Validation of the ns-3 802.11s model and proposed changes compliant to IEEE 802.11-2012

[Extended Abstract - Poster Presentation]

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ABSTRACT

The correct implementation of the protocols and proper exchange of messages is very important for an easy comparison of the results of real measurements and network simulations. This work shows the validation of the ns-3 802.11s mesh module with respect to the actual IEEE Standard 802.11-2012 [3] and proposes changes which are needed to get the ns-3 implementation compliant to the actual standard. The ns-3 802.11s mesh module is described in [1] and based on the IEEE 802.11s Draft Standard 3.0 (2009). Therefore several changes in the ns-3 mesh module are needed to cover the actual standard (e.g. Category and Action Values, Information Elements and Element ID, structure of the Peering Management frame, Mesh Configuration and the Path Error frame). As independent monitoring tool Wireshark is used to validate the protocol implementation in ns-3.22 as the Wireshark parser is covering the actual protocol implementation of IEEE 802.11-2012. The source of the proposed changes in ns-3.22, which are described in the following sections can be found in [2].

1. ASSIGNMENT OF CATEGORIES AND ACTIONS

Action Frames are a type of management frame used to trigger an action in the Network. In Mesh Networks, Management Frames of Type Action are used for the establishment of Peer Links according to the Peering Management Protocol and path selection according to the Hybrid Wireless Mesh Protocol (HWMP) (see [1] and [3]). The category value describes the action frame type (e.g. Block Ack, Mesh, Multihop and Self-protected as defined in [3] chap. 8.4.1.11 tab. 8-38). Important actions according to chap. 8.4.1.11, 8.5.16 and 8.5.17 of [3] are shown in Figure 1 (gray marked squares are not implemented in ns-3 so far).

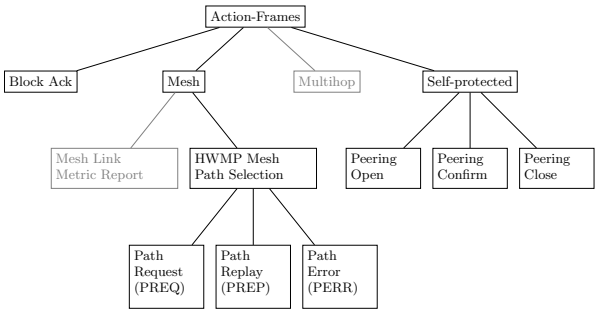

Figure 1: Important Action Frames of IEEE 802.11-2012

Categories and actions are defined as enum structures in the file */wifi/model/mgt-headers.h* and assigned with values. The classification of the categories and actions was made in order to make them compatible with the IEEE 802.11s Draft Standard 3.0 (see [1]). Table 1 shows the differences of the categories between the ns-3 implementation and the IEEE 802.11-2012 Standard. The numbers show the corresponding category codes and the categories used in the ns-3 implementation are marked with an ×. Because of the draft implementation, the analysis in Wireshark leads to a wrong interpretation and the category code 30 is shown as unknown. All following frame contents were misinterpreted as well. Figure 2(a) shows the misinterpretation of the Peer Link Open frame of the example file *mesh.cc* in Wireshark. Therefore the actions in the file */wifi/model/mgt-headers.h* have been changed in order to correctly represent the standard. The category MESH_PEERING_MGT was changed to *SELF_PROTECTED=15*. MESH_LINK_METRIC, MESH_PATH_SELECTION and MESH_INTERWORKING are obsolete and changed to *MESH=13*. MESH_RESOURCE_COORDINATION and MESH_PROXY_FORWARDING are changed to *MULTIHOP=14*. Because of these amendments it was necessary to change the functions *GetCategory* and *GetAction* in */wifi/model/mgt-headers.cc* as well. In addition the class *GetCategoryWifiActionHeader* needed to be updated because of the definition of the actions and categories in this file [2]. Further changes were needed

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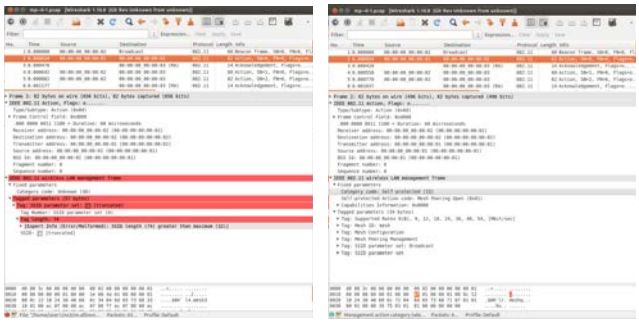
Table 1: Categories (× used, –not used)

IEEE 802.11s Draft 3.0		IEEE 802.11-2012		
BLOCK_ACK	3	BLOCK_ACK	3	×
MESH_PEERING_MGT	30	SELF_PROTECTED	15	×
MESH_LINK_METRIC MESH_PATH_SELECTION MESH_INTERWORKING	31 32 33	MESH	13	×
MESH_RESOURCE_COORDINATION MESH_PROXY_FORWARDING	34 35	MULTIHOP	14	–

in the files */mesh/model/dot11s/hwmp-protocol-mac.cc* and */mesh/model/dot11s/peer-management-protocol-mac.cc*. Finally Figure 2(b) shows the correct interpretation of the Peer Link Open frame in Wireshark after the implementation of the proposed changes [2]



