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Enhanced MAC for Multichannel Ad-Hoc Wireless Communication using Multipower-interfaces

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***Abstract* - The multichannel transmission in Ad-Hoc wireless networks can improve the network performance by reducing interferences among nodes. Here proposed an enhanced medium access control (MAC) protocol for Ad-Hoc wireless multichannel transmission. The proposed protocol accomplished the multichannel communication by using multiple interfaces. These interfaces follows randomly generated hopping pattern. The interfaces are considered as antennas. These interfaces can support high and low power transmissions. The high power antennas for long distance transmission and low power antennas for short distance transmission. The introduction of power interfaces can reduce the total energy consumption of the entire communication system. The channels used for both interfaces may be same or different but not similar at a time. Proper hopping and coordination control elements are implemented for the synchronization and effective channel usage. MAC layer level modifications are done and simulating the scenarios that follows the proposed MAC using Network Simulator 2 (NS-2). Evaluate the performance of proposed concept in terms of throughput, loss, energy consumption etc.**

Index Terms– Multichannel transmission, Multi-power interfaces Medium access control protocol.

I. INTRODUCTION

The Ad-Hoc wireless networks are decentralized networks. The term ad hoc indicates the meaning that these networks never relay upon a pre-existing infrastructure. Every nodes in the ad-hoc system participates in routing by forwarding data to other nodes. The principle behind ad hoc networking is multi-hop relaying in which messages are sent from the source to the destination by relaying through the intermediate hops or nodes. Mobile ad-hoc is a collection of two or more devices or nodes or terminals with wireless communications and networking capability that communicate with each other without the aid of any centralized administrator. It is an autonomous system in which mobile hosts connected wirelessly and the wireless links. All nodes in a wireless ad hoc network act as a router and host. The network topology posses dynamic nature, because the connectivity between the nodes may vary with time due to some of the node left and new node arrived. The major goals in Ad-Hoc networks are increasing network capacity by the effective use of available bandwidths along with the parallel communications among adjacent nodes [12]. Utilizing multiple non-overlapping channels, as provided in wireless communication standards like IEEE 802.11 enable adjacent nodes to communicate in different channels [1], [2], [3], [4], [5], [6]. This will increase the packet delivery ratio, deduct the latency of network traffic, and thereby, the overall throughput in the network increases significantly.

The Medium Access Control protocol (MAC) deals with the channel accessing and sensing, so a MAC protocol which enables the multichannel transmission can be develop. Eventhough the multiple channels were used for the communication, there will be a chance for increasing probability of collision with the increase in number of nodes. This problem can be solved with multi-channel, multi-interface approaches [7], [9], [10]. The introduction of multiple interface–multichannel communication helps to explore the different possibilities of multichannel communication in ad-hoc networks. Along with the channel collision problem, the problems such as, channel switching overheads, large energy consumption etc are need to be addressed. The proposed concept (multichannel- multi-power interface communication) inspired from these problems and it can be developed as a robust, energy efficient medium access control protocol which accelerate the network performance and other aspects of wireless communication. This proposal covers the concept of a multichannel- multi-power interface MAC which enables the wireless transmission through multiple channels by frequency hopping channel assignment mechanism. These power interfaces provide communication in two different ranges [14] using different channels. The rest portions of the paper divided as follows: Section II reviews the related works, section III present the motivation and overview of our proposal, section IV briefly describes the proposed concept, and finally section V discussed about the simulation environment, VI presents the performance evaluation and finally VII concluded this paper.

II. RELATED WORKS

The studies and researches based on multichannel wireless transmission and MAC protocols for wireless multichannel transmission has been going on for the past few years. This section involves an extensive survey on different MAC protocols existed for the wireless multichannel transmission

and their features. The nodes in the single channel transmission are periodically listen to the same channel while transmission in the single channel transmission. But the multichannel communication network nodes can switch among channels for maintaining parallel communication. Before the parallel communication happens, these channel would reach an agreement and this will coordinated by channel assignment mechanisms.

