Background: Various VPN Protocols

- VPN Client Devices
  - PCs: Windows, Mac, iOS, Android, ...
  - Routers: Cisco, Juniper, NEC, IIJ, ...

- VPN Protocols
  - SoftEther VPN
  - L2TP/IPsec
  - SSTP
  - OpenVPN
  - L2TPv3/IPsec
  - EtherIP/IPsec

- System Administrators have to prepare multiple VPN Servers for each VPN protocol.
## Characteristics of VPN Protocols

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>L2TP</th>
<th>SSTP</th>
<th>PPTP</th>
<th>OpenVPN</th>
<th>L2TPv3</th>
<th>EtherIP</th>
<th>SoftEther VPN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Protocol</td>
<td>IP</td>
<td>IP</td>
<td>IP</td>
<td>Ethernet</td>
<td>Ethernet</td>
<td>Ethernet</td>
<td>Ethernet</td>
</tr>
<tr>
<td>Transport Protocol</td>
<td>IPsec</td>
<td>HTTPS</td>
<td>GRE</td>
<td>Specific TCP/UDP</td>
<td>IPsec</td>
<td>IPsec</td>
<td>HTTPS</td>
</tr>
<tr>
<td>Proxy Support</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>Restricted FW</td>
<td>Blocked</td>
<td>PASS</td>
<td>Blocked</td>
<td>Blocked</td>
<td>Blocked</td>
<td>Blocked</td>
<td>PASS</td>
</tr>
<tr>
<td>Client OS (PC)</td>
<td>Windows/Linux/Mac</td>
<td>Windows</td>
<td>Windows/Linux/Mac</td>
<td>Windows/Linux/Mac</td>
<td>-</td>
<td>FreeBSD</td>
<td>Windows/Linux</td>
</tr>
<tr>
<td>Client OS (Smartphone)</td>
<td>iOS/Android</td>
<td>-</td>
<td>iOS/Android</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Client OS (VPN Routers)</td>
<td>Cisco</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Cisco IIJ SEIL</td>
<td>NEC IX</td>
<td>-</td>
</tr>
</tbody>
</table>
Various VPN Protocols

- SSL-VPN
- MS-SSTP
- L2TP over IPsec
- L2TP over IPsec
- L2TPv3 over IPsec
- L2TPv3 over IPsec
- EtherIP over IPsec
- Various VPN Protocols
Such a VPN Server Program doesn’t exist.

A VPN Server Computer

Ideal All-in-One VPN Server Program

SSTP
Server Function

OpenVPN
Server Function

SSTP VPN Tunnel

SSTP VPN Client (e.g. Windows)

OpenVPN Tunnel

OpenVPN Client (e.g. Mac OS X)
A Problem:

There is No Such an Ideal VPN Server Program.
## Existing VPN Server Programs Compatibles

<table>
<thead>
<tr>
<th></th>
<th>L2TP</th>
<th>SSTP</th>
<th>OpenVPN</th>
<th>L2TPv3</th>
<th>EtherIP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microsoft RRAS</td>
<td>✓</td>
<td>✓</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mac OS X Server</td>
<td>✓</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>OpenVPN</td>
<td>-</td>
<td>-</td>
<td>✓</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cisco IOS</td>
<td>✓</td>
<td>-</td>
<td>-</td>
<td>✓</td>
<td>-</td>
</tr>
<tr>
<td>NEC IX Router OS</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td>IIJ SEIL Router OS</td>
<td>✓</td>
<td>✓</td>
<td>-</td>
<td>✓</td>
<td>-</td>
</tr>
</tbody>
</table>
Supporting Multi VPN Protocols by Single VPN Server Computer

Two VPN Server Programs Run Together on a Host.

