A Survey on Channel Coordination for Multi-Channel Wireless Networks

NEHA .K.Y.,
PG Scholar/Department of CSE,
Karunya University, Tamil Nadu, India,

DEVA PRIYA. I,
Assistant Professor/Dept. Of CSE,
Karunya University, Tamil Nadu, India,

Abstract

In wireless networks, multi-channel is used to increase the throughput as well as concurrent transmissions. If the channel is not properly shared among neighbouring nodes then performance degradation occur due to hidden terminals, missing receivers and broadcast deafness problems. To overcome those problems many protocol was proposed. Based on that, protocols are divided into three category called synchronous, asynchronous and semi-synchronous multi-channel coordination protocol. The literature survey has been done in various protocols to know how they reduce channel switching overhead, achieve higher throughput and lower delay and also advantages and disadvantages of each of them are studied.

Index Terms – Wireless network, Channel coordination, Multi-channel, Medium access control.

1. Introduction

Wireless Sensor Networks (WSNs) consist of a large number of sensor nodes, which consist of sensing unit, data processing unit and communication components. Sensor nodes are usually scattered in an ad hoc fashion over a geographic area. They can be uniformly or non-uniformly distributed with various densities depending on an application. Data are taken from elements sensed such as temperature, light, sound, motion, etc., and forwarded to a base station named sink.

In wireless network there are many MAC (medium access control) protocols that have been proposed, where a common channel is shared by mobile hosts and such protocols are called single-channel MAC protocol. IEEE 802.11 is a single-channel model which has been widely accepted as a standard. However, the MAC protocol of IEEE 802.11 Distributed Coordinate Function (DCF) is designed for sharing a single channel between the hosts [1]. In single-channel MAC protocol, network performance gets degraded quickly due to higher contention/collision and as the number of mobile host increases.

Single-channel contention/collision problem can be overcome by using multichannel approach. In multichannel approach throughput can be increased because there will not be any limitation for bandwidth of the channel as in single channel MAC protocol and probability for collisions are less compared to single channel protocol.

Physically, a channel can be divided based on frequency band under FDMA, or based on orthogonal code under CDMA [8]. Categorizing mobile host based on its capability to access multiple channels as follows:

• Single-transceiver: A mobile host can only access one channel at a time.

• Multiple-transceivers: Mobile hosts can access multiple channels simultaneously.

The paper is organized as follows: Section 2 presents the challenges in channel coordination in wireless sensor networks. Section 3 explains the different protocols for channel coordination in wireless sensor networks and the advantages and disadvantages of each scheme are discussed. In section 4 comparison of different protocol are done. The conclusion of the paper is given in section 5.

2. Problem Statement

Earlier systems used a single-channel, where a channel was allocated for communication and because of that channel switching was less. To overcome channel switching problems we use multi-channel coordination and there by enhance channel utilization. In case of multi-channel allocation there exist three problems; they are hidden terminal problem, missing receivers and broadcast deafness problems.

• Multi-channel hidden terminal: When sender-receiver pair exchange control messages about their channel usage, some neighbouring nodes cannot overhear the control messages [7]. Because of incomplete channel usage information, a sender-

receiver pair attempts to use a data channel that is currently occupied, thereby experiencing collisions [7].

- Missing receiver: When a sender fail to identify the channel where its corresponding receiver resides.
- Broadcast deafness: once a node broadcasts a message and a few neighbouring nodes inside the transmission vary doesn't reply thereto, which might disturb routing activities.

As a result of those problem throughput of corresponding protocol gets reduced, as well as delay increases and channel switching get decreased. Due to these problems the overall performance is reduced.

3. Multi-Channel Protocol Based On Channel Coordination in WSNs

In this section, multi-channel MAC protocols based on channel coordination in WSN literature is described and their main shortcomings are outlined. The protocols are categorized in to synchronous and asynchronous and semi-synchronous protocol. Then, these protocols are classified according to their performance and are compared with each other in the following section.

