ns-3 wifi module maintenance report

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Background: ns-3's Wi-Fi module was originally authored over fifteen years ago, based on the IEEE 802.11a standard. Since that time, Wi-Fi technology has evolved considerably, with the latest standard (Wi-Fi 6, or 802.11ax) and upcoming standard (Wi-Fi 7, or 802.11be) making significant changes to protocol operations. In addition, there are related standards (WAVE/802.11p, mesh, WiGig) based on the core Wi-Fi standards. Over the past few years, the ns-3 Wi-Fi module has been refactored to provide better support for 802.11ax and 802.11be. However, the project has lost compatibility with these related standards, and there has been no funding source (outside of the ns-3 Consortium) to keep these related models aligned with ns-3's mainline Wi-Fi stack.

Current effort: Hany Assasa and collaborators at IMDEA Networks Institute and the United States National Institute of Standards and Technology (NIST) have developed 802.11ad/ay (WiGig) models for ns-3 based on the old ns-3 Wi-Fi architecture [1-4]. However, these models made intrusive changes to the old ns-3 Wi-Fi models and are no longer compatible. The ns-3 Consortium has been funding ns-3 Wi-Fi maintainer Sébastien Deronne to work with Hany on a deep refactoring of the WiGig code.

Work performed:

A new WiGig module has first been created in the ns-3 simulator (in src/wigig) and is initially a copy of all the source files present in the Wi-Fi module of the 802.11ad/ay IMDEA repository. Hence, the Wi-Fi module has first been disabled to avoid name collisions since both modules are using the same 'ns3' namespace. In that first step, some changes were also needed to be ported to the Spectrum module and some fixes were required to have the project compiled with both GCC and CLANG compilers.

In the meantime, v0.5 of the WiGig code was publicly released by IMDEA, so the changes of that release have been ported to the new WiGig module. Most of the tests and examples have been ported as well and are currently located in the scratch directory. The benefit of such an approach is that we can keep on checking that no regression is being introduced in the process. In order to speed the process and to limit the complexity of this project, all the code related to EDMG (802.11ay) has been temporarily cleaned out from the Wigig module. This has been done in a separate commit to have a better visibility of what has been trimmed, and to be able to bring it back in a next step.

The Wi-Fi module has some files used to define common pieces among all standards (wifi-phy-common.h and wifi-standards.h), hence these files have been modified to add some DMG-specific code, such as defining new standards, new frame formats, and so on.

The WifiMode is a major class that is being used by most of the classes in the Wi-Fi module and it has been deeply refactored over the last few years in order to make use of callbacks, enabling the calling of static functions in each PHY entity to perform rate calculations. However, current Wigig code was still relying on an outdated WifiMode framework, which consisted in providing the pre-calculated PHY and DATA rates to the constructor, and when a rate was needed, the WifiMode was reading the hardcoded value passed at construction. It has first been moved to the format before refactoring, where PHY and DATA rates are calculated by the WifiMode class itself based on the constellation size, symbol duration, bandwidth, and so on. This removes the need to pre-calculate the PHY and DATA rate for each WifiMode and makes the constructor signature much easier. Afterwards, it was rather straightforward to move to the new architecture by moving all these calculations to callback functions

called by the WifiMode. Note that we did not have DMG PHY entity defined in the Wigig module yet, hence these callbacks have temporarily been implemented in the DmgWifiPhy class.

Afterwards, some classes of the Wi-Fi module have been progressively enabled while making the WiGig module use more and more of the implementation done in the Wi-Fi module. In parallel, the implementation of a DMG PHY entity class has been started by making use of the new Wi-Fi design implemented last year. Similarly, a new FEM (frame exchange manager) has been created (but not implemented yet) for the MAC low layer. For the MAC high layer, after some investigations, it has been agreed to define a new DmgWifiMac class, which inherits from WifiMac. In that process, WifiMac and RegularWifiMac class have been merged since there were no valid reason to keep these separated. ApWifiMac, StaWifiMac and AdhocWifiMac won't be used by the Wigig module since only a few of their functionalities can be reused. Instead, DmgAp/Sta/AdhocWifiMac will be used and will inherit from the DmgWifiMac class. The latter will thus contain all changes that had originally been implemented in WifiMac for DMG.

The ongoing work can be found in the following repository:
https://gitlab.com/sderonne/ns-3-dev/-/tree/wigig_module

Work remaining:

The current work focuses on enabling the Wi-Fi classes that are still disabled, which requires to subclass most of these classes still present in the WiGig module.

Furthermore, the implementation of the DMG PHY entity and the DMG Fem are only at their early stages and some additional efforts are required to have them completed and used by the WiGig code.

Finally, the WiGig module should be extended to support EDMG, by porting removed parts in a previous step into the new Wigig architecture. In that step, a new EDMG PHY entity and a new EDMG FEM will have to be implemented as well.

References:

[1] Hany Assasa and Joerg Widmer. 2016. Implementation and Evaluation of a WLAN IEEE 802.11ad Model in ns-3. In *Proceedings of the Workshop on ns-3* (*WNS3 '16*). Association for Computing Machinery, New York, NY, USA, 57–64.

[2] Hany Assasa and Joerg Widmer. 2017. Extending the IEEE 802.11ad Model: Scheduled Access, Spatial Reuse, Clustering, and Relaying. In *Proceedings of the Workshop on ns-3* (*WNS3 '17*). Association for Computing Machinery, New York, NY, USA, 39–46.

[3] Hany Assasa, Joerg Widmer, Tanguy Ropitault, and Nada Golmie. 2019. Enhancing the ns-3 IEEE 802.11ad Model Fidelity: Beam Codebooks, Multi-antenna Beamforming Training, and Quasi-deterministic mmWave Channel. In *Proceedings of the 2019 Workshop on ns-3* (*WNS3 2019*). Association for Computing Machinery, New York, NY, USA, 33–40.

[4] Hany Assasa, Nina Grosheva, Tanguy Ropitault, Steve Blandino, Nada Golmie, and Joerg Widmer. 2021. Implementation and evaluation of a WLAN IEEE 802.11ay model in network simulator ns-3. *Proceedings of the Workshop on ns-3 (WNS3 2021)*. Association for Computing Machinery, New York, NY, USA, 9–16.