Enabling new multicast distribution architectures through the introduction of IGMP/MLD proxy with multiple upstream interfaces

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***Abstract*— The deployment of IGMP/MLD proxy functionality in telecom networks is now common from long, with clear engineering and operational rules. Existing IGMP/MLD proxy implementations are limited to a single upstream interface, then receiving all the multicast traffic through that interface in a well-defined manner. However this mode of operation seems to not be enough for enabling some appealing multicast distribution cases. Such new service scenarios rise the need of extending the proxy functionality by enabling the support of multiple upstream interfaces, at the cost of imposing the support of more functionality in the element acting as a proxy. The paper introduces the use cases of interest and overviews the additional functionality required to evolve next generation of IGMP/MLD proxies in this direction. Future directions on the standardization of this solution are also provided.**

Keywords*— *multicast; proxy; IGMP/MLD.

I. INTRODUCTION

The Internet Group Management Protocol (IGMP) [1][2] for IPv4 and the Multicast Listener Discovery Protocol (MLD) [3][2] for IPv6 are the standard protocols for hosts to initiate the process of joining or leaving multicast sessions.

A proxy device performing IGMP/MLD-based forwarding, known as IGMP/MLD proxy [4], maintains multicast membership information signaled by means of IGMP/MLD protocols on the downstream interfaces, and sends such IGMP/MLD membership report messages via the upstream interface to the upstream multicast routers only when the aggregated membership information for a channel changes (e.g., when an end user behind the proxy becomes the first user in soliciting a channel, or the last user requesting to leave a given content). The proxy device forwards appropriate multicast packets received on its upstream interface to each downstream interface based on the subscriptions of each downstream interface.

Existing specifications of multicast subscription proxies [4], for either IPv4 based on IGMP, or IPv6 based on MLD, do allow solely a single upstream interface for requesting the multicast group from the network, with one or more downstream interfaces. An IGMP/MLD proxy device hence performs the router portion of the IGMP or MLD protocol on its downstream interfaces, and the host portion of IGMP/MLD on its upstream interface. The proxy device must not perform the router portion of IGMP/MLD on its upstream interface. This implies that the proxy can only join at one time a unique branch of a multicast distribution tree, and, in consequence, the content is provided solely by a single provider at once.

This fact, even simplifying the real implementation of the proxy, since it merely acts as a relay point for hosts to initiate the action of joining or leaving multicast sessions, produces limitations for certain distribution scenarios either present in current networks or perceived as enablers for new business situations. These are scenarios like the merging of networks with different multicast services, the enabling of a multicast wholesale offer for residential services, or simply the migration of an existing multicast service to another. The paper will describe them with more detail.

For making feasible all of these scenarios, the proxy device shall be able to receive multicast packets simultaneously from different upstream interfaces, forwarding them afterwards to the downstream interfaces according to the subscription requests received. Which groups are being received depends on the use case. In a migration scenario, the is usually received from an upstream single interface which needs to be changed "on the fly". In other scenarios – e.g. wholesale – different groups are received from different upstream interfaces and the proxy needs to know how to relay the requested content based on the IGMP or MLD messages received from the corresponding downstream interfaces for each of the different groups.

For all these cases, the existence of multiple upstream interfaces would be needed for simplifying the way in which the end customer receives the desired multicast content. Figure 1 graphically presents the global scenario.

Through the different upstream interfaces, the proxy can be simultaneously connected to separate content providers, as in Fig. 1, or it could be connected to the same multicast content provider but via alternative branches of the same distribution tree. Furthermore, both situations could even co-exist, providing greater flexibility to the system.

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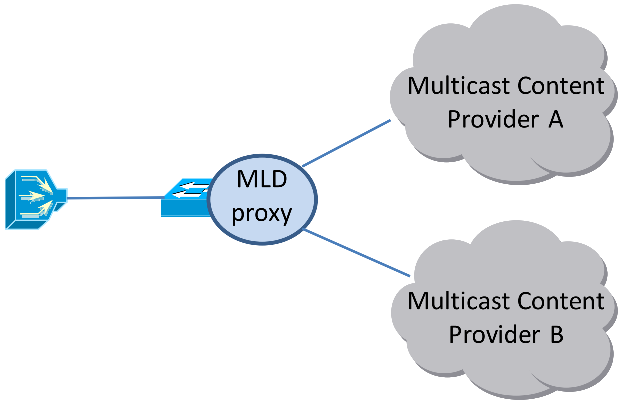

Figure 1. MLD proxy with multiple streams

The structure of the paper is as follows. Section II presents realistic use cases that require from the support of multiple upstream interfaces in order to be implemented. Section III provides insight on the required incremental functionality to be supported by the proxy elements for enabling the aforementioned use cases. Section IV identifies the challenges for making these proxies operational. Finally Section V provides some concluding remarks and next steps towards the definition of the overall solution.

