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Enhance Throughput in Multi-Channel MAC Protocol for Cognitive Radio Networks

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ABSTRACT

Modern wireless technologies have the problem of improving the throughput and security of Multi-channel Medium Access Control (MMAC) protocols. We design a protocol called Full Duplex Multi-channel MAC(FD-MMAC) that exploits recent advances in full duplex (FD) communications to coordinate channel access in a distributed manner. Compared with prior MMAC designs, this protocol eliminates the use of dedicated in-band or out-of-band control channels for resolving contention, discovering the resident channel of destinations, and performing load balancing. We employ the randomized dynamic channel selection for load balancing among channels and the standard backoff mechanism for contention resolution on each available channel. FD-MMAC enables the operation of multi-channel exposed terminals. The elimination of the control channel improves spectral efficiency and mitigates denial-of-service attacks. FD-MMAC achieves significantly higher throughput. We theoretically analyze the throughput performance of FD-MMAC and verify our analysis via simulations.

KEYWORDS-Denial-of-service, full duplex, jamming, media access control, multi-channel, security, wireless networks.

I. INTRODUCTION

Wireless technologies accommodate parallel transmissions over orthogonal frequency bands, herein referred to as channels, to alleviate contention and interference. Access to those channels is coordinated at the medium access control (MAC) layer, which is also responsible for reliable frame delivery, destination discovery, contention management, and load balancing. In the simplest form of medium access control (e.g., 802.11a/b/g), terminals remain tuned to the same channels for long periods of time. As a result, some channels become saturated while others remain underutilized. The design of efficient multi-channel MAC (MMAC) protocols poses significant fundamental challenges.

These challenges are unique in the multichannel domain and thus absent in the single-channel MAC counterparts. First, senders must employ low-overhead mechanisms for discovering the resident channel of their respective destinations. Second, parallel transmissions must be efficiently distributed over all channels to alleviate contention. Load balancing across channels must be achieved so that capacity of those channels is fully exploited. In a single-channel domain, no such destination discovery or load balancing is necessary as terminals share a single channel. Furthermore, the availability of multiple channels provides an opportunity to design MAC protocols that are resilient to DoS attacks. Single channel MACs are hard to defend against these types of attacks, because only one channel is available.

However, the majority of existing MMAC protocols relay on the Common Control Channel (CCC) for addressing the above challenges. This leaves them vulnerable to the same types of attacks as in single-channel MACs, as the CCC constitutes a single point of failure. Finally, most existing MMAC protocols fail to address the multi-channel exposed terminal problem, whereby a sender switching to a busy channel, but being exposed to a transmitter, cannot proceed with a parallel non-interfering transmission. To improve the spectral efficiency and jamming resilience of MMAC protocols, we exploit recent advances in full duplex (FD) communications over a single channel. In certain low-power wireless environments, sophisticated self interference suppression (SIS) techniques allow for concurrent transmission and reception over a single channel. This is achieved by suppressing a significant portion of self interference (up to 110 dB), using a combination of antenna-based SIS, signal inversion, and RF/digital interference cancellation. The integration of FD communications provides unique opportunities for reducing the control overhead, increasing the spatial channel reuse, and improving resilience to jamming.

II. RELATED WORK

A.CSMA/CN: Carrier Senses Multiple Accesses With Collision Notification

A wireless transmitter learns of a packet loss and infers collision only after completing the entire transmission. If the transmitter could detect the collision early [such as with carrier sense multiple access with collision detection (CSMA/CD) in wired networks], it could immediately abort its transmission, freeing the channel for useful communication. There are two main hurdles to realize CSMA/CD in wireless networks. First, a wireless transmitter cannot simultaneously transmit and listen for a collision. Second, any channel activity around the transmitter may not be an indicator of collision at the receiver. This paper attempts to approximate CSMA/CD in wireless networks with a novel scheme called CSMA/CN (collision notification). Under CSMA/CN, the receiver uses PHY-layer information to detect a collision and immediately notifies the transmitter. The collision notification consists of a unique signature, sent on the same channel as the data. The transmitter employs a listener antenna and performs signature correlation to discern this notification. Once discerned, the transmitter immediately aborts the transmission. We show that the notification signature can be reliably detected at the listener antenna, even in the presence of a strong self-interference from the transmit antenna. A prototype test bed of 10 USRP/GNU Radios demonstrates the feasibility and effectiveness of CSMA/CN.

