Multicast Routing Debugger (MRD) - A System to Monitor the Status of Multicast Network

Jaeyoung LEE, Heonkyu PARK, Woohyung CHOI, and Kilnam CHON

Abstract-- **IP Multicast can efficiently provide enormous bandwidth savings by enabling sources to send a single copy of a message to multiple recipients who explicitly want to receive the information. But due to the complexity of IP multicast and its fundamental differences from unicast, there are not very many tools available for monitoring and debugging multicast networks, and only a few experts understand the tools that do exist. This paper proposes a Multicast Routing Debugger (MRD) system that monitors the status of a multicast network. This system is aimed to multicast-related faults detection. In this paper, first, we define the set of information that should be monitored. Second, the method is developed to take out such information from multicast routers. Third, MRD system is prototyped to collect, process information from heterogeneous routers on a multicast network and to display the various status of the network comprehensively. The prototype of MRD system is implemented and deployed. We perform experiments with several scenarios. Experimental results show we can detect various problems as information that we define is monitored. The MRD system is simple to use, web-based and intuitive tool that can monitor the status of a specific multicast network.**

Index Terms— **multicast, network monitoring, network measurement**

I. INTRODUCTION

The exponential growth of the Internet combined with multimedia content is increasing the average size of the data transfers and pushing bandwidth constraints to their limits. IP Multicast efficiently can provide enormous bandwidth savings by enabling sources to send a single copy of a message to multiple recipients who explicitly want to receive the information. Unfortunately multicasting has been slow to catch on, except for the research-oriented Multicast Backbone [1], [2]. There are a variety of reasons for the difficulties in widespread multicast deployment [12]. One of largest current barriers is the difficulty in managing multicast traffic [13]. Due to the complexity of IP multicast and its fundamental differences from unicast, there are not many tools available to assist in monitoring the various status such as member-subnets,

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connectivity, statistics and forwarding state in a multicast network in order to diagnose above problems.

In order to know the status of a multicast network, several multicast routers on the network need to be involved in monitoring as an organized set for management. Currently, most of multicast routers are Cisco's router but many mrouteds[13] (software router implementing Distance-Vector Multicast Routing Protocol (DVMRP) [14]) are available on the research-oriented organizations and schools in the world. We need the management system to collect and process information from heterogeneous multicast routers in order to display the status of the multicast network. The mrouted does not support any tools to provide information needed in monitoring the multicast status, while Cisco's router supports some commands of Internetwork Operating System [15] (IOS) release. So the mrouted needs the new functionality which can provide its status information.

In this paper, Multicast Routing Debugger (MRD) system is introduced. The primary goal was to create a simple to use, web-based and intuitive tool that can monitor the status of a specific multicast network. The system would be able to collect information from heterogeneous multicast routers and process it online to give a current snapshot of the multicast network. The MRD system was implemented and deployed in the Asia-Pacific Advanced Network-Korea (APAN-KR)[3] research network.

II. RELATED WORK

A. SNMP-based tool

SNMP-based (Simple Network Management Protocol) tools provide the information to be queried to SNMP-enabled router and visualize it. This information should be defined in Management Information Bases (MIBs) of the router. Mstat[9] allows an SNMP-enabled router to be queried for information, including routing tables and packet statistics. Mtree[10] attempts to use cascading SNMP-enabled router queries to determine an entire multicast tree rooted at a given router. The resulting tree is returned in textual format.

Mview[11] is a tool for visualization Mbone topology and monitoring and collecting performance information. Mview relies on other utilities like Mrinfo [14], mtrace [14], mstat [9] and mtree [10]. The building of the topology requires a user to click on a node and specify one or more information finding actions. Due to the large number of options and tools provided,

mview requires a reasonable degree of network knowledge to operate.

SNMP-based multicast tools have limited value outside a particular administrative domain, because most multicast routers are not configured to respond to public SNMP queries. As a result, mstat, mtree, and mview are only useful for debugging and managing the local domain portion of a multicast group. The information obtained by SNMP must be defined as MIBs. Currently MIBs do not have session-related information. The session is a set of multicast groups and plays the important role like the domain name of IP address.

B. Multicast route tracing tool

Mtrace[4] is a tool designed to provide hop-by-hop path information for a specific source and destination. For a specific group, mtrace will tell a user hop-by-hop packet loss, multicast path and round trip information. Given a multicast distribution tree, tracing from a source to a multicast destination is hard, since we do not know down which branch of the multicast tree the destination lies. However, walking up the tree from destination to source is easy, as most existing multicast routing protocols know the previous hop for each source. The party requesting the traceroute (which need be neither the source nor the destination) sends a traceroute Query packet to the last-hop multicast router for the given destination. The last-hop router turns the Query into a Request packet by adding a response data block containing its interface addresses and packet statistics, and then forward the Request packet via unicast to the router that it believes is the proper previous hop for the given source and group. Each hop adds its response data to the end of the Request packet, then unicast forwards it to the previous hop. The first hop router (the router that believes that packets from the source originate on one of its directly connect networks) changes the packet type to indicate a Response packet ad sends the completed response to the response destination address.

