IEEE 802.11s Mesh Networking NS-3 Model

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Plan

Introduction

Most often Wireless Mesh Network (WMN) means a Mobile Ad-hoc Network (MANET) which

- operates transparently to the network layer (at L2);
- used in static topologies to create a community network or infrastructure-less backbone.

IEEE 802.11 (WiFi) based WMNs are popular. A large number of difficult problems still exists as well as a large number of available mesh solutions (both proprietary and open). IEEE 802.11s is a mesh-enabling “patch” to the 802.11 Standard being standardized by IEEE WG. Current version is Draft v3.0 dated by March 2009.

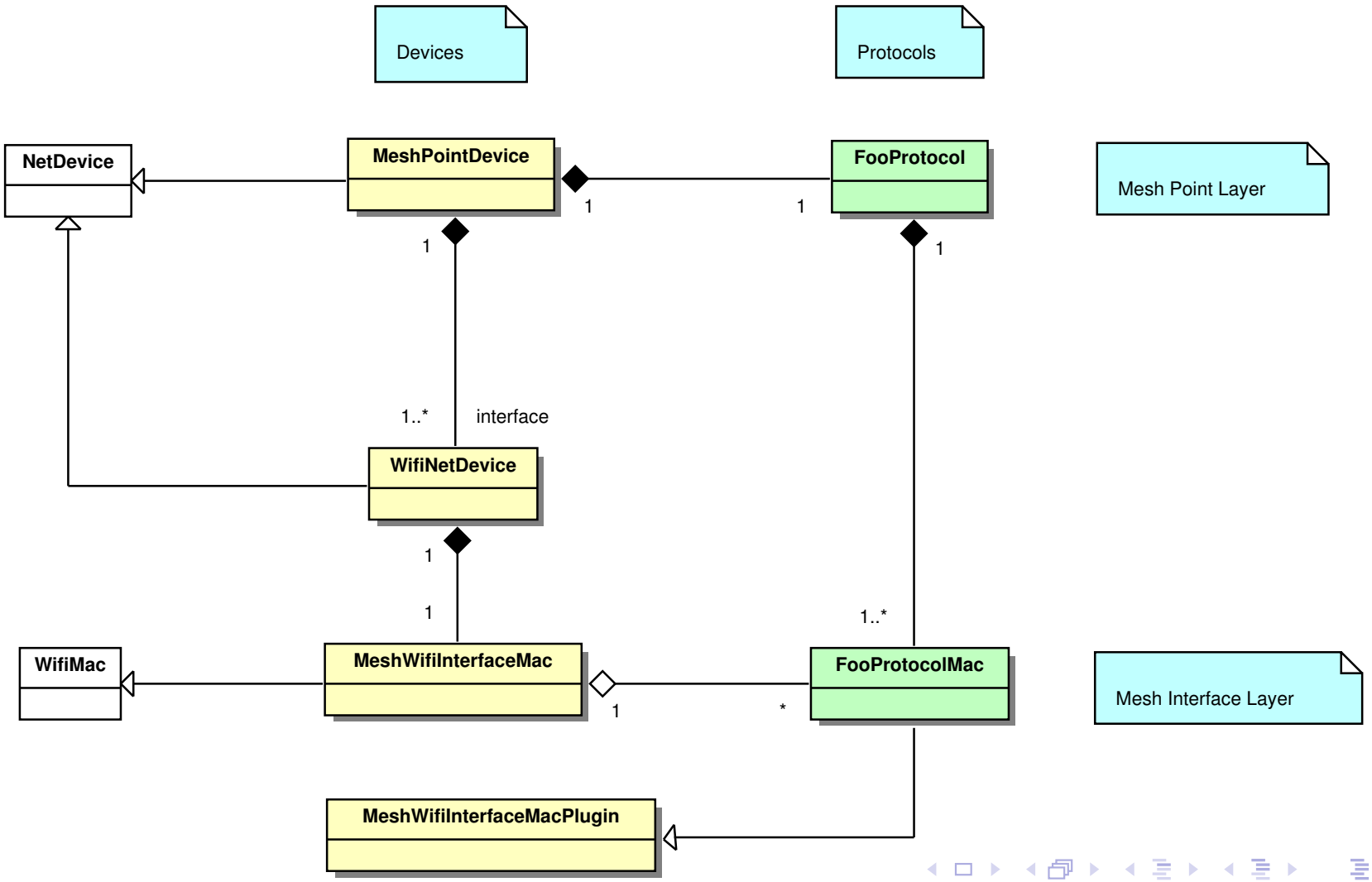
Project goals

1. Create a detailed NS-3 model of IEEE 802.11s draft.
2. Develop an architecture flexible enough to support any other WiFi based L2 meshing solution.
3. Implement FLAME (Forwarding LAyer for MEshing) protocol to prove point 2.

