ESVT (Experiment Specification and Visualization Tools) Version II MANUAL

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1. Overview

The ESVT (Experiment Specification and Visualization Tools, or GUI in this manual) provides an integrated environment to interact with DETER or EMULAB test-beds and to conduct network security emulation/simulation experiments. The ESVT is a modular, component-based topology editor, a TCL script generator, a worm experiment designer and a visualization tool for experimental results. First, the tools offer a topology editor toolbar for user to draw network topologies including computer/end-host nodes, switch nodes, router nodes, sub-network/Internet interfaces and links. Each of these network components has configurable properties such as bandwidth and link latency, which can be stipulated and modified. Alternately, user can import a scale-free topology generated by GT-ITM tool into ESVT editor. The GUI can then generate a TCL script from a designed network topology in several formats: NS/2 format, DETER/EMULAB format without LAN, DETER/EMULAB format with LAN and virtualized nodes. Finally, the GUI can visualize the resulting experimental data (captured in TCPDUMP format or from MySQL database tables with NETFLOW-like format) by animation, sliding charts and figures, and other advanced views.

New features in version II:

- Support of binary TCPDUMP trace file;
- New flow (NetFlow similar) format for network traffic and automatic conversion from TCPDUMP trace file to flow/packet dual tables;
- Database (MySQL) for trace management;
- User-defined link traffic visualization, including entropy and chi-square view.

2. Getting started

2.1. System requirements

Currently, the EMIST GUI only runs on Windows XP and Windows 2000 platforms and requires at least 1000MByte of a combination of RAM and virtual memory.

2.2. Installation

Copy the executable PsuESVT2.exe to the chosen directory. During its first run, the GUI program will register itself with Windows and will associate itself with '.wor' file type.

2.3. MySQL Database

ESVT can store (with conversion) experimental trace data (TCPDUMP files currently) with MySQL database. To use this feature, MySQL database server is to be installed with the following account and database set up:

1. Default super user account with empty string '' as user id and password.
2. One user database named "deter_exp".
3. In database deter_exp, one user table 'experiments' with the following structure:

```
{exp_name varchar(20) KEY;
 link_name varchar(10);
 note      varchar(100);
}
```

3. Topology Design

3.1. Basic operation

The ESVT can be used to design network topology which includes five different network components: computer/host, switch, router, link and Internet/sub-network.

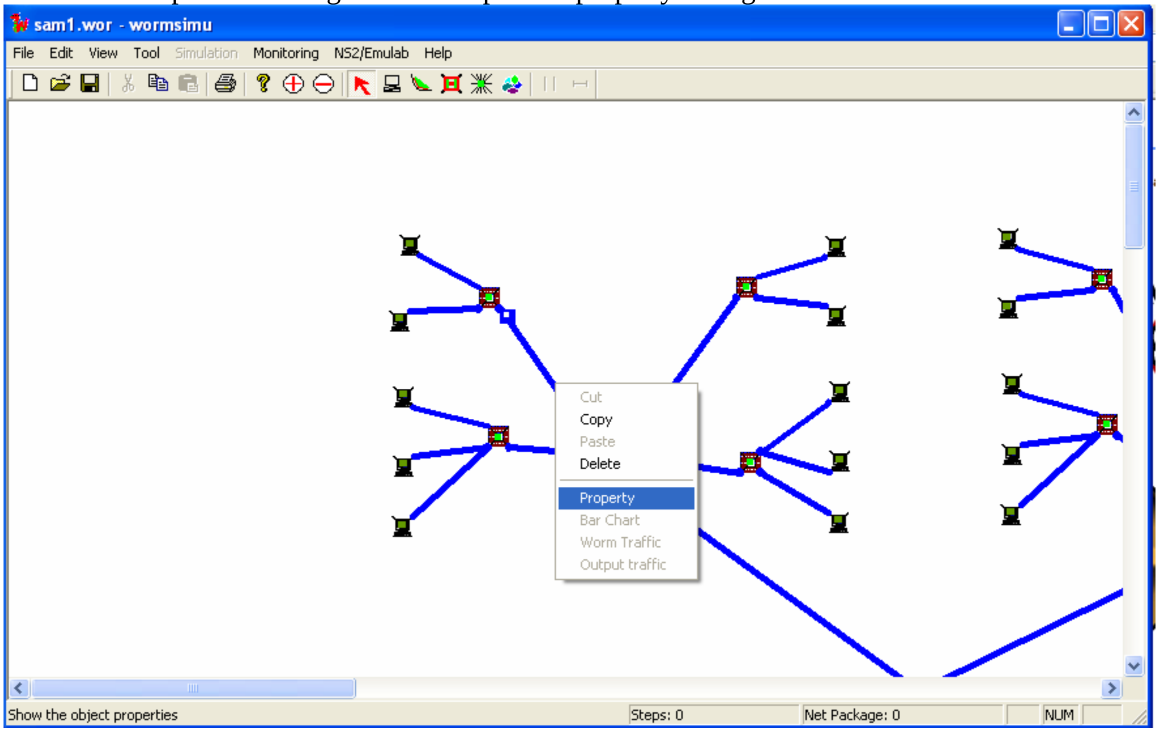
Adding a network component: Click on the corresponding component icon on the toolbar, move the mouse pointer to the main window and click on the desired location to add a new component. To add a link, click on the source component, hold the mouse button down and move the mouse pointer to the target component, then release the mouse button.