(a) ns-3 802.11s implementation based on Draft 3.0

(b) Updated ns-3 implementation compliant to IEEE 802.11-2012

Figure 2: Detection of MAC-Frames in Wireshark 1.10.8

2. INFORMATION ELEMENTS AND ELEMENT ID

The IEEE 802.11 standard includes the notion of Information Elements, which are encodings of management information to be communicated between STAs in the payload of various frames of type Management. Basic information elements are defined in the file */wifi/module/wifi-information-element.h*. In this file, no changes were necessary because the data correctly represents [3]. Information elements that are used in relation with 802.11s are defined in the file */mesh/modul/mesh-information-element.h*. The changes in this file are limited to the adjustments of the element ID values. [2]

3. STRUCTURE OF THE PEERING MANAGEMENT FRAME

By analyzing the packet capture (PCAP) files with Wireshark it was noticed that the peering management frames had too many octets at some positions. Because of that, the subsequent frame body elements are not properly captured and detected. Therefore some changes in the file */mesh/-model/dot11s/peer-link-frame.cc* were needed to solve this issue. [2]
Firstly, the reason code was transferred separately, although it is already included in the *m_config Element*. Another issue was the *m_protocol* variable. In this variable the Peering Protocol version is submitted. But this is not necessary, since the protocol version is already transmitted in the Mesh Peering Management Element. In the file */dot11s/ie-dot11s-peer-management.h* the enum values of the *PmpReasonCode* and *Subtype* were updated. [2]

4. MESH CONFIGURATION

The assignment of the Mesh Configuration element is performed in the file */mesh/model/dot11s/ie-dot11s-configuration.cc*. In the corresponding header file, the individual information fields, e.g. the Active Path Selection Protocol Identifier, were defined with four octets. In [3] only one octet is used. Therefore the parameters have been changed, that only one byte per information field will be transmitted. The values of the information fields had to be adjusted as well. Because of the changed size of the information fields it was necessary to change the functions of read and write of the information fields (ReadLsbtohU32 and WriteHtolsbU32) to ReadU8 and WriteU8. [2]

5. HWMP – PATH ERROR FRAME

The Path Error (PERR) frame contains, among others, the octet flag in which several flags are represented by individual bits. In addition, two octets for the reason code are included. This flags and the reason code were not transmitted in the ns-3 implementation so far. In order to adapt the ns-3 implementation the necessary changes have been included in */mesh/model/dot11s/ie-dot11s-perr.cc* and */dot-11s/ie-dot11s-perr.h*. The corresponding fields are transmitted and received in their intended length (1 or 2 octets) with the value 0 as default. It is not critical to occupy the fields with zeros, since the flag octet contains only a single used flag according to the standard [3]. This flag provides information, whether an external address is specified or not. Since the simulator does not support forwarding as well as proxy and thus the use of external addresses is not provided, the information of this flag is negligible. The assignment of a Reason Code is decided by scenarios defined in the standard [3]. The first case is present when the next hop is not feasible. Then the Reason *MESH-PATH-ERROR--DESTINATION-UNREACHABLE* is specified with Code 63. Two more cases occur in the absence of forwarding or proxy information. Only the first case can occur in the simulator, since, as already noted, the simulator does not support forwarding and proxy functionality. [2]

6. CONCLUSION

With the described changes it was reached that the messages of the Peering Management Protocol and Hybrid Wireless Mesh Protocol in ns-3 will be transmitted compliant to the standard IEEE802.11-2012 [3]. It was ensured that the

messages are correct on byte and bit level. Figure 3 shows a Peering Management Open frame as an example. Categories and self-protected action values are assigned properly. With this analysis it is assumed that even for complex simulations all protocol actions will be carried out properly. Therefore simulations of complex wireless mesh networks can be easily compared with results of measurement test beds. The Source Code with the proposed code changes can be found in [2].

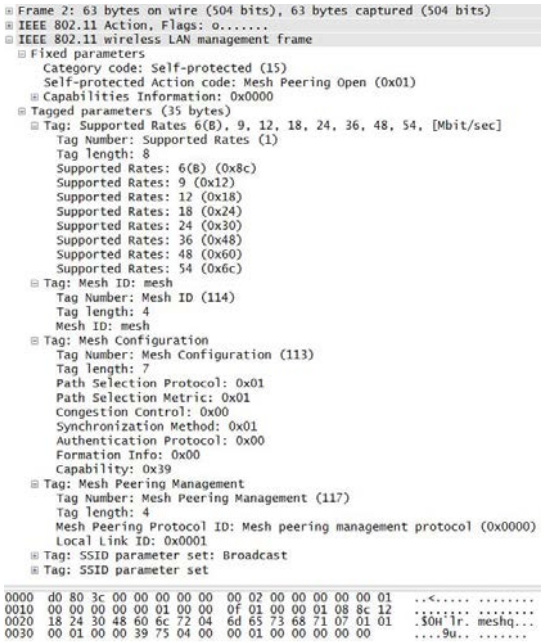


Figure 3: Mesh peering open frame

7. OPEN ISSUES

The UDP packets which are generated in the simulator ns-3 are not recognized as UDP packets in Wireshark. They are erroneously detected as LLC packets. Further investigations solving this issue are needed.

8. REFERENCES

[1] K. Andreev and P. Boyko. IEEE 802.11s Mesh Networking NS-3 Model. *http://www.nsnam.org/workshops/wns3-2010/dot11s.pdf*, 2015-03-01.

[2] C. Hepner. Codereview - mesh module compliant to IEEE 802.11-2012. *https://codereview.appspot.com/217910043*, 2015.

[3] IEEE Computer Society. Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications. *IEEE Std 802.11*, 2012.