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SOCKS5-based Firewall Support For UDP-based Application

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Abstract

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SOCKS5-based Firewall Support For UDP-based Application

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At present, firewalls are mostly designed for outgoing traffic or for some well-known incoming application protocol such as http, ftp or smtp. But there is no generic way of accepting incoming UDP traffic via a firewall. This project aims to provide a generic mechanism for all UDP-based protocol to traverse through a firewall. The transport proxy protocol SOCKS5 model is adopted as the foundation for development.

To achieve this, an enhancement to the SOCKS5 protocol is proposed. This enhanced SOCKS5 protocol will support the establishment of incoming UDP association via a SOCKS5-based firewall. It will resolve the issues with the current SOCKS5 protocol support for incoming UDP traffic. The enhanced SOCKS5 protocol will also support the outgoing UDP traffic via the SOCKS5-based firewall. A prototype for the enhanced SOCKS5 protocol was implemented by using the existing source code for SOCKS5. The Real Time Streaming Protocol (RTSP) application, which is using UDP for delivering multimedia stream, is used to test the enhanced SOCKS5 protocol. The testing was found to be successful. This enhanced SOCKS5 protocol will provide secure traversal of all UDP traffic through the SOCKS5-based firewall which will be transparent to the applications layer.

Acknowledgement

My special thanks go to my supervisor Dr. Rocky K. C. Chang for his valuable guidance, ideas, comments and advice. I would also like to thank my co-examiner Dr. Jiannong Cao for his comments and advice. Lastly, I would like to express my gratefulness to my families for their support in my dissertation work.

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1. Introduction

1.1 Issues with UDP Traversal via Firewall

1.1.1 Dynamic Assignment of UDP Ports

At present, firewall provides packet filtering by means of the static configuration on the security rules. The security rules are in the form of source address - destination address pair and the application protocol . The application protocol defines the TCP or UDP destination port number used by the applications. For example, telnet protocol will use TCP port 23 and DNS protocol will use UDP port 53. With this type of static packet filtering rules, the firewall will support applications which are using well-known TCP or UDP destination ports for communications.

Recently, there is a growing demand in using dynamic UDP ports for communications over the internet. Both the source UDP address and the destination UDP address are assigned dynamically by the clients and the servers. One of the major categories of application, which makes heavy use of it, is the multimedia applications. Some of the popular applications like Real Audio Player by Real Networks, VDOLive by VDONet , Streamworks by Xing are using dynamic UDP port for sending multimedia stream to the clients. Other than that, there is an emerging multimedia communications protocol called Real Time Streaming Protocol (RTSP, Ref.1) which is using dynamic UDP port for sending multimedia stream.

Most of these multimedia applications assume there is a direct communication path between the client and the server. But with the growing issues of internet security, the servers and clients are usually separated by a firewall. As the UDP connection made from the server back to the client is using a dynamically assigned UDP port, the security rule in the firewall does not have in advance the UDP port number for the connection. The firewall could not perform the packet filtering for the dynamically assigned UDP port on the client and the server. Only the applications clients and the applications servers know about this dynamically assigned UDP port number as they communicate these information

through their application protocol. But there is no way for the applications clients to inform the firewall the dynamically assigned UDP port so that the firewall could adjust its security rules dynamically to allow the UDP traffic through that UDP port. So the UDP packet for the clients and the servers will be rejected by the firewall.

One workaround for this is to fix the destination UDP port to a particular UDP port. This is not scalable as multimedia applications may need a number of UDP ports for different media types. Moreover, the particular UDP port at the firewall will need to be always open up to permit incoming UDP traffic to each client which may run that particular applications. It will be insecure and difficult to be managed. Any source UDP address could send UDP traffic to the fixed destination UDP port. Real audio player is using this approach when it needs to work through a firewall. It uses a fixed destination UDP port for the incoming UDP stream.

The best approach is to have on-demand assignment & permission of UDP ports on the firewall based on the requirement of the multimedia applications. UDP ports will be assigned and open up in the firewall subject to the request by the applications running by the client. Once the clients do not need the UDP ports, the UDP ports assigned by the firewall will be closed and no more packets could go through those particular UDP ports. In addition to that, there should be a mechanism for the firewall to learn the source UDP address and the destination UDP address so that it could carry out the proper packet filtering for the UDP traffic.

1.1.2 Network Address Translation by the Firewall

Another issue posed by the existing firewall on the applications is the network address translation (NAT) performed by the firewall. Firewall usually hides the internal network from the Internet by means of network address translation (RFC 1631). The internal address of the client will be translated to the external address of the firewall when the packets go through the firewall. The applications servers in the Internet are communicated with the external address of the firewall

instead of the actual internal address of the clients. Most of the applications will work with network address translation as the applications are not aware of the actual network address of the clients on which they are running.

However, most of the multimedia applications are aware of the actual network address of the clients and the servers. The clients will communicate using the application protocol their actual network address to the server. The server will then send the UDP packet to the actual network address of the clients. The UDP packets could never reach the clients as the actual network address of the client is a private network address which is not existing in the Internet.

In order to make it work, the clients need to know the translated address at the firewall. They could then communicate the translated address of the firewall to the applications servers. The servers will then send the UDP packets to the translated address of the firewall. But there is no way for the client applications to learn the translated address from the firewall. unless the network address translation is configured statically at the firewall.

Fig. 1 illustrates the classical example of the impact of the network address translation by the firewall on the Real Time Streaming Protocol (RTSP) applications. The RTSP client just knows its actual network address (A.B.C.D) and it will tell the RTSP server this actual network address (A.B.C.D) via the RTSP TCP control connection. The RTSP server will send UDP packets to the network address A.B.C.D which is not existing in the Internet. So the UDP packets from the RTSP server will never reach the RTSP clients. In fact, the RTSP server should send UDP packets to the external address of the firewall (W.X.Y.Z). The firewall will then relay the packets to the actual network address (A.B.C.D) of the RTSP clients.

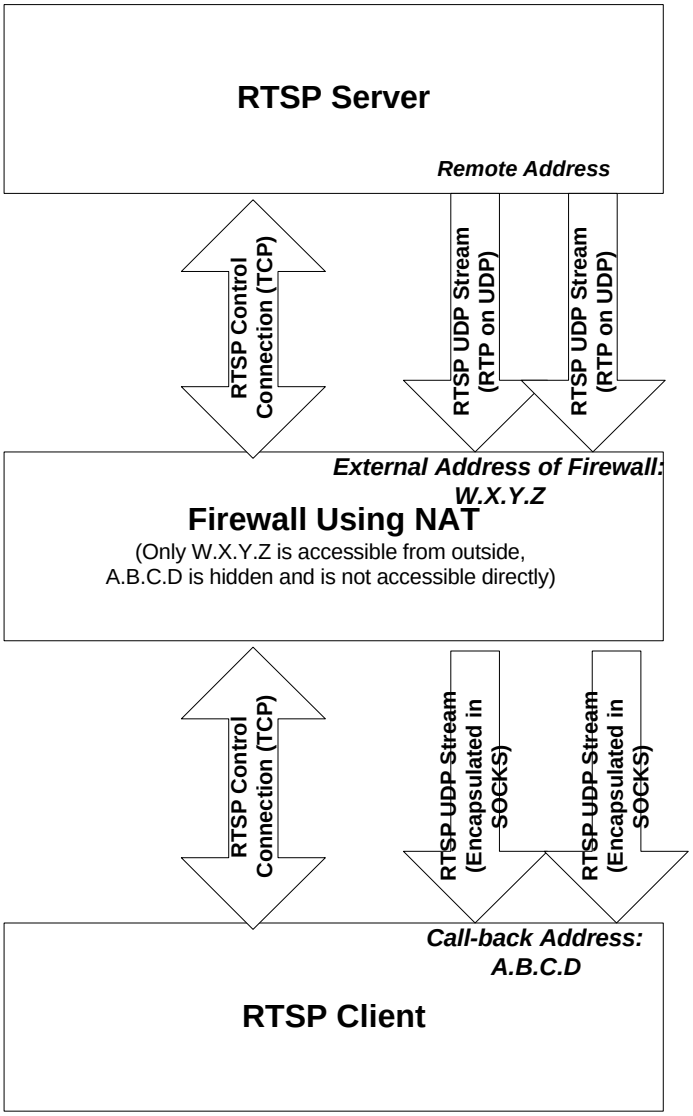


Figure 1: Diagram Illustrating the Issues For UDP Stream Via a NAT Firewall

1.2 Proxy For the Firewall

1.2.1 Application Proxy For the Firewall

To overcome the three issues mentioned above, one solution is to develop an application proxy for the application on the firewall and to add in proxy support for the client . This will be similar to the approach of the http proxy. The client will treat the firewall as an application proxy server and send the application request to the pre-defined TCP port of the application proxy on the firewall. The firewall will act like the actual application server and send the application reply back to the client. On the other side, the application proxy on the firewall will then act like the application clients and relay the request to the actual application server. The application server will treat the application proxy on the firewall as the application client. The issues with dynamic UDP port assignment and network address translation no longer exist. The dynamically assigned UDP port by the application proxy will be learnt by the firewall as they are in the same box. The application proxy will use the external address of the firewall to communicate with the application servers. No address translation is needed for the application proxy when it talks to the applications servers.

However, this arrangement will require each firewall developer to produce a specific application proxy for each application. This will complicate the firewall design as the firewall needs to use additional overhead to process each application protocol. The firewall needs to interpret the application protocol, extract any application protocol statements related to the UDP transport establishment and perform appropriate transport establishment procedure. If there are future enhancements and modifications to the application protocol, the applications proxy on each firewall needs to be modified to support those changes. Besides that, the applications need to be aware of the application proxy server. Additional coding needs to be implemented in order to support the application proxy. This additional proxy support needs to be built in each clients of the application so that it could work with application proxy.

1.2.2 Generic Transport Proxy For the Firewall

Another approach to resolve the two issues discussed above is to use a generic transport proxy to handle those types of applications. It will simplify the design of firewall by developing a generic transport proxy to fulfil different transport requirement by the applications. The generic transport proxy will act as a proxy server in the transport layer. It is transparent to the application layer. The client application does not know the existence of the generic proxy. The generic proxy will intercept the socket call procedure invoked by the application and set up the proxy connection based on the transport requirement of the application. UDP port will be assigned dynamically by the generic proxy server based on the requirement from the application layer. The issue with NAT at the firewall will be resolved as the application will be able to learn the translated address at the firewall from the generic proxy server.

In the past few years, there is an effort to develop a generic transport proxy for the firewall using the SOCKS protocol (Ref. 2). The current version of SOCKS5 protocol (RFC 1928) has limited support for UDP. It could only learn the local address of the SOCKS5 client. It could not learn the "remote address". It does not have the complete local address – remote address pair to do the proper packet filtering. So, the issue with dynamic address assignment for UDP protocol at the firewall is only resolved partially by this SOCKS5 protocol. The issue with NAT at the firewall is still unresolved. The application client is still unable to learn the translated address at the firewall from the SOCKS5 protocol. So it could not support incoming UDP association. As a result of these two unresolved issues, it supports only outgoing UDP association by setting the "remote address" to "any address". With such setting, the outgoing UDP packets could go to any destination UDP address and the level of access control will be reduced a lot.

To overcome the outstanding issues of the SOCKS5 protocol (RFC 1928), there are two recent Internet draft which try to tackle the issues with the support for the UDP. The Internet draft "SOCKS Protocol version 5, draft-ietf-aft-socks-pro-v5-03" (Ref. 5) is a revised version of RFC 1928. Another Internet draft "SOCKS5 UDP and Multicast Extensions to Facilitate Multicast Firewall Traversal, draft-ietf-aft-mcast-fw-traversal-01.txt" (Ref. 3) propose an enhanced UDP mode to handle the UDP binding at the SOCKS5 proxy server. Both of these two Internet drafts resolve the issues with NAT. The translated address at the firewall is communicated via these revised SOCKS5 protocols from the SOCKS5 server to

the SOCKS5 client. They also attempt to resolve the issues with the "remote address" for UDP packets filtering. But the SOCKS5 models they adopt have fundamental problem on the assumption of the availability of the "remote address" from the application layer. As a result of that, these SOCKS5 protocols are not able to resolve the issues with the "remote

1.3 Unresolved Issues with SOCKS5 Support For Incoming UDP Connections

As mentioned above, the two revised Internet drafts for SOCKS5 protocol try to resolve the issue with dynamic UDP port assignment at the firewall and the issue with NAT for UDP at the firewall. However, there is still some fundamental problem with the availability of the "remote address" by these SOCKS5 protocols.

When the UDP binding is carried out by these SOCKS5 protocols, the "remote address" needs to be communicated from the SOCKS5 client to the SOCKS5 server. For outgoing UDP connections, the "remote address" is available during the UDP binding. But for the incoming UDP connections, the "remote address" is not readily available by the client during the UDP binding. So these two SOCKS5 protocols could not support the incoming UDP connections. In fact, most of the multimedia applications make use of the incoming UDP connections for the delivery of the multimedia stream from the server to the client. These types of applications cover a major proportion of the UDP-based applications in the Internet. So it is important that the SOCKS5 protocol will provide support for the incoming UDP connections.

Usually, the "remote address" is available to the client application after the UDP binding. So if the provisioning of the "remote address" could be postponed after the UDP binding, this issue with SOCKS5 UDP binding for incoming connections could be resolved.

However, another issue with SOCKS5 UDP support will come up. This issue is how the SOCKS5 client acquires the "remote address" from the application layer. This is not currently addressed in the SOCKS5 protocol. Although it seems that this issue is related to the implementation, it will be shown in later section that this needs to be clearly defined in the

SOCKS5 protocol. Otherwise, SOCKS5 will not operate properly with the applications layer. The interface between SOCKS5 protocol and the application layers needs to be well defined in the SOCKS5 protocol so that the exchange of address information could be carried out properly.

1.4 Summary of Work

To support the incoming UDP connections, this project proposes an enhancement of the SOCKS5 protocol to overcome the issues discussed above. The SOCKS5 support for outgoing UDP connection will also be modified to match the socket call sequence. The proposed enhancement is a new SOCKS5 model for UDP association. This new model adopts the enhanced UDP mode packet structure of the Internet draft "SOCKS5 UDP and Multicast Extensions to Facilitate Multicast Firewall Traversal, draft-ietf-aft-mcast-fw-traversal-01.txt" (Ref. 3). This enhanced SOCKS5 protocol will provide complete support of UDP connections across the firewall.

The following protocol enhancements are made to SOCKS5 protocol:

- Passive UDP opening & UDP listening are introduced in the SOCKS5 protocol model to support the incoming multimedia stream.
- UDP binding through the SOCKS5 protocol is transformed from a single step binding process into a two step binding process with the introduction of a half-binding state.
- Active UDP opening which is already available in existing SOCKS5 protocol is also incorporated into the new two steps binding process to provide a generic UDP binding mechanism via SOCKS5 protocol.
- Wrapper socket calls from SOCKS5 library are mapped properly to the new two steps SOCKS5 UDP binding process so that the source and destination address are communicated properly between the application layer and the SOCKS5 layer.

As discussed earlier, most of the multimedia applications make use of the incoming UDP connections to deliver the multimedia stream from the multimedia server to the multimedia client. To test the modified SOCKS5 protocol, a

multimedia application should be used. This provides us an insight into the interaction between the multimedia application and the SOCKS5 transport proxy. The application selected for testing should be a good representation of most of the multimedia applications. It should adopt the transport model which is used by most of the other multimedia applications. With these criteria, the Real Time Streaming Protocol (RTSP) is selected as the multimedia application for the testing of the enhanced SOCKS5 protocol in this project. RTSP has a transport model similar to other popular multimedia applications like Real Audio, VDOLive and StreamWorks. A RFC (RFC 2326) for RTSP has already been published. There will be more and more applications adopting this standard. So it will be good to test the interface between RTSP and the enhanced SOCKS5 protocol to ensure that the enhanced SOCKS5 protocol will support the incoming UDP connections for the multimedia applications.

The transport establishment procedure for the UDP stream in existing RTSP is not well defined. So a guideline for the UDP transport establishment procedure for RTSP stream is specified to ensure the proper socket calls are made to set up the UDP stream via the enhanced SOCKS5 protocol. This guideline will also be applicable for other multimedia applications as well.

1.5 Overview of Chapters

Chapter 2 begins with an overview on the existing SOCKS5 protocol and the Real Time Streaming Protocol (RTSP). The model using SOCKS5 server as an generic proxy firewall for RTSP will then be explained. The issues in terms of the incoming UDP support with the two recent Internet drafts for SOCKS5 will be discussed. The requirement for the application interface with SOCKS5 layer is outlined at the end of this Chapter.

Chapter 3 will detail the proposed enhancement to the SOCKS5 protocol. Socket call procedures for RTSP clients to interface with SOCKS5 protocol is proposed. Three types of UDP port binding are analysed. Based on the analysis, a two steps SOCKS5 UDP binding process is proposed for the three types of UDP port binding. The proposed two step binding process will then be mapped to the socket call procedure and fit into the existing SOCKS5 protocol model.

Chapter 4 will specify the required transport establishment procedure in Real Time Streaming Protocol to work with the proposed SOCKS5 protocol.

Chapter 5 will describe the program implementation of the prototype for the proposed SOCKS5 protocol enhancement and the program modification of the RTSP applications for the testing of the SOCKS5 prototype. Analysis of the existing source code and the required modification of the source are highlighted in these sections.

Chapter 6 will give the testing results when the prototype for the enhanced SOCKS5 protocol was tested with RTSP-based applications. Chapter 7 concludes all the works and the contribution of this dissertation. Chapter 8 will propose some future work that could be carried out to extend the capability of the SOCKS5 model.

2. SOCKS5 Protocol Support For UDP

2.1 Overview of SOCKS5 Protocol

SOCKS5 protocol is a session layer protocol which provides a generic mechanism for IP traffic to traverse a firewall. It acts as an generic transport proxy for TCP and UDP protocol. A TCP/UDP data connection is initiated by the SOCKS5 server to the remote server on behalf of the actual SOCKS5 client. The SOCKS5 client is hidden away from the remote server.

In addition to that, SOCKS5 protocol provides authentication, access control and network address translation. The transport layer is established on demand. Each SOCKS5 client will be authenticated. The access requirement will be provided by the SOCKS5 client and will be compared against the access control policy established in the firewall. This provides a more dynamic way of performing access control via the firewall.

