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An Improved Load Balanced Distributed Weight-based Energy-efficient Clustering Hierarchy Routing Protocol for Military Application in MANET

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Abstract

Objectives: MANET has access to excess of real-time data in today's modern military applications. A portion of military Internet protocol network has a number of challenging task to attain the quality of service to achieve load balancing and energy efficiency. The backhaul radio connected with routing protocol to create a network node doesn't consider the load balancing problem. **Methods:** This paper proposes an improved Load Balanced Distributed Weight-based Energy-efficient Clustering (LBDWEC) hierarchy routing protocol algorithm for load balancing in cluster based MANET. A hierarchical routing path is tracked and stored in the cluster heads instead of the network nodes. Thus the routing overheads are reduced effectively. The performance of the Cluster Head (CH) in an unhinged and a non-reliable state degrades the network performance since the cluster head plays a dominant role in routing and tracing of messages between the source and the destination. Selecting a prominent cluster head is based on the electing and priority basis. The formation of a cluster results in three different levels like cluster head, strong and the weak nodes. The differentiation of stronger and weaker node is based on the evaluation of the network density, residual energy and transmission of data between source and destination. A multi agent routing based algorithm is generated to make a possible load balanced route between the source and the destination in the cluster supported network. **Findings.** A load balanced scheme is presented in this paper to achieve energy efficiency considering both energy usage and congestion amongst the network. The threshold value is accounted here to evaluate the overloading intermediate node with crisis to the queue length across the path. The proposed LBDWEC hierarchy routing protocol uses an optimal path to calculate the energy usage. The algorithm shows better results in achieving the throughput, message delivery ratio and energy efficiency with respective to load balancing in the clustering network.

Keywords: Clustering, Energy, Hierarchical Routing, Mobile Ad-hoc Networks (MANETs), Load Balancing

1. Introduction

A Mobile Ad hoc Network (MANET) can be self configured to figure out a temporary network without the assistance of the current infrastructure or the centralized management. Such self configured networks are categorized by extremely prone to security threats, variable capacity links, energy constrained operations, dynamic topologies and existence to provide constrained bandwidth. Due to the above mentioned factors routing becomes a most important issue in the mobile ad-hoc networks[1].

The main purpose of performing routing in a network is to reduce the network traffic by selecting the paths that may be either hierarchical or flat in structure[2]. In the flat structure[3] the network nodes have the same responsibility and pecking order. This flat structure can suites only for the small network. The flat routing structure in large network produces a more information flow, which can saturate the network[4]. The hierarchical

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structure[5] has been proposed to address this issue, using the hierarchical routing protocol. The cluster maintains the local information about the nodes within the cluster and limited information of the nodes that are outside the cluster. This hierarchical routing protocol provides higher scalability for the network, where the responsibility of routing is accomplished only by the selected nodes[6]. But the hierarchical routing method shows continuous change in its topological structure. Topological routing management is prior, than the actual routing in the mobile ad hoc networks.Thus, the hierarchical structure improves the efficiency of the dynamic network.

To reduce the bare bones of structuring a network is a significant pace in routing approach in MANETs. Various routing algorithms that support clustering techniques have been proposed in the paper[7]. The main idea of using clustering is to partition the network nodes into groups or clusters that are closely related in its geographical nature. It is an efficient method to optimize and abridge the network functionalities. Here, routing protocols are used to reduce the traffic occurring in the networks and to make the routing methods simpler. There are different clustering schemes that have been proposed with various characteristics to meet the design issues on the mobile communication platforms, in which the mobile proliferations have a huge attention towards small sized mobile equipments for the last few decades.

The subsequent push based and pull based schemes are appropriate for the nodes with stable network that the source can be reachable at all time and suites for dynamic networks respectively.

Load balancing amongst the nodes is the best practiced solution for gaining efficiency and to increase the networks' life time. The load balancing algorithm on the whole distributes the load equally to the nodes with minimized execution time and maximum utilization of the nodes. Load balancing becomes the most specific issue for research in both the wireless[8] and the wired[9] networks. The foremost intention is to guarantee that the nodes are not overloaded, by providing consistent load distribution to all the nodes. The benefit of using the load balancing approach leads to the extension of the method to new application under different environments (multimedia, military, large scale applications, etc.).The mobile environment supports various parameters when compared to the wired networks such as mobility, wireless communications and bounded resources.

