Implementation Details of BT-FDMAC in NS-3

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***Abstract*—In this paper, we show the details of the core wireless module which has been modified in Network Simulator-3 (NS-3). The physical layer has been extensively refined to incorporate the functionalities of in-band full-duplex (IB-FD) wireless in NS-3. We have added a new state called ”FD state”. A node which is in FD state can transmit and receive signals at the same time in the same frequency band. In this paper, we have shown the state transition diagram of an IB-FD wireless node. We have also discussed the interference model that has been used to model a received packet's success and failure rate.**

1. Introduction

Network Simulator-3 (NS-3) [1] is the most popular network simulator which is widely used by the researchers to simulate new concepts and algorithms in both wired and wireless networks. At present, NS-3 core wireless module is half-duplex. A node can not transmit and receive signals within the same frequency band simultaneously. To make NS-3 wireless module in-band full duplex (IB-FD), it has been re-designed by adding a new state called "FD" state. Therefore, a wireless node can be in any of the eight (8) states at a particular time in NS-3. Our proposed A Novel Busy Tone Medium Access Control Protocol with hidden station suppression for Wireless Networks (BT-FDMAC) has been simulated according to the implementation details presented in this paper.
A wireless station can be in any of the following states in our modified NS-3.

- IDLE state
- TX state
- RX state
- FD state (newly added state)
- CCA_BUSY state
- SLEEP state
- SWITCHING state
- OFF state

2. Description of States and Their Transitions

In this section, we describe all of the states and the transitions of a station among these states. It is important to mention here that the word ”physical layer state” also resembles a station's state. The state transition diagram of an IB-FD node is shown in Fig.1. In Fig.1, we depicted 7 states. We have intentionally omitted the OFF state of an IB-FD node in the diagram in Fig.1. A station can make a transition to an OFF state from any state at any time when there is a power failure. During OFF state a station does not sense the medium. Therefore, while a station is in OFF state, it does not make any transition until it is powered on.

2.1. IDLE State

Initially the station starts in an IDLE state. While the station is in IDLE state, it continuously senses the medium to overhear whether or not there is any on-going transmissions. It does it by calculating the energy power of the signal in the medium. If the computed energy level is greater than a threshold called "clear channel assessment threshold", the station switches to CCA_BUSY state. It stays in CCA_BUSY state until the CCA_BUSY duration is ended. If the energy level is greater than energy detection threshold, the station detects an incoming transmission and switches to RX state. The physical layer switches to SWITCHING state, if the station wants to perform any frequency or channel switching. In that case, the stations stays in SWITCHING state for a fixed amount of time. While the station is in IDLE state and it starts a transmission, the physical layer switches to TX state. The physical layer switches to FD state while both the transmission and reception starts at the same time. A station may go to SLEEP state when that sleep timer is started.

2.2. TX State

While a station gets access to the medium and it starts a transmission, the physical layer switches to TX state. The station stays in TX state until the transmission time is ended. During TX state, a station may receive transmission from other neighbor stations. In this case, the station switches to FD state. If the station is in TX state and transmission duration ends, the station switches back to IDLE state. Moreover, if the station is in FD state and the transmission duration expires, it makes a transition to RX state.

2.3. RX State

A station stays in RX state for the whole reception duration. During RX state, A station may get access to the medium and it may start a transmission. In this case, the

