A Central-Controllable and Secure Multicast System for Universal Identifier Network

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Abstract

In recent years, many institutes and organizations have been made efforts into developing new network architecture. Universal Identifier Network(UIN) is one of them which is designed to provide better mobility, better security and better reliability. Multicast is the basic network layer service that is designed to save bandwidth for the whole network. The deployment of existing multicast scheme is restricted because of low security and the lack of control in sources. In this paper we have designed a central-controllable and secure multicast(CCSM) system for UIN that aims to achieve better security and scalability. We design the group management protocol and multicast routing protocol. The former one restricts the group members' joining with authentication and the latter one provides a secure way to install multicast entries on routers. We evaluate CCSM by comparing it with PIM-SM, and the results show that CCSM is more secure and reduces the multicast flow entries for the whole network.

Keywords: Universal Identifier Network, Multicast, SPT, Intensive Calculation

1 Introduction

The Internet that we are using was designed over nearly 50 years ago when people was not able to imagine what it was going to grow into and how broad it could become. With more and more services and applications provided in the Internet, today we have discovered and identified the shortcomings of traditional Internet[13], such as low security, poor mobility and high energy consumption. Many work has been done to alleviate these problems. However, these additional options can not completely resolve these problems but make the Internet more and more complicated.

Thus researchers would like to go another way, which is desgning a whole new network architecture. There are many institutions and organizations working on this area, such as ICN[12], DCNA[9], SCN[14] and so on[8][7]. Universal Identifier Network(UIN) is one of them[2], whose biggest feature is Identifier/Locator Separation mechanism. Figure1 is the simplified model of UIN, which is composed by two main levels of network, the Core Network and the Access Network. The Core Network is composed by network devices and its topology is stabilized. While the Access Network is designed to handle massive access of isomeric users. In this way, massive changes are limited in Access Networks and the changes that could happen in the Core Network are greatly reduced. The two levels of network uses two different kinds of identities(that is the same concept of IP address in Internet), which are the Router Identity(RID) in the Core Network and the Access Identity(AID) in Access Networks. When the packets are transmitted from Access Networks to the Core Network, the Access Switch Router(ASR) would encapsulate the RIDs in the head of the packets, which would be recognized by router in the Core Network

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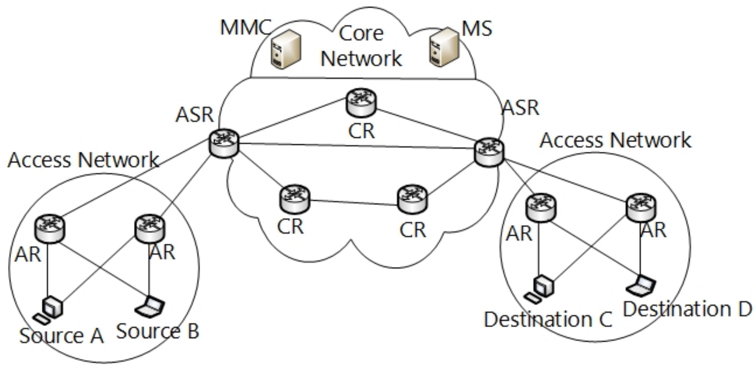

Figure 1: simple model of UIN

for transmitting. The routers in the Core Network are called Core Router(CR) and routers in Access Network are called Access Router(AR).

As for multicast, the essence of multicast is to deliver the same content from one or more sources to a group of destinations. It was designed to save bandwidth consumption of the whole network. What's more, the bandwidth benefit that the source could gain from multicast is huge, mostly from O(n)(n is the number of destinations in one multicast group) to O(1). The bandwidth stress is spread over the routers on the forwarding paths. The most popular multicast scheme is PIM-SM[3] in the traditional Internet. It is open to access, because sources have no control of destinations' access. That's fatal insecurely for the content providers and the routers in the network. It uses shared tree and shortest-path tree to forward packets. The frowarding trees are constructed distributedly, which is inferior to the computation-intensive trees like steiner tree[5][6]. Another shortcoming of PIM-SM is that multicast entries are installed in routers without authentication. Too many multicast entries could consume limited memory.

In this paper, we design a central-controllable and secure multicast(CCSM) system for UIN. The system architecture is given in Figure1. We define a multicast management center(MMC) as the central controller of multicast service. In practice, we shall deploy many MMCs in order for handling high availability and high concurrency. MMC mainly takes two responsibilities: manage the group members and calculate forwarding paths. In order to manage group members, we design the group manangement protocol. In order to distribute multicast routing entries, we first calculate the multicast forwarding SPTs and then send routing information to the relevant routers. The calculation and distribution of SPT is supported by the routing protocol. The size of Core Network is the main factor that influences calculation performance. Luckily, the Core Network is designed to be much smaller than the whole network, so the calculation time is greatly reduced and intensive calculation is feasible.

