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A comparative analysis of inter-domain multicast routing protocols

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A comparative analysis of inter-domain multicast routing protocols
Thesis directed by Professor Stanley E. Bush

It has been suggested that further work is needed in the area of multicast routing and that an evaluation of current multicast routing protocols is encouraged [Deering-98, Deering-98c]. This thesis presents a comparison of the two most important proposals for Inter-Domain Multicast Routing (IDMR). Advantages and disadvantages of each protocol are pointed out and goals that a new proposal should meet are stated.

Researchers have proposed many protocols for IDMR. The IETF has advanced two protocols to the experimental standard status: Core Based Trees (CBT) [Ballardie-97] and Protocol Independent Multicast - Sparse Mode (PIM-SM) [Estrin-98]. The IETF hopes that the market will decide which is the best solution, however it does not provide criteria on how to compare the protocols. This thesis summarizes the key features of CBT and PIM-SM, and makes a comparison based on extensive criteria. Other recent proposals are introduced but only these two are compared.

The criteria used to compare the protocols are composed of five parts: protocol status, basic characteristics, technical criteria, operational criteria and overall assessment. More importance is given to the operational criteria, since this thesis simulates the type of analysis a network manager would do to compare the protocols.

This thesis argues that the Protocol Independent Multicast - Sparse Mode (PIM-SM) proposal is the best solution currently available. This protocol should be chosen as the inter-domain multicast routing protocol to be deployed in the enterprise if a solution is needed immediately. However, it is also shown that neither PIM-SM nor CBT meet all the requirements of a good inter-domain multicast routing protocol. Specifically, the inability of scale (flooding and no aggregation) and lack of support of policies and heterogeneity are the main drawbacks of the protocols. This author argues that none of these protocols will be the final solution adopted in the Internet. The Border Gateway Multicast Protocol [Kumar-98, Thaler-98] has started to move in the right direction and should be the protocol to watch in the near future.

As background information, this thesis reviews internetworking basics, unicast routing, multicast basics, multicast operations, multicast market and multicast routing.

Keywords: PIM-SM, CBT, multicast, routing, IDMR, DVMRP, MOSPF, PIM-DM, MBONE, RIP, OSPF, BGP, IGMP.

Chapter 11 - Summary and Conclusions

11.1 - Summary of work accomplished

This thesis has presented a comparison of the two most relevant proposals for inter-domain multicast routing (CBT and PIM-SM). The comparison was done based on the criteria outlined in chapter 8. There are a significant number of newer proposals, which are summarized in chapter 6.

A review of other comparisons of inter-domain multicast routing protocols was presented in chapter 7. The work presented in [Billhartz-XX][1] is the most similar to the work presented in this thesis. Chapters 9 and 10 present the protocol analysis for CBT and PIM-SM, respectively.

This thesis covered a number of review chapters. Specifically, the following areas were reviewed: components of today's Internet, unicast routing, multicast basics and intra-domain multicast routing protocols (See chapters 2 through 5). These chapters cover background that aids to better understand the comparative analysis presented in this thesis. The following sections in this chapter present a summary of the comparative analysis, and the conclusions of the comparison.

11.1.1 - Summary - Background

DVMRP [Waitzman-88] and PIM-DM [Estrin-96] periodically flood data packets throughout the network. Networks with no group members send prunes back to the source. This "Flood and Prune" mechanism exhibits poor scaling properties. It consumes bandwidth in links that do not lead to group members and requires every router in the network to keep state information for every active source/group pair. MOSPF [Moy2-94] floods group membership information to all routers in the network so that they can build multicast distribution trees. This flooding mechanism cannot be used in the global Internet either. In general, flooding control packets to the entire Internet does not scale. Any protocol that uses flooding of data packets or control packets is not a good solution for an Inter-Domain multicast protocol for the entire Internet.

Even though DVMRP is not a scalable solution it is the one that is used today in the Internet. The reason for that is that DVMRP was the only solution available in 1992. However, today it is clear that it is not a good solution (it does not scale because of flooding).