Selecting a component: Click the **Select** icon on the toolbar (Arrow icon) to switch to "select mode", then click on the target component (the selected component will be highlighted). To select a group of components, hold the mouse button down to draw rectangular box over the components. To deselect a component or group of components, click on a blank space in the main window.

Tip: *Click on a switch component while holding the CTRL key will select the switch and all the host nodes connected by the switch.*

Moving a component: Select the component (single left-click on the component) and drag it to the target location.

Editing a property of a component: Each component has various properties which can be modified, select the component and right-click to open the property dialog window.



Show the object properties Steps: 0 Net Package: 0 NUM

Figure 1: Topology design—property editing

User can also change the properties of a group of components or all components by invoking the "Global component and script property configuration" (**Tools-> Global component and script property**). The currently globally changeable properties include *host susceptibility* and *link bandwidth*.

Deleting a component: Select the component and choose menu **Edit->Delete** to delete it.

3.2. Miscellaneous features

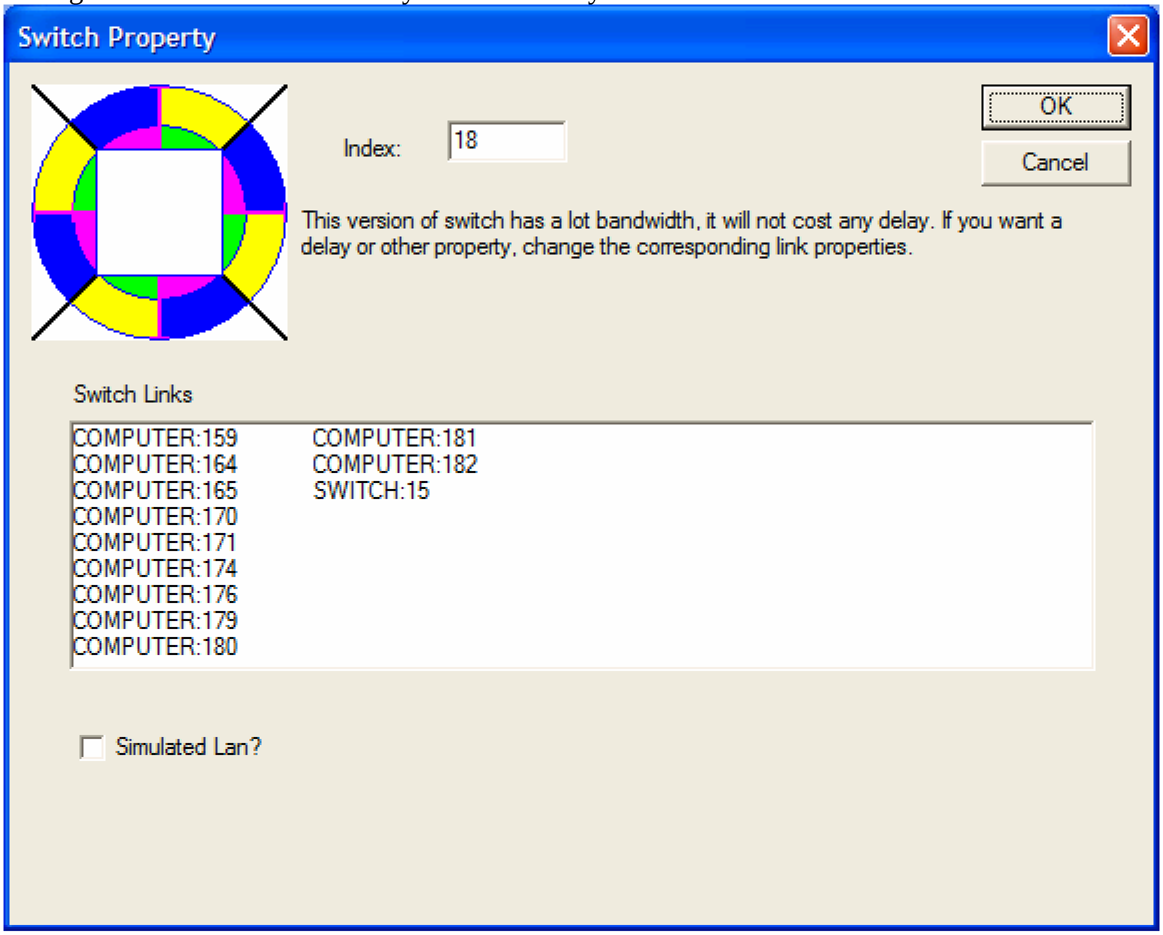
There are some other helpful features in the GUI, which include:
Topology zoom: Zoom in, zoom out, zoom by, and click-zoom. Click the **zoom in** or **zoom out** icon on the toolbar for larger or smaller zoom. Right-click on a blank space to open the zoom-by window. Hold down the '**CTRL**' key and right-click on the main window to zoom to level 8 centered at the click point.

