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Weighted Double Cluster Head Based Approach for Enhancing Route Stability in MANETS

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Abstract: Routing in MANET must be efficient and resource-saving. One way to reduce routing control traffic is to divide the network into clusters. Clustering of nodes into groups efficiently minimizes flooding and routing traffic overhead. The main issue in cluster based routing is to elect an appropriate cluster head. Because, cluster heads may move often due to high mobility that leads to frequent re-clustering. Most of the existing cluster based routing protocols were based on single cluster head election. The elected cluster head consumes more battery power than other nodes as it has the extra responsibility of forwarding packets; it is very difficult to maintain network stability. Therefore, we propose a new double cluster head based routing protocol to improve network stability and to reduce frequent path failures. The performance of the proposed scheme is evaluated with NS2 simulator and shows better performance in terms of the packet delivery ratio, throughput and delay when compared to a distributed weighted Cluster Based Protocol (CBPMD).

Key words: MANET, clustering, flooding, stability, protocol

INTRODUCTION

Mobile wireless networks are gaining its popularity in recent years. It has two variations. They are infra structured mobile network and infrastructure less mobile network, commonly known as ad hoc network. The types of ad hoc networks are as follows: Mobile Ad hoc Networks (MANETs), Vehicular Ad hoc Networks (VANETs), internet based Mobile Ad hoc Networks (iMANETs), Intelligent Vehicular Ad hoc Networks (InVANETs) (Bokhari *et al*., 2012).

MANET: Mobile ad hoc network has no fixed routers; all nodes are capable of movement and can be connected dynamically in an arbitrary manner. Nodes of these networks function not only as an end system but also as a router to discover and maintain routes to other nodes in the network. Example applications of mobile ad hoc networks are: emergency search and rescue operations, conventional meetings in which persons wish to share information and data acquisition operations on inhospitable environment. Research issues in MANETs are generally categorized into several topics such as routing, energy management, fault tolerance, security (Sumathi and Sumathi, 2011).

Routing in MANET: The primary goal of ad hoc network routing protocols is to provide correct and efficient route establishment between a pair of nodes, so that the messages may be delivered on time (Agarwal *et al*., 2012). Route construction should be done with a minimum of overhead and bandwidth consumption (Aruna and Subramani, 2014). Because of the limitations of power, transmission range and node mobility, path failures are very frequent in this type of networks. To accommodate frequent path failures, special routing protocols are necessary (Aruna and Subramani, 2014).

Basically, routing protocols in MANET can be broadly classified as proactive, reactive and hybrid routing. In proactive or table-driven protocols each node maintains a routing table, containing routing information on reaching every other node in the network. All the nodes update these tables so as to maintain a consistent and up-to-date view of the network. DSDV (Destination-Sequenced Distance Vector) is one of the popular proactive routing protocols.

In reactive or on-demand routing, all up-to-date routes are not maintained at every node. Instead, the routes are created as and when needed. When source wants to send data to the destination, it invokes a route discovery mechanism to find the path to the destination. DSR (Dynamic Source Routing) AODV (Ad hoc On-Demand Distance Vector Routing) are some of the popular reactive routing protocols.

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Hybrid protocols combine the benefits of both proactive and reactive routing and overcome their shortcomings. Normally, hybrid routing protocols for MANETs exploit hierarchical network architecture. That is, proactive and reactive routing approaches are exploited in different hierarchical levels, respectively (Aruna and Subramani, 2014). That is if the mobile nodes in MANET are assigned different roles and functionalities, the network topology is said to be hierarchical.

In cluster-based hierarchical routing, nodes are hierarchically organized into clusters or groups based on their relative proximity to one another. It greatly increases the scalability of routing in ad hoc networks by increasing the robustness of routes. Example: Cluster Gateway Switch Routing (CGSR) (Naser, 2014).

