Cooperative Channel Assignment with Dynamic Cluster Management Scheme under MANET

Ms. V. Harini, MPhil., Research Scholar,
Mr. P. Ragupathi, MSc., MPhil., Assistant Professor (CS),
SSM College of Arts & Science, Komarapalayam, Tamilnadu, India

Abstract

Data communication based on infrastructure less environment is supported in Mobile Ad-hoc Network (MANET). MANET data communication traffic is highly increased with its applications. Battery power and delay factors are considered in the bandwidth utilization process. Uniform load levels are managed with coordinated channel access protocols. Uncoordinated channel access protocols support non-uniform load levels. Demand based channel assignment is supported by infrastructure based coordinated protocols.

Cooperative channel assignment and load balance strategies are adapted for the cluster based MANET environment. Throughput, power consumption and Inter-Packet Delay Variation (IPDV) factors are considered in the cooperative channel assignment protocols. Bandwidth scheduling for the MANET is achieved with Dynamic Channel Allocation algorithm. The load is distributed with cooperative load balancing model. The bandwidth scheduling is tuned for all types of load levels.

The cooperative channel assignment scheme is constructed with dynamic cluster management mechanism for the MANET. Medium Access Control (MAC) layer and local broadcasting services are supported by the cooperative channel assignment scheme. The scheme also handles the load that is generated in the local link layer broadcast services. The channel assignment scheme also integrates the network flooding operations. Priority factors are also considered in the channel assignment process. The clusters are reconstructed with dynamic node movement conditions. Channels are reassignment with dynamic clustering status information. All the bandwidth allocation operations are managed with channel coordinators selected with the cluster information.

1. Introduction

A mobile ad-hoc network is a kind of wireless ad-hoc network and is a self-configuring network of mobile routers connected by wireless links – the union of which forms an arbitrary topology. The routers are free to move randomly and organize themselves arbitrarily; thus, the network's wireless topology may change rapidly and unpredictably. Such a network may operate in a standalone fashion, or may be connected to the larger Internet. Mobile ad-hoc networks became a popular subject for research as laptops and 802.11/Wi-Fi wireless networking became widespread in the mid- to late 1990s. Many of the academic researches evaluate protocols and abilities assuming varying degrees of mobility within a bounded space, usually with all nodes within a few hops of each other and usually with nodes sending data at a constant rate. Different protocols are then evaluated based on the packet drop rate, the overhead introduced by the routing protocol and other measures. The Children's Machine One Laptop per Child program hopes to develop a cheap laptop for mass distribution to developing countries for education. The laptops will use ad-hoc wireless mesh networking to develop their own communications network out of the box.

2. Related Work

The optimal placement of monitoring nodes for monitoring coverage maximization, in single-channel wireless networks, has been studied by Subhadrabandhu et al. The work studies the problem of how to select an optimal subset of monitoring nodes to execute Intrusion Detection Modules (IDSs), given a budget on the number of monitoring nodes to be used. The goal is to maximize the number of nodes covered by the selected monitoring nodes. The work allows for IDSs that may periodically stop functioning due to operational failure or compromise by intruders.

It develops a framework to counter the failure of IDSs, and studies the problem of how to find a minimum set of monitoring nodes to execute IDSs, while covering all nodes in the network. The work allows for IDSs that may periodically fail to detect attacks and generate false alarms, and develops a similar framework, nodes are assumed to use a single common channel, and thus there is no issue of channel assignment for monitoring nodes.

The sniffer-channel assignment problem in multichannel wireless networks has been studied by the work [1]–[16], with different problem formulations and different perspectives. The works [5]–[11] have studied OSCA, its variant, or a generalized problem. Our prior work [5] have studied a more generalized problem than OSCA, i.e., how to optimally place sniffers and assign their channels to monitor multi-channel WMNs, assuming stationary networks. Chhetri et al. [6], [7] have studied OSCA for two models of sniffers, assuming different capabilities of sniffers in capturing traffic. Our previous work [8] has studied a generalized version of OSCA allowing for imperfect sniffers, where each node must be monitored by a required number of sniffers to ensure an acceptable quality of monitoring. Chen et al. [9] have studied the sniffer-channel selection problem for monitoring Wireless Local Area Networks (WLANs), formulating the two optimization problems: how to minimize the maximum number of channels that a sniffer listens to; how to minimize the total number of channels that the sniffers listen to. The recent works [10], [11] have studied the sniffer-channel selection problem, with the goal to maximize the quality of monitoring. Du et al. [10] presented a Monte Carlo enhanced Particle Swarm Optimization (MC-PSO) algorithm, while Xia et al. [11] proposed a Multiple Quantum Immune Clone Algorithm (MQICA).

