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Token Bucket Algorithm with Modernization Techniques to avoid Congestion in DEC Protocol of WSN

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***Abstract*—A wireless sensor system is an essential aspect in many fields. It consists of a great deal of sensor nodes. These sensor networks carry out a number of tasks, including interaction, distribution, recognition, and power supply. Data is transmitted from source to destination and plays an important role. Congestion may occur during data transmission from one node to another and also at cluster head locations. Congestion will arise as a result of either traffic division or resource allocation. Energy will be wasted due to traffic division congestion, which causes packet loss and retransmission of removed packets. As a result, it must be simplified; hence there are a few Wireless sensor networks with various protocols that will handle Congestion Control. The Deterministic Energy Efficient Clustering (DEC) protocol, which is fully based on residual energy and the token bucket method, is being investigated as a way to increase the energy efficiency. In the event of congestion, our proposal provides a way to cope with it and solves it using this method to improve lifespan of the sensor networks. Experiments in simulation show that the proposed strategy can significantly enhance lifetime, energy, throughput, and packet loss.**

***Keywords*—Token bucket; Queue; Packet size; Base station; Residual energy,Congestion**

I. INTRODUCTION

Now-a-days, the advancement in the design of micro-chip has led to the fabrication of light weight sensor nodes. The deployment of these sensor nodes can be found in different applications where monitoring is required. Those applications include health-care, agricultural lands, and disaster-prone areas etc. Many a time, the deployment of these wireless sensor networks depends on how the battery life is managed. The constraint in the capacity of batteries in wireless sensor networks would make them costlier and has become a challenge for us to deploy them on a large scale. Therefore, it has become a necessity to develop a protocol which results in the optimization of energy that was consumed. It has been recognized that we need to use an energy-aware protocol which will control the energy consumption by configuring itself.

Clustering can be used to manage WSNs [1-4]. The sensors that are nearer to each other are formed as clusters. In each cluster, a leader is elected from the available sensor nodes. This process is known as Clustering. Information from the cluster members is supplied to the cluster heads after they have been elected, and the cluster heads filter the data gathered using methods like data compression before sending it to the base station (BS) [5-7]. In any case, for proper working, head of the clusters would require more energy. Instead of fixing the same node as cluster-head, rotating cluster-head among the members would result in more gains in energy. Therefore, the design for distributive Wireless Sensor Networks on how far it is able to manage the consumption of energy has been one of the major factors which would determine the success of a better protocol. Previously, the cluster-heads were rotated at random, and there is no certainty in optimizing the selection of cluster-heads. Hence, a protocol which aims at electing a better cluster-head should be employed in order to check the congestion phenomena. One such protocol is DEC protocol. In this protocol, the criterion for electing cluster-heads is monitoring the residual energy of the nodes.

When a particular sensor node's load of traffic exceeds the allocated buffering capacity, it results in WSN experiencing network blocking. Blocking can indeed occur as a result of an inequitable distribution of a network's resources [8-9]. Blocking is typically caused by existing constraints at the sensor node, and there are two types of blocking: node-level blocking and link-level blocking. The buffer utilisation, or the disparity between the traffic response time and the traffic depart rate, is usually examined in node-level blocking. On the other hand, the channel usage is determined by monitoring link-level blockage. Early detection of congestion and network remediation are crucial in both situations.

II. MATERIALS AND METHODS

To regulate energy usage in wireless sensor networks, we employed a probabilistic-based approach. By using global data gleaned from a WSN rather than local data, this protocol's main objective is to increase a wireless sensor network's endurance. The residual energy of each node is what constitutes local information. The drawback of such protocols is that the amount of cluster-heads (CHs) who will be elected, or the elected cluster-head, will not have enough energy to lead the process. We may also use a deterministic cluster-head selection method instead of a probabilistic-based technique. Due to the fact that the deterministic cluster-head method outperforms the

