Full Duplex MAC Protocols

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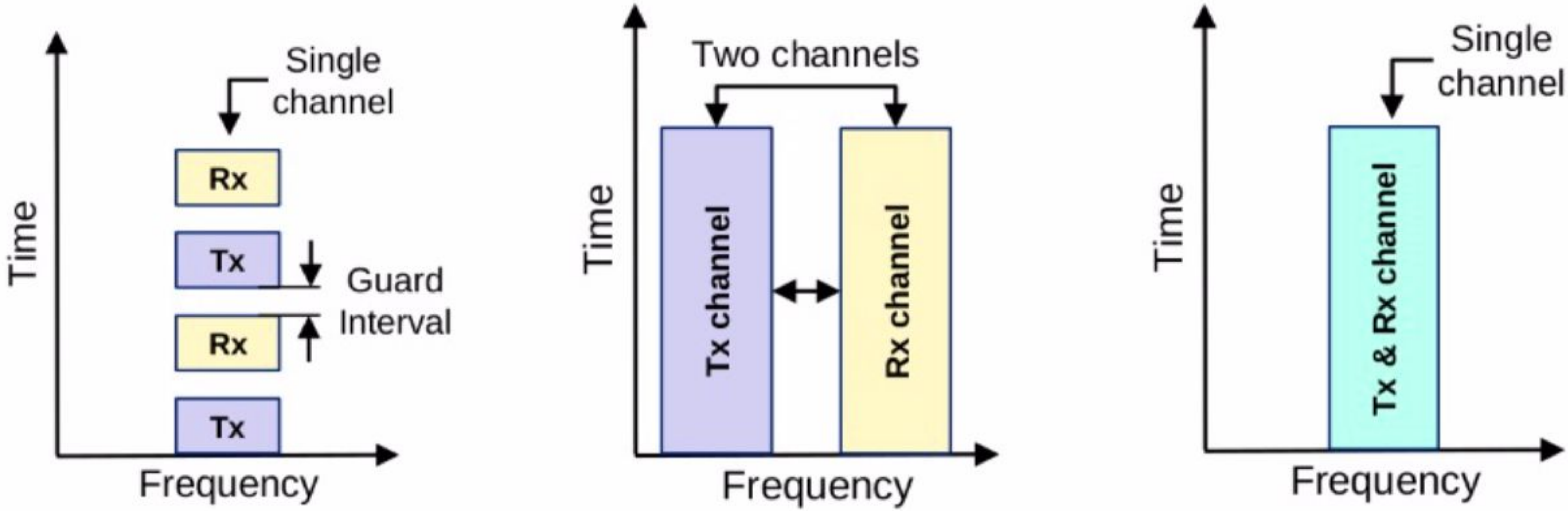
Overview

- Introduction
- Literature Survey
- Open Challenges
- Novel Idea(s) to solve one/multiple open problems
- Conclusion
- References

Introduction

- What is Full Duplex Communication?
- Half-Duplex vs Full-Duplex
- Why Full Duplex?
- Self Interference?
- How can we achieve Full-Duplex and avoid Self Interference?

Half Duplex Vs Full Duplex

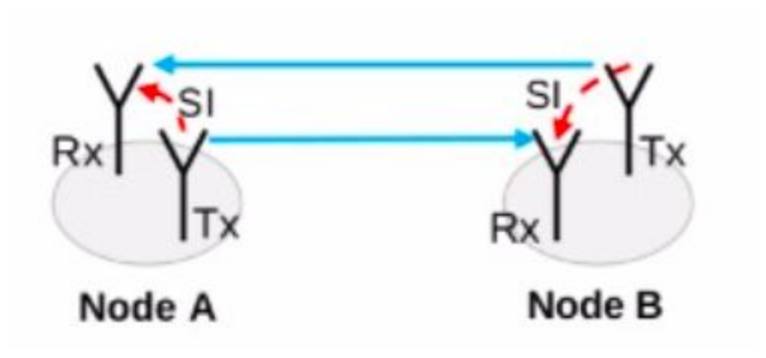


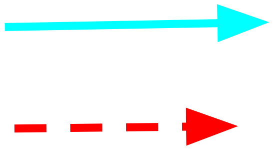
(a) Time-division duplex (HD).

(b) Frequency-division duplex (HD).

(c) Full-duplex.