Index display: GUI internal component index number starts from 0 for each class of components. To show the index number of each network component, choose menu **View->show computer index, View->show switch index** or **View->show router index.**

Computer node finder: Choose **View->Zoom to component** to open the dialog, and then input the computer node index. The found node will be located on the center of the main window.

Copy and Paste: Select a component or a group of components, then copy and paste using the right-click menu.

*Virtual node***:** A switch component has one special property "**Simulated Lan**". Modifying this property will change the way the GUI generates a DETER/EMULAB script. A virtualized switch is distinguished from a real switch by its color and symbol.



Index: 18

This version of switch has a lot bandwidth, it will not cost any delay. If you want a delay or other property, change the corresponding link properties.

Switch Links

```
COMPUTER:159       COMPUTER:181
COMPUTER:164       COMPUTER:182
COMPUTER:165       SWITCH:15
COMPUTER:170
COMPUTER:171
COMPUTER:174
COMPUTER:176
COMPUTER:179
COMPUTER:180
```

☐ Simulated Lan?

Figure 2: Virtualized LAN

4. Topology conversion and script generation

After finishing the topology design, you can save and restore your design using **File->Save** and

File->Load menu items. Besides the customized binary representation, the GUI supports exporting the design in four different output formats: NS, one-to-one DETER format, DETER format with virtual nodes, and DETER format with VM nodes. You can generate a script file in a specific format by choosing "output format" from menu **NS2/Emulab**.

