Mobile Ad-hoc Network (MANET) Multicast Routing Perspective

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Internet Engineering Task Force 101

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Outline

- MANET Routing Protocol Synopsis
- Multicast Routing for MANET
- Simplified Multicast Forwarding (SMF)
- Emerging Techniques
- Forwarding Plane Considerations

MANET WG Unicast Routing Protocols

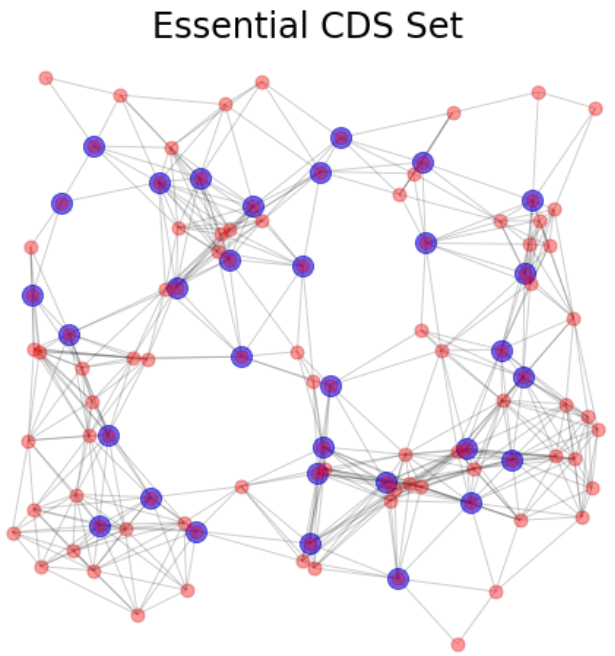
- Original Experimental RFCs:
  - Optimized Link State Routing (OLSR) – RFC 3626
  - Ad-hoc On-Demand Distance Vector (AODV) – RFC 3561
  - Dynamic Source Routing (DSR) – RFC 4728
  - Topology-Dissemination Based on Reverse-Path Forwarding (TBRPF) – RFC 3684
- Proposed Standards:
  - Optimized Link State Routing version 2 (OLSRv2) – RFC 7181
    - Supported by NHDP (RFC 6130) and PacketBB (RFC 5444)
- Other related protocols
  - Routing over Low-Power/Lossy Networks (RPL)
  - BABEL routing protocol
  - OSPF MANET extensions

MANET Multicast Routing

- Challenges:
  - May forward packets via same interface as received
  - Highly dynamic topologies
  - Packet loss often higher with multicast than unicast (e.g., 802.11)
  - Often lower rate transmission than unicast (e.g., 802.11)
- Early Proposed Concepts:
  - Multicast AODV (MAODV)
  - Multicast OLSR (MOLSR)
  - On-Demand Multicast Routing Protocol (ODMRP)
  - Piggy backing plugin for olsr.org code reused routing dissemination forwarding
- Where the working group landed:
  - Simplified Multicast Forwarding (SMF) – RFC 6621

Simplified Multicast Forwarding (SMF)