The next few paragraphs summarize the main protocols available for multicast routing, their characteristics and when they would be used. Table 11. 1 and Figure 11. 1 provide high level classification for multicast routing protocols.

Protocol	**Unicast Protocol Requirements**	**Network Size**
DVMRP	It provides its own.	Small
MOSPF	OSPF	Small
PIM-dense mode	Any	Small
PIM-sparse mode	Any	Large, but not global
CBT	Any	Large, but not global

Table 11. 1 - Comparison of Routing Protocols

Multicast routing protocols can be classified depending on the join type and the type of delivery tree they create. Figure 11. 1 describes these relationships. Explicit join trees are more efficient since they save bandwidth, i.e. multicast traffic only appears in networks that desire the traffic. Implicit join trees require flooding to

[1] Harris Corporation's work started around 1993 and their work is available in several

the entire network to discover new receivers. Source based trees provide low delay but use more memory in routers, while share trees create sub-optimal paths, but use less memory in routers.

Implicit Join - PIM-DM - DVMRP	**Explicit Join** - MOSPF - CBT - PIM-SM
Source Based Trees - DVMRP - MOSPF - PIM-DM - PIM-SM	**Shared Trees** - PIM-SM - CBT

Figure 11. 1 - Classification of routing protocols by join type and tree type.

11.2 - Summary of the comparison

11.2.1 - Summary - Protocol Status

PIM-SM is **commercially** available in Cisco routers while CBT is not supported by any vendor. This issue gives a stronger position to PIM-SM if deployment is required immediately. This may be a strong criterion on choosing which protocol to deploy in the enterprise or in an ISP network.

11.2.2 - Summary - Basic Characteristics

PIM-SM uses **explicitly joined shared trees** emanating from a "Rendezvous Point". CBT also uses explicitly joined shared trees originated from a router that is called "core". This is a more efficient mechanism than the "flood and prune"

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places [Billhartz-95, Billhartz-95, Billhartz-96a, Billhartz-96, and Billhartz-97].

algorithm used by of other protocols such as PIM-DM and DVMRP. The core and the RP have the same function, which is to serve as the center of the shared tree.

The use of shared trees allows for all senders to use the same tree thus reducing considerably the amount of memory necessary in routers[2]. However, it introduces new problems such as increased end-to-end delay [Billhartz-97], center failure, center location [Thaler-97], address partitioning problems [Estrin-98b] and traffic concentration around the center [Wei-94]. These issues do not have a clear answer at this point, which means that there is room for improvement.

PIM-SM provides the option to switch to shortest path trees for sources that exceed a bandwidth threshold. The ability to switch to a source-based tree decreases end-to-end delay and allows specifying source specific policies. However, it makes the protocol more complicated to debug for network managers and also more complicated to develop for software developers.

PIM-SM **does not require having a specific unicast routing protocol**. The only thing that is needed is the presence of a routing table. Similarly, CBT does not depend on any specific unicast routing protocol either. This feature allows these two protocols to be developed independently from unicast routing protocols. This is an improvement over other protocols such as DVMRP, which has its own unicast routing protocol, or MOSPF, which is tied to OSPF.

CBT creates **bi-directional trees** that exhibit low bandwidth consumption. However, CBT cannot support unidirectional policies, neither can support source-

[2] The amount of memory needed in shared trees is in the order of the number of groups known by the router, while in source-based the amount of memory is in the order of the product of senders by groups. In mathematical terms, shared trees scale to O(G) while source trees scale to O(SxG), where S is the number of senders and G is the number of groups.

specific policies. PIM-SM offers source-based trees for certain sources. This means that it supports better source specific policies.

CBT uses "**hard states**", which means that messages are acknowledged and repeated after a time-out. PIM-SM uses "**soft state**" in which join messages are repeated a regular intervals, the states are cached and simply "disappear" if the information is not refreshed. Soft state mechanisms require fewer control overhead packets. This makes PIM-SM more efficient since it uses less bandwidth to create the distribution tree.

Both protocols are compliant with the **RFC-1112**. This enables interoperability, but then the protocols inherit the problems introduced by the IP Multicast Model. These problems are that any source can send to a group and that senders cannot account for who is listening to a multicast feed (see section 4.5).