In[10] proposed WBACA clustering approach which deals with the position information for locating a system, usually known as Global Positioning System (GPS). With the utilization of comprehensive formula, weight has been calculated by considering transmission rate, transmission power, degree, mobility and battery power into account. The algorithm calculates the local minimum weights for the purpose of selecting the cluster heads and also describes that two cluster heads can't be a one hop neighbor.

In[11] proposed Overlapping Cluster Algorithm (OCA) which consists of two phases. Based on the key input parameters, the startup phase executes partitioning of the network nodes into the cluster. The input factor includes transmission range, bandwidth capacity, mobility and buffer, battery capacity, and density of the local area. The maintenance phase checks for the network topological structure periodically and updates the status of the present network condition for global and local re-clustering. OCA mainly concentrates on providing higher reliability to the applications other than cluster formations.

In[12,24] proposed load balancing is used for the most part of electing the cluster head. A cluster head provides radio source assistance to its member along with the routing message for nodes in the belonging to some other clusters. Thereby, the cluster heads are supposed to be lightly loaded and not desirable to be overloaded. Frequently the nodes are attached and detached from the cluster heads, thus simultaneous load balancing becomes a difficult job in the system. The nodes are allowed to be the part of the cluster heads by providing an extension of duration to live in the network based on the key parameters.

In[13] proposed Enhancement on a Weighted Cluster to provide a higher degree of stability with improved load balancing in the network. With reduced energy consumption and operating cost, a best node is found out to share the loads. By knowing the no. of nodes a cluster head can cover up, a pre-defined threshold is determined for load balancing. The detachment of nodes from the present cluster and attachment with the other cluster should be reduced to improve the stability of the network. The local election procedure is performed to regulate the number of mobile nodes in the cluster, when the cluster size is increased or decreased.

In[14] proposed a load balancing algorithm with respective to the clusters. The 'cluster heads' has been elected to balance the load by knowing the subset of nodes, thereby reducing the communication cost. The load information of the individual cluster is gathered by the cluster head, to ensure the load balancing of the global member. Each cluster is provided by minimum threshold energy. When the threshold energy is attained, cluster head election is called off. It is also called off when the node doesn't find any cluster for attachment when it is detached from the cluster.

In[15] proposed a dynamic energy efficient clustering algorithm, in which the cluster head is selected based on its mobility and energy, also altering the network topology locally to increase the lifetime of the network by reducing the energy consumption and periodic monitoring of energy consumed by the nodes. Here two different energy thresholds are computed: the red threshold triggers the re-clustering of network locally and the yellow threshold distributes the load to all the clusters equally to achieve load balancing.

In[16] initiated load balancing based on the transmission range amongst the cluster. The loaded cluster head reduces its transmission range while the unloaded cluster head increases its transmission range, to achieve the distribution of nodes in the cluster. Previous investigations[17–19] proposed Alternate Path Routing (APR), Dynamic Load Aware Routing (DLAR) load balancing routing protocols for data transmission effectively in MANET. From the existing survey[20-23], it is concluded that there exists a tradeoff to elect a cluster head and cluster members for a network.

We propose a new approach LBDWEC hierarchy routing protocol algorithm to accomplish load balancing in MANET to convince military necessitates. Clustering is initiated by organizing the nodes into groups or clusters, where cluster heads and other nodes are coordinated to perform message transmission across the networks. The organization of nodes into cluster affords various benefits such as the reduced operational cost of transmitting data, improved utilization of bandwidth, reduced energy consumption. The main aim of the proposed work is to increase the network lifetime, to minimize the communication overheads with reduced execution time.

2. Proposed Methodology

The proposed LBDWEC hierarchy routing protocol is developed mainly for military applications to communicate with the destination by cluster formation using MANET has been demonstrated in this section.

2.1 System Overview

Figure 1 demonstrates the overall recital of the proposed system. By considering the key parameters such as mobility, network density, distance, residual energy and transmission range the cluster head is selected, in a load balanced distributed weighted energy efficient clustering algorithm. Based on the priority and voting, the cluster head is elected. There are three levels in a cluster or group formation, namely the cluster head, weak nodes and strong nodes. Certain criteria's such as network density, transmission and residual energy are used to estimate the strong and the weak nodes. The CH or gateway candidate is accessed by the PTX. The capacity of the candidate to transmit a message to its neighbor is done by PTX. Load balancing phase, cluster head election phase and cycle phases is the three arenas in LBDWEC clustering hierarchy protocol.