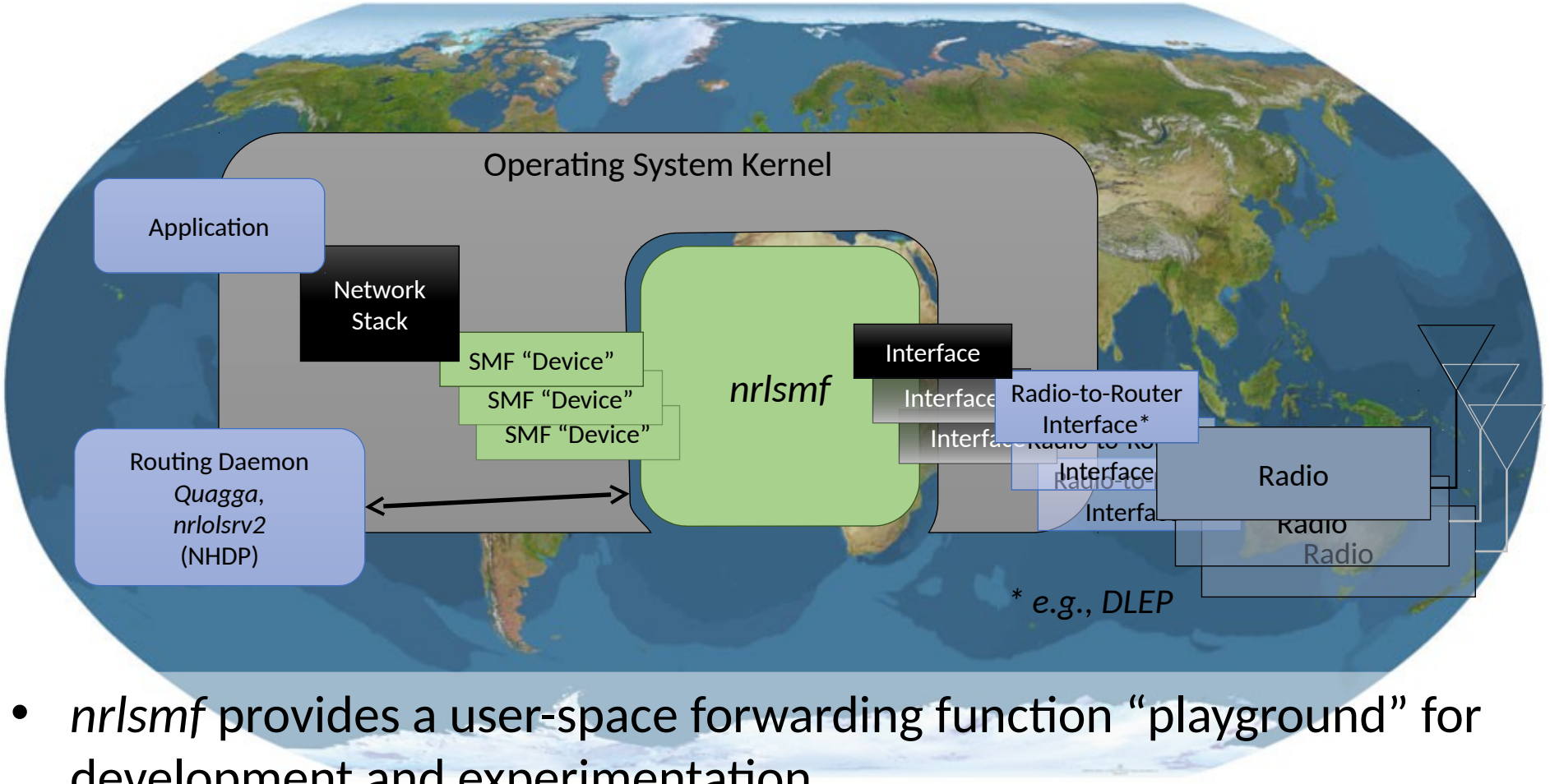
- Floods multicast packets within a MANET routing area
  - Contention range of many wireless systems greater than communication range so flooding on a small diameter network often not much worse than group-based routing
- Uses duplicate packet detection (DPD) to safely flood
  - Identifier- and hash-based techniques specified for IPv4 and IPv6
- Compatible with efficient flooding techniques enabled by distributed, Connected Dominating Set (CDS) relay set selection algorithms
  - Only relies upon local neighborhood information
- Relay Set Selection Algorithms
  - Source-based Multipoint Relay (S-MPR)
  - Essential Connected Dominating Set (E-CDS)
  - Other variations
  - Enhancement have been explored:
    - Metric-based selection with redundancy
    - “Sticky” techniques for improved stability