The current version of SOCKS5 protocol RFC 1928 provides transport proxy for outgoing TCP connections and outgoing UDP connections. The SOCKS5 protocol standard does not support the incoming UDP connections.

The SOCKS5 protocol exchange involves two main processes. The first process is the transport proxy establishment. First, a TCP control connection will be established between the SOCKS5 client and the SOCKS5 server. After that, a standard SOCKS5 packet format will be used for the TCP/UDP binding request. The SOCKS5 server will do the binding at its external interface and set up the internal TCP/UDP relay data connection between the SOCKS5 server and the SOCKS5 client. The second process is the actual data relay for the TCP and UDP connection. The TCP /UDP data packet from the SOCKS5 client to the remote server will be relay via the SOCKS5 server.

The diagram below illustrates the SOCKS5 protocol exchange sequence:

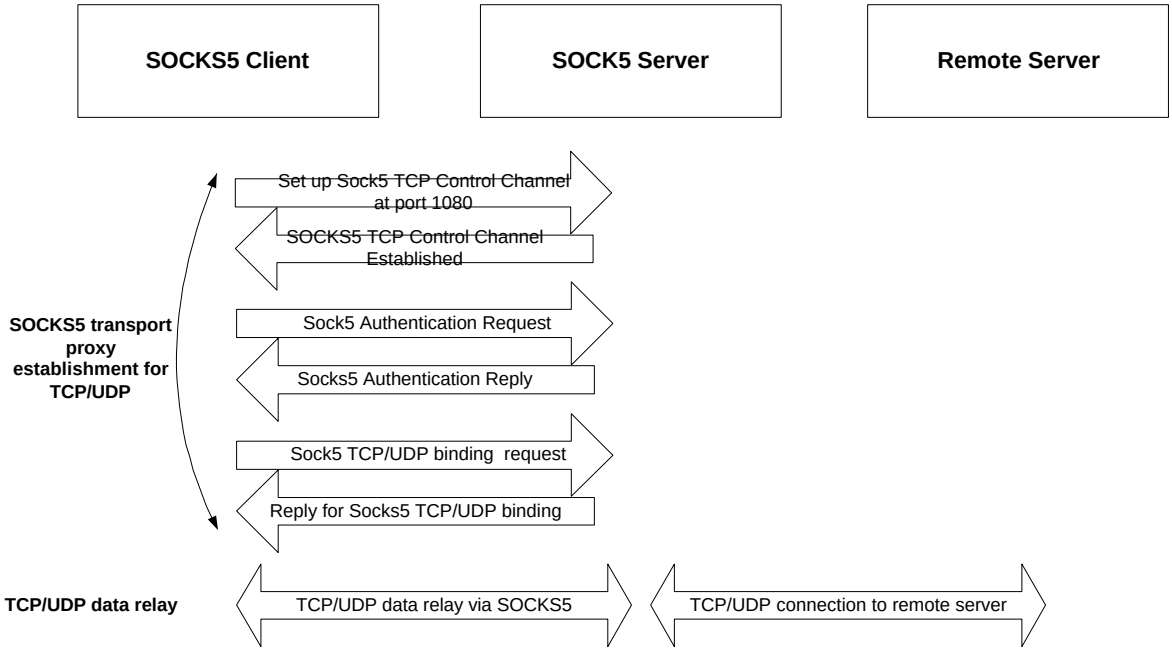


Figure 2: SOCKS5 Transport Proxy Establishment Sequence

2.1.1 Transport Model of SOCKS5 TCP Binding

The transport model of the SOCKS5 protocol for TCP connection is an in-band model. One TCP control connection is established for each SOCKS5 TCP connection. Initially, the SOCKS5 authentication and the SOCKS5 TCP binding will be performed using the SOCKS5 protocol over the TCP control connection. After the successful SOCKS5 binding for TCP connections, the TCP control channel will become the TCP data connection for TCP data relay. TCP data, which is destined for the remote server, will be relayed from the SOCKS5 client to the SOCKS5 server. This TCP data will

subsequently be sent via the external TCP connection to the remote server. Similarly, TCP data from the remote server will be transported in the reverse direction using the SOCKS5 server as a TCP data relay.

2.1.2 Transport Model of SOCKS5 UDP Binding

The transport model of the SOCKS5 protocol for UDP makes use of an out-of-band transport model. It consists of one TCP control connection for each SOCKS5 UDP data connection and one UDP data relay connection. SOCKS5 authentication and SOCKS5 UDP port binding will be performed through the TCP control connection. A separate UDP data relay connection will be set up to relay UDP data between the SOCKS5 client and SOCKS5 server. The UDP data is encapsulated in SOCKS5 UDP data relay packet. The encapsulated UDP data packet from the SOCKS5 client will be sent to the SOCKS5 server. The SOCKS5 server will extract the actual UDP data and send it to the remote server. On the other side, the raw UDP packet from the remote server will be encapsulated by the SOCKS5 server and will be sent to the SOCKS5 client. The SOCKS5 client will then extract the UDP data and pass the data to the applications layer.

The diagram below illustrates the transport models of the SOCKS5 protocol for TCP and UDP:

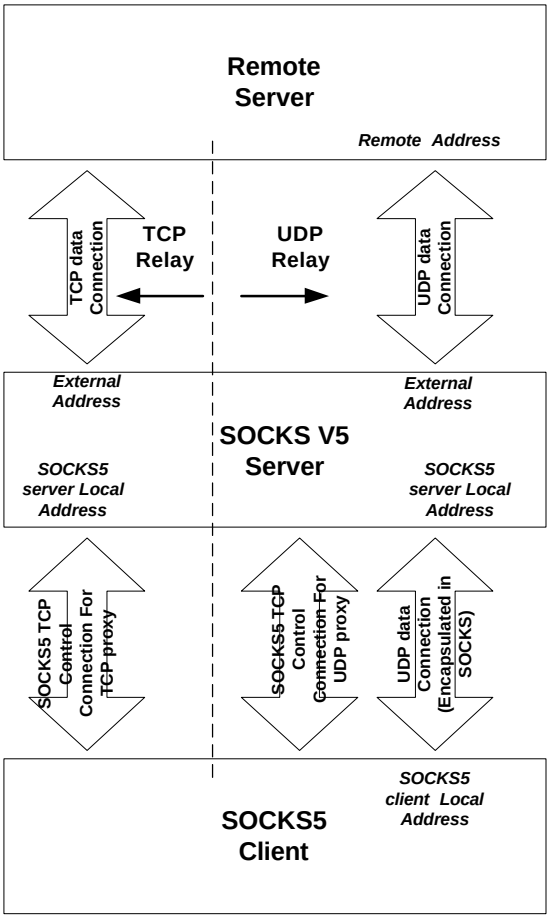


Figure 3: Transport Model of SOCKS5 Protocol

2.2 Overview of Real Time Streaming Protocol

In the Internet community, there is a growing number of multimedia applications in the past few years. As there is no common standard on how to deliver multimedia stream between servers and clients, each vendor has its own method to implement their applications. The usual pattern for the delivery of multimedia traffic consists of two parts. One part is the control connection and the other part is the incoming UDP packets from the multimedia servers to the multimedia clients. The control connection is usually a pre-defined TCP port while the incoming UDP packets will go through a randomly assigned UDP port.

In 1996, an initiative was established by the MMUSIC group in IETF to develop a Real Time Streaming Protocol (RTSP) (Ref. 1) which will provide a common protocol for multimedia applications across the Internet. Various vendors of the Internet community and research institutions participated in the development of the protocol. The transport model of the RTSP protocol adopts the common approach described above with one TCP control connection and one or more UDP/multicast stream for multimedia data (Fig. 4). So this transport model could be used as a foundation for future development work on network transport facilities to carry multimedia stream.

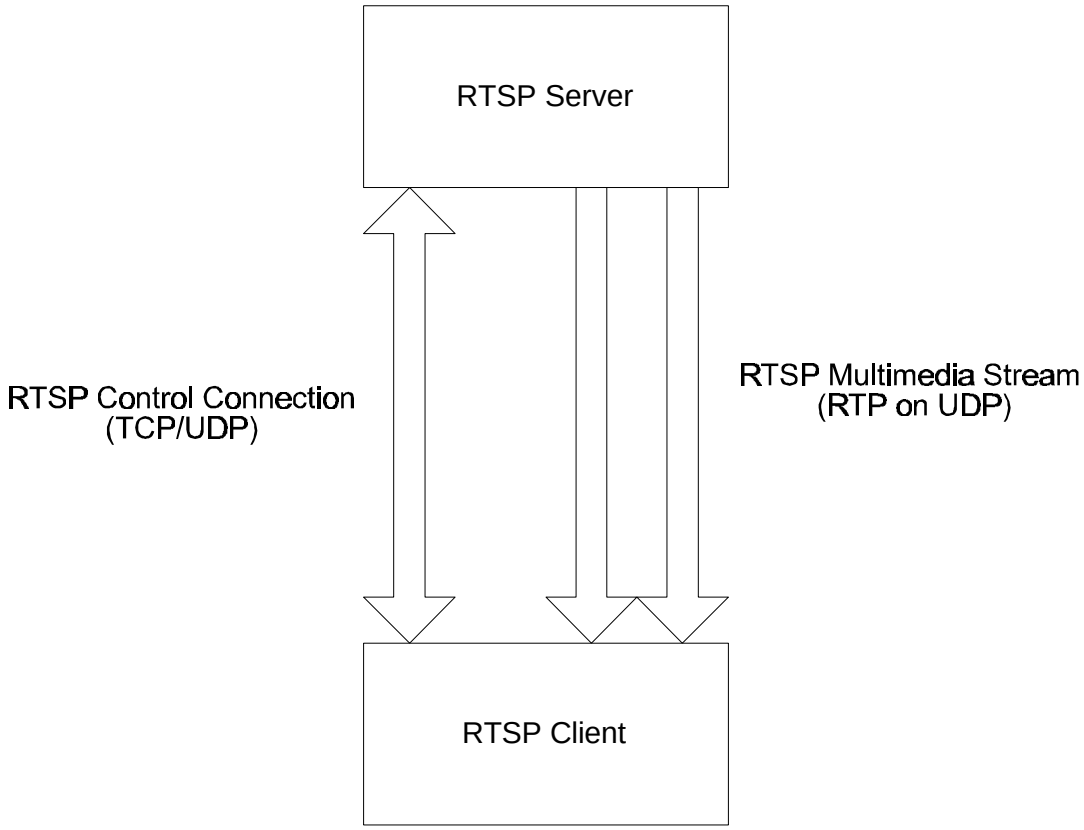


Figure 4: Transport Model For Real Time Streaming Protocol

2.2.1 Transport Establishment Procedure For RTSP Stream

RTSP makes use of UDP to transport multimedia stream from RTSP server to RTSP client. The transport establishment procedure for RTSP multimedia stream needs to be understood so as to see how the SOCKS5 protocol will support the UDP transport proxy.

RTSP provides a common framework for the establishment and manipulation of various types of audio and video stream. This is achieved through the TCP control connection between the RTSP client and the RTSP server. Initially, the RTSP client will set up the TCP control connection to a well-known port 554 of the RTSP server. Then it will begin RTSP protocol exchange via this TCP connection. The following diagram indicates the sequence of protocol exchange between RTSP client and RTSP server to play a multimedia stream:

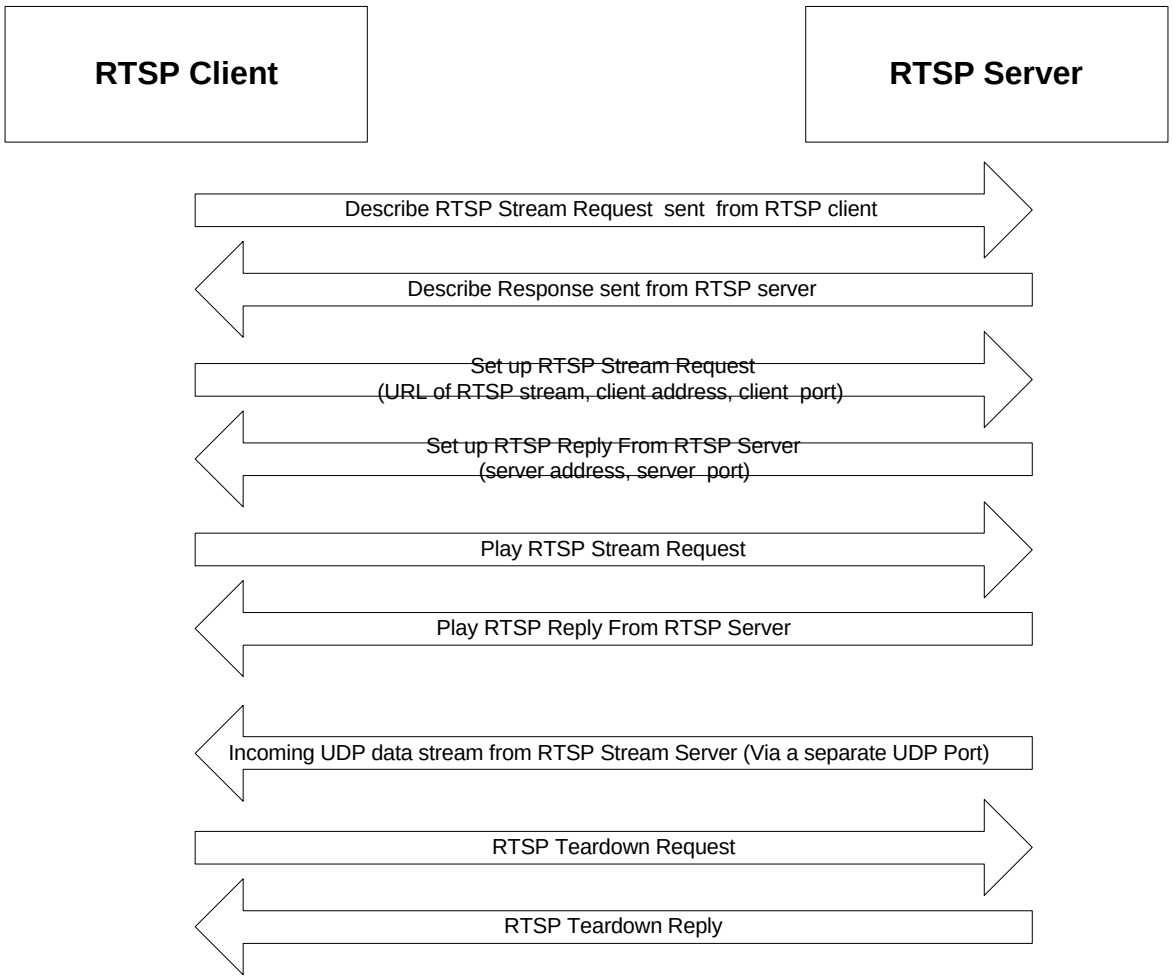


Figure 5: Protocol Exchange Sequence To Play a RTSP Multimedia Stream

The RTSP client sends a "Describe" request to ask for the description of a particular multimedia object. The RTSP server will reply with the description of the multimedia object such as media type or media length. The RTSP client will then issue a "Set up" request to set up a multimedia stream for a multimedia object. This will involve the establishment of the proper transport mechanism for the delivery of the multimedia stream. The common transport mechanism are RTP over unicast UDP or RTP over multicast. After the "Set up" request finishes the transport establishment procedure, the "Play"

request will specify where to start the playback and how long it should play. This is very similar to the playback control of a CD player. One could program the player to play from track 3 to track 5 instead of playing all the tracks. The multimedia stream will then be delivered from the RTSP server to the RTSP client via the established transport mechanism. In the above diagram, this is delivered via a UDP stream. After the RTSP client finishes playing the multimedia stream, it issues a "Teardown" request. This will remove the transport established for the multimedia stream between the RTSP client and the RTSP server. If the RTSP client wants to play the same multimedia object, it needs to issue the "Set up" request again to initiate the transport for the multimedia stream.

2.3 Using SOCKS5 Server as a Generic Proxy Firewall For RTSP

The SOCKS5 model and the RTSP model will be combined together to see how the RTSP will make use of the SOCKS5 protocol to traverse through a firewall. The combined model will illustrate how the RTSP applications interact with the SOCKS5 layer and the role of the SOCKS5 transport proxy. It will serve as a framework to understand the issues with the incoming UDP connections via the SOCKS5 server and to analyse the requirement for supporting incoming UDP connections via SOCKS5 server. The following diagram illustrates the combined SOCKS5 and RTSP model:

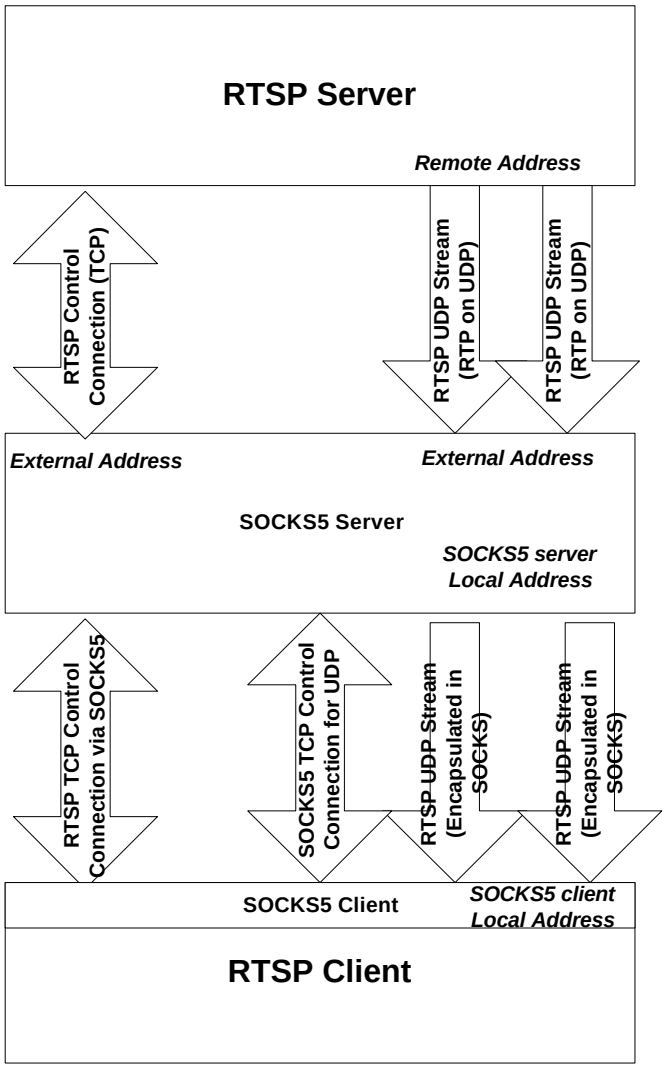


Figure 6: Generic SOCKS5 Transport Proxy Model For Real Time Streaming Protocol

The SOCKS5 server will act as a generic transport proxy for both the RTSP TCP control connection and the RTSP UDP stream from the RTSP server to the RTSP client. The RTSP client and the SOCKS5 client are running in the same machine. The RTSP client interfaces with the SOCKS5 client using the standard socket library calls. The SOCKS5 connection is initiated from the SOCKS5 client to set up the proxy transport for the RTSP TCP control connection. Once

this RTSP TCP control connection is established, the RTSP request and reply will be relayed via this SOCKS5 TCP proxy connection. Then a second SOCKS5 connection will be initiated from the SOCKS5 client to set up the proxy transport for the incoming UDP stream. Once this SOCKS5 UDP association is established, a UDP binding will be established at the external address of the SOCKS5 server by the RTSP client. The RTSP server will send the UDP stream to the external address of the SOCKS5 server. This incoming UDP stream will subsequently be relayed to the SOCKS5 client via a separate UDP channel by encapsulation in SOCKS5 UDP packet. The RTSP client will receive the actual UDP data from the SOCKS5 Client.

