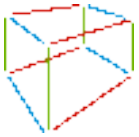
InetVis 2.1.0 Manual

September 25, 2017



Contents

1 Description **2**
- 1.1 About . . . 2
  - 1.1.1 Inetvis 0.9.x and 1.x (unreleased) . . . 2
- 1.2 Concept . . . 2
- 1.3 Input . . . 3
- 1.4 Supported Protocols . . . 3
- 1.5 Plotting scheme . . . 3
- 1.6 Features . . . 3

2 Usage **4**
- 2.1 Command Line . . . 4
- 2.2 User Interface and Controls . . . 4
  - 2.2.1 Control Panel . . . 5
- 2.3 InetVis Display . . . 5
  - 2.3.1 Navigation via Mouse Controls . . . 5
  - 2.3.2 Navigation via Keyboard Controls . . . 5
  - 2.3.3 Other Keyboard Controls . . . 6
- 2.4 Plotter Settings Dialogue . . . 6
- 2.5 Reference Frame Settings Dialogue . . . 7
- 2.6 General Settings Dialogue . . . 7
  - 2.6.1 Record Settings . . . 8
  - 2.6.2 Home Network settings . . . 9
  - 2.6.3 Log File Settings . . . 9
  - 2.6.4 Snapshot Settings . . . 10

3 Usage Notes **10**
- 3.1 Tool tips as Helpful Hints . . . 10
- 3.2 Applying Settings . . . 10
  - 3.2.1 Setting the Home Network Range Before Playback . . . 10
  - 3.2.2 Setting Address Ranges with CIDR Notation . . . 10
- 3.3 Recording . . . 11
  - 3.3.1 Record to Capture File . . . 11
  - 3.3.2 Taking an Image Snapshot . . . 11
  - 3.3.3 Dumping Rendered Frames to Image Files . . . 11
- 3.4 Minimum System Specification . . . 12

4 Known Issues **12**
- 4.1 Stability and Performance . . . 12
- 4.2 Limitations and Feature Wish List . . . 13

5 Running Inetvis **13**
5.1 Installation 13
5.2 Uninstalling InetVis 14
5.3 Disclaimer 14

6 Building and Developing InetVis **14**

7 Contact **15**

8 Credits **15**

9 Licence **15**

10 Software Dependencies and Licensing **16**
10.1 *Libpcap License* 16

1 Description

InetVis - **I**nter**net Vis**ualization

Version 2.1.1

Rrelease Date: 2017/09/21

InetVis is a 3-D scatter-plot visualization for network traffic. It's more or less like a media player, but for network traffic. At the moment its just an academic toy for reviewing packet capture files, but may be useful in other endeavours. For example, InetVis has been used to verify and critique the accuracy of scan detection algorithms in the Snort IDS and Bro IDS.

1.1 About

Inetvis was originally developed in 2005-2007, as part of a research project by JP van Riel in the Department of Comuter Science at Rhodes Uinversity. 10 years later the project has been resurected by Yestin Johnson as part of his Masters Degree research. both Projects have been supervised by Barry Irwin.

The Current version of Inetvis (2.x branch) has been ported across to run on Qt5.x (including Qt5.5) and on modern operating systems, and is now hosted on GitHub.

Current Author: Yestin Johnson (2017) <yestinj@gmail.com>
Reseach Supervisor: Barry Irwin
Institute: Department of Computer Science,
Rhodes University,
Github: `https://github.com/yestinj/inetvis`
Original Inetvis Concept Paper: `https://doi.org/10.1145/1108590.1108604`

1.1.1 Inetvis 0.9.x and 1.x (unreleased)

Original Author (InetVis 1.x): Jean-Pierre van Riel (2005 - 2007) <jp.vanriel@gmail.com>
Website: http://research.ict.ru.ac.za/G02V2468/
Grahamstown, 6140, Eastern Cape, South Africa

1.2 Concept

The original source of inspiration for InetVis is the "*The Spinning Cube of Potential Doom*" (by Stephen Lau). Whilst many other network visualizations employ lines as a metaphor for connection, the 3-D scatter-plot of points proves to scale well with larger volumes of data. The visualization makes network scanning and port scanning readily evident as horizontal and vertical lines respectively. InetVis offers numerous extensions that enhance the original basic concept.

Lau's Original Paper: `https://doi.org/10.1145/990680.990699`

Original Article:`http://www.nersc.gov/news-publications/nersc-news/nersc-center-news/1998/cube-of-doom/`

1.3 Input

InetVis visualizes packet captures of network traffic using Libpcap to either

- capture live traffic from the default interface
- replay traffic from a pcap file.

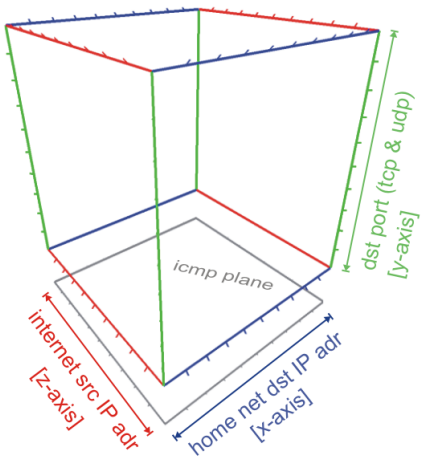
Tcpdump (`http://www.tcpdump.org`), Wireshark (`http://wireshark.org`) and Snort (`http://www.snort.org`) are examples of other applications can use and produce network packet captures in the Libpcap file format.

1.4 Supported Protocols

Currently only Ethernet based IPv4 packets are supported. Within the TCP/IP suite explicit support is provided for TCP, UDP and ICMP protocols. Other protocols may be silently dropped by the builtin base BPF filter ("`ip[6:2] & 0x3fff`"). See Section 4.2 for details.

1.5 Plotting scheme

1. Destination address (home network) plotted along blue x-axis (horizontal).
2. Source address (external Internet range) plotted along red z-axis (depth).
3. Ports (TCP and UDP) plotted along green y-axis (vertical).
4. ICMP traffic plotted below TCP/UDP cube grey/white ICMP plane.