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probabilistic model [1]. This statement is made by taking energy consumption into consideration. The Eq. (1) represents a generic probabilistic model which is given by making use of these protocols,

$$T(n) = \begin{cases} \dfrac{p}{1-\left(rmod\,\dfrac{1}{(P_x)}\right)*P} \times Q \; if n_x \in G; \\ 0 \qquad\qquad\qquad Otherwise, \end{cases} \quad (1)$$

where nrm, int or adv which stands form normal, intermediate or advanced nodes represents x and Q which are constant values that can be considered as an additional quantity. Consider an example where Q is set to a value one [10-14]. Every node will opt to be head of the cluster for each round r in line with the function in Eq. (1), which shows threshold value, and the sensor node will select a random value between 0 and 1 as the head of the cluster. If the value of the sensor node is less than the threshold set for node n, T, it will become a Cluster-head (n). Q and$P_x$represent a collection of non-elected cluster members and the likelihood of being chosen as Cluster-head (CMs).

According to the DEC protocol, clustering occurs when $E_{T\,x}$ signifies the energy wasted per bit for the transceiver circuit and $d_{to\,CH}$ specifies the distance threshold for changing amplification models. The setup phase is the initial step, during which all nodes elect CHs using the indication function. A k-bit message will be sent to the selected Cluster-heads broadcast, and the advertisement message, known as ADV, will use the non-preserving Carrier Sense Multiple Access (CSMA MAC) method to distribute radio resources. An announcement message has both a header and a Cluster-heads ID. The cluster-members (CMs) are nodes that have not been elected [1, 13]. Using the CSMA MAC protocol, cluster members will select their cluster based on the received signal strength of the advertisement message and send join requests to the head of the cluster with the lower communication cost. This message contains the header indicating that it is a request, along with the CM-ID, CHID, and other details (cluster head-ID). For intra-cluster communication, the Cluster-heads will set up TDMA. This step brings the setup procedure to an end. When sensed data is transmitted from CM's to CH's and from CH's to Base-Station, the steady-state phase starts. The direct sequence spread spectrum method can be used for inter-cluster communication (DSSS).

Congestion in a system can occur due to a variety of challenges in data transmission. They could include buffer overflow, time-varying in channel, and so on. Congestion detection is the process for detecting abnormal in normal traffic. Specifically, while sending a packet between one node to another via unique [15-16]. Cluster - based level congestion causes multiple packet losses. If there is a rise in packet loss, it assumes minimal energy consumption and reduces link exploitation. Though many sensor nodes attempt to access the channel at the same time, link congestion occurs. All nodes attempt to send traffic across the link at the same time when link-level congestion develops. Packet collisions occur as a result. Furthermore, link usage is lowered as an effect of link-level congestion. Congestion must be well handled or avoided in order to avoid all of the above-mentioned consequences. The token bucket algorithm is one such technique [17].

A. Token Bucket

It is an integrate procedure used for traffic flow strategy delivering to handle incoming packets at any rate. This algorithm waits until the buffering metrics with continuous scope are completed. To overcome with packet loss at the time of congestion, tokens are forwarded initially rather than packet data directly. The reason behind forwarding tokens rather than data is to save packet loss, if there is congestion. It operates in a FIFO style, as illustrated in Figure 1. This technique is been adopted in DEC protocol.

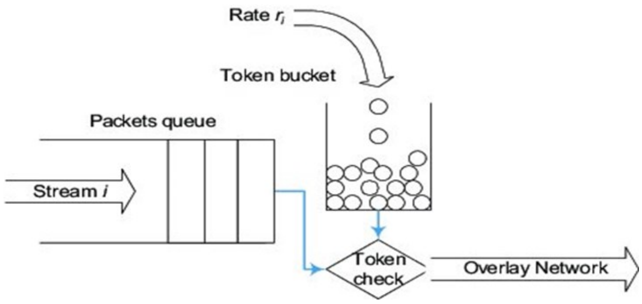


Fig.1. Working of token bucket algorithm

If the token queue has reached its capacity, the set value of the queue size must be approximated. The entire set of resulting packets is distributed until enough space is available for inbound packets to be preserved. This algorithm is used at the network's access point to secure the data from packet bursts. As a result, network data rates are kept back to worthy levels, avoiding congestion and improving QoS.

