DCA: DYNAMIC ALLOCATION OF CHANNELS FOR CLUSTER-BASED WIRELESS SENSOR NETWORKS

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Abstract

WSNs with homogenous load distributions may benefit from coordinated channel access procedures. Due to the absence of DCA procedures in infrastructure-based coordinated protocols, these protocols are not as well suited for non-uniform load distributions as uncoordinated channel access protocols. Here, we introduce (DCA) a transparent dynamic allocation of channels mechanism and a co-operative load balancing (CLB) technique for cluster-based WSNs to solve this issue. These strategies were included in the protocols to enhance throughput, energy consumption, and inter-packet delay variance performance. DCA and CLB increase bandwidth efficiency under non-uniform load distributions via comprehensive simulations.

Keywords: DCA, VGRP, CFDSCA, WSN, FIND,QoS, Cluster, Channel Allocation

1 INTRODUCTION

There has been a recent shift in wireless sensor networks (WSNs) study and development. As a result of its self-organizing, self-configuring, dependable service and Internet connection capabilities, WSNs are an intriguing technology to study. Sensor routers and mobile client nodes make up WSNs. A sensor router provides an Internet connection and an access point for mobile-client nodes [1]. A sensor-router (node) is equipped with several Wireless Network Interfaces (WNICs) based on the same or alternative wireless access technologies to enhance sensor networking versatility further. Multimedia programs and Internet connections are more popular today [2][3]. The quality of service is the most critical criterion for these applications (quality of service). We usually increase bandwidth by adding extra channels to deal with heavy traffic [4]. As a result, simultaneous broadcasts would be possible with little interference from the interfering wireless networks [5]. Allocating available channels to network interfaces of nodes with the purpose of LB is at the heart of channel assignment techniques. To ensure network connection and minimize interference, the available bandwidth of virtual wireless links should be proportionate to the projected demand [6]. We've used a clustering method to simplify channel assignment. Wireless channels may be efficiently allocated and reused across several clusters with clustering [7].

The main contributions

i) lightweight DCA scheme for cluster-based WSNs;
ii) A CLB algorithm;
iii) Incorporate these two algorithms into our earlier TRACE (FIND) framework leading to DCA-FIND and CDCA-FIND;
iv) Combine both algorithms to provide support for non-uniform load distributions and propose CDCA-FIND. We compare the performance of these algorithms for varying network loads.

Many sensors (SNs) constitute a WSN, an ad hoc network that gathers data and transmits it wirelessly [8]. The number of nodes depends on the application. One of the essential design objectives for SNs is energy economy since they are battery-powered, and their lifespan should be maximized [9]. One or more sensors serve as sinks through which the sensory data collected by the sensors can be sent to be further aggregated. It has been found that the sensors closest to the sink consume energy more quickly than other sensors [10], [11], [12], so the network's lifespan will be significantly impacted [13]. It is possible to determine the goal of increasing energy efficiency via studying the network lifespan. Each node must be built to manage its local energy supply to optimize the overall network lifetime [14]. Node life span isn't as crucial in many setups as the minimum node lifespan. Many sensors are placed to transmit and link the information distributed across the network [15].

This will soon deplete the sensor network's energy supply. Clustering may be used to address these concerns [16]. Cluster Heads (CHs) are chosen for each cluster generated in clustering. All information is sent to the appropriate CH, which records it. A central base station may receive it [17] [18]. Clustering facilitates the optimal use of the limited energy resources of SNs, hence extending network life. Clusters of nodes communicate over small distances, whereas nodes outside the cluster communicate over large distances using a lot of energy, comparatively, in the cluster [18] [19].

After this introduction, the rest of this study is organized: Prior research, routing protocol design challenges, and justifications are summarised in Section 2. Details on the DCA system may be found in Section 3. DCA's simulation metrics, parameters, and results are compared with earlier systems in Section 4. This concludes the paper by describing future study directions.

