International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161
Available at http://inpressco.com/category/ijcet

Research Article

Multi-Channel Allocation and Medium Access Control in Wireless Sensor Network

Ms. Priyanka Parve[1] and Mrs. Mansi Bhosale[2]

[1]PG Scholar, [2]Asst. Professor, Department of Computer Engineering G H Raisoni College of Engineering and Management, Pune, India

Received 10 Nov 2020, Accepted 10 Dec 2020, Available online 01 Feb 2021, **Special Issue-8 (Feb 2021)**

Abstract

The aggregate capacity of wireless mesh networks can be improved significantly by equipping each node with multiple interfaces and by using multiple channels in order to reduce the effect of interference. Since the number of available channels is limited, it is desired to allocate and reallocate channels on-demand. In this paper, a Cluster Channel Assignment (CCA) approach is proposed, to maximize the aggregate throughput by exploiting spatial reuse and local dynamic switching of the channels. A clustering approach is employed in order to maximize the network capacity while minimizing the interference and taking advantage of the possibility of reuse of channels among clusters.

Keywords: *Channel Assignment, Clustering, Load Balancing, QoS and Wireless Mesh Networks.*

1. Introduction

Recently, wireless mesh networks (WMNs) are in the focus ofacademia and industry research. The reason is that WMNs have several interesting characteristics, such as self-organization, self- configuration, reliable services and Internet connectivity. WMNs consist of mesh-routers and mobile clients nodes. A mesh-router is used to route the data to Internet connection and as well as an access point to the mobile-client nodes. To further improve the flexibility of mesh networking, a mesh-router (node) is equipped with multiple Wireless Network Interfaces (WNIC) built on either the same or different wireless access technologies. Today, the usage of multimedia applications and Internet connection is rapidly rising. The most important requirements for these applications are quality of service (QoS). To support high traffic load, we generally add more bandwidth by setting up additional channels. The interfering wireless links would then be able to operate on different channels enabling multiple parallel transmissions with a minimum interference. The goal of channel assignment approaches is to allocate the available channels to network interfaces of nodes in a way that satisfies load balance and provides reasonable services to the users, i.e., the available bandwidth of the virtual wireless links should be proportional to the expected load, while taking into account ensuring network connectivity, and minimizing the overall interferences. To reduce the complexity of channel assignment, we have employed a clustering strategy. In fact clustering provides an effective way to allocate and reuse the wireless channels among different clusters.

2. Literature Survey

Bahl et al. [1] propose the dynamic switching of channels in such a way that the neighbors meet periodically on a common channel to communicate. The advantage of the approach is that it neither requires the modification of the MAC protocol nor multiple network interfaces. The drawback is the synchronization of the nodes, which is difficult to achieve. So et al. [2] propose that the nodes which have packets to transmit negotiate with the destination that sends in a specific time window. This approach assumes also that all nodes are synchronized. Wu et al. [3] suggest to divide the overall bandwidth in n + 1 channels, one channel for control information and the other n to transmit data packets. There are also approaches which assume multiple interfaces per node. Shin et al. [4] show that optimal channel assignment is NP-hard, and propose to assign as many distinct channels as possible to a node to improve the performance while satisfying the constraints of limited NICs and available channels. The channel selection to particular network interfaces is done randomly. Raniwala et al. [5] propose a distributed channel assignment joined with routing. They represent a WMN as multiple spanning trees, and assume that a node can join multiple spanning trees to distribute the load among the trees. In their channel assignment approach nodes positioned higher in the tree hierarchy get a higher priority, since they are connected to the Internet. The nodes lower positioned in the tree hierarchy get lower priority in choosing channels and that may result in discriminating these nodes which can affect their communication performance negatively. Ko et al. [6] propose a distributed channel assignment algorithm where each node can choose greedily a channel that minimizes its local objective function depending only on local information. Every node selects a channel that minimizes the sum of interference cost within its interference range. The advantage of their approach is that channel assignment can be achieved based on local information among nodes. However, they don't consider the number of interface cards per node and they don't deal with interface violation constraint mentioned earlier. Another two approaches for channel assignment that are close to our presented approach are Tabu-based [7] and CLICA-SCE [8]. Subramanian et al. [7] designed a centralized Tabu-based algorithm and a Distributed Greedy algorithm. Both algorithms assign channels to communication links with the objective of minimizing network interference. Tabu-based algorithm consists of two phases. The first phase tries to find a good solution with minimum interference. However, this solution may violate interface constraint which is handled in the second phase. Furthermore, Tabu-based does not work well when the number of radio interfaces is limited. Marina et al. [8] propose a polynomial-time heuristic algorithm (CLICA) for assigning channels to nodes radios. The algorithm assigns each node a given priority; and depending on this priority, the coloring decision is taken. Starting from the node with the highest priority, the algorithm tries to color all uncolored incident links from this node.