B. Algorithm for token Bucket

```
Begin
Declare the packet_size(p_size)
Declare the buffer_size
Set buffer Size, interval, second=0
For(j=0; j<number of packet, j++)
If (p_size[i] +p_sz_rm)>buffer_size
If (p_size [i] >buffer_size)
Fall packet
Else
Append tokens to bucket: rate * time passed
Hold it in bucket;
Second, surge the interval;
Transmit packet
Available tokens = available tokens – 1
}}
End.
```

III. EXPERIMENTAL

To avoid congestion in the channel process and at nodes, token bucket algorithmic concept is taken and implemented in an energy efficient protocol called DEC. Adaptive Modification of Source Node and Bottleneck Node produced Transmission Traffic are the suggested approaches that takes traffic control measurement into account to prevent packet drops and improve the efficiency of the data delivery.

A. Energy calculation:

The energy required for forwarding bit packet across a distance is expected to be as follows:

$$E_{tx}\ k, d = E_{elect} * k + \varepsilon f_s * k * d * d\ \ if\ (d < d_0) \quad (2)$$
$$E_{elect} * k + \varepsilon amp * k * d * d * d * d\ \ if\ (d > d_0) \quad (3)$$

Where $\varepsilon f_s$is permissible space, εamp is a multipath loss, d is a distance among initial and ending nodules and d_0 is limit distance

$$d_0 = square\ root\ (\frac{\varepsilon f_s}{\varepsilon amp}) \quad (4)$$

The receiving radio energy

$$E_{Rx}(k) = k * E_{elect} \quad (5)$$

B. Control of Bottleneck Node Traffic:

A higher performance of the network for the examination of this informational collection can be ensured, according to quantitative evidence, if the relevant inputs on a node can be changed based on the network performance factors [18-19]. Various transmission rates were set to member nodes in stages in our traffic order to verify the suggested, adapting to the fluctuation of network resources. This generally makes a participant node's traffic concur with the traffic condition of the source node (SN), and can prevent congestion brought on by traffic outbursts.