Complementary to the works above, there have been studies [12]–[14] on trade-offs between assigning the radios of sniffers to channels known to be busiest based on the current knowledge, versus exploring channels that are under observed. Arora et al. [12] proposed two policies that sequentially learn the user activities while making decisions on the sniffer-channel assignment. A drawback of the two sequential learning policies in [12] is high computational costs due to the NP-hardness of the decision problem. Hence, Zheng et al. [13], [14] presented two approximate online learning algorithms that are computationally efficient. In the works [15], [16], Hassanzadeh et al. proposed taxonomy to categorize existing solutions for intrusion detection in WMNs. In [15], they investigated the attack-and-fault tolerance of IDS. In [16], they studied two classes of monitoring techniques for intrusion detection in WMN, namely, traffic agnostic and resourceful, and traffic aware and resourceful. Zeng et al. [1] proposed a measurement architecture using distributed sniffers for delay monitoring in wireless sensor networks, and studied a sniffer placement problem for efficient delay measurement.

The aforementioned works [5]–[11], which studied OSCA, its variant, or a generalized problem, focus on centralized algorithms. In contrast, the works [2], [3] and our earlier work [4], upon which this paper builds, presented distributed algorithms to solve OSCA. While the work [14] also presents a distributed algorithm, it is under a different setting, i.e., for online learning. A major difference between the works [2], [3] and this paper is the very different approaches to solve the problem, in terms of the trade-off between the optimality of the solution and the time complexity of algorithm. Specifically, our proposed distributed algorithm, DA-OSCA, which is based on the LP rounding approach, is a polynomialtim algorithm that guarantees an approximation ratio of 1 − 1e

The distributed algorithms based on a Gibbs sampler approach, guarantee the optimality of the solution but may not converge in polynomial time. We would like to point out that our approach, which sacrifices the optimality for time efficiency, is more suitable for distributed algorithms that need to be agile to the changes of network. Besides, this paper addresses the practical issue of how to efficient adjust the sniffer-channel assignment as the network changes, which is not handled by presenting the two operational modes of DA OSCA.

3. Cooperative Channel Allocation (CCA) Scheme

Mobile ad hoc networks (MANETs) have been an important class of networks, providing communication support in mission critical scenarios including battlefield and tactical missions, search and rescue operations, and disaster relief operations. Group communications has been essential for many applications in MANETs. The typical numbers of users of MANETs have continuously increased, and the applications supported by these networks have become increasingly resource intensive. This, in turn, has increased the importance of bandwidth efficiency in MANETs. It is crucial for the medium access control (MAC) protocol of a MANET not only to adapt to the dynamic environment but also to efficiently manage bandwidth utilization.

MAC protocols for wireless networks can be classified as coordinated and uncoordinated MAC protocols based on the collaboration level. In uncoordinated protocols such as IEEE 802:11, nodes contend with each other to share the common channel. For low network loads, these protocols are bandwidth efficient due to the lack of overhead. As the network load increases, their bandwidth efficiency decreases. Also, due to idle listening, these protocols are in general not energy efficient. In coordinated MAC protocols the channel access is regulated. Fixed or dynamically chosen channel controllers determine how the channel is shared and accessed. IEEE 802.15.3, IEEE 802.15.4 and MH-TRACE are examples of such coordinated protocols. Coordinated channel access schemes provide support for quality of service (QoS), reduce energy dissipation, and increase throughput for dense networks. Extensively deployed cellular networks also use a coordinated MAC protocol in which the channel access is regulated through fixed base stations.

Some of the key challenges in effective MAC protocol design are the maximization of spatial reuse and providing support for non-uniform load distributions as well as supporting multicasting at the link layer. Multicasting allows sending a single packet to multiple recipients. In many cases, supporting multicasting services at the link layer is essential for the efficient use of the network resources, since this approach eliminates the need for multiple transmissions of an identical payload while sending it to different destinations.

