A Mobility-Aware Cluster Based Routing for Large Wireless Mesh Network

Tapodhir Acharjee
Department of Computer Science & Engineering
Assam University, Silchar
Assam, India

Sudipta Roy
Department of Computer Science & Engineering
Assam University, Silchar
Assam, India

***Abstract*— Recently, Wireless Mesh Network has become one of the most important wireless technologies around the world mainly because of its use in low-cost home broadband facility. Wireless mesh network spreading across a city or a university campus is now getting more prominence. In this scenario, there are needs for more efficient routing protocols for Wireless Mesh network which may support larger areas as well as more mobility. Hierarchical routing protocols are found to be better suited for networks with scalability. In the hierarchical routing protocols the nodes are grouped into clusters. The clusters will be consisting of Cluster head, cluster member and Gateway nodes. Then the routing will be possible via different cluster heads, gateway nodes. Here we propose a mobility-aware hierarchical cluster based routing protocol for large Wireless mesh network. We consider mobility and scalability as the two important criteria. We compare the simulation results with another cluster based routing technique and found that our proposed method works better in enhanced scalability.**

Keywords*— *Wireless Mesh Network; Scalability; Mobility; Cluster Head ; gateway

I. INTRODUCTION

Wireless Mesh Network (WMN) has become a very important wireless technology for several new and promising applications, e.g., broadband home networking, community and neighborhood networks, battlefield surveillance, VoIP, intelligent transportation systems etc. Most importantly, it is gaining more attention as a tool for Internet service providers (ISPs) and other end-users to provide consistent wireless broadband service access at minimum cost. Thus, WMN is said to be a promising wireless technology that can overcome the limitations of WLAN[1].

WMNs architecture has been classified into three categories, i.e. Infrastructure WMNs, client/Infrastructure-less WMNs and Hybrid WMNs .This classification is based on the fact that the mesh clients are having any infrastructure created by mesh routers or not or it is the combination of both(hybrid)

For providing last mile connectivity, scalability is an important issue for Wireless Mesh Network. Cluster based and Hierarchical routing protocols are found to be quite efficient in this case. All the important routing performance parameters like, throughput, packet delivery ratio, end to end delay, bandwidth consumption, energy consumption may be improved with good clustering techniques [2]. Efficient clustering protocols try to solve different design goals for the application they are designed for.

The remaining sections of the paper are structured as follows: In section 2, a study about related methods is made. Section 3 discusses the proposed method. In section 4, Simulation results are presented and analysed. Finally, a conclusion is drawn in section 5.

II. RELATED STUDY

Various clustering algorithms are proposed in the literature especially, for Mobile Ad-hoc Networks(MANETs) and Sensor Networks(WSNs). Very few cluster based routing algorithms are proposed for WMNs. In this section we discuss some cluster based schemes proposed for various types of wireless Networks.

A. Mobility prediction-based clustering (MPBC) scheme[3]

A mobility prediction-based clustering (MPBC) scheme for MANETs with high mobility nodes was proposed by Ni et al. The relative speed estimation for each node in the whole network plays a significant role in this algorithm. Each node broadcasts Hello packets periodically in a dedicated control channel during the clustering phase. The authors presented two different approaches of estimating the relative speed of a given node to another node, depending on whether the two nodes are approaching to or going far from each other. Based on the Hello packets exchanges, every node estimates its average relative speed with respect to its neighbors. The Nodes which are having lowest relative mobility are selected as CHs. The situations created by relative node movements including the case when a CM moves out of its CH's coverage area or CH rotation are dealt in the cluster maintaining stage with the help of predicted mobility information. When two CHs move within the reach of each other, one is required to give up its CH role. This approach helps in stable clusters formation by extending the connection lifetime. But overlapping clusters may be formed here.

B. MOBIC[4]

This technique is based on "Least Clusterhead Change(LCC)" algorithm proposed by Chiang et al[5].Here ,the assumption is that a node with high mobility should not be elected a CH, otherwise reclustering will be frequent as the clusters will

978-1-5090-4620-1/16/$31.00 ©2016 IEEE

break very often . Each node calculates the pairwise relative mobility metrics by measuring the received power levels of two successive "Hello" message transmissions from every neighbor and the aggregate relative mobility metric before sending the next broadcast packet. Cluster Contention Interval (CCI) is used in MOBIC to avoid unnecessary reclustering. After the CCI time period has expired, if two CHs are still neighbors, the one with the lowest ID shall take up the role of CH. Thus, the CHs maintenance is reduced here They have shown by simulations that MOBIC results in more stable cluster formation over the LCC algorithm. However, the limitations of LCC algorithm are not completely eliminated. Number of cluster as well as overhead is quite high here.