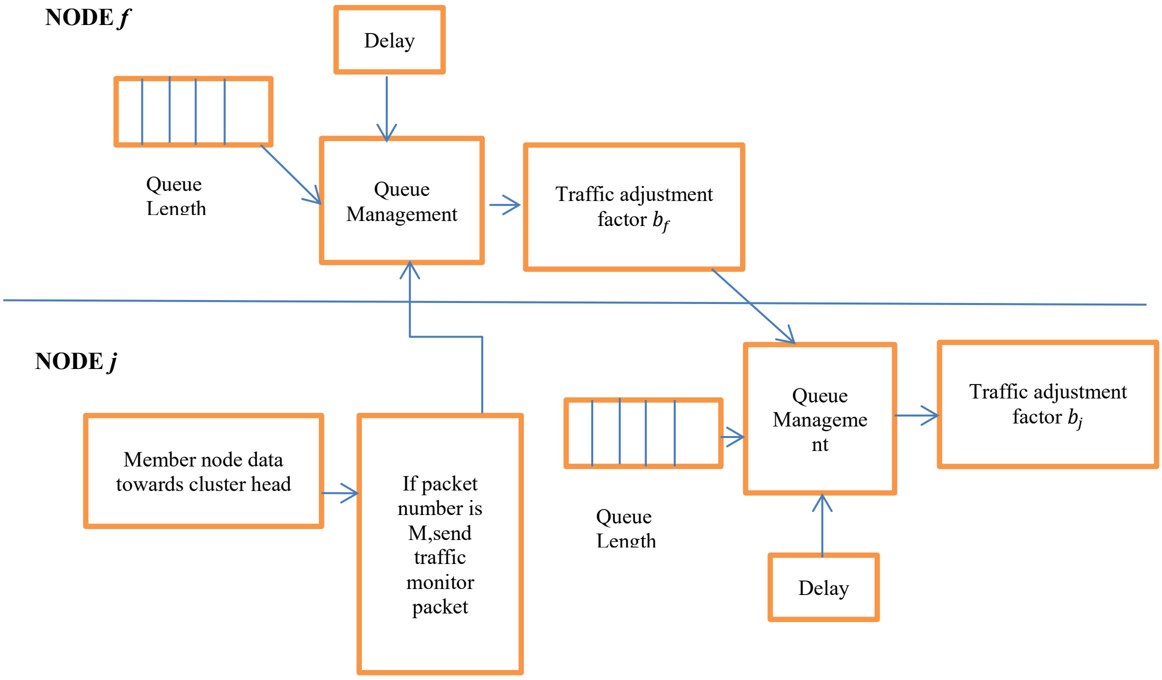


Fig. 2. The design of the traffic control algorithm

In order to enhance the consumption of network capacity, it is crucial to carefully evaluate the SN model of transmission and acquire an acceptable assignment technique and strategy for the rate of transmission of member nodes. The following equation shows the total delay of transmission for the monitor packet and the controlling factor.

$$RTT_j = Tf_j + Tb_j \quad (6)$$

Permit j-to-f data traffic to be h (t), which fulfils $0 \le h(t) \le d(t) \le d_{max}$, then Node f 's queue length is,

$$x(t) = \begin{cases} 0 & t \le 0 \\ \sum_{j=1}^{n} a_j\left(\tau - T_{f_j}\right) d_\tau - \int_0^t h(\tau) d_\tau & t > 0 \end{cases} \quad (7)$$

where n is the maximum number of member nodes linked to the Sink node and $a_j(t)$ meets the following criteria

$$\forall_j \forall_{t<0} a_j(t) = 0\ and\ \forall_j \forall_{t>0} a_j(t) = b_j\left(\tau - T_{b_j}\right) \quad (8)$$

Due to the forward transmission delay, $(t < Tf\min) = 0$.

Let T_{j_k} be the instant that the k^{th}traffic sensing message belonging to the j^{th} connection link feeds back to the j^{th} member node, then

$$\forall_{t\in[t_{j,k+1}]} a_j(t) = a_j(t_{j,k}) = b_j\left(t_{j,k} - T_{b_j}\right) = const \quad (9)$$

Suppose that sensor nodes start transmitting data right away. $t = 0$, and $tj, 1 = RTT_j$ when $k = 1$, then $tj, k+1$ may be calculated using the following equation

$$\int_{t_{j,k}}^{t_{j,k+1}} a_j(\ \tau - RTT_j) d\tau = M \quad (10)$$

Noting the time of every rate readjustment as $\varnothing_{m,}$ $m = 1.2 \ldots,$, it can be known that within $\alpha_m = \theta m + 1 - \theta m$

$$\forall_{t\in[\varnothing_m, \varnothing_{m+1,}]} \forall_j \quad a_j\left(t - T_{f,j}\right) = a_j\left(t_{j,k} - T_{f,j}\right) = const \quad (11)$$

Using the network distribution model, let a_{min} represent the anticipated overall convergence rate in the following level, and A denotes the converging rate before a burst of data stream occurs. The projected traffic may exceed the network's maximum bandwidth utilisation, d_{max} , despite the fact that the system currently has a maximum amount of bandwidth available. , viz.,

$$a_{min} \leq h(t) \leq d_{max} \leq A \tag{12}$$

At this moment, The downlink nodes must be given the convergent rate and the maximum numerical packet rates, or the endurable well-proportioned rate a_{max}, so that when the parental node has become the bottleneck node because of the easy streaming of data of its children nodes, it can propagate stream of data to the SINK node at the optimum utilisation of network capacity without congestion, assuming $a_{max} = d_{max}$is simply guaranteed.