All current multicast routing protocols rely on the **Reverse Path Forwarding** (RPF) algorithms (packets get dropped if not received on the shortest path to the source). Therefore, these protocols are not suited for asymmetric networks. Hodel proposed a multicast routing protocol called Policy Tree Multicast Routing (PTMR) that addresses this issue [Hodel-98].

11.2.3 - Summary - Technical Criteria

In general, **flooding** control packets to the entire Internet does not scale. Any protocol that has flooding of data packets or control packets is not a good solution for an Inter-Domain multicast protocol for the entire Internet. Both PIM-SM and CBT flood packets to the entire Internet. It is likely that neither of these solutions will be used in the Internet as the long-term solution because flooding does not scale.

Scalability of multicast routing protocols is directly affected by the amount of **forwarding state** that routers need to keep in order to forward multicast packets. That is, the protocol will scale better if it requires less memory in routers. Shared trees require less state but have more end-to-end delay and concentrate traffic around the center among other problems.

The **join time** is the time that elapses between a join request from a host and the reception of a multicast feed. PIM and CBT join times are low and about equal [Billhartz-97]. They both use a "join" mechanism towards the center of a tree.

The **end-to-end delay** that a multicast packet experiences by using a distribution tree built by PIM-SM using source-based trees is less than using a shared tree built CBT [Billhartz-97]. However, the delays are low and very similar. This criterion does not seem to have much impact on which protocol is the best. This factor only affects how much time a user has to wait to get packets from a group.

Shared trees do not provide minimum delay paths [Wei-94]. So, they are not a good solution for tele-conferencing that is a time-sensitive application. However, for applications with many senders, as in the case of Distributed Interactive Simulation (DIS), it is better to use shared trees because they consume less state in routers than source trees do.

Shared trees may not be optimal as Source-Based trees are. Shared-based trees have 10% worse latency that Source-Based Trees [Wei-95]. This implies that source-based trees are better suited for applications with real-time constraints such as video-conferencing. PIM-SM supports source-based trees, which makes it a better solution for multimedia applications with real-time constraints.

Neither PIM-SM nor CBT offer support for **Quality of Service (QoS)**. This is a limiting factor of these two protocols; it does not seem that in the near future, they will include support for QoS. Newer proposals such as YAM [Carlberg-97] and QoSMIC [Faloutsos-98] [Banerjea-98] propose alternatives that support quality of service.

Neither PIM-SM nor CBT offer support for **multipath routing**. That is, they only provide one route from each source to each recipient. In some applications, it is necessary to load balance traffic between links (e.g. high bandwidth applications). Multipath routing may increase considerably the size of the routing table. For example, if an implementation chooses to use source based trees and keep three routing entries for each source (S) sending to a group (G) present in the Internet then the state will be in the order of O(3 x S x G). This may create huge routing tables, but that may not be a big issue since memory prices are getting cheap everyday.

11.2.4 - Summary - Operational Criteria

It seems quite **easy to configure** multicast in a Cisco router. Just a global command and one command per interface. Support from a commercial vendor is a clear advantage of PIM-SM over CBT. However, PIM-SM is only supported in the latest versions of the Cisco's IOS. This implies that many existing routers may need to be upgraded which could be cumbersome for network managers in charge of large networks. cost

Both PIM-SM and CBT are dependent on the multicast routing protocol that is running internally in a domain. This makes these protocols a bad choice for inter-domain multicast routing. Ideally, an inter-domain multicast routing protocol should be able to glue **heterogeneous domains** (each is running a different multicast routing protocol). MASC/BGMP [Kumar-98, Thaler-98, Estrin-98b] promises to be a solution that interconnects heterogeneous domains. Other old proposals tried to propose a hierarchy in the past but failed: HPIM [Handley-95] and HDVMRP [Thyagarajan-95].

None of the proposals offer the ability to do **billing**. This is one of the reasons ISPs are hesitant to deploy IP Multicast [Bellman-97].

There is also very little work on **security** and multicast. For example, in the current model a sender can send to a group without authorization. In the future, when multicast appears as a paid service, this issue will be of greater concern (see section 4.5).