3. Proposed System

A. The main goal of channel assignment approaches is to allocate the available channels to network interfaces of nodes in a way that maximizes the average throughput, i.e., the available bandwidth of the virtual wireless links should be proportional to the expected load. B. To achieve this goal some requirements, must be fulfilled: • Ensure network connectivity: The wireless mesh network must not be split due to channel assignment. This can happen, if a node does not share a common channel with any of its neighbors. • Minimize the overall interferences: The interference generated by neighboring nodes (1-hop, 2-hop etc.) should be minimized to decrease the packet loss probability and improve thereby the overall performance of the network. • Adaptive to the traffic load: The channel allocation must be on-demand and based on the load of nodes. In order to reach these objectives, a clustering strategy has been deployed. The purpose of clustering is to minimize the complexity of channel assignment into small local problems that are easier to handle. METHODOLOGY A. Channel allocation schemes are required in mobile networks to allocate bandwidth and channels to mobile stations. • The main objective of channel allocation is to achieve maximum efficiency by means of channel reuse by avoiding adjacent and co-channel interferences among nearby cells or networks that share the bandwidth. B. The hierarchical WSN architecture is based on grouping the sensor nodes into clusters followed subsequently by choosing a cluster head (CH) in each cluster. The CH then performs the task of intra-cluster data aggregation, followed by local sensor fusion and transmission of the relevant information to the data sink through other intermediate CHs. • Since communication with the distant base station is significantly energy consuming, one can significantly decrease energy consumption by restricting a dominant fraction of the CH communication to intra-cluster i.e. with the nodes in the cluster followed by intelligent local sensor fusion. • In order to maximize the overall WSN performance, one must optimize the intra-cluster communication efficiency. • Channel Assignment Problem in Cellular Mobile Networks The available radio frequency spectrum is assumed to lie on a straight line which is divided in equal intervals, with each such interval being termed as a channel and numbered as 0, 1, 2…. in the increasing order of their center frequencies. • Thus, the frequency separation between two channels i and j can be abstracted as .. The Chanel Assignment Problem in a cellular mobile network is then represented by means of a channel assignment problem graph (CAP graph) as follows. Each call to a cell is represented by a node of the CAP graph and two nodes i and j are connected by an edge with weight C ij (c ij >0), where c ij represents the minimum frequency separation requirement between a call in cell i and a call in cell j to avoid interference. Let us now consider the following example of CAP graph as presented in Reference Example.

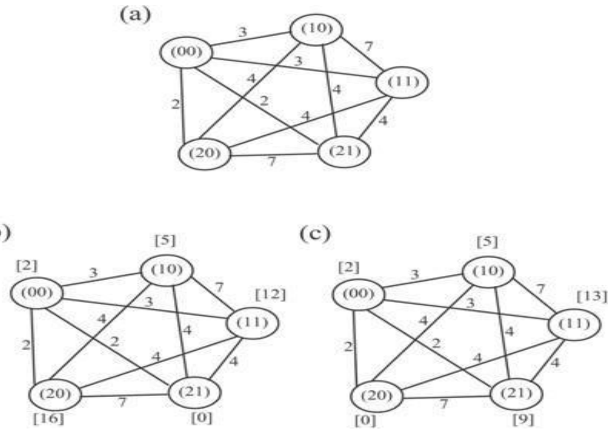
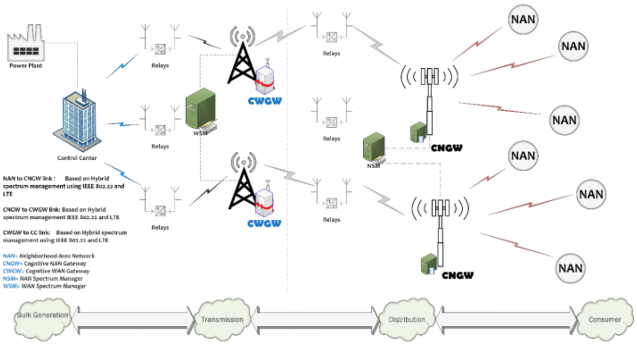