Mesh module architecture requirements

1. Do not break existing 802.11 MAC models.
2. Don't copy-paste them either!
3. Keep mesh protocols as much independent and separated from each other as possible.
4. Support any number of simultaneously active mesh protocols (e.g. neighbor management and routing).
5. Support multi-radio solutions (i.e. coordinated work of several 802.11 devices).

Solution: 2×2 layers



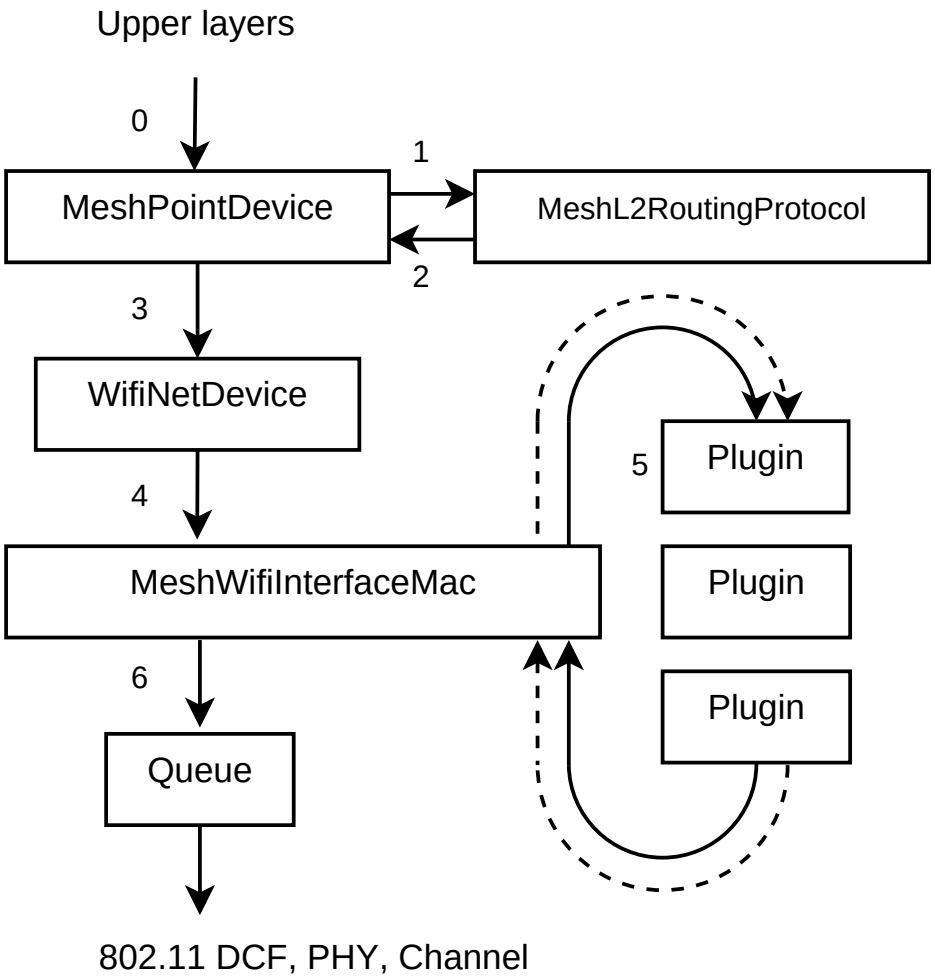
Mesh point *vs.* mesh interface

- Single mesh point device interacts with L3 (e.g. has an IP address) and coordinates work of several mesh interface devices. Mesh point doesn't have PHY and doesn't interact with the wireless channel directly.
- Every mesh interface device has its own MAC and PHY and operates on behalf of the mesh point. Mesh interfaces do not interact with L3 directly.