It could be seen that the SOCKS5 server acts both as a firewall and a transport proxy. The RTSP server is communicating directly with SOCKS5 server and it treats the SOCKS5 server as the RTSP client. In fact, this SOCKS5 server is sending and receiving packet on behalf of the RTSP client which is located inside the internal network. The internal network is hidden from outside. The TCP and UDP binding are done on-demand from the internal RTSP client. It will last only for the duration that the internal client needs that. Once the RTSP client application is closed, the TCP and UDP binding on the SOCKS5 server will be removed. The SOCKS5 server should be able to accept TCP & UDP binding dynamically based on the requirement from the client applications. There is no need to pre-configure this SOCKS5 server statically the address translation for each binding required by different client applications.

This generic transport proxy supports both TCP and UDP. So effectively any applications making use of TCP & UDP as the transport protocol could make use of the SOCKS5 transport proxy to traverse through the firewall. The SOCKS5 transport proxy is located at the session layer and is transparent to the applications. The application server and the application client are not aware of the existence of the SOCKS5 transport proxy. Hence, it will simplify the application development process for those applications which need to go through a firewall.

2.4 Issues with the “Remote Address” in SOCKS5 Protocol For UDP

As mentioned in section 1.2.2, the current version of SOCKS5 protocol RFC 1928 (Ref. 2) supports only outgoing UDP associations. To support incoming UDP connections, the SOCKS5 protocol needs to be extended to include support for incoming UDP associations. As stated earlier, there are two Internet drafts proposing two approaches to enhance the UDP associations in RFC1928. Both of them are based on the basic SOCKS5 protocol RFC1928. They use the same SOCKS5 transport model and SOCKS5 authentication process. The difference between them is mainly on the UDP binding and UDP data relay process. However, both of them have fundamental problems on the assumption of the availability of the "remote address". This will be discussed in this section.

2.4.1 SOCKS5 UDP and Multicast Extensions to Facilitate Multicast Firewall Traversal

The first approach is from the Internet draft for SOCKS5 UDP & multicast extension (Ref. 3) which extends the UDP associations for both UDP & multicast traffic. This approach introduced an enhanced UDP mode on top of the basic SOCKS5 protocol. To enter into the enhanced UDP mode, the SOCKS5 client will send the enhanced UDP mode request (SOCKS5 command "0x04") to the SOCKS5 server by using the basic SOCKS5 packet structure. Once the SOCKS5 client and the SOCKS5 server are in the enhanced UDP mode, a new packet structure for the enhanced UDP mode and a new command set for enhanced UDP mode will be used. This new packet structure is used to facilitate the special requirement of the UDP & multicast. It consists of two address fields instead of one. The two address fields are for the local address and the remote address. Other than that, it provides an association identifier (AID) for each UDP association. So each SOCKS5 control channel could serve multiple UDP associations.

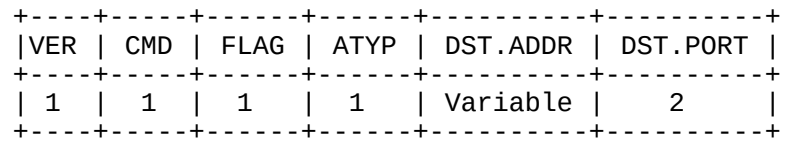
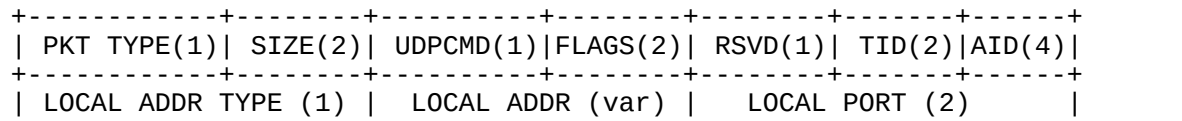


Figure 7: Basic Packet Structure Of SOCKS5 Packet



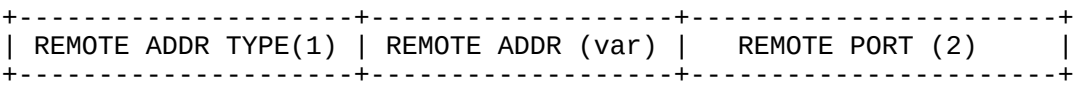


Figure 8: Packet Structure Of Enhanced UDP Mode in SOCKS5 UDP & Multicast Extensions

In the enhanced UDP mode, the SOCKS5 client will send an "enhanced UDP bind request" using the enhanced UDP mode packet structure to the SOCKS5 server. The "local address field" will be populated with the IP address and IP port number at which the SOCKS5 client will receive or send UDP data. The "remote address field" will be populated with the ultimate destination address which is the remote address. The SOCKS5 server will send a reply using the same enhanced UDP mode packet structure. The "local address field" of the reply will be populated with the local address of the SOCKS5 server and the "remote address field" will be populated with the external address of the SOCKS5 server. As the "remote address" is required in the "enhanced UDP bind request", the "remote address" has to be readily available by the SOCKS5 client during the UDP binding process.

2.4.2 Revised SOCKS5 Protocol with UDP Support

Another approach is proposed recently as an Internet draft for the revision of SOCKS5 RFC1928 (Ref. 5) The proposed solution makes use of the original UDP association command from RFC 1928 and the basic SOCKS5 packet structure. It introduces two ways of performing incoming UDP associations. Both ways make use of the flag field of the SOCKS5 UDP association packet.

The first way is to set the flag field to "use_client_port" (0x01) when the SOCKS5 client sends a SOCKS5 UDP association request to the SOCKS5 server. The address field of the SOCKS5 packet will be populated with the local address and local port from which the SOCKS5 client will relay UDP data. Once the SOCKS5 server sees this flag, it will set the external port number same as the local UDP port number specified by the SOCKS5 client in the SOCKS5 UDP association request. It will then send back a reply in which the address field will be populated with the local address and the local port of the SOCKS5 server. The SOCKS5 client should send data to be relayed to this local address and local

port. In this way, the SOCKS5 client will know the external port number of the UDP binding at the SOCKS5 server. However, the SOCKS5 client is not able to know the external address of the UDP binding.

The second way is to set the flag field “interface_request” (0x04) in the SOCKS5 UDP association request. The address field of the SOCKS5 packet will also be populated with the local address and the local port from which the SOCKS5 client will relay UDP data. The SOCKS5 server will in turn send back a reply in which the address field will be populated with the local address and the local port of the SOCKS5 server. Other than that, the SOCKS5 server will expect an additional “interface data” subcommand (0x01) from the SOCKS5 client. The subcommand will use the basic SOCKS5 packet structure. The SOCKS5 client will make use of this subcommand to learn the external address of the SOCKS5 server for this UDP association. The address field of the “interface subcommand” will be populated with the ultimate address which is the “remote address”. The SOCKS5 server will send back a reply for this subcommand. The address field of the reply will be populated with the external address and external port of the UDP binding at the SOCKS5 server. The second way is very similar to the enhanced UDP mode of the UDP & multicast extensions (Ref. 3). Both of them use another set of command to learn the external address of the UDP binding. In fact, the existing SOCKS5 library available from NEC is using a very similar approach in their implementation.

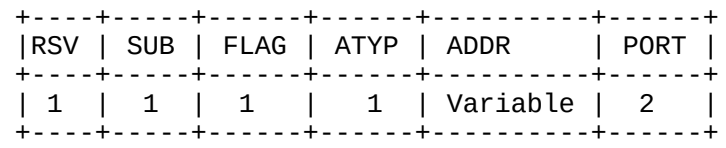


Figure 9: Packet Structure of SOCKS5 Sub-command for UDP

In order to the learn the external address of the UDP binding at the SOCKS5 server, the second approach, which makes use of the “interface data” subcommand, has to be used. This second approach requires the SOCKS5 client to provide the “remote address”. Again, the “remote address” needs to be readily available by the SOCKS5 client during the UDP binding.

2.4.3 Unavailability of "remote address" in UDP Bind Socket Call

As mentioned above in the UDP binding process of the two Internet drafts, the "remote address" has to be available during the SOCKS5 UDP binding. But this is not achievable in the actual implementation. The application will make use of the UDP bind() socket call to perform UDP binding. When the SOCKS5 client receives the UDP bind() socket call, it will begin the SOCKS5 UDP binding using the proposed SOCKS5 UDP binding schemes. However, the UDP bind() socket call does not provide the "remote address" and the "remote port" in its argument. So the SOCKS5 client will not know the "remote address" and the "remote port". Without this information, the proposed UDP binding schemes in these two Internet drafts will not work. So in these two Internet drafts, the fundamental assumption that the "remote address" is readily available during the UDP binding is not correct.

2.4.4 Deadlock Situation in the Information Exchange Between RTSP Client & SOCKS5 Server

As mentioned in last section, the "remote address" is not available from the UDP bind() socket call because the argument of the UDP bind() socket does not support this. But even if the UDP bind() socket call support the "remote address" field in its argument, the "remote address" is still unavailable from the applications client. This is due to the mismatch in the sequence of exchange of address information between the multimedia applications and the SOCKS5 protocol. As RTSP will be used to test out the SOCKS5 protocol support for UDP, the RTSP protocol exchange sequence will be used to illustrate this issue below.

One important requirement from RTSP application is that when the RTSP client sends the SETUP request, it needs to know the assigned client address and assigned client port (which is the external address of the UDP binding at the SOCKS5 server). But this external address is only available after a successful SOCKS5 UDP association. But based on the SOCKS5 protocol requirement, when the RTSP client set up the SOCKS5 UDP associations, it needs to provide the "remote address" to the SOCKS5 server. However, the "remote address" will not be available until a RTSP SETUP request is sent and the SETUP reply is received. So it gets into a deadlock situation. The RTSP client needs to get the

"external address" of the SOCKS5 server before it could get the "remote address" while the SOCKS5 server needs to get the "remote address" before it could send the "external address" to the RTSP client. So in terms of the sequencing of the address information flow, the two proposed Internet drafts for SOCKS5 UDP support are still incompatible with the requirement of the multimedia application such as the RTSP.

The diagram below illustrates the fundamental contradiction in requirements between SOCKS5 protocol and the RTSP protocol:

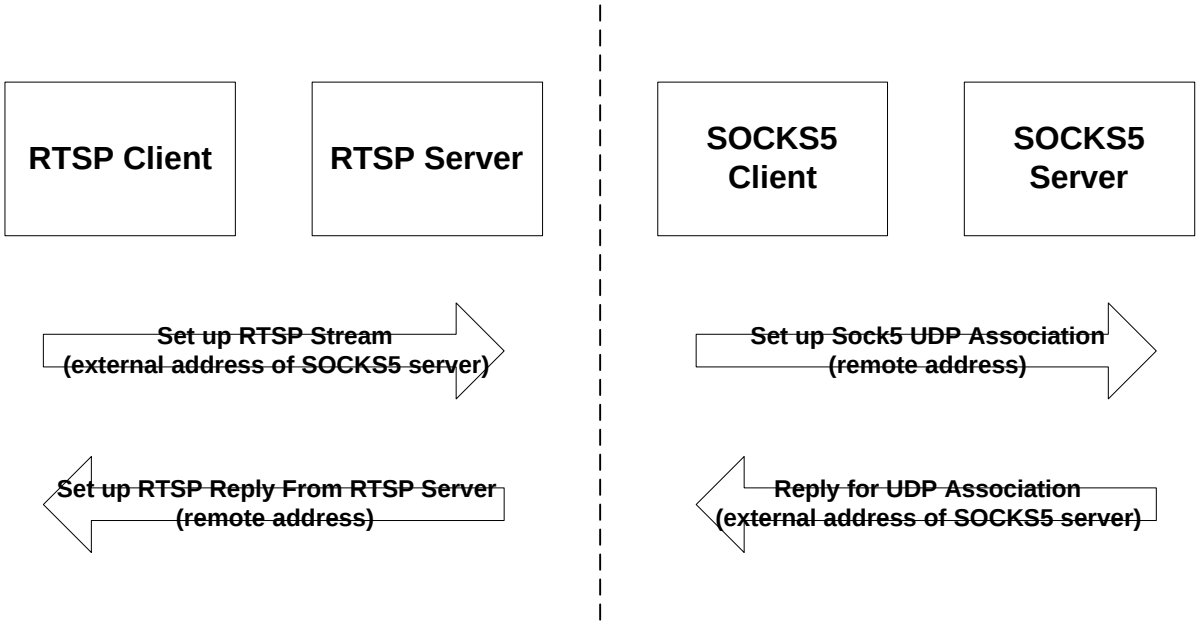


Figure 10: Deadlock Situation between RTSP & SOCKS5 protocols

2.4.5 Workaround of SOCKS5 protocol implementation to support incoming UDP connection

In order to resolve this fundamental issue, the NEC SOCKS5 protocol implementation tries to support the incoming UDP streaming connections by means of some workaround. To tackle the unavailability of the remote address, the SOCKS5

protocol implementations make use of the remote address of the previous SOCKS5 TCP connection from the SOCKS5 client as the remote address. This is based on the assumptions that the TCP control connection to the application servers and the incoming UDP connection are originated from the same remote server. This is correct in most cases. However, this may not be correct all the time. In some cases, the application server may be different from the UDP streaming server. This will happen in the scenario that multiple UDP streaming servers are used to increase the scalability of the number of UDP stream. To tackle the unavailability of the UDP port of the remote server, the UDP port of the remote address is set to "any" ports in the SOCKS5 server such that any UDP ports from the remote server will be accepted. This is insecure as the whole range of UDP ports outside the SOCKS5 firewall will be open up for the incoming UDP connection.

2.5 New Requirements For the SOCKS5 Protocol

2.5.1 A New Approach To Resolve the Issues with "remote address"

In order to resolve the issues with the unavailability of the "remote address", the proposed enhancement for SOCKS5 protocol will not base on the assumption that the "remote address" is readily available during the UDP binding. It will assume that the "remote address" will be available before the actual data relay takes place. The SOCKS5 server needs to acquire the "remote address" before actual relay of UDP data so that it could perform the proper packet filtering on the UDP packets based on the source address and the destination address. There should be a mechanism for the application to communicate the "remote address" to the SOCKS5 layer.

In order to resolve the other issue with the deadlock situation, the existing SOCKS5 UDP association mechanism needs to be extended so that it could support the RTSP protocol requirement as described above. The enhanced SOCKS5 protocol should be able to handle the scenario that the ultimate destination address (remote address) is unavailable during an UDP association. To achieve that, the SOCKS5 UDP protocol has to accept the reverse sequence of exchange of network address information between the SOCKS5 client & SOCKS5 server. SOCKS5 server should send the external address to

SOCKS5 client before SOCKS5 client sends the “remote address” to SOCKS5 server. But at the same time, the current approach of UDP associations in SOCKS5 needs to be preserved to support the outgoing UDP associations.

2.5.2 Protocol Interface Procedure between RTSP Clients and SOCKS5 Transport Layer

The main issue with the current SOCKS5 protocol support for UDP is on the availability of the “remote address”. The “remote address” which is provided by the RTSP client has to be communicated to the SOCKS5 layer. So the interface between the RTSP clients and the SOCKS5 layer needs to be analysed to see how this could be achieved with the existing transport establishment procedure in RTSP. A protocol interface procedure will be established such that the RTSP client and the SOCKS5 layer will get the necessary information to set up the incoming UDP stream connection via the SOCKS5 server. This protocol interface procedure will be based primarily on the transport establishment procedure of the RTSP client. The enhanced SOCKS5 protocol support will be developed based on this protocol interface procedure. This will ensure that the transport establishment procedure in RTSP could be preserved.

The existing SOCKS5 protocol library provides wrapper program to interface with the client program. So the actual protocol interface between the RTSP client and the SOCKS5 layer is the wrapper program. These wrapper programs will take control of all the standard socket library calls for TCP and UDP. The bind() socket call for UDP will be replaced by the corresponding lsUdpBind() call for SOCKS5. Same arrangement for other calls such as connect() & recv(). The wrapper program will then exchange SOCKS5 protocol with the SOCKS5 server. The wrapper program could be treated as the SOCKS5 client in the SOCKS5 protocol model.

2.5.2.1 RTSP Control Connection

In RTSP, the RTSP control connection could be either an unreliable protocol (rtspu) or a persistent connection (rtsp). If the persistent connection is used, a TCP control connection will be initiated from the RTSP client via the SOCKS5 server to the RTSP server. This could be achieved with the standard SOCKS5 protocol as standard SOCKS5 protocol supports TCP outgoing connections.