Figure (a) shows a CAP graph with 3cells where channel demands on cells 0, 1 and 2 are 1, 2, and 2 respectively. Each node in Figure is labeled as (rs) where r is the cell number at which a call is generated and s is the call number to this cell r . That is, the node (10) represents call 0 in cell 1. The frequency separation requirements for this example are given by the following matrix:

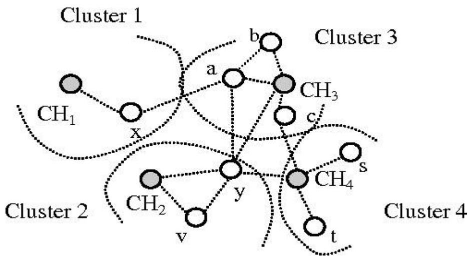
$$\begin{array}{llccc} & cell \quad no. \rightarrow & 0 & 1 & 2 \\ & \downarrow & & & \\ C = & 0 & 7 & 3 & 2 \\ & 1 & 3 & 7 & 4 \\ & 2 & 2 & 4 & 7 \end{array}$$

System Architecture:



System Model and Problem Formulation

The considered wireless mesh network (WMN) constitutes a graph G(V, E, K), where V = {v1, v2, . . . , vn} is the set of nodes, K = {k1, k2, . . . , kc} the set of available channels, and E = {(vi , uj , kr)|vi , uj ∈ V ∧ kr ∈ K} the set of virtual wireless links between the nodes vi and its neighbors uj on channel kr. For the sake of simplicity we will denote l a i,j = (vi , uj , a) ∈ E as the wireless link between node vi and uj on channel a ∈ K. The set Li = {l a i,j} describes all wireless links of the node i. A node vi with mvi wireless network interfaces may allocate up to mvi different channels, if available. The set of assigned channels to node vi is denoted as Kvi = {k1, k2, . . . , kn}, n ≤ mvi . Furthermore, Na v denotes the one step neighbors of node vi on channel a and all neighbors are given by Nv = S a∈ Kv Na v . Based on the previousterms, the channels of all neighbors of node vi are given by KNv = S u∈ NvKu. B. Clustering Our approach requires a clustering at the beginning, wherein the router nodes are grouped into subsets of nearby nodes C = {C1, C2, . . . , Cc}. We deploy the Highest Connectivity Cluster (HCC) algorithm, where a node is elected as a clusterhead (CH) if it is the most highly connected node (having the highest number of neighbor nodes). It is also possible to employ any clustering algorithm which realize a uniform clustering and where the clusterhead is in the center of the cluster. C. Traffic Load Estimation Additionally, the second phase of our approach requires the information about the current load on a wireless link l a v,u and the quality of the link. The approach we deploy is based on the packet loss probability. For that purpose, each mesh router vi counts all sent packets s(l a v,u, t) and acknowledgment packets received r(l a v,u, t) for the sent packets on the link l a v,u, where the channel is a, during a specified time interval t. The packet loss probability on link l a v,u from the point view of node vi is given by: P(loss on l a v,u) = 1 − r(l a v,u,t) s(l a v,u, t). There are many reasons for packet loss. These reasons include the high usage of the channel, hidden terminal problem, and interference from nearby nodes. The node vi shares the link information with its neighbors uj as well as with a clusterhead. Notice, that all these calculations are done locally on each node and only represent the view of the network from the point of view of node vi , since wireless links show strong asymmetry. Therefore, each clusterhead gather all links information belonging to its cluster to control the dynamic channel switching for on demand. Furthermore a clusterhead can share these information with neighbors clusterheads for the purpose of QoS routing and load balancing



Cluster Channel Assignment

The Cluster Channel Assignment consists of two stages. In the first stage the clustering algorithm mentioned is applied to compute the clusters. Subsequently, the available channels in the network are equally distributed to the clusters in a way that two neighbored clusters get disjoint sets of channels. In the case that the clustering is not uniform, we distribute the available channels K to neighbored clusters as follows:

Table I Notation

Symbol	Definition
Ci	Cluster *i*
CHi	A cluster head of cluster *i*
K	Set of available channels
KCi	Set of channels allocated to
NCi BCi	cluster *i*
v, u	Set of neighbors cluster of cluster
Nv mv	*i*
kx	Set of border nodes of cluster *i*
Kv	A node in the network
$\lvert K_v \rvert$	Set of neighbors node of node *v*
	The number of WNIC in *v*
	A channel in *K*
	Set of assigned channels to node *v*
	The number of divers channels
	allocated to the WNICs of node *v*

Symbol Definition Ci CHi K KCi NCi BCi v, u Nv mv kx Kv |Kv| Cluster i A cluster head of cluster i Set of available channels Set of channels allocated to cluster i

Set of neighbors cluster of cluster i Set of border nodes of cluster i A node in the network Set of neighbors node of node v The number of WNIC in v A channel in K Set of assigned channels to node v The number of divers channels allocated to the WNICs of node v.

Algorithm 1 Static CCA Phase 1: Static CCA
1: Each cluster Ci
2: while node v in Ci do
3: {/* Allocate one channel from KCi to all nodes in the cluster Ci*/}
4: Given kx ∈ KCi
5: Assign channel kx tov
6: if v ∈ BCi then
7:{/*If node v is a border node and has free WNIC, then assign the channel of the neighbor cluster to it*/}
8: if (|Kv| < mv) ∧ (∃ j ∈ NCi)
then
9:Given ky ∈ KNCi
10:Assign channel ky to v, Kv = (ky ∪Kv)
11: end if
12: end if
13: end while

Algorithm 2 On demand CCA
Phase 2: On demand CCA
1: Each cluster-head CHi
2: if (|Kv| < mv) ∧ (∃ u ∈ Nv, |Ku| < mu)then
3: {/*Both partners have an unused WNIC*/}
4: if (∃ kx ∈ KCi) then
5: {/*The cluster has a freechannel*/}
6: Allocate channel kx to v and u
7: else
8: Send borrow-request to the neighbor cluster NCi who offers kx = freechannel{KNCi } ∨ min load {KCi ∪ KNCi }
9: Allocate channel kx to v andu
10: end if
11: else if (|Kv| < mv) ∧ (6 ∃ u ∈ Nv, |Ku| < mu)then
12: {/*Only router v has a free WNIC*/}
13: kx = min load {KNv}
14: Allocate channel kx 15:

A. On-demand CCA

In this phase, the cluster head tries to locally modify the channel assignment to minimize the experienced loss rate and thereby maximize the overall performance. After the initialization of static phase, each router in each cluster periodically estimates the load of all its communication links and records the probability of loss P(loss on l a v,u) on all links of router v. These information is send to the clusterhead and neighboring nodes.

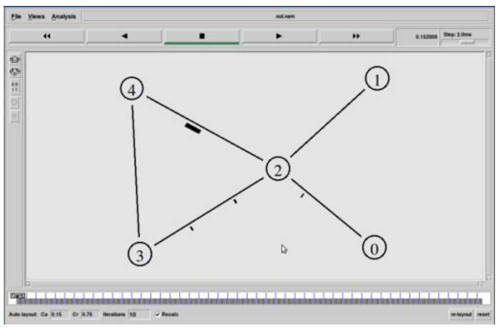
There are two methods to exchange the information of the link status and channel usage. Either the router periodically sends out broadcast messages to its neighbors or it sends this information on demand as soon as one of its neighbors announces a channel switch. The first solution is more reliable and saves the overhead of the data collection prior to a channel switch but it creates a relatively high network overhead. We chose the second possibility since channel switches are not assumed to happen frequently.

