XORP Multicast Forwarding Engine Abstraction

Version 0.1

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1 Introduction

1.1 Overview

This document provides an overview of the XORP Multicast Forwarding Engine Abstraction (MFEA). It is intended to provide a starting point for software developers who wish to modify this software.

The main purpose of the MFEA is to abstract the underlying system and the multicast forwarding engine, and to provide a consistent interface to multicast-related modules such as PIM and MLD/IGMP. Thus, if we want to use PIM and MLD/IGMP on different platform/hardware for example, we would have to modify only some part of the MFEA. In addition, all the complexity associated with network sockets, sending and receiving packets, and so on are moved out of the protocol modules to the MFEA. This reduces greatly code duplication, and eliminates the development overhead of dealing with protocol-independent issues when implementing a new protocol. In addition, if we want to use PIM and MLD/IGMP in simulation environment, it will be sufficient to add the simulation environment support to the MFEA only.

Currently (December 2002), the MFEA supports abstraction for the following systems:

- Free,Net,OpenBSD OS (tested only on FreeBSD-4.5).
- Linux OS (tested only on Red Hat Linux 7.2 with kernel 2.4.18)

In the future, the MFEA will support simulation environment, and abstraction for Click [1] forwarding path [1]. Support for other systems will be added on-demand if there are available resources.

Currently (December 2002), for simplicity the MFEA is a separate process from the unicast FEA. One of the reasons is because multicast routing/forwarding should have minimum impact on the unicast routing/forwarding. If the FEA and MFEA were a single process, then if the PIM-SM daemon for example starts blasting a huge amount of requests to the unified FEA/MFEA process, then it may block the operation of that process, and it may affect not only multicast, but unicast routing/forwarding as well. If the FEA and the MFEA are separate processes, the impact will be localized. Note that the unicast and multicast forwarding tables in the kernel may be unified, this is up to the implementation; however, it should allow access by more than one daemons at the same time (eventually through a locking mechanism).

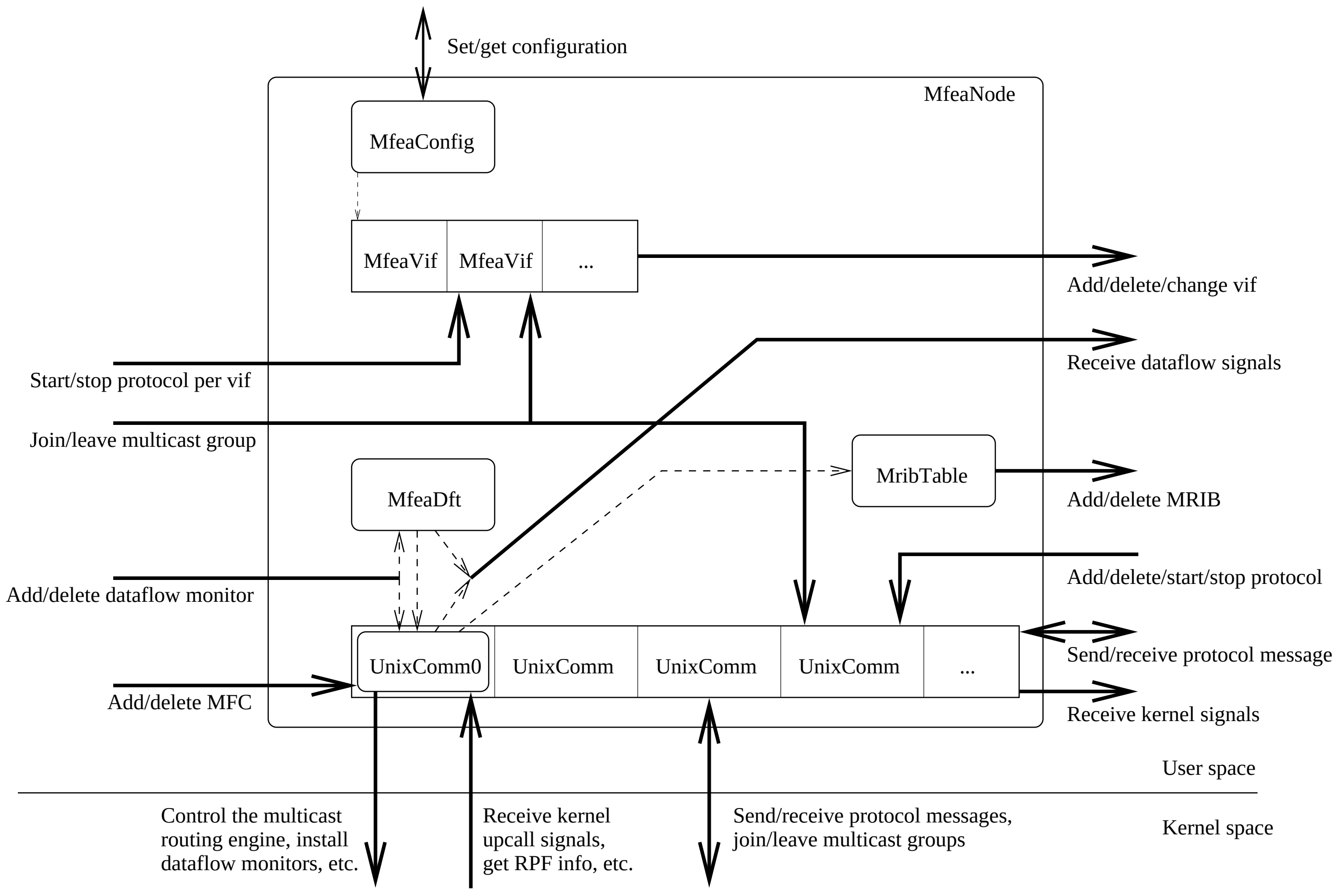
[1] Currently (December 2002) Click does not support multicast yet.