The traditional multi-channel MAC protocols can be classified into two generalized categories such as single rendezvous and multi rendezvous and this single rendezvous can be classify based on different channel assignment mechanisms and they are fixed channel assignment, semi dynamic channel assignment and dynamic channel assignment. The dynamic channel assignment can be can be categorized as: (i) dedicated control radio, (ii) split-phase, and (iii) frequency hopping [11].

In fixed channel assignment scheme[11], radio interfaces of both sender and receiver cannot change the operating channel during communication. Semi-dynamic [11] scheme provides a fixed channel to either sender or receiver and nodes switch their interfaces to a selected channel for communication. Here switching between different frequencies take place. In the dynamic channel assignment approach [11], nodes can dynamically switch among their channels in order to communicate with their neighbours and deliver the data. Therefore, every data transmission takes place after a channel selection.

Along with these multichannel concepts, the introduction of multiple interfaces on wireless nodes for optimizing the channel capacity while transmission, discussed in [7], [9], [10], [12], that is the concept of multichannel-multi interface wireless-communication. This concept mainly experimented with Wireless Sensor nodes (WSNs) [10], Ad-Hoc networks, Mesh networks [11] etc. The related works briefly explained different multichannel MAC protocols as well as multiple interface concepts in multichannel transmission.

A Multichannel MAC Protocol [2] which support multichannel transmission, having a single half duplex transceiver for every node. This helps in either the listening or the transmission, but only in a simultaneous manner.This scheme requires only one transceiver for each host. The nodes in the network are synchronized by beacons, and the channels are negotiated in the ATIM window using ATIM packets [3].

The hop reservation multiple access HRMA [4] protocol operates with simple FHSS radios. This scheme can dynamically allocate frequency bands to nodes using a common frequency-hopping pattern, in such a way that data and acknowledgements are transmitted without hidden-terminal interference. HRMA's features are achieved using simple half duplex slow frequency-hopping radio without carrier sensing for multichannel communication.

Seed slotted channel hopping scheme SSCH) [5] is a link-layer protocol for distributed coordination of channel hopping. Provisioning an arrangement for the multiple flows within radio range sent over separate channels. This allows bandwidth to scale linearly with the number of flows. This scheme is unique in that there is no dedicated channel for control information. A parallel rendezvous approach for multichannel transmission Mc-MAC [6] having nodes with multiple interfaces for independent frequency hopping. Random hopping sequence generation, discovery, synchronization and parallel scheduling are the themes used in [6]. Providing dual radio interfaces nodes for fast and slow hopping sequences. The discovery and synchronization module deals with the channel accessing and sensing. The concept of nodes with multiple interfaces in the proposed system inspired from this approach. Another multichannel MAC [1] which supports half duplex radio interfaces follows same working principle of [6] can avoid busy receiver problem, congestion etc. [1] provided a dynamic channel switching scheme.

In reference [7], different interfaces tuned to different channels, which can essentially improve network capacity. A common channel assignment (CCA) [8] is used, here. In CCA radio interfaces at each node are assigned to the same set of channels. Eventhough this scheme provide network efficiency, problems arise in areas like proper channel sensing, collision etc.

Reference [10] discusses a dual interface multi-channel transmission schemes which introduce interfaces for both high and low band width channels. The difference in this scheme when compared with others is it introduces a switching agent, sitting on top of dual routing agents. This will monitors the traffic flow or the end-to-end delay and switches on the high-bandwidth interface whenever the traffic rate becomes high (load-balancing) [9] or the end-to-end delay exceeds a threshold. As a part of energy saving energy, the switch agent caches the routes established previously. Dual mode interfaces are used for multichannel communication in [14]. These dual mode interfaces support communication in two different ranges.

III. Motivation And Objective

The multichannel wireless transmission can be possible with both nodes having single interfaces and multiple interfaces. In the case of multiple channels-single interfaces, each node in the network switches dynamically between channels using its single interface and it must ensure some coordination with neighbour nodes for communicating over a common channel. This coordination require a strict time synchronization between participating nodes and can causes the huge increase of end-to-end delays in the network during communication. Therefore, this solution cannot be applied to large ad-hoc networks. But in the case of Multichannel-multiple-interfaces, implementing multiple interfaces per node allows the simultaneous transmission and reception through two different interfaces, which are tuned to different channels. It can possibly improve network capacity. The issues in multiple interfaces is the channel assignment problem which involves assigning channels to radio interfaces by such a way, to achieve efficient utilization of available channels. Another problem is the energy consumption of the communication system. Our main objective is to modify the standard MAC which enables the wireless transmission through multiple channels by frequency hopping channel assignment mechanism and using multiple interfaces (power interfaces).These power interfaces provide communication in two different ranges in an energy efficient manner.