If an unreliable protocol (such as UDP) is used for the control connection, the existing SOCKS5 protocol version (RFC 1928) will support this. It will be an outgoing UDP connection initiated from the RTSP client to the RTSP server.

The existing SOCKS5 protocol will support the establishment of the RTSP control connection. So the existing protocol interface procedure for the SOCKS5 layer could be used for the RTSP control connection.

2.5.2.2 RTSP Incoming UDP Stream

For the incoming UDP streaming protocol, a protocol interface procedure needs to be developed for the proper exchange of information between the RTSP client and the SOCKS5 layer. The protocol interface procedure will be embedded as part of the transport establishment procedure of the RTSP client.

The transport establishment procedure of the RTSP client will consist of the following sequence of steps:

1. RTSP client will perform a SOCKS5 UDP binding.
2. SOCKS5 layer will send the UDP binding address and the UDP binding port (external address of SOCKS5 server) to the RTSP client so that the RTSP client could inform the RTSP server the RTSP client address and the RTSP client port.
3. RTSP client will send the UDP binding address and the UDP binding port to the RTSP server
4. RTSP server will send the RTSP server address and the RTSP server port to the RTSP client.
5. After that, the RTSP client will send the RTSP server address and RTSP server port (remote address) to the SOCKS5 layer so that the SOCKS5 server will know the source address of the incoming connection.
6. RTSP server will begin sending UDP data to the external address of the SOCKS5 server.
7. RTSP client will begin receiving UDP data from the SOCKS5 layer.

Step (3), Step (4), Step (6) and Step (7) are the transport establishment procedure of the RTSP applications. Step (1), Step (2), step (5) and step (7) are the protocol interface procedure between RTSP client and the SOCKS5 layer. This interface procedure focuses specifically on the interface between the RTSP client and the SOCKS5 layer. The enhanced SOCKS5 protocol needs to follow these four steps of information exchange so that the transport establishment procedure of the UDP stream for the RTSP will work properly. This will be discussed later in this document.

2.6 Connection States of the UDP Stream for RTSP

RTSP makes use of a TCP control connection (TCP port 554) to do the establishment of all multimedia stream. SOCKS5 server has to obtain address information & connection state of UDP multimedia stream from the RTSP clients. As mentioned in last section, the correct exchange sequence of network address between the RTSP client and the SOCKS5 layer is essential for the establishment of the stream via the SOCKS5 server. Other than that, the correct exchange of the state of the UDP association between the RTSP client and the SOCKS5 layer is also important.

Fundamentally, UDP connection usually does not have states. But in a stream-based connection, it does have a state. The state information is maintained at the RTSP server and the RTSP client. The state indicates there is a stream connection between a RTSP server and a RTSP client. It will be in the form of a source address and destination address. So the stream could be treated as a connection-oriented protocol. But it is using UDP as the transport layer. The prime reason for using UDP to transmit multimedia stream is that UDP has low over-head and it have the non-guarantee delivery feature which is needed in the transmission of multimedia stream. Ideally, if there exists a connection-oriented protocol with low overhead and non-guarantee delivery, it will be even more suitable than UDP.

Both the RTSP client and the SOCKS5 layer should be in synchronous in terms of the UDP states. When the SOCKS5 completes the UDP binding for the RTSP client, the RTSP client should be aware of this. When the RTSP clients issue a "TEARDOWN" command to the RTSP server and close the socket handle of the UDP binding for the UDP stream, the UDP binding at the SOCKS5 server should be closed. As the UDP protocol does not provide in-band communication of the states between end-points, the state of the UDP stream has to be communicated via the out-of band SOCKS5 control channel. The SOCKS5 layer should be able to signal the states to the RTSP client. Alternatively, the RTSP client should be able to signal the states to the SOCKS5 layer.

3. Proposed Enhancement of SOCKS5 Protocol for UDP

The new requirements as outlined in section 2.5 have to be fulfilled so as to resolve the issues with the SOCKS5 Protocol support for UDP. A new mechanism will be introduced to communicate the "remote address" to the SOCKS5 layer. Three types of UDP binding scenario (Active UDP Open, UDP Listen and Passive UDP open) will be analysed when SOCKS5 protocol is applied for each type of these UDP bindings. A two step UDP binding process will be introduced for the Passive UDP open scenario which is used for incoming UDP connection. The two step UDP binding will then be extended to the UDP binding for the Active UDP Open and UDP listen scenario. To implement the two steps UDP binding process, the enhanced UDP mode of the Internet draft "SOCKS5 UDP & Multicast Extension" will be adopted. The enhanced UDP packet structure and the enhanced UDP command will be used in the two steps UDP binding process.

3.1 Passing the "remote address" to SOCKS5 Layer

The RTSP client makes use of the Real Time Protocol (RTP) on top of UDP to receive the streaming packets . But as most of the applications for RTSP client only need to receive UDP packets, it only needs to invoke the bind() socket call and the recv() socket call. The bind() socket call and the recv() socket call do not have an argument for the "remote address". So there is no way for the RTSP client to pass the ultimate destination address (remote address) to the SOCKS5 client via

these two socket calls. In order to overcome this issue, the RTSP client could invoke either a connect() socket call or a sendto() socket call. The connect() socket call and the sendto() socket call have the argument for the "remote address". The SOCKS5 clients will be able to get the "remote address" from either one of these two socket calls.

A connect() socket call will associate a UDP port with a fixed remote address. This matches the concept of a multimedia stream which is in fact a fixed source address - destination address pair. With this arrangement, it does not allow other multimedia stream to use the same UDP port. As RTSP uses one distinct UDP port for one multimedia stream, it will not violate the principal of RTSP protocol if the UDP association is a one-to-one mapping. So we could make use of the connect() socket call to associate one UDP port with a remote address. It will not affect the operation of the RTSP protocol if we make use of the connect() socket call. The connect() socket call will only associate a distinct destination address for a given UDP socket. This could then fulfil the protocol interface requirement for the SOCKS5 protocol by passing the "remote address" from the application layer to the SOCKS5 layer.

3.2 Types of UDP Port Binding

The focus of this project is on the incoming UDP port binding. However, the solution should be as complete as possible so that a different framework does not need to be established for other type of UDP port binding. In order to provide a comprehensive and complete solution for UDP port binding using SOCKS5 protocol, the different types of UDP ports binding scenario need to be analysed at the same time.

3.2.1 Active UDP Open

Active Open is similar to the active opening of TCP ports. The main difference is that the same UDP port may open multiple connection to different remote servers. When a client is performing an active open of UDP ports, it is performing an outgoing UDP connection. The current approach of the UDP association in SOCKS5 RFC 1928 is classified as an active opening. In this type of UDP binding, the remote address is available to the SOCKS5 clients before

the UDP binding and will be supplied in the UDP port binding. This is important for UDP applications which need to make outgoing UDP connections. A typical example will be a RTSP server which is sitting behind a SOCKS5-based firewall. It could obtain the remote address of the RTSP client before it starts the UDP association with the SOCKS5-based firewall.

3.2.2 UDP Listen

UDP Listen corresponds to the connectionless server scenario. Any hosts could send packet to it. But it will not set up a connection with those hosts. It may or may not reply to the hosts. A client application using UDP listen may have one-to-many UDP associations. In fact, this is the original nature of UDP which could have many-to-many associations. One typical example is Domain Name System in which the DNS server could be queried by any clients using UDP protocol. It opens up UDP port 53 and listen to DNS requests by any clients. But there is a loophole on the SOCKS5 server in this type of application. There is no control over which remote machines could send UDP packets to this listening port. This types of application is not currently addressed in the SOCKS5 protocol for UDP. However, the SOCKS5 protocol should be able to support such requirement as there are a number of Internet applications which need to make use of UDP listen.

3.2.3 Passive UDP Open

This is similar to the passive opening in TCP. This is exactly what is addressed in this project for the incoming UDP connection requirement. The final outcome after the binding is similar to Active Open of UDP port. The remote address is mapped to a distinct UDP port in the SOCKS5 server. The main difference from the Active Opening of UDP ports is the time at which the "remote address" is available to the SOCKS5 client. The SOCKS5 client need to complete the UDP binding at the SOCKS5 server before the remote address is available. The enhanced SOCKS5 protocol for the UDP associations will preserve the Active Open Mechanism and support the UDP listen. In fact, the first half of Passive Open is similar to UDP Listen. The SOCKS5 client will request for an external address from the SOCKS5 server. The difference between Passive UDP Open and UDP Listen is whether the “remote address” will be provided by the SOCKS5 client after the UDP binding. For Passive UDP Open, the SOCKS5 client will provide that. For UDP listen, the SOCKS5

client will not provide that. In Passive UDP Open, both the source address & the destination address will be available for the SOCKS5 server to do packet filtering.

If the “remote address” could be provided by the RTSP client to the SOCKS5 layer after the UDP binding, it will resolve the deadlock situation produced by the inconsistency of the RTSP stream establishment procedure and the SOCKS5 UDP port binding procedure. It will meet the address exchange sequence of RTSP. The RTSP client needs to get hold of the external address binding at the SOCKS5 server first. The “remote address” will be available after the RTSP client send the SETUP request with the external address binding at the SOCKS5 server and get a SETUP reply from the RTSP server.

3.2.4 State transition & network address exchange of UDP binding

The state diagram below indicates the Active UDP Open, UDP Listen & Passive UDP Open mechanism:

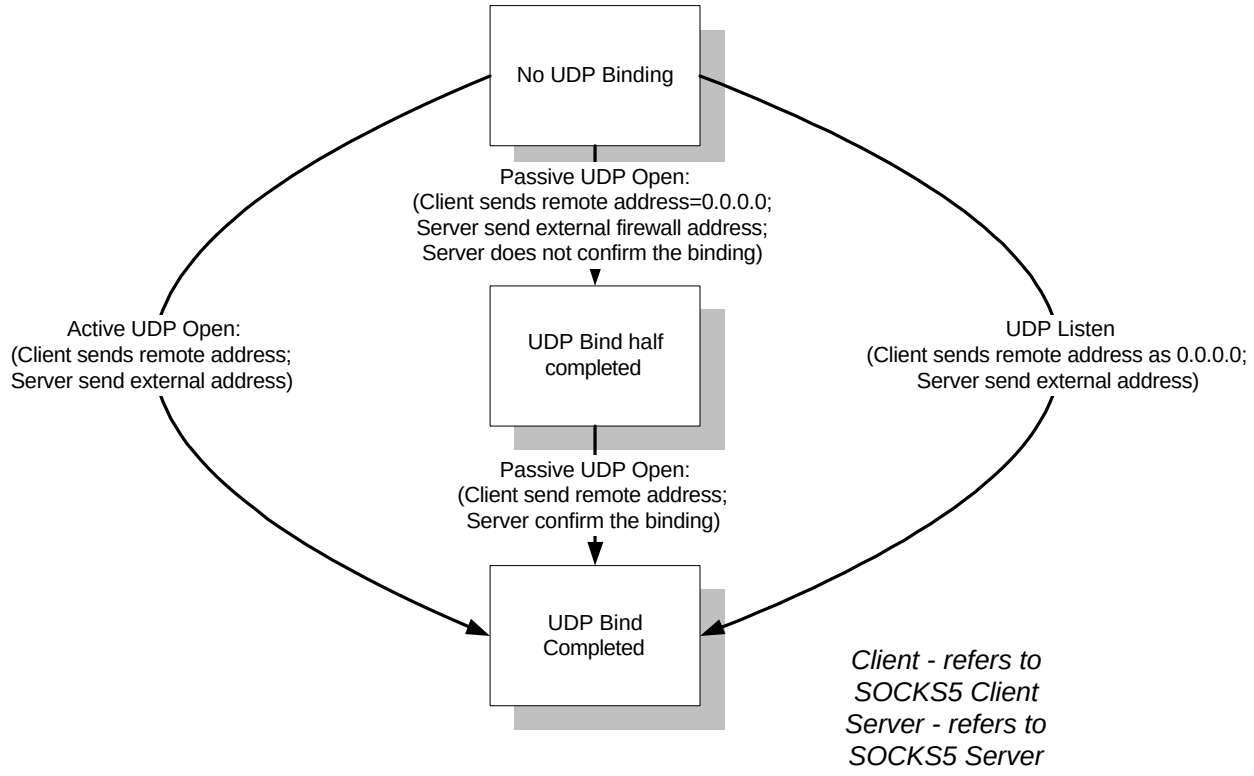


Figure 11: State Diagram of Three Types of UDP Binding over SOCKS5 Protocol

In Active Open of UDP port, there is only one state change. The SOCKS5 client sends the "remote address". The SOCKS5 server will reply with the "external address" of the UDP port binding at the SOCKS5 server. This will complete the binding process as both source address and destination address are available to the SOCKS5 firewall.

In UDP Listen, there is only one state change. As the "remote address" is any server, the SOCKS5 client sends the IP address 0.0.0.0 to indicate that the remote address is “any address”. The SOCKS5 server will reply with the "external address" of the UDP port bind at the SOCKS5 server. This will complete the binding.

In Passive Open of UDP port, there will be two state transitions. As the "remote address" is not available before the binding, the SOCKS5 client will send the IP address 0.0.0.0 to indicate that the remote address is “any address”. Same as the UDP Listen, the SOCKS5 server will reply with the "external address" of the UDP port binding at the SOCKS5 server. However, the UDP port binding is not yet completed as the "remote address" is not available to the SOCKS5 server. So the UDP port binding is only half-completed and it is in a "half-binding state". To finish the UDP port binding, the SOCKS5 client will send the "remote address" to the SOCKS5 server. The SOCKS5 server will then confirm the UDP binding. This will bring the UDP port binding to a completion state.

As the above state transition model covers all three types of UDP port binding, this model will be used as the basis for the development of enhanced SOCKS5 protocol support for UDP.

3.3 Two Step UDP Binding Process

As stated in last section, the Passive UDP Opening has to be used in order to resolve the deadlock situation produced by the inconsistency of the RTSP stream establishment sequence and the SOCKS5 UDP port binding sequence. The Passive UDP Opening will split the UDP port binding into two steps of UDP binding process. The two steps UDP binding process involved the protocol exchange between the SOCKS5 client and the SOCKS5 server.

As stated in section 3.1, there will be a modified socket interface procedure between the RTSP client and the SOCKS5 client. The interface between RTSP client & SOCKS5 layer is originally via the bind() socket call only. The SOCKS5 client needs to know exactly the “remote address” from the RTSP client. However, the bind() socket call is not able to provide that. So the socket interface procedure has be to modified to support that. The modified socket interface procedure will involve two socket system calls. The first socket call will be a UDP bind() socket call. This will provide the SOCKS5 client the external address binding at the SOCKS5 server. This will be followed by a UDP connect() socket call which is used to communicate the “remote-server address” from the RTSP client to the SOCKS5 client.

In order to make sure that the socket interface procedure works properly with the proposed two steps UDP binding process, these two socket call sequence need to be mapped to the proposed two steps UDP binding process in SOCKS5. If the bind() socket corresponds to the first step of the UDP binding of Passive UDP open, the UDP bind() socket call will trigger the first SOCKS5 protocol exchange sequence. The local address & local port of the SOCKS5 client will be sent to the SOCKS5 server. The SOCKS5 server will reply with the external address and external port to the SOCKS5 client. This will fulfil the UDP bind() socket call requirement as the external address and external port of the SOCKS5 server will be available to the RTSP client upon completion of this first step. If the UDP connect() socket call corresponds to the second step of the UDP binding of Passive UDP open, the UDP connect() socket call will trigger the second SOCKS5 protocol exchange sequence. When the RTSP client issues the UDP connect() socket call, it will provide the "remote address" and the "remote server port" to the SOCKS5 layer. The second SOCKS5 protocol exchange will then send the "remote address" & the "remote port" to the SOCKS5 server. The SOCKS5 server will reply with the same external address and external port binding at the SOCKS5 server to the SOCKS5 client. The UDP connect() call will fulfil the requirement of the second step of UDP binding in SOCKS5 as the SOCKS5 client will get the "remote address" and the "remote port" from the UDP connect() call. Once this second step is completed, the UDP binding process for passive UDP opening is complete.

As discussed above, this modified UDP socket call sequence by RTSP client will match the two steps UDP binding process of the Passive UDP opening. In fact, this socket call sequence of the RTSP client is already part of the transport establishment procedure of the RTSP client as discussed in section 2.5.2.2. The UDP bind() call corresponds to step (1) and step (2). The UDP connect() call corresponds to step (5). Hence, this modified socket call sequence will fit into the transport establishment procedure of the RTSP client as well as the two steps SOCKS5 UDP binding process for passive UDP opening. So the transport establishment procedure of RTSP will be properly linked to the SOCKS5 UDP binding process.

Fig. 9 below combines both the RTSP protocol exchange sequence and the SOCKS5 UDP protocol exchange sequence for the passive UDP opening mechanism and show how they work together to support the establishment of an incoming UDP stream for RTSP via the SOCKS5 server. It indicates the protocol exchange sequence between the following entities:

- RTSP clients and RTSP server (via the RTSP protocol)
- RTSP client and SOCKS5 client (via the system socket calls)
- SOCKS5 client and SOCKS5 server (via the enhanced SOCKS5 protocol)

Sequence of protocol exchange:

1. RTSP client will first establish a TCP control channel to a RTSP server.
2. Then the RTSP client will initiate a UDP bind() socket call. This will in turn trigger the first step of the UDP bind process. The SOCKS5 protocol exchange for first step of SOCKS5 UDP bind will take place. The SOCKS5 client will establish the SOCKS5 control channel with the SOCKS5 server. This will be followed by the first step SOCKS5 UDP bind command from the SOCKS5 client to the SOCKS5 server.
3. The RTSP client will send a Set-up request to the RTSP server.
4. The RTSP server will send a Set-up reply to the RTSP client.
5. The RTSP client will initiate the UDP connect() socket call. This will trigger the second step of the UDP bind process. The SOCKS5 client will send second step SOCKS5 UDP bind command with the remote address to the SOCKS5 server. This will complete the two step UDP binding process.
6. The RTSP client will initiate the UDP recv() socket call. Incoming UDP data stream will be relay from the SOCKS5 server to the SOCKS5 client and will be retrieved by the RTSP client from the UDP recv() socket call.