If the router v experiences a loss rate P(loss on l a v,u) ≥ σ on channel a, especially on a currently link l a v,u, it proceeds to the on demand phase. Based on the connectivity matrix, the router calculates all node disjoint paths to its destination. If it discovers an additional unused path using neighbor x 6= u, it checks its local assignment table to find the channel b so that l b v,x ∈ Lv. If a 6= b the router simply activates the newly found path in its routing table and starts using the multiple paths according to the route selection algorithm (see Section V- C). If there are additional paths but none of them uses a different channel, then v send a CH REQUEST message to the clusterhead CHi belong to it. The CH REQUEST message contains the channels Kv currently used by router v and their loss values. The message also indicates whether an unused WNIC is available on v and the possible next hops Nv to its destination. CHi checks whether a suitable u ∈ Nv has an unused WNIC, then it looks for a free channel kx and compiles a CH REPLY message to inform v and u. In case of no free channel, CH BORROW message is compiled to request a free channel from the neighbors clusterhead (NCi). After that, kx is allocated for the link lv,u. In the worst case a available channel with minimum load is commanded.

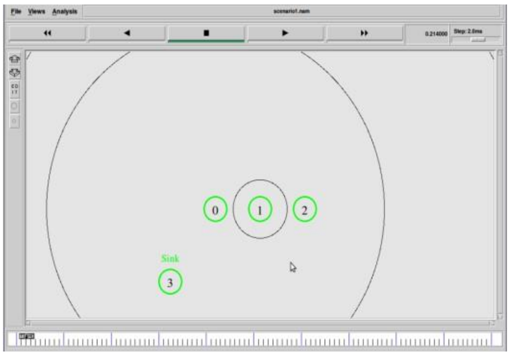
B. Route Selection

In our approach we considered two possible mechanisms for the route selection: round robin and single path. Round robin uses each of the multiple paths one after the other where single path uses only one path to the destination. Directly after a channel switch the newly created path is preferred. After a certain damping time twait = 10s another path might be chosen according to the loss rate of the first links, the path length or any weighted combination of both. The waiting time twait is introduced to prevent alternating channel assignments and route changes.

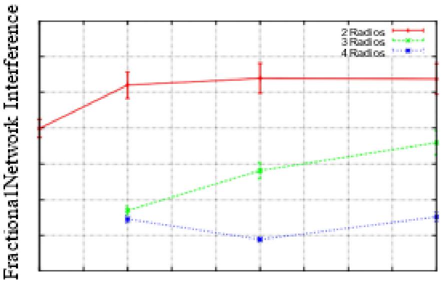
Implementation details: Connectivity of nodes and data transfer between nodes:



Sensor Field of nodes with cluster head (sink) 3:



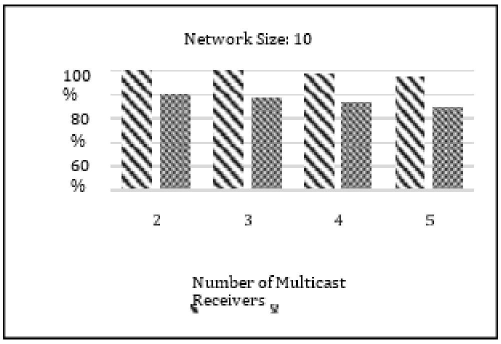
Fractional interference of 50 nodes



Number of channels

The scale of the fractional interference between can be seen that with increasing number of nodes, the fractional interference decrease diminishes.

Packet delivery ratio for a network with 10 nodes and different number of multicast receivers



Conclusion

In this paper, we have presented a novel approach for dynamic channel assignment which is adaptive to the traffic load. We have seen that through this on demand strategy of allocation we can successfully respond to high packet losses occurring due to heavy loads on some nodes. The approach assigns new free channels for those heavy loaded nodes. The registered improvement could not have been realized using only a static assignment strategy, since it can not predict in any way the expected load on the different links of the network. We have also used a clustering strategy in order to simplify and reduce the complexity of dynamic channel assignment into local problems handled within clusters. The simulation results show that by deploying our approach a significant improvement in the aggregated throughput have been achieved.