II LITERATURE REVIEW

In WSNs, the X-layer operating model is commonly used to estimate the energy consumption compared to transmitting and receiving modes, including idle and sleep modes, depending on the energy level. Using a cross-layer evaluation, the energy consumption of the proposed model is compared to that of the EQSR (Energy Efficient & QoS Aware Multipath Routing) and IEEE 802.15.4 standard models. An EQRS must be suggested specifically for WSNs utilizing an approach based on service quality. The protocol uses multiple multi-path routes to select the most effective path from source to sink. The approach may cross-layer its routing link preference selection based on the NXTHN's PHY layer components. The components may include the remaining power of the node, the signal-to-noise ratio, and the availability of interface buffers between two neighboring nodes (Al-Jemeli et al., 2015) [1].

Mudasser Iqbal et al. [22] propose that Energy-efficient dynamic clustering (EEDC) gives a flexible example for reconfiguring the network in resource-controlled ad hoc sensor networks to maximize the network's lifetime. The content summaries of parent nodes (PNs) may describe their present state and evaluate probable failures caused by energy loss due to high loads on certain PNs. Their research proposed a novel technique for dynamic clustering for route-efficient content-balanced routing. The set of rules uses the traffic pattern and content and the energy consumption rate of each node to calculate the efficiency of each node and the route. Contrary to the strategy provided in [23], which always chooses the route with the fewest hops to the base station, their suggested routing mechanism may choose a longer path that permits a more fair allocation of energy consumption among the SNs. In contrast to the routing strategy outlined in [24], their suggested process uniformly distributes energy consumption among network nodes, maximizing network lifetime. Energy efficiency is a fundamental criterion for designing any WSN protocol.

E.M. Saad et al. [25] have devised a distributed network architecture that capitalizes on network durabilityştiintştiintiy. The fundamental objective of the proposed topology is to develop an energy-conscious clustering technique that is robust to network perturbations. Their proposed clustering method aimed to cluster network SNs near CH nodes with relatively large residual energy. Meanwhile, guarantee homogeneous distribution of CHs over the whole sensing region.

Jing Yang et al. [26] supported the use of the multi-path routing protocol (MRP) based on dynamic clustering and ant colony optimization (ACO). This strategy may take advantage of the network's longevity and reduce energy consumption. A crucial component of WSNs was their limited power supply in the recommended dynamic approaches; a CH was selected from the nodes in the event zone, allowing for the retention of certain characteristics, such as residual energy. Then, an upgraded ACO algorithm sought several pathways between the CH and sink node.

Tao Shu and Marwan Krunz [27] proposed examining the increase in coverage time of a clustered WSN by balancing the power consumption of CHs. They suggested a coverage-time-optimal joint clustering/routing technique in which the best clustering and routing parameters are calculated using a linear programming methodology. For the stochastic configuration, they investigate a cone-shaped sensing zone with uniformly distributed sensors and develop optimal power allocation algorithms that ensure (in a probabilistic sense) maximum end-to-end (inter-CH) route dependability. Here are two ways to achieve balanced energy consumption among nodes. Examples include routing-aware optimal cluster planning and clustering-aware optimal random relay. Clustering was an effective way of regulating the topology of WSNs, which boosted the scalability and durability of the network.

Mao Ye et al. [28] introduced a novel clustering schema, EECS, for wireless sensor networks (WSNs) and periodic data gathering applications. In addition, it offers a novel method for balancing the load among the CHs. Using local radio communication, their strategy selects CHs with greater residual energy while achieving a decent CH dispersion. In recent years, there has been growing interest in the possible use of WSN in applications such as disaster management, military field surveillance, border protection, and security monitoring.

Ameer Ahmed Abbasi and Mohamed Younis [29] created a taxonomy and classification of reported clustering approaches. Lifespan expansion, which is limited by the energy capacity of batteries, is the fundamental design goal for WSNs. Clustering is one of the most efficient means of energy conservation in wireless sensor networks (WSNs).