- Microsoft RRAS
  - SSTP Server Function

- OpenVPN Server
  - OpenVPN Server Function

IP Routing Between Two VPN Servers

A VPN Server Computer

SSTP VPN Tunnel

SSTP VPN Client (e.g. Windows)

OpenVPN Tunnel

OpenVPN Client (e.g. Mac OS X)
Supporting Multiple VPN Protocols by Single VPN Server

• **Overhead Problem**
  - Context Switching Costs
  - User-to-Kernel Switching Costs
  - Memory Copying Costs

• **Management Problem**
  - User Management Tasks
  - Log File Management Tasks
  - Inefficient IP Address Polls
Management Problem

- **Microsoft RRAS**
  - SSTP
  - Server Function
  - OpenVPN
  - Server Function

- **VPN Server Admin**
  - Register
  - Register
  - Same Users

- **A VPN Server Computer**
  - User A
  - User B
  - User C

- **OpenVPN Server**
  - User A
  - User B
  - User C
Log File Problem

Confusing

Log Files of MS-RRAS

VPN Server Admin

Log Files of OpenVPN

Microsoft RRAS
SSTP Server Function

OpenVPN Server
OpenVPN Server Function

A VPN Server Computer
IP Address Pool Duplication Problem

192.168.0.101-192.168.0.150

192.168.0.151-192.168.0.200
## Goal of the Research

<table>
<thead>
<tr>
<th></th>
<th>L2TP</th>
<th>SSTP</th>
<th>OpenVPN</th>
<th>L2TPv3</th>
<th>EtherIP</th>
<th>SoftEther VPN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microsoft RRAS</td>
<td>✓</td>
<td>✓</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mac OS X Server</td>
<td>✓</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>OpenVPN</td>
<td>-</td>
<td>-</td>
<td>✓</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cisco IOS</td>
<td>✓</td>
<td>-</td>
<td>-</td>
<td>✓</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>NEC IX Router OS</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>✓</td>
<td>-</td>
</tr>
<tr>
<td>IIJ SEIL Router OS</td>
<td>✓</td>
<td>✓</td>
<td>-</td>
<td>✓</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>SoftEther VPN</strong></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
"SoftEther" means Software Ethernet.

SoftEther VPN Server

A high-performance VPN server which supports multiple VPN protocols.

Supported protocols:
- SE-VPN
- OpenVPN
- L2TP
- EtherIP
- MS-SSTP
- L2TPv3

Supported devices:
- Windows
- Linux
- Mac
- iPad
- Android Tab
- Windows RT
- iPhone
- Android
- Windows Phone
- Cisco VPN Routers

Supports various VPN client devices.
Difficulties of the Research

• 7 VPN protocols by one VPN server
  • Inter-VPN protocol packet exchange
  • Bridges between L2 (Ether) / L3 (IP)

• Management
  • User authentication
  • Dynamic IP address assignment to VPN clients

• Security
  • Security policy / Packet filter
  • Packet log
  • Isolation
How to Support 7 VPN Protocols?

<table>
<thead>
<tr>
<th>L2 VPN Protocols</th>
<th>L3 VPN Protocols</th>
</tr>
</thead>
<tbody>
<tr>
<td>SoftEther VPN</td>
<td>L2TP/IPsec</td>
</tr>
<tr>
<td>OpenVPN (L3)</td>
<td>SSTP/IPsec</td>
</tr>
<tr>
<td>EtherIP/IPsec</td>
<td>OpenVPN (L2)</td>
</tr>
<tr>
<td>L2TPv3/IPsec</td>
<td></td>
</tr>
</tbody>
</table>

- **Strategy #1**
  - Separate L2 VPN Ethernet / L3 VPN Router
  - Layer-conversions between L2 / L3
  
  Problem: Duplication of Security Implementations, Complicated Codes

- **Strategy #2 [adopted]**
  - Treat all L3 VPN as L2 VPN
  - All L3 packets will be descended to L2 Ether frames.
  
  Benefit: Single Security Implementations, Simple Codes
Design #1

- Ethernet (L2) as Common Bus.
  - Virtual Ethernet Switching Hub.
  - Layer conversion for IP-based VPN protocols (L2TP, SSTP, OpenVPN L3).
- Virtual DHCP Client.
Design #2

- Kernel-mode
  - Difficult to debug
  - Lack of portability

- Multiple User-mode Process
  - Easy to implement
  - Overhead Problem still occurs

- Single User-mode process [adopted]
  - Easy to implement
  - Reduce overhead
Virtual Ethernet Switching Hub
L3/L2 Transparent Conversion

Virtual Hub

DHCP Server
IP Address Pool

Insert an Ethernet Header

L3 <-> L2
Protocol Converter

Ethernet Frame

L3-VPN
User IP Pkt
Insert an Ethernet Header

DHCP Request

DHCP Response

ARP Request

ARP Response

Other Hosts on Ethernet

Session

L2 (Ethernet)

L3 (IP)

User IP Pkt

L3-VPN

VPN
User IP Pkt
All-in-One VPN Server

L2-VPN Protocol Module (e.g. SE-VPN, L2TPv3, etc.)