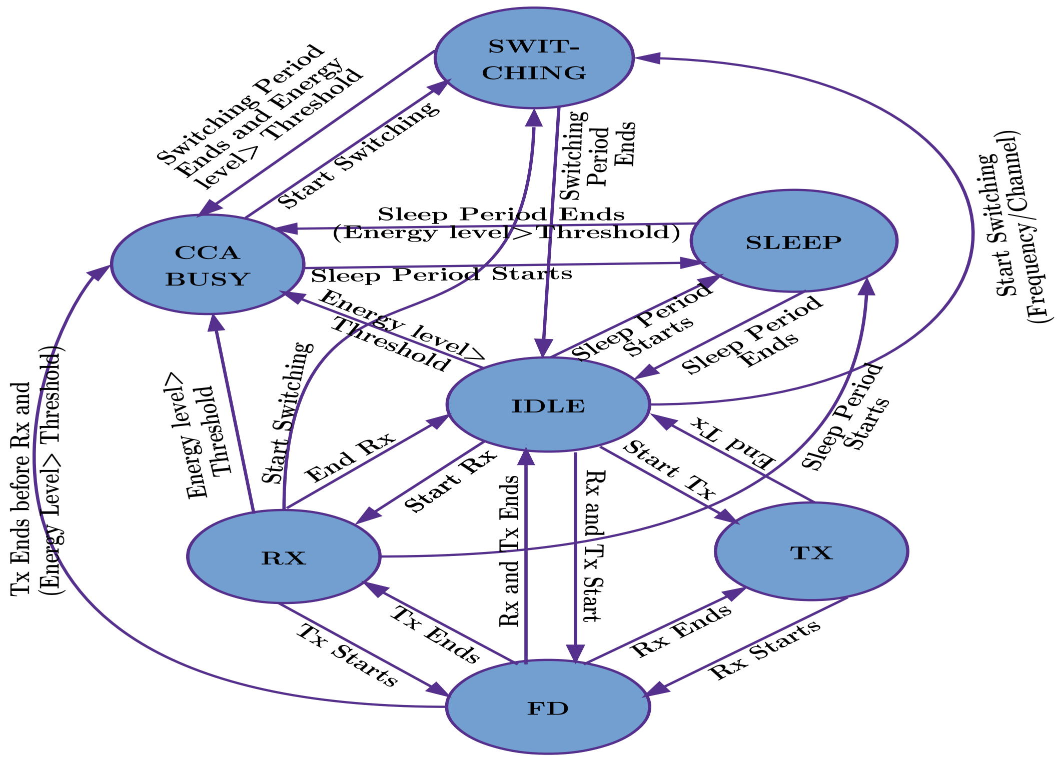

Figure 1: State Transition of an IB-FD wireless node

station goes to FD state. While a station is in RX state and the station wants to switch to another frequency or other channel, the station drops the currently receiving packets and it makes a transition to SWITCHING state. If the dropped packet's reception duration is greater than transition duration to IDLE state plus the switching duration, the station goes to CCA_BUSY state after the channel switching. Usually a station can not receive another transmission while it is in RX state. In this case the received signal is added as interference. If the reception duration of an incoming packet is greater than transition duration to IDLE state, it goes to CCA_BUSY state for the remaining duration. But, a station can enable its own frame capture model [2]. In this case, if the station is in RX state and it receives a higher strength packet, it drops the currently receiving packet and starts receiving the newly incoming packet. If a sleep timer is enabled and it expires during RX state, the station immediately goes to SLEEP state and drops the currently receiving packet. The station goes to IDLE state after the RX duration is expired.

2.4. FD State

During FD state, a station transmits and receives simultaneously. Transmission and reception duration could be asymmetric. If the transmission duration is greater than the reception duration, reception ends earlier. In this case, the station switches to TX state. In the other case, the station switches to RX state. If both the duration are equal, the station switches to IDLE state after the end of FD duration. While a station is in FD state and another transmission arrives, the station drops the newly incoming packet if no frame capture model is used. The incoming transmission is added as interference .In case of symmetric FD in which both the transmission and reception duration are equal, the station switches to CCA_BUSY state after the end of FD duration if the reception duration of the incoming packet is greater than this symmetric FD duration. In the case of asymmetric FD, if the interference duration is greater than the FD duration, the station switches directly to CCA_BUSY state. This switching informs the channel access manager about the condition of the medium. It helps the manager to take decision for granting future access of medium to the station.

2.5. CCA_BUSY State

If CCA_BUSY duration is expired, the station switches to IDLE state. During CCA_BUSY state, a station might want to switch to another operating frequency or other channel for transmission or reception, the physical layer directly transits to the SWITCHING state. It waits there for channel/frequency switching duration. If the sleep timer is started and the station is in CCA_BUSY state, it directly goes to SLEEP state.

2.6. SLEEP State

A station dwells in SLEEP state for the sleep period. After the sleep duration is expired, either the station goes to IDLE state or CCA_BUSY state. As soon as the sleep period is ended, the station senses the medium for signal detection. If the detected signal energy is greater than clear channel assessment energy threshold, it goes to CCA_BUSY state. Otherwise the station goes to IDLE state.