B.Combating hidden and exposed terminal problems in wireless networks

The hidden terminal problem is known to degrade the throughput of wireless networks due to collisions, while the exposed terminal problem results in poor performance by wasting valuable transmission opportunities. As a result, extensive research has been conducted to solve these two problems, such as Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA). However, CSMA-like protocols cannot solve both of these two problems at once. The fundamental reason lies in the fact that they cannot obtain accurate Channel Usage Information (CUI, who is transmitting or receiving nearby) with a low cost. To obtain additional CUI in a cost-efficient way, a cross layer design, FAST (Full-duplex Attachment System) is proposed. FAST contains a PHY layer Attachment Coding, which transmits control information independently on the air, without degrading the effective throughput of the original data traffic, and a MAC layer Attachment Sense, which utilizes the PHY layer control information to identify the hidden and exposed nodes in real time. Firsttheoretically analyze the feasibility of the Attachment Coding, and then implement it on a GNU Radio test bed consisting of eight USRP2 nodes, also conduct extensive simulations to evaluate the performance of FAST, and the experimental results show that FAST can effectively solve both the hidden and the exposed terminal problems.

Multi-channel hidden terminal problem: Consider the topology, Let A and B reside on channel f_1, while C resides on f_2: Topologically, C is a hidden terminal to A. Assume that A performs an RTS/CTS exchange over f_1 before communicating P_A to B. Let the transmission of P_A start at t_0 and terminate at t_1. Assume that C switches to f_1 at t_2 with $t_0 < t_2 < t_1$: Because $t_2 > t_0$, terminal C will not overhear CTS_B. Moreover, the transmission of P_A is ongoing when C switches to f_1. At time $t_3 < t_1$; C causes a collision at B.

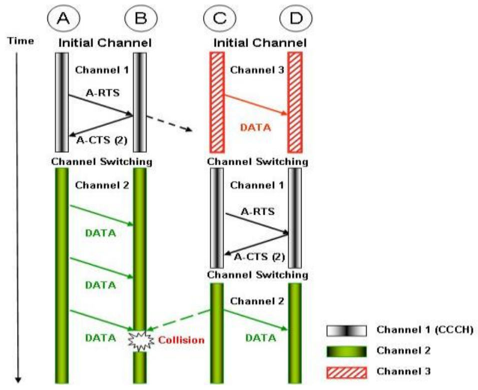

Fig.1.Multi-Channel Hidden Terminal Problem

Although hidden terminals may appear less frequently when terminals are distributed over multiple channels, they can still cause significant throughput degradation in applications with high user density such as deployments in metropolitan areas, conference halls, stadiums, etc. Split-phase and DCC MMACs avoid multi-channel hidden terminals by performing channelnegotiations on a default control channel.

C.Asynchronous multichannel MAC design with Difference-Set-Based hopping sequences

Most existing multichannel medium access control (MAC) protocols have at least one of the following four performance bottlenecks: 1) global synchronization among users; 2) dedicated control channel for signaling exchange; 3) dedicated control phase for signaling exchange; and 4) complete knowledge of all users' channel selection strategies. In this paper, first design a hopping sequence by combining multiple difference sets to ensure a high rendezvous probability of users over multiple channels. Applying the hopping sequence to all users, then propose a difference-set-based multichannel MAC (DSMMAC) protocol to overcome the performance bottlenecks. Because all users use the same sequence for frequency hopping and channel access, significant signaling overheads can be reduced. The proposed protocol achieves high system throughput and low access delay without the need for global synchronization or a dedicated control channel/phase. Our analytical and simulation results show that the proposed DSMMAC protocol can achieve up to a 100% improvement in system throughput and a 150% reduction in channel access delay compared with an existing multichannel MAC protocol.