1.2 Acronyms

Acronyms used in this document:

- **MFC**: **M**ulticast **F**orwarding **C**ache: another name for an entry in the multicast forwarding engine (typically used on UNIX systems).
- **MFEA**: **M**ulticast **F**orwarding **E**ngine **A**bstraction
- **MLD/IGMP**: **M**ulticast **L**istener **D**iscovery/**I**nternet **G**roup **M**anagement **P**rotocol
- **MRIB**: **M**ulticast **R**outing **I**nformation **B**ase
- **PIM-SM**: **P**rotocol **I**ndependent **M**ulticast–**S**parse **M**ode
- **RIB**: **R**outing **I**nformation **B**ase

1.3 MFEA Design Architecture Overview



Set/get configuration
MfeaNode
MfeaConfig
MfeaVif
MfeaVif
...
Add/delete/change vif
Receive dataflow signals
Start/stop protocol per vif
Join/leave multicast group
MfeaDft
MribTable
Add/delete MRIB
Add/delete dataflow monitor
Add/delete/start/stop protocol
UnixComm0
UnixComm
UnixComm
UnixComm
...
Send/receive protocol message
Add/delete MFC
Receive kernel signals
User space
Kernel space
Control the multicast routing engine, install dataflow monitors, etc.
Receive kernel upcall signals, get RPF info, etc.
Send/receive protocol messages, join/leave multicast groups

Figure 1: MFEA design overview

Figure 1 gives a general overview of the MFEA components. For each component there is a C++ class with exactly the same name. The main components are briefly described below:

- **MfeaNode:** a representation of a single MFEA unit (*e.g.,* as part of a virtual multicast router). Typically, there would be a single MfeaNode per multicast router.
- **MfeaVif:** MFEA-specific virtual interface that is used to keep state per interface.
- **MfeaConfig:** contains MFEA-specific configuration.
- **MfeaDft:** table with dataflow-related information for estimating the bandwidth per dataflow.
- **MribTable:** the table with MRIB information.
- **UnixComm:** per-protocol UNIX-specific unit for communication with the underlying system.
- **UnixComm0:** special protocol-independent UnixComm unit for communication with the underlying system.

Those components are described in details in Section 2. For information about the interaction between the MFEA and other modules see [2].

2 Components Description

2.1 MfeaNode Description

MfeaNode is a representation of a single MFEA unit (*e.g.,* as part of a virtual multicast router). Typically, there would be a single MfeaNode per multicast router. However, in some cases a multicast router may have more than one MFEA unit. For example, it could have one MfeaNode for IPv4, and another one for IPv6 multicast routing. Further, if we want to run MFEA in a simulation environment, each multicast router within that simulation will have a single MfeaNode.