Rajni Meelu and Rohit Anand [30] investigated the performance of the (DEEC) Distributed energy-efficient clustering protocol in terms of network lifetime, energy consumption, and energy balancing. Similarly, a novel clustering approach has been devised to extend the network's lifespan further. According to the model's results, the longevity of the proposed routing protocol was 40 percent greater than DEEC, and its energy consumption was well-balanced compared to that of existing protocols.

III MATERIAL AND METHODS

Using a DCA mechanism, channel coordinators increase their bandwidth allotment in response to rising local network demand. Although successful in providing support for non-uniform network loads, the channel coordinators' reactive reaction creates interference across the whole system.

a) Co-operative Load Balancing and DCA: The channel coordinators are burdened by the needs of standard nodes. Many network nodes have access to many channel coordinators. The CLB technique concept is that the active nodes may continually check the channel coordinators' load and transition from severely laden coordinators to those with available resources. These nodes may detect the depletion of a coordinator's channels and move their burden to other coordinators with greater available resources. Other nodes without access to any other channel coordinators may use the resources vacated by switching nodes. This raises the total number of nodes that may access the channel, boosting the service rate and throughput.

The nodes in the network are outfitted with a single transceiver that can function in either transmission or reception mode. Nodes cannot broadcast and receive at the same time.

b) Channel sensing: Even for messages that cannot be decoded into a valid packet, the receiver node may detect the existence of a carrier signal and evaluate its strength.

In the event of simultaneous transmissions in the system, neither packet can be received until one of the broadcasts grabs the receiver. If the power level of one broadcast is much greater than the power level of all other simultaneous transmissions, the receiver may be seized. This capture technique is the primary force behind the channel reuse benefits.

Channel coordinators are responsible for managing and distributing channel resources. These coordinators may be picked from a pool of standard nodes or specialized nodes. These channel coordinators supply the channel to the network nodes for transmission requirements. It is also expected that the system is a closed system in which all nodes adhere to the channel access regulations.

In addition to DCA-FIND, DCA-FIND contains two additional mechanisms: a method to keep track of the interference level from the other CHs in each frame, and ii) a mechanism to detect the interference level from the transmitting nodes in each data slot in each frame.

c) DCA-FIND: In DCA-FIND, some nodes, known as cluster-heads, take the duties of channel coordinators. All CHs transmit periodic Beacon packets to their neighboring nodes to proclaim their existence. A node takes the function of a CH when it has not received a Beacon packet from any CH for a certain duration of time. This technique guarantees the presence of at least one CH surrounding each network node.

In DCA-FIND, time is split into superframes of equal duration, then repeated and subdivided into frames. Each CH utilizes one of the frames in the superframe structure and provides nodes within its communication range with channel access [20].

Each frame inside the superframe is subdivided further into subframes. The control subframe is used for signaling between nodes and the CH, whereas the data subframe transmits the payload. CHs indicate their presence and the number of available data slots in the current frame in the Beacon slot. The CA slot estimates interference for CHs operating inside the same frame (co-frame CHs). During the CA slot, CHs broadcast a message with a certain probability and listen to the medium to compute interference generated by other CHs operating in the same frame [21].

The number of IS slots and data slots is equal in the rest of the frame. During the IS slots, nodes transmit brief packets that summarise the data they transmit in the subsequent data slot. By listening to the somewhat shorter IS packets, recipient nodes get informed of the data that will be sent and may opt to sleep during the data slots. These slots contribute to the method for conserving energy by allowing nodes to sleep during the considerably longer data slots whose IS packets cannot be deciphered. IS packets may also include routing data.

d) Dynamic Channel Assignment in FIND

Each CH in DCA-FIND operates in one of the superframe's frames. The CH can only give channel access to a restricted number of nodes due to the constrained amount of data slots. Due to the dynamic nature of WSNs, a channel may be overcrowded while others have unused data slots. Although there are unused data slots in the superframe, the overcrowded CH would only allow a limited number of nodes access to the channel, equal to the number of data slots per frame. The CH would deny others' channel access requests. The system must use a DCA technique to enable access to more nodes.