L3-VPN Protocol Module (e.g. L2TP, SSTP, etc.)

Virtual Hub (Software Ethernet Switch) Module

Ether Frame Decapsulate
Encapsulate
Convert to Ethernet Frame
Pass Converted Ether Frame

User IP Pkt
User Authentication

Supports PAP (Password Authentication Protocol) and MS-CHAPv2 (Microsoft Challenge-Handshake Authentication Protocol ver 2) via Local User-auth DB and External Radius/Active Directory Server.
Virtual Hub

Security Functions

Packet Filter

Security Policy Enforcer

Packet Logger

Exchange Frames

Ether

User IP Pkt

Packet Logs to the Disk

Session #1

Session #2

Packet Filter Rules

User Authentication Database

Security Policy Enforcer Packet Logger
Isolation between Virtual Hubs

VPN Server Process

Virtual Hub #1

Virtual Hub #2

L2-VPN Tunnel

L3-VPN Tunnel

L2-VPN Client

L3-VPN Client

Ether

User IP Pkt

VPN Group #1

VPN Group #2

Isolated
Implementation

• SoftEther VPN Server
  Current features
  • Virtual Ethernet Switching Hub
  • Security Policy / Packet Filter Enforcement
  • Packet Logging
  • Internal and External User-authentication

Language
• C / C++

IPsec Modules based on
• BitVisor IPsec Client (Univ of Tsukuba)
OS Abstraction Layer

- SoftEther VPN Functions (Cedar Module)
- Library Routines (Mayaqua Module)
- Abstraction Layer
  - Function Calls
  - System Calls
    - User Mode
      - NDIS Virtual Network Adapter Driver
    - Kernel Mode
      - NDIS Local Bridge Driver
      - tap Driver
      - SOL_PACKET Raw Sockets
    - Win32: 9x, NT
    - UNIX: Linux, FreeBSD, Solaris, Darwin

OS Independent Parts
OS Dependent Parts
### 7 Protocol Modules

#### SoftEther VPN Server

#### Virtual Hub

<table>
<thead>
<tr>
<th>Protocol Module</th>
<th>OS</th>
<th>Device</th>
<th>L2 VPNs</th>
<th>L3 VPNs</th>
</tr>
</thead>
<tbody>
<tr>
<td>SE-VPN Protocol Module</td>
<td>Windows</td>
<td>Windows</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L2TP/IPsec Protocol Module</td>
<td>Linux</td>
<td>Linux</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSTP Protocol Module</td>
<td>Mac</td>
<td>Mac</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OpenVPN (L3) Protocol Module</td>
<td>iPad Android Tab</td>
<td>iPad Android Tab Windows RT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OpenVPN (L2) Protocol Module</td>
<td>iPhone Android</td>
<td>iPhone Android Windows Phone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L2TPv3/IPsec Protocol Module</td>
<td></td>
<td>Cisco VPN Routers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EtherIP Protocol Module</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Various Types of VPN Clients**
Divide 7 VPN Protocols into Sub Modules

• Overlapped Parts of Processing VPN Protocols
  • “PPP stack” is used by L2TP and SSTP.
  • “IPsec stack” is used by L2TP, L2TPv3 and EtherIP.
  • “OpenVPN stack” is used by OpenVPN L2 and L3.
  • A portion of “L2TP stack” is used by L2TPv3.

• Divide into Sub Modules
  • Minimize Volumes of Codes
  • Reduce Bugs

• Connections between Sub Modules
  • “Tube”: A new fast in-process pipe
    • for Single-thread and Multi-thread inter-module communication.
“Tube”
(fast lightweight pipe)

Module A (on Thread 1)

TubeSend()
Packet

Module B (on Thread 1)

TubeRecv()
Packet

Tube for Single Thread

Queue
Packet
Packet
Packet
Packet

Synchronization Object

GetCancel(), WaitSockEvent() etc.