1.6 Features

- Adjustable replay position to seek through the traffic capture files.
- Variable playback speed (time scaling), from as slow as 0.001x (1 ms/s), or as fast as 86400x (1 day/s).
- Variable time frame/window to view events for the past 100 ms up to 5 years.
- Transparent decay of events - points fade as they age (with respect to the time window).
- New events are highlighted by pulsing once (a momentarily bulge of the point).
- Filtering capability via BPF filter expressions (as used in Libpcap and Tcpdump).
- Various colour schemes for colouring points and adjustable point size.
- Setting the data ranges and scaling down into sub-domain IP addresses (destination and source) as well as port ranges to view a subset of the traffic data.

- Adjustable logarithmic plot for stretching out (thus increasing visibility) lower port range where, in general, most TCP/UDP traffic occurs.
- Various reference frame controls, i.e. toggling visibility of axes, markers, transparent grid lines, labels, and background colour.
- Orthographic and perspective projection modes.
- Immersive navigation - scaling (zooming), translating (moving) and rotating.
- Record single snapshot image, or dump all image frames (useful for manually encoding video clips).
- Record output back to pcap binary file format, for further detailed analysis with other applications (e.g. Tcpdump, Wiresahark and Snort).

See the CHANGELOG file in the source distribution for updated feature additions.

2 Usage

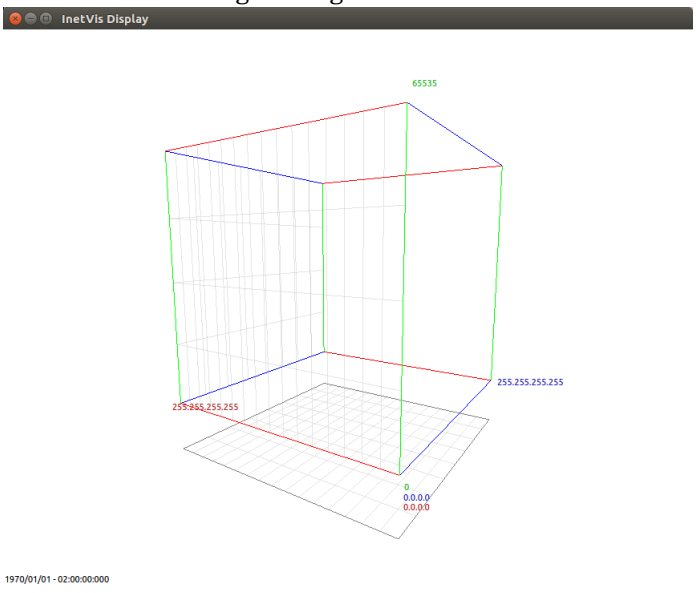
2.1 Command Line

```
$ ./inetvis
```

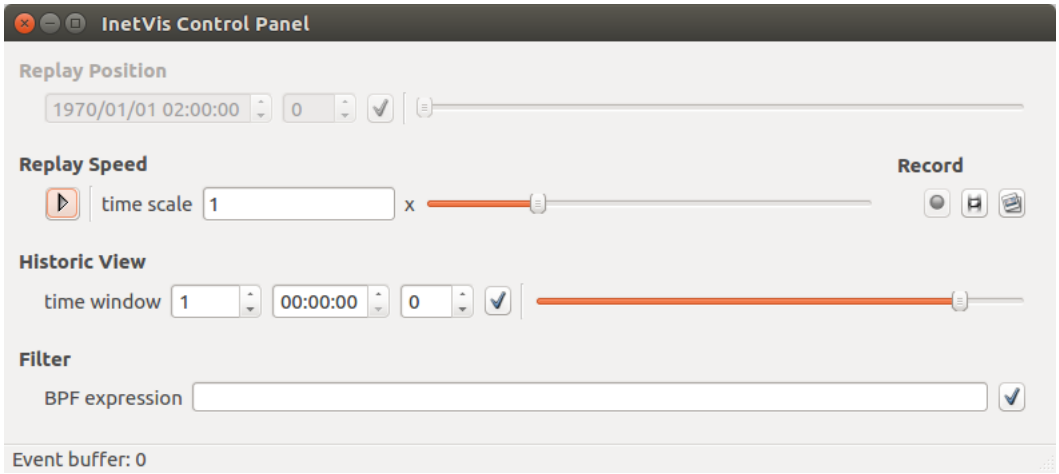
Inetvis takes no commandline arguments at this time.

2.2 User Interface and Controls

The display pane and control panel are in separate windows, with a plotter settings dialogue and reference frame settings dialogue accessed via the 'view' menu of the control panel



2.2.1 Control Panel



- main menu to open files, set mode (monitor local host or replay file), or to access other dialogues (view).
- Replay position controls.
- Playback and replay speed controls.
- Recording controls.
- Time window controls (Historic View).
- Filter.
- Task-bar reports the number of packets currently in the buffer.

2.3 InetVis Display

This is the primary visualization display pane.

2.3.1 Navigation via Mouse Controls

- Holding left button and moving rotates.
- Holding right button and moving translates along x and y (horizontally and vertically respectively).
- Rotating scroll wheel translates along z (depth).
- Holding middle button and moving zooms.