IV. PROPOSED SYSTEM

A multichannel, multi-interface MAC protocol for wireless ad-hoc is proposed here. This MAC supports multiple interfaces for multi channel transmission and these are power interfaces. The selection of interfaces are depend on distance between the sender and the receiver or the range of receiving nodes ie; for a long distance transmission high power interfaces are used and for short distance communication low power interfaces are used. This will results in the considerable reduction of overall power consumption of the communication. Every node in the communication system has two interfaces which provide communication in two different ranges simultaneously. These interfaces can follow the frequency hopping pattern, which are generated randomly.

A pseudo random generator generates the hopping patterns. Communicating nodes can transmit and receive data either through high power interfaces or low power interfaces. But at a time the transmission and reception cannot possible through the same interfaces. The hopping pattern follow by these two interfaces are different at a time, so the different interfaces never use the same channel at the same time. The sending interfaces of the sender node and the receiving interface of the receiving node should know each other via control messages. The proper coordination of sender and receiving interfaces of transmitting and receiving node can help in the channel switching process, ie; a sender node can switch to a channel which is followed by the receiver interface of the destination node while transmitting. If there any kind of channel interferences within a specified range between the two interfaces,(when high power interface select the channel which is used by the other interface), then the node which is responsible for the interference get noticed by the other node and the responsible node's interface randomly switch to another feasible channel for a time period. For this a time based random channel switching scheme is used.

The control elements that included in the proposed concept are, Hopping control, and Coordination control. The hopping control element is used to generate hopping sequences. It guarantees that the two interfaces do not share the same channel at the same time. The channels in the generated hopping pattern must falls within the available channels in the communication system. In the coordination control, the nodes should periodically transmit control packets over channels through either of its interfaces. These packets include the information about the hopping pattern of respective interfaces. Here we assumed that both the control packets and data packets are used same channels and no overheads due to these control packets.

The proposed concept can be summarized like this, when a node has a packet, the node determines, the range of the destination node, if it falls within the specified range or the distance between source and the destination are short then transmitting node choose the low power interface. Otherwise it selects high power interface. This helps a node in such a way that it can send and receive data at a time using its interfaces. This may reduces the channel interferences.The main contributions of proposed MAC protocol are; multi interface, multichannel-communication, reduction in system's power consumption, reduction in node interference, congestion etc.

A. Architecture

The figure.1 shows a sample architecture of the proposed system. In this architecture multiple interfaces are implemented to only one node. The figure consist three nodes such as A,B and C. Node A wants to communicate with both B and C. It can use its multiple interfaces for the transmission. LPA and HPA are low power and high power interfaces respectively. A can communicate to B using low power interfaces and communicate to C using its high power interface. The selection of interfaces depend upon the position of both sender and receiver node. So the interface selection can said to be dynamic in nature. The range of a destination node can evaluate on the basis of a predefined range value. The communication which involves high and low energy requirement can be identified and routing can done according to this requirement. Since there is a clear separation in use of antennas in each case of communication, the power efficiency of the system is very high.