II. USE CASES FOR PROXY SUPPORT OF MULTIPLE UPSTREAM INTERFACES

Conventional multicast services in telecom networks have been widely deployed during the last decades. Those services have been based on the assumption that a single provider sets up a common distribution tree in the network, controlling all the content to reach the customer, end to end.

However, richer scenarios can be assumed in modern networks, either making possible the co-existence of multiple multicast content providers on top of the same infrastructure, enabling a better and more flexible engineering of the network, or simply facilitating a simpler way of operating the network, which otherwise would require costly mechanisms of solving the same problem.

Several can be the scenarios of interest for the need of a IGMP/MLD proxy with multiple upstream interfaces. The next sub-sections describe in more detail some of them.

A. *Enabling multicast wholesale offers for residential services*

The motivation for this use case is the possibility of commercializing complementary multicast services to those offered by the owner of the network where the customer is connected to. This will happen when multiple providers offer video services distributed via multicast. Both providers could offer distinct multicast groups. However, more than one subscription to multicast channels of different providers could take place simultaneously.

This case considers the co-existence of two or more different providers. Taking the simplistic example of only two providers, the first provider would represent the one operating the network where the end user is connected (e.g., an incumbent operator), while the other one would provide complementary content services to the end user. Both of them can include in their respective service offerings multicast content, in such a way that the end customer can decide to subscribe both content offerings independently. This is beneficial to the customer since it is giving much more flexibility to the user at the time of consuming video service, independently of which provider distribute the content.

Despite this is exemplified with just two providers, the case could be scaled up to several of them, maybe specialized per kind of content.

Obviously, the complementary providers, as different administrative domains, will require to reach agreements with the incumbent provider for using the infrastructure (i.e., the telecom network) to distribute the content in the same way as the incumbent does.

B. *Increased resiliency via fast switching among upstream interfaces*

Current solution for multicast delivery relay on the routing capabilities of some protocols to guarantee some levels of resiliency for the distribution of multicast content. This is the case, for instance, of PIM [5] and VRRP [6], which help to rebuild the distribution tree in the event of network failures (like link or node failure).

A simpler scheme could be achieved by implementing the support of differentiated upstream interfaces on IGMP/MLD proxies, providing path diversity through the connection to distinct leaves of a given multicast tree.

It is assumed that only one of the upstream interfaces is active in receiving the multicast content, while the other is up and in standby mode for fast switching. Thus, the proxy can easily switch among the designated upstream interfaces in case of some problems are detected on the original multicast delivery path.

C. *Load balancing for multicast traffic in the aggregation segment of the telecom provider*

Typically, aggregation segments in telecom networks are built in the form of rings, collecting traffic from different aggregation nodes that provide the necessary capillarity to reach the end users. Two nodes act as head-ends of the ring providing connection diversity towards the rest of the network. The capacity of those rings is usually built by using one or several links of either 10 GEth or 100 Geth, depending on the number of nodes in the ring and the traffic collected per node. For multicast distribution, the nodes in the ring can act as IGMP/MLD proxies, including the ones playing the role of head-ends.

A single upstream interface in existing IGMP/MLD proxy functionality typically forces the distribution of all the channels on the same path in the last segment of the network. Furthermore, in the case of having multiple links constituting the ring, the multicast traffic typically use only one of those links. This is due to the way of working of the hashing algorithms used trying to equally distribute the load among the existing links, which unfortunately do not perform well for the multicast case.

Under situations like the ones described before, the availability of multiple upstream interfaces in the proxies could naturally help to split the demand among the existing links in the aggregation segment, by smartly selecting different channels in each of the upstream interfaces. In this mode, the bandwidth requirements in the metro segment can be alleviated since the load is shared at least in the both directions of the aggregation ring.