2 Related work

There are limited work that has been done in UIN up to now. As for multicast, the work that we can refer to is even fewer. However, the Core Network of UIN has much in common with Software Defined Network(SDN) which has been contributed by a lot of researchers. For example, they both deploy central controllers or management centers that provide services for routers. The controller of SDN could acquire the full topology of routers in his network. While MMC could acquire the full topology of the Core Network as well. They both support installing routing tables for routers.

Research on SDN is springing up in recent years. It is wise to study these works. Tim Humernbrum and his team proposed a simple but outstanding multicast scheme for SDN that could give the source full control over group members[4]. In the meantime, they developed algorithms for calculating multicast forwarding trees based on Branch-Aware Modification and Early Branching algorithms together. They achived the maximal reusing unicast flow table entries. This could reduce the utilization of memory than usual multicast algorithms but could not minimize the total consumption of bandwidth. Shan-Hsiang Shen and his team proposed a reliable multicast tree called Recover-aware Steiner Tree(RST) for SDN[10]. But RST is NP-hard problem so they accomplish an approximate algorithm called Recover Aware Edge Reduction Algorithm(RAERA). This paper taked recovery nodes into consideration, which could reduce number of the total retransmitted packets and the overall latency that users would experience. This is an excellent idea for stream providers. But Internet operators should think over the deployment of recovery nodes, it could increase the number of status on routers and cause the performance reduction of other service. Jeremias Blendin and his team[1] considered from the perspective of Internet Service Providers(ISPs). And they found that the approaches that had been proposed keep state at every network equipment. They proposed a new approach named Adaptive Software Defined Multicast(ASDM). ASDM helps ISPs to dynamically adjust the tradeoff between bandwidth and state for all multicast service. The experiment results show that ASDM could reduce up to 30% bandwidth consumption compared to unicast while only a seventh of network state of multicast is used. This scheme could alleviate the server load a little for ISPs but is not a revolutionary improvement.

Many papers are working on the construction of multicast forwarding tree in order to achieve the goal of minimum cost of bandwidth. In our multicast scheme, we build the Shortest-Path Tree intensively in the Core Network in MMC. The topology is updated once in a fixed time so that SPT could always be efficient. We set a root router for a multicast group so that all sources in one group could reuse the SPT because the calculation of SPT is high-cost. We try to reduce the calculation times of SPT as much as possible. All routers in the Core Network would support the multicast scheme so that MMC could install the multicast forwarding entries in them.

3 System Design

The CCSM we proposed is mainly composed by three parts: registration, member's join/leave and SPT generation. Registration is conducted first and then join procedure. Every time one member join in, MMC needs to calculate the forwarding path for it.

3.1 Registration

If anyone in UIN wants to provide service through multicast, he has to register in MMC and MMC starts the acounting for it. Then MMC replies to source a multicast address and a token for secure issue. If the destinations want to consume such service, he has to request to source for permission. The source replies to destinations telling them the multicast address and token. Then destinations could register to MMC with multicast address and token. MMC maintain the tokens corresponding to certain multicast address so he could tell whether one destination is legitimate. Figure2 shows the registration procedure.

In single-source multicast, the only source execute all the priviledges. He registers in MMC, authorizes the destinations and sends multicast data. While in multi-source multicast, only one router could execute all the priviledges, named primary source. The other sources' priviledges are authorized by the primary source.

In this way, we could have a full control over the group members and multi-source group could be organized centrally. The token is used in Join/Leave procedure to assure that legitimate users are taken in while illegitimate users will be declined.

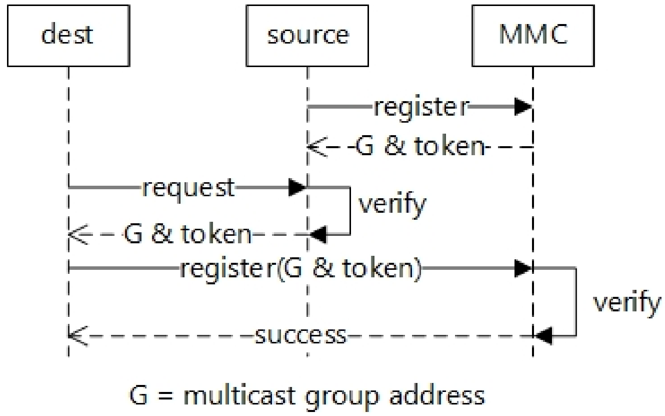

Figure 2: Registration procedure

3.2 Member Join/Leave Procedure

Members are all in Access Networks. When one wants to join a multicast group, he needs to send join message with multicast group address and matched token to his ASR. Then ASR transfers this request to MMC to check if he has registered in this group. If yes, the ASR then checks if there is already other group members in this Access Network. Only If there hasn't a member joined such multicast group in the Access Network, ASR would send to MMC join message with multicast address, user address and token. If there has members joined such multicast group, ASR would not send join request to MMC. Figure3 shows the procedure of member join/leave.