C. *Neighbourhood Stability based mobility prediction[6]*

Here, an MH is considered for taking up the responsibility as CH, if its neighbourhood is more stable compared to the other candidate hosts' neighbourhood. To estimate the probability of the stability of neighbourhood for each MH, the authors proposed a way to find out the movements of MHs after any given time. They combined the mobility prediction scheme and highest degree clustering technique, and proposed a distributed algorithm which builds a small and stable virtual backbone for the whole network. A node which is having the highest weight among its neighbors is selected as the CH. The problem of changing the CH frequently caused mobility is eliminated here by allowing a node to become a CH or joining a new cluster without initiating a reclustering phase. Overlapping clusters formation is possible here.

D. *Cluster Based Routing Protocol (CRP)[7,8]*

Mesh point portal (MPP) elects one node as a cluster head (CH) and some node as member of this cluster and stores the cluster head information like CH id, CH neighbours etc in its own table. They gave some extra power and responsibility to mesh portal point (MPP) and cluster head of each group. The Initial broadcast to all nodes is reduced here by partitioning the network into the clusters. As each cluster has one cluster head that have all information about its neighbor and so path requests are only multicast to different cluster heads only. The scheme distributes the whole mesh network into groups of clusters.

The drawbacks of CBRP are that the load on MPP is quite high here and also, even when destination MP is in the same cluster, the Mesh Points (MPs) must communicate with the CH for communicating with the other MP.

E. *Hierarchical Cluster Based Routing For Wireless Mesh Networks Using Group Head[9]*

.

This method is an extension to the CBRP . Here, the WMN consists of several domains and each domain is controlled by a Group Head(GH) as shown in fig 1. GH is used to decrease the load on the MPP. Under each domain there are a number of clusters. Each cluster will be having one Cluster head(CH). MPP maintains the information about all the GHs. An MP cannot be CH and GH at the same time

Here, MP10, MP2 and MP7 are group heads and maintain two clusters each. Big circle is denoting one cluster and every cluster is having one cluster head(CH) .Here MP15, MP1, MP14,MP3,MP19 and MP11 are cluster heads.

This approach have been further modified in [10].Here, the authors have included an Assistant Cluster head(ACH) to decrease the load in the CH. Also, the authors have shown that the modified method improves the overall performance of the WMN in case of scalability.

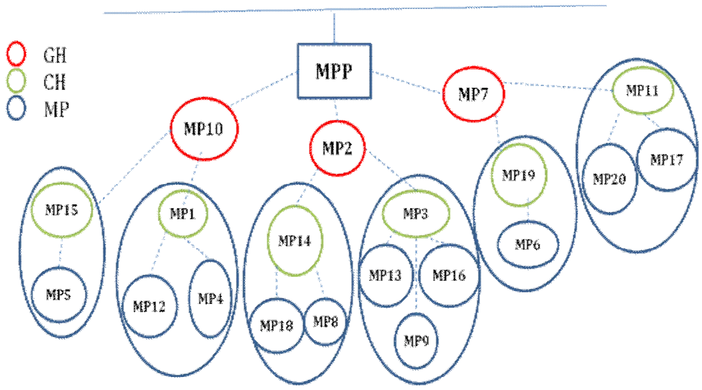

Fig. 1. Wireless Mesh Network divided in Domains

III. PROPOSED ROUTING PROTOCOL

Before presenting our proposed method, we introduce the different input parameters which are used to find out the final score of each node. Here we give most significance to mobility of a node, the degree of a node is given more significance than the other two parameters namely, residual energy and distance between node and GH.

A. *Input and output Parameters*

Our proposed scheme uses three input parameters to evaluate the output parameter i.e. the final score of individual node. The four input variables are: Node degree, Node Mobility, Node Residual Power, Distance between GH and MP.

i. Node Degree(W_1)

Number of 1-hop neighbors of a node is called this node's degree. Node degree denotes the number of nodes under the coverage area of this node. CH should be the node which is having more node degree. Because this denotes the centrality of the CH node and also more number of nodes can be accommodated in a cluster. This reduces the number of cluster, which decreases overheads and increases efficiency. For a node vi ∈ V ,the node degree of vi is the number of one hop neighbour which can be represented as:

$$n\ deg(v_i) = \sum_{d=1}^{n} (v_d) \qquad (1)$$

ii. Residual Energy(W_2)

Every node is capable of measuring its own residual energy. This remaining energy measurement is also important for a CH, as it helps in choosing the node as the CH which will not be drained out of battery power in near future.

iii. Distance between Group Head and MP(W_3).