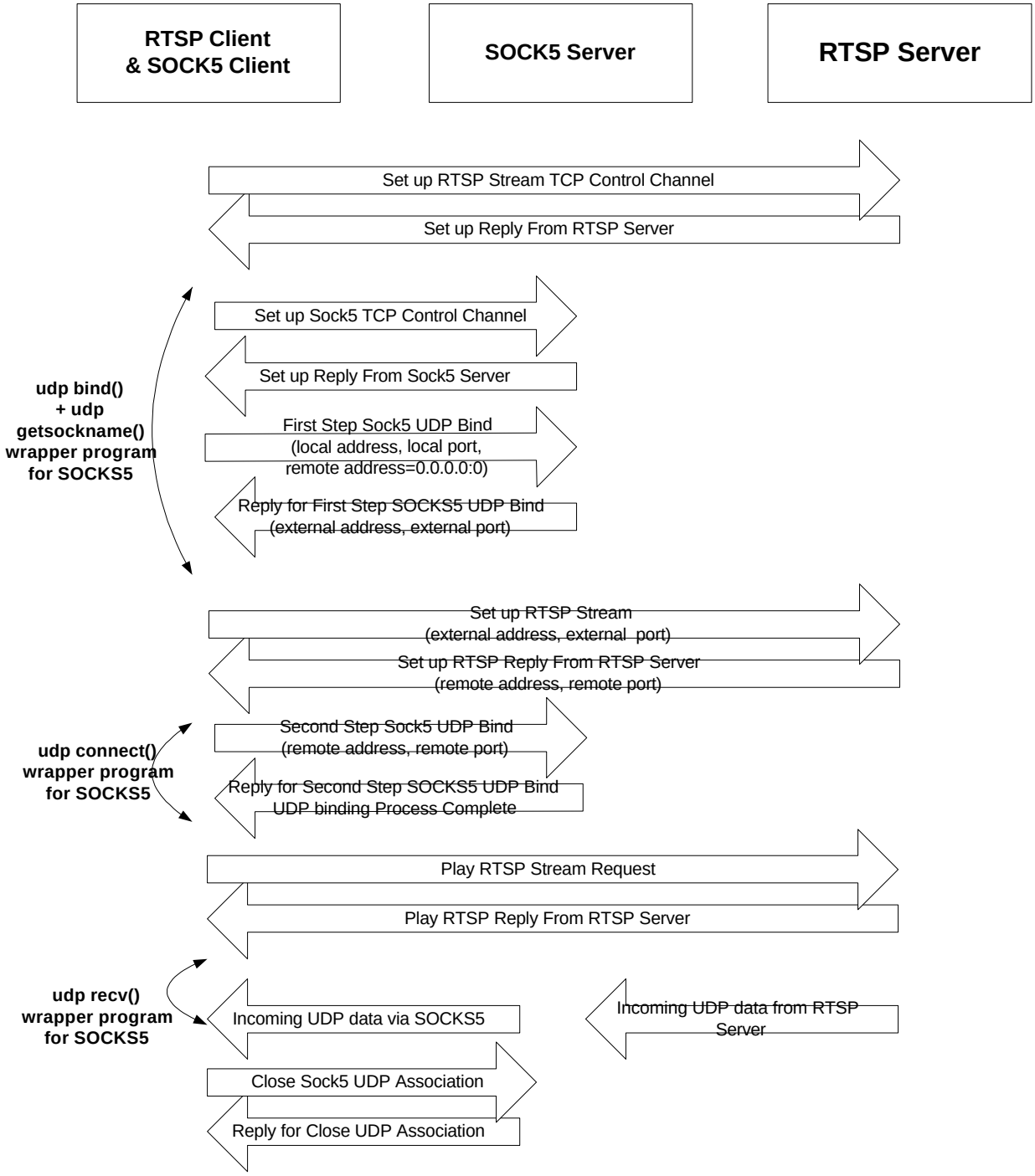


Figure 12: Command sequence for setting up a UDP association via SOCKS5 server for RTSP clients

3.4 Two Steps UDP Binding Process and the New half-binding state

The original SOCKS5 UDP binding involves only one UDP bind command. To support the passive UDP open mechanism, one UDP bind command is not sufficient and two UDP binding steps are needed. A new UDP binding state UDP half-binding is introduced to denote that the UDP binding is not completed. After receiving the first step SOCKS5 UDP bind command, the SOCKS5 server will in turn provide the external address and the SOCKS5 server will go into the UDP half-binding state. The SOCKS5 server will expect another UDP bind command with the remote address. Once this second step SOCKS5 UDP Bind command is received, the SOCKS5 UDP binding process will be completed.

3.4.1 Two Steps UDP Binding Process For Three types of UDP binding

Based on the above discussions, the two steps UDP binding process seems to apply to the passive UDP open mode only. However, it could be seen that the two steps UDP binding process is applicable to both the UDP listen and the Active UDP open. This will be discussed in the following paragraphs.

Based on the state diagram for the three types of UDP binding (Fig. 11), when the SOCKS5 client is using the UDP listen mode, it will send the “remote server address” 0.0.0.0 to the SOCKS5 server. Only one SOCKS5 UDP bind step is needed for UDP Listen. If the first step SOCKS5 UDP bind command is used for that, there is no way for the SOCKS5 server to differentiate between the passive UDP open mode and the UDP listen mode. This is because both of them are using the same SOCKS5 UDP bind command and they carry the same “remote address” which is 0.0.0.0. One solution for that is to create a SOCKS5 UDP bind command for UDP listen and not to use the first step UDP bind command. The SOCKS5 server will then be able to identify the SOCKS5 UDP binding for UDP listen mode. However, this will increase the complexity of the SOCKS5 command set.

The other solution is to transform the SOCKS5 UDP binding for UDP listen into the two steps UDP binding process. The first step of the SOCKS5 UDP Listen is the same as the first step of the SOCKS5 passive UDP open. The SOCKS5 client will send the first step SOCKS5 UDP bind command with the remote address 0.0.0.0 to the SOCKS5 server. The SOCKS5 server will then be at the "half-binding state". To complete the binding, the SOCKS5 client will issue the second step SOCKS5 UDP bind command with remote address 0.0.0.0 to the SOCKS5 server. When the SOCKS5 server receives that, it knows that this is a UDP Listen binding because the remote address is not a specific IP address. So the two steps SOCKS5 UDP binding will work for UDP Listen mode.

The two steps SOCKS5 UDP binding could be introduced into the Active UDP open mechanism as well. The original SOCKS5 UDP binding of Active UDP open involve only one UDP binding step. This one step process will be transformed into the two steps UDP binding process. In the Active UDP opening mode, the first step SOCKS5 UDP binding is the exactly same as the first step of the Passive UDP open. The SOCKS5 client will send the first step SOCKS5 UDP bind command with the remote address 0.0.0.0 to the SOCKS5 server. The SOCKS5 server will then be at the "half-binding state". To complete the binding, the SOCKS5 client will issue the second step SOCKS5 UDP bind command with the specific remote address to the SOCKS5 server. In fact, this is exactly the same as the protocol exchange sequence of passive UDP open.

The following diagram indicates how the three types UDP port opening are handled with the introduction of the two step SOCKS5 UDP binding process and the new half-binding state.

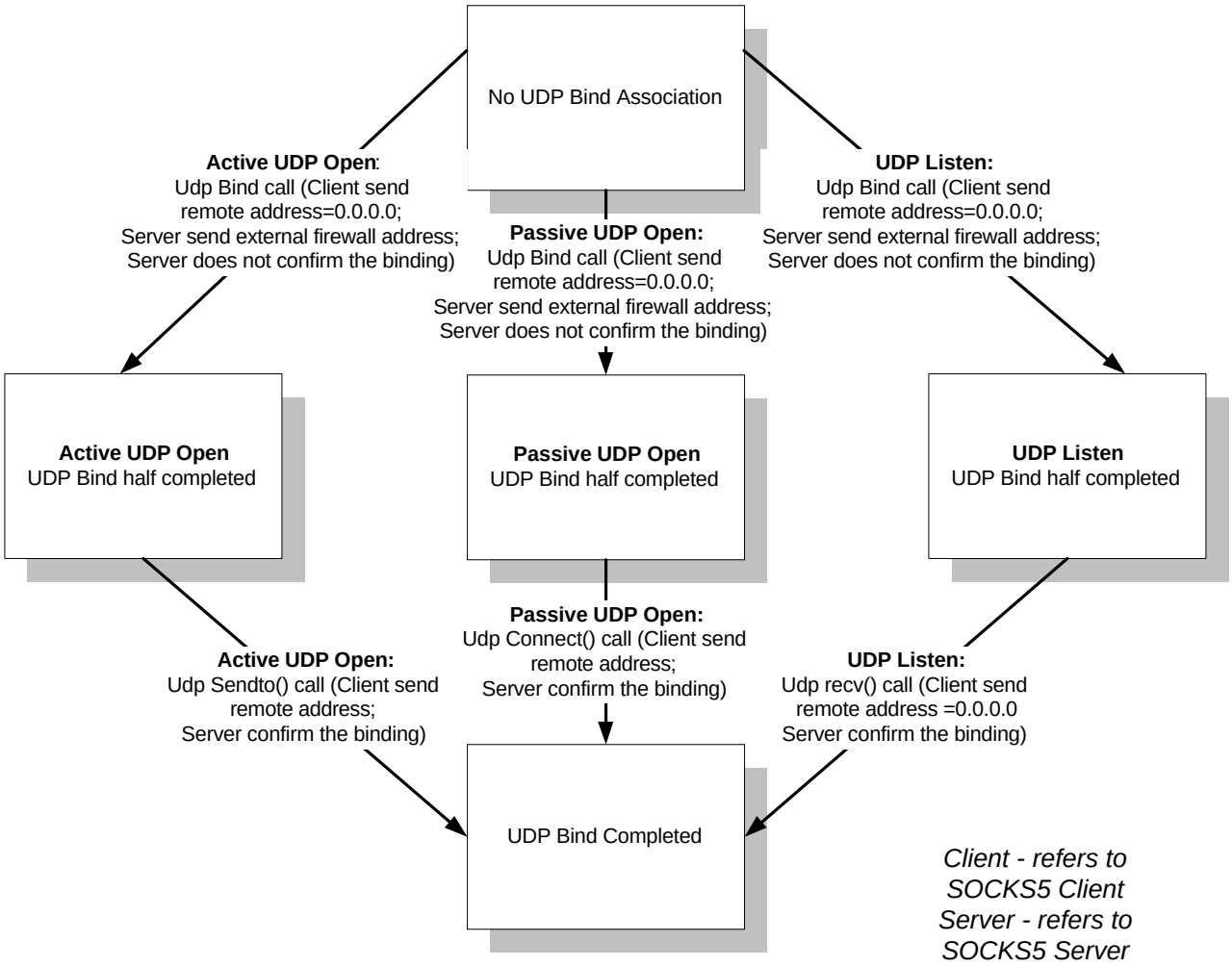


Figure 13: State Diagram of the Two Step SOCKS5 UDP Binding Process

The new two steps UDP SOCKS5 UDP Binding and the "half-binding states" are introduced for the three types of UDP port binding as mentioned above. This will give a consistent framework for UDP port binding. The “half-binding state” is communicated from the SOCKS5 client to the SOCKS5 server by sending a first step SOCKS5 UDP bind command with a remote address of 0.0.0.0. When the SOCKS5 server receive this command, it will go into the “half-binding state”

and send back the external address of the SOCKS5 server. It will then wait for the second step SOCKS5 UDP bind command. Once this second step SOCKS5 UDP bind command is received, it will complete the two steps of UDP binding process.

3.4.2 Two Steps UDP Binding Process and the Socket Call Procedure

To indicate which types of UDP port binding is using, the appropriate socket calls need to be invoked from the client to signal the SOCKS5 client. Normally, one UDP bind() socket call is used for UDP port binding in most applications. In the bind() UDP call, there is no remote address carried in the UDP bind() socket call. So it could not provide sufficient information for the second step of the SOCKS5 UDP binding process. In order to solve this problem, a second socket call need to be used to communicate the remote address to the SOCKS5 client.

The first socket call for all three types of UDP port binding is the UDP bind() socket call. The second socket call will then indicate the types of UDP port binding and it will inform the SOCKS5 client the remote address. For the new active UDP open, it will invoke either a UDP sendto() or a UDP connect() socket call For the passive UDP open, it will just invoke a UDP connect () socket call. . Both of the UDP sendto() and UDP connect() socket call have a destination address argument which will carry the remote address. For the UDP listen, it will invoke the UDP recv() socket call. For active and passive UDP open, the actual "remote address:" will be sent to the SOCKS5 server via the second step SOCKS5 UDP bind command. For UDP listen, the "remote address" will still be set to 0.0.0.0. When the server receive this second step SOCKS5 UDP bind command, it will complete the binding and let UDP traffic to go through.

As discussed previously, the two steps SOCKS5 UDP binding process need to make use of the SOCKS5 protocol exchange between the SOCKS5 client and SOCKS5 servers to carry out the SOCKS5 UDP binding and to indicate the type of the UDP binding. The two steps SOCKS5 UDP binding also need to be tied closely with the socket calls from the applications as mentioned above. The table below summarises how the new binding state is tied to the existing socket calls.

Type of UDP Opening	**half-binding**	**Complete binding**
New active UDP open	• Socket call interface- UDP bind() • SOCKS5 protocol - SOCKS5 client sends "local UDP address" & "remote address" 0.0.0.0 to SOCKS5 server	• Socket call interface - UDP sendto() or UDP connect() • SOCKS5 protocol - SOCKS5 client sends "local UDP address" and specific "remote address" to SOCKS5 server.
New passive UDP open	• Socket call interface- UDP bind() • SOCKS5 protocol - SOCKS5 client sends "local UDP address" & "remote address" 0.0.0.0 to SOCKS5 server	• Socket call interface - UDP connect() • SOCKS5 protocol - SOCKS5 client sends "local address" and specific "remote address" to SOCKS5 server.
New UDP listen	• Socket call interface- UDP bind() • SOCKS5 protocol - SOCKS5 client sends "local UDP address" & "remote address" 0.0.0.0 to SOCKS5 server	• Socket call interface - UDP recv() • SOCKS5 protocol- SOCKS5 client sends "local address" and "remote address" 0.0.0.0 to SOCKS5 server.

Table 1: Mapping of socket call against the proposed two steps SOCKS5UDP Binding

3.5 UDP & Multicast Extension vs Revised SOCKS5 For UDP Support

As mentioned in section 2.4, there are two Internet drafts which propose ways to support SOCKS5 UDP associations. During the initiation of this project, only the UDP & multicast extension proposal (Ref. 3) was available. It provides more information in the enhanced UDP mode packet structure (see the diagram for the packet structure in section 2.4.1). The second approach which is a revised version of SOCKS5 RFC1928 was proposed by the recent Internet draft (Ref. 5). The second approach tries to adopt the existing SOCKS5 packet structure (see the diagram for the packet structure in 2.4.2). Hence, the UDP & multicast extension approach provides a much better foundation for future growth and enhancement.

Other than that, the UDP & multicast extension approach makes use of a hierarchical command structure. The UDP & multicast command are located in second level command set which have a different packet structure. This hierarchical command structure provides extra flexibility in terms of future expansion. In future, different protocol requirement could be implemented as a second level command set with different packet structure. However, the revised SOCKS5 approach is still using the flat command structure of the original SOCKS5 protocol. So it does not have the additional flexibility which could provide future enhancement on the SOCKS5 protocol. It is bound by the basic SOCKS5 packet structure. In terms of efficiency, UDP & multicast extension approach is able to support multiple UDP binding with one SOCKS5 control while revised version of SOCKS5 (Ref. 3) could support only one UDP binding per SOCKS5 control connection. Hence, the UDP & multicast extension will produce less overhead.

Based on the above discussion, the UDP & multicast extension approach has obvious advantage over the revised SOCKS5 approach. So the UDP & multicast extension approach will be adopted as the basis for development in this project.

The table below summarises the difference of the revised SOCKS5 protocol & the UDP & multicast extension protocol.

Revised SOCKS5 Protocol (Ref. 5)	SOCKS5 Protocol with UDP & Multicast Extension (Ref.3)
One address field for either remote or local address information	Two address fields for both remote & local address information
One byte flag to support options negotiation	Two byte flag to support more options negotiation
No transaction identifier (TID)	Provide transaction identifier (TID) which could support multiple UDP association in one SOCKS5 control channel
No association identifier (AID). Need to make use of the destination address to identify each UDP association.	Provide a unique association identifier (AID) which identify each UDP association.
Flat Command Structure – Both the basic SOCKS5 packet and the packet for UDP sub-command have the same packet structure	Hierarchical Command Structure – The packet structure of the enhanced UDP packet provides extra field for SOCKS5 protocol exchange.

Table 2: Comparisons of Revised SOCKS5 Protocol and the SOCKS5 Protocol with UDP & Multicast Extension

3.6 SOCKS5 UDP bind commands for the Two Step UDP Binding Process

In the two steps UDP Binding process, it involves two distinct steps. To identify these two steps, one simple solution is to use two separate UDP binding commands. In the UDP & multicast extension for SOCKS5 protocol, there is only one enhanced UDP bind command (with command code 0x05). This enhanced UDP bind command could be used in the first step SOCKS5 UDP binding. An extra enhanced UDP bind command for SOCKS5 has to be created for the second step SOCKS5 UDP binding.

In fact, it is not necessary to have two separate commands for each step. In each step of the two steps UDP binding process, it requires only the local address field and the remote address field. The enhanced UDP bind command already has these required fields to carry the address information. The main problem is how the SOCKS5 server identifies these two steps from the enhanced UDP bind command it receives. This could be achieved by using the TID (Transaction ID) of the enhanced UDP mode packet. The transaction ID will be the same for the first enhanced UDP bind command and the second enhanced UDP bind command. So when the SOCKS5 server receives a SOCKS5 UDP bind command, it will check if it has received the TID before. If it finds the same TID in the previous SOCKS5 UDP binding, it will treat the SOCKS5 UDP bind command received as the second step of the SOCKS5 UDP binding process. Otherwise, it will treat the SOCKS5 UDP bind command as the first step of the two steps binding process. Hence, the existing enhanced UDP bind command could be used in both steps of the two steps SOCKS5 UDP binding process. There is no need to add an extra UDP bind command for the second step.