There is an optimal queue length, in accordance with reference, if there are no storage gaps or bandwidth drop during the detecting period, which is defined as x. To optimise network transmission performance, it is essential to manage a node's queue length and maintain it around x. Characterize the queue controller as follows:

$$\tilde{a}(t) = \begin{cases} a_{min} \text{ if } W(t) < a\text{min} \\ W(t) \text{ if } a\text{min} \leq W(t) < a\text{max} \\ a_{max} \text{ if } W(t) > a\text{max} \end{cases} \tag{13}$$

W(t) is the queuing adaptation measures, which is defined as the maximum rate during a streaming data outburst and the relatively low rate before to the streaming data outbreak, respectively.

$$W(t) = K\left[x_d - x(t) - \sum_{j=1}^{n} \int_{t-RTT_j}^{t} b_j(\tau)d\tau\right] \tag{14}$$

where K signifies the proportion control gain, $x(t)$ is the immediate queue length of the head node f, and $\sum_{j=1}^{n} \int_{t-RTT_j}^{t} b_j(\tau)d\tau$ is the sum of the traffic collected at f within the round trip time of the control packets. As shown in (10), the control function synthetically considers the node's queue length, round trip time delay of transmission, and converging rate. Assuming that $b_j(t)$is the expected rate of the regulating factor intending at the communicate transmission of the i-th member node, the following equation can be obtained using the algorithm,

$$bj(t) = \begin{cases} 0 & \text{for } t < -Tbj \\ a\text{min}/n \text{ for } -Tbj \leq t < Tfj & \\ \tilde{a}(tj;k - Tbj)/n \text{ for } t \geq Tfj \; t \in [tj;k - Tbj\,;\, tj;k+1 - Tbj] & \end{cases} \tag{15}$$

That is, during the time period among any two successful rate changes, the rate changing's upper limit is $a\text{max}/a\text{min}$.. As a result of uniting (2) and (3), the queue control function can be written as

$$W(t) = K[x_d - \sum_{j=1}^{n} \int_0^t b_j(\tau)d\tau - \int_0^t h_j(\tau)d\tau] \tag{16}$$

and the derivative of (12) is

$$\frac{d}{d_t}\tilde{a}(t) = K[h(t) - \sum_{j=1}^{n} b_j(t) \tag{17}$$

The optimum changing rate of the queue control system, according to (11) and (12), is

$$\frac{d}{d_t}\tilde{a}(t) \leq K[a\text{max} - \sum_{j=1}^{n} b_j(t)] \leq K[a\text{max} - a\text{min}] \tag{18}$$

and the shortest time for rate changing is.$1/K$ If assuming that

$$K \geq [\min(Mn = a\text{min}, \sum_{j=1}^{n} RTTj/n)] - 1 \tag{19}$$

In addition to ensuring that the minimum rate required by the traffic model can be met during the latency of the anticipated traffic detecting message and the traffic regulating factors, converged traffic also assure that the update of child node transmission capacity can acclimate to interactive changes in network bandwidth. The traffic controlling classifier can make up for the pure delay time of network control packets on the blocking control system as a result of the analysis of the traffic model. The impact of time lag on the reliability of the control system can thus be totally eradicated. When there is congestion, the regulating factor may be lost along with other data packets as a result of variables such signal channel competition, data transmission, and link interruption. The uplink node won't be able to recognise congestion without the regulating element; therefore it will continue to transfer data packets at a higher rate to the congested area. Therefore, it is necessary to guarantee the transmission dependability of the control packet. On a channel, a timer is used to track the presence or absence of a traffic-regulating component to identify when congestion occurs. The multi-frequency capabilities of nodes are utilised to address this issue for wireless channels. The system will assign distinct communication frequencies to regulate packets, when it anticipates congestion, while also offering alternate channel for the reverse transmission of the regulating factor to guarantee the successful application of the congestion management strategy.