The utility of mtrace is often limited by the multicast topology. Where multicast and unicast topologies are not aligned (as is the case in many multicast-enabled networks) mtrace may not function. The mtrace provides hop-by-hop path information between a source and a receiver, so several mtraces are issued in order to know the network status. Since every successful mtrace requires a response from every router along the path from the receiver to the source, the network can be overload.

C. Multicast Reachability Monitor (MRM)

The MRM[5] is a network fault detection and isolation mechanism for administering a multicast routing infrastructure. An MRM based fault monitoring system consists of two types of components: an MRM manager that configures tests, collects and presents fault information, and MRM testers that source or sink test traffic.

The MRM testers can be any routing devices or trusted end hosts. They provide statistics about received data packets, to be used to derive the network routing status. A system (usually a router) originating MRM data packets for testing purposes is also called a Test Source (TS). A configured set of MRM testers receiving the test traffic, and collecting receiver statistics are also called Test Receivers (TRs). An MRM manager initiates configuration requests to the MRM testers and assigns the roles of TSs and TRs. The MRM manager informs the TSs and TRs the types of monitoring or diagnostic tests to run. The MRM manager also specifies the type of reports the TRs should send. The functions of MRM include:

- Fault logging and real-time (passive) monitoring
- Pro-active tests include service provisioning and impact analysis.

After MRM manager initiate the test for existing active session group or test group with Test Source as source, Test Receiver sends packet loss report to MRM manager when its packet loss goes beyond the threshold for fault detection. When the network administrator sees the status reports of Test Receivers collected by MRM manager, he does lots of inference in order to derive what faults happened if he has packet loss information of Test Receivers.

For monitoring the network status, MRM has architecture involved by several routers and hosts. But the packet loss information provided by MRM Test Receivers lacks for more detailed fault detections.

III. MODEL

A. Multicast Observation

Multicast routing can behave abnormally in different ways. We review commonly encountered problems based on [18] and [19]. Session announcement questions are those which relate to the user's session announcement software. Sample complaints include:

- No conferences were visible in the session announcement tool.
- Conference X was not visible in the session announcement tool.
- I can receive conferences listed in SDR (Session DiRectory), but sometimes when I join conferences via a Web site, I cannot receive them.

Traffic reception questions are those where the user has successfully received the session announcement, but was unable to receive one or more media streams for the session joined. Sample complaints include:

- I joined conference X, but nothing happened.
- I joined conference X, got video but no audio.
- I joined conference X, and got intermittent audio.
- I can not see source X, but source X can see me (or vise versa).

No traffic reception happens when there are routing or forwarding problems.

Multicast router problems are divided into two types of

problems. They include:

- Routing problem
  - Topological disconnectivity
- Forwarding problems
  - Blackholes in forwarding path
  - Non-pruning routers

The topological disconnectivity happens when a route for a subnet of the networks is not in the routing table. No multicast packet can get through to certain receivers, even though the network topology is perhaps intact. A possible cause could be disabled multicast forwarding. Another possibility is pruning errors. A router that fails to prune (whether it be a router that does not support pruning or a misconfigured router that sends prunes to the wrong place) causes that router to act as a sink for all multicast traffic.

B. Requirement

The major goal of monitoring the status of multicast network is to detect the problems reviewed at previous section. The specific information is needed in showing the status of the multicast network. We consider the requirements for status information based on above observation and below questions.

1) Session announcement

1. What sessions are announced.
   (session name)
2. What are the members of 224.2.127.254 (sap.mcast.net) directly connected at the specific router.
   (IGMP group, member)
3. Whether the upstream router forwards the packets of (source, sap.mcast.net) to the router connected by above found members or not.
   (specific router, source, incoming interface, RPF neighbor)
   (upstream router, source, group, forwarding interface, next hop)

2) Traffic reception

1. Whether a local host monitoring the specific group joins to the group or not.
   (IGMP group, member)
2. What is the amount of the traffic of (source, relevant group).
   (source, group, packets per second, bytes per second)
3. Whether the upstream router forwards the packets of (source, relevant group) to the router directly connected by above found members or not.
   (specific router, source, incoming interface, RPF neighbor)
   (upstream router, source, group, forwarding interface)

3) Multicast router

1. How many times does a router fail to find the Reverse Path First(RPF) neighbor in its routing table.
   (RPF failed)
2. What are the (source, group) pairs which are forwarded by the specific router.
   (source, group, forwarding interface, next hop)
3. Whether local hosts join to the above found groups or not.
   (IGMP group, member)
4. Whether the downstream router forwards the packets of (source, relevant group) to neighbor routers or not.

TABLE I
REQUIREMENT INFORMATION FOR MULTICAST NETWORK STATUS

Problem	Required information
Session Announcement	Session information IGMP Group information Routing, Forwarding information
Traffic Reception	Statistics IGMP Group information Routing, Forwarding information
Multicast Router	RPF failure Routing, Forwarding information

TABLE II
ATTRIBUTES FOR REQUIREMENT INFORMATION

Required information	Attributes
Routing information	source, incoming interface, RPF neighbor
Forwarding information	source, group, forwarding interface
Session information	session, source, groups
IGMP Group information	group, member
Statistics	packets per second, bit per second

(specific router, source, group, forwarding interface, next hop)

(downstream router, source, group, forwarding interface)

Table I and Table II summarize the requirement of the information for multicast network status.

