Dynamic Tunnel Configuration for Network with Uni-Directional Link

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Abstract

In this paper, dynamic tunnel configuration scheme is designed and implemented. This scheme makes virtual return path for unidirectional link in the network consisted of unidirectional and bidirectional links. This mechanism is implemented by IP tunneling.

In the network which includes unidirectional link, current dynamic routing mechanism can not use unidirectional link. To solve this problem, tunneling scheme is proposed by several researchers. In the proposed scheme, return path corresponding to the unidirectional link is constructed by tunnel within the bidirectional link network. However, current proposal is based on static configuration for tunnels. It does not provide scalability.

This paper proposes dynamic tunnel configuration scheme by utilizing both of unidirectional and bidirectional link. Furthermore, data link address resolution is handled by dynamic IP address assignment to receiving nodes.

Proposed scheme improves scalability of network configuration including unidirectional links.

1 Introduction

As Internet grows, the number of users increases dramatically. These end users are using low speed and cheaper connection such as analogue modems, ISDN circuits, and low speed leased lines. These lines provides cheap connectivity to the small office or home. However, connection bandwidth is low speed such as 56kbps to 128kbps. Many users use the Internet as information retrieving tool. For example, World Wide Web is used generally. As a result, traffic from backbone to users or downstream is bigger than the traffic from user to backbone or upstream. Almost of the existing Internet communication path are symmetric ones. So, well adapted network configuration to this traffic trend is difficult.

In the other hand, communication infrastructure of wider bandwidth and connectivity to the ordinary users are concerned. Cable television channel(CATV) or satellite communication channel provides wider bandwidth and asymmetrical links. These types of links are referred as unidirectional links.

However, Deployment of these types of links in the Internet has some unresolved problems. These problems are routing, datalink layer address announcement, and IP address assignment.

About routing problems, there are several researches. One research modifies current routing protocol such as OSPF and RIP to adapt unidirectional links.[1] [2] Another research realizes return path of unidirectional link with tunneling[3]. IP address translation scheme is also proposed[4]. Routing protocol modification method and tunneling method has scalability problem. Address translation method does not satisfy security requirement such as protecting source address spoofing. Data link address advertisement and IP address assignment are not resolved in these schemes.

In this paper, expanding method of unidirectional link use is proposed. Proposed scheme deploys dynamic tunneling method to resolve scalability problem. Furthermore, datalink layer address resolution scheme and IP address assignment method are also introduced to resolve these problems.

In section 2, problems about unidirectional link deployment in the Internet are summarized. In section 3, proposed scheme is described. In section 4, design of proposed scheme is discussed. In section 5, implementation detail is described. Section 6 evaluates this scheme. Section 7 summaries this work and describes future work.

2 Current problem of unidirectional link

In this section, problems of deploying unidirectional link in the Internet. Unidirectional links are classified to two types. These are point to point type and broadcast type. Point to point type connects one transmitting or originating node and one receiving node. broadcast type provides communication from one transmitting node or feeder to multiple receiving nodes. In this paper, broadcast type is discussed, because of CATV and satellite communication channel provide broadcast type unidirectional links.

2.1 Routing problem

Current Internet routing algorithm are designed based on bidirectionality of communication path. Basically, routing in the Internet is depend on routing information exchange between neighbor routers. For example, the situation that routers are connected via unidirectional link is discussed. Via unidirectional link, sender can not receive routing information from receiver. Because of thir reason, the router of receiver side can not advertise itself to the router of sender side. So, ther router of sender side can not know nor detect the route to receiving routers or networks via receiving routers. Therefore, This unidirectional link is not used as communication path. To use this communication path as ordinary route, tunneling scheme that provides return path from receiver side to sender side is proposed.

However, proposed schemes use static tunneling configuration, it has scalability problem. It seems to be many receiver connect to unidirectional link such as CATV or satellite. So, configuring tunnel statistically by hand is not realistic method. To deploy unidirectional link, dynamic configuration tunnel is

required.

2.2 datalink layer address resolution

To use broadcast type communication channel, the sender node need to know the datalink layer address or MAC address to specify end point of communication path. On the Ethernet, ARP[5](Address Resolution Protocol) is used to discover the end point address. ARP broadcasts request for datalink layer address resolution before real communication. Corresponding end node replys this request. On the unidirectional link, end node can not respond the request via unidirectional link. Therefore, sender node can not resolve datalink address with conventional ARP method.