By listening to the medium in the CA slot of their frame and the Beacon slots of other frames, the DCA-FIND structure enables CHs to measure the interference from other CHs in their frame and other frames. In DCA-FIND, CHs employ this process to choose the interference frame with the least amount of interference. DCAFIND employs the same structure. To account for transient variations in interference levels that may occur due to CH resignation or unanticipated packet losses, an exponential moving average update technique is employed to compute the current interference levels in each frame.

e) Collaborative Load Balancing for FIND: In FIND protocols, nodes compete for channel access from one of the CHs containing open data slots. After successful contention, they cease monitoring the available data slots of the CHs in their vicinity. During a data stream, a cluster with many open data slots may become overloaded due to the dynamic nature of network traffic. To address this problem, nodes should evaluate the CH's load while competing for channel access, after acquiring a reserved data slot, and during the life of their data stream.

To elaborate, nodes are source nodes and must compete for available data slots from a CH. Each CH has six data slots accessible. In DCA-FIND, if contentions are processed in alphabetical order, node G would identify CH1 as full and request access to CH2 if CH1 was already in use. Nonetheless, if node G obtains a data slot from CH1 before any of the other nodes, one of the source nodes will be unable to access the channel.

Once CH1 has allocated all of its slots in DCA-FIND, it activates the process of choosing a new frame. However, it may not always be able to access one more frame if the interference levels on the other frames are too high. In addition, accessing more frames increases interference in these frames' Beacon and Header slots. It may cause CH resignations and reselections across the remainder of the network, briefly disrupting data flow on the resigned CHs. Lastly, accessing more frames creates interference on the IS and data slots of the new frame, hence reducing the possible range of these packets. Propose CDCA-FIND and CDCA-FIND, which add co-operative CH monitoring and reselection to DCA-FIND and DCA-FIND, respectively, to address these issues. In DCA-FIND and CDCAFIND, nodes continually monitor the available data slots at CHs in their immediate vicinity, as notified by Beacon signals. When all available data slots for a CH have been allotted with probability p, the active nodes try to initiate the CLB mechanism. When CLB is activated, the node presently using a data slot from the highly loaded CH competes for data slots from neighboring CHs while maintaining and utilizing its reserved data slot until it gets a new data slot from another CH.

Cooperative LB introduces little extra contention overhead to nearby CHs. It is crucial to remember that only active nodes having access to another CH with available resources may initiate a CLB mechanism. Probabilistic algorithm activation significantly minimizes this demand. BecauseFIND already has a low contention cost due to its automated channel reservation scheme for active nodes, the modest increase in contention overhead does not substantially impact protocol performance.

Algorithm 1: Allocation of Channels (C)in WSN

```
Input: InterferingLinkList (LL), InterferingChannelList, C, LL
Output: AssignedLL, AssignedCL
N← ordered links toLL
interfering ← interfering links at two hops
InterferingCL ← interfering channels at two hops
for each element,I∈N do
    link ← element i
    if the link is the link that received the Interaction message, then
        ch ← channel received by the Interaction message
    else
        for each element j ∈ C do
            for each element, k ∈ InterferingCL do
                if element j in C is not in InterferingCL, then
                    ch ← channel of C with the largest spectral distance
                else
                    if all elements in C are in InterferingCL, then
                        ch ← interfering channel with the lowest number of occurrences in InterferingCL
                    end if
                end if
            end for
        end for
    end if
    AssignedLL ← link
    AssignedCL ← ch
end for
```

