ns-3 Wi-Fi module upgrade - Status

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1 Summary

During the second part of this project, these items have been addressed:

1. Added a new error rate model based on link-to-system mapping
2. Updated and fixed issues in LAA-Wi-Fi coexistence model
3. Extended the bianchi validation to 802.11n/ac/ax
4. Merged 802.11ax OFDMA PHY changes to the ns-3 mainline tree
5. Reviewed refactoring efforts to facilitate integration of future 802.11 PHY amendments

In the following, some additional details are given on the changes that have been done in ns-3-dev along this project.

2 Implementation of a new error rate model based on link-to-system mapping

FUNLaB @ University of Washington (UW) ECE Dept. (`https://depts.washington.edu/funlab`) has led significant work over the past few years to develop new link-to-system error models for 802.11n/ac/ax simulations. However, these efforts have not been integrated into any ns-3 official release to date, even though this model has shown to provide results that are better matching with performance measured with 802.11 COTS. In this project phase, the latest version of the error models has been refactored and cleaned up in order to meet ns-3 mainline code quality requirements. Furthermore, few bugs have been fixed and the models extensively unit-tested.

Initially, the model were showing slow run-time performance compared to existing Yans and Nist models (around 4 times slower!). Several additional changes on how the tables were stored and accessed have enabled to reach a similar run-time performance as Yans and Nist models. The final version of the code has been merged and is available in ns-3.33 (`https://gitlab.com/nsnam/ns-3-dev/-/merge_requests/364`). Note that, since that release, this model is defaulted instead of the Nist model.

Finally, while extending this model for 802.11ax, support for LDPC FEC encoding has been added and different tables have been defined for BCC and LDPC. These changes for 802.11ax have already been merged and are also part of ns-3.33 (`https://gitlab.com/nsnam/ns-3-dev/-/merge_requests/436`).

3 Update of LAA-Wi-Fi coexistence model

Some support has been brought to the LAA-Wi-Fi coexistence model, the latest version of the model is located at `https://bitbucket.org/ns3lteu/ns-3-dev-lbt/` (and the most recent branch is laa-wifi-coexistence-rebased).

First, a wifi issue related to the TXOP durations not being traced in the LAA example has been discovered and fixed upstream in commit `https://gitlab.com/nsnam/ns-3-dev/-/commit/da2d7757447912a6c01d2c3ea6519c58bf0ada79`. Second, the repository has been rebased to a more recent version of ns-3 (ns-3.32). Finally, various fixes inherent to the LAA wifi code have been integrated (`https://bitbucket.org/ns3lteu/ns-3-dev-lbt/pull-requests/4`).

4 Bianchi extension to 802.11n/ac/ax

Significant efforts were spent in fixing issues to have ns-3 simulation results aligned to the Bianchi theoretical model for 802.11a, using existing Matlab scripts; these are now very well-aligned for all cases of interest. Further, the scripts have now been extended to support 802.11n/ac/ax, and 802.11ax performance have been validated for 20, 40, 80 and 160 MHz channel widths, and for MCSs from MCS-0 to MCS-11.

The development branch can be found at `https://gitlab.com/sderonne/ns-3-dev/-/commits/11ax_bianchi`, and is proposed to be part of ns-3.34 release.

5 802.11ax OFDMA PHY integration

In 2019, a large project was initiated to support 802.11ax OFDMA features. This required many changes at both the PHY and the MAC in the ns-3 wifi module. This has required huge reviewing efforts from all the ns-3 wifi developers and delayed integration of 802.11ax OFDMA into ns-3. The ns-3 wifi maintainers agreed to include 802.11ax PHY DL-OFDMA in ns-3.33, and the 802.11ax PHY UL-OFDMA in ns-3.34. The changes done at the MAC layer of the model will be handled in a different thread.

While integrating 802.11ax OFDMA PHY to the ns-3 mainline tree, care was taken to properly and logically re-order and squash all the commits, and to limit the size of each review request to not more than 10 commits.

DL OFDMA PHY has been split as follows (part of ns-3.33, already merged):

1. OFDMA preparations: https://gitlab.com/nsnam/ns-3-dev/-/merge_requests/415
2. DL-OFDMA PHY part 1: https://gitlab.com/nsnam/ns-3-dev/-/merge_requests/446
3. DL-OFDMA PHY part 2: https://gitlab.com/nsnam/ns-3-dev/-/merge_requests/447
4. 802.11ax OFDMA PCAP support: https://gitlab.com/nsnam/ns-3-dev/-/merge_requests/472

UL OFDMA PHY has been split as follows (will be part of ns-3.34, not merged yet):

1. UL-OFDMA preparations: https://gitlab.com/nsnam/ns-3-dev/-/merge_requests/493
2. HE TB PPDUs TX: https://gitlab.com/nsnam/ns-3-dev/-/merge_requests/502
3. HE TB PPDUs preambles RX: https://gitlab.com/nsnam/ns-3-dev/-/merge_requests/514

4. HE TB PPDUs payloads RX: https://gitlab.com/nsnam/ns-3-dev/-/merge_requests/515
5. UL-OFDMA improvements: https://gitlab.com/nsnam/ns-3-dev/-/merge_requests/516
6. UL-OFDMA power control: https://gitlab.com/nsnam/ns-3-dev/-/merge_requests/517

6 Wi-Fi PHY refactoring for future amendments

A NSOC project has been proposed in 2020-21 to restructure the PHY layer of ns-3 wifi model so that future amendments can be integrated with minimal changes into the ns-3 mainline wifi module. This project aims to decouple standard-specific implementation from the main PHY processes (sending, receiving, ...). This lead to the introduction of PhyEntity classes to handle all the amendment (or "clause") specific (i.e. OFDM/HT/VHT/HE etc) parts of the PHY process. Such an architecture should also facilitate the addition of other amendments, such as 802.11ad/ay (Wigig) and 802.11ah (HaLow).

The following are expected to be integrated in ns-3 (before releasing ns-3.34):

1. Part 1: Introduction of PhyEntity classes, including mode and duration computation (`https://gitlab.com/nsnam/ns-3-dev/-/merge_requests/347`)
2. Part 2: WifiPpdu refactoring (`https://gitlab.com/nsnam/ns-3-dev/-/merge_requests/518`)
3. Part 3: Tx and Rx path refactoring (`https://gitlab.com/nsnam/ns-3-dev/-/merge_requests/519`)
4. Part 4: WifiMode refactoring (`https://gitlab.com/nsnam/ns-3-dev/-/merge_requests/524`)