To use unidirectional links, a scheme is required to get the end node datalink layer address .

2.3 IP address assignment

Recently, IP address space shortage or exhaust get bigger problem. On unidirectional links, a lot of users or receivers are expected to connect. A lot of IP addresses are required to make static IP address assignment to all of these receivers,

If dynamic IP address assignment scheme is available, a receiver can releases used IP address after its use. This scheme improves not only efficiency of IP address usage, but scalability of unidirectional link deployment.

3 Dynamic Tunneling Scheme

In this section, dynamic tunneling configuration scheme, datalink layer address notification, and dynamic IP address assignment scheme are propsed. These methods solve problems described in section 1. This scheme is based on message exchanges between senders and receivers on a unidirectional link. Exchanged packets are transferred through both of UDL and BDL.

3.1 Dynamic Tunnel Configuration

Tunneling function provides a datalink layer tunnel from a receiver to a sender on UDL. This tunnel is configured and released dynamically according to UDL events. UDL events consist of joining and leaving of a receiver, link down or outage of unidirectional link.

3.2 Data link address notification

Datalink address notification mechanism enables sender node on UDL know the datalink layer address of the receiving node. There are two types of datalink address resolution method. One is requesting the address when a node is to send the packet. Ethernet ARP is an example of this type of address resolution. This method is called "On demand type". The other type registers datalink address of receiver to the sender before communication. A sender constructs a mapping table between IP addresses and datalink addresses of receivers. This method is called "Pre registered type". On a short delay link, on demand type is better than pre registered type. An on demand type is easily implemented, because it does not have to maintain ARP table. On a long delay link, resolving datalink address per packet degrades performance. Therefore, design of this paper uses pre registered type.

4 Design of dynamic tunneling scheme

In this section, we describe the design of dynamic tunneling scheme.

4.1 General description of design

This mechanism is based on message exchanges UDP message pakcets via UDL and BDL. This mechanism is parted sender side and receiver side program, both programs collaborate each other. Each programs have 2 modules, Virtual link module and control module. Virtual link module manipulates their tunnels and interfaces. Control module manages message

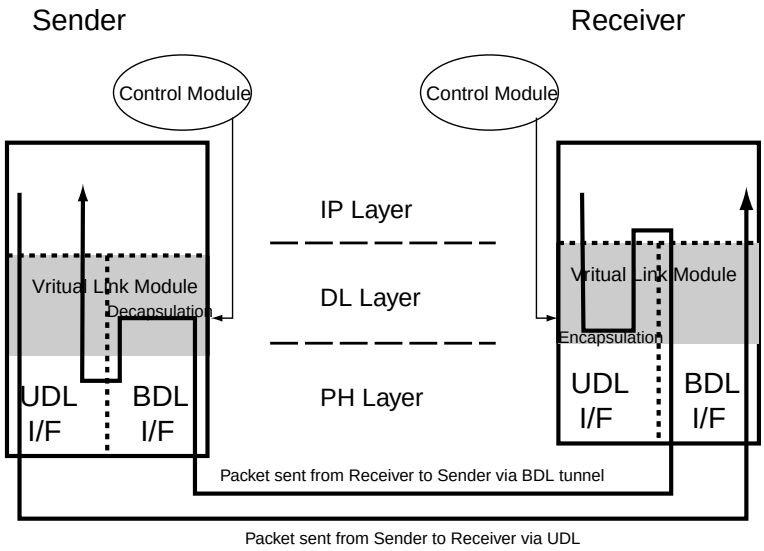

Figure 1: Module and Layer

exchange. We show the relationships of modules, physical layer, data link layer nad network layer in figure 1.

4.2 Virtual link module

A host on UDL has UDL interface and BDL interface. This module constructs entrance and exit point of tunnel, thus encapsulate and decapsulate the packet. This module configures tunnel and interface appropriately and provides bi-directional data link interface that is UDL with tunnel for upper layer. In sender module, this module decapsulate the tunneling packet received from BDL interface. In receiver module, this module encapsulate the pakcet should send via UDL and send to sender BDL interface via BDL.