2.3.2 Navigation via Keyboard Controls

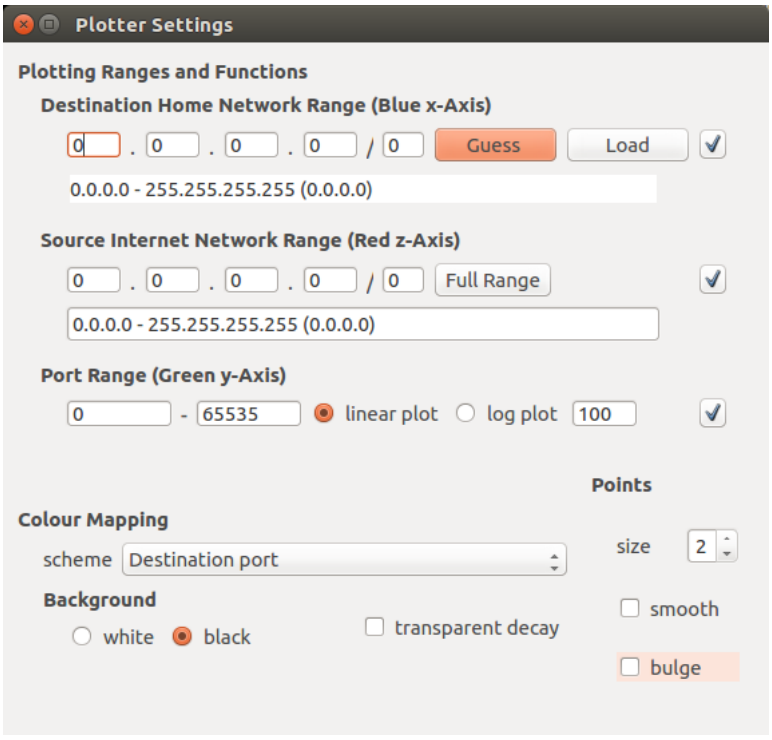
- ← ↑ ↓ → to rotate the cube.
- Ctrl + ← ↑ ↓ → to translate (x and y).
- Alt + ↑ or Alt + ↓ to translate (z).
- + and - to scale (zoom).
- Ctrl + L Set Left View (up x axis)
- Ctrl + R Set Right View (down x axis)
- Ctrl + T Set Top View (down y axis)
- Ctrl + B Set Bottom View (up y axis)

- Ctrl + F Set Front View (up x axis)
- Home Set Front view (down y axis)
- End Set Back View (down z axis)

2.3.3 Other Keyboard Controls

- F Toggle full screen.
- Esc Exit full screen
- ~ Toggle *Harlemshake*
- 0 Clear the visualisation pane
- 1 Rotation Toggle
- 2 Decrease Rotation
- 3 Increase Rotation
- Ctrl + H Hide Home Range (addresses prefix replaced with *the.drk.net*)
- F Take single frame Screenshot
- Pause/Resume the visualisation
- Ctrl + Q Quit the application
- P to bring up Plotter Settings Dialogue.
- R to bring up Reference Frame Settings Dialogue.
- C to bring up Control Panel Dialogue.

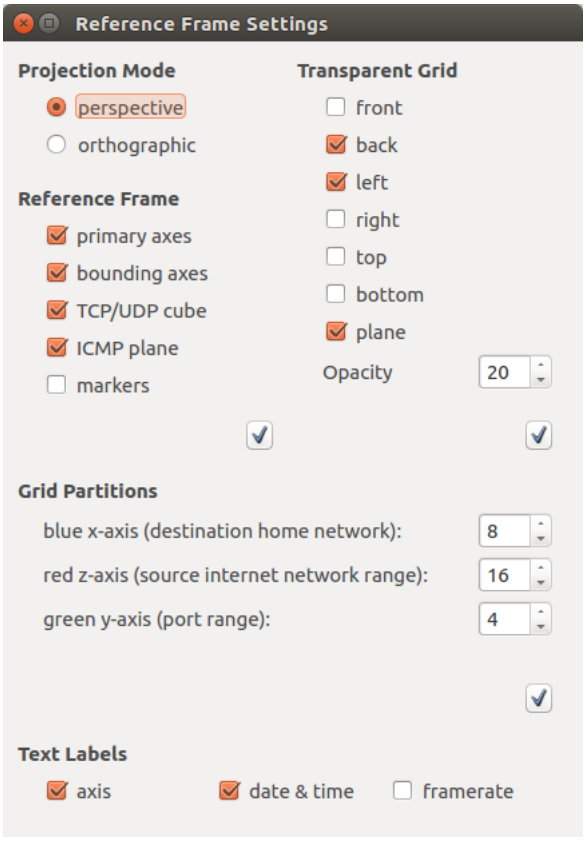
2.4 Plotter Settings Dialogue



- Set the destination home network range (or drill down into it).

- Set the source Internet range (drill down into a domain).
- Set the port range (drill down into a port range).
- Set linear or logarithmic plotting for ports.
- Set colour mapping, toggle transparent decay, and set background colour (black or white).
- Set point size, point bulging (highlight new events), and toggle point smoothing (rounded points).

2.5 Reference Frame Settings Dialogue



- Set projection mode (Orthographic or perspective).
- Toggle visibility of reference frame axes and markers.
- Toggle visibility and transparency of grid lines.
- Set number of divisions along x, y, and z for markers and grid lines.
- Toggle text labels (time, axes ranges, frame rate).

2.6 General Settings Dialogue

New functionalituy addedin in version 2.1.0 is the ability to have inetvis save a config file. The location of this file depends on the way QT handles it in a patfrom specific manner

Ubuntu ~/.config/Rhodes\ University/InetVis.conf

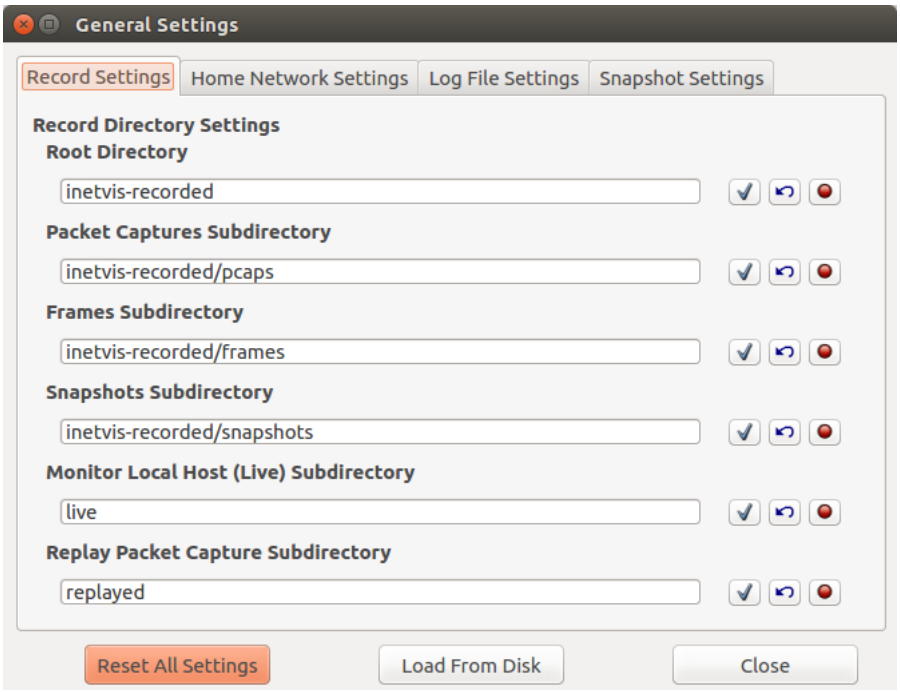
MacOSX <todo>

Windows <todo>

An example of a default config file is shown below.