Self Interference





signal

self interference

Physical Layer Protocols:

1. Passive Suppression
2. Analog Cancellation
3. Digital Cancellation

Literature Survey

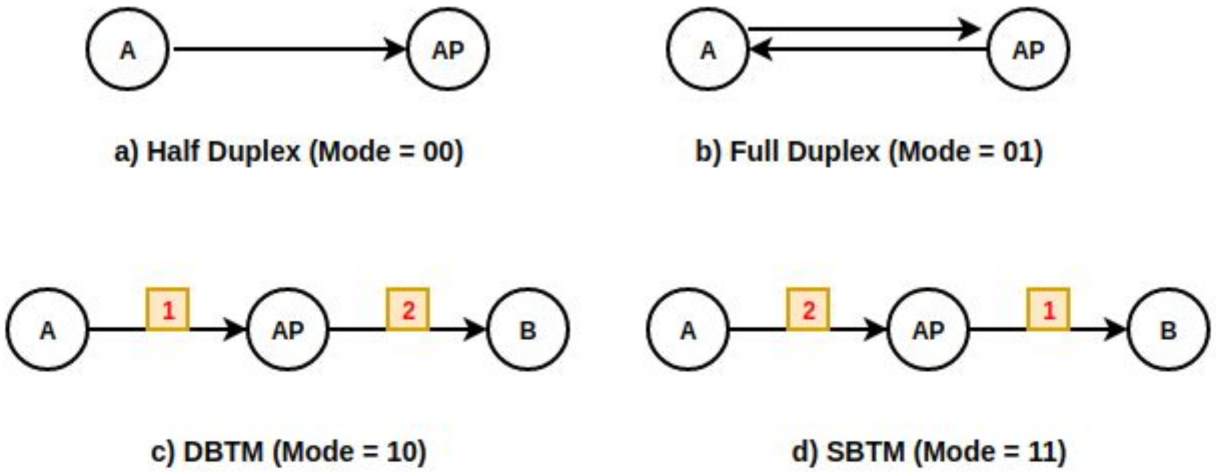
Paper1:

Simultaneous Transmit and Receive Operation in Next Generation IEEE 802.11 WLANs: A MAC Protocol Design Approach, IEEE Wireless Communications, December 2017

Concepts:

- Modes of Full Duplex Communication between nodes.
- Hidden Terminal Problem - How to solve it using FD