III. FULL DUPLEX MULTI-CHANNEL MAC PROTOCOL

Design of MAC protocols for efficient sharing of white spaces and appropriate protection of transmissions from primary users (PUs) on licensed frequency in cognitive radio networks (CRNs). We propose a novel FD–MMAC protocol that allows concurrent spectrum sensing and transmission on each channel as well as efficient access and load balancing among the channels. In our design, each SU adopts the randomized channel selection to choose its channel, which is slowly updated over time for load balancing. Moreover, SUs employ the standard p-persistent CSMA mechanism for contention resolution on the selected channel, and the winning SU follows a two-stage procedure for spectrum sensing and access. Specifically, the winning SU performs simultaneous sensing and transmission during the first stage and transmission only in the second stage. This design enables appropriate protection of PUs and efficient exploitation of white spaces on all the channels. The system architecture is in the figure1. It shows how the system is work through the channels and the performances.

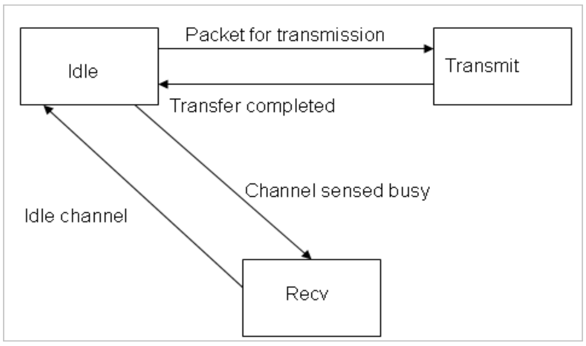

Fig.2.System Architecture

Here we propose FD-MMAC protocol that makes use of full duplex communications to coordinate multi-channel access at low control overhead and it also eliminates control signaling to reduce jamming attacks and improve spectral efficiency. And we employ the randomized dynamic channel selection for load balancing among all channels. This load balancing parameters is indeed important to achieve the largest throughput performance.Designing FD-MMAC as a time-slotted protocol based on CSMA/CA. To improve spectral efficiency, FD-MMAC eliminates the message overhead associated with virtual carrier sensing. Moreover, to mitigate jamming attacks on the control channel, destination discovery and channel assignment are performed independently by senders and destinations, without converging to a common channel. The key idea behind FD-MMAC is for destinations to switch to an idle channel as soon as their resident channel becomes busy. This makes them available to receive transmissions from senders while distributing traffic across all channels.It improves spectral efficiency by reducing the controlsignaling for coordinating transmissions.It increases the spatial channel reuse by enabling the operation of multi-channel exposed terminals.It mitigates jamming attacks by eliminating the use of default control channels.

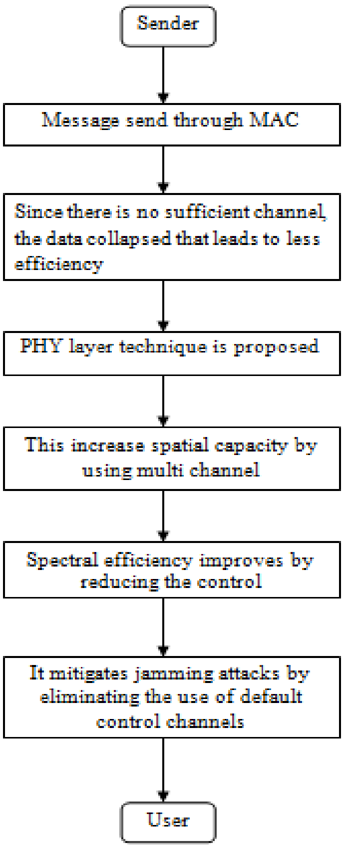

Fig.3.Flow Chart

IV. THROUGHPUT ANALYSIS OF FD-MMAC

FD-MMAC improves its anti-jamming properties. Specifically, we investigate cryptographic interleaving at the PHY-layer and random channel switching. First, terminals do not continuously hop in a synchronous fashion. Second, when a terminal is in “Switch” state.On the other hand, FD-MMAC has inherent anti-jamming properties due to the elimination of control channel, while maintaining high throughput in the absence of jamming.The throughput results in figures 4,5&6. We evaluated the performance of FD-MMAC via a node level simulations using network simulator 2. It indicates that the anti-jamming properties of FD-MMAC are primarily due to avoiding the jammer, overall it yields better performance. This strategy maximizes the throughput. It increases the spatial channel reuse by enabling the operation of multi-channel exposed terminals. It mitigates jamming attacks. The transitions between the nodes are represented as the following states in simulations.