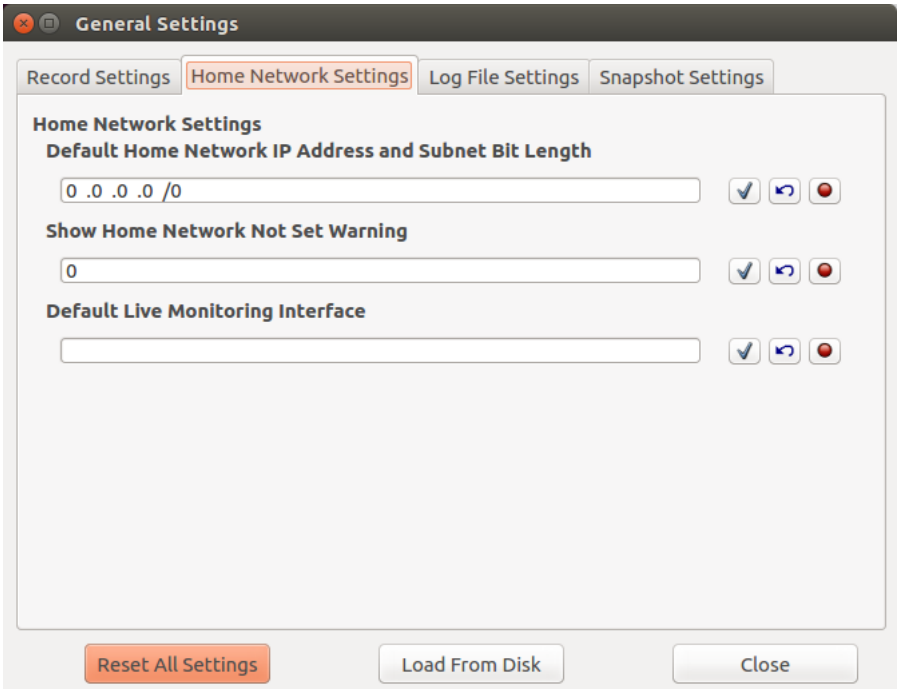
```
[dataproc]
home_network\default_home_network=0.0.0.0/0
home_network\monitor_interface=
home_network\show_not_set_error=false
recording\default_dir=inetvis-recorded
recording\frames_subdir=inetvis-recorded/frames
recording\live_subdir=live
recording\pcaps_subdir=inetvis-recorded/pcaps
recording\replay_subdir=replayed
recording\snapshots_subdir=inetvis-recorded/snapshots
screenshot\screenshot_extension=png
screenshot\screenshot_format=png
screenshot\screenshot_quality=-1

[glviswidget]
pos=@Point(186␣127)
size=@Size(704␣605)

[logging]
root_dir=logs
stderr_filename=stderr
stdout_filename=stdout
```

2.6.1 Record Settings



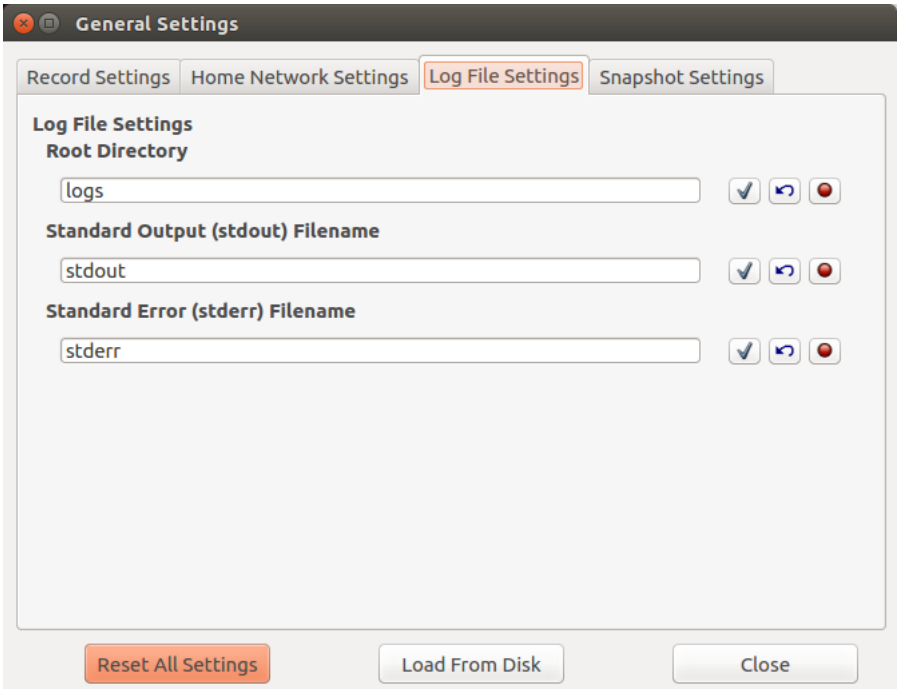
These directories are all relative to the directory in which inetvis is run.

