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A Study on Wireless Mesh Network with Hierarchical Cluster

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***Abstract*—** Wireless Mesh Networks (WMNs) is a Communication network made up of radio nodes organized in a mesh topology and it is part of Ad-hoc network. WMNs have emerged as a key technology for next-generation wireless networking. Because of their advantages over other wireless networks [1], WMNs are undergoing rapid progress and inspiring numerous applications. WMNs is dynamic and Infrastructure less network. Due to dynamic nature it has many constraints like message collision, power consumption and congestion and Bandwidth. To maintain some of those constraints in wireless mesh network we use Hierarchical Clustering technique. Hierarchical Clustering makes the network fast, more efficient and reliable. Hierarchical Clustering techniques are used to solve routing and congestion control problems because it offers scalability and reduced overheads [5].

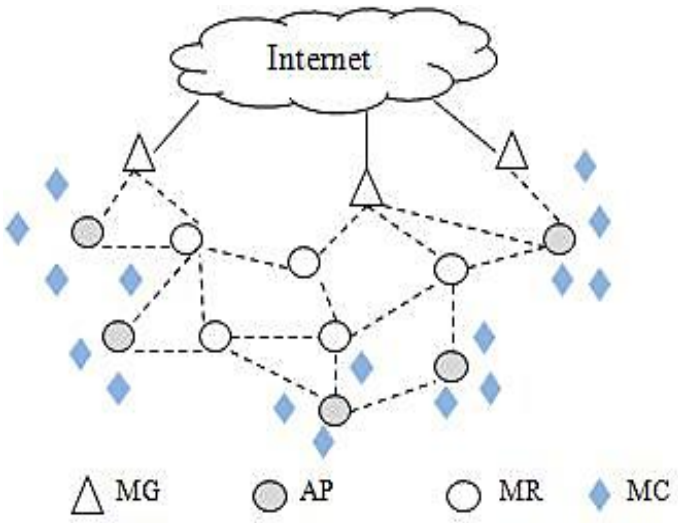
Index Terms- Wireless mesh network, Hierarchical Clustering

I. INTRODUCTION

Wireless mesh networks (WMNs) is a Communication network made up of radio nodes organized in a mesh topology [1]. When one node can no longer operate, the rest of the nodes can still communicate with each other, directly or through one or more intermediate nodes [5]. WMNs are comprised of two types of nodes, that is mesh routers (MR) and mesh clients (MC) with each node having the capability of operating not only as a host but also as a router. It can be deployed without any wiring and major infrastructure support. WMNs can self-organize and self-configure in continuously changing dynamic topology and connectivity of the network [2]. Mesh clients can be laptops cellular phones and any other devices. Mesh clients can form self organized ad hoc networks which can access services by relaying requests to wireless backbone network. Wi-MAX, Wi-Fi, cellular, sensor networks are different standard technologies that cannot communicate with each other directly [3]. Mesh routers are used to form a multi-hop and multi-path wireless relay backbone capable of communicating with gateways and clients.

WMNs can be seen as a special type of wireless ad-hoc network. A wireless mesh network often has a more planned configuration, and may be deployed to provide dynamic connectivity over a certain geographic area. An ad-hoc network, on the other hand, is formed ad hoc when wireless devices come within communication range of each other. The mesh routers may be mobile, and be moved according to specific demands arising in the network. Often the mesh routers are not limited in terms of resources compared to other nodes in the network and thus can be exploited to perform more resource intensive functions. In this way, the wireless mesh network differs from an ad-hoc network, since these nodes are often constrained by resources [9].

Fig. 1 illustrates a typical WMN infrastructure.



In this infrastructure, mesh routers form an infrastructure for clients, as shown in Fig. 1, where dashed and solid lines indicate wireless and wired links, respectively. Access Points (APs) provide internet access to Mesh Clients (MCs) by forwarding aggregated traffic to Mesh Routers (MRs), known as relays, in a multi-hop fashion until a Mesh Gateway (MG) is reached. MGs act as bridges between the wireless infrastructure and the Internet. The WMN infrastructure/backbone can be built using various types of radio technologies, in addition to the mostly used IEEE 802.11 technologies. The mesh routers form a mesh of self-configuring, self-healing links among themselves. With gateway functionality, mesh routers can be connected to the Internet