Spatial reuse is tightly linked to the bandwidth efficiency. Due to the lossy nature of the propagation medium, multiple devices can use the same channel resources in spatially remote locations with minimal effect on each other. Integrating spatial reuse into a MAC protocol drastically increases bandwidth efficiency. On the other hand, due to the dynamic behavior in MANETs, the traffic load may be highly non-uniform over the network area. Thus, it is crucial that the MAC protocol be able to efficiently handle spatially non-uniform traffic loads. Uncoordinated protocols intrinsically incorporate spatial reuse and adapt to the changes in load distribution through the carrier sensing mechanism. Coordinated protocols require careful design at the MAC layer, allowing the channel controllers to utilize spatial reuse and adopt to any changes in the traffic distribution.

Similar to cellular systems, coordinated MANET MAC protocols need specialized spatial reuse and channel borrowing mechanisms that address the unique characteristics of MANETs in order to provide as high bandwidth efficiency as their uncoordinated counterparts. Due to node mobility and the dynamic nature of the sources in a MANET, the network load oftentimes is not uniformly distributed. Two algorithms to cope with the non-uniform load distributions in MANETs:

- a light weight distributed dynamic channel allocation (DCA) algorithm based on spectrum sensing, and
- a cooperative load balancing algorithm in which nodes select their channel access providers based on the availability of the resources.

The two algorithms are applied for managing non-uniform load distribution in MANETs into an energy efficient real-time coordinated MAC protocol, named MH-TRACE. In MH-TRACE, the channel access is regulated by dynamically selected cluster heads (CHs). MH-TRACE has been shown to have higher throughput and to be more energy efficient compared to CSMA type protocols. Although MH-TRACE incorporates spatial reuse, it does not provide any channel borrowing or load balancing mechanisms and thus does not provide optimal support to non-uniform loads. The dynamic channel allocation and cooperative load balancing algorithms are applied to MH-TRACE, creating the new protocols of DCA-TRACE, CMH-TRACE and the combined CDCA-TRACE.

The contributions of the system are: i) A light weight dynamic channel allocation scheme is employed for cluster-based mobile ad hoc networks; ii) A cooperative load balancing algorithm is adapted to manage the loads in the network iii) the two algorithms are incorporate into the TRACE framework leading to DCA-TRACE and CMH-TRACE; and iv) both algorithms are combined to provide support for non-uniform load distributions and constructs CDCA-TRACE.

4. Problem Statement

The Mobile Adhoc Network (MANET) communications are carried out with the support of the intermediate nodes. The bandwidth allocation and load distribution are the major issue in the MANET. Cooperative channel allocation schemes are used to handle the bandwidth scheduling process. The load distribution operations are applied to distribute the load to other nodes. Load distribution methods are employed to handle the uniform load levels. The channel allocation and load distribution tasks are carried out under the cluster based MANET. The following drawbacks are identified from the existing system.

- Delay sensitive communication is not handled in the system
- Local broadcast services are not supported in the load distribution process
- Channel allocation process is not tuned for Network Flooding protocols
- Channel allocation is not optimized for dynamic cluster conditions

5. Enhanced Cooperative Channel Allocation (ECCA) Scheme

The Cooperative Channel Allocation (CCA) scheme is adapted to handle the bandwidth allocation for the mobile nodes in the MANET environment. The nodes are clustered with location and resource levels. Each nodes coverage is analyzed for the cluster construction process. The bandwidth and energy levels are analyzed for the resource status in the node. The Channel

Coordinator (CC) is selected for each cluster environment. The coverage and resource level details are considered in the Channel Coordinator selection process. The bandwidth allocation operations are handled by the Channel Coordinator. The clusters are formed with initial node status information only in the Cooperative Channel Allocation (CCA) scheme. The broadcast operations are verified with channel allocation tasks.

The sensitive data handling process, local broadcast service management, network flooding support and dynamic cluster management operations are supported in the Enhanced Cooperative Channel Allocation (ECCA) method. The sensitive data management process is carried out with priority based channel allocation mechanism. The local broadcast services and network flooding operations are improved in the Enhanced Cooperative Channel Allocation (ECCA) scheme. The Channel Coordinator (CC) selection is enhanced with dynamic cluster conditions. The node mobility is monitored periodically. The clusters are reconstructed with current node status information. The Channel Coordinators are reselected with current coverage and resource levels. The channel reassignment operations are initiated by the Channel Coordinators. The clusters are integrated with multi hop communication model to minimize the cluster load levels.

6. Cooperative Channel Assignment with Dynamic Cluster Management

The mobile ad-hoc networks are formed to handle the data transmission under infrastructure less environment. A lightweight dynamic channel allocation mechanism and a cooperative load balancing strategy are applicable to cluster based MANETs. The protocols are designed with throughput, energy consumption and inter-packet delay variation (IPDV). Dynamic channel allocation algorithm handles the bandwidth allocation for the MANET. Cooperative load balancing mechanism is applied for the load distribution process. The bandwidth allocation scheme is designed for the uniform and non-uniform load distributed environment.