The two steps SOCKS5 UDP binding will support all three types of UDP port binding and it will be incorporated into the SOCKS5 server. The same SOCKS5 server will still be able to support the original one step SOCKS5 UDP binding for the active UDP opening. The SOCKS5 server is able to differentiate the enhanced UDP bind command for two steps process and the enhanced UDP bind command for the one step process. For the first step SOCKS5 UDP binding, the "remote address" field of the enhanced UDP bind command will be filled with 0.0.0.0. For the second step of the SOCKS5 UDP binding, the "remote address" of the enhanced UDP bind command will either be filled with 0.0.0.0 or a specific address. For the one step SOCKS5 UDP binding, the "remote address" field will always be filled with a specific address. So if the "remote address" is 0.0.0.0 and the TID is new, the SOCKS5 UDP bind command represents a first step SOCKS5 UDP bind. If the "remote address" is a specific IP address and the TID has occurred before, the SOCKS5 UDP bind command represents a second step SOCKS5 UDP bind. If the "remote address" is a specific IP address and the TID is new, the SOCKS5 UDP bind represents a one step SOCKS5 UDP bind. Base on these criteria, the SOCKS5 server could determine whether a SOCKS5 UDP bind command is representing the first step SOCKS5 UDP binding, the second step SOCKS5 UDP binding or the original one step SOCKS5 UDP binding.

3.7 Comparison of current SOCKS5 protocol and the proposed modification

The proposed solution overcomes the existing limitations of the SOCKS5 protocol and the issues with the current SOCKS5 implementations in terms of the support of UDP-based protocol. Other than that, the proposed modification of the SOCKS5 protocol provides a complete solution to handle all UDP binding via a SOCKS5 firewall. The table below summarises the limitations and issues and how the proposed modifications tackle those limitations and issues:

Limitation of Existing SOCKS5 protocol for UDP	**Issues with current SOCKS5 implementations**	**Proposed Modification of SOCKS5 protocol**
The current protocol does not support passive UDP opening. The remote address has to be available before the UDP binding take place.	The current NEC implementation work around this limitation by using the remote address of previous SOCKS5 connection for UDP binding.	The passive UDP open is introduced into the protocol. A two steps UDP binding process is introduced in the SOCKS5 protocol.
The current protocol does not consider the interface requirement of UDP socket binding process. The UDP bind() socket does not provide the remote address in the argument.	Since the socket call UDP bind() does not provide the remote address in the attribute, the remote address of previous SOCKS5 connection is used instead.	The mapping from the socket call to the SOCKS5 protocol is re-defined to provide the remote address for SOCKS5 protocol.
NA	The UDP port no. of the remote address is not checked. Access control is only up to the host level.	With the full remote address available from the socket call, the UDP port no. of the remote address will be available.
The current protocol does not support UDP listen.	NA	The UDP listen is supported by means of the two steps UDP binding process.

Table 3: Summary of limitations, issues of existing SOCKS5 protocol and the proposed solution

4. Proposed Transport Establishment Procedure In RTSP Protocol To Work With SOCKS5 Protocol

As discussed in last section, the socket call procedure for each type of UDP binding will consist of two socket. All UDP-based application need to follow the same socket call procedure to properly set up the UDP transport via SOCKS5 layer. In this section, the transport establishment procedure of RTSP protocol will be discussed to illustrate what are the mandatory requirements for that. This same model will be applicable to all other UDP-based applications which need to traverse through the SOCKS5-based firewall. In fact, this transport establishment procedure is similar to the normal UDP transport establishment procedure without a firewall. The same transport establishment procedure will work for a normal direct connectivity without a firewall. The main difference is in passive UDP open which requires an additional step of UDP connect() socket call after the UDP bind() socket call.

4.1 Transport Header of RTSP

RTSP establishes the transport for the multimedia stream by using the RTSP transport header in the RTSP "Set up" request and reply. Although the transport header contains source address, source port, destination address and destination port, there is no control whether these fields are mandatory in RTSP. For example, it is stated in RTSP that the source address of the RTSP stream server may be specified when it is different from the RTSP server. In one of the example of the Internet draft for RTSP, the source address and the source port is not specified in the transport header. In the other example, both the source address and the destination address are ignored in the transport header. This is applicable only when the source address and the destination address of the RTSP stream is the same as those of the RTSP TCP control connection. Hence the source address and the destination could be derived from the address of the RTSP TCP control connection. As we look at the protocol interface between the RTSP client and the SOCKS5 layer, it could be seen that

some of these fields are essential for the operation of the SOCKS5 protocol. In order to provide sufficient information for transport establishment with the SOCKS5 protocol, some of these fields need to be mandatory.

If the RTSP client and RTSP server could talk to each other directly, the “destination address” is same as the client address of the RTSP TCP control connection. So it may be skipped in the transport header when there is no firewall in between them. But with the SOCKS5 firewall between the RTSP server & the RTSP client, the “destination address” will be the “external address” of the SOCKS5-based firewall. So the external address of the SOCKS5-based firewall has to be communicated to the RTSP server. The RTSP server will then send the UDP stream to the “external address” of the SOCKS5-based firewall and the UDP stream will be subsequently relay to the RTSP client. The RTSP client should not assume that the “destination address” of the RTSP stream is the same as that of the RTSP TCP control connection. It should use the IP address obtained from the getsockname() socket call as the “destination address”. It should not skip the “destination address” in the transport header unless it could confirm that the “destination address” of the UDP binding and the client address of the RTSP TCP control connection are the same.

On the other hand, the RTSP server must reply with the “source address” and the “source port”. With the “source address” and the “source port”, the RTSP client could inform the SOCKS5 server the source address of the incoming UDP stream. The “source address” and the “source port” is communicated to the SOCKS5 layer via the socket library call. The SOCKS5 firewall will allow only the incoming UDP stream from the specified source address. This information is essential for the filtering of the incoming UDP packets by the SOCKS5 server.

4.2 Socket Call Procedure For UDP Stream

Although RTSP does not specify the transport establishment procedure for the UDP stream, it is important that the source address and the destination address for the UDP stream are properly communicated to the SOCKS5 transport layer. The current implementation of RTSP does not provide sufficient address information from the application layers of RTSP to the SOCKS5 transport layer.

The socket call is the prime channel for the communication between the RTSP application layer and the SOCKS5 transport layer. At present, only the bind() socket call is invoked to set up the UDP stream. The bind() socket call does not provide the RTSP server address to the SOCKS5 transport layer. In order to provide the RTSP server address to the SOCKS5 transport layer, the connect() socket call will be invoked once the RTSP server address is obtained. This will align with the proposed two step UDP binding sequence in SOCKS5 protocol.

In fact, it is a good practice to add the additional connect() socket call after the bind() socket call for RTSP applications. The reason for this is that the UDP port for a multimedia stream is always bind to a single UDP port and a single RTSP server. So it is a one-to one UDP binding instead of the one-to-many UDP binding.

4.3 Procedure for Establishing RTSP Stream

The requirement in the transport header of RTSP and the socket call procedure described above are the essential components for the establishment of RTSP stream via the SOCKS5-based firewall. These components need to tie tightly with the RTSP request and reply sequence so that the proper sequence of information is exchanged between the RTSP clients and the SOCKS5 clients in the same machine. Fig. 14 outlines the sequence of events between RTSP clients, RTSP servers and the SOCKS5 clients. The sequence of events should be organised in this order so that the RTSP stream could be set up properly via the SOCKS5 firewall.

The UDP bind() socket call, the UDP connect() socket call and the UDP recv() need to be executed at the right sequence between the RTSP request and response. The UDP bind() and the getsockname() socket call need to be executed before the RTSP Setup Request. The UDP connect() socket call needs to be executed after receiving the RTSP Setup Reply and before sending the RTSP Play Request. The UDP recv() socket call needs to be executed after receiving the RTSP Play Reply.

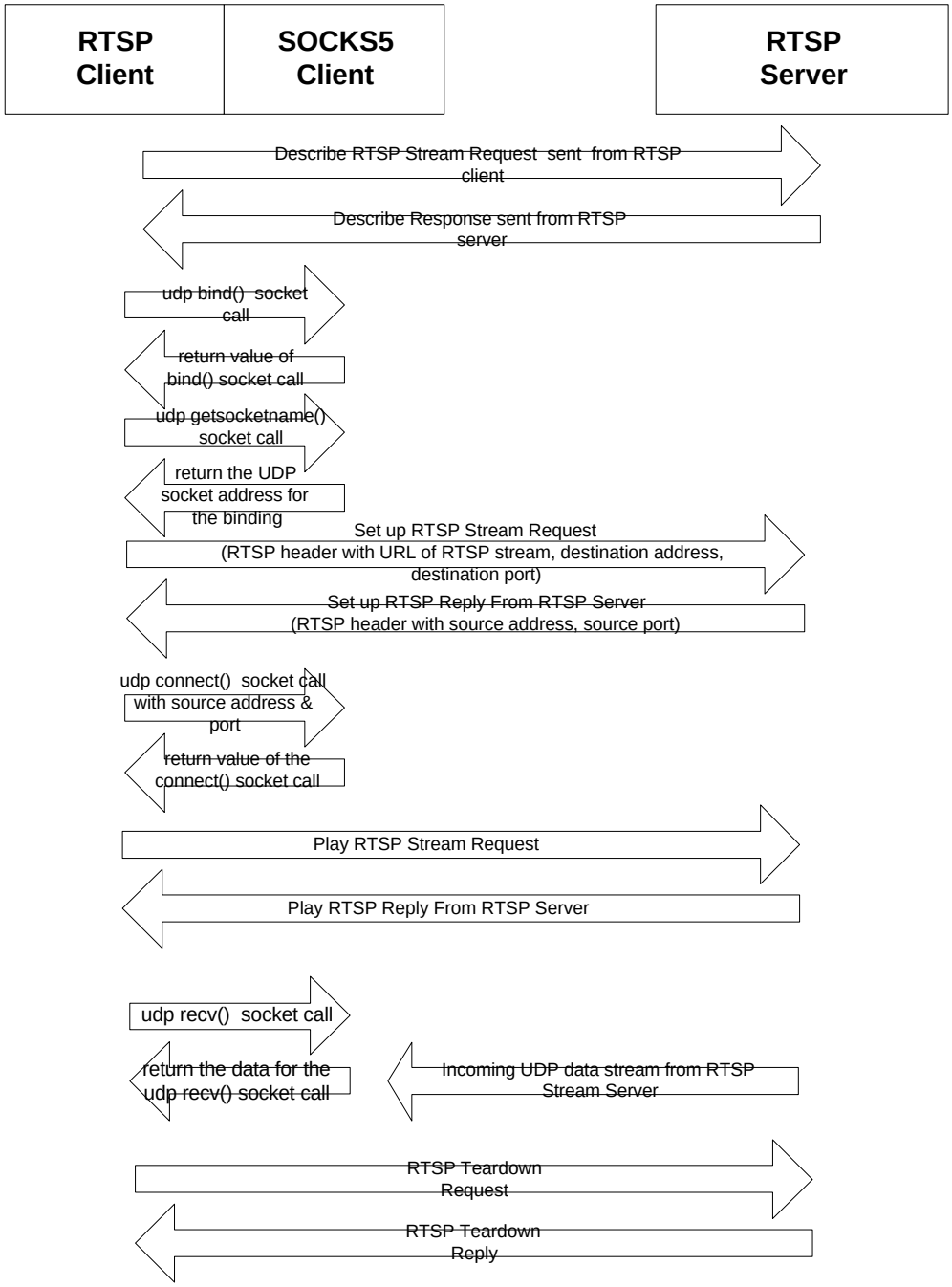


Figure 14: RTSP Stream Establishment Procedure and the Socket Call Procedure

5. Implementation

5.1 Configuration of the Program Development Platform

As mentioned earlier, the RTSP will be used as the multimedia streaming applications to test the enhanced SOCKS5 protocol with the streaming UDP protocol support. A configuration is set up which consists of the RTSP clients, the RTSP server, the SOCKS5 client and the SOCKS5 server. The following diagram illustrate the configuration of the program development platform:

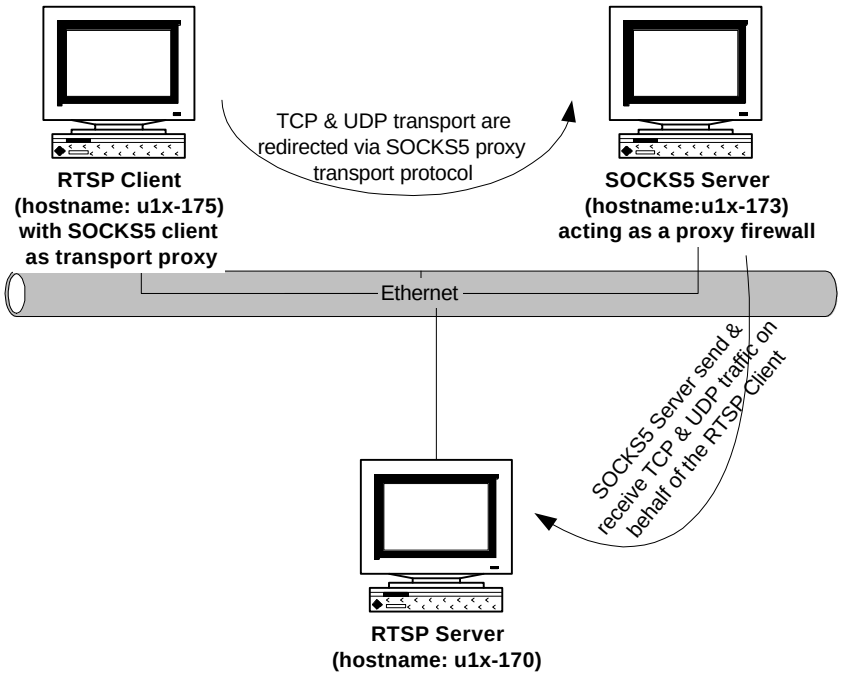


Figure 15: Configuration of the program development platform

The RTSP client, RTSP server , SOCKS5 client and SOCKS5 server are all running in SUN Solaris 2.6 environment. The RTSP client and SOCKS5 client are running on the same SUN Solaris machine (hostname: u1x-175). The SOCKS5 server are running in a standalone SUN Solaris machine (hostname: u1x-173) and it is acting as a firewall. All the TCP and UDP traffic between the RTSP client and the RTSP server needs to go through the SOCKS5 server. The RTSP server is running on another standalone SUN Solaris machine (hostname: u1x-170).

The TCP control connection between the RTSP client and the RTSP server makes use of the TCP port 554 for communication. The RTSP server applications will listen to request on TCP port 554. As the TCP port 554 is a privileged port, it is accessible only by root users. In order to facilitate program development without using the root access, the TCP port for RTSP control connection is changed to TCP port 1554 which is accessible by non-root users.

The TCP control connection between the SOCKS5 client and the SOCKS5 server makes use of the TCP port 1080 for communication. The SOCKS5 server will listen to request on TCP port 1080. As the TCP port 1080 is a non-privileged port, it is accessible by non-root users. So there is no need to change the TCP port for SOCKS5 server.

5.2 Source Code For Program Development

The source code for SOCKS5 program development is obtained from NEC laboratories. NEC has developed commercial products for SOCKS4 and SOCKS5 protocol. They have released part of the SOCKS5 source code for third party program development. Version 1.4 of the SOCKS5 source code was obtained from NEC to develop the enhanced SOCKS5 protocol for UDP support.

The source code consists of SOCKS5 server and some popular SOCKS5 clients such as telnet and ftp. The source code is based on the SOCKS5 standard RFC 1928 (Ref. 2) with some additional enhancement for UDP as discussed in another internet draft (Ref. 5). The source code for system socket call such as bind() and connect() are in the SOCKS5 clients and server source code library. In order to make use of the SOCKS5 proxy for other applications, these source code for the system socket call need to be compiled with the source code of the applications so that the socket calls made by the applications will be redirected to the SOCKS5 client.

The source code for RTSP program development is obtained from Progressive Network. Progressive Network is the developer of the commercial Real Audio Player & Real Audio Server. They are the one of the key players in the development of the RTSP standard. They have developed RTSP reference implementation. The source code was available for interoperability testing by other parties. Version 0.4 Alpha of source code for RTSP reference implementation was obtained from Progressive Network to develop the necessary interface with the SOCKS5 clients.

The source code for SOCKS5 and RTSP are all in ANSI C language. GCC compiler is used to compile the source code to do the program development.

5.3 Compilation & Testing of the Original Source Program

In order to make sure that the source code support the basic function for the program development, the source code need to be compiled to test the basic functionality. These tests will ensure that the original program is running properly so that the enhancement to the original program could be made in a proper foundation.

5.3.1 Testing of the original source code for SOCKS5 Client & SOCKS5 Server

The source code for SOCKS5 server and the SOCKS5 telnet client were compiled to test the interoperability. The SOCKS5 server was running on the host machine u1x-173. The SOCKS5 telnet client was running on the host machine

u1x-175 which is the same host machine which was going to be used for the RTSP client. The host machine u1x-170 is used as a telnet server. Telnet sessions were initiated from u1x-175 using the SOCKS5 telnet client and the TCP session was redirected to the SOCKS5 server. But it was found that it does not get redirected to the SOCKS5 server and relay to the telnet server. Instead, the TCP session is connected directly from the telnet server. This was checked by using the UNIX "netstat –a " command to show all the TCP & UDP binding of the telnet server. After checking the codes of the SOCKS5 socket library, it was found that one of the function call (lsHowToConnect()) for checking how to connect to the destination server in the SOCKS5 socket library is causing the problem. The function call will check the destination host address of the TCP connection. If the destination address is on the same network, it will not redirect to the SOCKS5 server and it will connect directly to the destination address. As the telnet client and the telnet server are on the same IP network of the computer department, the SOCKS5 socket library will not redirect it to the SOCKS5 server. In order to allow the testing of the SOCKS5 program, some of the codes for the checking how to connect to the destination address in that function call is commented out so that it will always redirect to the SOCKS5 server.

After commenting out the source code mentioned above, the telnet client was recompiled again. It was then tested again by initiating a telnet session to the telnet server. From the telnet server, it was confirmed that the telnet session is coming from the SOCKS5 server. From the SOCKS5 server, it could be seen that a SOCKS5 connection to TCP port 1080 is initiated from the telnet client. So the SOCKS5 redirection works properly after the change.