Modes of Operation of FD nodes

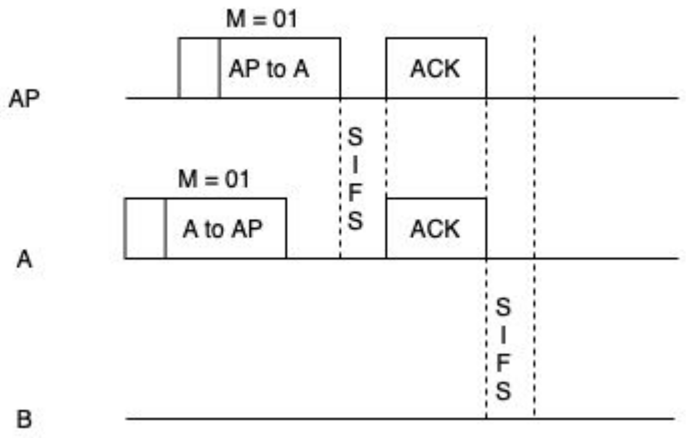


DBTM: Destination Based Transmission Mode

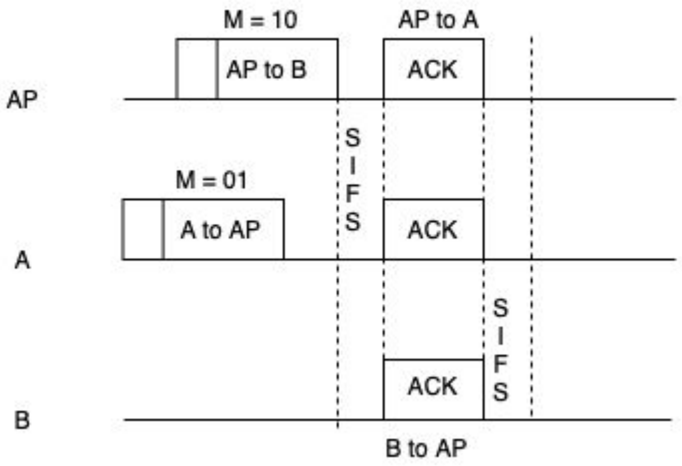
SBTM: Source Based Transmission Mode

Hidden Terminal Problem-FD resolves

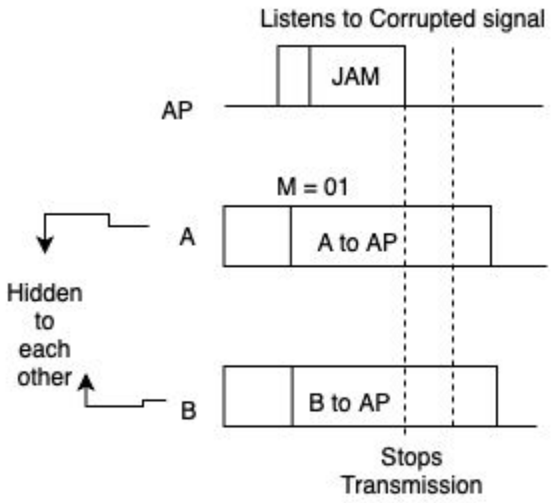
- Legacy: RTS/CTS
- How FD resolves it without header overhead



a) A and AP in Bi-directional transmission



b) A to AP, AP to other node



c) A, B starts at the same time, AP sends a JAM signal

Literature Survey

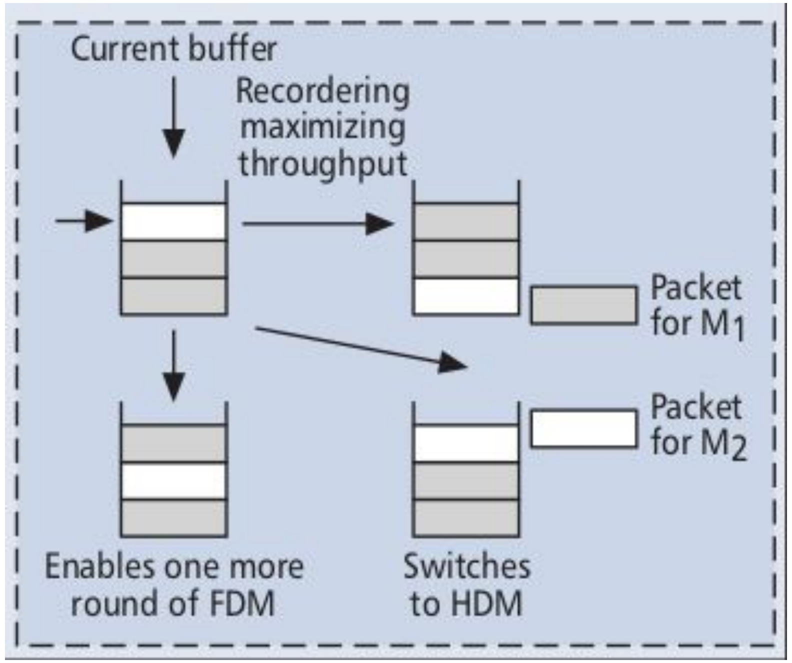
Paper2:

Medium Access Control Design for Full Duplex Wireless Systems: Challenges and Approaches, IEEE Communications Magazine, May 2015