4.3 Control module

Control module handles messages. Sender and receiver's control module exchange messages as UDP packet. Control module sets and releases tunnel, sets interface IP address, handles data link address, based on messages of UDL events. Messages have 2 types. One is uni-directional message on UDL. It is called "Notify message". Notify message is sent from UDL sender to receiver periodically. This message contains UDL sender's informations. Another is bi-directional message on BDL. It is called "Control message". Sender and receiver exchange request and reply commands. We show all kinds of Notify message in table 1, and Control message in table 2. And, the example of exchanging message in figure 2.

Table 1: Notify Message

Message type	Description
HELLO	Notify sender information periodlically. This message contains as follows: Sequence Number, Tunneling protocol, Sender BDL and UDL IP address, UDL netmask

5 Implementation

In this section, we describe the implementation of dynamic tunneling scheme.

We implemented this mechanism on FreeBSD 2.2.1-RELEASE. In our implementaion, we use BDL as Ethernet, and UDL as Ethernet with modified data link routine that could not send any packets. We adopt IP in IP

Table 2: Control Message

Message type	Description
REQUEST	Tunnel set up and IP address assignment Request. This message contains as follows: Sender UDL IP Address, Receiver UDL IP Address, Receiver data link type, address and length.
REPLY	Replying for REQUEST
REFRESH	Extending tunnel and IP Address lease time.
RELEASE	Terminating tunnel and IP Address use.

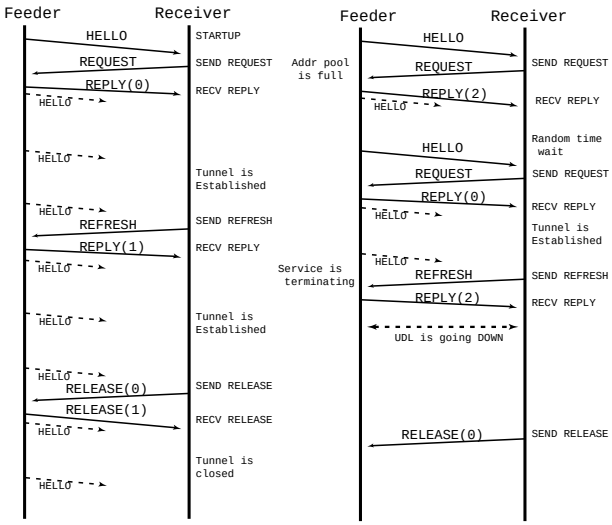

Figure 2: Example of exchanging message

Encapsulation[6] for tunneling protocol.

5.1 Implementation of virtual link module

Our implementation modified data link layer routine in Unix kernel. Modified kernel had host and interface infromations, BDL or UDL, and Sender or Receiver. These informations were manipulated by ioctl routine. In our implementation, UDL and BDL were Ethernet. So encapsulation function was implemented in ether_output, and decapsulation function was in ether_input at if_ethersbur.c. When the interface sent a packet, ip_input routine called ether_output routine. If the interface was set as receiver UDL interface, packet was passed encapsulation routine. The packet was encapsulated in this, so passed ip_input routine again. When the interface received a packet, kernel called ether_input routine. If the interface was set as sender BDL interface, packet was passed decapsulation routine. The apcket was decapsulated in this routine, and passed ether_input routine again. When the interface was set as sender UDL interface, this interface acted as send-only interface. All packets received from this interface were discarded. If this interface would send a packet, kernel didn't call arpresolv routine. Instead of this, kernel looked for mapping table between IP address and data link address, and got destination data link address. We describe mapping table afterward. When the interface was set as receiver UDL interface, this interface acted as receive-only interface. All packets this interface would sent were discarded.

5.2 Implementation of Control module

Control module was inplemented as user process appliacation. This program was running conformed parameters. Details of parameters are subscribed afterward. Control part sent and received UDP message packet, and manipulated virtual link part. Table 3 is details of parameters at the receiver. Table 4 is details of parameters at the sender. Sender module's control part retain mapping table between IP address and data link address.

This table is called "Virtual link information table". This table is composed as table 5. Details of each entries in this table, we describe in table 6.