2.6.2 Home Network settings



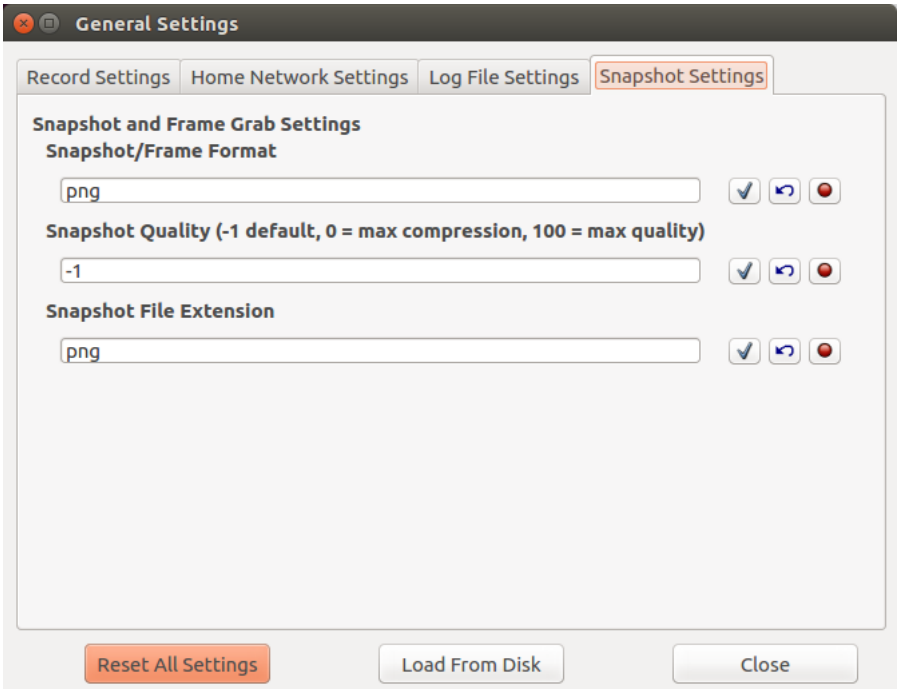
Dialogs for setting the home network (useful if the same network is being monitored)

2.6.3 Log File Settings



Logging data relative to startup directory

2.6.4 Snapshot Settings



Format and configuration to support screenshots. PNG is now supported. PPM support depricated.

3 Usage Notes

3.1 Tool tips as Helpful Hints

Majority of the controls, buttons and fields in the GUI provide tool tips to help explain their function and usage. Tool tips can be seen by hovering the mouse cursor over the GUI component in question.

3.2 Applying Settings

Many of the settings are grouped together and require the user to click the apply button (button with a tick icon) once they are ready to apply the new settings.

3.2.1 Setting the Home Network Range Before Playback

After opening a file, set the home network address (in Plotter Settings dialogue) to scale the data along the blue axis - otherwise all traffic is rendered in a narrow single band with respect to the x-axis. A 'guess' button can help infer this home network range by checking the destination addresses contained within the file. In the case of monitoring the local network interface (live packet capture), the application will automatically retrieve the home network address from Libpcap.

3.2.2 Setting Address Ranges with CIDR Notation

Setting the address ranges entails using 'dots-slash' (CIDR) notation to specify network sub-domains. For example 192.168.0.0/24 is the network with address 192.168.0.0, subnet mask 255.255.255.0, giving the network range 192.168.0.0 to 192.168.0.255\. The number after the slash represents the number of bits in the subnet mask. Thus the octet classed network masks are:

Legacy Class A 255.0.0.0 = /8

Legacy Class B 255.255.0.0 = /16

Legacy Class C 255.255.255.0 = /24

Values other than /8, /16 and /24 are trickier as they involve bits in between the four octets of a 32 bit IP address. The Plotter Settings dialogue has a field below the dots-slash edit boxes that show the range and subnet mask to help as guide. For bits added on to a full octet (i.e. /8+x or /16+x or /24+x), the following octet in the mask will have the value:

/+1	/+2	/+3	/+4	/+5	/+6	/+7
.128	.192	.224	.240	.248	.252	.254

For example, 192.168.120/20 has subnet mask 255.255.248.0 and represents 8 /24 (Legacy Class C) networks in the range 192.168.120.0 to 192.168.127.255.

3.3 Recording

All three record methods, recording to capture file, taking a single image snapshot, or dumping rendered frames to image files, can be used simultaneously and used in conjunction with playback.

Recording back to capture file, taking a snapshot image, or dumping frames, creates a directory hierarchy relative to the InetVis running directory.

recorded/frames Sequences of framed which can be stiched together to create video

recorded/pcaps files in pcap format

recorded/snapshots individual image snapshots

Within these directories, sub-directory structures follow and should be self explanatory. Some file and directory names include numeric timestamps of the form yyyymmdd-hhMMsszzz (where MM is minutes and zzz milliseconds) - the timestamps refer to timestamps in the capture file (or live capture).

3.3.1 Record to Capture File

InetVis can record back out to a Libpcap packet capture file which can later be reviewed with any other tool capable of reading the file format (e.g. Wireshark or tcpdump). A record session begins when the record button (with the round red record symbol) is toggled on, and stops once the button its toggled off. Everything seen in the current display (and time window), as well as any consequent playback, will be recorded while the red record button is toggled on.

3.3.2 Taking an Image Snapshot

Pressing the record button with a picture symbol allows the user to take a snapshot of the current image in the visualization pane of the InetVis Display window. To save a single frame to disk the Z key can be used when uin the plotter window.

3.3.3 Dumping Rendered Frames to Image Files

InetVis can record rendered frames to image files. Frame record sessions work much the same way as capture file record sessions. Whilst the record button with the film symbol is on, the application dumps each frame to an image file, and stops when the button is toggled off. For each frame, a raw copy of the image buffer is copied into an uncompressed image file (.ppm format). Consequently, recording image frames uses up a large amount of disk space at a rapid rate and can degrade the applications performance - setting the window to a smaller resolution will help reduce the performance hit. During frame recording, the timing is fixed to produce frames suitable for encoding video clips at 25 frames per second (fps). Even if, whilst recording, it appears that playback is degraded to less than 25 fps, the timing between each frames is calculated with respect to the data in the file and according to the replay speed. Therefore, when the frame capture files are encoded to video a clip at 25 frames per second, the video clip has the correct timing and replay speed while despite the recording process appearing slower. As a consequence, playback of some video clips may appear faster that the original recording.

3.4 Minimum System Specification

The Original system was devloped with very modidst hardware requirements by modern standards (see below). Performance on more modern multicore systems is very good, and able to achieve frame rates of 25 FPS even using software rendering in a virutal machine. Siginificant performance hits still occur when dumping successive fames to disk (this is especially evident when using the PNG file format).