The characteristics of WMNs

1. Using fewer wires means it costs less to set up a network, particularly for large areas of coverage.
2. The more nodes you install, the bigger and faster your wireless network becomes.
3. WMNs can provide no LOS (Line Of Sight) connectivity among users without direct LOS links.
4. They rely on the same Wi-Fi standards (802.11a, b g and s) already in place for most wireless networks.
5. Mesh networks are "self configuring;" the network automatically incorporates a new node into the existing structure without needing any adjustments by a network administrator.
6. Mesh networks are "self healing," since the network automatically finds the fastest and most reliable paths to send data, even if nodes are blocked or lose their signal.
7. Wireless mesh configurations allow local networks to run faster, because local packets don't have to travel back to a central server.
8. Wireless mesh nodes are easy to install and uninstall, making the network extremely adaptable and expandable as more or less coverage is needed.

Applications

Mesh networks may involve either fixed or mobile devices. The solutions are as diverse as communication needs, for example in difficult environments such as emergency situations, tunnels, oil rigs, battlefield surveillance, high speed mobile video applications on board public transport or real time racing car telemetry. An important possible application for wireless mesh networks is VoIP. By using a Quality of Service scheme, the wireless mesh may support local telephone calls to be routed through the mesh.

Some current applications:

1. U.S. military forces are now using wireless mesh networking to connect their computers, mainly ruggedized laptops, in field operations.
2. Electric meters now being deployed on residences transfer their readings from one to another and eventually to the central office for billing without the need for human meter readers or the need to connect the meters with cables.
3. The laptops in the One Laptop per Child program use wireless mesh networking to enable students to exchange files and get on the Internet even though they lack wired or cell phone or other physical connections in their area.
4. The 66-satellite Iridium constellation operates as a mesh network, with wireless links between adjacent satellites. Calls between two satellite phones are routed through the mesh, from one satellite to another across the constellation, without having to go through an earth station. This makes for a smaller travel distance for the signal, reducing latency, and also allows for the constellation to operate with far fewer earth stations that would be required for 66 traditional communications satellites.1

Wireless mesh network is dynamic and Infrastructure less network. Due to dynamic nature it has many constraints like message collision, power consumption, congestion and Bandwidth. To maintain some of those constraints in wireless mesh network we use Hierarchical Clustering technique. Hierarchical Clustering makes the network fast, more efficient and reliable. Clustering techniques is used to solve routing and congestion control problems because it offers scalability and reduced overheads [5].

Congestion occurs when resource demands in a network exceed the capacity the network can provide. Identifies some factor that contributed to congestion in a network to include network topology, number of flows, traffic characteristics of the flows and their routes as well as channel capacity and the available transmission rate at the physical layer.

Put more formally, if, for any time interval t, the total sum of demands on a network resources is more than its available capacity, then, the network resources is said to be congested for that time interval, i.e. [5]

Σdemands > available resources

Due to congestion in network, it leads to **message collision** and because of it performance decrease in network and network congestion can severely deteriorate network throughput.

II. HIERARCHICAL CLUSTERING

The simplest meaning of clustering is grouping. Grouping the similar are different types of nodes by applying proper and appropriate techniques or methods [6]. Clustering will take place in Routing layer (Network Layer).

Cluster and clustering are words that are used broadly in computer networking to refer to a number of different implementations of shared computing resources. Clustering of wireless network nodes into groups with proper cluster head (CH) selection will impose a regular structure in the network and makes it possible to guarantee basic levels of system performance such as throughput and delay, even in the presence of mobility, energy resources and a large number of mobile nodes. However, mobility and energy resources are not major issues in infrastructure WMNs. CH are the communication hotspots. The cluster head works as the local coordinator for its member nodes and does the resource management among them similar to a base station of cellular architecture.

Cluster algorithms may be used in improving database access and network performance. The network performance metrics such as routing delay, bandwidth consumption, energy consumption, throughput, and scalability [10] are highly improved with appropriate clustering techniques. A clustering algorithm splits the network into disjoint sets of nodes, each centering on a chosen cluster-head. Efficient clustering protocols rely on different design goals, depending on the application they are designed for.

Cluster analysis is an unsupervised process that divides a set of objects into homogeneous groups. There have been many clustering algorithms scattered in publications in very areas such as Pattern Recognition, AI, Computer Science, Networks, Image processing, Biology, Psychology, and Marketing. It is very difficult to identify an appropriate algorithm for their applications.

