ns-3 Wi-Fi module upgrade - Report 1

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1 Summary

During the first part of this work, mainly three items have been addressed:

1. Fix OFDM PHY reception model and add missing primitives;
2. 11a/b/g bianchi validation and add script to regression;
3. Fix and enhance ideal rate manager for 11n/ac/ax (channel width, MIMO, ...).

In the following, some additional details are given on the changes that have been done in ns-3-dev along this project. All the mentioned changes are part of the upcoming ns-3.31 release, planned for June 2020.

2 DCF Single BSS Network Simulation

Since [1], IEEE 802,11 DCF MAC performance evaluation via simulation (such as ns-3) are expected to be validated against the analytical predictions - for the scenarios [single BSS, saturation traffic] under which the analysis was conducted. For a considerable time, DCF validation in ns-3 was conducted for *ad-hoc* mode, see [2] for example, due to other limitations on stack implementation aspects needed for infrastructure mode (such as correct operation of beacons). However, these have now been fixed and both ad-hoc and infrastructure mode simulations of 802.11a DCF performance evaluation are being conducted. However it has been observed that ns-3 simulation results for a single BSS with release 3.30 were significantly deviating from the Bianchi model predictions, especially for larger number of stations.

The above was mainly caused by multiple issues in the ns-3 PHY reception model noted below - these have been addressed.

1. It was first observed that the ns-3 PHY model was not in line with the standard nor the proposed reception model in [3], where PHY should move to RX state only if the PHY header is successfully received, and indicate CCA-BUSY otherwise. This has been fixed in commit 4b97988a, along with commit e4057ac2 which adds missing transition to CCA-BUSY.

2. Another problem that has been fixed - some PHY internal states and variables were not properly reset at the end of the reception if it failed at one stage. Commit 4b97988a introduced a new function at the PHY that resets these states and variables at the time indicated in L-SIG. If L-SIG is not received, then RX is aborted and PHY is immediately reset.

3. Finally, the choice between DIFS and EIFS was also not properly done, because some variables were not always reset in the channel access manager. This has been fixed in commit 35bb6770.

4. Besides these fixes, some missing PHY primitives have been added, namely the PHY-RXSTART indication, that indicates the PHY header has been successfully received and PHY has just started the reception of a PSDU, and the PHY-TXEND indication which is raised when the last bit has just been transmitted. These changes have been addressed in commits d982bc30 and 948e9395, respectively.

3 Recent Bianchi re-validation

As noted, several users had contributed simulation script to validate ns-3 single BSS WiFi throughput against the well-known Bianchi model for saturation traffic scenarios and it was reported (`https://gitlab.com/nsnam/ns-3-dev/-/issues/152`) that ns-3 output was deviating significantly from the Bianchi model predictions.

Besides issues located at the PHY as described in the previous section, some MAC changes had also been integrated to align ns-3 in line with the current standard for DCF operation, but were not reflected in the Matlab script producing the Bianchi curves. One major change was that a station that has successfully transmitted a frame selects 0 as backoff value and hence makes another transmission after a DIFS. More details about the model as well as the obtained results are available in [4].

Finally, in order to track updates to the DCF models in ns-3 as we extend to include MAC changes (11ax/be. . .), the Bianchi simulation script has been added to the ns-3 regression test suite (see commits from changeset 072c8841 to changeset 979b0713).

4 Ideal rate manager extensions for 11n/ac/ax

Ideal rate manager was not able to handle 11n/ac/ax major features, such as channel bonding and MIMO.

4.1 Channel bonding

Ideal is using the last SNR feedback from the peer to select the TXVECTOR for the next transmission. Currently, the channel width is fixed in ns-3, therefore the ideal rate manager has to select the best MCS based on the SNR feedback and the fixed channel width (this fixed channel width is the maximum between the supported channel width by the transmitter and the one supported by the peer to send to).

However, a 40 MHz transmission results in a SNR of about 3dB less than a 20 MHz transmission, a 80 MHz transmission results in a SNR of about 6 dB less than a 20 MHz transmission, and so on. And since the last SNR feedback can be from a transmission of a different channel width than the one that is selected for the upcoming transmission, it might happen that a too high or a too low MCS is selected, resulting in some cases where the receiver is not able to decode the frame. Some unit tests have been written to reproduce such cases, and were added to the ns-3 wifi regression test suite (in order to verify the implemented solution and to make sure this does not break over time).

The implemented solution, recently merged in ns-3-dev (see commits from changeset 2874e810 to changeset 410d8cc2), consists in providing feedback to the ideal rate manager about the channel width corresponding to the SNR feedback value, and perform calculations to determine to corresponding SNR for a different channel width.

Finally, the ideal rate manager has been extended to support modifications of the supported channel width at run-time (commit 7ce1ea81), which will be very convenient once dynamic channel bonding and 11be C-OFDMA will be integrated.

4.2 MIMO

Even though the ideal rate manager had been enhanced few releases ago to support MIMO settings, remaining work has been addressed in this project. First, it has been extended to support runtime changes of MIMO settings, by rebuilding its SNR thresholds vector once a change is detected.

Second, the ideal rate been extended to support cases where TX and RX MIMO settings are unbalanced, and unit tests have been added to test all possible combinations.

Furthermore ,some additional work has been done to handle diversity in ideal rate manager (MRC). If a peer is using diversity, it benefits from a higher SNR, hence a higher MCS might be chosen for that station. A similar approach as the channel width (exposed in previous section) has been implemented, where ideal rate manager gets feedback about diversity capabilities of the peer along with the SNR feedback, and can compute an equivalent SNR for a given number of spatial streams used for the upcoming transmission.

Finally, fixes in the computations of SNR gains obtained thanks to diversity have also been addressed in the scope of this work, using model provided by Leonardo Lanante and now described in the ns-3 wifi model library documentation (see section 1.3.1. - InterferenceHelper).

The changes exposed in this section have been recently merged in ns-3 (see commits from changeset 376d5d62 to to changeset e24eee2d).

References

[1] Giuseppe Bianchi. Performance analysis of the ieee 802.11 distributed coordination function. *IEEE Journal on selected areas in communications*, 18(3):535–547, 2000.

[2] R. Patidar, S. Roy, T. Henderson, and M. Mehrnoush. Validation of wifi network simulation on ns-3, 2017.

[3] L. Lanante, S. Roy, S. Carpenter, and S. Deronne. Improved abstraction for clear channel assessment in ns-3 802.11 wlan model. In *Proceedings of the 2019 Workshop on ns-3, WNS3 2019*, 2019.

[4] H. Yin, S. Roy, S. Deronne, and S. Avallone. Validation of wi-fi 802.11a dcf in ns-3 vis-a-vis bianchi, 2020.