References

[1] Vladimir Sokolov, Andress Carlson ,"Scheme for Dynamic Channel Allocation with interference reduction in Wireless Sensor Network", 2017

[2] Mack Jermy , " Dynamic channel Selection in Cognitive Radio WiFi Network, Aug 2014

[3] Shreraz alam, Aqdas Naveed, Ijaz Mansoor, Sajjad Ghauri, "Clustering-Based Channel Allocation Scheme for Neighborhood Area Network in a Cognitive Radio Based Smart Grid Communication", 2018

[4] V. Buyachok , g Gulak, G. Sokolov, "Miniaturization of Wireless Monitoring System",2015

[5] Krishna N. Ramachandran, Elizabeth M. Belding, Kevin C. Almeroth, Milind M. Buddhikot, "Interference-Aware Channel Assignment in Multi- Radio Wireless Mesh Networks", 2016

[6] Rasoul Behravesh , Mohsen Jahanshahi, "Interference- Aware and Cluster Based Multicast Routing in Multi- Radio Multi-Channel Wireless Mesh Networks, 2017

[7] P. Bahl, R. Chandra, and J. Dunagan, "SSCH: Slotted seeded channel hopping for capacity improvement in IEEE 802.11 ad-hoc wireless networks," in Proceedings of the 10th annual international conference on Mobile computing and networking (MOBICOM), 2004, pp. 216–230.

[8] Pharatlhatlhe O, Daka JSJ, Gower Botswana, "Cellular Cluster Channel Allocation Using an Edge Weight Frequency Assignment Algorithm", 2018

[9] A. B. M. Alim Al Islam, Md. Jahidul Islam, Novia Nurain, Vijay Raghunathan," Channel Assignment Techniques for Multi-radio Wireless Mesh Networks: A Survey", 2018

[10] Ting-Chao Hou, Tzu-Jane Tsai, "On the cluster based dynamic channel assignment for multihop ad hoc networks", 2014

[11] Adebola Orogun, Oluwaseun Fadeyi, Ondrej Krejcar, "Sustainable Communication Systems: A Graph- Labeling Approach for Cellular Frequency Allocation in Densely- Populated Areas", 2018

[12] So Young Hwang, Jong Jun Park, Hoon Jeong, Bong Soo Kim, Seong Soon Joo, Jong Suk Chae, "Mesh routing method and mesh routing apparatus in beacon enabled wireless AD- HOC networks", 2013

[13] J. So and N. H. Vaidya, "Multi-channel mac for ad hoc networks: Handling multi-channel hidden terminals using a single transceiver," in Proceedings of the ACM int. symposium on Mobile ad hoc networking and computing (MOBIHOC), 2004, pp. 222–233

[14] S.-L. Wu, C.-Y. Lin, Y.-C. Tseng, and J.-P. Sheu, "A new multichannel mac protocol with on-demand channel assignment for multihop mobile ad hoc networks," in Proceedings of the 2000 International Symposium on Parallel Architectures, Algorithms and Networks (ISPAN '00). Washington, DC, USA: IEEE Computer Society, 2000, p. 232.

[15] M. Shin, S. Lee, and Y. ah Kim, "Distributed channel assignment for multi-radio wireless networks," in Proceedings of the IEEE Conference on Mobile Adhoc and Sensor Systems (MASS), 2006, pp. 417–426.

[16] R.Raniwala and T.Chiueh, "Architechture and algorithms for an IEEE 802.11- based multi-channel wireless mesh network," in Proceedings of the Conference on Computer Communications (INFOCOM), 2005.

[17] B. J. Ko, V. Misra, J. Padhye, and D. Rubenstein, "Distributed channel assignment in multi-radio 802.11 mesh networks," in Proceedings of IEEE Wireless Communications and Networking Conference (WCNC), 2007.

[18] A. P. Subramanian, H. Gupta, and S. R. Das, "Minimum Interference Channel Assignment in Multi- Radio Wireless Mesh Networks," in Fourth Annual IEEE Communications

[19] Society Conference on Sensor, Mesh, and Ad Hoc Communications and Networks (SECON 2007), San Diego, California, USA, June 2007.

[20] M.K.Marina and S.R.Das., "A topology control approach for utilizing multiple channels in multi-radio wireless mesh networks," in Proceedings of IEEE BroadNets, Boston, 2005, pp. 381–390.

[21] M. Gerla and J. T.-C. Tsai, "Multicluster, mobile, multimedia radio network," Wirel. Netw., vol. 1, no. 3, pp. 255–265, 1995. "The ns-2 network simulator." [Online]. Available: http://www.isi.edu/nsnam/ns/ G. Bianchi, "Ieee 802.11saturation throughput analysis," in IEEE Communications letters, vol. 2, no. 12, December.