Module B (on Thread 2)

TubeSend()
Packet

TubeFlush()

Tube for Multi Threads

Queue
Packet
Packet
Packet
Packet

Module A (on Thread 1)
Programming

• C / C++ Source Codes
  • 396,867 Lines (11.5MB)
    (including 31,686 comment lines)

• Compiler
  • Visual C++ 2008 for Windows Binaries
  • gcc (any version) for UNIX and Linux Binaries

• Planning to be Open Source (GPL) in Mid 2013.
  • Now translating a lot of comments into English before releasing the source.
Screen Shots

SoftEther VPN Client

The VPN Connection is Established.
Your assigned IP address is 192.168.2.69.
Screen Shots

SoftEther VPN Server (GUI Config Tools)
A lot of VPN Server Setting Screens (total 70+ dialogs)
L2TP / L2TPv3 / EtherIP
OpenVPN (L2 & L3) / SSTP
Ethernet over DNS, Ethernet over ICMP
(Enjoy your Wi-Fi Life!)
Screen Shots

Beautiful Installer for SoftEther VPN
Screen Shots

SoftEther VPN can be installed by one of two methods.
Please select the System Mode normally.

If you cannot use the administrator privilege for some reasons, you can select the User Mode to continue the installation.

- **System Mode (Recommended)**
  Install the VPN software to this computer normally. The administrator privilege is required.

- **User Mode**
  Install the VPN software with the normal user privilege. No administrator privilege is required. Some functions such as Local Bridge will be disabled. Runs only the user "yagi" is logged on Windows.

User-Mode Install Option
(System Admins will be Surprised!)
Screen Shots

SoftEther VPN: Configure the Display Language

The current display language is: English (English)

This software supports the following display languages. Select one and click Next.

Multi-languages Support
1. Functional Tests
   • Self Test
   • Beta Test

2. Performance Tests
   • Simple throughput test
   • Comparison to existing methods
L2TP/IPsec

iOS

Android

Windows

Mac OS X

SSTP
OpenVPN
L2TPv3/IPsec, EtherIP/IPsec

L2TPv3: Cisco IOS, IIJ SEIL
EtherIP: NEC IX
## Results of Self Functional Tests

<table>
<thead>
<tr>
<th>VPN Protocol</th>
<th>VPN Client Software / Device</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>L2TP/IPsec</td>
<td>iPhone (iOS 4.x, 5.x, 6.x)</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>iPad (iOS 4.x, 5.x, 6.x)</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Android (2.x, 3.x, 4.x)</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Windows XP, Vista, 7, 8, RT</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Mac OS X (10.6, 10.7, 10.8)</td>
<td>✓</td>
</tr>
<tr>
<td>SSTP</td>
<td>Windows Vista, 7, 8, RT</td>
<td>✓</td>
</tr>
<tr>
<td>OpenVPN (L3)</td>
<td>Windows, Linux, Mac, iPhone, Android</td>
<td>✓</td>
</tr>
<tr>
<td>L2TPv3/IPsec</td>
<td>Cisco 892J</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Cisco 1812J</td>
<td>✓</td>
</tr>
<tr>
<td>EtherIP/IPsec</td>
<td>NEC IX2015</td>
<td>✓</td>
</tr>
<tr>
<td>OpenVPN (L2)</td>
<td>OpenVPN 2.2 for Windows, Linux</td>
<td>✓</td>
</tr>
</tbody>
</table>
Results of Beta Tests

4,007 Users on Jan 09, 2013.
## Achievement

<table>
<thead>
<tr>
<th></th>
<th>L2TP</th>
<th>SSTP</th>
<th>OpenVPN</th>
<th>L2TPv3</th>
<th>EtherIP</th>
<th>SoftEther VPN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microsoft RRAS</td>
<td>✓</td>
<td>✓</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mac OS X Server</td>
<td>✓</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>OpenVPN</td>
<td>-</td>
<td>-</td>
<td>✓</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cisco IOS</td>
<td>✓</td>
<td>-</td>
<td>-</td>
<td>✓</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>NEC IX Router OS</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>✓</td>
<td>-</td>
</tr>
<tr>
<td>IIJ SEIL Router OS</td>
<td>✓</td>
<td>✓</td>
<td>-</td>
<td>✓</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>SoftEther VPN (Old)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td>SoftEther VPN (New)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
# Performance Tests

