DCBSRP routing protocol is determined. Moreover, the participation statistics observed for ordinary nodes was about 95.9 %.

TABLE 3. Communication cost comparison.

Scheme name	No. of Packets	No. of Bits Sent
Liu et al. [17]	7	14336
Roselin et al. [20]	6	12288
Arghavani et al. [21]	5	10240
Yin et al. [23]	8	16384
Our Scheme	6	6144

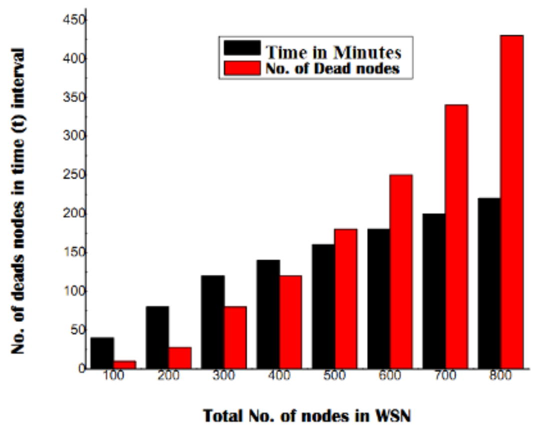

FIGURE 4. Statistical analysis of the DCBSRP protocol for ordinary participating nodes in WSNs.

The results shown in Figure 4 were obtained during the simulation, during which the number of sensor nodes and operational time of the network were continuously adjusted to verify the survival time of ordinary nodes in the network. The overall participation shown for ordinary nodes in the network was quite consistent and remarkably high owing to a dynamic CH selection and unicast communication.

E. NETWORK LIFESPAN RESULTS FOR DCBSRP AND RIVAL SCHEMES

The network lifespan is the time during which sensor nodes are alive and in operation according to their assigned task. The network lifespan of the DCBSRP protocol was shown in the simulation environment by varying the time and sensor nodes in the WSN. The results of our scheme in terms of the network lifespan were significant in comparison to those of the competitor schemes. The dynamic cluster head selection minimizes the network overhead, and it has also been seen that almost the maximum number of nodes can act as a CH. During the simulation, the participating sensor nodes in the network were found to survive until the end stage of the network. Moreover, once the relaying node (CH) completes its turn, it is no longer eligible for CH selection during the next five cycles. The same was shown during the simulation results of the extraction. Likewise, according to the working procedure of the DCBSRP protocol, the node transmits its collected data in a unicast fashion, which allows it to balance its energy consumption with other participating nodes. The proposed energy model is used in our scheme to verify the reliability of the network lifespan.

The network lifespan results of the DCBSRP protocol and rival schemes are shown in Figure 5.

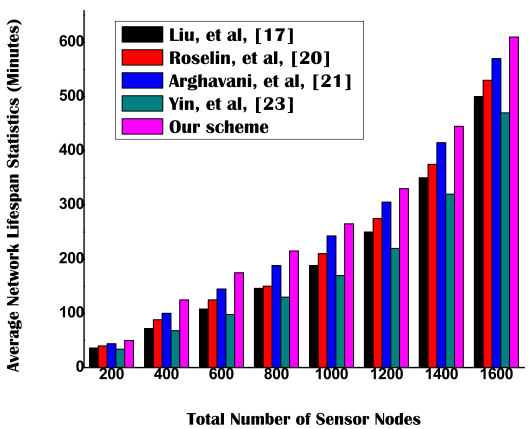

FIGURE 5. Network lifespan statistics of DCBSPR with rival schemes.

The statistics shown in Figure 5 were evaluated through a simulation of the DCBSPR routing protocol during the operational scenario. The efficiency of our proposed model in extending the network lifespan was remarkably high because the formation of small clusters not only balances the load of the network, it also plays a promising role in extending the network lifetime, which is shown in Figure 5 above. Furthermore, the network life in minutes is shown on the y-axis and the total number of sensor nodes on the x-axis. The minutes on the y-axis, however, represent the average time taken for statistical analysis of our scheme and its rival schemes.

F. LATENCY RESULTS OF DCBSRP PROTOCOL: END-TO-END DELAY

The performance metrics of the DCBSRP routing protocol were also shown in terms of the latency during the simulation to verify the network reliability. As stated earlier, load balancing and a lifetime extension without a proper network performance are meaningless because an efficient utilization of the resources in a constraint-oriented network increases its effectiveness. Therefore, in designing or implementing a resource-limited network, parameters such as the latency, communication cost, computational cost, throughput, and packet loss ratio should be considered. Bearing in mind the above facts, while designing our scheme, we considered all of the above mentioned metrics to design a reliable protocol that not only balances network traffic and energy consumption of the network, it also focuses on the latency and throughput issues of the network. The latency observed during the simulation of our proposed scheme is shown in Figure 6, which was found to be quite consistent because the unicast communication of the clusters minimizes the chance of a network overhead. The detailed statistics of our proposed model and the competitor schemes in terms of latency are shown in Figure 6.

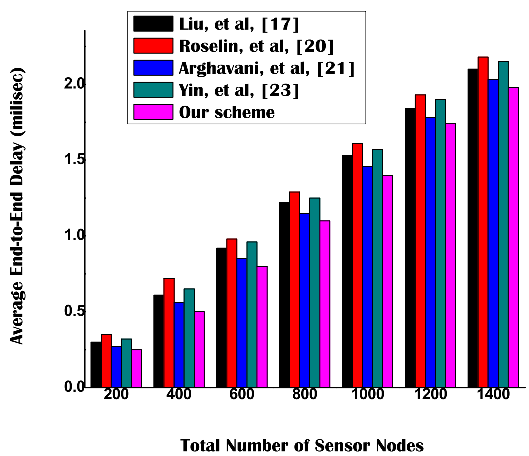

FIGURE 6. End-to-end delay (latency) analysis of DCBSPR protocol with rival schemes.