C. Basic Components

The structure of the Internet can be decomposed into four levels. First, the hosts of the users are connected to a Subnetwork such as Ethernet or Token ring. The designated router is connected to other routers, forming domains such as campus networks, which is the second or Local Network level. A Local Network is connected to the nearest Regional Network such as Access Point (AP) or GigaPop for more efficient interconnection between Local Networks. We consider Local Networks and Regional Networks as domains. Because Local Networks and Regional Networks provide high-speed networking, multicast traffic can move within each domain fast enough so that the information such as Domain Wide Multicast Group membership Multicast [17] can reflect the status of each domain in time. Finally, a Regional Network is interconnected with each other by national or international backbone networks forming the Connectivity Cloud. The backbones are high-speed switched networks designed to support traffic between Regional Networks.

Figure 1 illustrates overview of the proposed MRD system. A multicast router obtains the routes information from its neighbor routers using the routing protocol and updates its
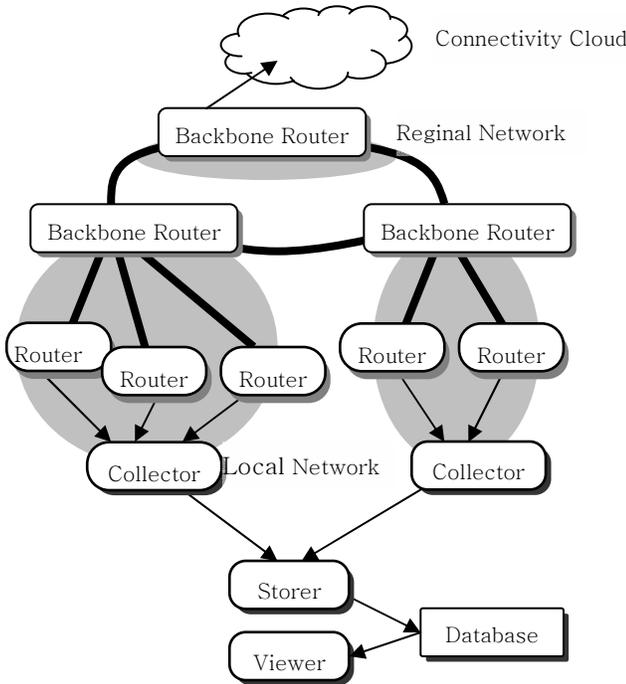
Fig. 1. MRD System Overview

Fig. 2. MRD Basic Components
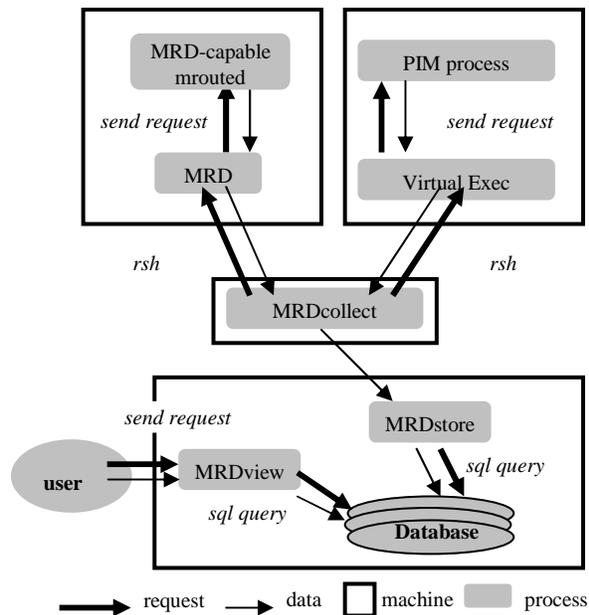
Fig. 3. MRD Process Architecture

routing table.   And it obtains the group membership information from its local hosts using IGMP or from neighbor routers by join / prune messages. It locates in a regional network, local network or subnetwork i.e., in all levels of networks. A collector gathers the multicast status information from one or more routers and locates in one domain for reflecting the status of each domain in time. A storer stores the status information gathering from one or more collector in a database and locates in one or more regional networks. A viewer retrieves the status information from the database system stored by the storer and displays it to users.

The system, as shown in Figure 2, is divided into four components based on functionality. We describe four parts in more detail:

1. Status report module accepts request and provides the status information obtained from a routing table and a forwarding table.

2. Collect module does a request for the status report to one or more routers and gathers data from them.

3. Store module stores the status information collected by one or more collectors in a database.

4. View module displays the multicast status based on the contents of the database on demand.

IV. DESIGN AND IMPLEMENTATION

A. System Overview

MRD system consists of five programs, which are four programs prototyped from four basic modules of model and an additional status request program. Figure 3 illustrates the

process architecture of our system.