Concepts: 2 MAC protocols

- Virtual Contention
- Header Snooping

Virtual Contention Resolution

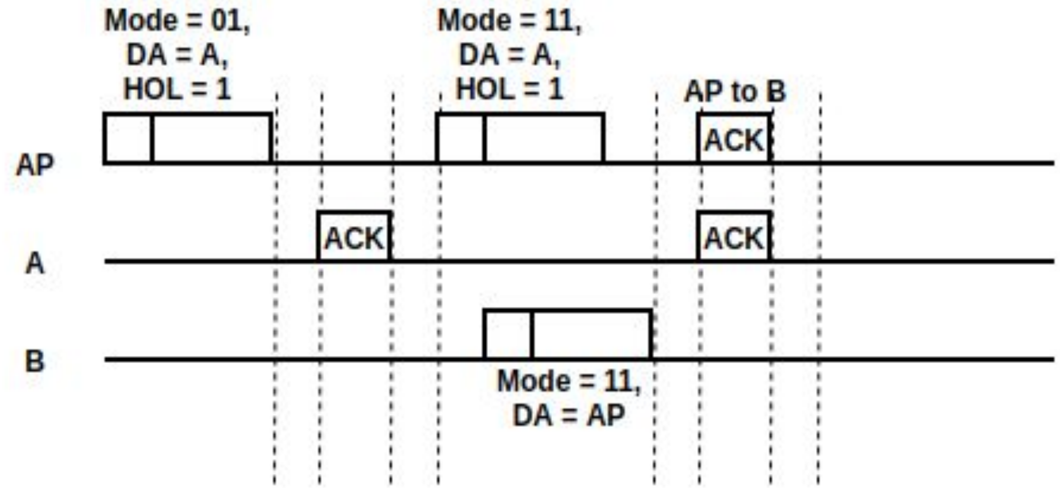


AP can transmit packets (other than HOL) from buffer to increase the throughput.

Ex: A initiates transmission to AP, if AP’s HOL is not for A, AP searches in buffer for a packet to A and sends to A.

Header Snooping

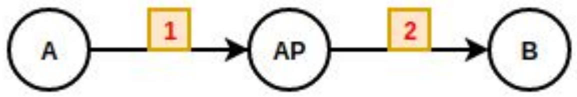
Header Snooping is reading packet headers going through the channel.



Here, node B snoops the packets in the channel. On hearing mode of AP as 11, it gets to know that AP is free for receiving data. It can directly start transmitting.

Challenges

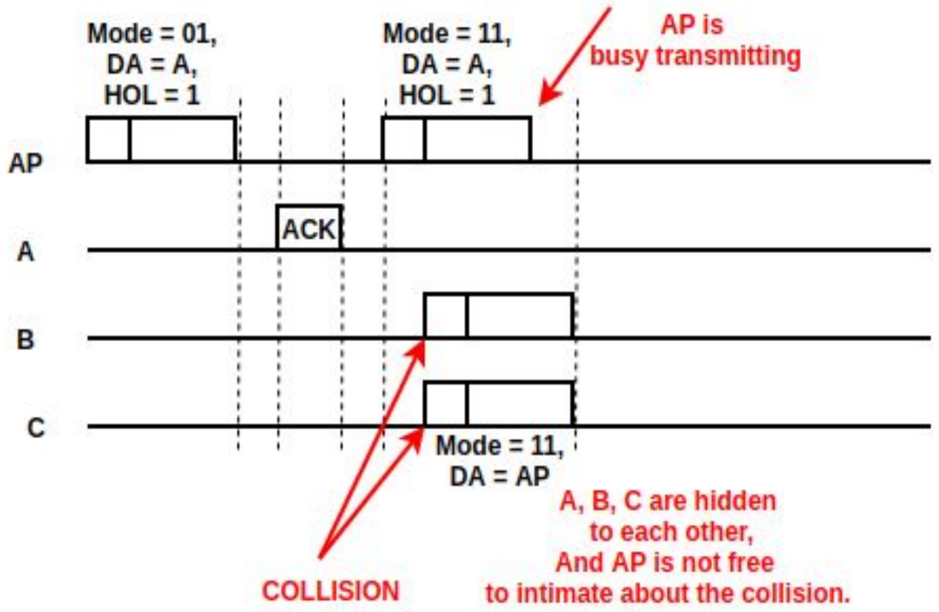
1. Virtual Contention: Delaying HOL is not always feasible, starvation
2. **Header Snooping: Collision may take place**
3. High processing capability and sufficiently large buffers are required for simultaneous transmission and reception.
4. Selection of 3rd node in uni-directional transmission has to be taken care by AP.