G. THROUGHPUT RESULTS OF DCBSRP PROTOCOL

The analysis of the DCBSRP protocol is ongoing, and herein we compare the throughput of our scheme with field-proven schemes such as the comparative schemes mentioned above in terms of the throughput of the network, the transmission capability of the network, how much data a transmission channel can accommodate, and the relaying node process. Therefore, the throughput of a wireless network is an extremely important aspect when evaluating the network performance. The dynamic cluster head and unicast communication minimize the network overhead, avoiding congestion in the network and improving the overall throughput of the network. The results observed for our scheme are shown in Figure 7. The small cluster formation and unicast

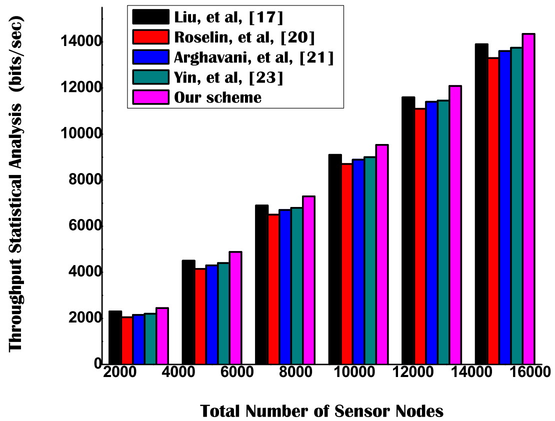

FIGURE 7. Throughout analysis of DCBSPR protocol with rival schemes.

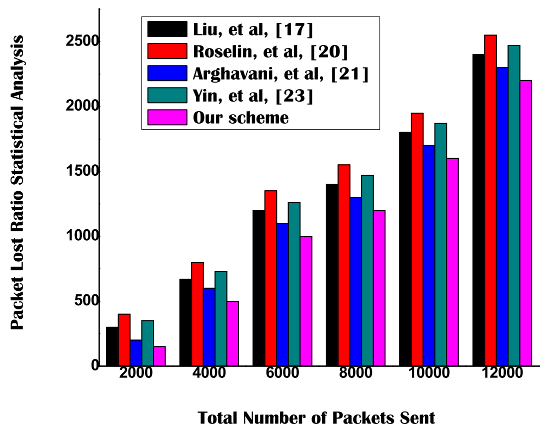

FIGURE 8. Packet loss ratio of DCBSPR protocol compared with rival schemes.

communication in our scheme showed exceptional results for the throughput in the presence of the competitor schemes.

H. PACKET LOSS RATIO OF DCBSRP PROTOCOL

The results of the DCBSRP protocol were also shown in terms of the packet loss ratio (PDR). The last ratio of the network packets can be defined as the number of packets sent by the source node to the number of packets received by the destination nodes or relaying nodes in a WSN. The results of the packet loss ratio for our scheme were consistent and remarkable throughout the simulation. The unicast communication of clusters enables a reliable communication infrastructure, as shown in the simulation of the DCBSRP protocol. For a dynamic CH selection and static routing of the cluster nodes with a specific CH, the proposed model showed exceptional results compared to the rival schemes. Figure 8 shows the graphical statistics of the PDR of both the proposed model and the rival schemes.

VI. CONCLUSION

In this article, we proposed an energy proficient routing protocol scheme to prolong the network lifespan of constraint-oriented network. The communication mechanism adopted in the proposed model uses dynamic CH nodes for a defined interval of time (T), with a static route configuration to exchange information in an operational network. The DCBSRP protocol, during both offline & operational phases, leverages the RREQ and RREP packets to select CH nodes dynamically and form small clusters in the network, which operate for a defined interval of time (T). In time (T), all ordinary nodes connected in the clusters are attached through a static routing. Furthermore, during a static routing configuration, ordinary nodes of the network share their collected information in a unicast fashion with the specific CH node for further processing in the network. Once the defined interval for a CH against static routing is completed, all connected nodes of the CH are released. After release, all ordinary nodes of the cluster are allowed to advertise their candidateship as a CH node, except the one that recently had the role. The node that receives the maximum number of RREP packets as a relaying node is selected as the CH node, and this process continues until the final stage of the WSN is reached. However, the nodes with the role of a CH are not allowed to advertise their CH candidateship for five consecutive cycles during the CH selection process.

Likewise, the previously selected CH nodes operate as ordinary nodes in the cluster formation and share their information in a unicast fashion, which enables the ordinary nodes of the network to balance their energy consumption. Our proposed DCBSRP scheme allows ordinary nodes to have an opportunity to play the role of a CH, thus minimizing the chance of relaying nodes consuming extra energy in the network. Consequently, the load balancing scheme of the proposed DCBSRP protocol ensures the operational capabilities of the ordinary nodes in anticipation of the failure of the maximum nodes i.e., allowing participation in the network until the final stage. The ordinary nodes participation results observed for our proposed scheme was about 95.9 %. In this way, the proposed DCBSRP scheme prolongs the lifetime of constraint-oriented networks with balanced energy consumption. The simulation results validated in OMNet++ showed that our proposed approach surpasses the existing state-of-the-art schemes in terms of energy efficiency, network lifespan, end-to-end delay, packet loss ratio, and computational and communication costs.

COMPLIANCE WITH ETHICAL STANDARDS

CONFLICT OF INTEREST

All authors declare that they have no conflict of interest.

ETHICAL APPROVAL

This article does not contain any studies with human participants or animals performed by any of the authors.

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