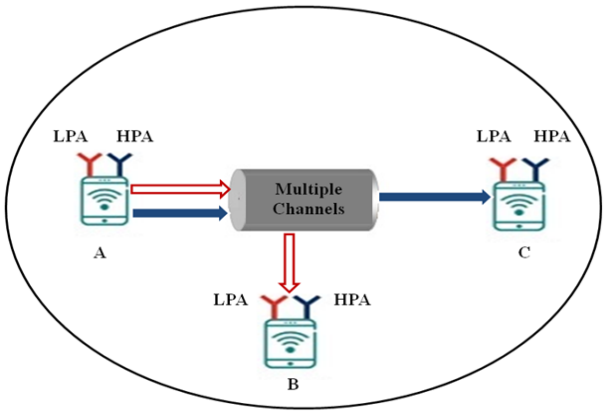

Figure. 1: Architecture of proposed system

B. System Model

Consider that the system consist of n nodes and k orthogonal channels. All nodes are equipped with two power interfaces such as and these can be switch between multiple channels. The interfaces I_L and I_H are the low and high power interfaces respectively. Dt be the threshold distance value. This value can initially calculated based on the range of interfaces and initial position of communicating nodes. When these nodes got mobility then dynamically calculate the current position and range of both the sender and receiver and interface selection decision take place. So interfaces are dynamically selected. The distance between sender node and receiver node falls within the threshold range then it can be considered as short distance communication and use I_L. otherwise I_H. The distance calculations can be done by using

d=sqrt(pow((x1-x2),2)+pow((y1-y2),2))

(1) where x1,x2,y1,y2 are the sending and receiving nodes position in x axis and y axis. The hopping and coordination control elements ensures that whenever a channel interference occurs a random switching of the current channel to another by the interface for a time period T. According to hopping

control each channel Ci must befalls within C which is a set of available channels and i must be modular to k where i ={1...n} and k is total number of available channels.

V. SIMULATION ENVIRONMENT

We implemented the protocol in the Network Simulator- 2 (NS-2) and evaluated it. The steps involved in the simulation of proposed protocol using NS2 are:

- Creation of traffic and topology
- Implementation of multichannel and dual power interface support in protocol
- Simulation using NAM
- Analysis of trace file and Performance evaluation

Proposed scenario contains ten nodes including transmitting and receiving nodes. If the source and destination node falls within a specified range, then it can use low power interface for routing packets otherwise high power interface. The core code level implementation including modification of standard 802.11 MAC file for dual power interfaces, multichannel communication and control elements. This core codes have the connection with both TCL files and ns library files.

Here used the Ad hoc on demand distance vector routing protocol (AODV). Efficient routing protocols can provide significant benefits to Ad hoc networks in terms of both performance and reliability. AODV initiates a route discovery process, which goes from one node to the other until it reaches to the destination or an intermediate node has a route to the destination. Considered the Two Ray Ground model for radio propagation and the NS-2 IEEE 802.11 model for the Medium Access Control. These models can account for creating a scenario similar to a real communication network, using parameters of commercial devices. The idle power, transmission power and receiving power of communicating nodes are initialized. For the energy calculation, energy model used. Other simulation parameters are shown in table I.

TABLE I
SIMULATION PARAMETERS

Parameters	Environment
Channel Type	Wireless Channel
Radio Propagation Model	TwoRayGround
Network Interface Type	WirelessPhy
MAC Type	Mac/802_11
Interface Queue Type	DropTail/PriQueue
Link Layer Type	LL
Antenna Model	Omni Antenna
Number of Wireless nodes	10
Initial Energy	150
Routing Protocol	AODV
X Coordinate value	875
Y Coordinate Value	637
Simulation Stop Time	50 seconds

VI. PERFORMANCE EVALUATION

The Performance evaluation of the proposed protocol carried out by using multichannel and single channel scenarios. The parameters used for the analysis are throughput, packet loss and energy dissipation of nodes.

A Parameters Evaluated

Throughput calculated at the receiver nodes. The receiver nodes in the simulation are node 8 and node 9 in simulation. The multichannel scenario divided as, scenario without mobile nodes (Simulation 1), with mobile nodes (Simulation 2). The single channel scenario with and without mobile nodes are respectively simulation 3 and Simulation 4. The result in table II shows that the throughput of the multichannel scenarios are higher than single channel scenarios. The location changes of communicating nodes can influence the change in throughput.

The comparisons are made up between a multichannel multi-interface communication system and single channel communication, on the basis of system's total throughput and packet loss. The table III shows the analysis and from the values we can conclude that the proposed concept outperforms the single channel communication scenarios.