The users can not send join request to MMC directly. He has to let his ASR be agent. In this way MMC could calculate SPT of the Core Network according to ASRs of members. In the meantime ASR would generate the SPT for it in Access Network.

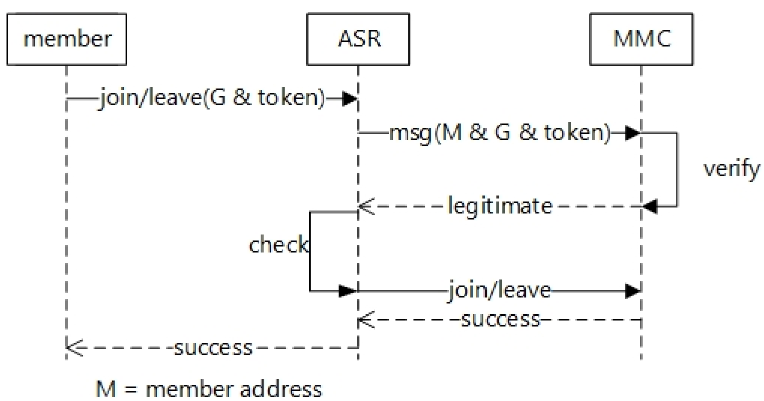

Figure 3: Member join/leave procedure

3.3 SPT Generation

SPT is the forwarding paths of multicast from root to all ASRs that have joined one group. The calculation of SPT is executed in MMC. We need full topology of the Core Network and elected roots as preconditions. In the beginning of CCSM system, topology acquiring and roots election need to be done, and they are excuted once in a fixed time to ensure the topology and roots election are up to date. Figure4 shows the overview procedure of MMC.

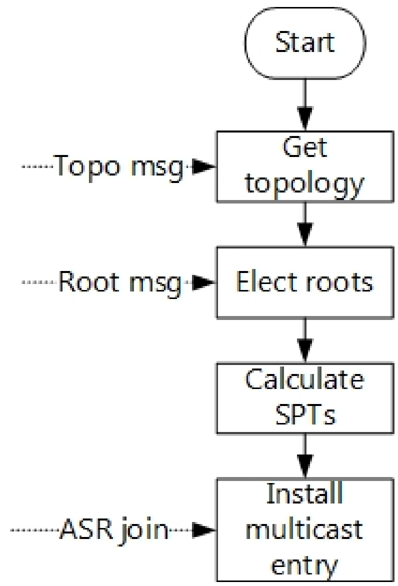

Figure 4: Overview procedure of MMC

3.3.1 Full Topology and Root Election

Acquiring topology is conducted at the beginning of CCSM system. When a new CR/ASR joins in the Core Network which are infrequent or one CR crashes, acquiring topology is triggered to inform MMC the change. Root election is conducted before SPT calculation. During the transmitting of multicast packets the sources first send packets to root, then root transmits the packets along the paths. There can not be only one root in the Core Network because the traffic is too heavy. The plan is that all routers report to MMC periodically about their priority, which is calculated according to location, bandwidth, performance of machine and so on. Then MMC chooses one router with the biggest priority for one multicast group.

3.3.2 Path Calculation

Only when acquiring full topology and root election are finished, SPT calculation could conduct. The calculation isn't conducted when a new group is going to serve. That is too late. Since we allocate the roots for multicast groups, we could conduct the calculation long before the source starts to serve. In fact, we could select several roots and calculate the SPTs to every ASR and store these SPTs. In this way, we could greatly reduce the time cost when constructing paths for multicast groups. We implement the calculation with dijstra algorithm[11]. The topology acquiring procedure could help us have a more detailed and real-time reference value of all edges. That's what the distributed calculation can't achieve.

After calculating the paths, MMC sends the multicast routing entries to routers on the paths. Only MMCs have this authority, unlike PIM-SM. Entries installation is very crucial because too many entries may run out of the memory of routers, causing paralysis.

In the Access Network, SPT is calculated distributedly. The main reason is that the topology of Access Network is unstable. If we calculate SPTs intensively, frequent topology changes could lead to frequent calculations of SPTs, which is a great cost and could lead to the performance reduction of ASRs. So the way of SPT construction in Access Network is quite the same to the way PIM-SM[3] implements.