Clustering in MANET: Clustering technique is one of the most important techniques that help to provide resource management in MANET (Chauhan *et al*., 2011). In this technique, the nodes in the network can be either grouped into a number of overlapping or dis-joint clusters. The cluster-based MANET defines three types of nodes as shown below:

- Cluster Head (CH): it acts as a coordinator within its group or cluster
- Cluster member: it is ordinary nodes that communicate only with its CH
- Gateway node: it is a node that is within the transmission range of more than one (Zangi *et al*., 2012)

Problem identification: One of the major challenges of a cluster based routing protocol is the election of an efficient cluster head. The cluster head can be elected either by considering single performance metric or multiple performance metrics. Multiple metrics based clustering schemes outperforms single metric based clustering scheme hence, it takes multiple parameters such as degree, degree difference, mobility, remaining battery power, etc., therefore, in the proposed clustering algorithm, researchers take multiple performance factors for the selection of cluster head.

Another important issue of cluster based routing is to address the mobility of CH during the route discovery process. During the route discovery phase, only cluster heads and gateway nodes are flooded with Route Request (RREQ) and Route Reply (RREP) packets. Therefore, due to the nature of high mobility of ad hoc networks, any intermediate CH or gateway may move during the route reply process. That is the RREP packet while on its way to the source node, it could not recognize the new intermediate CHs formed and finally when the timer expires this whole route discovery process has to be repeated again. So, in order to address the cluster head mobility, we propose a double cluster head based protocol to facilitate route discovery and maintenance.

LITERATURE REVIEW

According to the way of grouping nodes within clusters, several techniques have been proposed (Naser, 2014). Most of the techniques consider a single performance factor for election of CH. These performance factors may be node ID, connectivity, mobility, battery power, etc. but considering only one performance factor for calculating quality of nodes as a CH may results in degradation of performance of the network. Some research works have been done in the area where a No. of performance factors is combined to find the quality of nodes as CHs. This study gives a review of clustering algorithms.

Single metric based clustering: These schemes consider only one performance factor for clustering decisions. A No. of clustering algorithms has been proposed under this scheme. Some of them are: in Lowest-ID Cluster algorithm (LIC) (Agarwal *et al*., 2012), a node with the minimum-ID is chosen as a CH. That is each node is assigned a unique-ID. Periodically, the node broadcasts the list of nodes that it can hear. A node with lowest ID will act as a CH. Drawback of LID algorithm is that certain nodes are prone to power drainage due to serving as CHs for longer period of time.

In Highest Connectivity Clustering algorithm (HCC) (Agarwal *et al*., 2012), the degree of a node is computed based on its distance from others. Each node broadcasts its ID to the nodes that are within its transmission range. The node with maximum number of neighbors (i.e., maximum degree) is chosen as a CH. The drawback of this algorithm is that it does not have any restriction on the upper-bound on the number of nodes in a cluster. And when No. of nodes in a cluster is increased, the throughput gets decreased. The re-affiliation count of nodes is high due to node movement and the CH may not be re-elected even if it loses one neighbor.

K-CONID (Agarwal *et al*., 2012) combines two clustering algorithms such as LID and HCC. In order to select CHs, connectivity is considered as a first criterian and lowest ID is considered as a second criterian.

Adaptive Multihop Clustering algorithm (Agarwal *et al*., 2012) sets upper bound and lower bound on the No. of cluster members with in a cluster that a CH can handle. When the No. of cluster members in a cluster is less than the lower bound, the cluster needs to merge with one of the neighboring clusters. And if the No. of cluster members in a cluster is greater than the upper bound, the cluster is divided into two clusters.

Mobility-based d-hop clustering (Aruna and Subramani, 2014) partitions an ad hoc network into d-hop clusters based on mobility metric. The objective of forming d-hop clusters is to make the cluster diameter more flexible. Local stability is computed in order to select some nodes as CHs. A node may become a CH if it is found to be the most stable node among its neighbors. Thus, the CH will be the node with lowest value of local stability among its neighbors.