D. *Merging of provider networks with different multicast services*

The consolidation of service provider's network is a common fact in mature markets, as a way of improving benefits and economic margins. One of the difficulties faced during the integration of that networks is the integration of the services themselves without impacting in any manner the final user, which can decide to abandon its existing service subscription if service impacts or inconveniences arise. The video or IPTV service enabled by the multicast distribution of content is one of the most sensitive for the end customer, who usually pays a relevant amount of money for accessing such contents.

In some network merging situations, the multicast services provided before in each of the merged networks are maintained for the respective customer base. This is initially conceived to be done in a temporal fashion until the multicast service is redefined in a new single offer, but not necessarily. This could be even not implemented or possible in short term, e.g. because of commercial agreements for each of the previous service offers.

In order to assist such network merging situations, IGMP/MLD proxies with multiple upstream interfaces can help in the transition towards a unique and common video or IPTV offer, simplifying the service provisioning and facilitating service continuity, without affecting the customer perception of the service received.

E. *Migration of multicast services in an operational network*

Any kind of migration in an operational network can produce interruption in the service, which can impact negatively in the perception of the end customer and the reputation of the telecom operator. The severity of the interruption will depend on the time the service become unavailable, which depends on the complexity of the service to be migrated. The multicast services are especially sensitive to this fact since the service interruption can affect to the complete customer base since all the customer potentially subscribe to the same set of channels.

This use case considers the situation where a multicast service needs to be migrated. By applying IGMP/MLD proxies with multiple interfaces, the migration can be in principle performed just by switching from one upstream interface to another upstream interface.

In this case the multicast content is initially offered in both upstream interfaces and the proxy dynamically switches from the first to the second upstream interface, according to certain policies, and enabling to shut down the first upstream interface once the migration is completed. The migration can become smooth and without any service interruption at all by delivering migrated channels to new subscriptions while keeping old subscriptions receiving the previous content till the subscription expires.

III. Functionality Required for Supporting Multiple Upstream Interfaces

The previous section has presented some realistic cases that can be benefitted, or even enabled, with the availability of proxies supporting multiple upstream interfaces. On this situation, control mechanisms or policies are required for selecting the proper interface for receiving the multicast traffic. For instance, the decision on which upstream interface to be selected could be based on the subscriber address prefixes, the channel subscribed, session identifiers, or some particular interface priority values.

Additionally, it could be considered the deployment of centralized computation elements that could assist on the proper selection of the upstream interface to be used for a given channel, taking into account situations like network congestion, shortest multicast path, etc. These centralized elements will need to establish ways of signaling control messages with the proxies, in order to automatize the behavior of the system.

Whatever the mechanism is employed, the flexibility on selecting the upstream interface which becomes active enables different behaviors. Thus, when a proxy device selects just one upstream interface from the candidate upstream interfaces per channel, it is enabling load balancing capability for that channel. Alternatively, when a proxy device selects at the same time more than two upstream interfaces from the set of candidate upstream interfaces, it potentially receives duplicate (or redundant) packets for the same session / channel through the different selected upstream interfaces facilitating a robust data reception in this case. Finally, when a selected upstream interface is going down or the state of the link attached to such interface is inactive, one of the other active candidate upstream interfaces can take over the upstream interface with problems.

IV. Challenges

Having multiple upstream interfaces creates a new decision space for delivering the proper multicast content to the subscriber. Basically it is now possible to implement sophisticated decision criteria for the delivery of the multicast traffic, for instance based on the channel to be distributed or the subscriber requisting a given content. Then, the selection of the upstream interface will be performed according to mechanisms or policies that could be defined during the multicast service provisioning.

Each of these options have different implications on the technical realization of the IGMP/MLD proxy. Existing proxy implementations are limited to a single upstream interface. The proxy now requires to implement some logic for the decision as well as some capabilities to maintain the status of the traffic per interface, both upstream and downstream. This can impose limitations which are necessary to be addressed.

All these possibilities open a new problem space to be investigated for the development of efficient content delivery solutions.

V. Solution prospection

In this section we introduce a potential solution for developing functional IGMP/MLD proxies with multiple upstream interfaces. The objective is to receive multicast sessions or channels through the different upstream interfaces. The solution proposed consists on the usage of a mechanism for selecting the upstream interfaces to be used, as well as the configuration of the potential upstream interfaces to assists on the decision of selection.