Clustering techniques are used to group the similar nodes with reference to the resource level information. The cooperative channel allocation scheme is enhanced with the consideration of the MAC layer with local broadcasting services. The load balancing process is improved to handle the load generated by the local link layer broadcast services. Network flooding protocols are also combined with the channel allocation and load distribution process. Priority based channel allocation mechanism is also applied to manage the load with emergency conditions. Dynamic node mobility conditions are also adapted for the clustering process. The channel reassignment process is initiated with reference to the dynamic cluster conditions. Cluster reconstruction and channel reassignment operations are handled with dynamic network information.

The channel allocation and load balanced data communication are carried out with the Cooperative Channel Assignment and Enhanced Cooperative Channel Assignment methods. The system is divided into four major modules. They are network construction, clustering process, channel assignment and transfer process. The MANET is formed in the network construction module. The clustering process groups the similar nodes in the same coverage. Channels are assigned in the channel assignment module. Transfer process is designed to handle the data transfer process.

7. Performance Analysis

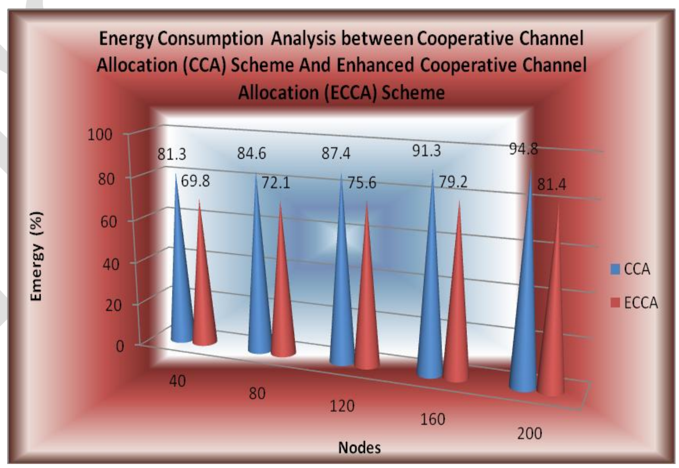

Figure 6.1. Energy Consumption Analysis between Cooperative Channel Allocation (CCA) Scheme And Enhanced Cooperative Channel Allocation (ECCA) Scheme

The mobile ad-hoc networks are constructed to perform data access through the hops. The channel allocation operations are used to assign bandwidth to the nodes. The clustering techniques are used to group the similar nodes in the same coverage. The cluster head controls the nodes the clusters. The Cooperative Channel Allocation (CCA) Scheme And Enhanced Cooperative Channel Allocation (ECCA) Scheme are used to manage the channel allocation in the MANET.

The system is tested with two performance measures. They are energy and traffic level parameters. The power consumption is verified in the energy analysis. Figure 6.1.shows that the ECCA scheme reduces the energy consumption 15% than the CCA scheme. The traffic analysis is used to verify the bandwidth utilization rate. Figure 6.2 shows the traffic analysis between the ECCA and CCA schemes. The analysis results show that the ECCA scheme reduces the traffic level 25% than the CCA scheme.

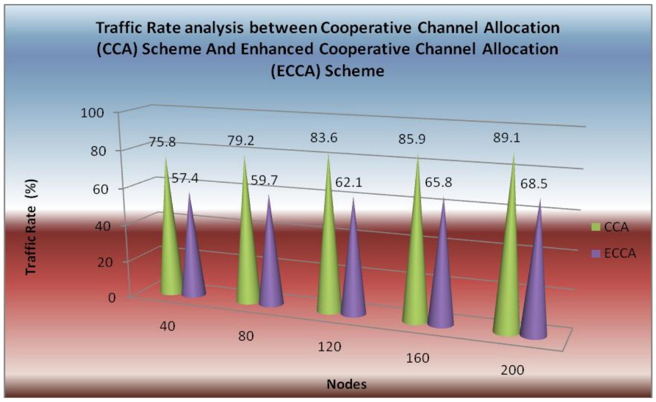

Figure 6.2. Traffic Rate analysis between Cooperative Channel Allocation (CCA) Scheme And Enhanced Cooperative Channel Allocation (ECCA) Scheme

8. Conclusion And Future Enhancement

The wireless communication tasks are handled with Cooperative Channel Assignment methods. Load distribution operations are integrated with the system. Uniform load and non-uniform loads are handled by the cooperative channel allocation mechanism. The broadcast services are supported by the channel assignment process with priority levels. Local link based broadcast services are efficiently handled by the system. The MANET nodes are grouped with resources and spatial properties. The clusters are dynamically updated with its neighbor details. The bandwidth scheduling and load balancing operations are carried out with reference to the current cluster information. The system can be enhancing with the following features. The system can be integrated with the attack detection process. Data security schemes can be integrated with the communication services.