The 3-hop Between Adjacent Cluster heads (3-hBAC) algorithm (Agarwal *et al*., 2012) introduces a new node status, called “cluster guest” which means this node is not within the transmission range of any CHs but within the transmission range of some cluster members. When a mobile node finds out that it can not serve as a CH or join a cluster as a cluster member but some neighbor is a cluster member of some cluster, it joins the corresponding cluster as a cluster guest.

Load Balancing Clustering (LBC) (Agarwal *et al*., 2012) provide a nearby balance of load on the elected cluster heads. Once a node is elected as a CH, it is desirable for it to stay as a CH up to some maximum specified amount of time or budget. Initially, mobile nodes with the highest ID in thier local area will win the cluster head role. LBC limits the maximum time units that a node can serve as a CH continuously so, when a CH exhausts its duration budget, it resets its VID to 0 and becomes a normal member node. But the drawback is that the cluster head serving time alone may not be a good indicator of energy consumption of mobile nodes.

Multiple metric based clustering: Combined metrics based clustering or weight based clustering takes a No. of metrics into account for cluster configuration. Main advantage of this scheme is that it can flexibly adjust the weighting factors for each metric to adjust to different scenarios. For example, in a system where battery power is more important, the weight factor associated with energy capacity can be set higher. The choice of the CH is based on a generic weight (i.e., a real number ≥ 0) associated with each node. The node with the highest weight in its area will act as a CH. And when the weight of a node is inversely proportional to its speed, the mobile nodes with lowest weight will be selected as cluster heads. Since, these nodes either do not move or move slower than other nodes thier cluster is guaranteed to have a longer life.

The Weight-based distributed Clustering Algorithm (WCA) (Aruna and Subramani, 2014) takes into consideration, the ideal degree, transmission power, mobility and battery power of mobile nodes. Depending on specific applications, any or all of these parameters can be used in the metric to elect the CHs. This is based on fully distributed approach where all the nodes in the mobile network share the same responsibility and act as CHs. The time required to identify the CHs depends on the diameter of the underlying network graph. This method keeps a predefined threshold value for No. of mobile nodes in a cluster. The CH election procedure is invoked only on-demand thus reduces routing control overhead.

Advanced efficiency and stability combined weight based Distributed Clustering algorithm (Muthuramalingam and Rajaram, 2010) proposes combined weight-based distributed clustering approach with hierarchical structure that can able to maintain MANET topology as stable as possible.

In order to decrease the initial overhead that is generated during clustering setup phase this algorithm uses “local minima” instead of using “global minima”. That is, minimum weight is calculated for all nodes in the network to select and manage CH.

The cluster head in each cluster group is selected with a smallest weight among its one-hop neighbors and plays the role of CH within the range of predefined threshold. In this algorithm, if a node disconnected directly from the CH due to mobility and if distribute gateway affiliated to the same cluster, it can continue to connect with its cluster-head through the distributed gateway. Therefore, the cluster member does not needs to perform re-clustering process even though it moves, thus improves stability of the entire network.

PROPOSED SOLUTION

Overview: The proposed protocol which is named Stable Weighted Double Cluster-head Based Routing Protocol (SWDCBRP) is a double cluster head based routing in which two CHs namely primary and secondary CH will be elected for each cluster. SWDCBRP aims at improving route stability by reducing frequent path failures through primary and secondary CHs.

Estimation of metrics

Estimation of Mobility (M): Compute the average speed for every node until the current time T. This gives the measure of the mobility M_v, based on the X co-ordinate and Y co-ordinate of the mobile node at all previous time instance t (Verma and Vatsa, 2012):

$$M_v = \frac{1}{T}\sum_{t=1}^{T}\sqrt{(X_t - X_{t-1})^2 + (Y_t - Y_{t-1})^2} \quad (1)$$