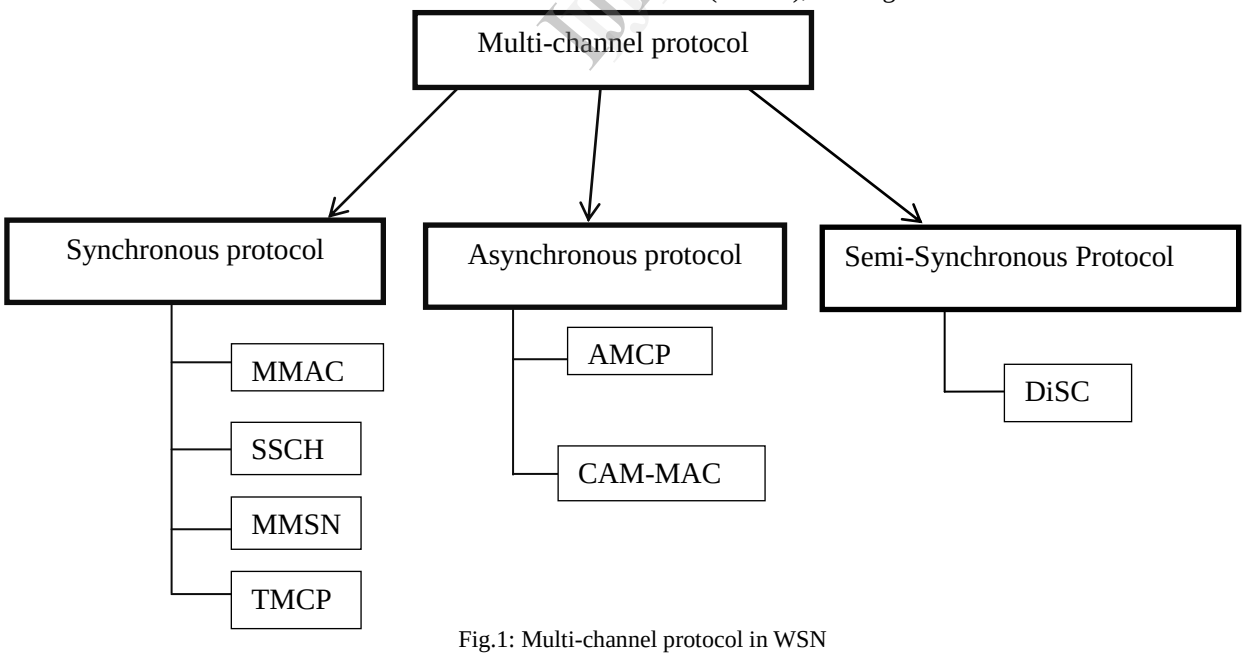

Fig.1: Multi-channel protocol in WSN

3.1. MMAC protocol

Multichannel MAC (MMAC) protocol is a protocol for ad-hoc wireless network. In MMAC protocol, which took the concept of power saving mechanism (PSM) to synchronize clocks between neighbouring nodes [1] [7]. MMAC has two fixed section based on the separation of time; one for negotiation and other for data transmission. During negotiation session, where nodes exchange control packets between sender-receiver pair. After that sender-receiver pair switches to data channel in the following session.

MMAC protocol can successfully exploits multiple channels to improve total network throughput over IEEE 802.11 single-channel [1]. Power saving mechanism used in IEEE 802.11 can be integrated with MMAC for energy efficiency. Due to this protocol we can achieve throughput, better load balancing and can solve hidden terminal problem, missing receiver problem as well as time synchronization can be done efficiently. Drawback while using this protocol is hardware complexity, size of Announcement Traffic Indication Message (ATIM) window cannot be changed and fixed length for negotiation. Compare to other protocols MMAC use more channel for data transmission.

3.2. AMCP protocol

Asynchronous multichannel coordination protocol (AMCP), is designed to address the root cause of

starvation of CSMA protocols in single channel multi-hop wireless network and dual coordination problem that arise due to multiple channels. AMCP is a way of alleviating the starvation problem, in this phenomenon where few dominating flows take most bandwidth and because of that rest of the flow get little or none [2] [7].