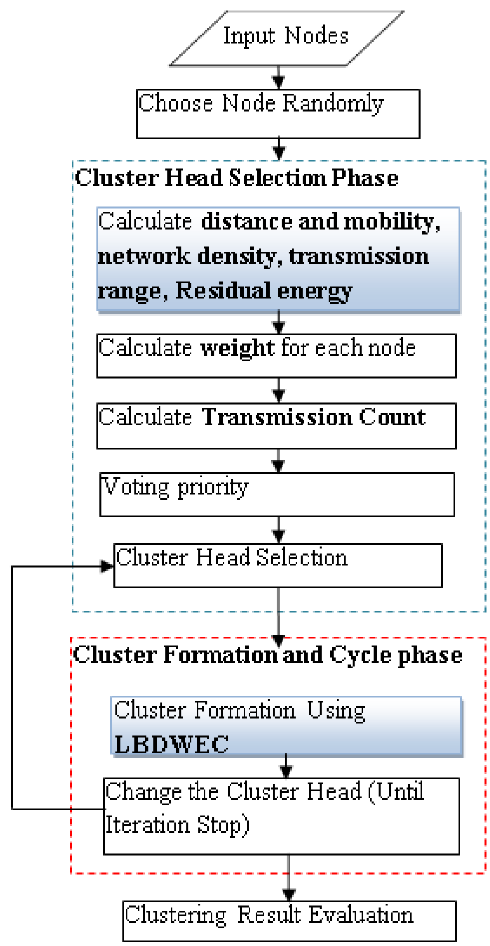

Figure 1. Overall performance architecture of proposed system.

2.2 Cluster Head Election Phase

The behavior level in clustering mainly focuses on the selection of the cluster heads by introducing different key parameters.

The information about the nodes in the cluster and the ID value is broadcasted to the neighbors; in which every node contains its own ID value. The neighborhood table is created based on the broadcasted information.

A graph G with vertices G (V, E) is considered, the nodes and edges are given by n_i and e_i respectively. The flow from node n_i to the node n_j with the given edge weight is w_{ij}.

The neighboring node should be placed within the transmission range of that particular node Δ_i, where,

$d(n_i, e_i)$ < Transmission range of n_i % of neighborhood contribution is given by $cp_{n_i} = \frac{1}{\Delta_i}$

The transmission range is computed by using the formula,

$$T_r = \sqrt{\left((dn_d / dn_c) \middle/ coverage\ area \right)} \quad (1)$$

where,

dn_d → Desired node degree and

dn_c → Current node degree,

The total coverage area is equal to the cluster coverage area.

dn_d=S+1,

$$S = nodedensity * d(C,N) \quad (2)$$

$$d(C,N) = \sqrt{\sum_{i=1}^{n} (N_i - C_i)^2} \quad (3)$$

C-cluster head, N-node.

The total energy consumed is given by,

$$E_t(s_i, d) = \begin{cases} s_i E + s_i \varepsilon_{fs} d^2, d \le d_0 \\ s_i E + s_i \varepsilon_{mp} d^2, d \le d_0 \end{cases} \quad (4)$$

$$d_0 = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \quad (5)$$

The energy required to transmit and receive 1 bit message is represented by E.

ε_{fs}→ Amplification coefficient of free-space signal a

ε_{mp}→multi-path fading signal amplification coefficient

d→distance between transmitter and receiver;

s_i→ bit amount of sending information.

The value depends on the amplifier model.

2.2.1 Network Density

The network density depends on the mobility and the optimal node density to provide connectivity in a network. The optimal node density is usually higher in the mobile background.

P→ Probability of the connectivity.

n→ number of nodes located in the area.

μ is represented by

ρ→density,

π→circumference

r→ radius of the transmission

$$P(k\text{-}con) \approx (1 - e^{-\mu}))^n$$

$$\mu = \rho \times \pi \times r_0^2$$

$$\rho = n/A$$

where, n → Neighbor node count

A →Pre-defined area size,

r_0^2→T transmission radius

ρ=density, π=3.142,

2.2.2 Distance and Mobility between Two Nodes

The factor influencing the stability or mobility is decided by the cluster head. The cluster head is expected to be stable, to avoid frequent changes in the cluster head. Re-affiliations are caused due to the change in the cluster head position and detachment of the nodes in the network. Re-affiliations increase the computational cost and the processing time. The durability of the node link improves the cluster strength. The stability of the node is estimated based on the movement of the nodes and detachment of the nodes. The durability of the link is estimated by,