Table 3: Receiver Parameters

udl-if	The name of UDL interface
bdl-if	The name of BDL interface used tunnel entrance
pseudo-ifaddr	Temporary IP address when start up
pseudo-netmask	Temporary netmask when start up
ref-border	Span of holding tunnel and assigned IP address
ta-timeout	Message exchanging timeout
udl-timeout	HELLO timeout
seq-threshold	Sender reset sequence number difference

Table 4: Sender Parameters

udl-if	The name of UDL interface
bdl-if	The name of BDL interface used tunnel exit
interval	HELLO message interval
leasetime	IP address and tunnel leasetime
ipaddr	IP address pool for receiver

Table 5: Virtual link information table

IP addr	Status	DL addr	Leasetime left
:	:	:	:

Table 6: Information tabel details

IP Address	Assigened receiver's IP address
Status	Receiver's status
DL Address	Receiver's data link address
Lease Time Left	IP address and tunnel leasetime left

6 Evaluation

We evaluated our implementation on experimental network in figure6. All hosts' OS were FreeBSD 2.2.1-RELEASE and running Gated revision 3.5Beta3.
We tested dynamic routing protocol on our implementation. We used RIP, and tested items as follows:

- UDL is used when UDL is up.
- UDL isn't used when UDL is down.

In figure6, set route configuration as table7.

Table 7: Route configuration

Host	Route configuration
Sender	UDL is metric 1 BDL is metric 1
Receiver1 Receiver2	UDL is metric 2 BDL is metric 1
Router	Both BDL are metric 1

Receiver's UDL IP address was assigned dynamically, by our mechanism.
When UDL was up, the result of 'traceroute' command at sender to Host1 was figure 8. According to the result, packet was routed UDL. On the other hand, when UDL was down, pakcet wasn't routed UDL. Figure 9 shows the result of traceroute command.

7 Conclusion

In this paper, we describe problems of network with unidirectional link. We mention dynamic routing, IP address assignment, and data link address resolution problem. And we describe dynamic tunnel configuration scheme for solving these problems. Dynamic tunnel configuration scheme is message base mechanism. This mechanism provides dynamic tennel configuration, dynamic IP address assignment, and data link address resolution scheme

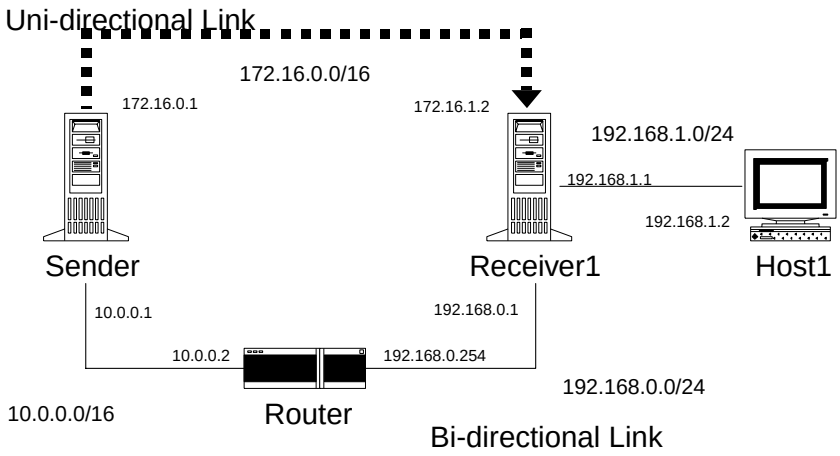

Figure 3: Experimental network topology

Table 8: Traceroute result when UDL is up

```
sender % traceroute host1
traceroute to host1.kirc.wide.ad.jp(192.168.1.2): 1-30 hops, 38 byte packets
 1  172.16.1.2 (172.16.1.2)  1.510 ms  1.068 ms  1.022 ms
 2  host1 (192.168.1.2)  1.929 ms  1.875 ms  1.776 ms
```

Table 9: Traceroute result when UDL is down

```
sender % traceroute host1
traceroute to host1.kirc.wide.ad.jp(192.168.1.2): 1-30 hops, 38 byte packets
 1  router (10.0.0.2)  1.004 ms  0.760 ms  0.699 ms
 2  receiver1 (192.168.0.1)  1.531 ms  1.284 ms  1.248 ms
 3  host1 (192.168.1.2)  2.163 ms  2.091 ms  1.998 ms
```

for UDL. We implement our mechanism, and evaluate it. We present usability of this scheme for the network with unidirectional link.
In this paper, we tested RIP only but current Internet uses many types of dynamic routing protocol. In the furture, we'll test other dynamic routing protocols. And we'll improve performance and scalability for practical use.

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