Estimation of Link Quality (LQ): Calculate the Mean Distance (MD) between a mobile node 'A' and all its neighboring nodes 'N' as:

$$MD_A = \frac{1}{N}\sum_{i=1}^{N} D_{A,\,i} \quad (2)$$

Then, calculate the stability, i.e., link quality of a mobile node 'A' by finding the difference between the mean distance at time 't' and 't-1' as:

$$LQ_A = MD_t - MD_{t-1} \quad (3)$$

Estimation of remaining energy (R_s):

$$R_S = E_i - E_c \quad (4)$$

Where:
E_i = Initial energy
E_c = Energy consumed
R_S = Energy left (i.e., residual energy)

Estimation of available Band Width (BW): Available bandwidth of a mobile node can be estimated as (Sumathi and Sumathi, 2011):

$$\text{Available Band Width (BW)} = \text{Channel capacity} - \text{Utilized band width} \quad (5)$$

Cluster formation: The following assumptions are made before cluster formation:

- Each mobile node joins exactly with one cluster-head
- The optimal number of nodes in the cluster is assumed to be 'n'
- The co-efficient values used in the weight calculation of nodes are assumed the following: w1 = 0.3, w2 = 0.3, w3 = 0.2, w4 = 0.2. The sum of these co-efficient is 1

These co-efficient values are used to normalize the factors such as mobility, link quality, residual energy and bandwidth efficiency of the mobile node, during node weight calculation. Diagrams of cluster formation phase is shown in Fig. 1.

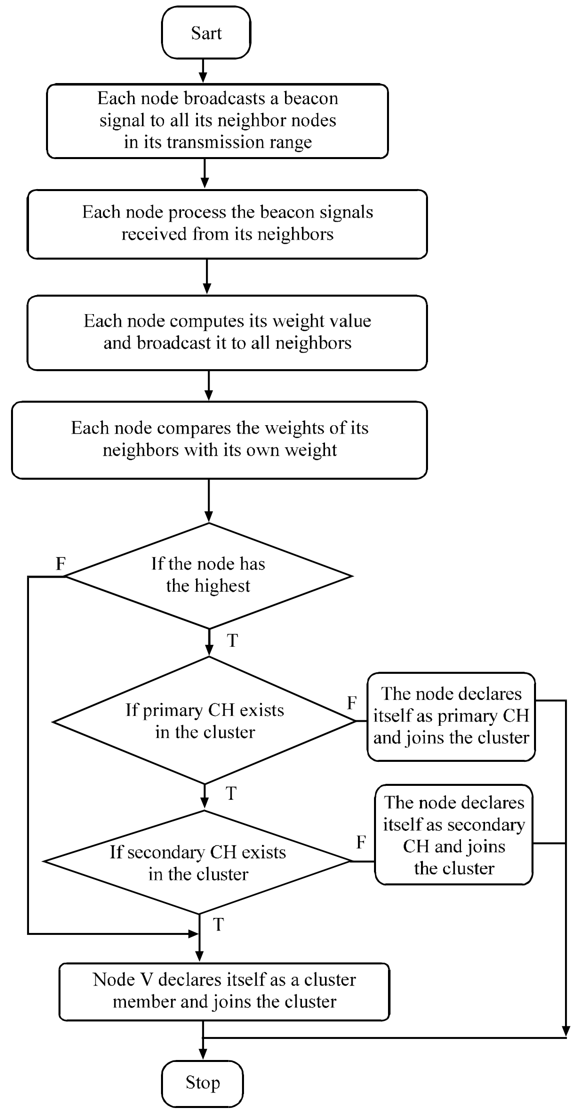

Fig. 1: Cluster formation phase

Double cluster head selection: Initially, each mobile node broadcasts a beacon message BCN to notify its presence to its neighbors. The BCN contains the state of the node.