The MRD-capable mrouted program is responsible for multicast routing and status report method. To support status report method, we modified mrouted source files, whose version is 3.9 beta 3.

The MRD program is responsible for doing request to MRD-capable mrouted program and making it available to users on the local host and remote host. Its functionalities are similar to Cisco's IP Multicast Routing commands.

Now MRD-capable mrouted and MRD support five commands to users. :

- show ip mroute
- show ip mroute active
- show ip mroute count
- show ip mroute summary
- show ip igmp groups

The MRDcollect program is responsible for collecting data from MRD-capable mrouteds by executing MRD program and from Cisco's router by executing Cisco's IP Multicast Routing commands. The MRDcollect is executed every 5 minutes. For reflecting the status of multicast network in time, it locates in one domain.

The MRDstore program is responsible for storing data collected by MRDcollect program in the database system. We use mSQL (Mini SQL) whose version is 2.0.11 made by Hughes Technologies [6] to make and query a database.

The MRDview program is responsible for displaying the status of multicast network based on sql query of the database system.

The MRDview is actually the set of Lite[6] scripts on W3-mSQL[6] in order to display the result of mSQL query on Web pages.

The MRDview consists of three Lite scripts, session.msql, reception.msql and forwarding.msql. The status which they display is as follows:

- Session Announcement Status
- Multicast Traffic Reception Status
- Multicast Forwarding Status

B. MRD-capable mrouted and MRD

A mrouted is a popular and public domain program that provides a platform for implementing one of multicast routing protocols, Distance-Vector Multicast Routing Protocol (DVMRP) on hosts running the Unix operating system.

All mrouted processing is done within a single Unix process and DVMRP and IGMP are implemented as several tasks. A MRD program as a client has a Unix domain stream client-server architecture for interprocess communication with a MRD-capable mrouted. The MRD-capable mrouted is a modified mrouted to support status report module as a single task, associated with a single Unix domain stream socket whose descriptor is added to the set of descriptors.

The mrouted maintains a single routing table that contains routes discovered by DVMRP, two forwarding table (one locates in the memory and other does in the host's kernel). If the packet with a new (source, group) pair arrives at the kernel, it upcalls to the mrouted process. After the mrouted updates the forwarding table, it invokes a function adding a new entry to the kernel forwarding table. The routing table carries multicast routing topology information to decide upon the RPF (Reverse Path First) neighbor in dense mode routing protocol

TABLE III
MRD DATABASE SCHEMA

Table Name	Attributes
Routing	[†] **Router**, **Source**, InVif_Name, InVif_Type, InVif_RemoteAddr, RPF_Nbr
Forwarding	**Router**, **Source**, **Group**, Pruned, ForwVif_Name, ForwVif_Type, ForwVif_RemoteAddr, State
IGMP_ Group	**Router**, **Group**, **If**, Member
Statistics	**Router**, **Source**, **Group**, pps, bps, Pkts, Bytes, RPFfailed
SDR	**Router**, **Session**, **Source**, Media, Group, TTL

[†] Bold character is for Primary Key set of the attributes.

or the location of RP (Rendezvous Point) in sparse mode routing protocol, and it does not consider the group membership. The forwarding table is built based on a combination of the topology information contained in the routing table, active groups, and group membership information reported by join or leave messages.

C. MRDcollect

A MRDcollect gathers the status information from routers periodically. (in our case, 5 minutes) It issues a remote shell (rsh) command in order to execute an IP multicast routing command of Cisco router or a MRD program remotely. The rsh copies its standard input to the remote command, the standard output of the remote command to its standard output.

The MRDcollect gathers the results of *show ip mroute, show ip mroute count, show ip igmp groups* commands from Cisco's router and MRD-capable routers using rsh. In Cisco's router, MRDcollect also executes *show ip sd detail*. The MRDcollect executed every 5 minutes by using crond.

D. MRDstore

A MRDstore stores the status information collected by one or more MRDcollects in a database. The MRDstore has a TCP client-server architecture and is a concurrent server which calls fork to spawn a child to handle each client. This allows the server to handle numerous clients at the same time, one client per process.

The MRDstore stores data gathered by collector in a database by using mSQL (Mini SQL) whose version is 2.0.11 made by Hughes Technologies [6]. The mSQL is originally commercial but free of charge to Universities and schools.

We used msql binary commands in order to create database and Mini SQL 2.0 C Programming API in order to create tables, insert data and select data in the database.

The MRDstore reads stream sent by MRDcollect from TCP socket, parses them and store in a database. It is a relational database and Table III shows its schema.

A Routing Table and a Forwarding Table are the parts of the routing table and the forwarding table of a multicast router and have the important and minimal information as attributes. A IGMPGroup Table has the information about a group membership. When a member of the group is present on the directly connected interface of a router, the entry is inserted. A Statistics Table has the statistics information of (source, group) pair on a router. As we discussed earlier, the important statistics of multicast traffic are packets per second (pps), bits per second (bps). In order to calculate pps and bps during the last 5 minutes average in mrouted case, packets and bytes are also attributes of this table. A SDR Table has session information. The multicast session is advertised by an announcement source multicasting to sap.mcast.net (224.2.127.254) and has one or more media groups. The media are audio, video, whiteboard, text and application.