$$LD = \frac{-(ab+cd) + \sqrt{(a^2+c^2)^2 - (ad-bc)^2}}{a^2+c^2}$$

where, $a = v_i \cos\theta_i - v_j \cos\theta_j$, $b = x_i - x_j$, $c = v_i \sin\theta_i - v_j \sin\theta_j$, $b = y_i - y_j$ and v_i are speeds of mobility. To estimate the strength of the node, GPS is required in some cases. Link duration is estimated and reversed. Link node stability is given by,

$$N_s = e\text{-}LD$$

Stable links are given by the smaller value N_s

The transmission range of the neighbourhood node is checked initially, if it lies within the range the information of the node and the ID value is broadcasted to the neighboring node. The weight of the node is calculated by,

$$W=\alpha\ F(MD)+\beta\ F(\Delta C)+\gamma\ F(Y)-\phi F\left(\frac{E_t}{E_0}\right), 0\le\alpha,\beta,\gamma,\phi\le 1$$

where,
α, β, γ, ϕ are coefficients,
Y→ no. of times CH so far,
E_t→ Residual energy,
E_0→Initial energy,
MD→ mean distance to neighbors and
ΔC→Optimum deviation.
MD can be calculated as given below:

$$MD=\frac{\sum_{i=1}^{N_s} DV(i,x)}{N_s}$$

where,
X→ nodes' ID,
N_s→ Number of neighbors,
DV→distance vector,
DV(i, j)→Distance between the nodes i and j
ΔC can be calculated as:

$$\Delta C=|N_s-N_0|$$

where,
N_s→ Number of neighbors
N_0→Optimum number of the neighbors.

$$N_0=\text{floor}(N_r)$$

$$N_r=\begin{cases}1\times N_m & D>Dt_1\\ C_1\times N_m & Dt_1>D>Dt_2\\ C_2\times N_m & Dt_2>D>Dt_3\\ C_3\times N_m & Dt_3>D\end{cases}$$

$$0<C_3<C_2<C_1<1$$

where,
D→distance from Source Node (SN),
N_m→Maximum cluster size,
Dt_1, Dt_2 and Dt_3→ threshold values of distance
C_1, C_2 and C_3 → coefficients and are less than 1 (C_1, C_2, C_3< 1).

The nodes that are far away from the source nodes form the bigger cluster and closer to SN forms smaller clusters. Thus load balancing can be achieved. The weight of each node is calculated and broadcasted sequentially. Finally, the routing table includes the weight of the neighborhood nodes in its Table 1.

Table 1. Primary nodes' information from the network topology

Neighbors	ID	Distance (m)	Weight
1	32	0̃56	W1
2	57	4̃41	W2
...	...	...	...
M	4	3̃1	Wm

Based on the weight of the neighborhood nodes, priority list is generated, which is broadcasted with the voting message to vote the greatest node. That is, the vote list is the sorted ID values of the nodes based on its weight. The node with the higher number of votes is elected as the cluster head. Thus, it introduces itself by sending a cluster head message. The election phase of the cluster head is shown in the Figure 2.

The weight of each node is calculated periodically, and broadcasted to the neighboring nodes, which are in the transmission range with a hello message. When the weight is estimated it *pushes* it to the cluster head, and *pulls* to the possible cluster heads. The higher weighted node is elected as cluster head and all the other nodes are members in the cluster. The higher weighted nodes are considered to the stronger node and it directly communicates with the cluster head. The node reaches the cluster head with less energy consumption. The node determines itself to a 'h' level member i.e.) no. of hops to the cluster head or to a first-level member in the cluster. The weak node communicates with the stronger node and be a second level member. Based on energy evaluation, node density and transmission range, the stronger node and the weaker node is estimated. The nodes with lesser battery consumption, transmission range and density are considered to be a stronger node whereas others are weaker nodes.

To estimate the stability of the cluster head, the proposed LBDWEC clustering hierarchy protocol think of the Transmission Count (PTX), link condition and the node status. The PTX is given by the ability of the contestant to transmit the message to the exact neighborhood node. The PTX of the cluster head is determined by the residual energy, transmit power and the link quality. The nodes in the cluster periodically broadcast a hello message to determine the forward delivery ratio, reverse delivery ratio and distance between the neighbors. If the PTX value and the weight of the node are higher, the probability of becoming a cluster head is higher.