5.3.2 Testing of the original source code for RTSP Client & RTSP Server

The source code for RTSP Client and RTSP Server were compiled to test the interoperability. The RTSP server was running on the host machine u1x-170. The RTSP client was running on the host machine u1x-175. The RTSP server program (rtsp-server) was running in the foreground and the TCP port for the control connection is configured to 1554. The RTSP client program (rtsp-player) was executed. A RTSP connection was then initiated from the RTSP client to the RTSP server by specifying the RTSP server address and the TCP port 1554(open RTSP://u1x-170:1554). It could be seen from the messages on both the RTSP client and the RTSP server that the TCP control connection is established. To

further confirm that, the “netstat –a “ command was executed to verify the TCP control connection from the RTSP client to the RTSP server.

After the successful establishment of the TCP control connection, the delivery of UDP stream from the RTSP server to the RTSP client was tested. The RTSP command “get rtsp.wav” was executed in the RTSP client. This command is equivalent to the “play” request in the RTSP protocol. The audio stream “rtsp.wav” will be delivered by UDP from the RTSP server to the RTSP client and it will be played by the RTSP client. The messages from the RTSP client and RTSP server indicated that the stream file was successfully delivered and played. To further confirm that, the “netstat –a” command was executed to verify the UDP stream from the RTSP client to the RTSP server. As the UDP port binding will only exist during the delivery of the UDP stream, the “netstat –a” command need to be executed during the delivery time. The messages from the RTSP server will indicate the UDP port on the RTSP client to which it will send the UDP stream. So this UDP port number could be used to match the output from the “netstat –a” command in the RTSP client.

5.4 RTSP Client Program

5.4.1 Organisation of the original program

The transport establishment procedure of the RTSP client is performed in a Send_setup_request() function call & Handle_setup_reply() function call in the RTSP player program. The Send_setup_request() function performs the RTSP “Set up” request and sends the RTSP “Set up “ request packet to the RTSP server. The Handle_setup_reply() function receives the RTSP “Set up” reply from the RTSP server and completes the RTSP Set up process.

The Send_setup_request() perform the following functions:

1. Conduct UDP binding for the UDP stream
2. Get the UDP port of the binding
3. Send the UDP port of the binding to the RTSP server

The Handle_setup_reply() function of the original program perform the following functions:

1. Receive the RTSP “Set up” reply from the RTSP server
2. Check if the status code of the reply is an error condition.
3. Check if the transport settings is present in the reply.
4. Retrieve the UDP port number of the RTSP server from the reply.

5.4.2 Function of the revised program for the RTSP transport establishment procedure

Send_setup_request()

1. The first step of the passive UDP port opening is performed by using the UDP bind() socket call to do a half-binding.
2. The external address and the external port number of the SOCKS5 server is obtained.
3. This function issues a RTSP “Set up” request to the RTSP server with the external address and external port binding.

Handle_setup_reply()

1. This function handle the setup reply message from the RTSP server.
2. The remote address is obtained from the reply of the RTSP server.
3. A UDP connect() socket call is performed to communicate the remote address to the SOCKS5 interface.

5.4.3 Addition / Modification to the original RTSP client program

Send_setup_request()

The following function calls highlight the location that is related to the modification requirement. The bolded function is the location where changes / addition is required.

/ Send RTSP Set up Request to RTSP Server */*

Send_setup_request() *player.c*

/ Assign udp file handle for the UDP data stream */*

Assign_udpfd() *player.c*

/ Perform UDP bind() socket call for the UDP stream*/*

Udp_open() *player.c*

/ Perform UDP recv() socket call to receive UDP stream data */*

Udp_data_recv() *player.c*

/ Perform UDP getsockname() socket call to get the IP address and the port no. of the UDP binding */*

Udp_getport() *player.c*

/* Send the RTSP Set up Request packet to RTSP Server */

bwrite() *player.c*

The sequence of events of the original program has already fulfilled the requirement for the half-binding of the UDP port. UDP bind() socket call is performed. It is then followed by UDP getsockname(). However, only the port no. of the UDP binding is put in the RTSP Set up Request packet and is delivered to the RTSP server. Hence, the IP address of the UDP binding has to be retrieved by the UDP getsockname() call as well. Then it has to be delivered in the RTSP Set up Request packet.

The other difference from the requirement is the recv() function. The recv() socket call should be called after the UDP connect() socket call. If the UDP recv() socket call is called right after the UDP bind() socket call, it will be treated as a UDP listen in the proposed UDP port opening model. But since the implementation is focus only on the passive UDP open

scenario, this could be skipped in this implementation. In an actual full implementation of the proposed model, the UDP recv() socket call should be performed after the UDP connect() call in the Handle_setup_reply() function.

Minor coding change is needed in the Send_setup_request() function. The only coding change required is to retrieve the IP address of the UDP binding and then put it in the RTSP Setup Request. In addition to that, the wrapper socket calls from SOCKS5 has to be used instead of the system socket call. The wrapper socket call will redirect the bind(), recv() and getsockname() socket call to the wrapper program by SOCKS5. In order to do that, the code needed to be recompiled with the socket call library from SOCKS5. This is done by modifying the "Makefile" of the RTSP clients and recompiling the codes. After that, check point was established in the wrapper socket program to make sure that the wrapper socket call from SOCKS5 was used instead of the system socket call.

Handle_setup_reply()

/* Handle the RTSP Set up Reply from the RTSP Server */

Handle_setup_reply() *player.c*

> /* Addition code for retrieving the RTSP server address and RTSP server port from the RTSP Set up Reply */
>
> **New Codes**
>
> /* Addition code for performing UDP connect() to the RTSP server */
>
> ***connect()*** *player.c*

The original code for the Handle_setup_reply() function call does not retrieve the RTSP server address. In fact, it does not check whether the transport header of the RTSP Reply consists of the server address. It just checks the server port and records it. The server address is not a required field in the transport header.

In the proposed transport establishment scheme, the server address and the server port is required in the transport header. New codes is put in the Handle_setup_reply() function to retrieve the RTSP server address and RTSP server port from the transport header.

The RTSP server address and server port will then be used as the argument for the UDP connect() socket call which is added to the Handle_setup_reply() function. The connect() socket will complete the UDP binding by providing the remote address and the remote port.

As mentioned previously in the Send_setup_request() function call, the UDP recv() socket call should be performed after the UDP connect() socket call. This could be skipped in this implementation as the prime focus of this implementation is on the passive UDP opening. In a full scale development of the proposed model for UDP port opening, this should be done properly to prevent wrong interpretation by the SOCKS5 client.

5.5 SOCKS5 Client Program

5.5.1 Organisation of the original program

The wrapper socket calls UDP bind() and UDP connect() is the key program that need to be used for the proposed model for passive UDP port opening. The RTSP client will call up these two socket call programs to do the UDP port binding.

The UDP bind() perform the following functions:

1. Establish SOCKS5 TCP control channel to the SOCKS5 server
2. Perform authentication with the SOCKS5 server
3. Send the UDP assocation request to the SOCKS5
4. Receive the UDP association reply from the SOCKS5 server.

5. Exchange UDP sub-command with the SOCKS5 server and use the SOCKS5 server address as the remote address.
6. Retrieve the UDP bind port from the SOCKS5 server's reply to the UDP sub-command.

The UDP connect() perform the following functions:

1. Check if the SOCKS5 TCP control connection exist.
2. If SOCKS5 TCP connection does not exist, establish SOCKS5 TCP control channel to the SOCKS5 server
3. Check if there is a UDP connection to the destination address
4. If there is no previous UDP connection to the same destination address, Send the UDP association request to the SOCKS5 server.

5.5.2 Function of the revised program for the SOCKS5 Client Program

UDP bind() socket call:

1. Establish enhanced UDP mode by sending the enhanced UDP command (0x04) via SOCKS5 standard mode.
2. Bind a real UDP port and put this local UDP address & UDP port in the local address field of the enhanced UDP bind request. Send this enhanced UDP binding request to the SOCKS5 Server with the enhanced UDP mode packet structure. Use 0.0.0.0 as remote address to indicate half-binding.
3. Receive enhanced UDP binding reply from SOCKS5 Server and retrieve the external UDP address & UDP port bind at the SOCKS5 server. This external UDP address & port will be located at the remote address field of the enhanced UDP binding reply.
4. Set the status to be "half bind".

UDP connect() socket call:

1. Check if the status is "half bind".

2. If the status is “half bind”, send another enhanced UDP binding request to the SOCKS5 Server with the enhanced UDP mode packet structure. Use the destination address argument in the connect() call as the remote address in the enhanced UDP binding request.
3. Set the status to be “connection established”.

5.5.3 Addition / Modification to the original SOCKS5 Client Program

lsUdpbind()

/* This is the wrapper program for UDP bind(). It calls up proxy_bind() to perform the UDP binding. */

lsUdpbind() *wrap_udp.c*

/* This function call lsLibProtoExchg() and ls LibExchgUdpCmd to set up the SOCKS5 UDP half-binding**. */**

proxy_bind() *wrap_udp.c*

/* Half-binding state is established by setting the remote address to 0.0.0.0. */

New Codes

/* This function perform the establishment of SOCKS5 connection to the SOCKS server. It sends the enhanced UDP command to switch to the enhanced UDP mode.*/

lsLibProtoExchg() *libproto.c*

/* This new function perform the exchange of enhanced UDP command*/

LsLibExchgEUdpCmd() *libproto.c*

/* This new function send the SOCKS5 enhanced UDP binding request and read the enhanced UDP binding reply from the SOCKS5 server. */

LsEUDPSendRequest() *protocol.c*

/* This new function packed information into the enhanced UDP mode packet format and send it to the SOCKS5 Server */

LsEUDPSendProto() *protocol.c*

The structure of the function call within lsUdpbind() socket call is preserved. Instead of issuing the UDP association request in lsLibProtoExchg() function, the enhanced UDP command (0x04) is used to switch to the enhanced UDP mode. A new function LsLibExchgEUdpCmd() which resembles the original LsLibExchgUdpCmd() function is introduced. The original function performs the UDP sub-command while the new functin performs the enhanced UDP command.

The new function LsEUDPSendRequest() resembles the original LsEUDPSendRequest() function and it sends the enhanced UDP binding request and receives the enhanced UDP Reply. The new function LsEUDPSendProto() packed the address information into the enhanced UDP mode packet format. Some of the additional fields such as the transaction identifier (TID) and the association identifier (AID) in the enhanced UDP mode packet structure is not essential to the operation of the UDP port binding process. These fields are left empty at the moment to simplify the implementation.

At the end of the lsUdpBind() call, the status of the binding will be set to “CON_HALFBIND” indicating a “half bind” status.

lsUdpconnect()

/* This is the wrapper program for UDP connect() */

lsUdpconncect() *wrap_udp.c*

/* Send the remote address to the SOCKS5 server to complete the UDP binding from the half-binding state. */

New Codes

/*Make use of the function calls used by lsUdpbind() to send the remote address via enhanced UDP bind request to the SOCKS5 server */

LsLibExchgEUdpCmd() *libproto.c*

LsEUDPSendRequest() *protocol.c*

LsEUDPSendProto() *protocol.c*

The lsUdpConnect() function call makes use of the same set of functions used by lsUdpbind() to complete the UDP binding process. It will check the status of the connection. If it is “half bind”, it will complete the binding by sending another enhanced UDP binding request to the SOCKS5 server. It will include the remote address in the enhanced UDP binding request. After completing the binding, the status will be set to “CON_ESTABLISHED” indicating that the binding is complete. Other codes of the lsUdpConnect() function call is preserved for compatibility with existing functions.

5.6 SOCKS5 Server Program

5.6.1 Organisation of the original program

The UdpSetup() is the main function call performing the UDP association in the original program. This is the key program for handling UDP association request and UDP binding sub-command. For the proposed model, the enhanced

UDP binding request will be handled similarly by this function. The original UdpSetup() function call performs the following functions:

1. Authorisation of the SOCKS5 request.
2. Receive SOCKS5 UDP association request.
3. Send reply for SOCKS5 UDP association.
4. Receive SOCKS5 UDP binding sub-command.
5. Send reply for SOCKS5 UDP binding sub-command.
6. Perform real UDP binding for the UDP port for relaying UDP traffic.
7. Perform real UDP binding for the external address of the SOCKS5 server.

5.6.2 Function of the revised program for the SOCKS5 Server Program

UdpSetup():

1. Switch to enhanced UDP mode.
2. Handle SOCKS5 enhanced UDP binding request.
3. Perform half-binding upon receiving the first enhanced UDP binding request.
4. Complete the binding upon receiving the second enhanced upd binding request.

5.6.3 Addition / Modification to the original SOCKS5 Server Program

HandleS5Connection():

/* This function receive the standard SOCKS5 command. The enhanced UDP mode command (0x04) is added to support the enhanced UDP mode The UdpSetup() function will be called once the enhanced UDP mode command is received */

HandleS5Connection() *proxy.c*

/* This function will bind Socks5 Server local UDP address by using MakeOutSocket() to associate file handle *u-relay* for relaying UDP traffic to the SOCKS5 client. It will send this local UDP address (&pri->bndAddr) to Socks5 client.

UdpSetup() *udp.c*

/* This function will make an outgoing UDP port to the SOCKS5 client */

Make_out_socket() *udp_util.c*

/* This function will receive SOCKS5 enhanced UDP request & perform UDP data relay.*/

UdpRecvMsg() *udp.c*

/* This function will handle SOCKS5 Enhanced UDP request (UDP bind, UDP release)

EUDPHandleCommand() *udp.c*

/* This function will read the SOCKS5 packet in enhanced UDP mode. Details will be extracted from the enhanced UDP packet. */

LsEUDPReadRequest()

/* This function will handle the SOCKS5 enhanced UDP binding request. It will perform both half-binding or complete binding based on the current binding status. */

EUdpBindhalf() *udp.c*

5.7 RTSP Server Program

5.7.1 Original RTSP Server Program

The Handle_setup_request(), Handle_setup_reply() and Handle_play_request() perform the function of handling the RTSP Request for transport establishment for the UDP stream.

The Handle_setup_request() perform the following functions:

1. Check the transport header and retrieve the destination port from the RTSP Setup request.
2. Check the stream setting and stream format for the media from the RTSP Setup request.

The send_setup_reply() performs the following functions:

1. Send the stream ID to the RTSP client via the RTSP Setup Reply.
2. Send the RTSP server port number using the RTSP client port number via the RTSP Setup Reply.

The Handle_play_request() performs the following functions:

1. Check the url of the multimedia object from theRTSP play request.
2. Check the play settings from the RTSP play request.
3. Check if the stream is already available.
4. Set up stream by establishing a new UDP port.

5.7.2 Function of the revised program for the RTSP Server Program

Handle_setup_request():

1. Check the transport header from the RTSP Setup request.
2. Retrieve the destination address and destination port from the RTSP Setup request.
3. Establish UDP port binding on the RTSP server for the UDP stream.
4. Check the stream setting and stream format for the media from the RTSP Setup request

Send_setup_reply():

1. Send the stream ID to the RTSP client via the RTSP Setup Reply.
2. Send the RTSP server address and server port number via the RTSP Setup Reply

5.7.3 Addition / Modification to the original RTSP Server Program

Handle_setup_request():

Handle_setup_request() server.c

/* This will retrieve the RTSP client address from the transport header and store it in the state variable */

New Codes

/* This will establish a UDP port binding for the UDP stream. */

New Codes

Send_setup_reply():

Send_setup_reply() server.c

/*This will send the RTSP server address and the RTSP server port in the RTSP Setup reply. */

New Codes

Handle_play_request():

Handle_play_request() server.c

Start_stream() streamer.c

/*This will use the UDP port binding established in Handle_setup_request() function to start the media stream */

New Codes

6. Testing on the Prototype

6.1 Test Performed on the Prototype

The test was based on the sequence of events in Fig.12. The RTSP TCP control connection would be initiated from the RTSP client to the RTSP server via the SOCKS5 server. A “get rtsp.wav” command would be issued from the command line interface to the client and it would trigger the RTSP “setup” request and the RTSP “play” request”. In the RTSP “setup” request, the RTSP client would set up the UDP transport for the stream file “rtsp.wav”. The two steps SOCKS5 UDP binding would be performed. In the RTSP “play” request, the RTSP client would initiate a “play” request and the audio stream “rtsp.wav” would be delivered from the RTSP server to the RTSP client. After that, the RTSP client application would be closed.

6.2 Screen Capture During the Test

The following key steps will be identified in the screen capture:

- Establishment of TCP connection for RTSP control connection via SOCKS5 server.
- UDP wrapper bind() socket call.
- First step SOCKS5 UDP binding.
- UDP wrapper getsockname() socket call.
- Send RTSP “Setup” Request to RTSP server.
- Send RTSP “Setup” Reply to RTSP client.
- UDP wrapper connect() socket call.

- Second step SOCKS5 UDP binding.
- UDP wrapper recvfrom() socket call.

6.2.1 RTSP Server

```
[u1x-170:c5717021] /home/msc/yr95/it/c5717021/s5/rtsp_server:>rtsp-server-loop
(start RTSP server program)
Fri May 21 02:52:01 HKT 1999
Control channel port set to 1554.
BasePath set to "."
Listen on port 1554.
TCP control channel established.
(Establish TCP control connection for RTSP client)
HELLO request received.
HELLO response sent.
HELLO sent.
HELLO reply received.
DESCRIBE request received.
Describe response message:
RTSP/0.6 200 2 OK
Date: 20 May 1999 18:52:57 GMT
Content-type: application/sdp
Content-Length: 231

v=0
o=- 2890844256 2890842807 IN IP4 158.132.8.170
s=RTSP Session
i=An Example of RTSP Session Usage
```

u=rtsp://u1x-170/rtsp.wav

t=0 0

m=audio 0 RTP/AVP 101

a=MaxBitRate:176400

a=MaxPktSize:1102

a=TypeSpecificData:"AAEAAQAAViIACAAB"

DESCRIBE response sent.

SETUP request received.

