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Scalable ID-Based Communication

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Abstract. The philosophy behind the ID and locator separation is that an identity must be used for denoting a communication entity and must be independent from the topological location of the entity. While the ID and locator separation provides a sound solution to mobility and handling topology changes, which cannot be solved inherently by the current Internet, its benefits are overshadowed by the routing scalability since the IDs cannot be aggregated. Unlike the traditional Internet that deals with the scalability issue at the address-level by aggregating IP addresses in the headers of the IP packets, we solve the scalability issues by structuring the network with hierarchically organized domains. In this paper, we present a highly scalable ID-based communication scheme, ID based route computation, and ID based forwarding under the framework of our architecture, ID-based networking Architecture (IDNet).

Keywords: Future Internet, Inter-domain routing, ID-based routing, ID-Based communication

1 Introduction

The original Internet architecture is based on several principles, such as narrow waist layers of UDP and TCP over IP, often called the hour-glass model, end-to-end principle, global routability, and a single address space of IP address that play the role of both locators and host identifiers at the same time. These principles are suitable for static and well-managed flat network topology. As the Internet evolved from a small research network to a worldwide information network, a growing diversity of commercial, social, ethnic, and government interests led to a revision of the Internet architecture, so called “clean slate” approach.

One of the innovative trends in the future Internet is the separation of identity and locator, which says the identity must be used to denote a communicating entity and must be independent from the topological location of the entity. While topological addressing as in the current Internet solves the routing scalability by aggregating topologically adjacent addresses into a single unit, it may generate serious problems in case of mobility or topology changes. Location independent ID, which can solve the above problems, however, is severely limited by routing scalability.

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This paper focuses on how to build a scalable ID-based communication scheme, which is defined in ID-based networking architecture. The scheme consists of three major components: how to map an ID onto locator(s), how to compute routes to the entity with that ID, and how to forward the packet.

This paper is organized as follows: Section 2 discusses the related works. Section 3 introduces our proposal for a scalable ID-based communication. A brief introduction to our prototype implementation of scalable ID-based communication is given in Section 4. Finally, this paper is concluded in Section 5.

2 Related Works

The biggest and the most immediate concerns in the current Internet are the scalability and security issues. With growth in the number of devices that are connected to the Internet, it becomes difficult to cope with the exponential growth of their routing table size (entry explosion problem), size of network graph representing the topology, and the number of topology update messages (routing scalability). The topologically dependent assignment of IP addresses is useful in fixed network environment and when provider assigns IP addresses. However, increasing requirements for mobility and multi-homing expose the limitation of address based routing - routing and forwarding are based on location dependent IP addresses.

The routing scalability is mitigated by dividing the Internet into set of Autonomous Systems (AS), where non-scalable routing protocols such as OSPF and IS-IS are used only within an AS and additional inter-AS routing protocol are used to stitch the ASes. The de facto inter-AS routing protocol of the current Internet, BGP, takes in the order of minutes to re-converge from topology change or link failure.

All the issues mentioned above are hardly resolved by the patch solutions that are implemented on the present Internet's routing and forwarding scheme.

3 Scalable ID-Based communication

Our ID-based communication uses the approach "get closer to the destination and ask for directions again" approach. This is one of the most frequently used approaches in real life, such as when a person is trying to visit a place he does not know or how mails are processed in the post offices. The goal of routing is to reduce the problem space of routing until the destination is found. In this section, we present a scalable ID routing architecture.

3.1 Inter-Domain Routing

Our routing architecture is composed of two phases - building a global topology database and computing the routing table based on the database. In this paper, we primarily focus on the former problem, building a global topology database, and just briefly point out an interesting point regarding the latter problem.

Building a global topology database to compute the routing table is not a new concept and is widely used in protocols, such as OSPF. However, its use is severely limited to small networks due to its limited scalability. Although our inter-domain routing is based on building a global topology database, to make it scalable, we introduce a graph reduction method that we call fish-eye graph reduction, which significantly reduces the size of the network topology graph.

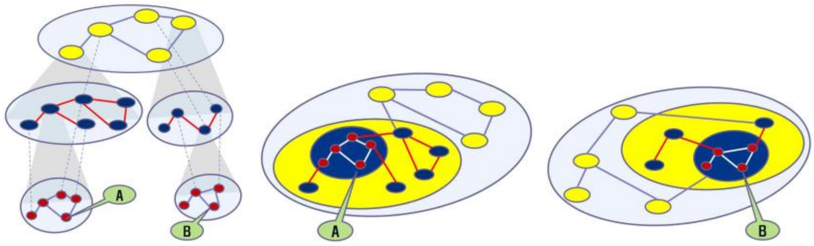
3.1.1 Fish-eye Graph Reduction

The term "fish-eye" routing [5] was initially proposed in mobile ad-hoc networks to reduce size of the update message by having closer nodes send more frequent update message than distant nodes. And, this naturally leads to a fish-eye view for each node - a more accurate view of the closer nodes and a less accurate view of the distant nodes.

In our architecture, we use a similar concept in that a given node has a detailed and fine topological view of the nodes in its domain and has a distant and course view of the nodes outside of the domain. Although the concept of fish-eye is similar its construction is completely different.

The definition of fish-eye graph reduction is given in Definition 1.

Definition 1. Fish-eye graph reduction is a graph reduction made from the perspective of node X in domain D such that the reduced graph consists of the nodes in domain D including node X and the lowest common ancestor domains of node X and nodes that do not belong to domain D.



