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Improving the Performance of Metro Ethernet Network

A Thesis
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Abstract

Ethernet has traditionally been the dominant technology in enterprise Local Area Networks (LAN) and is today the standard for communication between clients and servers in enterprise networks. Over time, Ethernet technology has evolved in response to the changing requirements of such networks. Ethernet switches have proved to be an excellent tool for scaling up Ethernet enterprise networks.

Ethernet is today preparing to enter the Metropolitan Area Network (MAN). Extending Ethernet to the MAN offers new opportunities for network operators. In particular, it promises relatively inexpensive high speed access, which can then be combined with new networking services from the enterprise domain.

A Metro Ethernet Network is generally defined as the network that connects geographically separated enterprise LANs while also connecting across the core networks that are generally owned by service providers. The Metro Ethernet Networks provide connectivity services across Metro geography utilizing Ethernet as the core protocol and enabling broadband applications.

Many of the applications and services used in Metro Ethernet Networks rely on multicasting and since Ethernet switches treat broadcast and multicast addresses as unknown destinations and flood these frames over all ports of the switch within the network segment, a problem arises as this will consume the bandwidth of the network creating a bottleneck. This may be acceptable in LANs but when dealing with carrier Ethernet this will not be accepted.

This thesis proposes two solutions either of them when deployed in Ethernet switches with the IGMP Snooping technique enables the Ethernet switches to deal with multicast frames through Layer 2 processing without flooding the frames or sending them to uninterested network segments.

The first Solution uses the Ethertype field of the Ethernet frame while solution two relies on using the source address field in order to enable the Ethernet switches to build a multicast MAC address table with unique addressing instead of using the recent way that results in overlapping addresses.

Opnet Modeler simulator is used to evaluate the performance of the Metro Ethernet Network while using the two proposed solutions relative to the traditional two solutions that relied on the forwarding of the frames depending on the destination IP address or the destination MAC address.

The evaluation showed a significant enhancement in the performance of the network when using the proposed solutions especially in the end-to-end delay and link utilization.

This thesis is organized as follows; Chapter 1 presents the statement of the problem the thesis discuses showing the recent ways used to deal with this problem and why it is not so effective. Chapter 2 will present the Ethernet and metro Ethernet technologies, their main features and the main services offered by the Metro Ethernet Network. Chapter 3 focuses on the challenges that face deploying metro Ethernet networks concentrating on the multicast problem in the Ethernet environment and presenting two solutions that can enhance the multicast forwarding of Ethernet frames in the Metro Ethernet Network. Chapter 4 explains the simulation model used to evaluate the proposed solutions. Chapter 5 presents the simulation model results and their analysis. And finally Chapter 6 concludes the results followed by suggestions for future work related to this thesis.

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List of Acronyms

Acronym	Name
APS	Automatic Protection Switching
ATM	Asynchronous Transmission Mode
BER	Bit Error Rate
BPDU	Bridge Protocol Data Unit
CAM	Content Addressable Memory
CE	Customer Equipment
CIR	Committed Information Rate
CoS	Class of Service
CPE	Customer Premises Equipment
CPU	Central Processing Unit
CRC	Cyclic Redundancy Check
DVMRP	Distance Vector Multicast Routing Protocol
EFM	Ethernet in the First Mile
ELS	Ethernet Line Service
EVC	Ethernet Virtual Connection
FCS	Frame Check Sequence
IANA	Internet Assigned Numbers Authority
IEEE	Institute of Electrical and Electronic Engineering
IGP	Interior Gateway Protocol
IGMP	Internet Group Management Protocol
IGRP	Internet Gateway Routing Protocol
IP	Internet Protocol
IS-IS	Intermediate System - Intermediate System
LAN	Local Area Network
LLC	Logical Link Control
LLDP	Link Layer Discovery Protocol
LSP	Label Switched Path
MAC	Media Access Control
MAN	Metropolitan Area Network
MBS	Maximum Burst Size
MEF	Metro Ethernet Forum
MEN	Metro Ethernet Network
MP2MP	Multi-Point to Multi-Point
MPLS	Multi Protocol Label Switching
NIC	Network Interface Card

OAM	Operation Administration and Maintenance
OSI	Open System Interconnect
OSPF	Open Shortest Path First
OUI	Organizational Unit Identifier
P2P	Point to Point
P2MP	Point to Multi-Point
PDU	Protocol Data Unit
PIM	Protocol Independent Multicast
PIR	Peak Information Rate
PVC	Permanent Virtual Circuit
QoS	Quality of Service
RIP	Routing Information Protocol
RSTP	Rapid Spanning Tree Protocol
SFD	Start Frame Delimiter
SLA	Service Level Agreement
STP	Spanning Tree Protocol
TE	Traffic Engineering
TDM	Time Division Multiplexing
UNI	User Network Interface
UTP	Unshielded Twisted Pair
VLAN	Virtual Local Area Network
VoIP	Voice over Internet Protocol
VoD	Video on Demand
VPN	Virtual Private Network
WAN	Wide Area Network