Neither PIM-SM nor CBT offer the ability to control multicast traffic in a network, because none of them support **policies**. ISPs don't like this because they need to control from whom they receive multicast feed and also limit the amount of bandwidth used by multicast applications. This limitation is very crucial and it is a big obstacle to the deployment of IP multicast in the Internet. Hodel's recent work is offering an alternative for this issue but it is still too early in the development stage of his proposal [Hodel-98]. The BGMP protocol is another protocol that has a proposal on how to support policies for multicast [Thaler-98, Kumar-98].

Shared trees require traffic to travel through a core or RP. This creates the **third party dependency problem** [Meyer-97]. Autonomous Systems do not like to depend on a third party core. This is a main problem of PIM-SM and CBT that has slowed down their deployment.

Neither CBT nor PIM-SM support **Policy and QoS**. This is a big limitation of these protocols that makes them a less than an attractive solution for Inter-Domain Multicast Routing. There are two main recent proposals that offer ideas on how to solve these issues [Thaler-98, Hodel-98].

11.2.5 - Summary - Overall Assessment

Table 11. 2 is summary of the advantages and disadvantages of CBT and PIM-SM found by doing the comparative analysis done in this thesis.

	CBT	PIM-SM
Advantages	• Less State information • Better BW utilization • Better scalability • Unicast independence • It is free • Simple	• Commercial availability • Better bandwidth utilization • Less end-to-end delay • Unicast independence • Better robustness • Possibility of support of QoS • Soft state
Disadvantages	• Flooding of core set • No support of policies • Immaturity • Sub-optimal paths • Traffic Concentration • No heterogeneity • No aggregation • Core Failure • No support for billing • Third party dependency • No support of advanced features • Core Location • No security	• Flooding of core set • No support of policies • Unidirectional state • Complex • More state • No heterogeneity • No aggregation • RP failure • No support for billing • Third party dependency • No support of advanced features • RP location security ?

Table 11. 2 - Advantages and Disadvantages of PIM-SM and CBT

11.2.6 - Summary - Table

Table 11. 3 is a summary of the comparative analysis presented in this thesis. Five sets of criteria were presented: Protocol Status, basic characteristics, technical criteria, operational criteria and overall assessment. For an explanation of the criteria meaning see chapter 8. The criteria are weighted so that the sum of the criteria is 100. Each protocol is "graded" from 1 to 10. The perfect protocol would obtain 100 as the "final grade".

It is shown that both protocols obtain low subjective ratings in many areas. This indicates that these two protocols require a review and that is not likely that they will become the definitive standard. Each criterion is weighted depending on its relative importance to a network manager. For example, the criteria considered most important for network managers is the support of policies. This is why it is given the highest weight of all the criteria used for the comparison.

For some of the criteria information was not available. For example, no information was found on the convergence time of the protocol. For this type of criteria a weight of zero was assigned to the criteria, so that it does not affect the comparison.

Protocol Status

#	Criteria	W	CBT	G/10	PIM-SM	G/10
1	Specification	1	RFC 2189 [Ballardie-97]	10	RFC 2362 [Estrin-98]	10
2	Status	2	Experimental	6	Experimental	6
3	Availability	2	Freeware	2	Commercial	8
4	Supported Platforms	2	FreeBSD 2.2.[67]	6	FreeBSD-2.2.1, FreeBSD-2.2.5, NetBSD-1.3 and SunOS-4.1.3, Cisco IOS.	8
5	MIB	1	Internet Draft	6	Internet Draft	6
6	Implementations	2	One	2	Two	8
7	Features Tested	1	N/A	2	N/A	2
8	Operational Experience	2	None	6	Some (e.g. UUNET)	8
9	Router Vendor Support	2	None	5	Cisco	10
		15		7.2		11.4