4 Evaluation

In this section, we evaluate CCSM in terms of scalability and compare it with the traditional multicast. Since the main difference between CCSM and traditional multicast networks is in the Core Network. We analyzed the amount of multicast flow entries that CCSM and traditional multicast would install in the Core Network.

4.1 Simulation Scenario

We compare CCSM with PIM-SM. Unlike PIM-SM, CCSM achieve load balance through dynamic root election in the Core Network, so it is advocated to install (*,G) entries for multicast group without concerning that roots are overloaded. While PIM-SM needs to convert Shared Tree(ST) to SPT to reduce the load on roots. Therefore the entries install in routers is (S, G). In multi-source groups, CCSM only needs to construct one SPT while PIM-SM needs to construct SPTs as many as the number of sources. We chose the Fat-Tree topology which is a extensively used in datacenters, industrial and campus networks. Figure depicts our 3-ary Fat-Tree topology. C0 - Cd represents CRs while S0 - Sb represents ASRs.

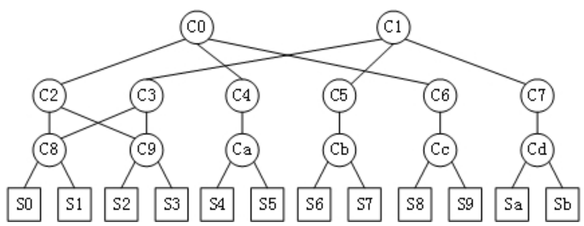

Figure 5: Topology used for experiment

4.1.1 The impact of source number

To evaluate the impact of source number. We set S1,S3,S5,S7,S9,Sb as destinations. The source sets areS0, S0,S2, S0,S2,S4, S0,S2,S4,S6, S0,S2,S4,S6,S8, S0,S2,S4,S6,S8,Sa respectively. Figure6 shows the total multicast flow entries that CCSM and PIM-SM that would install for one multicast group as the number of sources changes. We can get that as the number of sources grows, the multicast flow entries that PIM-SM installs increases almost linearly at a bigger rate than CCSM. As the number grows, the gap between two lines are larger and larger. So CCSM outperforms PIM-SM in multi-source multicast in terms of scalability.

4.1.2 The impact of group number

To evaluate the scalability of CCSM in terms of the group number. We suppose that the sources number of group ranges from 1 to 6 in an equal probability. The destinations and source sets are the same to 4.1.1. Figure7 shows the total multicast flow entries that CCSM and PIM-SM would install for all groups in the whole test network respectively. We can get that with the increase of group number, the installed multicast flow entries increases as well. However, it is obvious to see that the entries installed by CCSM is less than PIM-SM. That is mainly because CCSM installs less multicast flow entries for every multi-source group.

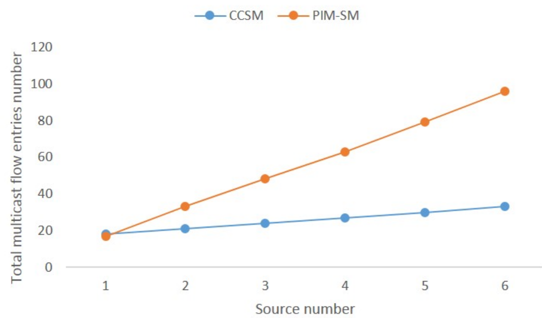

Figure 6: Total number of multicast flow entries vs source number

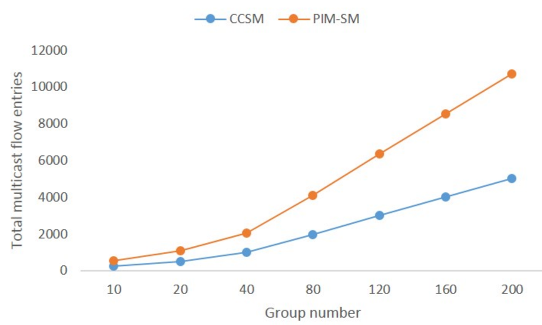

Figure 7: Total number of flow entries vs group number

5 Conclusion

In this paper, we proposed a central-controllable and secure multicast system for UIN to overcome the low security and reliability of traditional muticast. The proposed CCSM system demands all members to register in MMC first and then calculate multicast forwarding paths for legitimate members. This enables MMC to distinguish legitimate members from illegitimate members. The root election scheme enbales us to reuse one SPT in multi-source groups. We prefer to install (*, G) multicast flow entries than (S, G) for the shared SPT. So compared to PIM-SM, CCSM greately reduces the total number of multicast flow entries in the whole network. We could conclude that CCSM outperforms PIM-SM in scalability.

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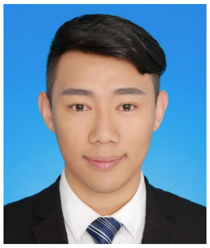

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