2.7. SWITCHING State

A station can transit to this state due to frequency switching which compels the station to operate on a complete new frequency. A station stays in this state for a fixed amount of time. After the switching duration is elapsed, the station continues to sense the medium in the newly assigned channel. If it finds the energy level of the medium is larger than CCA threshold, it switches to CCA_BUSY state. Otherwise the station make a direct transition to IDLE state after the end of switching duration.

3. Interference Modeling

Wireless spectrum is very scarce and the efficient usages of this spectrum is a challenge to achieve higher throughput gain in wireless network. While a station is in RX or FD state, it can be interfered by transmissions from other stations. The signal powers from those interfered transmitters are added as noise at the receiver. These extra signals can corrupt the currently receiving packet at the receiver. Signal to Noise and Interfere (SNIR) is used by the receiver to determine whether a received packet is correct or not.

There can be a number of interfering transmitters around a receiver. If these interfering transmitters get access to the medium and start theirs transmissions along with the original transmitter, several signals could reach at receiver at same time in the same frequency. These interfering powers are calculated according to Eqn.(1).

$$I_r = \sum_{x \epsilon T} P_x H_{x \to r} l \left\| r - x \right\| \quad (1)$$

Here, I_r is the total interference power received at the receiver (r) from transmitters other than the source node. T indicates the set of interferi P_x is the transmit power of an interfering trans-miter x and $H_{x \to r}$ denotes the power fading co-efficient of the channel between x and r. $l \left\| r - x \right\|$ is the path loss function depends on the distance between receiver (r) and transmitter (x).

The noise floor is a combination of thermal noise (white noise) and non-idealities of the receiver. The noise floor is calculated according to the the Eqn.(2).

$$N_{floor} = \eta * \kappa * B * exp(6) \quad (2)$$

Here,N_{floor} denotes the noise floor of the wireless environment. η is noise figure at the receiver. η is the difference in decibels (dB) between the noise output of the actual receiver to the noise output of an ideal receiver with the same overall gain and bandwidth when the receivers are connected to sources at the standard noise temperature T_0 (usually 290 Kelvin). κ is the Boltzmann constant. B is the channel bandwidth in Hertz (Hz).

As the performance a wireless network critically depends on the Signal-to-Noise plus interference ratio (SNIR) level at the receiver, the SNIR is calculated according to Eqn.(3).

$$SNIR = \frac{P_r}{I_r + N_{floor}} \quad (3)$$

While a packet is being transmitted, we assume that the received signal power remain same during the whole transmission duration to calculate the received success rate of a transmitted packet. In wireless network, A packet is consist of header and payload. The modulation schemes for header and payload transmission could be different and the packet success rate depends both on the success rate of header transmission and success rate of payload transmission. For a fixed modulation and coding scheme, the packet reception is succeeded if header success rate and payload success rate is greater than a fixed threshold value.

For a particular modulation and coding scheme, a chunk success rate is calculated with Eqn(4). The success rate is a function of three parameters.

$$S_{rate} = f(R, SNIR, L) \quad (4)$$

Here, S_{rate} is the success rate of a transmitted payload that consists of L bits. $SNIR$ is the signal-to-noise plus interference ration level at the receiver and R denotes the data rate of the transmitted payload in bit per second.

Upon the arrival of an incoming packet at a receiver, at first it calculates the success rate of the header portion of the packet. If the header reception is failed, the receiver drops the packet. The packet is added as an interference at the receiver. If the header part of the packet is received successfully, the receiver switches to either RX or FD state. Then, the payload reception starts. After the payload is received at the receiver, it calculates the payload success rate according to Eqn.(4). If the success rate falls below a threshold that is chosen from a randomly distributed number, the receiver drops the packet.Then, the receiver notifies its channel access manger about the erroneous reception. Each time a packet is received at the receiver, a random value is generated. This random value is chosen from a uniform random distribution. If the received packet's success rate is higher than the threshold, the receiver passes the packet to the higher layers. It also informs its channel access manger about the successful reception.

4. Conclusion

In this paper, we have discussed the implementation details of the modified core wireless module in NS-3 for in-band full duplex wireless networks. We have shown various states of an IB-FD node and its transitions among these states. We have also discussed the interference model used in NS-3.

Acknowledgments

The authors would like to thank...

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