Each node builds its neighbor list based on the beacon messages received. The cluster-head election is based on the weight values of the nodes and the node having the highest weight is chosen as a primary cluster-head. And the node with second highest weight is chosen as secondary cluster-head. Based on the following algorithm, each node computes its weight value:

Step 1: Broadcast a beacon signal to all its neighbor nodes in the transmission range.
Step 2: Process the beacon signals received from the neighbor nodes in the network and form the connection matrix 'A'.
Step 3: Compute the average speed for a mobile node until the current time T. This gives the measure of the mobility M, based on the X co-ordinate and Y co-ordinate of the mobile node at all previous time instance 't' (Pandey and Shukla, 2011) using Eq. 1.
Step 4: Compute the link quality LQ, i.e., stability of the mobile node by finding the ratio of first signal and last signal received,using Eq. 2.
Step 5: The energy consumption is assumed to be more for a cluster-head when compared to an ordinary node. Because, cluster-head is periodically sending beacon signals to its member nodes and routing the packets to its neighbor clusters, using Eq. 3.
Step 6: Bandwidth efficiency can be calculated by finding the difference between channel capacity of the mobile node and its utilized bandwidth, using the Eq. 4.
Step 7: The combined weight value W_v for a node is calculated based on the following equation:

$$W_v = \frac{W1\times LQ+W2\times R_S+W3\times BW}{W4\times M_v}$$

where, LQ is the link quality, R_s is the residual energy, BW is the available bandwidth and M_v is the mobility of the mobile node.
Step 8: Broadcast W_v to all its neighbor nodes.
Step 9: Process the signals received from the neighbor nodes and identify the weights of its neighbors.
Step 10: Compare the weights of its neighbor nodeswith its weight $W_t(V)$.
Step 11: The node with the highest W_v is elected as primary cluster head.
Step 12: The node with second highest W_v is elected as secondary cluster head. All the neighbors of the chosen primary and secondary cluster heads are no more allowed to participate in the election process.
Step 13: All the above steps are repeated only for the remaining nodes which is not yet elected as primary or secondary cluster head or assigned as a cluster member to a cluster group.

Pseudo code for the formation of cluster using the proposed SWDCBRP algorithm for Double Cluster Head election (DCH):

DCH (node V)
Begin
Broadcast a beacon signal to all its neighbor nodes in the transmission range;
Process the beacon signals received from the neighbor nodes in the network and form the connection matrix 'A';
Compute the weight value '$W_t(V)$' for a new node V as:

$$W_t(V) = \frac{W1\times LQ+W2\times R_S+W3\times BW}{W4\times M_V}$$

Broadcast $W_t(V)$ to all its neighbor nodes;
Process the signals received from the neighbor nodes and identify the weights of its neighbors;
Compare the weights of its neighbor nodes with its weight $W_t(V)$.
If ($W_t(V)$ has the highest weight) && (Primary CH does not exist in the cluster) then
{
Node V declares itself as primary CH and broadcasts this message to all its one hop neighbor nodes;
}
Else If($W_t(V)$ has the highest weight) && (Primary CH exist in the cluster) then
{
If (secondary CH does not exist in the cluster) then
{
Node V declares itself as secondary CH and broadcasts this message to all its one hop neighbor nodes
}
Else
{
Node V sends a join request to join the cluster formed by the neighbor.
}
}End;

An example of three non-overlapping clusters with primary and secondary cluster heads with gateway nodes are shown in Fig. 2:

Cluster maintenance: It is the second phase of the cluster algorithm. This phase performs two distinct operations: node movement to the outside of its cluster boundary and threshold property. Diagram of cluster maintanance phase is shown in Fig. 3.

Node movement: The movement of nodes can be in the form of node joining or node leaving a cluster. If the moving node is a member node, it will not affect the cluster structure. If the moving node is a primary or secondary cluster head, the cluster structure has to be reorganized by invoking the clustering algorithm to elect cluster heads. But, in the proposed clustering algorithm, the primary and secondary CH has been chosen based on the combined metrics such as mobility, link quality, residual energy and bandwidth. Therefore, cluster head movements would not happen frequently. But, due to high mobility, cluster heads may move. If primary cluster head is about to move from its boundary, it signals the secondary cluster head and secondary CH would take the role of primary cluster head, thus avoids path failure and improves cluster stability. Proposed pseudo code for the verification of node movement:

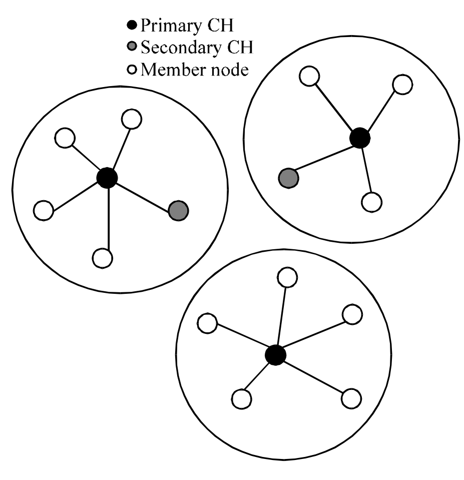

Fig. 2: Cluster formation in MANET

```
Node_Movement (node V)
Begin
If (node V is a leaving node) then
{
        Invoke Min_Threshold ( ) algorithm in order to maintain cluster stability;
}
Else If (node V is a joining node)
{
        Invoke DCH ( ) election algorithm in order to join into the cluster;
}
End;
```

Threshold property: Since the cluster heads involve in routing process, its energy decreases more rapidly when compared to cluster members. Similarly, the mobile nodes have less bandwidth capacity when compared to nodes in wired network. Therefore, when the primary CH battery or bandwidth consumption falls below the threshold, then it is no longer able to perform its activities and it sends a life down message to secondary CH. Then, the secondary CH would take the in charge of primary CH. The clustering algorithm is invoked to elect secondary CH. Proposed pseudo code for the verification of threshold property for a mobile node:

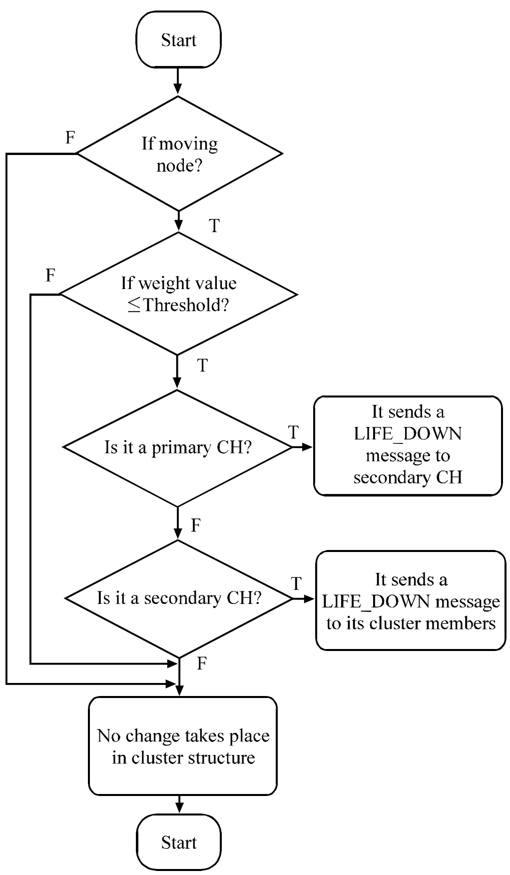

Fig. 3: Cluster maintenance phase

```
Min_Threshold (Node V)
Begin
Verify the weight value Wt (V) of node V;
If (Wt(V) ≤ threshold_value ) then
{
     If (moving node V is a Primary CH)
     {
            It sends a LIFE_DOWN message to Secondary CH to relinquish its role
            and to process its pending transactions and joins the cluster as an ordinary
        cluster member
     }
     Else If (moving node V is a Secondary CH)
     {
Send a LIFE_DOWN message to its one-hop neighbors; and all cluster members participate in the re-election process by invoking DCH election algorithm and the node with highest weight will declare itself as a new secondary CH;
     }
     Else If (moving node V is a cluster member)
     {
            Re-election is not needed;
     }
}
End;
```

SIMULATION RESULTS

Simulation model and parameters: The Network Simulator (NS-2) (Khiavi *et al*., 2012) is used to simulate the proposed architecture. In the simulation, mobile nodes are randomly deployed in 750×750 m region for 50 sec of simulation time. All nodes have the same transmission range of 250 m. The simulated traffic is Constant Bit Rate (CBR). The simulation settings and parameters are summarized in Table 1.