C. Adaptive Adjustment of Transmission Traffic produced by Source Nodes:

The correlations between various network packages can be divided into two categories based on the application domain. The first form of relationship is one of irrelevance. The network throughput in this scenario is proportional to the total relevant information of the produced events, and the best application strategy for this type of network is to maximise the network capacity utilisation factor. Similarity is the second sort of relationship, the minimal event detection degree (MEDD), which denotes the minimum number of packets that must be acquired in unit time at the sink node to achieve the application potency requirements, is used to assess the network's application performance. For instance, each of the three sensors must supply a distance packet at a moment when SN is required for target localization If the total number of packets arriving at the sink node in a given period of time falls below MEDD, the throughput of occurring packets has not complied with MEDD requirements, and node of the source transmission rates must be improved. The relevant source nodes will not transmit redundant packets if the total number of packets arriving at the sink node in a unit of time equals or exceeds MEDD. This will considerably cut traffic and prevent blocking. When applying the traffic regulating algorithm to the 2nd type of network application, the sink node must first analyse MEDD as per the network particular application, and then transmit the regulating factor to source nodes via reverse transmission to sustain the transmission traffic of source nodes all around network load. This prevents congestion control from resulting in a locally optimum solution like FUSION.

D. Implementation of token Bucket concept in DEC protocol with Adaptive Adjustment of Transmission Traffic and Node Traffic Control

Phase 1: Sensor hosts can be arranged in any order by using a common method.
Phase2: For clustering groups, the DEC protocol computation is used.
Phase 3: Apply the token bucket method on the nodes available in a various clusters. Sink will issue the CH-ticket, a better, unmatched type of response towards cluster members.
Phase 4: Assess then evaluate cluster heads those with tickets. Following is a description of the boundary.

$$T(n) = \{ {}^{t}/_{1-t} * (r \bmod {}^{1}/_{t}) \}$$

Where t is preferred CHs number
Phase 5: Through adjacent CHs, a subordinate section of nodes act as cluster members.
Phase 6: Ticket will be shared to the cluster members by the cluster head.
Phase 7: Nodes that are part of a ticket, share their data to respective sensed CH.
Phase 8: If congestion occur, Control of Bottleneck Node Traffic and Adaptive Adjustment of Transmission Traffic produced by Source Nodes will be performed.
Phase 9: Put on data in order to acquire information.
Phase 10: The information is then sent to the sink by the cluster head.
Phase 11: Estimate as well as inform about energies.
Phase 12: In every cluster the dead nodes are verified and tallied.
Phase 13: If all nodes in stage are dead, the lifespan is known; otherwise, go to phase 13 i.e. end of phase.

IV. Results and Analysis

The below given table 1 specifications are used as working parameters for testing results. For simulation results MATLAB platform is used.

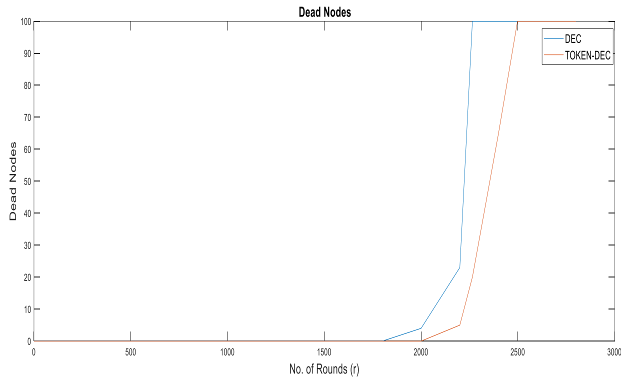
TABLE I
DESIGN SPECIFICATION

Parameter	Values
Eelec	50 nJ/bit
EDA	5 nJ/bit/message
E0	0.5J
K	4000
Popt	0.1
ϵ_{fs}	10 pJ/bit/m2
ϵ_{mp}	0.0013 pJ/bit/m4
n	1000