(a) (b) (c)

Fig. 1. Topology Graphs (a) complete topology graph (b) reduced graph from A's perspective (c) reduced graph from B's perspective

An example of the fish-eye graph reduction is shown in Figure 1. Figure 1(a) shows the domain hierarchy and how the topology graph would look like if no reduction were applied. Figure 1(b) shows the reduced topology graph from node A's perspective and Figure 1(c) shows the reduced graph from node B's perspective. Note that since the graph reduction is performed from each node's perspective, nodes in different domains would have a different topology graph.

For a network with N nodes, the full topology graph would have O(N) vertices. However, assuming the N nodes are placed into a domain hierarchy that has d child domains for each domain, the reduced topology graph would have O(d*logN) vertices, which is a significant reduction.

The fish-eye reduced graph topology can be created accomplished using a link state advertisement with simple filtering rules based on the tier number by the gateway of each domain. To a domain in tier n-1, the gateway blocks the link state advertisements at tier n, instead the domain ID that the gateway is part of is advertised. To the peer domain in tier n, the link state advertisements from other peers of tier n are forwarded. In addition, the gateway injects the link state advertisements from tier n-1. To tier n+1, every link state advertisements from the domains in tier n-1 and tier n is forwarded. This mechanism is illustrated in Figure 2.

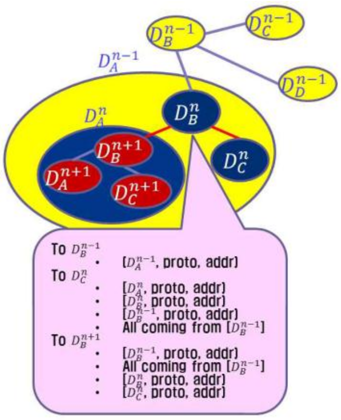


Fig. 2. Hierarchical structuring of Domains and an example of link state advertisements filtering at the gateway of domain D^n_B of tier n

Once a node obtains its own fish-eye graph of the topology, it needs to fill in the routing table. Although the algorithms for filling in the routing table is out of scope of this paper, one interesting feature is that not only the edges but also the vertices can have weights, such as latency, because some of the vertices in this topology graph is represents a domain, not a single node, and there may be a cost associated with traversing that domain.

3.2 Forwarding

Unlike the traditional IP network, where the aggregation of the IP addresses leads to a compact forwarding table, a compact forwarding table cannot be created for ID based communication since IDs cannot be aggregated. Also since the forwarding table is often implemented using expensive SRAMs for performance reasons, a large forwarding table is not desirable. Hence, the forwarding table entry explosion problem must be addressed for ID-based communications.

In our view, the only way to minimize the forwarding table entry in ID-based communication is to use reactive routing. However, this is not the only reason to use the reactive forwarding. Because the forwarding path determined at the time of sending a packet, a lot of flexibility can be incorporated into the forwarding path computation. This is especially import in supporting multi-homing, late-binding, and mobility. Of course, some forwarding paths, such as time-constraint paths, can be determined a priori as well.

3.2.1 Core Features

Since an ID itself does not contain any locator information, we proposed the IMS system for finding the locator information associated with the ID[6],[7]. However, even with the locator and the routing table, an actual path from the source to the destination is yet to be defined. For this purpose, we define a method called path discovery, which is explained in the next section.

3.2.2 Path Discovery

Once the locator for the destination ID is found, the next task is to set up the forwarding path between the source ID and the destination ID. The purpose of the path discovery process is to compute the next hop address at each gateway that lies in the forwarding path.

The heart of the path computation is the longest prefix math between the locator and the routing table. The next hop address information of the entry that produces the largest number of domain ID match against the locator is selected, and the destination ID and next hop address pair is installed into the forwarding cache.

At the beginning of the path discovery, the source node performs the longest prefix match using the locator of the destination ID and its routing table. After caching the destination ID and the obtained next hop address pair, the source node forwards the path discovery request to the next hop address, which should be one of the gateways of the domain. Then, similarly to the source node, the gateway computes the next hop address, installs it into its cache and forwards the path discovery request to the gateway that the next hop address belongs to. This process is repeated until the destination node is reached.

Once the path discovery is complete, the forwarding path between the source node and the destination node is completely configured, and the two nodes can communicate with each other.

4 Implementation

Currently, we have implemented a prototype to verify the feasibility and the scalability of our architecture [7]. At the time of writing this paper, the ID socket based packet exchange, IMS system, and the path discovery based on locators and static inter-domain routing tables have been implemented. And, we have implemented the fish-eye topology graph reduction based on the link state advertisement filtering as described in Section 3. Our implementation is accessible at http://www.idnet.re.kr/ [6].

5 Conclusion

Most of the traditional network architectures have been based on functional layering that decomposes complex communication tasks into vertical stack of protocols. Layering architecture, however, may add unnecessary complexity to the system, and may cause scalability and inter-layer dependency problems. Meanwhile, network architects often view a network as a collection of autonomous network segments. Consequently, we provides architectural framework for not only system designer but also network architects.

For scalable routing based on location-independent and flat ID, we proposes the innovative "fish-eye topology reduction" technique which utilizes hierarchically structured domains. This reduction makes it possible to represent the global scale Internet as a computable network graph size. From the reduced topology with different granularity in the view of each gateway, the routing table can be computed.

As the traditional Internet has been taking a role of communication infrastructure in global scale, the future Internet also must be global infrastructure. In this sense, architectural framework that can be shared by diverse research areas in future Internet is strongly required. We hope ID-based communication would be one of alternatives to provide simple and powerful framework for structuring the networks as well as developing individual communication systems.

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