Basic Characteristics

#	Criteria	W	CBT	G/10	PIM-SM	G/10
1	Tree Type	1	Shared Tree	5	Both (Shared and Source)	7
2	Uni/Bi-directional	1	Bi-directional	9	Uni-directional	5
3	Loop-free-ness	1	No	1	No	1
4	RPF-Check	1	No	7	Yes	5
5	Hard/Soft State	1	Hard	3	Soft	7
6	Protocol Independence	1	Yes	10	Yes	10
7	RFC-1112 Compliant	1	Yes	10	Yes	10
		7		4.5		4.5

Technical Criteria

#	Criteria	W	CBT	G/10	PIM-SM	G/10
1	Link BW overhead	5	Moderate	5	Moderate	5
2	CPU Utilization	5	Moderate	5	Moderate	5
3	Router Memory	2	O(G)	7	From O(G) to O(SxG)	3
4	End-to-end Delay	2	Medium	5	Medium - Low	7
5	Join Time	1	Low	5	Low	5
6	Leave Time	0	N/A	0	N/A	0
7	Convergence Time	0	N/A	0	N/A	0
8	Traffic Characteristics	2	Concentrated around core.	3	Concentrated around RP, but could also distribute.	7
9	Address Allocation	2	No	1	No	1
10	Address Aggregation	1	No	1	No	1
		20		8.8		9.1

Operational Criteria

#	Criteria	W	CBT	G/10	PIM-SM	G/10
1	Ease of Configuration	2	Cumbersome	3	Easy	9
2	Ease of Management	1	Limited management tools for multicast	3	Limited management tools for multicast	3
3	Robustness	4	Yes	7	Yes	7
4	Price	2	Free	9	Moderate	5
5	Interoperability	1	Yes	7	Yes	7

6	Installation Time	2	Not commercial yet	4	Depends on size of the network	9
7	Billing Capacity	3	No	1	No	1
8	Impact on existing network	3	High	2	High	2
9	Multipath routing	1	No	1	No	1
10	QoS Support	1	No	1	No	1
11	Mobility Support	1	No	1	No	1
12	Heterogeneity	3	No	5	No	5
13	Policy Support	8	No	1	No	1
14	Security	6	No	3	No	3
15	Complexity	2	Less complex	7	More Complex	3
16	Third-Party dependence	5	Yes	3	Yes	3
		45		15.2		15.8

Overall Assessment

#	Criteria	W	CBT	G/10	PIM-SM	G/10
1	Scalability	4	No	5	No	5
2	Suitability	3	Intra-domain	5	Intra-domain	5
3	Advantages *	3	Less state	5	Source Tree	8
4	Disadvantages *	3	Flooding of Core set	3	Flooding of RP set	3
		13		5.9		6.8

Total	**100**	**41.6**	**47.6**

* Only the main advantage and disadvantage are shown. For more see analysis in previous chapters

Table 11. 3 - Summary Table of the comparison

11.3 Conclusions

PIM-SM and CBT were designed with the aim to have a protocol that scales to the entire Internet. However, based on the comparative analysis performed, it is clear that many issues still need to be solved for IDMR protocols and that these two protocols are better suited to be used internally in a domain.

Neither PIM-SM nor CBT seem mature enough to become the final solution to become an Internet standard. If a protocol needs to be deployed immediately then PIM-SM is a better overall solution at this time. The main reason for this choice is that PIM-SM is supported by commercial routers, while CBT has not been implemented by any router vendor. In other terms, the two protocols are very similar (see Table 11. 3).

Many issues still need to be solved; however, there are four that are more important than other issues. These are: scalability, policies, heterogeneity and aggregation. The next paragraphs summarize these problems.

Scalability:

In PIM-SM and CBT, the mechanism to map group address to its core router requires **flooding** to the entire network the set of routers that are candidates to be a core. This flooding mechanism is called the "Bootstrap" method. This approach may work in small environments, but clearly it **does not scale** to the whole Internet. Recently, Otha et al. proposed a mechanism using DNS to advertise core routers associated with a group that does not require state in intermediate routers or control traffic overhead to map core to groups. This approach may scale better but it is still in draft status in the IETF and it may suffer considerable changes in the next few months [Ohta-98]. This is a flaw in the design of PIM-SM and CBT that clearly impedes its success as a good solution for Inter-Domain Multicast Routing (IDMR).