As we are following the architecture presented in fig 1, therefore, Group Heads are having very important role to play. Under a single GH there will be a number of CHs. So, routing between different clusters will be most of the time via GHs. Due to this, the nodes which are nearer to the GH will be having more preferences to be selected as CH. Distance between GH and Mesh Point(MP) can be found by using the equation no. 2, where(x_i,y_i) is the co-ordinate of mesh point and (x_j,y_j) may be the co-ordinate of GH.

iv. Node Mobility(W_4)

Node mobility is perhaps the most important parameter in our proposed approach.The nodes which are having less mobility should be preferred as CHs.The distance dist(x, y) between node x and y can be computed using the formula presented in Eq. 2:

$$\mathrm{Dist}(x,y)=\surd\{(x_i-x_j)^2-(y_i-y_j)^2\} \qquad (2)$$

Where (x_i,y_i) and (x_j , y_j)are the coordinate of node i and j respectively. The mobility for each MP from one place to another place is defined as the running average of the speed until a current time t in a network area prompt changes in the values of its coordinate parameter accordingly. This is given as shown in Eq. 3 :

$$M_v=1/T\{\sum_{i=1}^{T} \surd\{(x_i-x_{i-1})^2-(y_i-y_{i-1})^2\} \qquad (3)$$

v. Final Score**:**

To calculate the final score of a node we give more emphasis on mobility. If mobility of a node is higher, the less chance of that node to be selected as CH. Moreover, we give substantial importance on node degree also. As more number of cluster member in a cluster will lessen the number of clusters.

$$\text{Final Score}= (2*W_1 +W_2+ W_3)/W_4 \qquad (4)$$

B. Proposed cluster formation algorithm

Below we mention the proposed algorithms for cluster formation and routing for large WMNs. We assume the architecture given in fig 1 as the basis of our proposed methods.

Initially all the nodes N(x) are in undecided state. Nodes get information about their neighbor nodes by Hello packet exchange. All the nodes now compute the parameters:Node degree(N), Mobility, Distance from Group head, Residual Energy. Now, all the nodes can compute their own final score. All the neighboring nodes exchange these information. The node with the highest final score elects itself as Cluster head(CH). The node with second highest final score elects itself as Assistant Cluster Head(ACH). CH and ACH propagate the information about selection of themselves as CH/ACH to their neighbors. The node with mobility speed within a threshold and almost in the similar distance between two clusters elect itself as Gateway node between two clusters

CH/ACH includes Cluster members and GW in its cluster adjacency table and form the cluster.

Proposed Algorithm:

Input: Number of Nodes N
Output: Number of clusters with Cluster head and assistant cluster head

```
GetClustersHead(N)            // N is Number of Nodes
{                             /* N(x) is a node, whose id is x
 For Any node x < N           NeighbourInfo() returns List of
 {                              neighbour of x node */
  ParameterCalc( (N(x))
  {
   For any node N(z) < (N(x)) )
   {
    Deg=Count.NeighbourInfo( N(z)) ;
    compute M_Info(zx , zy, zx-1, zy-1, Threshold)
    compute Dist_GH(zx , zy, zx-1, zy-1)
    compute R_Energy(N(z))
    compute Total (Deg, M_Info,Dist_GH, R_Energy)
    N(z).Store_Total( Deg,M_Infoz, Dist_GH , R_Energy ,Total Scorez ))
    N(z).Send_Total(NeighbourInfo( N(z));
   }
     return Listinfo(N(x))
 }
   ExchangeInfo( NeighbourList(N(x))
    {
     E=  ParameterCalc( NeighbourList(N(x))
              For any i < E
                 {
                    if( E(i). Total < E(i+1).Total)
                     {
                       Swap(E)
                     }
                 }
            return E
    }
 CH_ACH_Election(  NeighbourList(N(x) )
    {                        //calculate highest score and sort
      L=ExchangeInfo( NeighbourList(N(x))
      CH=L(1)
      ACH=L(2)
     for any i < NeighbourList(N(x)
      {
       UpdateList(N(x).add(CH), N(x).Ach)
      }
   return UpdateList
   }  // 'UList' having similar meaning as 'UpdateList'
 NewList=getGetwayInfo(UList(N(x)), UList N(x+1))
End
```