<table>
<thead>
<tr>
<th>Computer</th>
<th>Fujitsu PRIMERGY TX100 S3 (3 Pieces)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU</td>
<td>Intel Xeon E3-1230 3.2GHz 8M</td>
</tr>
<tr>
<td>RAM</td>
<td>16GB (4GB 1333MHz DDR3 ECC CL9 DIMM x 4)</td>
</tr>
<tr>
<td>Chipset</td>
<td>Intel C202</td>
</tr>
<tr>
<td>NIC #1, #2</td>
<td>Intel 10 Gigabit CX4 Dual Port Server Adapter</td>
</tr>
<tr>
<td>OS</td>
<td>Windows Server 2008 R2 x64</td>
</tr>
<tr>
<td></td>
<td>Windows Server 2003 R2 x64</td>
</tr>
<tr>
<td></td>
<td>Linux 2.6.32 x64</td>
</tr>
<tr>
<td></td>
<td>(for OS abstraction-layer performance tests)</td>
</tr>
<tr>
<td></td>
<td>(for OS abstraction-layer performance tests)</td>
</tr>
</tbody>
</table>
Target Protocols

- SoftEther VPN Protocol
- L2TP/IPsec
- SSTP
- OpenVPN (L3)
- OpenVPN (L2)
Test 1. Each Protocol (Solo)

Our Implementation vs. Vendor’s Original Implementation

- for L2TP, for SSTP, for OpenVPN
- SoftEther VPN
- Microsoft's SSTP-VPN Implementation
- Our SSTP-VPN Implementation
- Examples (for SSTP)

PC-to-PC VPN

PC-to-LAN VPN
Test 1 Results (PC-to-PC)

Original VPN Software v.s. SoftEther VPN Server 4.0 (1 VPN Protocol, PC to PC)

- SEVPN
- L2TP
- SSTP
- OpenVPN (L3)
- OpenVPN (L2)

By Original VPN Software

- 974.8 Mbps
- 478.0 Mbps
- 664.3 Mbps
- 779.8 Mbps
- 89.8 Mbps
- 86.4 Mbps
- 80.0 Mbps
- 85.8 Mbps
Test 1 Results (PC-to-LAN)

Original VPN Software v.s. SoftEther VPN Server 4.0 (1 VPN Protocol, PC to LAN)

<table>
<thead>
<tr>
<th>Protocol</th>
<th>By Original VPN Software</th>
<th>By SoftEther VPN Server 4.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEVPN</td>
<td>980.0</td>
<td></td>
</tr>
<tr>
<td>L2TP</td>
<td>593.7, 614.0</td>
<td></td>
</tr>
<tr>
<td>SSTP</td>
<td>715.1, 737.8</td>
<td></td>
</tr>
<tr>
<td>OpenVPN (L3)</td>
<td>76.6, 89.8</td>
<td></td>
</tr>
<tr>
<td>OpenVPN (L2)</td>
<td>83.8, 90.1</td>
<td></td>
</tr>
</tbody>
</table>
Test 2.
Combination of 2 Protocols

Our Implementation (New) vs. Mixture of 2 VPN Programs (Traditional)

Example (for SSTP+OpenVPN L3)
## Combination Matrix

<table>
<thead>
<tr>
<th>No.</th>
<th>Protocol 1</th>
<th>Protocol 2</th>
<th>Bridge / Routing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SEVPN</td>
<td>L2TP/IPsec</td>
<td>IP Routing</td>
</tr>
<tr>
<td>2</td>
<td>SEVPN</td>
<td>SSTP</td>
<td>IP Routing</td>
</tr>
<tr>
<td>3</td>
<td>SEVPN</td>
<td>OpenVPN_L3</td>
<td>IP Routing</td>
</tr>
<tr>
<td>4</td>
<td>SEVPN</td>
<td>OpenVPN_L2</td>
<td>Ethernet Bridging</td>
</tr>
<tr>
<td>5</td>
<td>L2TP/IPsec</td>
<td>SSTP</td>
<td>IP Routing</td>
</tr>
<tr>
<td>6</td>
<td>L2TP/IPsec</td>
<td>OpenVPN_L3</td>
<td>IP Routing</td>
</tr>
<tr>
<td>7</td>
<td>L2TP/IPsec</td>
<td>OpenVPN_L2</td>
<td>IP Routing</td>
</tr>
<tr>
<td>8</td>
<td>SSTP</td>
<td>OpenVPN_L3</td>
<td>IP Routing</td>
</tr>
<tr>
<td>9</td>
<td>SSTP</td>
<td>OpenVPN_L2</td>
<td>IP Routing</td>
</tr>
<tr>
<td>10</td>
<td>OpenVPN_L3</td>
<td>OpenVPN_L2</td>
<td>IP Routing</td>
</tr>
</tbody>
</table>

