A Cluster Based Multi-Radio Multi-Channel Assignment Approach in Wireless Mesh Networks

Ghosh Saurav[1], Das Niva[1], and Sarkar Tanmoy[2]

[1] A.K. Choudhury School of Information Technology, University of Calcutta
[2] School of Mobile Computing and Communication, Jadavpur University
Kolkata, India
{sauravghoshcu,niva.cu,tanmoysarkar1}@gmail.com

Abstract. Wireless mesh networks (WMNs) are receiving increasing attention as an effective means to provide broadband internet. Throughput is a major QoS in WMNs keeping in view of their perceived application areas and others being connectivity and reliability. WMNs use multiple radios and orthogonal communication channels to reduce interference and increase throughput and at the same time providing path redundancy, reliability and connectivity. In our work we propose a cluster based channel assignment scheme for WMNs and assume that the wireless radio interfaces are equipped with IEEE 802.11 network interface cards (NICs). We have extensively simulated our work using ns-2 network simulator and compared it against well-known channel assignment techniques and our result exhibits a significant increase in throughput.

Keywords: Multi-Radio wireless mesh networks, algorithm, clustering, channel assignment, throughput, and simulation.

1 Introduction

Wireless Mesh Networks[1,2] are dynamically self-organized and self-configured with a high degree of fault tolerance having low deployment and maintenance cost. They are an alternative to the traditional Wi-Fi networks, which requires extensive infrastructure and suffers from the last mile connectivity problem. WMNs provide a platform to integrate various types of networks like WSN, Wi-Max, and Cellular and also to provide broadband internet connectivity to mobile nodes or to remote residential areas. All the perceived applications of WMNs require a high throughput, low latency and adequate path redundancy as its major QoS requirements. Multihop wireless communication in WMNs is beset with several problems such as high interference, increased collisions due hidden/exposed terminals and high levels of congestion with all aggregating to produce an extremely low end-to-end throughput. Due to the rapid advancement in electronics technology, it is feasible to equip each wireless node with multiple radios with each operating simultaneously over different orthogonal channels. The resulting network known as multi-radio multi-channel mesh (MR-MC WMNs) reduces wireless interference as adjacent radios operate over different orthogonal channels and the throughput increases. The mapping between a radio interface and an orthogonal channel is known as the channel assignment problem (CA)

V.V. Das, J. Stephen, and Y. Chaba (Eds.): CNC 2011, CCIS 142, pp. 487–491, 2011.

[3,7] and is critical to the proper functioning of the MR-MC WMNs. Various formulations for CA have been proposed in literature and it is proved that CA is a NP-Hard problem. As such, no deterministic polynomial bounded method exists for CA and we have to concentrate on developing heuristic methods.

2 Related Work

A number of channel assignment methods are proposed in literature and a good overview can be found in [7]. One such method BFS-CA [4], proposed by K. Ramachandran et al., models the MR-MC WMNs by Multi-Radio Conflict Graph (MCG), in which all the possible edges between radio interfaces are modeled as nodes in the MCG. Then a breadth first search is executed to visit and color each node such that two adjacent nodes are assigned different colors. It is a centralized approach in which all the computations are done by the gateway node. A distributed channel assignment approach in WMN proposed by Raniwala and Chiueh called `Hyacinth' which jointly performs channel assignment and its associated routing. Here a tree like topology is extracted on which the method runs. In both [4, 5] above both network connectivity and topology is preserved. Naveed et al. propose an all-in-one scheme called the CoMTaC [6] to jointly address the topology control, channel assignment and routing.

3 Proposed Work

A cluster-based approach is employed in two steps to divide the network into clusters and localize the channel assignment problem within each cluster maintaining network connectivity. In the first step, the network nodes are grouped into clusters and the cluster heads are selected. The second step focuses on the channel assignment. We assume that every node has knowledge of its hop distance from its nearest gateway node. The function Hopcount (v) is hop distance of node v from its nearest Gateway having id GID (v).The clustering algorithm is as follows:

Procedure Cluster:
Input: Connectivity Graph (V, E), number of nodes n, set of Gateway nodes V_G where $| V_G |= m$.
Output: Set χ containing cluster set $X_{i=1, 2, 3...}$ where X_i is the i^{th} cluster head.
Step 1: Initially there are no cluster heads in the network.
Set $\chi=\varphi$, $m=|V_G|$ and $p=m$: initial number of clusters.
for i = 1 to m do // initially each gateway node considered as a cluster head.
$X_i = v_i$, where $v_i € V_G$ and $\chi = X_i$.
end for
Step 2: Each node joining a cluster with a gateway node as cluster head.
for i = 1 to n do $x=GID (v_i)$: $v_i € V$
$X_x = X_x \cup \{v_i\}$, clusterdist (v_i) = hopcount (v_i)
CHID (v_i) = GID (v_i): CHID is cluster head ID
end for

Step 3: The number of Gateway nodes are limited, so the radius of the cluster is large. To restrict the size of a cluster to a radius $r \leq 2$ procedure ConstructCluster is called.

Set r=2. while clusterdist(x) > r for any $x \in \{X_1 \cup X_2 \ldots \cup X_p\}$ do
ConstructCluster (χ, p, n, V)
end while

End Procedure Cluster

Procedure ConstructCluster (χ, p, n, V)

h =x such that clusterdist(x) is maximum
p = p+1
$X_p = \{h\}$
CHID (h) = h
$X_{CHID(h)} = X_{CHID(h)} \setminus \{h\}$
for i =1 to n do if clusterdist(v_i) > dist(h, v_i) then
$X_p = X_p \cup (v_i)$
$X_{CHID(vi)} = X_{CHID(vi)} \setminus \{v_i\}$
CHID (v_i) = h
end if
end for
end **Procedure ConstructCluster**

The cluster radius, *r*,(maximum hop distance from the cluster) is a design parameter. We have set r=2. The cluster head selects other cluster head based on maximum hop distance from itself. Then the cluster is constructed around newly selected cluster head by adding nodes to 2 hop distances, as our interference range is two hops because of the protocol interference model as depicted in fig 1. The cluster head then checks among its one hop neighbor, who has the maximum neighboring nodes and selects them as control nodes (CN). The CN finds its child nodes from its one-hop neighbors and these nodes are controlled only by that CN.

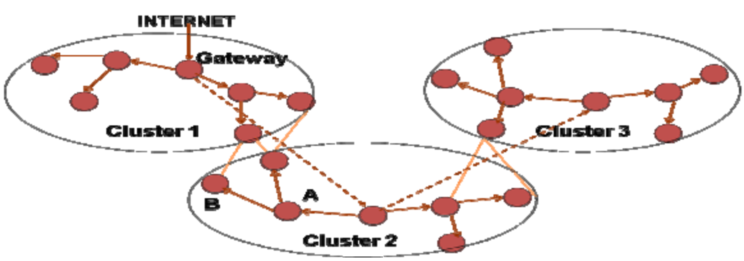

Fig. 1. Formation of Cluster

Procedure Control-Child Node Selection within a Cluster

Step 1. CH will sends “HELLO” packets to its one hop neighboring nodes (say node A in Fig 1.)

Step 2. The neighboring nodes (i.e.A’s) send an “ACK” packet to the CH.

Step 3. The neighboring nodes (i.e.A's) will send a "HELLO" packet to its 1-hop neighbors (say node B in Fig 1.).

Step 4. Two hop neighbors of the CH (i.e.B's) will send an "ACK" packet to one hop neighbors of CH (i.e.A's).

Step 5. One hop nodes (i.e.A's) Counts the number of "ACK" packets received from two hop neighbors (i.e.B's) and send it to CH.

Step 6. The CH selects the Control Nodes from among its one hop neighbors (i.e.A's) based on the basis of maximum number of children (i.e.B's) it has.

Step 7. CH sends a "JOIN" request to those selected Control Nodes.

Step 8. The selected Control Nodes sends "JOIN" request to its neighboring nodes (i.e.B's).

Step 9. On receiving the "JOIN" request, the nodes (i.e.B's) will send a "JOIN-ACK" message to the Control Node from which it gets the first "JOIN" request.

Step 10. Then the Control Node adds that node in its list of Child Node and sends an "ACCEPT" message to the child node.