AMCP has a dedicated control channel on which nodes contend to reserve data channel after exchanging RTS/CTS packets [2]. After successfully completing control packet then both sender and receiver switch to the reserved data channel and then transmit data packet. After completing the data packet they return to the control channel and set all channels as unavailable except using channel. They may content for data channel immediately or contend for other data channels after timers of those channel expire. AMCP can achieve throughput, can solve hidden terminal problem, missing receiver problem and single radio, without global synchronization. Main drawback of the protocol is that it cannot prevent starvation in multi-hop channels.

3.3. SSCH protocol

Slotted seeded channel hopping (SSCH) is a protocol which uses single transceiver and multi-channel. This protocol will increase the capability of associate degree IEEE 802.11 network by utilizing frequency diversity [3]. It uses a unique theme for distributed rendezvous and synchronization. it's a link-layer protocol. In SSCH, it does not have any control channel rendezvous and also can improve capacity using a single radio. SSCH does not require tight clock synchronization because it does not have a common control channel or a dedicated neighbour discovery interval between the sender-receiver pairs.

The SSCH can increase network capacity in several multi-hop and single-hop wireless networks. SSCH is a distributed protocol, suitable for deploying in a multi-hop wireless network [3]. In this it does not need a synchronization or leader election. Nodes get synchronized by themselves but due to lack of synchronization, there is a mild reduction in throughput. SSCH uses randomized channel hopping and optimistic synchronization due this we can eliminate the need of a predefined control channel. Using this protocol we can achieve network capacity, reduce packet delay and can increase throughput. Main drawbacks are large route discovery time and poor power consumption while comparing to other protocol.

3.4. MMSN protocol

Multifrequency MAC for WSN (MMSN) [4] is the first multi-frequency MAC protocol designed for WSN. It uses single transceiver devices. It was design based on toogle transmission and toogle snooping. It is based on slotted CSMA where at beginning of each time slot nodes need to contend for the medium before they transmit. The beginning of each slot is reserved for broadcasts. Before transmitting a packet each node need to listen its own frequency and destination frequency. MMSN are allowed to choose four available frequency such as, 1) Exclusive frequency, 2) Implicit-consensus, 3) Eavesdropping and 4) Even-selection.

MMSN have some drawback i.e., when a node want to send a data unit it has to switch between self-frequency as well as with destination at preamble sending time, which can increase delay and overhead. And this protocol can achieve higher throughput and energy efficiency.

3.5. CAM-MAC protocol

A single radio Cooperative Asynchronous Multi-channel MAC protocol called CAM-MAC [5].CAM-MAC is a simple protocol, which does not need any time synchronization. In this protocol, idle neighbours share control information with transmitter-receiver pair to overcome multi-channel coordination (MCC) problems, such as channel conflicts and deaf terminals. The CAM-MAC does not need any time synchronization. In design of cooperative MAC protocols in an environment where each node is equipped with a single transceiver and has multiple channel to choose the free channel to use.

CAM-MAC employs a handshake which consists of three phases: a probing phase, a feedback phase and a confirm phase. Due to this protocol, idle neighbours share the control information to sole MCC problem, no clock synchronization, and increase throughput. Drawbacks are energy consumption as well as multiple responses. Due to this protocol can achieve improvement in terms of number of collisions and throughput.

3.6. TMCP protocol

TMCP is a tree-based multi-channel protocol for data collection application in WSNs. Aim of this protocol, is to use multichannel to improve communication performance. The main idea of TMCP protocol is to partition the whole network

into multiple vertex-disjoint sub-trees all rooted at the base station. In this protocol, segrates the nodes in to trees, delegating a channel to each tree [6]. TMCP solve the problem of multi-channel nodes in a WSN. Since each tree has a single channel and no need for time synchronization. By using this we can reduce packet losses by eliminating inter-tree interference and exploiting spatial reuses of parallel transmissions among sub trees.

TMCP has three components they are channel assignment, channel detection, data communication. Some shortcomings of TMCP are as that in WSN is static therefore it is not applicable to dynamic WSNs, where new nodes join as well as die out. It is designed to support data collection traffic and difficult to have successful broadcasting due to partitions. Achievements are reduced packet losses, improved network throughput, channel coordination and decreased collision.