E. MRDview

A MRDview displays the status information on demand. The MRDview consists of the set of sql queries that are made by several scenarios. The MRDview is a web-based so that it is suitable for representing a multicast tree by using hyperlink.

The MRDview is the set of Lite[6] scripts on W3-mSQL [6] in order to display the result of mSQL query on Web pages. Lite is a scripting language designed to be used with mSQL. It is a light-weight scripting language that offers a syntax based on that of C language. MRDview consists of three Lite scripts, session.msql, reception.msql and forwarding.msql.
The status which they display is as follows:

- Session Announcement Status
- Multicast Traffic Reception Status
- Multicast Forwarding Status

F. Assumption

Basic assumptions for the MRD system are as follows:
- The whole network is configured as one or more domains.
- Each router is Cisco's router or MRD-capable mrouted.
- The user who executes MRDcollect can use rsh to all routers.
- The network operator knows the topology of a multicast network.

V. EXPERIMENT AND ANALYSIS

A. Experiment

We perform an experiment to measure the effect of our system. We show MRD usages based on scenarios and the various statistics. Based on our experimental results, we compare the related works with our system.

Our testbed is an Asia-Pacific Advanced Network-Korea (APAN-KR). The APAN-KR is the domestic consortium for research and development of advanced application and services in APAN. We choose Seoul-XP, Seoul-AP, Taejon-AP which are the backbone routers of APAN-KR as monitored
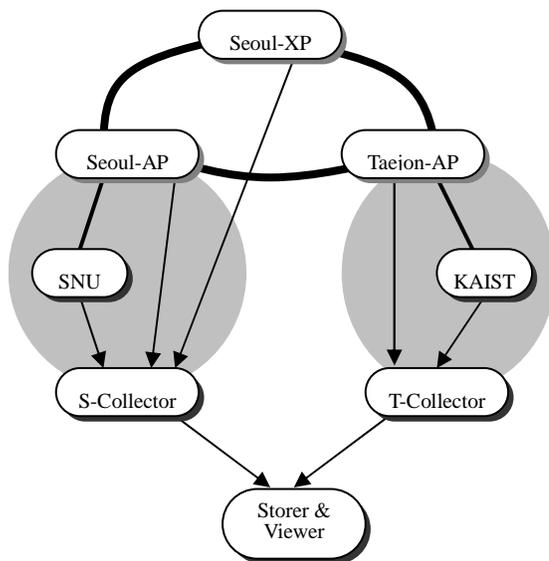

Fig. 4. Testbed for experiments

routers. And the routers of Seoul National University (SNU[7]) and Korea Advanced Institute of Science and Technology (KAIST[8]) are selected since they have the most traffic on APAN-KR. Figure 4 illustrates our testbed.

We divide our testbed into two domains. One is a Seoul region and the other is a Taejon region. As we mentioned earlier, a collector is located in a domain. So two collectors are located on our testbed. One storer and one viewer are located on our testbed.

B. Experimental Results

1) Scenario-based experiments

MRD system is used to detect various multicast-related problems based on various scenarios. These scenarios are as follows:

- "I can not see the IMJ-Channel 1."
- "I have some traffic but ..."
- "Where does traffic flow?"

The first scenario is to detect the session announcement problems. Figure 5 and Figure 6 shows the monitored sessions of Seoul-XP and Seoul-AP at the same snapshot, respectively. As you see, the sessions of Seoul-XP are different from those of Seoul-AP. The circles of Figure 5 point out the invisible sessions of each other. We could detect the problem; the session information was not announced.

The second scenario is to detect the multicast traffic reception problems. We use the example, IMJ-Channel 1 session is not announced at Seoul-AP for detecting this problem. We could find the reason of traffic reception problem. The session information is announced via a multicast group address, sap.mcast.net (224.2.127.254). Figure 7 shows sources sending traffic to sap.mcast.net, their statistics and RPF neighbor at Seoul-AP. We find 128.111.52.10/32 which
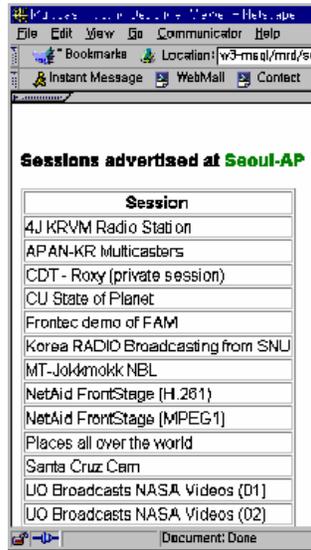
Sessions advertised at Seoul-XP

Session
4J KRVM Radio Station
APAN-KR Multicasters
CDT - Roxy (private session)
CU State of Planet
Frontec demo of FAM
IMJ – Channel 1
IMJ – Channel 2
Korea RADIO Broadcasting from SNU
MT-Jokkmokk NBL
NASA TV - Broadcast from NASA HQ
NetAid FrontStage (H.261)
NetAid FrontStage (MPEG1)
Places all over the world
Places All Over The World at 128K