SMF Implementations

- *nrlsmf* – cross-platform, user-space forwarding daemon
  - open source at https://www.nrl.navy.mil/itd/ncs/products/smf
  - Linux, Windows, Mac OSX, Android, etc. supported
  - Runs stand-alone for classic flooding or can be controlled by NHDP daemon with relay-set algorithms
- *olsrd* – OLSR daemon with Basic Multicast Forwarding (BMF) plug-in
  - Open source at https://www.olsr.org

nrlsmf's Place in the World



- *nrlsmf* provides a user-space forwarding function "playground" for development and experimentation
- Have been exploring forwarding plane considerations for MANET (Forwarding Information Base (FIB) constructs such as DPD state)

Recent MANET Multicast Concepts

- ODMRP-ASYM
  - Can work in topologies with non-reciprocal links
  - References:
    - *draft-gerla-manet-odmrp-asym-01 (expired)*
    - M. Gerla, Yeng-Zhong Lee, Joon-Sang Park and Yunjung Yi, "On demand multicast routing with unidirectional links," *IEEE Wireless Communications and Networking Conference, 2005*, 2005, pp. 2162-2167 Vol. 4.
- Elastic Multicast
  - Flow-based multicast routing paradigm
  - Builds from flooding mesh provided by SMF using token bucket limited user traffic or ”advertisement” control messages to announce flows
  - ACKs from “downstream” nodes (including group members) are propagated “upstream” towards source(s) to keep subset of flooding relays fully active
  - Gateway mechanism to/from enterprise multicast routing protocols (e.g. PIM) can be supported
  - References:
    - *draft-adamson-elasticmcast-00 (expired)*
    - C. Danilov, T. R. Henderson, O. Brewer, J. H. Kim, J. Macker and B. Adamson, "Elastic multicast for tactical communications," *MILCOM 2012 - 2012 IEEE Military Communications Conference*, Orlando, FL, 2012, pp. 1-6.
    - B. Adamson, J. P. Macker and J. W. Weston, "Elastic multicast: Design extensions and experimentation results," *MILCOM 2017 - 2017 IEEE Military Communications Conference (MILCOM)*, Baltimore, MD, 2017, pp. 581-586.

Forwarding Plane Considerations

- SMF adds duplicate packet detection (DPD) processing and state as compared to conventional destination-based forwarding
  - *nrlsmf* caches DPD state on a **per-flow** basis to help reduce false duplicates
  - A limited **window** of DPD history is kept per flow
- Flow-based constructs like Elastic Multicast also have some additional state and control-plane interaction requirements
  - New flow detection, flow status updates, etc
  - On-demand protocols (e.g., AODV) also have similar needs
- A common Forwarding Information Base (FIB) specification might be specified for these types of protocols