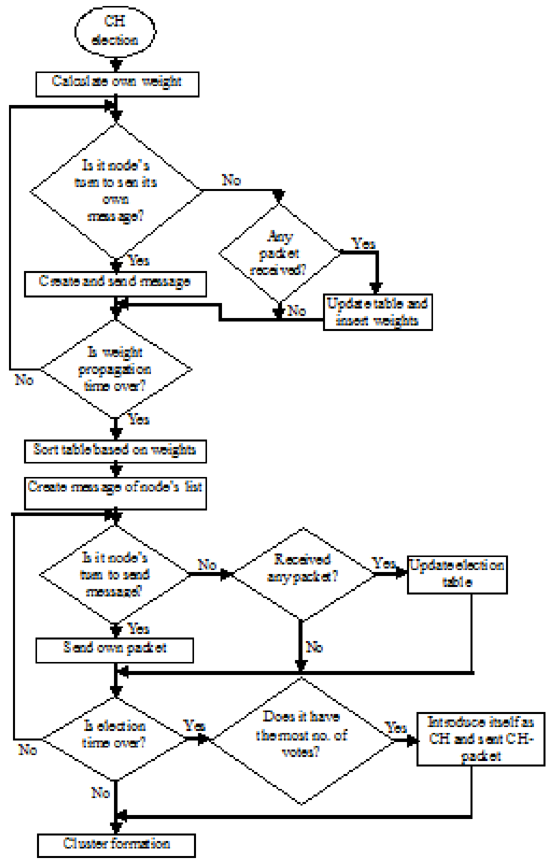

Figure 2. Flowchart of cluster head election phase.

2.3 Cluster Formation with Load Balancing

Initially the cluster head sends message to the neighboring nodes, which is in the transmission range limit. The nodes receive the message from the cluster head and conscious about the voting idea by responding to the cluster head i.e.) join message. The joining message from the neighbor nodes is accepted by the cluster head based on their weight ranging from lesser to greater. The node with lower weight is not accepted by the cluster head with reference to the weight sorted table. In primary clustering based on the priority voting idea, some of the nodes may not be accepted in the cluster because of the limited cluster size. In secondary clustering, the node with highest value introduces them as a new cluster head and the selection is in the iteration manner.

The main advantage in selecting the cluster head with iteration manner is that overlapping amongst the cluster can be avoided. For instance, the initial node Y with highest value in voting, all the neighbor nodes are familiar with the node Y. The selected cluster head accepts all the neighboring nodes and forms the cluster. If the density is higher in some network region, the size of the cluster is limited since the cluster is not organized and filled. After electing the cluster head at the final stage, the selected cluster head arranges the table for its members and processing done by using the cycle phase.

2.3.1 Routing in Cluster based Structure

The nodes in the cluster are connected with the graph with the probability of weight of the node is utmost one. Any node available in the network may extend the connection to the other nodes in the network. If a connection is needed to be established between the nodes A to B, initially the routes will be initiated first. Routing identifies whether the node B belongs to the same cluster or from the other.

- Inter_cluster routing: If node ('A' sender) wants to establish a connection with ('B' receiver), a route request message is transmitted to the cluster head of the node B. The message from the cluster A is propagated to the cluster head of the neighboring cluster head.

- Intra_cluster routing: The source node 'A' and the destination node 'B' belong to the same cluster head, the node A directly sends the positive ACK to the node B.

2.4 Cycle Phase

LBDWEC clustering hierarchy protocol periodically alters the cluster head to balance the energy consumption in the nodes. Reelecting the cluster head is triggered by T (K), until the cluster remains stable. The CH collects all the information of the neighboring nodes weight and elects the highest value containing node as the next cluster head. The overall communication overhead is reduced by this way. The re-election occurs in the older cluster heads to transmit the message temporarily to avoid the unnecessary k-hops among the neighbors.

4. Result and Discussion

This section demonstrates the effectiveness and pre-eminence of the LBDWEC hierarchy protocol when compared to the existing Balanced Clustering Algorithm with Distributed Self-Organization (DSBCA) and Improved Load Balanced Connection Aware (ILBCA) clustering hierarchy protocol. The network parameters like throughput, message delivery ratio, energy consumption, delay, network life time and load balancing are considered for measuring the performance.

4.1 Energy Consumption

While simulating, the average energy consumption of the individual nodes is expressed in terms of Joules (J).