**Total 10 Tests**
Test2 Results (Throughput)

<table>
<thead>
<tr>
<th>Protocol Combination</th>
<th>By Combination of Two Original VPN Software</th>
<th>By SoftEther VPN Server 4.0 Standalone</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEVPN+L2TP</td>
<td>546.8</td>
<td>608.0</td>
</tr>
<tr>
<td>SEVPN+SSTP</td>
<td>662.5</td>
<td>716.0</td>
</tr>
<tr>
<td>SEVPN+OVPNL3</td>
<td>83.4</td>
<td>86.6</td>
</tr>
<tr>
<td>SEVPN+OVPNL2</td>
<td>83.6</td>
<td>86.6</td>
</tr>
<tr>
<td>L2TP+SSTP</td>
<td>557.6</td>
<td>612.9</td>
</tr>
<tr>
<td>L2TP+OVPNL3</td>
<td>80.2</td>
<td>84.1</td>
</tr>
<tr>
<td>L2TP+OVPNL2</td>
<td>82.9</td>
<td>86.6</td>
</tr>
<tr>
<td>SSTP+OVPNL3</td>
<td>83.8</td>
<td>87.9</td>
</tr>
<tr>
<td>SSTP+OVPNL2</td>
<td>82.7</td>
<td>87.3</td>
</tr>
<tr>
<td>OVPNL3+OVPNL2</td>
<td>86.0</td>
<td>88.0</td>
</tr>
</tbody>
</table>

The chart compares the throughput for different protocol combinations using two original VPN software and SoftEther VPN Server 4.0.
Test2 Results
(Percentage of Improvement)
Test 3. Evaluation of OS-Abstraction Layer

4.1.1. SEVPN RC4 PC-to-PC OS Comparison (Throughput)

4.1.3. SEVPN RC4 PC-to-LAN OS Comparison (Throughput)

4.1.5. L2TP PC-to-PC OS Comparison (Throughput)

4.1.6. L2TP PC-to-LAN OS Comparison (Throughput)
Conclusions #1

• This Research Designs and Implements a New VPN Server Program.
  • Supports 7 VPN Protocols.
    • SoftEter VPN, L2TP over IPsec, SSTP, OpenVPN (L3, L2), EtherIP over IPsec and L2TPv3 over IPsec.

The World’s First VPN Server Program for Support All of Above VPN Protocols.

• Runs on Windows, Linux, Mac, FreeBSD and Solaris.
• Unified Management, Security, User-auth and IP Address Assignment.
Conclusions #2

- Results of Performance Tests show:
  - Generally better throughputs, compare to Microsoft and OpenVPN’s implementations.
  - Overheads of combination of different VPN protocols are reduced.
    (Performance Improvements: 102.3% - 111.2%)
  - OS Abstraction Layer works well.
Future Works

• More Improvements of Performance.

• Additional VPN Protocols.
  • IKEv2, PPTP and IPsec Tunnel Mode

• Release as Open-Source Software (GPL license).
  • “SoftEther VPN”, http://www.softether.org/
    Estimated release date: by end of March 2013.
    (First, close-source with binaries. Translate all
    Japanese comments to English and release it in
    middle 2013.)

• Enable third-Developers to Add More VPN
  Protocol Modules Easily.
Design and Implementation of SoftEther VPN

Daiyuu Nobori

Department of Computer Science, Graduate School of Systems and Information Engineering, University of Tsukuba, Japan.