(Receive “Setup” request from RTSP client)

server_name is u1x-170

rtsp_client : 158.132.8.173

(RTSP client address is the SOCKS5 server address for u1x-173)

Setup response message:

Session: 1

Content-Length: 0

Transport: rtp/udp;source=158.132.8.170;port=34309;server_port=36064;

(Send RTSP “setup” response with source address 158.132.8.170 and source port 36064)

SETUP response sent.

PLAY request received.

PLAY response sent.

(Receive the “play rtsp.wav” command from RTSP client and play via the established UDP stream)

TEARDOWN request received.

```
TEARDOWN response sent.
(RTSP client close)
```

6.2.2 SOCKS5 Server

```
[u1x-173:c5717021] /home/msc/yr95/it/c5717021/s5/socks5-v1.0r4/server:>source ~/
s5/setServer
[u1x-173:c5717021] /home/msc/yr95/it/c5717021/s5/socks5-v1.0r4/server:>socks5 -s
 -d –f
(start the SOCKS5 server)
02007: Socks5 starting at Fri May 21 02:52:40 1999 in normal mode
02007: Config: Reading config file: /home/msc/yr95/it/c5717021/sock5/socks5.conf
02007: Interface Query: if0 addr/mask is 7f000001:ff000000
02007: Interface Query: if0 is lo0(1) with 1 IPs
02007: Interface Query: if1 addr/mask is 9e8408ad:fffffe00
02007: Interface Query: if1 is hme0(1) with 1 IPs
02007: Config: Config file read
02007: Socks5 Logging (re)started at Fri May 21 02:52:40 1999
02007: Unresolvable service name: socks
02007: Socks5 attempting to run on port: 1080
02007: Accept: Waiting on accept or a signal
02008: Child: Starting
02008: lsCheckIntfc
02008: Route: dst on the same subnet
02008: Checking Authentication
02008: Auth: No line matched
02008: Socks5: Told client to do authentication method #0
02008: Socks5: Read initial protocol
```

```
02008: Socks5: Read address part of protocol
02008: Proxy: vers:5 cmnd:1 addr:158.132.8.170 port:1554 user:
(Receive SOCKS5 TCP Bind Command and establish TCP proxy for the RTSP TCP control
connection)
02008: Resolve Names: Starting
02008: Resolve Names: Looking up service name
02007: Parent: 1 child
02007: Accept: Waiting on accept or a signal
02008: Resolve Names: Looking up next proxy
02008: Proxy: dst on the same subnet
02008: Resolve Names: No Next Proxy
02008: TCP Connection Request: Connect (u1x-175:33070 to u1x-170:1554) for user
02008: Checking Authorization
02008: Check: Checking commands: Anything is ok
02008: Check: Checking auths: Anything is ok
02008: Check: Checking port range   (0 <= 33070 <= 65535)?
02008: Check: Checking port range   (0 <= 1554 <= 65535)?
02008: Check: Checking username,  is in -
02008: Perm: Line 2:matched
02008: lsCheckIntfc
02008: Route: dst on the same subnet
02008: lsSendResponse: reply is (158.132.8.173:33069)
02008: lsSendResponse: response sent
02008: TCP out interface 158.132.8.173:33069
02008: TCP Connection Established: Connect (u1x-175:33070 to u1x-170:1554) for u
ser
02008: Flow Setup: Allocated Buffer
02008: Flow Recv: Reading from client socket
```

```
02008: Flow Recv: Read 70 bytes from client socket
02008: Flow Send: Writing 70 bytes to server socket
02008: Flow Send: Wrote 70 bytes to server
02008: Flow Recv: Reading from server socket
02008: Flow Recv: Read 116 bytes from server socket
02008: Flow Send: Writing 116 bytes to client socket
02008: Flow Send: Wrote 116 bytes to client
02008: Flow Recv: Reading from client socket
02008: Flow Recv: Read 50 bytes from client socket
02008: Flow Send: Writing 50 bytes to server socket
02008: Flow Send: Wrote 50 bytes to server
02008: Flow Recv: Reading from client socket
02008: Flow Recv: Read 95 bytes from client socket
02008: Flow Send: Writing 95 bytes to server socket
02008: Flow Send: Wrote 95 bytes to server
02008: Flow Recv: Reading from server socket
02008: Flow Recv: Read 333 bytes from server socket
02008: Flow Send: Writing 333 bytes to client socket
02008: Flow Send: Wrote 333 bytes to client
02009: Child: Starting
02009: lsCheckIntfc
02009: Route: dst on the same subnet
02009: Checking Authentication
02009: Auth: No line matched
02009: Socks5: Told client to do authentication method #0
02009: Socks5: Read initial protocol
02009: Socks5: Read address part of protocol
02009: Proxy: vers:5 cmnd:4 addr:158.132.8.175 port:33072 user:
```

(Receive enhanced UDP mode command “0x04” from SOCKS5 client and switch to enhanced UDP mode)

```
02009: UDP Setup
02009: UDP Proxy Request: (u1x-175:33071) for user
02009: Checking Authorization
02009: Check: Checking commands: Anything is ok
02009: Check: Checking auths: Anything is ok
02009: Check: Checking port range   (0 <= 33072 <= 65535)?
02009: Check: Checking port range   (0 <= 33072 <= 65535)?
02009: Check: Checking username,  is in -
02009: Perm: Line 2:matched
02009: Make Out Socket UDP bind successful for address 158.132.8.173:0: Error 0
02009: lsSendResponse: reply is (158.132.8.173:34305)
02009: lsSendResponse: response sent
02009: UDP Proxy Established: (u1x-175:33072) for user
02009: UDP Setup 1
02009: UDP Receive: Selecting on outer sockets...
02009: UDP Receive: Selecting on inner socket...
02009: UDP Receive: Selecting...
02009: select results : 1
02009: UDP Recv Msg
02009: S5IOCheck: Checking socket status
02009: S5IOCheck: ok
02009: EUDPHandleCommand request  &pri->bndAddr (158.132.8.173:34305)
02009: EUDPHandleCommand request  &pri->srcAddr (158.132.8.175:33072)
02009: Socks5: Read initial protocol
02009: length of local address 6
02009: length of remote address 6
```

02009: Socks5: Read address part of protocol

02009: Socks5: Read address part of protocol 1.5

02009: Socks5: Read address part of protocol 1.6

02009: local address is 158.132.8.175:38054

02009: remote address is 0.0.0.0:0

(First step SOCKS5 UDP bind: Receive SOCKS5 enhanced UDP bind command with remote address 0.0.0.0:0)

02009: Socks5: Read address part of protocol 2

02009: EUDPHandleCommand request &pri->retAddr (:0)

02009: EUDP Command: Read command (5) request (0.0.0.0:0)

(First step SOCKS5 UDP bind: Receive SOCKS5 enhanced UDP bind command “0x05” from SOCKS5 client)

02009: UDP Command: Doing BIND command

02009: Resolve Names: Starting

02007: Parent: 2 children

02007: Accept: Waiting on accept or a signal

02009: Resolve Names: Looking up service name

02009: Resolve Names: Looking up next proxy

02009: Resolve Names: No Next Proxy

02009: lsCheckIntfc

02009: Route: dst on the same subnet

02009: Make Out Socket UDP bind successful for address 158.132.8.173:0: Error 0

02009: Make Out Socket UDP connect for address 158.132.8.173:34309: Error 0

02009: UDP Out interface: 158.132.8.173:34309

02009: EUDPHandleCommand request &pri->bndAddr (158.132.8.173:34305)

02009: lsEUDPSendResponse: local is (158.132.8.173:34305)

02009: lsEUDPSendResponse: remote is (158.132.8.173:34309)

(First step SOCKS5 UDP bind: Send SOCKS5 enhanded UDP bind reply with the external address 158.132.8.173:34309)

```
02009: version is 5
02009: lsEUDPSendProto
02009: lsEUDPSendProto
02009: lsEUDPSendProto
02009: lsEUDPSendProto size of local host: 4
02009: lsEUDPSendProto size of packet: 27
02009: lsSendResponse: response sent
02009: lsSendResponse: response sent
02009: UDP Receive: Selecting on outer sockets...
02009: UDP Receive: Selecting on inner socket...
02009: UDP Receive: Selecting...
02008: Flow Recv: Reading from client socket
02008: Flow Recv: Read 112 bytes from client socket
02008: Flow Send: Writing 112 bytes to server socket
02008: Flow Send: Wrote 112 bytes to server
02008: Flow Recv: Reading from server socket
02008: Flow Recv: Read 152 bytes from server socket
02008: Flow Send: Writing 152 bytes to client socket
02008: Flow Send: Wrote 152 bytes to client
02009: select results : 1
02009: UDP Recv Msg
02009: S5IOCheck: Checking socket status
02009: S5IOCheck: ok
02009: EUDPHandleCommand request  &pri->bndAddr (158.132.8.173:34305)
02009: EUDPHandleCommand request  &pri->srcAddr (158.132.8.175:38054)
02009: Socks5: Read initial protocol
```

```
02009: length of local address 6
02009: length of remote address 6
02009: Socks5: Read address part of protocol
02009: Socks5: Read address part of protocol 1.5
02009: Socks5: Read address part of protocol 1.6
02009: local address is 158.132.8.175:38054
02009: remote address is 158.132.8.170:36064
(Second step SOCKS5 UDP bind: Receive SOCKS5 enhanced UDP bind command with remote
address 158.132.8.170:36064)
02009: Socks5: Read address part of protocol 2
02009: EUDPHandleCommand request  &pri->retAddr (0.0.0.0:0)
02009: EUDP Command: Read command (5) request (158.132.8.170:36064)
02009: UDP Command: Doing BIND command
02009: Resolve Names: Starting
02009: Resolve Names: Looking up service name
02009: Resolve Names: Looking up next proxy
02009: Proxy: dst on the same subnet
02009: Resolve Names: No Next Proxy
02009: CheckCache: The dst (158.132.8.170:36064) is not cached
02009: Checking Authorization
02009: Check: Checking commands: Anything is ok
02009: Check: Checking auths: Anything is ok
02009: Check: Checking port range   (0 <= 38054 <= 65535)?
02009: Check: Checking port range   (0 <= 36064 <= 65535)?
02009: Check: Checking username,  is in -
02009: Perm: Line 2:matched
02009: lsCheckIntfc
02009: Route: dst on the same subnet
```

```
02009: Make Out Socket UDP connect for address 158.132.8.173:34309: Error 0
02009: UDP Out interface: 158.132.8.173:34309
02009: EUDPHandleCommand request  &pri->bndAddr (158.132.8.173:34305)
02009: lsEUDPSendResponse: local is (158.132.8.173:34305)
02009: lsEUDPSendResponse: remote is (158.132.8.173:34309)
(Second step SOCKS5 UDP bind: Confirm the binding by re-sending SOCKS5 enhanded UDP
bind reply with the external address 158.132.8.173:34309)
02009: version is 5
02009: lsEUDPSendProto
02009: lsEUDPSendProto
02009: lsEUDPSendProto
02009: lsEUDPSendProto size of local host: 4
02009: lsEUDPSendProto size of packet: 27
02009: lsSendResponse: response sent
02009: lsSendResponse: response sent
02009: UDP Receive: Selecting on outer sockets...
02009: UDP Receive: Selecting on inner socket...
02008: Flow Recv: Reading from client socket
02008: Flow Recv: Read 54 bytes from client socket
02008: Flow Send: Writing 54 bytes to server socket
02008: Flow Send: Wrote 54 bytes to server
02009: UDP Receive: Selecting...
02008: Flow Recv: Reading from server socket
02008: Flow Recv: Read 50 bytes from server socket
02008: Flow Send: Writing 50 bytes to client socket
02008: Flow Send: Wrote 50 bytes to client
02009: select results : 1
02009: UDP Recv Msg
```

```
02009: UDP Recv before recvfrom
02009: UDP Recv recvfrom
02009: UDP Receive: received a message from 158.132.8.170:36064
(Receive the UDP data packet from RTSP server)
02009: lsCheckIntfc
02009: Route: dst on the same subnet
02009: UDP Server Receive: Received valid message of length 1114
02009: UDP Recv end
02009: UDP Send: Sending to 158.132.8.175:38054
(Relay the UDP data packet to the SOCKS5 client)
02009: UDP Send: Sending a message of length 1124
02009: UDP Send: Client Recveived Message from 158.132.8.170:36064
```

6.2.3 RTSP Client

```
[u1x-175:c5717021] /home/msc/yr95/it/c5717021/s5/rtsp/player:>rtsp-player-test
(start the RTSP client program)
Fri May 21 02:52:51 HKT 1999

handle_command: o rtsp://u1x-170:1554
(Set up RTSP TCP connectin to RTSP server u1x-170)
lsGetCachedHostname: Not a fake hostname: 158.132.8.170lsLibProtoExchg: Connecti
ng to socks server 158.132.8.173:1080test libproto Exchg dest : 158.132.8.170:15
54
enter command ('?' or 'h' for help):
HELLO
get rtsp.wav
(Send RTSP “setup” request and “play” request to the RTSP server)
```

handle_command: get rtsp.wav

connection found lsGetCachedHostname: Not a fake hostname: 158.132.8.170lsLibPro toExchg: Connecting to socks server 158.132.8.173:1080test libproto Exchg dest : 158.132.8.175:33072

test proxy_bind na: 0.0.0.0:0

test proxy_bind dest: 158.132.8.175:38054

(Run wrapper program for UDP bind() call, send First step SOCKS5 UDP bind command)

udp open testing 7 testing assign_udpfd: 7

connection found lsGetCachedHostname: Not a fake hostname: 158.132.8.170 proxyca chefound test lsUdpGetSockname: 158.132.8.173:34309

testing udp_getport 34309

(Run getsockname() call and retrieve the port number 34309 of the external address of the SOCKS5 UDP binding)

connection found lsGetCachedHostname: Not a fake hostname: 158.132.8.170 proxyca chefound test lsUdpGetSockname: 158.132.8.173:34309

udp_getsockname() 158.132.8.173

(Run getsockname() call and retrieve the IP address 158.132.8.173 of the external address of the SOCKS5 UDP binding)

send_setup request

Send setup message:

SETUP rtsp://u1x-170/rtsp.wav RTSP/0.6 3

Stream-ID:0

Transport: rtp/udp;destination=158.132.8.173;port=34309

(RTSP client send RTSP “setup” request with destination address and destination port to the RTSP server)

strlen of b: 112 New session: 0

RTSP Stream server address: 158.132.8.170

RTSP Stream server port: 36064

(RTSP client receive RTSP “setup” reply and retrieve the source address and source port from the RTSP server)

UDP connect()

(RTSP client call the wrapper UDP connect() socket call program to pass the remote address 158.132.8.170:36064 to the SOCKS5 layer)

connection found lsGetCachedHostname: Not a fake hostname: 158.132.8.170 proxyca chefound PLAY started.

testing UdpRecvfrom testing rtp_ssrc=0 testing UdpRecvfrom testing rtp_ssrc=0

testing UdpRecvfrom testing rtp_ssrc=0 testing UdpRecvfrom testing rtp_ssrc=0

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testing UdpRecvfrom testing rtp_ssrc=0 testing UdpRecvfrom testing rtp_ssrc=0

(RTSP client run UDP recvfrom() wrapper program to get the UDP data from the SOCKS5 layer)

6.3 Testing Results

Based on the screen capture of the RTSP server, SOCKS5 server and the RTSP client, it could be seen that the two steps SOCKS5 UDP binding was carried out successfully. Each step is mapped correctly to the corresponding wrapper socket call program. UDP port binding at the SOCKS5 server was communicated from the SOCKS5 layer to the RTSP client. Source address and source port for the UDP stream were communicated from the RTSP client to the SOCKS5 layer. On the RTSP side, the external address binding at the SOCKS5 server was communicated from the RTSP client to the RTSP server. The source address and the source port for UDP stream was sent from the RTSP server to the RTSP client.

So the prototype demonstrated that the two step SOCKS5 UDP binding model will work with the passive UDP connection via the firewall.

7. Conclusions

The existing SOCKS5 protocol support for UDP is still having the two fundamental problems with the availability of the "remote address" from the applications client. The first problem is due to the limitation of using UDP bind() socket call to communicate the "remote address" to the SOCKS5 layer. The second problem is due to the deadlock situation between the SOCKS5 UDP binding process and the transport establishment procedure of the multimedia applications such as RTSP.

To resolve these problems, the two steps UDP binding process for SOCKS5 UDP binding is proposed. UDP binding is classified into three types which include active UDP open, UDP listen and passive UDP open. The two steps UDP binding process is applied to all three of them. The socket call procedure for the interface between the applications layer and the SOCKS5 layer is also clearly defined to support the two steps binding process.

A prototype for SOCKS5 client and SOCKS5 server is developed for the proposed two steps UDP binding process by using the SOCKS5 source code from NEC. The transport establishment procedure for the RTSP client and the RTSP server is also modified to use the socket call procedure required for the enhanced SOCKS5 protocol. Tests were performed successfully to set up a multimedia stream in UDP from the RTSP server to the RTSP client via the SOCKS5-based firewall. It demonstrated that the proposed SOCKS5 model will be able to be fully implemented in an actual environment and the enhanced SOCKS5 model will have no incompatibility issues with the applications client.

With this enhanced SOCKS5 protocol for UDP, all the UDP-based applications will be able to traverse through the firewall. The only requirement on the UDP-based applications is that they need to follow the proper socket call procedure to set up the UDP transport. By using this same socket call procedure, the UDP-based applications will work in an environment without a firewall as well. So this enhanced SOCKS5 protocol will simplify the applications development as the applications do not need to be aware of the existence of a firewall.

8. Future Work

The prototype is limited to the passive UDP open which is commonly used in multimedia applications. More work could be carried out to extend the prototype to the active UDP open mode and the UDP listen mode.

The two steps SOCKS5 UDP binding process provides a mechanism for the applications to inform the SOCKS5 layer the “remote address”. This will improve the security of the firewall as the firewall would be able to filter incoming connection based on the ”source address” of the packets. For the existing SOCKS5 TCP binding and the proposed SOCKS5 multicast support, the “remote address” is not available from the application clients. Hence, this two step model may be applicable for them to get this information. Further work could be carried out to see how the incoming TCP connection model and

the IP multicast model could work with the two steps SOCKS5 binding model. This will provide a more secure way for the firewall to do packet filtering on the incoming TCP connections and the incoming multicast traffic.

9. References

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