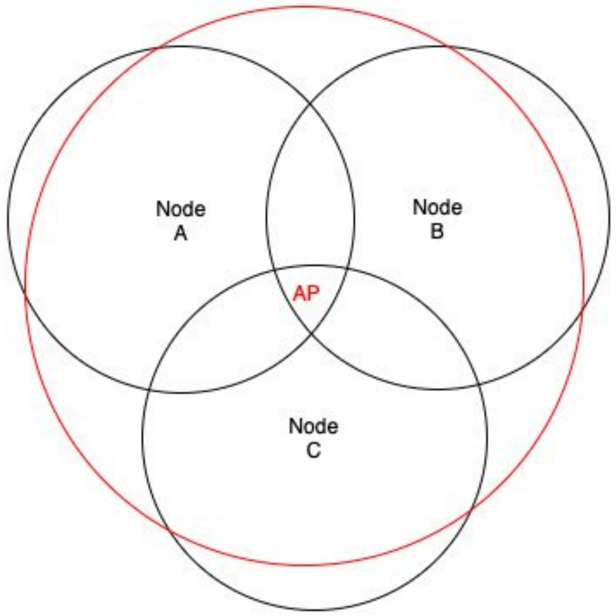


c) DBTM (Mode = 10)

(If B and A are in in interference range (not hidden to each other), signal A->AP and AP->B will both reach B and B receives corrupted packets.)

Header Snooping: Collision Scenario in FD





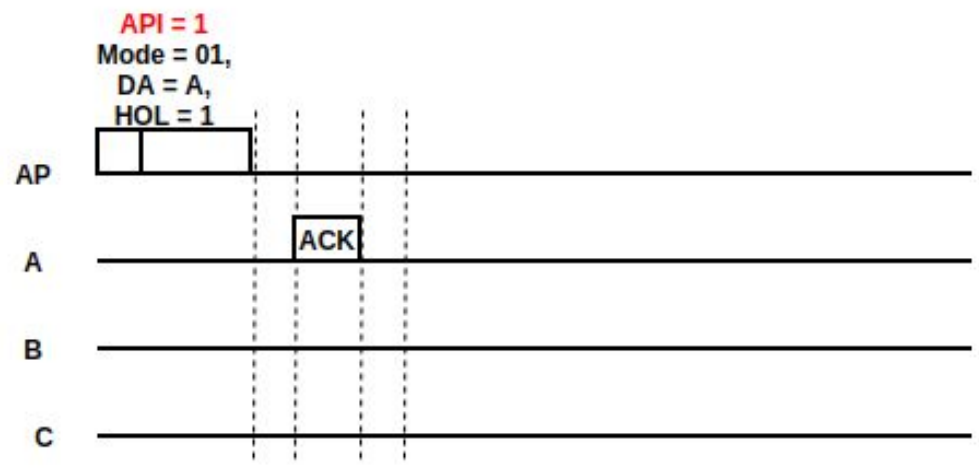
A, B, C are hidden to each other

Novel Idea

- How will the nodes know if they can contend before snooping the header?
- We are introducing a bit in MAC packet header to know if AP initiated the communication.
- **API** (Access Point Initiated Communication) = 1 if AP initiates the communication.
- Also introduced an algorithm for the **new back off counter** for contending nodes in this scenario.

Adding a bit to Packet Header (API)

API = AP initiated transmission bit



AP will be in **Mode = 01** in 2 cases.

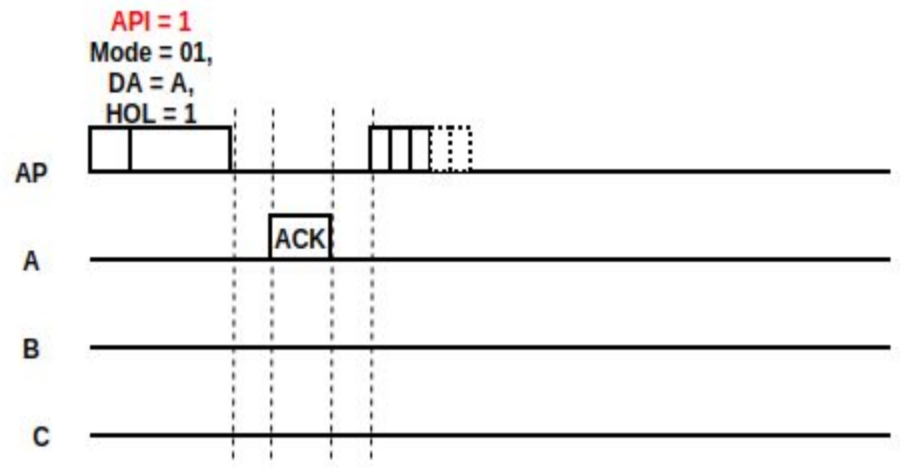
1. A has initiated the transmission and A, AP are in FD communication.
2. AP has initiated the transmission to A. AP may be free for receiving if A is not having data for AP.