C. Routing in proposed approach

Source node (S) checks for destination (D) in neighbor table (N) . If D is in N , S sends packet to D, otherwise S unicasts RREQ to CH. If CH is not overloaded, CH checks D in cluster adjacency table C, otherwise CH forwards RREQ to ACH. If D is in C, CH unicasts the REQ to D. D Sends RREP to S through the path where RREQ was sent. Otherwise, CH multicasts RREQ to gateway nodes. ACH check D in C table. If D is in C, ACH unicasts RREQ to D. D sends RREP to S using the path where RREQ was sent. Otherwise, ACH multicasts RREQ to gateway nodes. The receiving gateway nodes forward RREQ to CH and the process is repeated hierarchically until D is not found. If after certain timeout source CH doesn't get any reply forward RREQ to GH. GH multicasts RREQ to all CHs of clusters under it. All clusters search for the node D in their respective table by the same process. If after certain timeout GH doesn't get any reply, Forward RREQ to MPP. MPP multicasts RREQ to all GHs under it. All receiving GHs do the same process until D is found. If D is not found in MPP the MPP sends back RERR to the source node through the concerned GH and CH.

Proposed Routing Algorithm:

Input: Destination node d
Output: Route to the destination node

```
Routing(Node s, Node d )
{
  NeighbourList=NeighbourInfo( N(s))
  List=CH_ACH_Election( NeighbourList(N(s) )
  NewList=getGetwayInfo(List(N(s), List N(s+1))
  Msg1=isSameCluster(List) // if source and
  if(Msg1=RERR){    //destination are in same cluster
    Msg2=outSideCluster(NewList)
  }              // Msgi where i=1, 2, 3, 4. is a variable
else{            // if destination is outside of this cluster
    SendTo(RREP, s_Ch)
    SendTo(RREP,s_CH, s)
 }
if(Msg2=RERR){
    Msg3=sendPktInfoToGH(s_CH, D)
 }      // if D is not found in inside and outside cluster
 else{       // move to Group Head using this function
     SendTo(RREP, Gtw)
     SendTo(RREP,Gtw,s_CH)
     SendTo(RREP,s_CH, s)
}
If(Msg3=RERR){
    Msg4=sendPktInfoToMPP(s_CH, D)
 }                  // move to MPP using this function
else{
     SendTo(RREP, s_GH)
     SendTo(RREP,s_GH,s_CH)
     SendTo(RREP,s_CH, s)
 }
If(Msg4=RERR){
    SendTo(RERR, s_MPP)
    SendTo(RERR,s_MPP,s_GH)
    SendTo(RERR,s_GH, s_CH)
    SendTo(RERR,s_CH, s)
 }
 else{
     SendTo(RREP, s_MPP)
     SendTo(RREP,s_MPP,s_GH)
     SendTo(RREP,s_GH, s_CH)
     SendTo(RREP,s_CH, s)
           }
    }
End
```

IV. SIMULATION RESULTS AND DISCUSSION

Here we discuss the simulation results of our proposed approach and compare the results with hierarchical cluster based routing .We have simulated these methods in NS3 simulator 2.34[11]. Table 1 shows the simulation parameters that are considered for simulation environment. We have done the simulations ranging a number of nodes starting from 20 to 160.Obviously, much longer time is taken for formation of cluster and following that the routing in 160m nodes compared to other simulation considering less nodes.

Table 1: Simulation Environment

Parameter	Value
Simulator	NS 3.24
Network Area	1000m x 1000m
Number of Nodes	20-160
Simulation Time	382 sec
Mobility Model	Random Direction 2D model
Node placement	Random
Transmission Range	50-100 m
Mobility Speed	0-20m/s
Packet Size	512 bytes
Buffer Size	50B

We have performed the simulation for the two methods and evaluated the performance of these methods based on three important parameters, namely, throughput, packet delivery ratio(PDR) and end-to-end delay. The results are shown below:

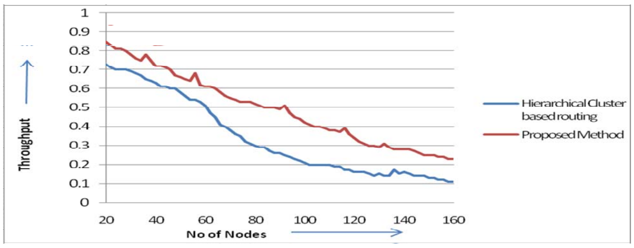

Figure 2: Variations of Throughput and Number of Nodes

Figure 2 shows that the throughput of proposed method is better than the hierarchical cluster based routing protocol. Proposed method is consistently showing better throughput and even in maximum number of nodes our method shows good results. The throughput is better here because in our method the nodes with even moderate mobility are also not chosen as CH. Therefore, the queries for route discovery and followed by routing go smoothly as compared to the hierarchical protocol in [9].