References

[1] W. Zeng, J. Cote, X. Chen, Y.-A. Kim, W. Wei, K. Suh, B. Wang and Z. J. Shi, “Delay Monitoring for Wireless Sensor Networks: An Architecture Using Air Sniffers,” Elsevier Ad Hoc Networks, vol. 13, pp. 549–559, 2014.

[2] P. Arora, N. Xia and R. Zheng, “A Gibbs Sampler Approach for Optimal Distributed Monitoring of Multi-Channel Wireless Networks,” in Proc. of IEEE GLOBECOM, 2011.

[3] Y. Wang, R. Zheng and Q. Wang, “Self-tuned Distributed Monitoring of Multi-channel Wireless Networks Using Gibbs Sampler,” Elsevier Computer Networks, vol. 64, 2014.

[4] D.-H. Shin, S. Bagchi and C.-C. Wang, “Distributed Online Channel Assignment Toward Optimal Monitoring in Multi-Channel Wireless Networks,” in IEEE INFOCOM, Mini-conference, 2012.

[5] ——, “An Optimization Framework for Monitoring Multi-Channel Multi-Radio Wireless Mesh Networks,” Elsevier Ad Hoc Networks, vol. 11, no. 3, pp. 926–943, May 2013.

[6] A. Chhetri, H. Nguyen, G. Scalosub, and R. Zheng, “On Quality of Monitoring for Multi-Channel Wireless Infrastructure Networks,” in Proc. of ACM MobiHoc, 2010.

[7] ——, “On Quality of Monitoring for MultichannelWireless Infrastructure Networks,” IEEE Transaction on Mobile Computing, vol. 13, no. 3, pp. 664–677, March 2014.

[8] D.-H. Shin, S. Bagchi, and C.-C. Wang, “Toward Optimal Sniffer- Channel Assignment for Reliable Monitoring in Multi-Channel Wireless Networks,” in IEEE Proc. of SECON, 2013.

[9] X. Chen, Y.-A. Kim, B. Wang, Y. Song, H. Dinh and G. Chen, “Sniffer channel selection for monitoring wireless LANs,” Elsevie Ad Hoc Networks, vol. 35, no. 16, pp. 1994–2003, September 2012.

[10] H.-Z. Du, N. Xia, J.-G. Jiang, L.-N. Xu and R. Zheng, “A Monte Carlo Enhanced PSO Algorithm for Optimal QoM in Multi- Channel Wireless Networks,” Journal of Computer Science and Technology, vol. 28, no. 3, pp. 553–563, 2013.

[11] N. Xia, L. Xu and C. Ni, “Optimal QoM in Multichannel Wireless Networks Based on MQICA,” International Journal of Distributed Sensor Networks, vol. 2013, 2013.

[12] P. Arora, C. Szepesvari and R. Zheng, “Sequential Learning for Optimal Monitoring of Multi-channel Wireless Networks,” in Proc. of IEEE INFOCOM, 2011.

[13] R. Zheng, T. Le and Z. Han, “Approximate Online Learning for Passive Monitoring of Multi-ChannelWireless Networks,” in Proc. of IEEE INFOCOM, April 2013.

[14] ——, “Approximate Online Learning Algorithms for Optimal Monitoring in Multi-Channel Wireless Networks,” IEEE Transactions on Wireless Communications, vol. 13, no. 2, pp. 1023–1033, February 2014.

[15] A. Hassanzadeh and R. Stoleru, “On the Attack-and-Fault Tolerance of Intrusion Detection Systems in Wireless Mesh Networks,” Lecture Notes in Computer Science, vol. 8487, pp. 387–401, 2014.

[16] A. Hassanzadeh, A. Altaweel and R. Stoleru, “Traffic-and- Resource Aware Intrusion Detection inWireless Mesh Networks,” Elsevier Ad Hoc Networks, vol. 21, pp. 18–41, Oct ober 2014.