But other nodes think AP is not free for receiving.

To distinguish the above 2 cases, we introduced API bit.

AP will wait for 2 to 5(max) time slots

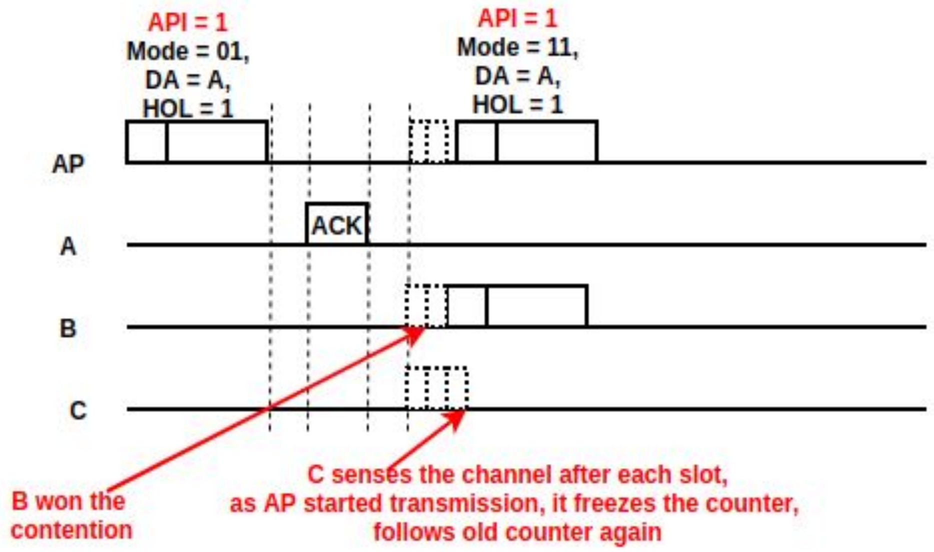
After the 1st AP initiated packet, if HOL=1 for A



In our algorithm, for exploiting FD communication, AP has to wait for some time to see any node is ready to contend for the channel.

Note: The nodes cannot directly send as in Header snooping, they need to contend to avoid collision.

New Back Off Counter for contending nodes



Back off counter usually lies between 0-1024 slots for the nodes who are waiting for channel access.

We can not make AP to wait for a lot of time.

So, for nodes who have packets to AP,

New_backoff = old_backoff * 0.01

Ex:

Let B has old_backoff = 120, new_backoff=1.2 slots, C has old_backoff = 535,new_backoff=5.35 slots

B won, So C changes the counter to old, freezes.

Algorithm

1. Let AP has a data packets to A as HOL packets. AP invites A for a FD communication with Mode = 01, HOL = 1, API = 1.
2. If A has a data packet to AP, it starts an FD communication.
3. Else, it responds with an ACK.
   a. At this point, AP has to wait for a 2 to 5 slot times to see if any of the nodes are interested in transmission.
   b. The nodes which have freezed their back off counters and are waiting for the channer to be free, will snoop the packets in the channel.
   c. Once they see the AP packet header with API = 1, they will wait for a Packet Time + ACK, and sense if the channel is free. If free, they starts contending for the channel.
   d. they start new_backoff_counter=old_backoff_counter*0.01. once the counter becomes 0, the node can start transmission if the channel is free.
   e. Once AP receives a bit, it resumes its transmission. Other nodes will get to know that channel is occupied, change back off to old_backoff_counter and freeze it.

References

1. Simultaneous Transmit and Receive Operation in Next Generation IEEE 802.11 WLANs: A MAC Protocol Design Approach, IEEE Wireless Communications, December 2017
2. Medium Access Control Design for Full Duplex Wireless Systems: Challenges and Approaches, IEEE Communications Magazine, May 2015
3. Energy Efficient MAC Protocol for Wireless Full-Duplex Networks, China Communications, January 2018
4. Full Duplex Techniques for 5G Networks: Self-Interference Cancellation, Protocol Design, and Relay Selection, IEEE Communications Magazine, May 2015
5. Full-Duplex Transmission in PHY and MAC Layers for 5G Mobile Wireless Networks, IEEE Wireless Communications, October 2015
6. Full-Duplex Wireless Communications: Challenges, Solutions, and Future Research Directions, Proceedings of the IEEE, July 2016

Thank You!