Routed End-to-End Ethernet Network
Proof of Concept

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Agenda

- Introduction
- Ethernet and IEEE 802.1 (layer 2)
- IPv4 and IPv6 (layer 3)
- RE2EE
- Proof of Concept
- Results
- Conclusions
Introduction

- Problems in the contemporary Internet
  - IPv4 address space is running out of addresses
  - Routing tables are getting oversized
- IPv6 has been implemented, but deployment is not progressing
- Something needs to be done!
Ethernet

- Ethernet has a large address space with its MAC addresses
  - Not expected to be exhausted sooner than the year 2100
  - EUI-48 (MAC) could be even enlarged with EUI-64
- Ethernet is widely used and low-cost to implement
- Does not have hierarchy in addresses -> no efficient routing -> does not scale well
IEEE 802.1 (1/2)

- There are many standards and drafts to enhance the scalability of Ethernet networks

- 802.1Q - Virtual LANs
  - Q-tag adds 2nd tier to network’s hierarchy
  - Inter-VLAN communication needed to be done using layer 3 routers

- 802.1ad - Provider Bridges
  - Q-in-Q added support for three-tiered hierarchy
  - Still supports only 4094 customer VLANs for ISPs
802.1ah - Provider Backbone Bridges

- MAC-in-MAC separates Ethernet network into customer and provider domains with complete isolation among their MAC addresses
- It encapsulates the customer MAC header with a service provider MAC header
- Supports a theoretical maximum of 16 million service instances
- Still a draft and the newest version is 4.0
Development of Ethernet headers

- **SA** = Source MAC address
- **DA** = Destination MAC address
- **VID** = VLAN ID
- **C-VID** = Customer VID
- **S-VID** = Service VID
- **I-SID** = Service ID
- **B-VID** = Backbone VID
- **B-DA** = Backbone DA
- **B-SA** = Backbone SA

**802.1**: Virtual LANs
Q-tag identifies VLAN

**802.1q**: Provider Bridges
Q-tag identifies customer

**802.1ad**: Provider Backbone Bridges
Customer frame is transparently tunneled from UNI to UNI
IPv4 and IPv6

- IPv4 became the main protocol for Internet because of the hierarchical addresses, which allowed efficient routing.
- Now IPv4 address space is running out of addresses.
- Network Address Translation has been postponing the problem, but at the same time causing other problems.
- IPv6 enlarges the address space.
- IPv6 has been implemented, but deployment is not progressing.
Routed End-to-End Ethernet

- The main idea is to use Ethernet instead of IP
- MAC addresses and NSAP addresses as network locators for hosts and servers
- Moving from layer 3 to layer 2 means that the technology must have routing capability
- Routing needs hierarchy in the addresses -> NSAP
- IS-IS could be the routing protocol for RE2EE
Network Structure in RE2EE

- **Network Core**
  - RE2EE network can have many network cores

- **Service Core**
  - Provides VPNs and Public Service Networks each in their own overlay
  - Supports parallel networks such as Internet, packet TV network, P2P network

- **Mobility Layer**

- **User Identity Layer**
  - Network Service Access Point (NSAP) addresses are used in the Provider side and MAC addresses are used in the user side
Service VLANs

- Internet
- P2P
- PSTN
- TV
Proof of Concept

- Proof of Concept does not implement all the features from the RE2EE concept
- Network is built on two PCs running Debian GNU/Linux
- Programming is done with Python
- Scapy is used for creating the Ethernet packets and sending/receiving them in the network
- Registry databases are created with MySQL
Network Diagram

4 hosts, 3 PE (Provider Edge) nodes and 1 Provider
RE2EE Network Elements

- Host
- PE node
  - Registry database
    - REGISTRY and PROVIDERS tables
  - Resolver
  - Forwarder
- Provider
  - Registry database
    - PROVIDERS table
  - Resolver
  - Forwarder
PoC Functionalities

- Home PE discovery by a host
- Host registering to Home PE
- Host sending data to other host
- Host receiving data from other host
- Inactivation of a host
Home PE discovery by a host

Host A

find_PE("identity_of_service")
dst_MAC="ff:ff:ff:ff:ff:ff"
src_MAC="host_A_MAC"

PE A

response("result")
dst_MAC="host_A_MAC"
src_MAC="PE_A_MAC"
Host registering to Home PE

Host A

register("identity_of_host_A")
dst_MAC="PE_A_MAC"
src_MAC="host_A_MAC"

PE A

response("result")
dst_MAC="host_A_MAC"
src_MAC="PE_A_MAC"
Host A sending a message to Host B under the same home PE node
Host A sending a message to Host C via PE A and PE B

1. send_packet("message","identity_of_host_C")
   dst_MAC="PE_A_MAC"
   src_MAC="host_A_MAC"

2. encapsulate"
   dst_MAC="host_C_MAC"
   src_MAC="PE_A_MAC"
   payload="identity_of_host_A"

3. decapsulate and forward"
   dst_MAC="host_C_MAC"
   src_MAC="PE_B_MAC"
   payload="identity_of_host_A"
1. \texttt{send\_packet("message","identity\_of\_host\_D")}
   \texttt{dst\_MAC="PE\_A\_MAC"}
   \texttt{src\_MAC="host\_A\_MAC"}

2. \texttt{encapsulate("")}
   \texttt{dst\_MAC="host\_D\_MAC"}
   \texttt{src\_MAC="PE\_C\_MAC"}
   \texttt{payload="identity\_of\_host\_A"}

3. \texttt{forward("")}
   \texttt{dst\_MAC="PE\_C\_MAC"}
   \texttt{src\_MAC="Provider\_MAC"}
   \texttt{dst\_MAC="host\_D\_MAC"}
   \texttt{src\_MAC="PE\_C\_MAC"}
   \texttt{payload="identity\_of\_host\_A"}

4. \texttt{decapsulate\ and\ forward("")}
   \texttt{dst\_MAC="host\_D\_MAC"}
   \texttt{src\_MAC="PE\_C\_MAC"}
   \texttt{payload="identity\_of\_host\_A"}

Host A sending a message to Host D via PE A, Provider and PE C
There is a need for a new protocol in Internet for transmitting packets.

It needs to have the following features:

- Large address space
- Routing
- Scalability
- Security
Address Space sizes

The graph shows the address space sizes for different network technologies. The x-axis represents the technology types, and the y-axis represents the address space size in units of 10^x. The technologies include IPv4, IPv4 + NAT, IPv6, Ethernet, RE2EE (EUI-48), and RE2EE (EUI-64). The graph illustrates the varying address space sizes across these technologies.
Routing

- Addresses need to have global hierarchy
- Ethernet has only Spanning Tree Protocol for routing -> need for better routing protocol like IS-IS

Scalability

- One Routed Ethernet Provider Edge device can serve a minimum of 50 000 users
- There are about 1 billion Internet users all around the world
- Less than 20 000 devices are needed to serve 1 billion users
Results from the PoC

- PoC showed that it is possible to build a RE2EE network with small modifications
- No IP addresses were used
- Ethernet with registry database is enough for forwarding the traffic
- Using only identities for communicating hides the network from the hosts
Conclusions

- Routed End-to-End Ethernet would provide a long lasting solution to the problems, which we are having at the moment in the Internet.
- RE2EE solution provides large enough address space, hierarchy, routing, security and scalability.
- It is possible to use the same hosts in RE2EE network as in IP network.
Future Research

- Make RE2EE network to work with IP networks
- Exact form of NSAP address
- Implement IS-IS routing
- Service discovery for different services
- Mobility management
Questions?