InetVis 0.9.x Requirements:
At least a Pentium III class processor with 256MB RAM and a 3-D graphics accelerator supporting OpenGL is recommended.
While InetVis may work with on-board video cards, poor performance and limited OpenGL support is a typical drawback.
Typical Performance:

- Tested on Ubuntu 7.04 with Intel Core2 (6300) 1.86 GHz CPU, 2GB RAM, GeForce 7600GS (256MB) graphics card.
- The application takes a best effort approach to rendering 25 frames a second. Once rendering at less than 25 frames per second, playback becomes slower than the chosen replay rate.
- During playback, handles 100MB capture file with about 500,000 packets at 25 frames per second.
- During playback, handles 200MB capture file with about 2,000,000 packets at about 5 FPS.
- When paused, handles 600MB capture file with about 6,000,000 packets at 8 FPS using an OpenGL display list optimisation.
- When recording frames, expect a significant performance hit due to heavy file I/O.

4 Known Issues

As of Version 2.1.0 the following known issues are still present:

- At present running the standalone app does not work on Mac OS, however opening with Qt Creator, building, and then running does work.
- Monitoring local network interfaces does not work under Mac OS at this time.
- Windows support is failing to compile.

4.1 Stability and Performance

1. Target frame rate is intentionally caped at 25 frames per second. The achieved frame rate is usualy a little slower and when the system reaches full processor usage, the replay rate is reduced to a best effort (plays slower than the chosen replay rate).
2. Large capture files can take a while to load while the GUI remains unresponsive. Similarly, some interactions require reloading the capture file, which, if not cached in RAM, will be applied with noticeable delay. This is minimised on modern systems with sufficient RAM
3. Attempting to view too many packets may exhaust system memory. The system will just about halt if the application starts running from swap space. (unlikley with >4GB ram)
   (a) To improve InetVis should (yet to be implemented) have a memory cap set and warn the user while automatically decreasing the time window to limit memory usage.
4. The Microsoft Windows (currently broken) and MacOS port is, not tested extensively and expected to be buggy.
5. Live monitoring is still has a few heisenbugs See `https://github.com/yestinj/inetvis/issues/46`.

A Full list of current issues can be found on GitHub https://github.com/yestinj/inetvis/issues.

4.2 Limitations and Feature Wish List

1. The option to aggregate packet traffic into flows would be a major improvement for dealing with production class network traffic.
2. Additional colour schemes would be nice. Furthermore, colour legends would help assist the users interpreting colours.
3. Axes labels overlap in certain orientations.
4. The reference frame and grid lines could be made more intelligent by dynamically scaling according to the data ranges chosen and only applying grids on the panes of the cube in the background.
5. Error reporting needs refinement (multiple reports and obscure references to code functions might be experienced).
6. InetVis lacks a mechanism to select a point an call up detailed textual information, such as the IP addresses, ports, and other such details.
7. The multi-window GUI is a little awkward and could do with re-factoring into a single integrated window with semi-transparent control overlays. This would allow the user to toggle controls and while making changes see the effect on the visualisation in the background.
8. Would be nice to have a 'play list' of capture files that can be queued for replay.
9. Proper file indexing, instead of re-reading the file from the start would improve manipulations (such as setting the filter, setting the domain/port ranges, changing the colour scheme, and so forth).
10. Currently, the application only caters for traffic captured from an Ethernet data link.
11. IP packets with options are processed, but the options are ignored. Fragmented IP packets are not yet handled and simply drooped by an implicit BPF filter "ip[6:2] & 0x3fff". Refer to RFC 791 for details about the fragment flags and offset field.
12. The ability to integrate IDS alerts, or at least scan detection alerts from an IDS, would be awesome.

Additional features in 'todo' status can be found on GitHub https://github.com/yestinj/inetvis/issues?q=is%3Aissue+is%3Aopen+label%3Aenhancement..

5 Running Inetvis

The instructions below have all been tested on the current version of Ubuntu, 17.04 64-bit. Installing and Running InetVis

A compiled version of InetVis is available under the releases section of https://github.com/yestinj/inetvis.

5.1 Installation

In order to install and run the software please do the following:

1. Download the latest release archive from the releases page.
2. Extract the archive which will be called something like inetvis-2.1.0.tgz
3. Change into the extracted directory, something like inetvis-2.1.0
4. Run the install_inetvis.sh shell script to install the software.

5. This script will:
   - install the software to /opt/inetvis-<version>
   - Create a symlink directory /opt/inetvis for convenience
   - Copy across the relevant files to the new directory under /opt.
   - Place an icon file in /usr/share/icons/hicolor/48x48/apps/
   - Place a desktop file in /usr/share/applications, allowing inetvis to be found in the menu on Ubuntu systems.
   - Create a symlink at /usr/local/bin/inetvis pointing to the main binary.
   - Set the cap_net_raw, and cap_net_admin=eip capabilities on the inetvis binary allowing for monitoring packets on local host without running as root.
     - `$sudo setcap 'CAP_NET_RAW+eip CAP_NET_ADMIN+eip'`
     - This needs to generally not be /home which on Debian/ubuntu systems is mounted nosuid
   - If the script completes successfully inetvis should now be in your path, and also be in the menu system of your distribution.
6. You should now be able to run the inetvis binary from the command line, as it will be in your path, or you can run it from the Ubuntu menu system, where it will show up as an item. Running from the command line allows you to view console messages produced while the application is running.

5.2 Uninstalling InetVis

A convenience script is included in the release archive, namely uninstall_inetvis.sh, which can be used to completely remove inetvis from your system at any time.

5.3 Disclaimer

This code may eat your homework — *Caveat emptor* .