3.7. DiSC protocol

Distributed and semi-synchronous multi-channel coordination (DiSC) protocol [7] was the first semi-synchronous wireless multichannel protocol. In DiSC, we are using single transceiver. It is used to efficiently coordinate multichannel operation, as well as enhance channel utilization with minimal channel coordination overhead. It also reduces channel switching. It does not need any additional synchronization process.

DiSC protocol has a key feature of semi-synchronization, and it can achieve a certain level of synchronization without any strict clock synchronization; because of this it can reduce the multichannel coordination complexity [7]. In DiSC protocol, it will establish a dynamic interval within which all sender-receiver can perform their negotiation as well as data transmission on control and data channel, by the end of the interval they will return to the control channel and that interval is refers as rendezvous interval. While comparing with other protocols DiSC has achieves performance enhancement and it had solved multichannel coordination problem such as hidden terminal, broadcast deafness and missing receiver.

4. Comparisons of Protocols

Table 1 compares the different multi-channel MAC protocols discussed in the preceding section. This comparison is from the viewpoint of different parameters apart from the challenges they respond.

Table 1. Comparing Multi-channel MAC protocols

Main classification	**Protocol**	**Implementation**	**Number of Transceiver**	**Objectives**
Synchronous protocol	MMAC	Centralized	Single	Better load balancing
	SSCH	Distributed	Single	Reduce packet delay
	MMSN	Distributed	Single	Increasing parallel transmission
	TMCP	Centralized	Multiple at sink	Efficient data collection
Asynchronous protocol	AMCP	Distributed	Single	Alleviate starvation
	CAM-MAC	Centralized	Multiple at cluster head	No clock synchronization
Semi-Synchronous protocol	DiSC	Distributed	Single	No strict clock synchronization

5. Conclusion

In this paper we study many different MAC protocol based on multi-channel. We classified the multi-channel protocol into synchronous, asynchronous and semi-synchronous protocol. Several MAC protocols for WSNs have been

proposed based on channel coordination but none of them is accepted as a standard protocol. So protocols are considered as general application specific. Most of the multi-channel MAC protocol proposed focus on channel coordination and thus reduce the delay as well as solve hidden terminal problems, broadcast deafness and missing receiver problem.

References

[1] J. So, N. Vaidya, "Multi-channel mac for ad hoc networks: handling multi-channel hidden terminals using a single transceiver", in: Proceedings of ACM MobiHoc, 2004, pp. 222–233.

[2] J. Shi, T. Salonidis, E. Knightly, "Starvation mitigation through multichannel coordination in CSMA multi-hop wireless networks", in: Proceedings of ACM MobiHoc, 2006, pp. 214–225.

[3] P. Bahl, R. Chandra, J. Dunagan, "SSCH: Slotted seeded channel hopping for capacity improvement in IEEE 802.11 ad-hoc wireless networks", in: Proceedings of ACM MobiCom, 2004, pp. 216–230.

[4] T.Y.T.H.J.A.S. Gang Zhou, Chengdu Huang, T.F. Abdelzaher, "MMSN: multi-frequency media access control for wireless sensor networks", in: Proceedings of IEEE INFOCOM, 2006.

[5] T. Luo, M. Motani, V. Srinivasan, "CAM-MAC: a cooperative asynchronous multi-channel MAC protocol for ad hoc networks", in: Proceedings of BROADNETS, 2006, pp. 1–10.

[6] T.H.J.L. Yafeng Wu, John A. Stankovic, S. Lin, "Realistic and efficient multi-channel communications in wireless sensor networks", in: Proceedings of IEEE INFOCOM, 2008.

[7] T. Kim, J. Hwang and H. Lim, "Distributed semi-synchronous channel coordination for multi-channel wireless networks", in: Proceedings of Ad HOC Networks, 2013, pp. 368-382.

[8] S.-L. Wu, C.-Y. Lin and Y.-C. Tseng, "A Novel MAC protocol with on-demand channel assignment for multi-hop mobile Ad Hoc networks", in IJAHUC, 2000.