Algorithm 2: Clustering Algorithm

```
Each cluster Ci
while node v in Ci do
    {/* Allocate dynamic channel from DCi to all nodes in the cluster Ci*/}
    Given $kx \in DCi$
    Assign channel kx tov
    if $v \in BCi$ then
        {/*If node v is a border node and has free WNIC, then assign the channel of the neighbor cluster to it*/}
        if $(|Dv| < mv) \wedge (\exists\ j \in NCi)$ then
            Given $ky \in DNCi$
            Assign channel ky to v, $Dv = (ky \cup Dv)$
        end if
    end if
end while
```

f) Co-operative Load Balancing and Monitoring Algorithm

The method for co-operative load distribution requires that a small set of states sufficiently characterizes a system. The chance of the system existing in each state is assigned. In terms of the index's up-and-down movement, the usual movement of the stock market may be seen as a simple two-state model. The co-operative LB method approximation for fading channels extends back to the early work of Gilbert, who created the Gilbert-Elliott channel, a two-state CLB algorithm. In a simplified Gilbert model, the error probability in "bad" states is 1, and in "good" states, they are 0. Assuming 1 and 0, the state transition represents successful and unsuccessful transmission at a particular slot. Normal indicates a flawless channel with the no-fault present (i.e., zero error probability). In contrast, the Lossy state denotes a wireless channel where no packet can be sent without mistake (i.e., error probability is one). The transition probabilities that determine the individual probabilities P(n) and P govern the channel statistics (N).

The data rate of discrete finite random variables $(a_1,a_2, ,,,, a_n)$ is defined as:

$$H_0 = \lim_{n\to\infty} H(a_1,a_2, ,,,, a_n) / n \text{ – (1)}$$

If the random variables are stationary, we have

$$\lim_{n\to\infty} H(a_1,a_2, ,,,, a_n) / n = {}_{n\to\infty} H(a_n|a1,,,,,a_{n-1}); \text{ -------- (2)}$$

and in the case of stationary LB sequence, we have

$$H_0 = \lim_{n\to\infty} H(a_n| a_{n-1}) = H(a_2 |a_1) \text{ ----(3)}$$

For a stationary LB sequence, the net probability flow between the two states is zero once the stationary distribution has been reached (*i.e., the* entropy of a state is constant at equilibrium). In our case, we have four equations, Equations (1)-(4), with six unknowns, and therefore, it is possible to assign the desired stationary probabilities to both states {P(n); P(N)} and calculate the transition probabilities {P(n|N); P(N|n)}accordingly.

$P(n) . P(N|n) = P(N) . P(n|N)$…………. (4)
$P(n) + P(N) = 1$ …………….. (5)
$P(n|n) + P(n|N) = 1$……………….. (6)
$P(N|N) + P(N|n) = 1$……………….. (7)

Using the two-state model, one may build a simulated wireless channel behavior and conduct realistic simulations for the protocol. Illustrated is the state transition behavior of the Gilbert model. The channel spends a portion of the overall simulation period in both the normal and lossy states, with the proportion being defined by the normal state. In addition, mistakes occur in bursts due to the channel's duration spent in both phases. Errors are introduced proportionally to the packet length when the channel is in the lossy state: the error for a longer packet is greater than the error probability for a shorted packet. In other words, data packets are more likely to include a mistake than beacon packets, which are the shortest in FIND.

IV RESULTS AND DISCUSSION

Using NS2 Simulator, our suggested protocol is simulated. Our DCA Model is compared to Virtual Grid-based Routing Protocol (VGRP) and Clustering with Fast and Dynamic Area Depth secured Cluster Routing (CFDASC). The network is 550 x 480 meters in size.

The Opportunistic Routing of the DCA method is dependent on the energy of the current forwarder as well as the average energy in the next expected forwarding region; and the Shortest Path Index (SPi), which is computed based on multiple hops to the sink and the average Depth of neighbors in the next expected hop. To address the issue of void holes and enhance the Packet Delivery Ratio (PDR).