If this is not fixed in the next versions of these protocols, then it is likely that another proposal will become the standard for IDMR.

Policies:

Current proposals for inter-domain multicast routing do not allow Internet Service Providers to control multicast transit traffic, that is, they do not support **policies**. In other words, it is not possible for an ISP to control the multicast packets that travel its network. Multicast traffic could affect the bandwidth available for unicast applications and there is no way to control it at this point. New proposals should focus in providing an AS with the flexibility and the autonomy to control the receive path of multicast data traffic.

Aggregation:

In order for multicast routing protocols to achieve scalability for the entire Internet they need to support some form of **aggregation** so that the state in routers does not grow without bound. As November 1998, there is no clear solution for this problem. Neither CBT nor PIM-SM has an answer for this issue.

Heterogeneity:

PIM-SM and CBT work in a single routing layer - i.e. there is **no hierarchy** associated with these protocols. This means that they are mainly suited for intra-domain environments. This creates the problem that the protocol does not support heterogeneous domains. Ideally, each autonomous system in the Internet should be able to choose ~~which protocol~~ a intra-domain multicast routing protocol independently

There is an opportunity to design a protocol that addresses all the issues not solved by current proposals. The qualitative analysis presented in this thesis serves as a starting point for a new proposal for an IDMR protocol. The following **goals** must be achieved by a new proposal in order to improve current protocols:

a) Scalability: The protocol should use mechanisms that could be used globally in the Internet. For example, flooding should be avoided.

b) Policies: The protocol should be able to accommodate policies from network managers so that they can control multicast traffic.

c) Aggregation: There should be a way to aggregate routing table entries and control traffic so that they do not grow without bound.

d) Heterogeneity: The protocol should allow each domain to run a different multicast protocol that fits its needs.

d) Other features: The protocol should support multipath routing, billing, QoS, mobility. However, these characteristics are not as important as the above characteristics.

Another conclusion from this work is that the IP Multicast Model described in RFC-1112 [Deering-89] needs to be reviewed. Multicast routing protocols comply with the model proposed by Deering, however this model introduces problems that are inherited by other multicast protocols and applications (see section 4.5).

Future Perspective

The work performed for MASC/BGMP [Thaler-98, Kumar-98] has started to move in the direction to support the above requirements. However, this work is in early stages and it should closely monitored in the near future. Other proposals have also recognized these problems, but MASC/BGMP seems to be having the most attention at this point in time (see chapter 6).

Finally, it should be expected several years will pass before a solution that satisfies these requirements for IDMR is encountered. The process might be accelerated if a killer application for multicast appears. At this point it seems that TV-like Internet broadcasting may become a killer application for multicast (see section 4.15).

Chapter 12 - Recommendations on Future work

There are many open issues in multicast technologies at the moment. The best place to find open research issues is a survey article written by Diot et al. [Diot-97]. This chapter attempts to summarize the state of multicast technologies as of November of 1998.

12.1 - Extend the comparison

This work could be expanded by comparing newer proposals for IDMR using as the basis the criteria presented in this thesis. For other alternatives for IDMR see Chapter 6.

12.2 - Simulation

A simulation would be helpful to better understand the proposals. Chapter 14 has an introduction to the trial simulations performed in this thesis.

12.3 - Review the IP Multicast model

The IP multicast model described in RFC-1112 is the basis of every other piece of work in IP multicast. This author argues that there are two design flaws in the model: a sender can send to any group it wants and a receiver can any join it desires. This may work in the research community but clearly it does not work in the commercial world. For more on this argument see section 4.5.

12.4 - Addresses management issues

There have been proposals to use DHCP to allocate multicast addresses. This technique is good for small groups however this technique is clearly not scalable for Internet scale networking. The Multicast Address-Set Claim (MASC) protocol is one of the newest proposals on the multicast address allocation issue [Estrin-98b].

12.5 - IP Multicast in IPv6

The future of multicast routing over Ipv6 is unclear at the time of this writing. It is highly unlikely that there will ever be a version of DVRMP for IPv6. OSPF is at the present time being defined by the IETF for IPv6, and M-OSPF will work similarly to the way it does with Ipv4. PIM (either of the versions) and CBT are easily modifiable to support Ipv6, because both only require that there be a unicast routing table present in the router.