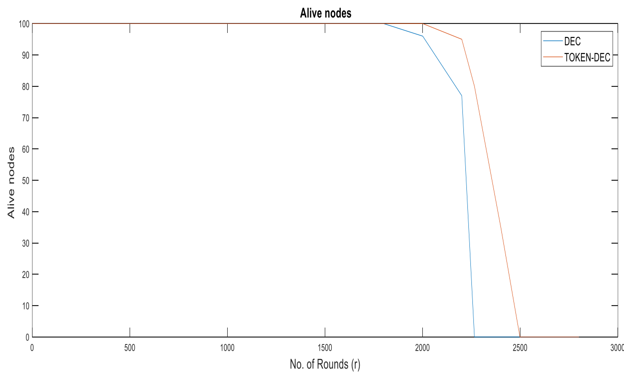
Stability Period: Study of Alive and Dead Nodes gives the stability period in the token-Congestion DEC (Token-CDEC). The number of cycles the network is active is shown in Figure 5 based on active nodes in the network. The RE of every individual node is examined after each cycle in the Token Token-CDEC protocol to elect cluster heads (CHs). Cluster heads will be more likely to come from nodes with a high RE. The same CH may continue to serve as the cluster head if its RE is higher than that of the previous CH. Consider that the RE of the current CH is lower than that of cluster members, in such situation, the cluster member with the greatest RE becomes the CH. Each cluster's designated CH collects information from member nodes and transmits it to the main station. Token-CDEC has a longer stability period when traffic flow plan is made to regard package receiving with arbitrary rate, as demonstrated in Fig. 3(a) and (b).The very first Token-DEC node died around 1972, whereas the first DEC node died at round 1860.
As a result, the stability period of Token -CDEC is over 5.9% longer than DEC.

TABLE II
ANALYSIS OF LIVE NODES

Rounds	Live Nodes	
	DEC	Token - CDEC
0	1000	1000
500	1000	1000
1000	1000	1000
1500	1000	1000
2000	982	1000



(a)



(b)

Fig.3 (a) & (b) Stability Period analysis in terms of Live and Dead nodes

CH's analysis: With the working of 100 nodes in a specified networking zone, Fig. 4 shows the count amount of CH nodes. It demonstrates that around round 2265 for DEC and in Token-CDEC 2396 the line sharply drops, suggesting that all of the nodes' energy has been exhausted (stage of falling to dead). As a result, head nodes of the cluster change into normal nodes at the conclusion of each cycle and interact with the sink independently. As a result, at the network's end, they come to a halt.

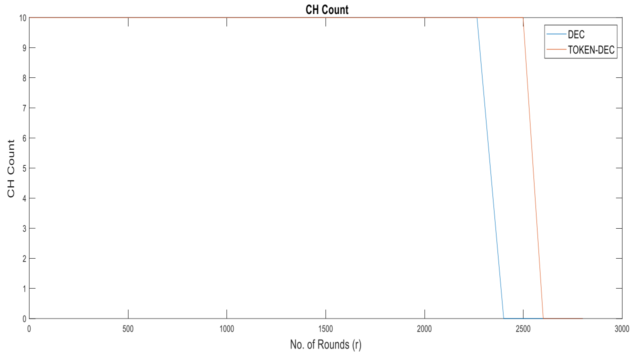


Fig.4 Analysis of Cluster head count

Packet Delivery Ratio (PDR): The number of packets sent to the delivered packets at destination is the ratio for PDR. It suggests that the proposed method is more efficient than the existing one as shown in Fig. 5.