From a developer's point of view, MfeaNode contains the front-end interface to interact with the MFEA unit, as well as all the state related to that unit. For example, MfeaNode contains the methods to start/stop or configure the MFEA, or to send/receive protocol control messages (*e.g.,* PIM or MLD/IGMP) to/from the unit. Those methods are described in the following files:

- `mfea/mfea_node.hh`
- `libproto/proto_node.hh`
- `libproto/proto_unit.hh`

MfeaNode provides the following abstraction to the multicast-related modules such as PIM and MLD/IGMP:

- Interface to add/delete/start/stop a protocol within the MFEA and the underlying system.
- Interface to send or receive protocol messages through the underlying system.
- Interface to receive (kernel) upcalls/signals from the underlying system and pass those signals to the interested multicast-related modules. Examples of such signals are NOCACHE or WRONGVIF/WRONGMIF in case of UNIX kernel when the underlying multicast forwarding engine has no multicast forwarding entry for a multicast packet or when a multicast packet has arrived on an interface that is not the expected incoming interface.

- Interface to add/delete dataflow monitors, to monitor network bandwidth per dataflow, and to send the appropriate signals to the interested multicast-related modules. For example, the PIM-SM module might be interested when the bandwidth of a given dataflow becomes zero, or above a threshold.
- Interface to inform the multicast-related modules about the available virtual interfaces (*e.g.,* network interfaces, tunnels, etc.) on the system, and to inform them about any changes on those interfaces (*e.g.,* interface going DOWN, network address change, etc.).
- Interface to join or leave a multicast group.
- Interface to add/delete MFC entries, *i.e.,* entries to the multicast forwarding engine.
- Interface to monitor the state of the underlying unicast forwarding table, to construct the MRIB table from it, and to send the MRIB information to the interested multicast-related modules.

MfeaNode itself does not implement the mechanisms to communicate with the multicast-related modules (*e.g.,* to send or receive control packets to/from the PIM module). Those mechanisms are outside the scope of MfeaNode, and must be implemented separately.

MfeaNode contains several pure virtual methods (*e.g.,* `send_add_mrib()` that is used to add MRIB entry to a multicast-related module that is interested in tracking the MRIB) that must be implemented by a class that inherits MfeaNode. For example, XrlMfeaNode is a class that uses MfeaNode as a base class, and that implements XRL-based communication mechanisms between MfeaNode and other XORP components such as the PIM and MLD/IGMP modules.

By default, MfeaNode is disabled; therefore it must be explicitly enabled, and then started.

2.2 MfeaVif Description

MfeaVif is a MFEA-specific virtual interface that is used to keep various state per virtual interface. Typically, there would be one MfeaVif virtual interface for each interface on the router: physical interfaces, tunnels, and the loopback interface. In addition, there will be one special MfeaVif virtual interface: the PIM Register virtual interface that is used for sending and receiving PIM Register messages [2].

One of the purposes of MfeaVif is to keep information about each interface available on the system: network address, subnet address, is the interface up or multicast-capable, etc. This state is used by the MFEA to keep track of any changes to an interface (*e.g.,* an alias address has been added/deleted, etc). If there is a change to an interface, the MFEA informs all protocol modules that have enabled the specific protocol on that interface [3].

Another purpose of MfeaVif is to keep track of the multicast groups joined per interface. For example, if a multicast-related module that uses the MFEA joins a multicast group on an interface, the MFEA will call the appropriate system call to join the group on the specified interface, and at the same time it will keep the appropriate state on the corresponding MfeaVif. Thus, if more than one modules join exactly same multicast group on the same interface, and later one of those modules leave that group, the MFEA will modify the appropriate state in MfeaVif, but will not use a system call to leave the multicast group on the interface.

Typically, from developer's point of view, all interaction with MfeaVif would be through MfeaNode [4].

[2] In the future (after December 2002), the PIM Register MfeaVif interface may not be part of the MFEA anymore, because it is strictly PIM-specifi c.

[3] Currently (December 2002), the MFEA reads the interface status from the underlying system only once (on startup); instead, it should keep monitoring the interface status by periodically reading that status for example, and/or by considering the information provided by the XORP Router Manager (within the XORP framework).

[4] Note that on few occasions in the current implementation (December 2002) XrlMfeaNode for simplicity uses direct access to MfeaVif.

The public interface for MfeaVif contains the methods to manipulate a virtual interface. Those methods are to start/stop/enable/disable a virtual interface, or to configure it. Those methods are described in the following files:

- `mfea/mfea_vif.hh`
- `libxorp/vif.hh`
- `libproto/proto_unit.hh`

By default, each MfeaVif is disabled; therefore it must be explicitly enabled, and then started.

2.3 MfeaConfig Description

MfeaConfig handles the MFEA-specific configuration [5]. This configuration is used to configure the following units:

- MfeaNode: how often to read the unicast forwarding table, and information about the network interfaces, etc.