12.6 - Interoperability

It is expected that there will be many different protocols deployed in the Internet. No single protocol would be able to meet the requirements for all the applications. This suggests that there is a need for inter-operability between all the existing multicast routing protocols. Since the MBONE core routing protocol is DVMRP, many vendors provide specifications on how to connect their routing protocol to DVMRP. For example, vendors providing support for MOSPF also provide a way to interoperate with DVMRP.

12.7 - Heterogeneity

It is desirable that a new protocol supports multiple domains running different multicast routing protocols. This will better serve the needs of the Internet. No single protocol has solved this issue as of today.

12.8 - Policy-based routing

Multicast policy and access-control do not exist in today's MBONE. Policy and access-control is done by packet filtering. A better solution is needed. Some form of policy-based hierarchical routing is required for Internet-scale operation. One of the possible alternatives is to have two levels of routing: one for the Intranet and another for the connection with the outside world. Just as the unicast routing protocol has an interior and an exterior routing protocol.

None of the current multicast routing protocols specify a mechanism to express and enforce multicast routing policies and forwarding policies among ISPs. The lack of policy control is one of the biggest reasons that multicast has not been deployed by many ISPs. They feel that they need a way to control the routing and forwarding of multicast traffic [Maufer-98].

However, the ISP's requirements are quite different from the Intranet managers. Current existing protocols such as DVMRP and MOSPF are perfect to be deployed in the internal network. However, they do not scale and have a lack of policy control mechanisms that ISPs need urgently in order to be able to deploy IP Multicast. Current multicast routing protocols do not allow ISPs to control how the routing and forwarding for multicast is done.

A recent piece of work by Hodel proposes a protocol that supports policies [Hodel-98].

12.9 - Congestion Control

How to do congestion control for multicast? Congestion control frames returning to a sender may create even more congestion.

12.10 - Convergence time

There is no previous work that focus on measuring how much time elapses between a change occurs in the network and the time that all the routers know about the change in multicast routing. Further research is needed in this area. It might be possible that the protocol behaves inadequately in the presence of link or router failures.

12.11 - Center Location

The placement of Cores in shared based trees is an area of open research at this time. Thaler presented a survey of current alternatives in [Thaler-97].

12.12 - ISP Billing and settlement issues

There is no mechanism to charge for multicast transmissions. The question on how to do billing for multicast is an open issue at this time. This is one of the reasons ISP have not deployed multicast yet [Bellman-97].

MBONE is free access and it does not generate any revenue. So, the people that maintain it do not have any urgency to solve its problems. The MBONE relies on the volunteer work of researchers and engineers around the world.

12.13 - Reliable Multicast Transport Protocols

A comparative analysis can be done on reliable multicast transport protocols. Several surveys can be found at [Diot-97] [Obraczka-98] [Tascnets-98]. One of the first proposals was presented in [Armstrong-92].

12.14 - Network Management for Multicast

There are very few tools to manage IP Multicast. The tools that exist are very rudimentary. There is room to create new improvements in this area. Thaler and Aboba presented a survey of existing tools in [Thaler-98b].

12.15 - Aggregation

Ways of bounding and aggregating control traffic in PIM is something with no answer at this point. This is an issue also for CBT [Ballardie-95]. Large-scale use of multicast may require some form of aggregation of IP level multicast tree indices (state in Mbone routers). As of November 1998, there is no clear alternative on how to aggregate multicast addresses and control traffic. In other words, there is a need to design the multicast version of CIDR.

12.16 - Multicast over different L2 technologies

It is not clear at this moment the mappings of IP multicast for many level 2 technologies. For example, work is underway to define the mappings of IP multicast over ATM, SONET, ADSL, Frame Relay, etc. The leading proposal for support of multicast in ATM is described in [Armitage-96].

12.17 - Chapter Summary

This chapter has presented some of the open areas of research in relation IP multicast technologies. Some of the issues presented in this chapter could serve as topics for a future thesis.

Chapter 13 - References

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