1. *Sense state:* In the "Sense" state, the destination continuously senses the resident channel. If the resident channel becomes busy, the destination transitions to the "Decode" state.
2. *Decode state:* In the "Decode" state, the destination attempts to decode the received signal. It transitions to the "FD" state if it is the intended destination and available for reception. Otherwise, it transitions to the "Switch" state.
3. *FD state:* In the "FD" state, the destination operates in FD mode. Based on the MAC header of the frame P that is being received, the destination determines the t_{ACK}. If P is successfully received, it transitions to the "ACK" state. Otherwise, it returns to the "Sense" state.
4. *ACK state:* After a successful frame reception, the destination replies with an ACK and returns to the "Sense" state
5. *Switch state:* In the "Switch" state, the destination autonomously determines its resident channel. This decision is based on a channel state table (CST) that records the expected time that each channel becomes idle (idle time).

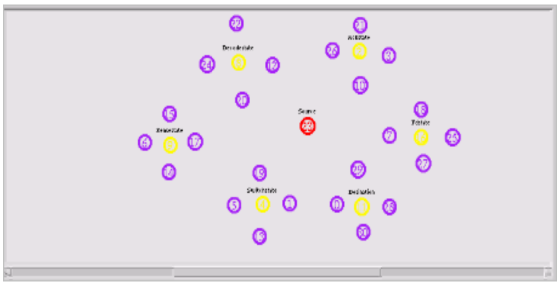

Fig.4.Node Deployment

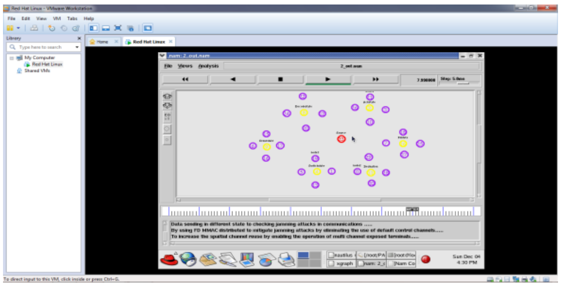

Fig.5.Data Transmission using FD-MMAC

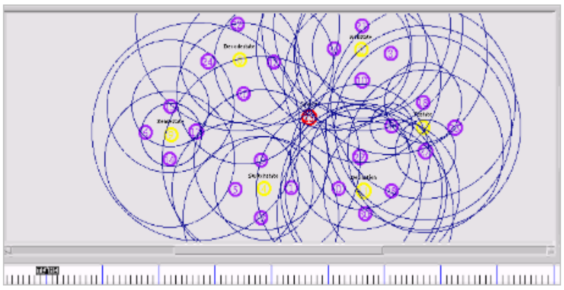

Fig.6.Data Sending Different State to Check Jamming attacks

V. CONCLUSION

We proposed FD-MMAC, a distributed MMAC protocol that exploits FD communications to coordinate multi-channel access at low control overhead. FD-MMAC eliminates control signaling over a common control channel to mitigate the impact of jamming attacks and improve spectral efficiency. The FD-MMAC properties are achieved by utilizing an advanced suite of PHY-layer techniques, including SIS, EVM and RSS measurements, and signal correlation techniques. We analytically evaluated the saturation throughput of FD-MMAC. Further the impact of possible jamming attacks on FD-MMAC is analyzed. Finally, we experimentally validated the PHY layer techniques and measured its performance via simulations. Our simulations showed that FD-MMAC achieves scalable performance at high spectral efficiency.

VI. REFERENCES

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