Example: XORP *mrouted* Interface

mroute.h

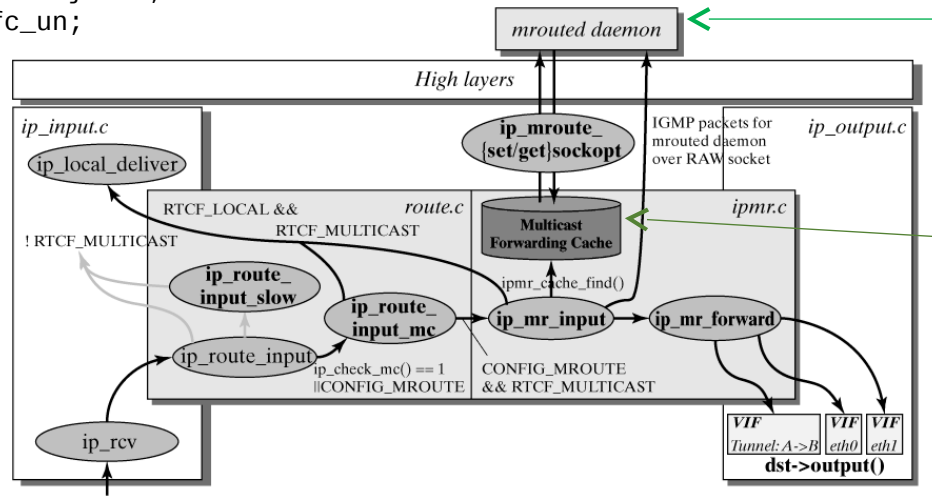
```
193 struct mfc_cache {
194         struct mfc_cache *next;                 /* Next entry on cache line     */
195 #ifdef CONFIG_NET_NS
196         struct net *mfc_net;
197 #endif
198         __be32 mfc_mcastgrp;                    /* Group the entry belongs to   */
199         __be32 mfc_origin;                      /* Source of packet             */
200         vifi_t mfc_parent;                      /* Source interface             */
201         int mfc_flags;                          /* Flags on line                */
202
203         union {
204                 struct {
205                         unsigned long expires;
206                         struct sk_buff_head unresolved; /* Unresolved buffers          */
207                 } unres;
208                 struct {
209                         unsigned long last_assert;
210                         int minvif;
211                         int maxvif;
212                         unsigned long bytes;
213                         unsigned long pkt;
214                         unsigned long wrong_if;
215                         unsigned char ttls[MAXVIFS];    /* TTL thresholds               */
216                 } res;
217         } mfc_un;
218 };
```

DPD?

