MOOSE: Addressing the Scalability of Ethernet

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Underlying problem: the MAC address namespace is unstructured
(as far as switches are concerned: a MAC address gives no hint as to its location)

The solution: MOOSE

Multi-level Origin-Organised Scalable Ethernet

• Modified switch performs address rewriting on ingress
• Introduce two (or more) level hierarchy to MAC addresses:
  \[ \text{ss:ss:ss:nn:nn:nn} \]
  \[ \text{switch ID} \quad \text{node ID} \]

Switch ID identifies the node’s local switch
  • Configured by administrator, or negotiated automatically
  • This may itself be hierarchical
Node ID is allocated by the local switch
  • New source address remains in frame when passed to destination

On large networks, broadcast can overwhelm slower links e.g. wireless

Inefficient routing:

- Spanning Tree
- Shortest path disabled!

Heavy use of broadcast

Broadcast ARP required for interaction with IP

Ethernet

Continues to be used for new network deployments
  • Simple, easy to implement, ubiquitous hardware
  • Layer-2; support multiple layer-3 (IP) networks over single common infrastructure
  • Convenient “lowest common denominator” protocol
But scalability issues are becoming increasingly significant

Previous solutions

(and why they don’t solve all the problems)

Most proposed solutions have so far relied on encapsulation of the Ethernet frame. This does not improve scalability.

Multiprotocol Label Switching (MPLS): [1]
  • Becoming popular throughout both the Internet and private LANs
  • Label Edge Router must convert frames’ destinations into a label ID
    Equivalent to Ethernet’s address table problem

Ethernet-in-Ethernet encapsulation: [2]
  • Edge switch must convert frames’ destinations into another MAC address
    Again equivalent to Ethernet’s address table problem

Broadcastless Ethernet: [3]
  • Fundamental redesign of the protocol
  • Perhaps a good idea, but it is incompatible with existing Ethernet devices
  • (Also, the link-state protocol must again track every MAC address)

The important difference:

• MOOSE leaves the hierarchical address as the frame’s source when delivering it to its destination
• Hosts only ever see other hosts’ hierarchical addresses: therefore no destination address rewriting is ever needed
• Subverts computers’ ARP tables to look up hierarchical addresses!

Security and isolation

• Source addresses rewritten ⇒ source spoofing ineffective
• Duplicate MAC addresses don’t matter

Minimisation of broadcast traffic

• No longer need any broadcast for node location
• Could use a distributed directory service on the switches for ARP
• Or could make the IP addressing hierarchy correspond to the MAC address hierarchy and dispense with ARP entirely

Hierarchical MAC addresses and their many benefits

Address tables

• Not only do we reduce the table size to 1-5%
• But we crucially also make it deterministic

Best-path routing and resilience

• Switches can participate in a routing protocol
• Many benefits
• This can now route prefixes, rather than individual addresses

http://www.cl.cam.ac.uk/~mas90/MOOSE/
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Poster abstract

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Ethernet, despite being an old protocol, continues to be used for new network deployments both in the core and at the edges of the Internet. It is desirable due to its simplicity, its ability to support multiple independent higher-layer (e.g. IP) networks over a single infrastructure, and its compatibility with the vast majority of currently-available products. Ethernet is a convenient “lowest common denominator” protocol.

However, it is well-known that Ethernet suffers from a few severe scalability problems. For example:

- It constrains packets to a spanning tree, by completely disabling links not on that tree. Shortest-path routing would make much better use of available resources.
- It makes heavy use of broadcast, for example when handling packets destined for unknown addresses and for higher-layer address resolution (ARP). Clearly the quantity of broadcast traffic increases with the number of systems connected to the network, and on large networks the broadcast traffic may even exceed the capacity of individual edge links.
- Each switch on a network must learn and store the location of every MAC address in use on the network, as a system’s MAC addresses give no hint as to its location.

Previous attempts to solve the problem have generally relied on encapsulation of Ethernet frames within another protocol — MPLS, for example — but as I illustrate they do not completely address the issue or have unwanted side-effects.

In this poster I present our work to help to eradicate these problems from Ethernet. Our extension to Ethernet, MOOSE (Multi-level Origin-Organised Scalable Ethernet), is a modified switch which performs in-place rewriting of the source MAC address in Ethernet frames entering the network. The replacement MAC address is hierarchical, which means that switches are no longer required to maintain an address database for the entire network. Furthermore this also permits easier implementation of shortest-path routing.

MOOSE has several desirable properties when compared with MPLS-based or similar solutions. In particular, rewriting of destination addresses is not necessary: as the hierarchical source address remains in the packet when it reaches the destination end system, hierarchical addresses make their way into that system’s ARP table and replies will be sent to the relevant hierarchical address directly. As a result, no lookup service to convert MAC addresses to hierarchical addresses is required; the requirement for such a lookup service is the downfall of several previous solutions. Hence, MOOSE is less prone to increasing broadcast traffic than alternative solutions.

This work forms part of the Intelligent Airport (TINA) project.1

1http://intelligentairport.org.uk/