Fig. 5. Session on Seoul-XP

Sessions advertised at Seoul-AP

Session
4J KRVM Radio Station
APAN-KR Multicasters
CDT - Roxy (private session)
CU State of Planet
Frontec demo of FAM
Korea RADIO Broadcasting from SNU
MT-Jokkmokk NBL
NetAid FrontStage (H.261)
NetAid FrontStage (MPEG1)
Places all over the world
Santa Cruz Cam
UO Broadcasts NASA Videos (01)
UO Broadcasts NASA Videos (02)

Fig. 6. Session on Seoul-AP

Forwarding Interfaces about Incoming Interface ATM1/0.4 (from Tokyo-XP) of Seoul-XP

A member of the group is present on the directly **connected** interface.

Source	Group	pps	kbps	InVif	ForwVif	Next Hop	Member
128.61.2.209/32	224.2.203.37	1	0	ATM1/0.4			
					ATM1/0.8	Taejon-AP	
128.61.2.77/32	234.7.117.3	1	0	ATM1/0.4			
					ATM1/0.8	Taejon-AP	
193.166.1.152/32	224.2.188.149	1	0	ATM1/0.4			
					ATM1/0.6	Seoul-AP	
128.223.83.26/32	224.2.246.13	1	0	ATM1/0.4			
					ATM1/0.6	Seoul-AP	
130.240.112.8/32	224.2.172.238		10	ATM1/0.4			
					ATM1/0.6	Seoul-AP	
					ATM1/0.8	Taejon-AP	

Fig. 8. Forwarding interface from Tokyo-XP of Seoul-XP

Sources and RPF neighbors of Group 224.2.127.254 at Seoul-AP

Route has been **pruned.**

Source	pps	kbps	RPF neighbor
128.59.39.163/32	0	0	Seoul-XP
128.111.52.10/32	0	0	
128.223.83.33/32	0	0	Seoul-XP
128.223.214.23/32	0	0	Seoul-XP
130.240.21.197/32	0	0	Seoul-XP
130.240.64.20/32	0	0	Seoul-XP
131.182.10.250/32	0	0	
147.46.14.34/32	0	0	SNU
147.46.14.35/32	0	0	SNU
147.46.14.39/32	0	0	SNU
147.46.14.44/32	0	0	SNU
158.165.1.26/32	0	0	
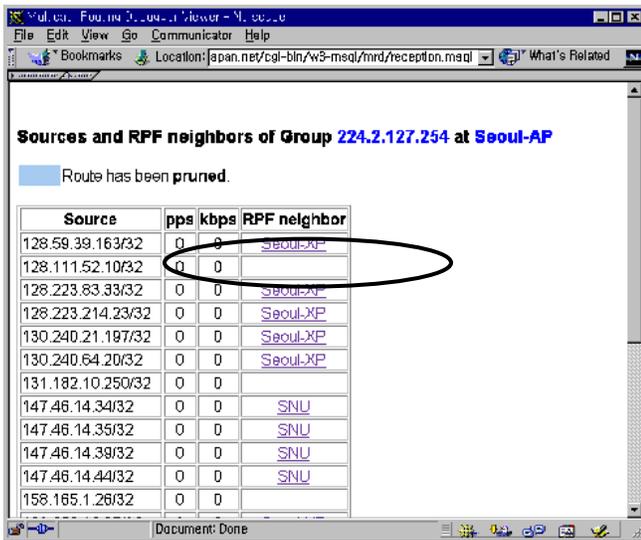
Fig. 7. Source and RPF neighbor of Seoul-AP

Forwarding Interfaces about Incoming Interface ATM1/0.8 (from Seoul-XP) of Taejon-AP

A member of the group is present on the directly **connected** interface.

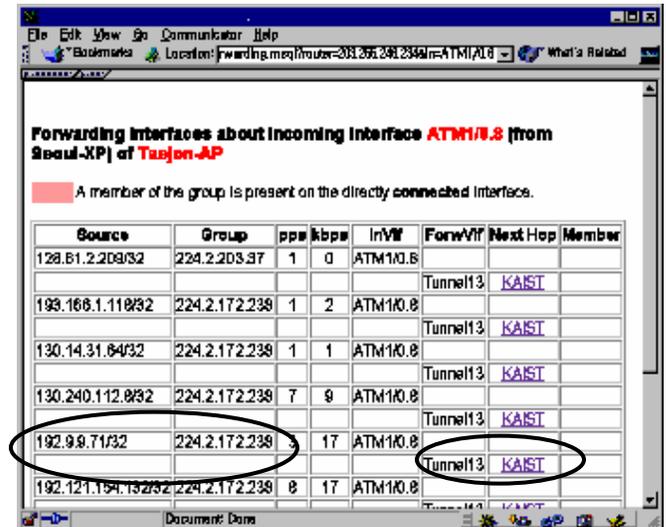| Source	Group	pps	kbps	InVif	ForwVif	Next Hop	Member
128.61.2.209/32	224.2.203.37	1	0	ATM1/0.8			
					Tunnel13	KAIST	
193.166.1.116/32	224.2.172.238	1	2	ATM1/0.8			
					Tunnel13	KAIST	
130.14.31.64/32	224.2.172.238	1	1	ATM1/0.8			
					Tunnel13	KAIST	
130.240.112.8/32	224.2.172.238	7	9	ATM1/0.8			
					Tunnel13	KAIST	
192.9.9.71/32	224.2.172.238		17	ATM1/0.8			
					Tunnel13	KAIST	
192.121.154.132/32	224.2.172.238	8	17	ATM1/0.8			