The mechanism is configured with either "channel-based upstream selection" or "subscriber-based upstream selection", or even both of them. Regarding the targeted upstream, the proxy device will present a number of candidate upstream interfaces from where to select one or more as upstream interfaces. The selection is performed considering as decision criteria the following parameters: "subscriber address prefix", "channel/session ID", and "interface priority value".

A. *Mechanism for selecting upstream interfaces*

Two basic mechanisms can be in place.

1) Channel-based upstream selection.

In this option of channel-based upstream selection, an IGMP/MLD proxy device selects one or multiple upstream interfaces from the candidate upstream interfaces in a per channel fashion, based on the configuration of some identifiers for the channel or session.

2) Subscriber-based upstream selection.

Alternatively, in this options of subscriber-based upstream selection, the IGMP/MLD proxy device selects one or multiple upstream interfaces from the candidate upstream interfaces according to the subscriber requesting the content. Essentially, it bases the decision on the subscriber address prefix.

B. *Configuration of the candidate upstream interfaces*

The configuration of the following parameters have to be taken into consideration.

1) Address prefix configuration

An IGMP/MLD proxy device can be configured with the "subscriber address prefix" and the "channel ID" for each of the candidate upstream interfaces. The channel ID consists of both the "source address prefix" and "multicast group address prefix".

Once all of this configuration applies, a proxy can decide to select an upstream interface from its candidate upstream interfaces based on the configuration such three-tuple: subscriber, source and multicast group address prefixes (the last two forming what has been previously called channel ID).

An additional tool for prioritizing different rules could apply playing with how specific is the prefix provided during configuration. For instance, the candidate upstream interface having the configuration of an explicit subscriber address prefix is prioritized. On the contrary, if the network operator wants to assign a specific upstream interface for specific subscribers without depending on source and multicast address prefixes, both source and multicast addresses in the address prefix record have to be configured as "null". Similarly, if the network operator wants to select specific upstream interface without depending on subscriber address prefix, the subscriber address prefix in the address prefix record has to be configured as "null".

All of this provides great flexibility to adapt the network to specific needs in each moment.

2) Channel ID

The configuration of the channel ID consists of the specification of both source and multicast group address prefixes.

In the same way as before, the more explicit the address prefix, the higher priority will apply on selecting a given upstream interface. For example, a candidate upstream interface having non-null source and multicast group address configuration is prioritized for the upstream interface selection. Thus, if a proxy device has two candidate upstream interfaces for the same multicast group address prefix but one of them has a non-null source address configuration, then that candidate upstream interface will be selected for the source and multicast address pair.

Furthermore, in the proposed solution, the source address prefix configuration will take priority over the multicast group address prefix configuration.

3) Interface Priority

The same address prefix may be configured on different candidate upstream interfaces. When the same address prefix is configured on different candidate upstream interfaces, the upstream interface selected for that address prefix will be based on particular interface priority values.

In these conditions, the candidate upstream interface with the highest priority is chosen as the upstream interface.

C. *Multiple Upstream Interface Selection for Robust Data Reception.*

When more than one candidate upstream interface are configured with the same source and multicast addresses for the "channel IDs", and "interface priority values" are identical, these candidate upstream interfaces jointly act as the upstream interfaces for the channels and receive the packets simultaneously. This multiple upstream interface selection produces duplicate packet reception from redundant paths. It may improve data reception quality or robustness for a given channel, as the same multicast data packets can come from different upstream interfaces at the same time.

However, it is worthy to note that this robust data reception does not guarantee that the packets come from totally disjoint paths. It only ensures that the adjacent upstream routers are different.

VI. CONCLUDING REMARKS AND NEXT STEPS

This paper presents a number of realistic use cases that support the need of extending existing IGMP/MLD proxy functionality by enabling the possibility of having more than one upstream interface in the device. Originally defined for supporting just one single interface, the aforementioned use cases shown the benefits of implementing the support of multiple upstream.

In order to advance in addressing this problem in the standardization fora, the authors have been working on a document in IETF describing such use cases and deriving from them a number of requirements that a potential solution should comply with. Those requirements can be found in [7].

Due the relevance of the topic and the need of having a common approach from the industry, the next steps include the proposal of the described solution to IETF for progressing on the normalization of the solution. Experimental implementations are expected to accompany the specification process to refine the solution and to validate the concept.

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