TABLE II
THROUGHPUT ANALYSIS OF DIFFERENT SCENARIOS

Simulations Number	Throughput (kb)	
	Node 8	Node 9
1	303.3	117.6
2	391.6	28.4
3	137.9	92.5
4	214.5	16.7

TABLE III
THROUGHPUT ANALYSIS OF PROPOSED AND EXISTING CONCEPTS

Method	Throughput (kb)
Proposed(multichannel multi-interface)	1537.12
Existing (Single channel)	678.23

The fig. 2 shown below describes the rate of packet loss in proposed and single channel communication scenarios. The X-axis for and Y-axis for time the number of packets dropped . Fig. 3 shows the energy dissipation of transmitting node (in simulation node 1) in scenario using power interfaces (energy1) and without power interface (energy1). The energy dissipation rate of transmitting node is higher in scenario which does not use power interfaces.The multichannel, multi-power interface communication have much higher throughput value when compared with single channel communications. The use of multi-power interfaces (dual power interfaces) can considerably reduces the total energy consumption of the system.

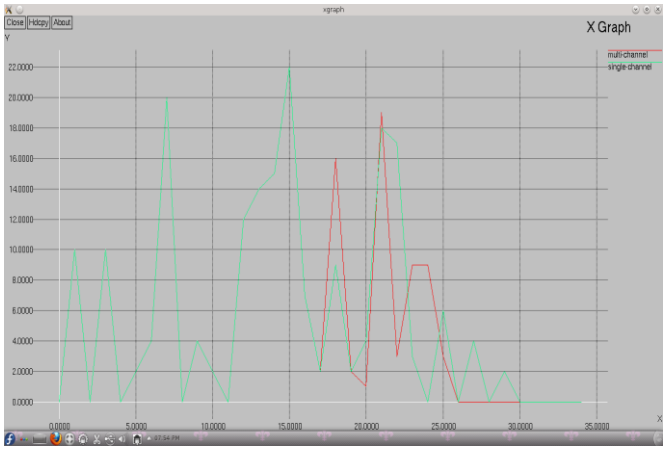

Figure. 2: Packet Loss

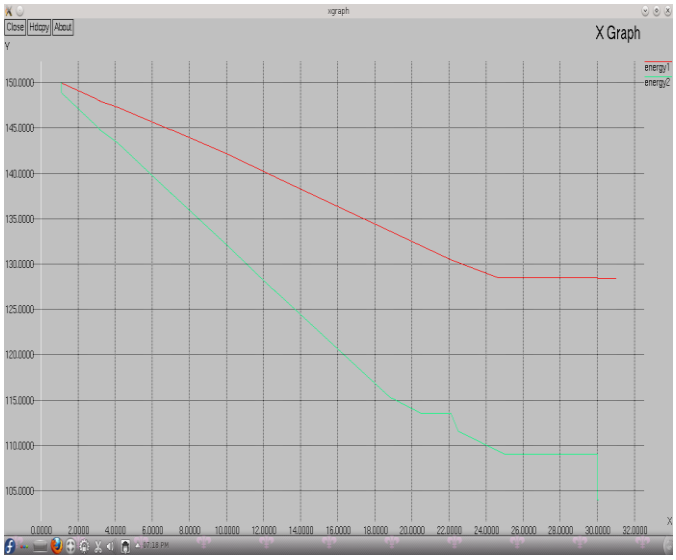

Figure. 3: Energy Dissipation

VII. CONCLUSION

Medium access control (MAC) protocols coordinate the channel access between wireless stations. MAC protocols that support a multichannel model can increase the throughput by enabling more simultaneous transmission pairs in the network. The network with nodes employs multiple (dual) power interfaces which facilitates multichannel transmission.The interfaces are considered as antennas. According to the proposed concept each interfaces can support high and low power transmission individually. Control elements are implemented for the proper channel switching.The proposed concepts are realized with help of a Network Simulator. An analysis carried out to evaluate the network performance of proposed protocol. The analysis showed that the multichannel transmissions are always efficient than single channel transmission in terms of throughput of the system. The usage of power interfaces can effectively manage the energy consumption and throughput of the multichannel communication system. The proposed protocol is always in accordance with the IEEE 802.11 MAC strategies.

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