Fig. 9. Forwarding interface from Seoul-XP of Taejon-AP

is the announced source of IMJ-Channel 1. We notice that its RPF neighbor is blank which is pointed by circle at Figure 7. Since 128.111.52.10/32 is located at U.S, we expect that the RPF neighbor of 128.111.52.10/32 at Seoul-AP is Seoul-XP. But blank means a router which is not monitored by our system, i.e., the RPF neighbor of 128.111.52.10/32 at Seoul-AP is wrong. At Seoul-AP, the packets sent by 128.111.52.10/32 income from Seoul-XP but the RPF neighbor of 128.111.52.10/32 is not Seoul-XP. So Seoul-AP discards these packets, finally Seoul-AP does not have IMJ-Channel 1 session information.

The third scenario is to detect the forwarding problems. When the bursty traffic incomes, we wonder whether this traffic is justifiable or not. Figure 8 shows (source, group) traffic incoming from Tokyo-XP at Seoul-XP. The next hop of (130.240.112.8/32, 224.2.172.238) which has more traffic relatively at Seoul-XP is Seoul-AP or Taejon-AP. We go

along with the forwarding path of (130.240.112.8/32, 224.2.172.238) to Taejon-AP. Figure 9 shows (source, group) traffic incoming from Seoul-XP at Taejon-AP. The next hop of (130.240.112.8/32, 224.2.172.238) at Taejon-AP is KAIST. We go along to KAIST. Figure 10 shows (source, group) traffic incoming from Taejon-AP at KAIST. Figure 11 is a part of traffic incoming state of Taejon-AP. We find the router of KAIST has members on its subnet, i.e., this (130.240.112.8/32, 224.2.172.238) traffic is justifiable.

2) Statistics

We obtain the various statistics of multicast status by using the MRD. One multicast session was monitored for twelve hours. The session name is "NASA TV - Broadcast from NASA HQ". NASA broadcast a NASA TV channel over the MBone 24 hours a day. NASA TV consists of various programming about NASA, including lectures, press conferences, educational programs, live shots from space
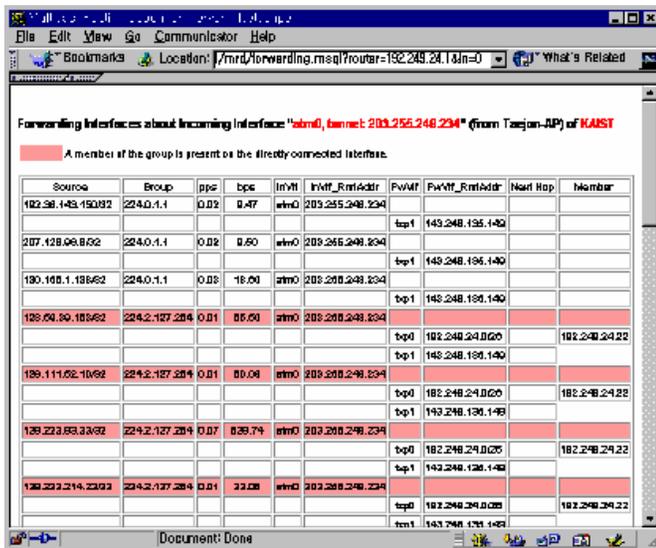
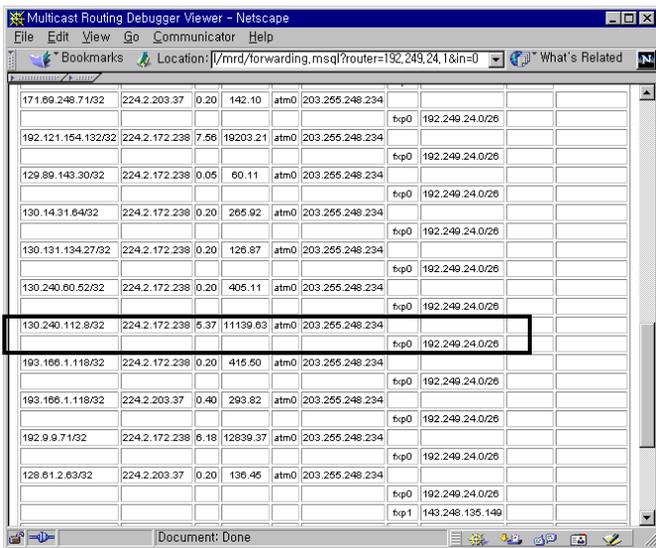Fig. 10. Forwarding interface from Taejon-AP of KAIST (a)

Fig. 11. Forwarding interface from Taejon-AP of KAIST (b)

shuttles and satellites, and live mission coverage. The session consists of two multicast group. The video multicast group address is 224.2.233.103/52218 and the audio multicast group address is 224.2.233.103/17262. We choose packets per second, bytes per second and the number of sources as statistics. Figure 12 shows packet per second, bytes per second and the number of sources for video group, respectively.