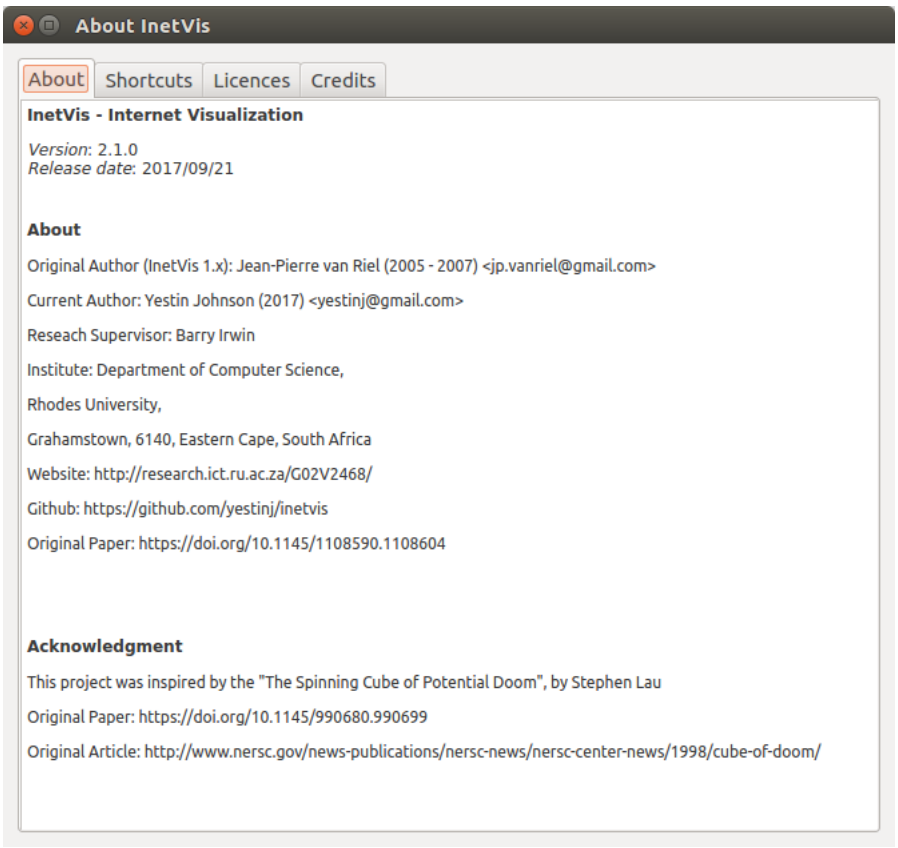
6 Building and Developing InetVis

In order to build InetVis onn your own system or VM please consider the following guidelines:

1. Update your system:
   (a) `sudo apt-get update` and `sudo apt-get upgrade`,
   (b) finally `sudo apt-get dist-upgrade`
   (c) Install the following dependencies: `sudo apt-get install libpcap-dev qt5-default`
2. It has been noted that the following dependencies were also required on *Linux Mint* based systems:
   (a) `sudo apt-get install libqglviewer-dev libqglviewer2`
3. Once the dependencies are installed, clone this repository if you haven't already.
   (a) Clone the github repo into the inetvis directory: git clone git@github.com:yestinj/inetvis.git
4. Change into the inetvis directory, and then change to src.
5. Checkout whichever branch you want to build, i.e. master or develop. git checkout master
6. Finally, build the inetvis binary:
   (a) qmake ; make
   (b) This will result in a new inetvis binary being generated within the source directory.
7. You may now run inetvis by simply running the generated binary. You will need to either run using sudo, or set packet capture capabilities (see instructions above) on the file in the event that you would like to monitor your local host for packets.

7 Contact

Any questions/queries can be directed to Yestin Johnson (2017) <yestinj@gmail.com>, or via GitHub.



8 Credits

Significant Contributions to this software beyond the base code have been made by:
Barry Irwin
Alan Herbert

9 Licence

InetVis - Internet Visualisation for network traffic analysis.

Copyright (C) 2005 - 2007, Jean-Pierre van Riel

Copyright (C) 2017, Yestin Johnson, Barry Irwin, Jean-Pierre van Riel *This program is free software; you can redistribute it and/or modify it under the terms of the GNU General Public License as published by the Free Software Foundation; either version 2 of the License, or (at your option) any later version.*

This program is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU General Public License for more details.

You should have received a copy of the GNU General Public License along with this program; if not, write to the Free Software Foundation, Inc., 51 Franklin Street, Fifth Floor, Boston, MA 02110-1301, USA.

10 Software Dependencies and Licensing

THIS NEEDS TO BE UPDATED

InetVis makes use of Libpcap/WinPcap, Qt and OpenGL. The open source version of Qt by Trolltech is licensed under the GPL, version 2 (as shown above). According to SGI, use of the OpenGL API requires no license. Libpcap is distributed under the BSD license. WinPcap, the windows derivative of libpcap is licensed by CASE Technologies. As required, the respective licenses are shown below.

10.1 *Libpcap License*

License: BSD

Redistribution and use in source and binary forms, with or without modification, are permitted provided that the following conditions are met:

1. Redistributions of source code must retain the above copyright notice, this list of conditions and the following disclaimer. 2. Redistributions in binary form must reproduce the above copyright notice, this list of conditions and the following disclaimer in the documentation and/or other materials provided with the distribution. 3. The names of the authors may not be used to endorse or promote products derived from this software without specific prior written permission.

THIS SOFTWARE IS PROVIDED "AS IS" AND WITHOUT ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, WITHOUT LIMITATION, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

WinPcap License

Copyright (c) 1999 - 2005 NetGroup, Politecnico di Torino (Italy). Copyright (c) 2005 - 2007 CACE Technologies, Davis (California). All rights reserved. Redistribution and use in source and binary forms, with or without modification, are permitted provided that the following conditions are met:

1. Redistributions of source code must retain the above copyright notice, this list of conditions and the following disclaimer. 2. Redistributions in binary form must reproduce the above copyright notice, this list of conditions and the following disclaimer in the documentation and/or other materials provided with the distribution. 3. Neither the name of the Politecnico di Torino, CACE Technologies nor the names of its contributors may be used to endorse or promote products derived from this software without specific prior written permission.

THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT OWNER OR CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

This product includes software developed by the University of California, Lawrence Berkeley Laboratory and its contributors. This product includes software developed by the Kungliga Tekniska Hogskolan and its contributors. This product includes software developed by Yen Yen Lim and North Dakota State University.

** * **

Portions Copyright (c) 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997 The Regents of the University of California. All rights reserved.