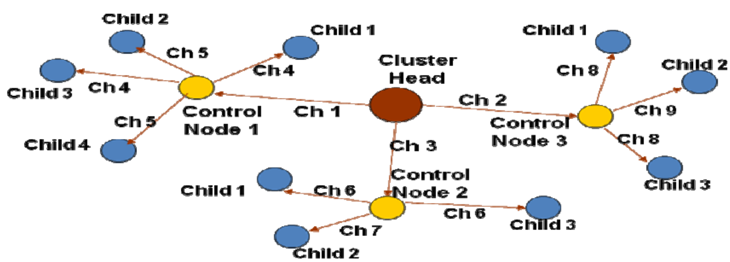

Fig. 2. Channel assignment to nodes within a cluster

A proportionate set of mutually orthogonal channels are being allocated to each CH based on the number of nodes in that cluster with adjacent clusters being allocated mutually non-interfering sets of orthogonal channels. The CH selects its communication channels to its control nodes and a set of non-interfering channels to each of its control nodes to communicate with their children as depicted in fig 2.

4 Simulation

A 25-node MR-MC WMN topology operating over twelve orthogonal channels and having four gateway nodes is created in NS-2.33 network simulator. Network interface cards (NICs) are divided into two classes: (1) UP-NICs that are used to connect to the parent and (2) DOWN-NICs that are used to connect to the children. We have assumed that each node runs the DSR routing protocol. We have compared our results i.e. scenario 3, with BFS-CA[4] i.e. scenario 2 and the naïve (single channel) approach i.e. scenario 1. The packet delivery ratio is of our method is approximately the same as BFS-CA[4] as shown in fig 3 but our method outperforms the latter with respect to throughput as shown in fig 4.

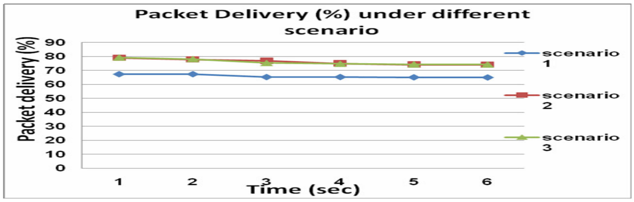

Fig. 3. Packet Delivery

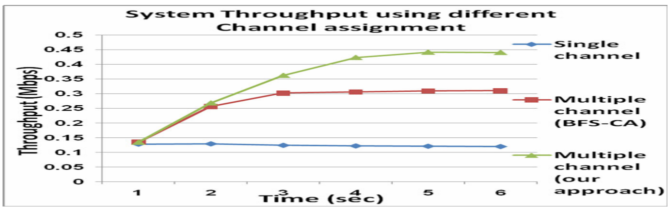

Fig. 4. System throughput

5 Conclusion

Our method does not consider network traffic or interferences from external networks working in the similar frequency ranges. A statistical analysis of the network traffic is an important pre-requisite prior to channel assignment and after that some soft computing techniques can be applied for channel allocation. Therefore, we shall try to make this possible for multiple gateway WMNs scenario and a better performance.

References

[1] Ishmael, J., Race, N.: Wireless Mesh Networks. In: Middleware for Network Eccentric and Mobile Applications (2009)

[2] Akyildiz, I.F., Wang, X., Wang, W.: A Survey on Wireless mesh networks. IEEE Radio Communications (September 2005)

[3] Conti, M., Das, S.K., Lenzini, L., Skalli, H.: Channel Assignment Strategies for Wireless Mesh Networks. In: Wireless Mesh Networks: Architectures and Protocols. Springer, Heidelberg (2007)

[4] Ramachandran, K., Belding, E., Almeroth, K., Buddhikot, M.: Interference aware channel assignment in multi-radio wireless mesh networks. In: IEEE INFOCOM (2006)

[5] Raniwala, A., Chiueh, T.-C.: Architecture and algorithms for an IEEE 802.11-based multi-channel wireless mesh network. In: IEEE INFOCOM (2005)

[6] Naveed, A., Kanhere, S.S., Jha, S.: Topology control and channel assignment in multi-radio multi-channel wireless mesh networks. In: IEEE MASS (2007)

[7] Si, W., Selvakennedy, S., Zomaya, A.Y.: An overview of Channel Assignment methods for multi-radio multi-channel wireless mesh networks. Journal of Parallel and Distributed Computing (2009)