Performance metrics: The proposed SWDCBRP is compared with the CBPMD protocol. The performance is evaluated mainly, according to the following metrics:

- Packet delivery ratio: it is the ratio between the number of packets received and the number of packets sent
- Packet drop: it refers the average number of packets dropped during the transmission

Table 1: Simulation settings

Parameters	Values
No. of nodes	100-500
Node speed	5-25 m sec^{-1}
Area size	750×750 m
Mac	IEEE 802.11
Transmission range	250 m
Simulation time	50 sec
Traffic source	CBR
Number of CBR connections	10
Packet size	512
Rate	50 kb
Initial energy	20 J
Transmission power	0.660
Receiving power	0.395

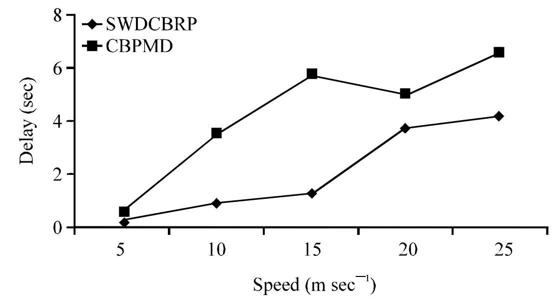

Fig. 4: Speed vs. delay

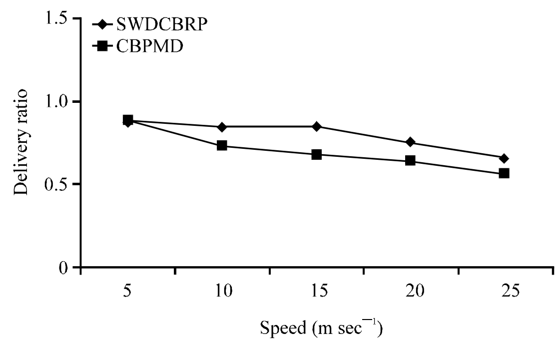

Fig. 5: Speed vs. delivery ratio

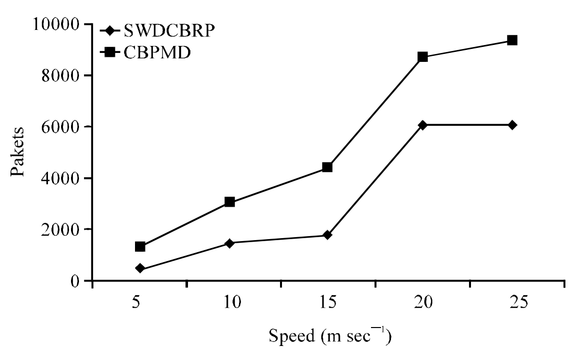

Fig. 6: Speed vs. packet drop

- Delay: it is the average end to end delay measured in seconds
- Energy consumption: it is the amount of energy consumed by the nodes to transmit the data packets to the receiver
- Throughput: it is the average number of packets received per second

Results

Based on node speed: The speed of the mobile node is varied from 5-25 m sec^{-1} for 100 nodes. Figure 4-8 show the results for delay, delivery ratio, packet drop,