In addition clustering increased processing power, shared computing resources in a cluster network also can provide scalability, high availability, and failover capabilities should one computing device have a problem.

Working steps of stable election protocol for clustering

It is a clustering protocol for creating clusters of nodes or derives and it is also a heterogeneity aware protocol. In the new creating cluster applies a cluster head selection method to select cluster head on the basics of their battery and computation power. The whole mesh network is composing into clusters and those clusters are connecting to another cluster by the cluster head [6].

Steps to create cluster and CH -

Step 1-Select number of nodes randomly in wireless mesh network and make clusters of those nodes on the basis of cut of frequency of the nodes.

Step 2-In a cluster cut of frequency selected by the user. The frequency is divided into three levels, Higher, Middle and Lower levels.

Step 3-Select the cluster head on the basis of battery power. Selection of cluster head in energy efficient techniques generally depends on the initial energy, residual energy, and average energy of the network or energy consumption rate or combination of these.

Step 4-Afetr selection of cluster head, for the communication between two cluster heads or other nodes. Established the connection between new cluster head to other nearest cluster heads in wireless mesh network.

The requirement for the reelection of cluster heads arises when the current heads fail to cover all the nodes in the network. Sometimes a node may move away from the transmission range of all the current cluster heads and becomes an orphan node. This demands a reelection of cluster heads. Even at times any of the cluster heads may drain out of energy or may even fail to work due to any fault occurrence and needs a head reelection process. However, such an unavoidable reelection increases the computation cost and the message complexity [10].

Now will Study Cluster Based Routing Protocol (CBRP), Here CBRP divides the network into different clusters and stores the path in the RREQ. Cluster based routing scheme for wireless mesh networks reduces broadcast messages and uses a clustering approach. In this approach clusters of mesh points (MPs) are formed. Mesh Point Portal (MPP) (MPs and MPP will discuss in Section III) chooses one MP as a cluster head from each cluster. MPP communicates only with these cluster heads and maintain the information about cluster heads. Cluster

head maintains the information about members of its own cluster as well as its neighbor cluster heads. If any Mesh Point (MP) needs to send data then it sends a Route Request (RREQ) to cluster head and if the cluster head does not find the destination in its routing table then it forward the RREQ to MPP. Then MPP forward the RREQ to remaining cluster heads and wait for the response. Other cluster head which receives the RREQ, tries to find the destination in its routing table. When any cluster head found the destination in its routing table it sends back the Route Reply (RREP) to MPP and then MPP forward it that cluster head, which had sent the RREQ.

Clustering providers many advantages such as it reduces the size of routing tables, conserve communication bandwidth, increase the battery life of the individual nodes, reduce the topology maintenance overhead, decrease the number of unnecessary packets and decrease the number of unnecessary packets.
Clustering techniques provides some draw back such as load on Mesh Portal Point(MPP) is high as well as Mesh Points (MPs) need to communicate with the cluster head even when destination MP is in the same cluster. To overcome this drawback we used Hierarchal clustering approach which explained with example below [7].
Hierarchal clustering approach is further extension of the cluster based routing scheme for wireless mesh networks. In this approach Mesh point portal, cluster heads and group heads have extra responsibility and power.
In this approach, WMNs are divided into different domains of MPs and these domains are further divided into different clusters.
Each domain contains one MP as a Group Head (GH) and each cluster contains one MP as a Cluster Head (CH). We distribute almost all mesh points into clusters. MPP maintains the information about all the GH.

As shown in figure 2. MP9 and MP10 are group head and maintain two clusters each. Big circle shows the cluster and mesh points under that big circle are within one cluster. Each cluster contains one cluster head such as MP1, MP3, MP5 and MP7 are cluster head. We assume that a single MP cannot become CH as well as GH both. This assumption reduces the overhead of a single node.