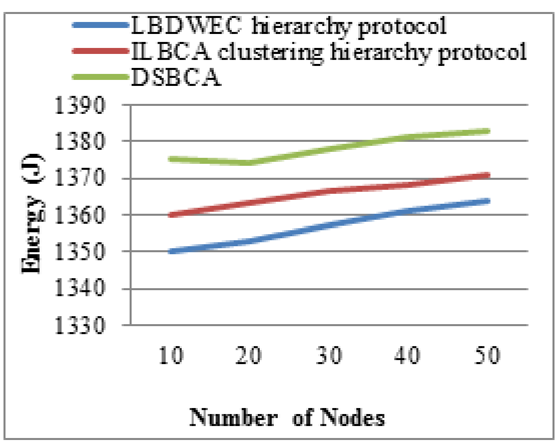

Figure 3. Comparison of energy consumption vs. number of nodes.

Figure 3 demonstrates the graphical representation of energy consumed by different nodes of a MANET for various military applications. The energy consumption of the LBDWEC hierarchy protocol is comparatively lower than DSBCA and ILBCA clustering hierarchy protocol. Based on the computed energy values the cluster formation is performed, by considering the energy of every individual node.

4.2 Lifetime Evaluation

Figure 4 demonstrates the lifetime of the mobile ad hoc network using the LBDWEC hierarchy protocol in comparison with DSBCA and ILBCA clustering hierarchy protocol's effective time. The figure illustrates the lifetime of the network decreases when the number of nodes increases for all the three schemes. The energy consumption of the cluster increases when the number of nodes increases with the load balancing in ILBCA clustering hierarchy protocol and DSBCA. In LBDWEC hierarchy protocol the lifetime of the mobile ad hoc network doesn't change much when the number of nodes increases. This is due to the small data effective time meets all the queries in the desired ILBCA clustering hierarchy protocol. When compared to the DSBCA and ILBCA clustering hierarchy protocol, the network shows higher lifetime with LBDWEC hierarchy protocol.

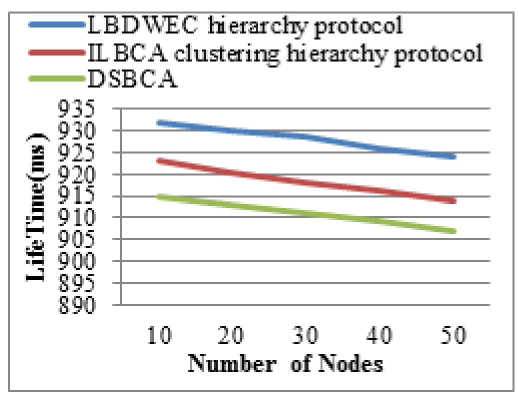

Figure 4. Comparison of network lifetime vs. number of nodes.

4.3 Delay Evaluation

The average delay occurs during data storage is demonstrated in Figure 5 using the three schemes, namely ILBCA clustering hierarchy protocol, DSBCA and the proposed LBDWEC hierarchy protocol. LBDWEC hierarchy protocol achieves much lesser average delay when compared to the existing DSBCA, ILBCA clustering hierarchy protocol. The data routing in the proposed system is comparatively easier than the existing methods. The data generated by the nodes are stored locally using the LBDWEC hierarchy protocol, thus decreases the average delay while storing and retrieving the data.

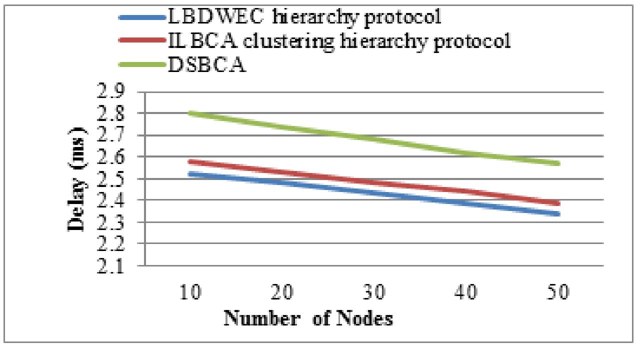

Figure 5. Comparison of delay vs. number of nodes.