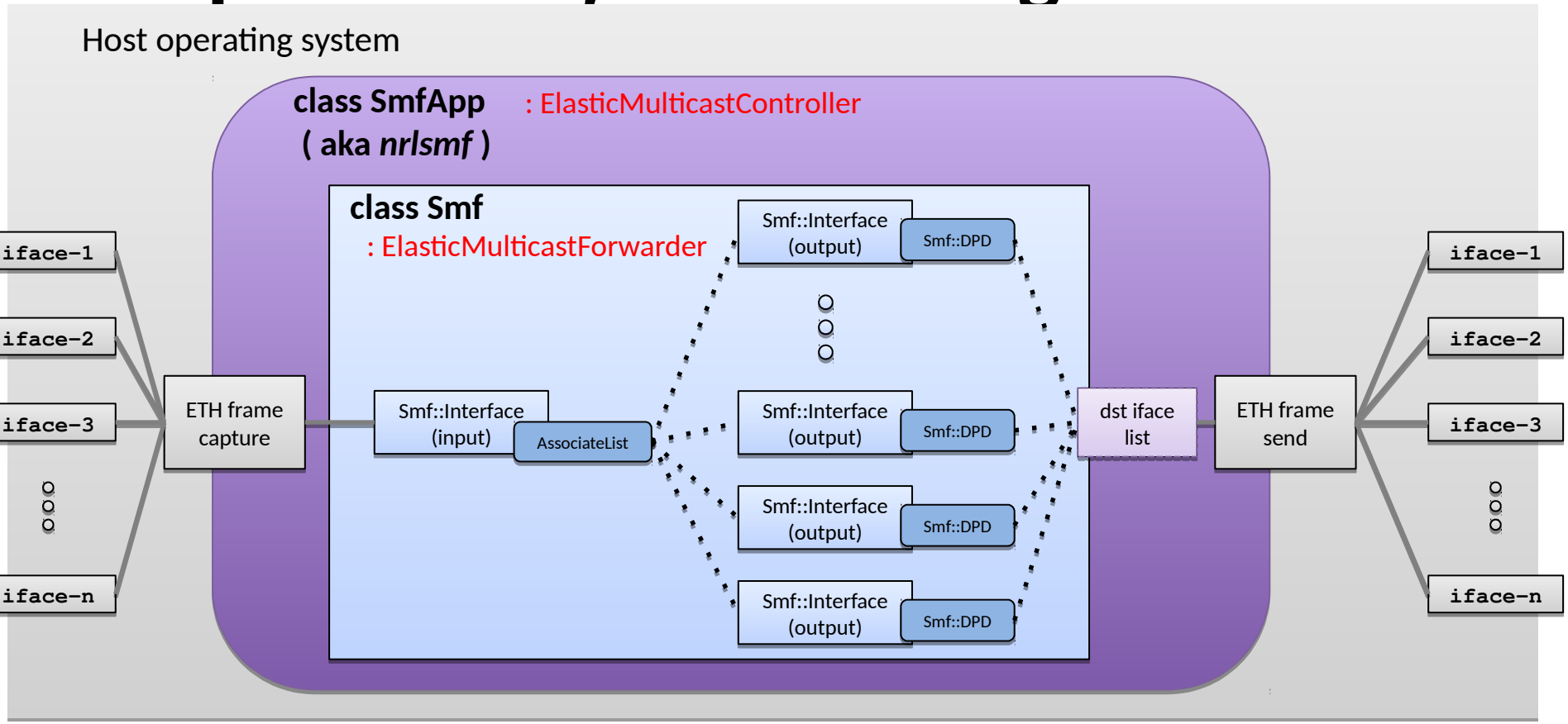
Other stuff

SMF / EM

Multiple tables

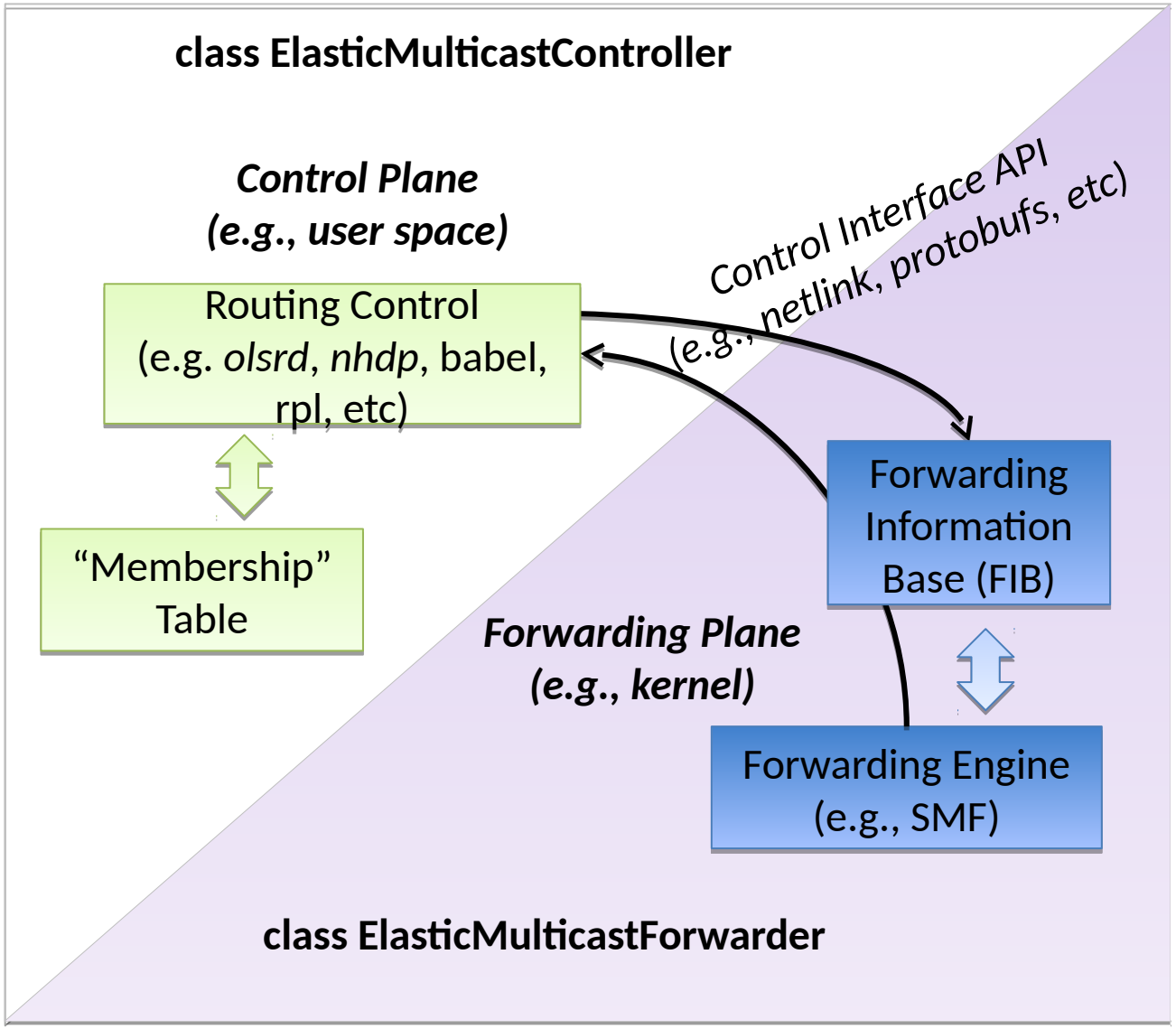


Example: *nrlsmf* Forwarding Architecture



- **`Smf::Interface::Associate`** defines forwarding relationship from an input interface to an output interface
  - An **`Smf::Interface`** may "self-associate" for forwarding on a MANET interface
- Forwarding decision is conducted in the **`Smf::ProcessPacket()`** method
  - **`Smf::ProcessPacket()`** code enhanced to conduct Elastic Multicast forwarding (principally at the post-DPD stage)
  - Detected flows are aged / pruned in the **`Smf::OnPruneTimeout()`** method
- Elastic Multicast controller functionality embedded in **`class SmfApp`** code