Redistribution and use in source and binary forms, with or without modification, are permitted provided that the following conditions are met:

1. Redistributions of source code must retain the above copyright notice, this list of conditions and the following disclaimer. 2. Redistributions in binary form must reproduce the above copyright notice, this list of conditions and the following disclaimer in the documentation and/or other materials provided with the distribution. 3. All advertising materials mentioning features or use of this software must display the following acknowledgement: "This product includes software developed by the University of California, Berkeley and its contributors." 4. Neither the name of the University nor the names of its contributors may be used to endorse or promote products derived from this software without specific prior written permission.

THIS SOFTWARE IS PROVIDED BY THE INSTITUTE AND CONTRIBUTORS "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE REGENTS OR CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

** * **

Portions Copyright (c) 1983 Regents of the University of California. All rights reserved.

Redistribution and use in source and binary forms are permitted provided that the above copyright notice and this paragraph are duplicated in all such forms and that any documentation, advertising materials, and other materials related to such distribution and use acknowledge that the software was developed by the University of California, Berkeley. The name of the University may not be used to endorse or promote products derived from this software without specific prior written permission. THIS SOFTWARE IS PROVIDED "AS IS" AND WITHOUT ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, WITHOUT LIMITATION, THE IMPLIED WARRANTIES OF MERCHANTIBILITY AND FITNESS FOR A PARTICULAR PURPOSE.

** * **

Portions Copyright (c) 1995, 1996, 1997 Kungliga Tekniska Hogskolan (Royal Institute of Technology, Stockholm, Sweden). All rights reserved.

Redistribution and use in source and binary forms, with or without modification, are permitted provided that the following conditions are met:

1. Redistributions of source code must retain the above copyright notice, this list of conditions and the following disclaimer. 2. Redistributions in binary form must reproduce the above copyright notice, this list of conditions and the following disclaimer in the documentation and/or other materials provided with the distribution. 3. All advertising materials mentioning features or use of this software must display the following acknowledgement: "This product includes software developed by the Kungliga Tekniska Hogskolan and its contributors." 4. Neither

the name of the University nor the names of its contributors may be used to endorse or promote products derived from this software without specific prior written permission.

THIS SOFTWARE IS PROVIDED BY THE INSTITUTE AND CONTRIBUTORS "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE INSTITUTE OR CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

** * **

Portions Copyright (c) 1997 Yen Yen Lim and North Dakota State University. All rights reserved.

Redistribution and use in source and binary forms, with or without modification, are permitted provided that the following conditions are met:

1. Redistributions of source code must retain the above copyright notice, this list of conditions and the following disclaimer. 2. Redistributions in binary form must reproduce the above copyright notice, this list of conditions and the following disclaimer in the documentation and/or other materials provided with the distribution. 3. All advertising materials mentioning features or use of this software must display the following acknowledgement: "This product includes software developed by Yen Yen Lim and North Dakota State University" 4. The name of the author may not be used to endorse or promote products derived from this software without specific prior written permission.

THIS SOFTWARE IS PROVIDED BY THE AUTHOR "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE AUTHOR BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

** * **

Portions Copyright (c) 1993 by Digital Equipment Corporation.

Permission to use, copy, modify, and distribute this software for any purpose with or without fee is hereby granted, provided that the above copyright notice and this permission notice appear in all copies, and that the name of Digital Equipment Corporation not be used in advertising or publicity pertaining to distribution of the document or software without specific, written prior permission.

THE SOFTWARE IS PROVIDED "AS IS" AND DIGITAL EQUIPMENT CORP. DISCLAIMS ALL WARRANTIES WITH REGARD TO THIS SOFTWARE, INCLUDING ALL IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS. IN NO EVENT SHALL DIGITAL EQUIPMENT CORPORATION BE LIABLE FOR ANY SPECIAL, DIRECT, INDIRECT, OR CONSEQUENTIAL DAMAGES OR ANY DAMAGES WHATSOEVER RESULTING FROM LOSS OF USE, DATA OR PROFITS, WHETHER IN AN ACTION OF CONTRACT, NEGLIGENCE OR OTHER TORTIOUS ACTION, ARISING OUT OF OR IN CONNECTION WITH THE USE OR PERFORMANCE OF THIS SOFTWARE.

** * **

Portions Copyright (C) 1995, 1996, 1997, 1998, and 1999 WIDE Project. All rights reserved.

Redistribution and use in source and binary forms, with or without modification, are permitted provided that the following conditions are met:

1. Redistributions of source code must retain the above copyright notice, this list of conditions and the following disclaimer. 2. Redistributions in binary form must reproduce the above copyright notice, this list of conditions and the following disclaimer in the documentation and/or other materials provided with the distribution. 3. Neither the name of the project nor the names of its contributors may be used to endorse or promote products derived from this software without specific prior written permission.

THIS SOFTWARE IS PROVIDED BY THE PROJECT AND CONTRIBUTORS "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE PROJECT OR CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

** * **

Portions Copyright (c) 1996 Juniper Networks, Inc. All rights reserved.

Redistribution and use in source and binary forms, with or without modification, are permitted provided that: (1) source code distributions retain the above copyright notice and this paragraph in its entirety, (2) distributions including binary code include the above copyright notice and this paragraph in its entirety in the documentation or other materials provided with the distribution. The name of Juniper Networks may not be used to endorse or promote products derived from this software without specific prior written permission.

THIS SOFTWARE IS PROVIDED "AS IS" AND WITHOUT ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, WITHOUT LIMITATION, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

Portions Copyright (c) 2001 Daniel Hartmeier All rights reserved.

Redistribution and use in source and binary forms, with or without modification, are permitted provided that the following conditions are met:

1. Redistributions of source code must retain the above copyright notice, this list of conditions and the following disclaimer. 2. Redistributions in binary form must reproduce the above copyright notice, this list of conditions and the following disclaimer in the documentation and/or other materials provided with the distribution.

THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTOR "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDERS OR CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

Portions Copyright 1989 by Carnegie Mellon.

Permission to use, copy, modify, and distribute this program for any purpose and without fee is hereby granted, provided that this copyright and permission notice appear on all copies and supporting documentation, the name of Carnegie Mellon not be used in advertising or publicity pertaining to distribution of the program without specific prior permission, and notice be given in supporting documentation that copying and distribution is by permission of Carnegie Mellon and Stanford University. Carnegie Mellon makes no representations about the suitability of this software for any purpose. It is provided "as is" without express or implied warranty.