4.4 Throughput Evaluation

The comparison of the throughput among the proposed LBDWEC hierarchy protocol and the existing DSBCA, ILBCA clustering hierarchy protocol is shown in Figure 6. The proposed LBDWEC hierarchy protocol accomplishes higher throughput compared to the existing ILBCA clustering hierarchy protocol, DSBCA algorithms. Thus, within a short hop count the probability of assembling the event data is higher in the proposed LBDWEC hierarchy protocol.

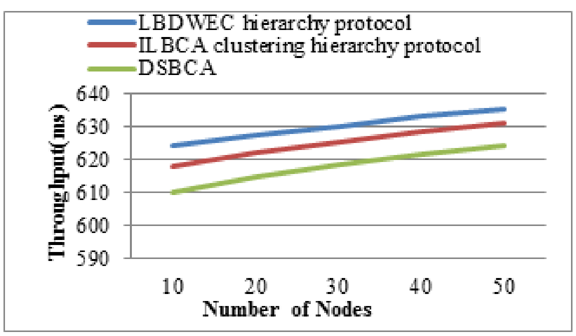

Figure 6. Comparison of throughput vs. number of nodes.

4.5 Packet Delivery Ratio (PDR) Evaluation

The graphical representation of the message delivery ratio with respect to the number of nodes is shown in the Figure 7 comparing the proposed and the existing clustering hierarchy protocol. PDR- Packet Delivery Ratio is given by the ratio of total message transmitted by the source to the total message received at the destination. In the existing methods, packet dropping may be encountered due to buffering and the congestion in the cluster heads. By maintaining a proper load balancing method, LBDWEC hierarchy protocol improves the packet delivery ratio.

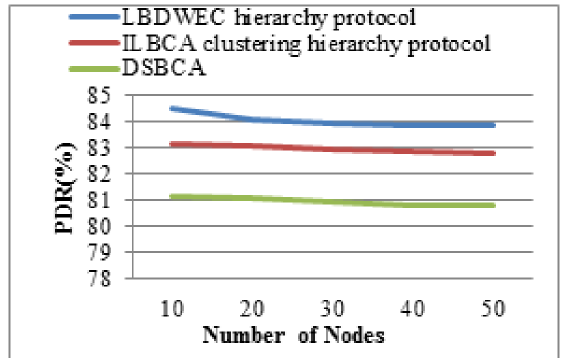

Figure 7. Comparison of PDR vs. number of nodes.

4.6 Load Balancing Factor

Load balancing factor is given by,

$$LBF = \frac{k}{\sum_{i=1}^{k} |(x_i - \mu)|^2}$$

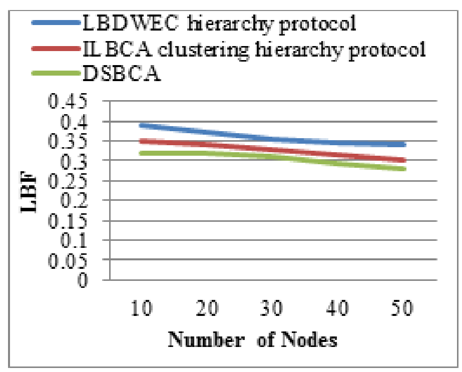

Figure 8. Load balancing factor Vs number of nodes.

An enhanced load distribution can be encountered when the load balancing factor is higher and liable to be infinity. In the existing DSBCA, ILBCA clustering hierarchy protocol non-uniform load distribution is achieved since it doesn't have any limited members in the cluster heads. The proposed LBDWEC hierarchy protocol provides uniform distribution of load and a better load balancing factor is achieved. This is shown in the Figure 8.

5. Conclusion

Ad hoc network is an easily deployable network with no fixed infrastructure and no preceding investments for accessing and manipulating data anywhere and anytime by the end users in a short span of time. This paper proposes an improved Load Balanced Distributed Weight-based Energy-efficient Clustering (LBDWEC) hierarchy routing protocol algorithm for proper load balancing in the clusters of the MANET for the military applications. The selection of Cluster Head (CH) is based on electing the active clusters on a priority basis. Cluster formation is based on the partitioning of cluster head, weak nodes and the strong nodes. The evaluation of the strong and the weak nodes are based on the network density, residual energy and transmission. It uses a routing algorithm to balance the node among the cluster network. To improve the performance, the uniform distribution of the load to the cluster is made with the proposed LBDWEC routing protocol. The PDR, E2E delay, energy consumption, lifetime and the throughput attainment shows the proposed algorithm is efficient compared to the existing methods. The future work may be extended with optimizing the cluster head location and adopting cluster based algorithm.

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