2.4 MfeaDft Description

Some protocols such as PIM-SM need the bandwidth of multicast data flows to be monitored: if the bandwidth of a specific data flow (defined by source and group address) is above or below a pre-defined threshold (per data flow), the protocol should be informed. For example, if the bandwidth of a data flow is zero for some amount of time, the corresponding multicast routing entry in the multicast routing protocol module might be deleted (as well as the corresponding multicast forwarding entry in the multicast forwarding engine). Another example is switching to the Shortest-Path Tree in case of PIM-SM: the SPT switch is triggered if the bandwidth from a specific source is above a pre-configured threshold.

If the multicast forwarding engine in the underlying system does support bandwidth dataflow monitoring and upcalls, then any addition or deletion of a dataflow monitor to the MFEA translates to a system call to the underlying system, and the MFEA itself does not need to keep any state. However, if the underlying system does not support bandwidth dataflow monitoring, then the MFEA needs to implement a work-around. In case of UNIX kernel for example, the kernel supports an ioctl() system call to get the number of octets and packets forwarded so far on an existing MFC entry. Thus, if the MFEA reads this information two times, it can compute the the forwarding bandwidth between the two readings.

The purpose of the MfeaDft table is to keep state about dataflows the MFEA should monitor their bandwidth of (only in the case the underlying system does not support bandwidth dataflow monitoring). For each entry in MfeaDft, the MFEA periodically reads the bandwidth forwarding statistics from the underlying system. If the forwarded bandwidth satisfies the pre-defined condition, the MFEA originates a dataflow signal to the module that has installed that dataflow monitoring entry. This signal is delivered every time the pre-defined condition is true (until the entry is explicitly deleted by the module that installed it).

2.5 MribTable Description

MribTable is the table with the MRIB information. Whenever this information is changed, the change is propagated to all interested parties that have registered interest in receiving it. For example, in case of PIM-SM the MRIB is used to compute the Reverse-Path Forwarding information toward the RPs or the senders.

[5] Currently (December 2002), MfeaConfi g is not implemented; rather, all state is kept into MfeaNode instead.

This information contains the next-hop router address and the interface toward that router, the routing metric and the metric preference.

Currently (December 2002) the MRIB information is obtained by periodically reading the underlying unicast forwarding table, but in the future the MRIB should be obtained by the interested parties directly from the RIB module instead of MFEA; the MFEA itself should be used only as a backup solution, and only if explicitly enabled for that purpose.

2.6 UnixComm Description

UnixComm is a per-protocol UNIX-specific unit for communication with the underlying system (the only exception is the very first unit, which is called UnixComm0 and is described in Section 2.7).

UnixComm implements UNIX-specific methods for calling the appropriate system calls to open or close a socket per protocol, to send or receive protocol message, join or leave a multicast group (per protocol per interface), etc. Typically, there is a single UnixComm entry per protocol; *e.g.*, one UnixComm for PIM, another one for IGMP (or MLD in case of IPv6), etc. When a protocol module registers a network protocol with MFEA, the corresponding UnixComm for that protocol is created (if it did not exist).

Each UnixComm entry is also used to keep information about various protocol preferences: *e.g.*, if a protocol module instance is interested in receiving various kernel upcall signals, MRIB information, etc. [6]

2.7 UnixComm0 Description

UnixComm0 is a special protocol-independent UnixComm unit used for communication with the underlying system. For example, UnixComm0 is used for the following purpose (this list may not be complete). In other words, UnixComm0 is used for all purposes that do not require protocol-specific socket:

- Start/stop the multicast forwarding engine.
- Add/delete a multicast-capable interface with the underlying system.
- Add/delete a MFC entry with the multicast forwarding engine.
- Install dataflow monitors (if the underlying system supports it).
- Read bandwidth forwarding statistics per dataflow.
- Read information about the available network interfaces in the system, and reports any changes about it (the latter not implemented yet).
- Read the underlying unicast forwarding table, and reports any changes about it.
- Send/receive protocol-specific packets (e.g., PIM or IGMP) to be sent/received to/from network interfaces.

UnixComm0 is started when MfeaNode is started, and usually stops operation when MfeaNode is stopped.

[6]From design point of view, this information should not be kept in the system-specifi c UnixComm entry, but in some system-independent entry. For simplicity, for now this state is kept in UnixComm; in the future (after December 2002), UnixComm may contain only the system-specifi c information and methods.

A Modification History

- December 11, 2002: Version 0.1 completed.

References

[1] The Click Modular Router Project. http://www.pdos.lcs.mit.edu/click/.

[2] XORP Multicast Routing Design Architecture. XORP technical document. http://www.xorp.org/.