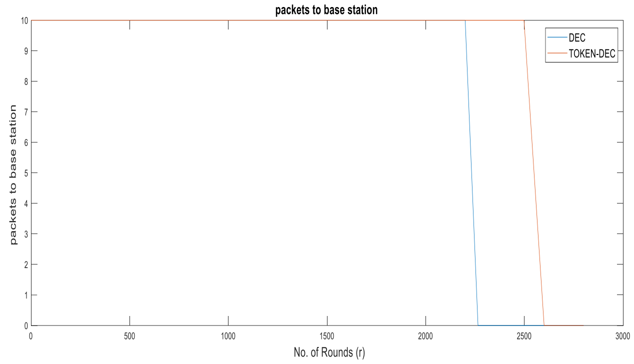
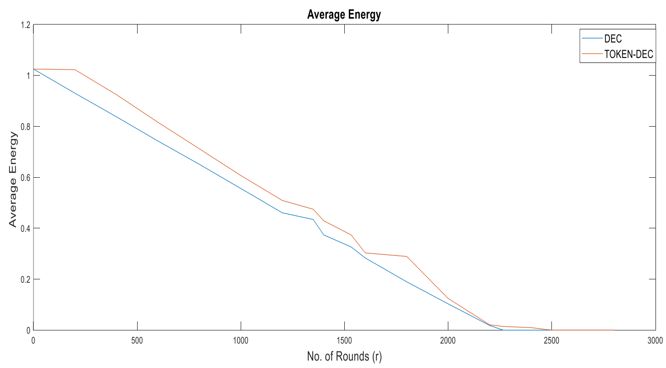


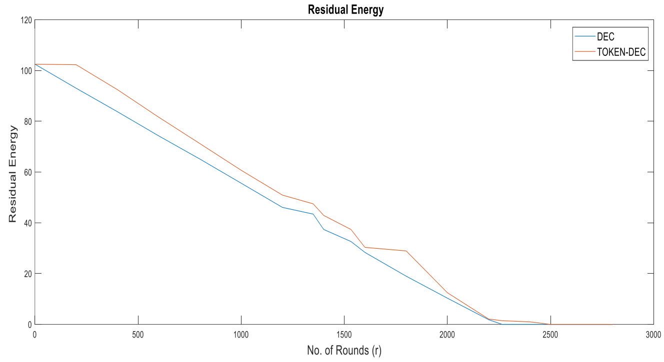
Fig.5 Analysis of packet to base station

Average Energy and Residual Energy Performance Analysis in DEC and Token-CDEC:

Figures 6 (a) & (b) demonstrate the assessment of mean and residual energy for the DEC and Token-CDEC methods. The outcomes of DEC protocol and Token-CDEC were shown through simulation and also compared in Table II. The acquired results show that the DEC protocol's total energy for round 2265 is zero, whereas Token-CDEC has energy of 1.09J. Token -CDEC services start to diminish at round 2385. Token-CDEC beats DEC when more rounds are added. When compared to the existing DEC protocol, Token- CDEC was shown to be better in performance by up to 5.34%



(a)



(b)

Fig.6 (a) & (b) Analysis of Residual and average energy for the Token-CDEC and the DEC.

TABLE II
ANALYSIS OF RESIDUAL AND AVERAGE ENERGY FOR THE TOKEN -CDEC AND THE DEC

Rounds	Residual Energy		Average Energy	
	DEC	Token - CDEC	DEC	Token - CDEC
0	102.5	102.5	1	1
500	79.15	84.53	0.791	0.799
1000	55.42	59.79	0.560	0.577
1500	33.13	36.54	0.331	0.354
2000	9.647	11.05	0.102	0.127

V. CONCLUSION

Congestion in a network occurs when information is transferred from source to destination; this can be avoided by using a Token bucket, i.e. an application based on the DEC protocol. The proposal is to address congestion issues in remote areas. In this research work, we used the Token bucket strategy as a queue replacement, and we examined network life, throughput, packet delivery ratio, and energy effectiveness etc. The proposed approach produces better results when compared to the current approach by applying the enhanced schemes of communication like Control of Bottleneck Node Traffic and Adaptive Adjustment of Transmission Traffic produced by Source Nodes to avoid congestion in the network .

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