Table 1: Simulation Parameters

Parameters	**Value**
SimulationTime	900(s)
NumberofNodes	0to101
Data Rate	1Mbps
RoutingProtocol	AODV
Bandwidth	2 Mb
SimulationArea	1300 x2250 m
TransmissionRange	250m
Threshold	100dbm
MAC	802.11
Power monitor threshold	120dbm

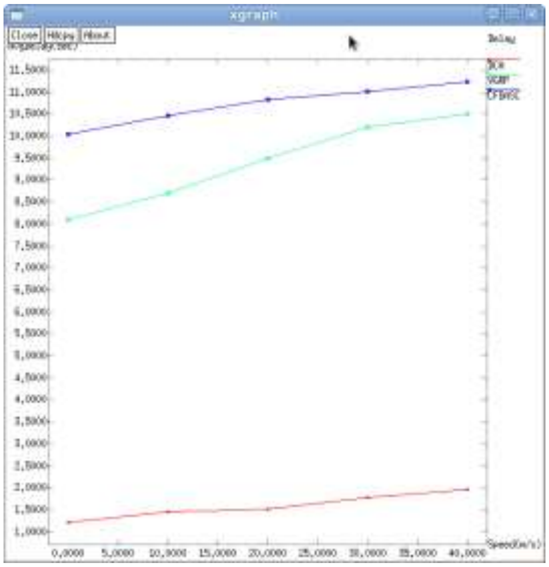

Figure 4: Transmission Delay

Figure 4 illustrates the data transmission delay. The VGRP and CFDASC methods are used for a high transmission delay. The DCA method has less delay in transmission. The X-axis represents the sink node, and the Y-axis represents the delay in time.

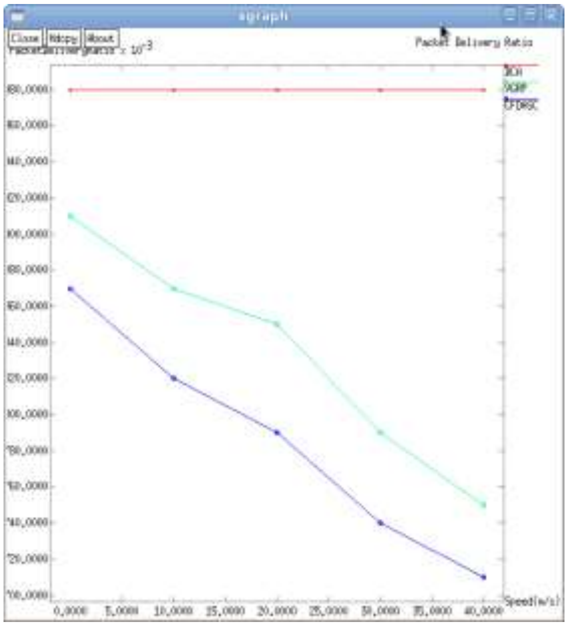

Figure 3: Packet Delivery Ratio

Figure 3 illustrates the data flow level by packet transmission: the VGRP and CFDASC methods are used as low data flow levels. The DCA method has a high data flow level by comparing the existing methods. The X-axis represents the data flow in seconds, and the Y-axis represents the packets.

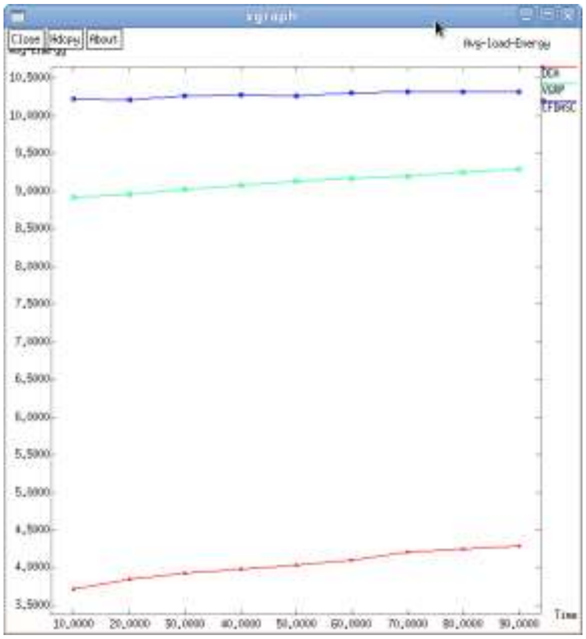

Figure 2: Energy consumption Comparison Chart

Figure 2 illustrates the time synchronization with energy consumption. In the DCA method, energy consumption is very less. The VGRP and CFDASC methods are high energy consumption of active nodes. The X-axis represents the time in seconds, and the Y-axis represents the energy level.