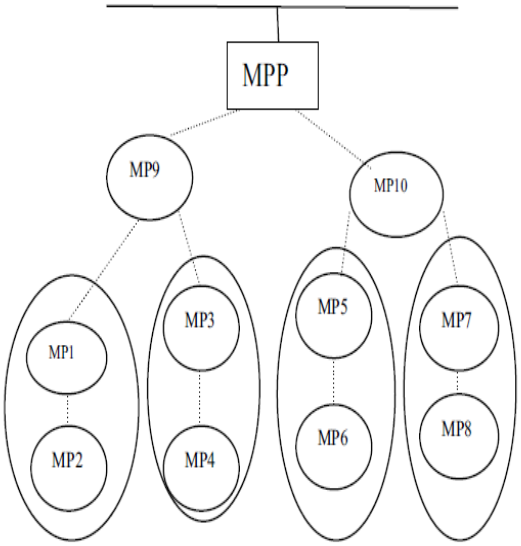


Fig. 2 illustrates a simple Example for Hierarchical Cluster

In this approach, CH as well as each MP stores the information about MP within the same cluster. CH also stores the information about its own GH and other CHs which are in the same group. For this purpose CH store the cluster ID and Node ID of CH. GH stores the information about CHs under its own group and MPP. In this approach, we use the concept of reverse path and forward path which is similar as in AODV protocol. Every intermediate node stores the reverse path, forward path and destination MP. In reverse path it stores the address of that node which sends the RREQ to it. In forward path it stores the address of that node which sends the RREP to it.

If a source MP needs to send some information to destination MP then it first checks its routing table which contains the information about all neighbor MPs. If destination MP is its neighbor MP then source MP directly sends the data to destination MP by using information stored in its routing table. If source MP does not find out routing information about destination MP then it sends a RREQ to its own CH with whom it is associated. CH checks its routing table to find the path of destination MP. If it finds the path of destination MP then it sends a RREP to source MP. If CH does not find out routing information about destination MP then it forwards the RREQ to its own GH. GH forwards this RREQ to all CHs under it except the one from which request came. After that, GH waits for a reply from any of the CH under it. All CHs which receives the RREQ

will search for destination MP in its routing table. If any CH finds routing information about the destination MP in its routing table then it sends a RREP to GH otherwise do nothing. If GH receives a RREP from any CH then it sends the RREP to CH through reverse path and CH sends the RREP to source MP. But if after certain timeout, GH do not receive any reply then it forward the RREQ to MPP.

MPP forwards the RREQ to all GH except the one from which request came. On receiving RREQ, all GHs forward the request to all CH associated with them. These CHs searches the information about the destination MP in its routing table and if any CH finds the information about destination MP, then it sends RREP to its own GH and that GH then forwards the RREP to MPP. After receiving a RREP by MPP, MPP forwards the RREP to the GH by using reverse path. GH forwards the RREP to the CH using reverse path. CH forwards the RREP to source MP and then source MP sends the data through the same path from which RREP came, i.e., forward path.

In this approach CH, GH and MPP play a very important role. The main purpose of GH is to share the load of MPP. If any MP needs to send some data within a group then RREQ does not reach up to MPP. Through this way, some load of MPP is shared by GHs

If request come from CH to GH then GH forwards it to all other CHs associated with it except the one which has sent RREQ. After this GH starts the timer and wait for the reply from any of the CH. If after a certain timeout GH does not receive a reply then it will resend the RREQ to MPP or if it receives the RREP by any of the CH associated with it then it forwards RREP to CH using reverse path. In case GH sends the RREQ to MPP then it starts the timer and again waits for the RREP from MPP. If till timeout it does not receive any RREP then it will send a RERR to the CH by using reverse path or if it receives the RREP by MPP then it forwards the RREP to the CH by using reverse path [12].

III OVERVIEW OF 802.11S ROUTING PROTOCOLS

Hierarchical Cluster approach here we are studying under the standard of 802.11 Task Group “s” namely 802.11s. IEEE 802.11s is an extension to the IEEE 802.11 standard which allows multiple wireless nodes to connect with each other without having an AP between them. If you have an AP at your home, and you want to copy a file to another laptop B which is connected to the same AP as your own laptop (laptop A), then A transmits the data to the AP, which in turn, transmits it to laptop B. So all the communication between A and B is done via the AP.

IEEE 802.11s, however, allows direct communication between A and B without the need for an AP. However, the real power of IEEE 802.11s manifests itself in the presence of multiple wireless nodes. Using the 802.11s mesh standard, the nodes can form a multi-hop network where all the links of the network are wireless. This means that no wired infrastructure is needed to setup the network. This is very handy in a lot of scenarios, for example, disaster relief teams can carry laptops with IEEE 802.11s support. This would enable them to exchange information with other laptops in the area even if those are not in direct range [8].