3) Analysis

We compared the related works with MRD system based on experimental results. The comparison factors are the required information mentioned earlier, portability and scalability. Table IV summarizes the result of comparison. SNMP-based tool provides all required information except session information. Since SNMP-enable router is required for SNMP-based tool, portability is middle. Scalability is also middle. Multicast route tracing tools provides the routing and forwarding information from source to receiver, hop-by-hop
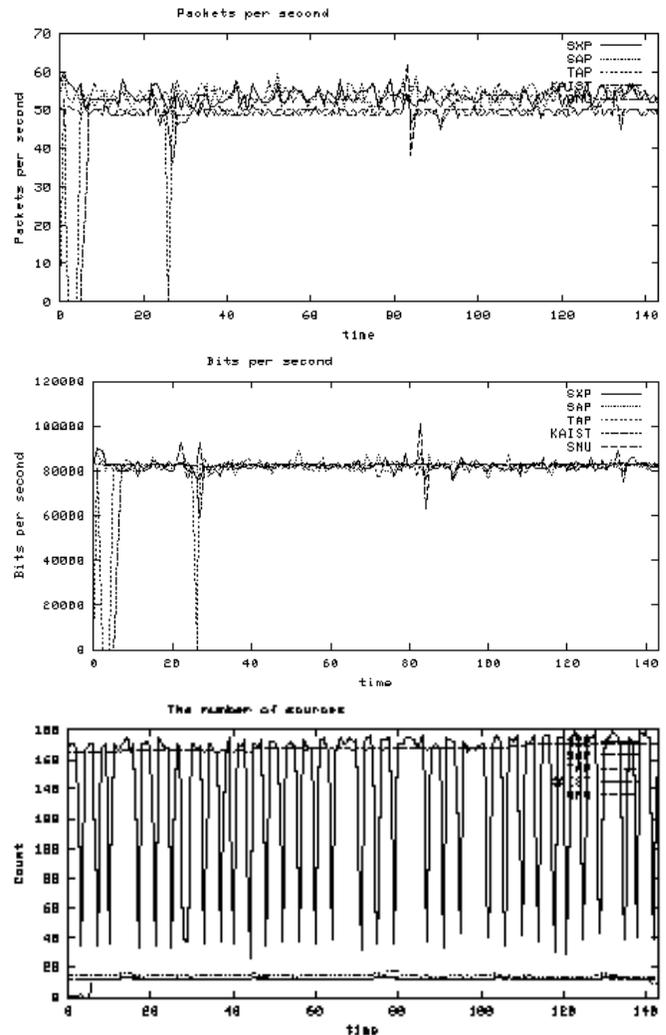

Fig. 12. Statistics for NASA TV Video

statistics. Since all routers support multicast route tracing, portability is high. Scalability is middle since where multicast and unicast topologies are not aligned (as is the case in many multicast-enabled networks) multicast route tracing tools may not function. Multicast Reachability Monitor provides packet loss information. Since Cisco's router supports Multicast Reachability Monitor, portability is middle. Scalability is also middle. Multicast Routing Debugger provides all required information. Since Cisco's router and MRD-capable mrouted support Multicast Routing Debugger, portability is middle. Scalability is low, since routers in the static domain are monitored.

VI. CONCLUSION

In this paper, we proposed the Multicast Routing Debugger (MRD) system that monitors the status of a multicast network. The proposed system was implemented and deployed on APAN-KR research network in Korea.

By reviewing commonly encountered multicast problems, we could define the information which should be monitored in

TABLE IV
MRD COMPARISON WITH RELATED WORKS

Factor Tool	Scope of Monitoring					Portability	Scalability
	Session	Forwarding	Routing	Statistics	IGMP Group		
SNMP-based Tool	X	O	O	O	O	△	△
Multicast Route tracing Tool	X	O	O	O	X	O	△
Multicast Reachability Monitor (MRM)	X	X	X	X	X	△	O
Multicast Routing Debugger (MRD)	O	O	O	O	O	△	X

order to detect the problems. Although there exist several types of multicast management tool, any tool is not satisfied with these requirements. Our proposed system was designed to collect and process these required information from heterogeneous routers. Since one type of these routers, mrouted does not support any tools to provide information needed in monitoring multicast status. We developed the MRD-capable mrouted for mrouted to support the status report functionality.

Our proposed system gave the various status of a multicast network with an easy to use, web-based and intuitive viewer tool. Since the status information was stored in a database system, it was comfortable to maintain and manage it. We could detect various multicast-related problems by using our system. It remains as a further work to expand the network monitored dynamically and the set of the status information. Because our system takes care of the specific network and its requirements are minimal. These works and their solutions should be further investigated in future works.

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