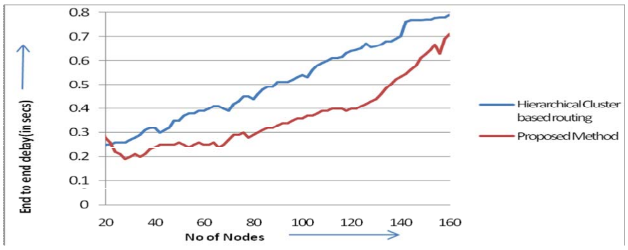

Figure 3 : Variations of End to end delay and Number of Nodes

Figure 3 shows end-to-end delay (in seconds) of proposed approach is lower than hierarchical cluster based routing. Upto 20 nodes end to end delay of proposed approach is more than the other method. But after the node increases the delay gets more and more for the other method and for proposed method it increases slowly. Initially, the delay is more in the proposed method because though the number of nodes is less, but substantial amount of time is required to form the cluster between them.

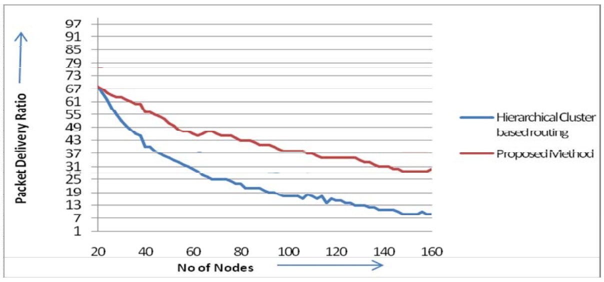

Figure 4 : Variations of Packet Delivery Ratio and Number of Nodes

Figure 4 shows packet delivery ratio (%) of proposed approach is lower than the other method. In our proposed method there is less packet loss as because there is use of ACH which can take the lead if the CH is overloaded. Similarly, with lower mobility based CH can have better chances of forwarding RREQ, RREP packets to their destinations.

V. CONCLUSION

In this paper, we can again prove that Hierarchical cluster based algorithms can give us good results in increased scalabilities. Our proposed method is based on the fact that the mobile nodes are not to be selected as CH in cluster based routing. If we do so, we can get better throughput and packet delivery ratio with minimum delay. In a scalable WMN this result is a motivating one. But, still these results can be improved by incorporating various soft computing methods especially fuzzy clustering. This may be done in future to get even better output.

References

[1] I. F. Akyildiz, X. Wang, and W. Wang, Wireless mesh networks: a survey. Computer Networks, vol. 47, no. 4, March 2005.

[2] S. Chinara an S. K. Rath "A Survey on One-Hop Clustering Algorithms in Mobile Ad Hoc Networks" J Netw Syst Manage (2009):183– 207 DOI 10.1007/s10922-009-9123-7

[3] M. Ni, Z. Zhong and D. Zhao. "MPBC: A Mobility Pre-diction-Based Clustering Scheme for Ad Hoc Networks," *IEEE TVT,* Vol. 60, No. 9, 2011

[4] C. Konstantopoulos, D. Gavalas and G.Pantziou. "Clustering in Mobile Ad Hoc Networks through Neighbor-hood Stability-based Mobility Prediction," 2008.

[5] C.C. Chiang, H.K. Wu, W. Liu, M. Gerla, "Routing in Clustered Multihop, Mobile Wireless Networks with Fading Channel," Proceedings of SICON 1997.

[6] P. Basu, N. Khan, and T.D.C. Little. "A Mobility Based Metric for Clustering in Mobile Ad Hoc Networks," *ICDCSW*, 2001, pp. 413-418.

[7] M. Singh, S.G. Lee, T. W. Kit and L.J. Huy," Clusterbased routing scheme for Wireless Mesh Networks," *Advanced Communication Technology (ICACT),* 2011 13th International Conference, Publication Year: 2011 , Page(s): 335 – 338.

[8] M. Singh, S.G. Lee and D. Singh, A Simulation-Based Performance Analysis of a Cluster-based Routing Scheme for Wireless Mesh Networks, International Journal of Multimedia and Ubiquitous Engineering, Vol.8, No.5 ,2013, pp.283-296

[9] D. Kaushal, G. Niteshkumar, B. Prasann K. and V. Agarwal. Hierarchical cluster based routing for wireless mesh networks using group head, International Conference on Computing Sciences (ICCS), Phagwara, pp. 163-167, 2012.

[10] T. Acharjee, S. Rajkonwar and S. Roy, "An improved Hierarchical Cluster based routing approach for Wireless Mesh Network," International Conference on Computer Communication and Informatics (ICCCI)*, Coimbatore, India, 2016, pp. 1-6.*

[11] NS-3, The ns3 network simulator, *Online+. Available: http://www.nsnam.org/, 2014. hierarchy