Controller/Forwarder Relationship

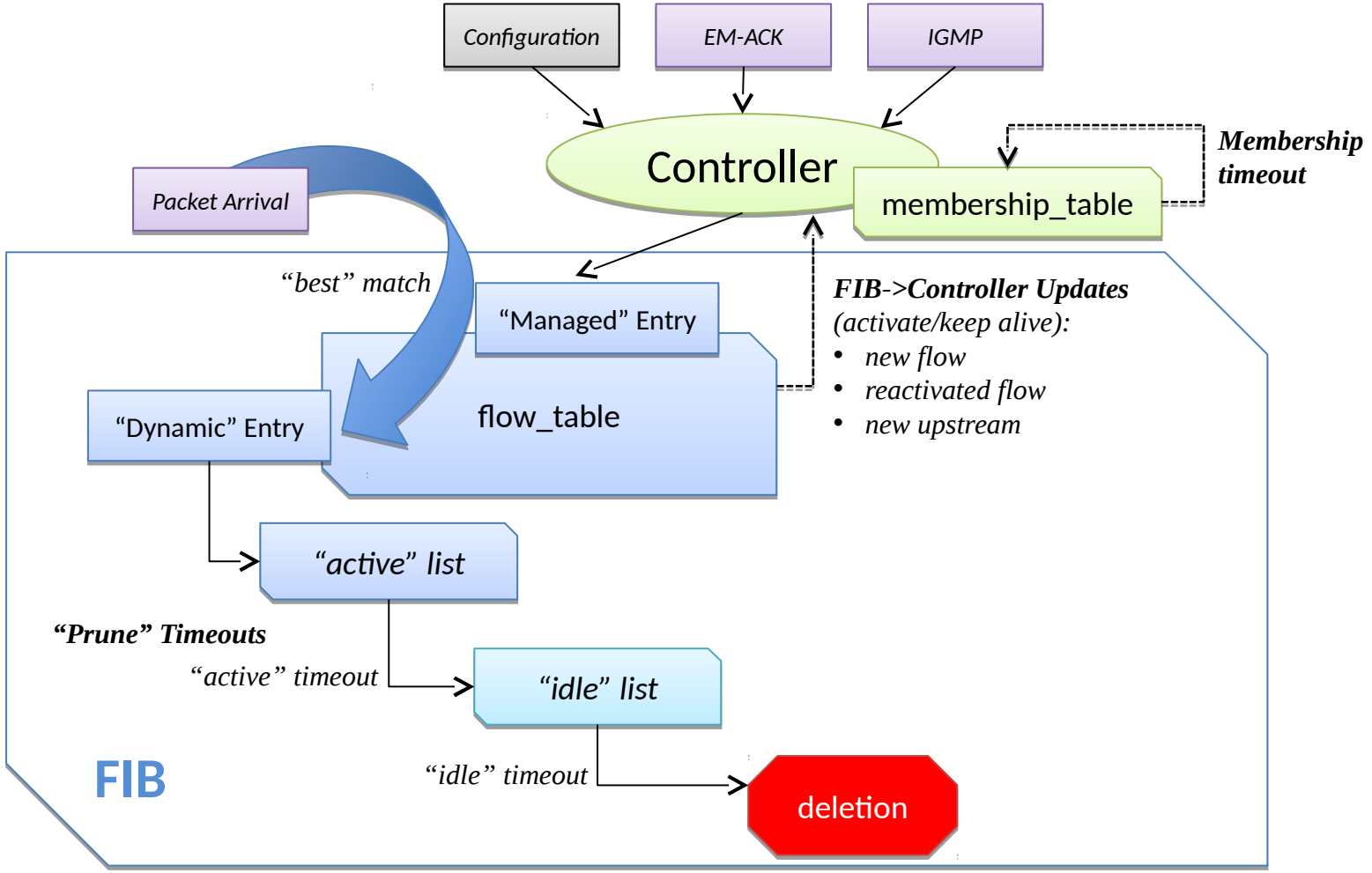


Conclusion

- MANET multicast routing concepts have some added considerations as compared to conventional multicast routing specifications.
- A common FIB and supporting control plane interface specifications could be developed to support these protocols as well as some unicast MANET/ROLL/BABEL protocols with special needs.
- MANET is chartered to develop this FIB looking for input on interests and best approaches to provide the largest benefit.

Backup Slides

Elastic Multicast FIB Entry Life Cycle



1. An entry may be dual-hatted as "managed" and "dynamic"
2. "Managed" entries are removed only by Controller
3. "Dynamic" entries inherit policy/parameters from matching "managed" entry
4. Non-matched dynamic entries are not acked or forwarded and follow default policy (unicast support will likely require explicit default policy entries to be made)

The Key: FlowDescription

- **`class MulticastFIB::FlowDescription`**
- Key is a tuple of *dst:src:class:protocol:ifaceIndex*
- Fields may be wildcarded
  - "Best match" search and prefix-based / matching iterators are provided using ProtoTree data structure (Patricia trie radix tree)
  - Could be extended to include port numbers for application-specific policies
- Controller uses FlowDescription with interface index as key for membership table entries
  - Can support ASM and SSM memberships and unicast flows for Adaptive Routing
- Forwarder uses FlowDescription as key for forwarding table entries (does not use interface index field)
- FlowDescriptions and interface indices are used as reference for controller<->forwarder interaction
  - E.g., a protobufs or netlink structure could be defined
- Prefix mask lengths allow prefix subnet entries for dst and/or src addresses

`dstLength : [dstAddr : dstMask] : srcLength : [srcAddr : srcMask] : class : protocol : index`

`dstLength` or **`srcLength == 0`** is "wildcard" dst or src address
(otherwise length of associated address field in bytes)
`dstMask` and **`srcMask`** are prefix mask lengths (in bits) for **`dstAddr`** and **`srcAddr`**
`class == 0x03` is "wildcard" traffic class (i.e. , ECN bits)
`protocol == RESERVED` (255) is "wildcard" protocol type
`index == 0` is "wildcard" interface index