Mesh protocol *vs.* MAC plugin

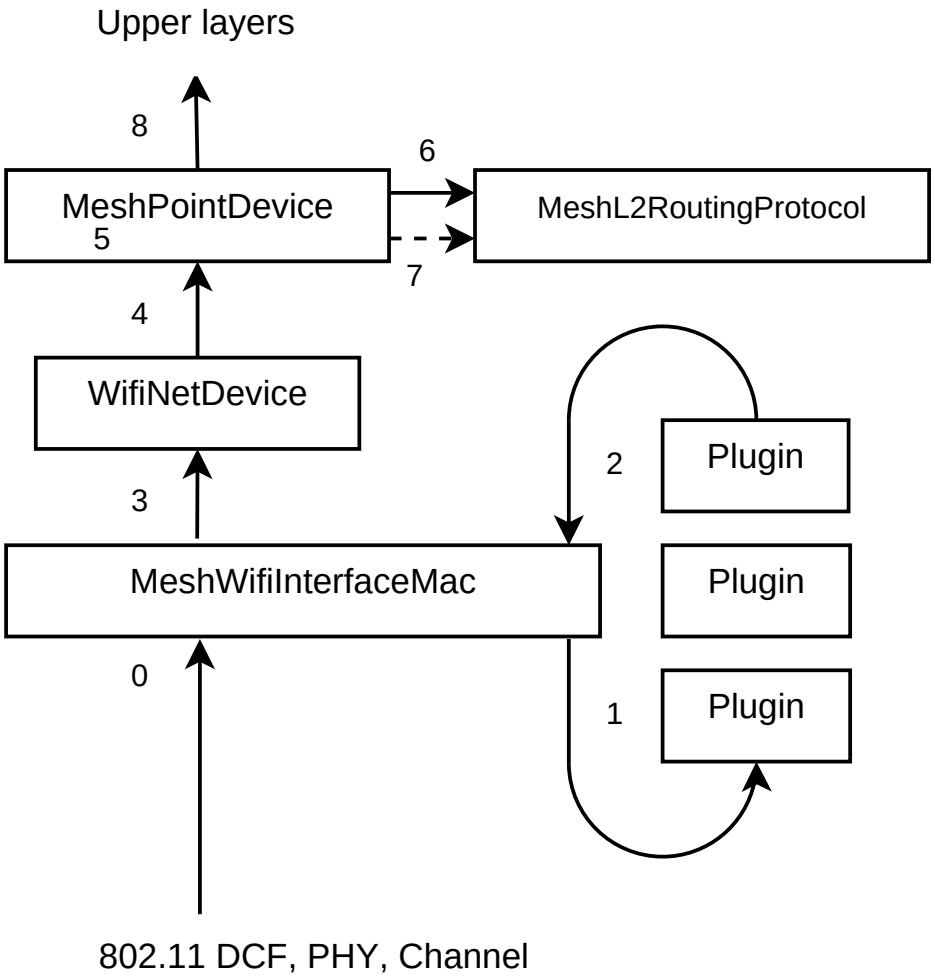
- Mesh point hosts (aggregates) a number of mesh protocols. Every protocol solves its own task (e.g. neighbor management or channel assignment). A set of simultaneously active mesh protocols is a *mesh stack*, e.g. "802.11s stack" or "FLAME stack". There is a dedicated routing protocol implementing `MeshL2RoutingProtocol` base class.
- Protocols should not care much about message "wire" formats and sending/receiving management traffic – this is delegated to MAC plugins hosted by every mesh interface. Every MAC plugin implements several hooks declared in `MeshWifiInterfaceMacPlugin` base class and is able to filter all incoming and outcoming packets as well as create new ones.

Packet flow: sending a packet



1. Call for routing protocol.
2. Routing returns a packet with tagged routing information.
3. Choosing a proper outgoing interface.
4. Adding LLC header (starting 802.11-dependent part).
5. Passing all packets through all MAC plugins in order.
6. Queue packet for PHY.

Packet flow: receiving a packet



1. Passing packet through plugins in the reverse order.
2. Frames may be dropped.
3. Removing LLC header
4. Passing a frame with a tagged routing information.
5. Decide whether to deliver or forward a packet.
6. Request for route (see above).
7. Remove all tagged routing information.
8. Forward a packet up.

Status of IEEE 802.11s Draft v3.0 model

Supported features:

- Peering Management Protocol (PMP) including link close heuristics and beacon collision avoidance.
- Hybrid Wireless Mesh Protocol (HWMP) including proactive and reactive modes, unicast/broadcast propagation of management traffic, multi-radio extensions.
- 802.11e compatible airtime link metric.

Verification:

- Comes with the custom Wireshark dissector.
- Linux kernel mac80211 layer compatible message formats.
- Large number of unit and PCAP based system tests.

Status of IEEE 802.11s Draft v3.0 model

Unsupported features:

- Mesh Coordinated Channel Access (MCCA), *in progress*.
- Internetworking: mesh access point and mesh portal.
- Security.
- Power save.
- Though multi-radio operation is supported, no channel assignment protocol is proposed for now.
- ...

Status of FLAME model

- No perfect "one-size-fits-all" wireless mesh approach exists.
- Forwarding LAyer for MEshing (FLAME) is an extremely simple L2.5 mesh protocol, proposed and implemented as Linux kernel module by Herman Elfrink some time ago.
- Full-featured FLAME model is provided to demonstrate that NS-3 mesh architecture is capable to support very different mesh solutions.
- Model your favorite mesh protocol!

Conclusions

- Proposed mesh architecture serves well.
- IEEE 802.11s NS-3 model can be used for out of the box WMN simulations starting from ns-3.7.
- The model is made to be easily extended with new protocols.
- We hope that models of the alternative L2 mesh protocols/stacks of protocols will follow.

Some perspectives of 802.11 MAC refactoring

Current set of 802.11 "high MAC" models:

1. QoS station/AP MAC.
2. Non-QoS station/AP MAC.
3. QoS ad-hoc MAC.
4. Non-QoS ad-hoc MAC.
5. Mesh interface MAC (QoS only).

Models yet to be created:

6. Mesh access point (QoS + non-QoS?)
7. Mesh portal (QoS + non-QoS?)
8. ...

Can we utilize 802.11 MAC plugin architecture to stop this copy-paste?