Many routing protocols were proposed for IEEE802.11s and still very emerging research area for WMNs even though many routing protocols were proposed for IEEE802.11s. Hybrid wireless mesh protocol (HWMP) is the default routing protocol for WMNs [11]. HWMP uses hierarchical routing to exploit this tree-like logical structure and an on-demand routing protocol to address mobility [12].

IEEE 802.11s defines three kinds of nodes that is Mesh Point (MP), Mesh Portal Point (MPP) and Mesh Access Point (MAP). All nodes have frame forwarding capability and can thus forward frames originating at a node and destined for some node.

Mesh Point (MP):

A MP supports a Peer Link Management protocol, which is used to discover neighboring nodes and keep track of them. Note that neighbor discovery is only limited to nodes which are in range of an MP.

Mesh Portal Point (MPP):

An IEEE 802.11s mesh network could be used for a variety of purposes. One of them is providing cheap Internet access. In this case, at least one node and potentially some of the nodes are connected to the Internet. Users connected to the mesh network can access the Internet via these gateway nodes called Mesh Portals (MPP) which are connected to both the mesh network and the Internet. Note that an MPP must bridge at least two interfaces to provide the gateway functionality.

Mesh Access Point (MAP):

A MAP is your traditional AP augmented with mesh functionality. So it can serves as an AP and be a part of the mesh network at the same time.

CONCLUSION

In this paper, we presented a study of hierarchical cluster for wireless mesh network to overcome some of the constraints like message collision, power consumption, congestion and Bandwidth. We studied about the WMNs characteristics, simple infrastructure of WMNs, applications, WMNs advantages and disadvantages, clustering, steps for creating clustering, working process of hierarchical cluster and the standard of IEEE 802.11s.

Hierarchical cluster approach also takes less number of hops between source mesh point and destination mesh point and if source mesh points and destination mesh points are in same domain then mesh point portal does not participate in the route discovery which reduces the burden of the mesh point portal by group head.

REFERENCES

[1] ian f. Akyildiz, georgia institute of technology xudong wang, kiyon, inc, "a survey on wireless mesh networks", ieee/acm transactions on networking, ieee radio communications september 2005.
[2] djohara benyamina, abdelhakim hafid, and michel gendreau ,"wireless mesh networks design — a survey", ieee communications surveys & tutorials, vol. 14, no. 2, second quarter 2012
[3] parth h. Pathak and rudra dutta. "a survey of network design problems and joint design approaches in wireless mesh networks" ieee communications surveys & tutorials, vol. 13, no. 3, third quarter 2011.
[4] nizar bouabdallah, rami langar, and raouf boutaba, "design and analysis of mobility-aware clustering algorithms for wireless mesh networks", ieee/acm transactions on networking, vol. 18, no. 6, december 2010.
[5] adebanjoadekiigbe, kamalrulnizam abu bakar andogunnusi olumide simeon , " a review of cluster-based congestion control protocols in wireless mesh networks" ijcsi international journal of computer science issues, vol. 8, issue 4, no 2, july 2011.
[6] yogesh birla,esh narayan and krishan kr. Saraswat "clustering in wireless mesh networks" in proc. Vsrd-ijcsit, vol. 2 (5), 2012, 413-418.
[7] djohara benyamina, abdelhakim hafid, and michel gendreau ,"wireless mesh networks design — a survey", ieee communications surveys & tutorials, vol. 14, no. 2, second quarter 2012
[8] Joseph D. Camp and Edward W. Knightly ;."The IEEE 802.11s Extended Service Set Mesh Networking Standard". Electrical and Computer Engineering, Rice University, Houston,
[9] T. Jaya, Merlin Sheeba, R. Dharanya and M.A. Athiqueahmed "Detection of selfish nodes in Wireless mesh networks using Hierarchial clustering" International Conference on Computing and Control Engineering (ICCCE 2012), 12 & 13 April, 2012.
[10] Suchismita Chinara Æ Santanu Kumar 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.
[11] Madhusudan Singh, Sang Gon Lee, Tan Whye Kit, Lam Jun Huy "Cluster–Based Routing Scheme for Wireless Mesh Networks" Dept of Ubiquitous IT, Division of Computer & Information Engineering, Dongseo University,Busan, Korea.
[12] Deepesh Kaushal, Gami Niteshkumar A., Buddhdev Prasann K., Varun Agarwal "Hierarchical Cluster based Routing for Wireless Mesh Networks using Group Head" Department of Computer Science and Engineering Motilal Nehru National Institute of Technology Allahabad, India