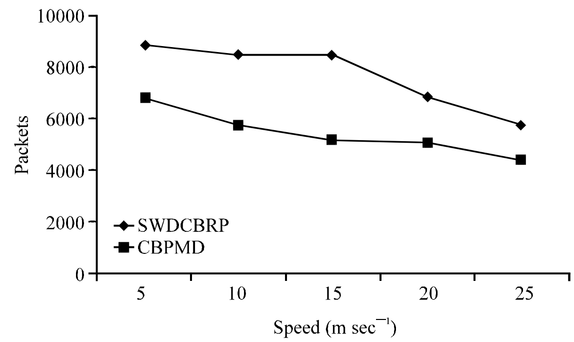

Fig. 7: Speed vs. throughput

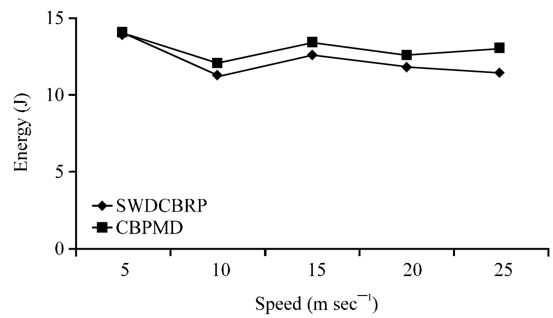

Fig. 8: Speed vs. energy

throughput and energy consumption respectively, for SWDCBRP and CBPMD protocols when the node speed is increased. From Fig. 4-8, we can see that SWDCBRP outperforms CBPMD in terms of delay by 53%, in terms of delivery ratio by 12%, in terms of packet drop by 50%, in terms of throughput by 28% and in terms of energy consumption by 6% when compared to CBPMD.

CONCLUSION

Mobility of nodes cause frequent route failure. Therefore, it is evident from the simulation results that the proposed protocol SWDCBRP gives better results in terms of increased throughput and packet delivery ratio when compared to CBPMD. As a result, average end to end delay is reduced and by designating double cluster heads, link breakages are avoided.

REFERENCES

Agarwal, R., R. Gupta and M. Motwani, 2012. Review of Weighted Clustering alogirthms for mobile ad hoc networks. GESJ: Comput. Sci. Telecommun., 33: 72-77.

Aruna, S. and A. Subramani, 2014. Comparative study of weighted clustering algorithms for mobile ad hoc networks. Int. J. Emerging Technol. Adv. Eng., 4: 307-311.

Bokhari, D.M., H.S. Hamatta and S.T. Siddigui, 2012. A review of clustering algorithms as applied in MANETs. Int. J. Adv. Res. Comput. Sci. Software Eng., 2: 364-369.

Chauhan, N., L.K. Awasthi, N. Chand and A. Chugh, 2011. A distributed weighted cluster based routing protocol for MANETs. Sci. Res. J. Wireless Sensor Network, 3: 54-60.

Khiavi, M.V., S. Jamali and S.J. Gudakahriz, 2012. Performance comparison of AODV, DSDV, DSR and TORA routing protocols in MANETs. Int. Res. J. Applied Basic Sci., 3: 1429-1436.

Muthuramalingam, S. and R. Rajaram, 2010. A transmission range based Clustering algorithm for topology control manet. Int. J. Appl. Graph Theory Wireless Ad Hoc Networks Sensor Networks, 2: 68-76.

Naser, M.A., 2014. Study analysis and propose enhancement on the performance of cluster routing algorithm in a mobile ad hoc network. J. Adv. Comput. Sci. Technol Res., 4: 12-21.

Pandey, S. and N.K. Shukla, 2011. Improved weighted clustering algorithm for mobile ad hoc networks. Int. J. Eng. Manage. Sci., 2: 20-25.

Sumathi, N. and C.P. Sumathi, 2011. Energy and bandwidth constrained QoS enabled routing for MANETs. Int. J. Comput. Networks Commun., 5: 37-46.

Verma, A. and A.K. Vatsa, 2012. Optimized Stable and Reliable Routing (OSRR) mechanism in MANET. Int. J. Sci. Technol., 1: 466-475.

Zangi, F.R., S. Mavizy and J. Badali, 2012. A stable distributed clustering algorithm for mobile ad hoc networks. Int. J. Comput. Sci. Issues, 9: 245-250.