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Chapter 1

Introduction

Internet Protocol (IP) and Ethernet are becoming ubiquitous, IP packets make up the majority of traffic carried over the world's communication networks and more often this traffic is presented to the network in Ethernet frames. In short, Ethernet is increasingly becoming the bearer technology of converging networks. In the last three decades, it has become the most widely used Local Area Networks (LAN) technology because of its speed, low cost, and relative ease of installation. This is combined with wide computer-market acceptance and the ability to support the majority of network protocols. Throughout its thirty-year history, Ethernet has shown an extraordinary capacity to adapt and grow.

On the other hand public networks are evolving into what is termed Full Service Broadband, which carries a steadily widening range of rich multimedia services to fixed and mobile devices over a common network with carrier-class characteristics, such as scalability, robustness, and resilience.

Current developments of Ethernet as a public network transport technology include the definition of standardized services to be provided by an Ethernet-based public network; flexibility, to enable scaling a network to a global size while supporting many concurrent service networks; comprehensive Operation, Administration and Maintenance (OAM) mechanisms for monitoring service quality and Service Level Agreements (SLA), and for detecting and locating faults and misconfigurations and the creation of a highly scalable transport control plane solution that facilitates rapid restoration of service and supports automated provisioning.

Despite this, Ethernet deployment still has weaknesses in the context of large-scale public networks. Standard Ethernet lacks key public network

features, in particular for operation, administration and maintenance, isolating customers, scalability and dealing with multicast traffic [1].

Overcoming the above challenges enables the deployment of Ethernet in public networks and over large scale allowing for a wide range of services to be carried over the same infrastructure.

1.1 Problem Statement

Metro Ethernet Networks (MEN) are rapidly becoming the networks of choice for aggregation of user traffic toward the core as service providers attempt to reduce operational and capital expenditures and increase revenues derived from their network infrastructures. Metro Ethernet Networks allow a wide variety of services to be carried over its infrastructure such as Voice over IP (VoIP) which requires minimum bandwidth but has strict limits on delay and jitter, video conferencing which needs high bandwidth, and very low delay and jitter, live video broadcast that needs high bandwidth and low delay and jitter, Video on Demand (VoD) which requires high bandwidth and less stringent delay and jitter requirements as video streams can be buffered, Interactive gaming which consumes low bandwidth but has strict bounds on delay and high-speed data services that requires just bandwidth guarantees and less stringent delay requirements [2].

Most of the above mentioned services need large bandwidth and low delay. Also these services rely on multicasting for efficient delivery of this kind of traffic. Ethernet switches firstly treated broadcast and multicast addresses as unknown destinations and flooded these frames over all ports of the switch within the network segment consuming its bandwidth [3].

An enhancement to this operation was introduced by snooping on the requests for multicasting to prevent the flooding of the multicast frames. But for this technique to be effective, a one to one mapping between the destination multicast IP address and the destination multicast Media Access Control (MAC) address should be available. A case that is not present as the mapping between these two addresses is not unique but in

fact there is thirty two multicast IPv4 addresses that map to the same MAC address [4]. This overlapping issue prevents the correct delivery of multicast frames to the intended Ethernet segments through the Ethernet switches. This problem needs to find a solution.

1.2 Related Work

IPv4 addresses are thirty two bits addresses which are classified into five different classes A, B, C, D and E. IPv4 multicasting uses class D addresses which is in the range of 224.0.0.0 to 239.255.255.255.

Most suggestions for the address overlapping problems rely on selecting multicast addresses so that different applications don't map their multicast streams into the same layer 2 MAC address as stated in section two in [5].

The first scheme depends on using globally unique low order 16 bits from the 32 bits of the class D IP address. By assuring that the last 16 bits of any class D address are unique, each class D address must map to a unique MAC address. In this scheme, addresses should be used from a pool based on the last 16 bits. That pool should exclude all addresses ending with the range 0.0 through 16.255 as many of those addresses are reserved for specific networks. That provides tens of thousands of possible address groups for use. In this scheme, the high order 16 bits can be any value from 224.0 through 239.255 as long as no two complete class D addresses share the same last two digits. So this scheme allows the use of any first two digits in the class D addresses as long as no two addresses share the same last two digits.

The drawback of this scheme is that the addresses may be difficult to track as the available ones cover a wide range of complete addresses.

The second scheme suggests the use of the 239.128.X.X through 239.255.X.X class D IP range. Once the range is decided, IP class D addresses should be assigned sequentially so that no two complete addresses within the range are the same. By following this process over 8 million unique class D multicast addresses will be available with each address mapping to a globally unique MAC layer multicast address.