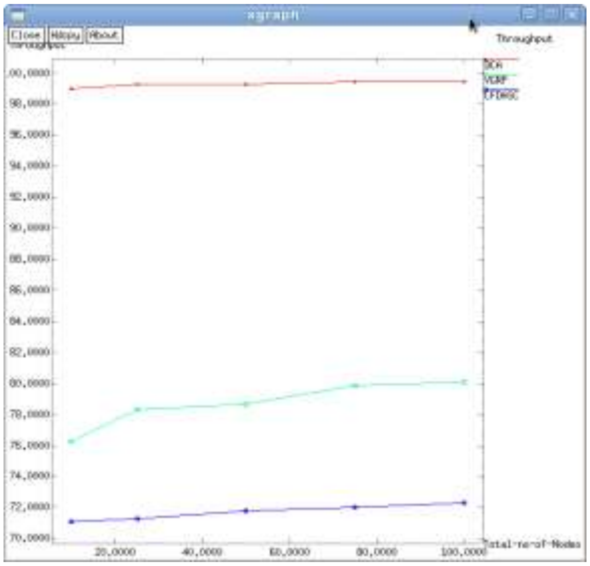

Figure 6: Throughput Comparison Chart

Figure 6 illustrates the routing with throughput. The accuracy of DCA is increasing the message communication. It shows the throughput comparison; the DCA has a better throughput than VGRP and CFDASC methods. In X-axis represents the time, and Y-axis represents the throughput levels.

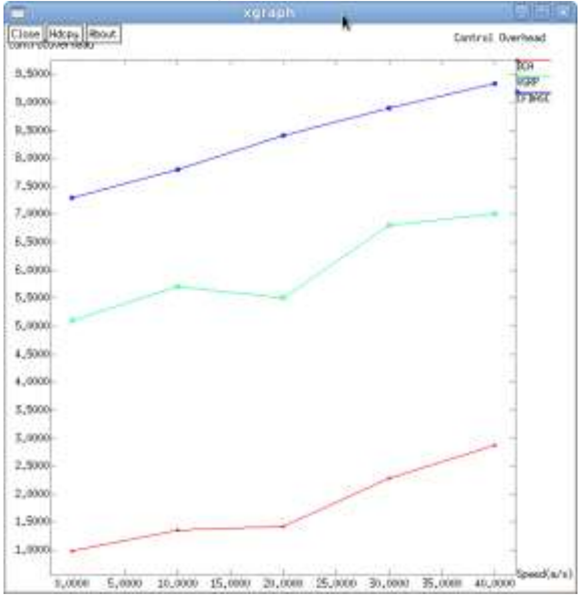

Figure 5: Bandwidth

Figure 5 illustrates the routing with bandwidth frequency: the VGRP and CFDASC methods used high bandwidth frequency levels. The DCA method has less usage in bandwidth. The X-axis represents the average energy, and the Y-axis represents the bandwidth frequency.

5 CONCLUSIONS

This research examines the DCA in WSNs for parallel transmission and interference reduction. In contrast to previous dynamic channel assignment protocols, we evaluated the issues given by the multi-channel co-ordinations to the energy limitation of WSNs and suggested a channel allocation clustering technique. DCA is widely dispersed and communicates very little information to allow SNs to pick channels dynamically. It almost certainly converges to the set of associated equilibriums. Correlated CLB indicates that all SNs adapt appropriately to the environment and the activities of other SNs, such as DCA-FIND. The network as a whole may also achieve acceptable poor performance. In addition, DCA may modify channel assignment among SNs to time-varying traffic and network structure, hence enhancing network performance over time. Simulations of both constant and time-variable flows and test-bed trials reveal that DCA may provide superior network performance than control, VGRP, and randomized CFDSCA in packet delivery ratio and packet Delay.

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