1) **NS2/Emulab->Save as a TEXT NS file**: GUI will generate NS scripts when File->Save menu item is invoked.
2) **NS2/Emulab->Save to DETER script (one 2 one)**: GUI will generate DETER format without virtual nodes.
3) **NS2/Emulab->Generate DETER script (V node)**: GUI will generate DETER format with virtual nodes.
4) **NS2/Emulab->Generate DETER script (VM node)**: GUI will generate DETER format with VM nodes for the virtualized LAN.

4.1. Node name and index conversion

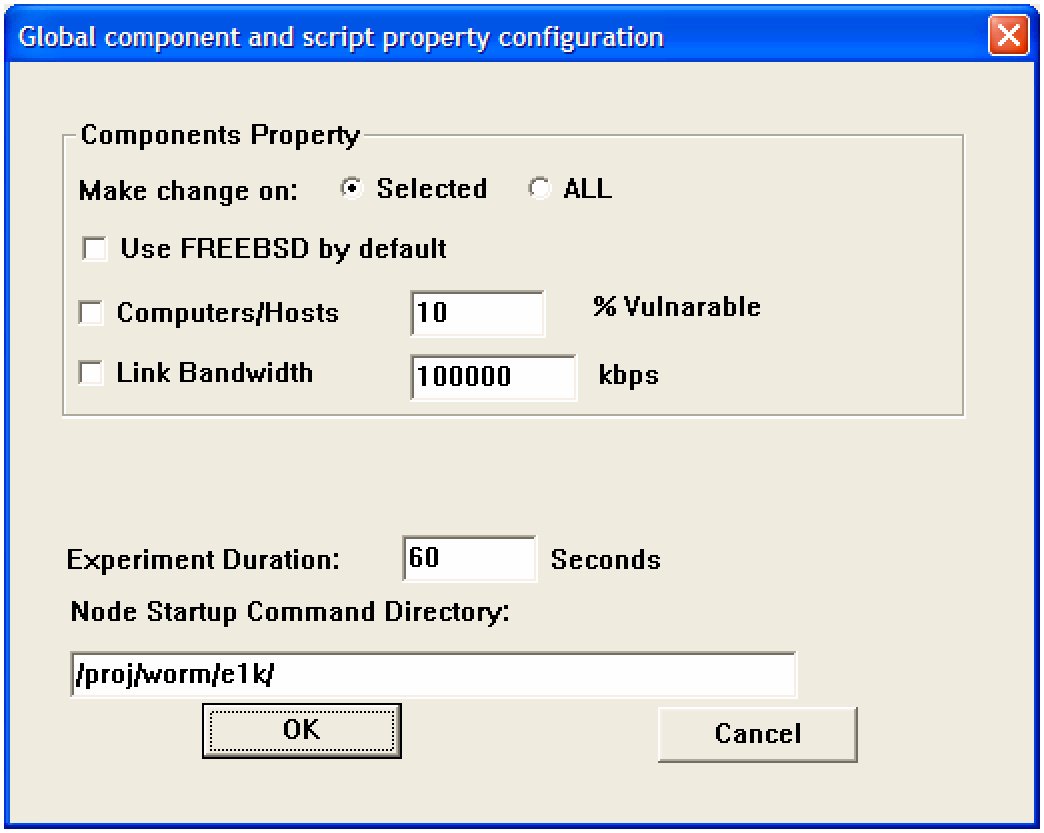
GUI internal component index number starts from 0 for each class of components. In the TCL script all components except link are named by the following formula:

Computer:	n-(GUIindex)
Switch:	n-(ComputerCount+GUIindex)
Router:	n-(ComputerCount+SwitchCount+GUIindex)
Network:	n-(ComputerCount+SwitchCount+RouterCount+GUIindex)

Currently script generator doesn't assign IP addresses for components. The mapping between node name and test-bed IP address is based on test-bed ***/etc/hosts*** file.

4.2. Additional start-up command scripts

In the DETER script, there are additional start-up commands after the topology script lines. You can modify or delete them for your particular experiment. Also you can change the root directory of start-up commands by change the "Node Startup Command Directory" field in the "Global component and script Property configuration" dialog.



Global component and script property configuration

Components Property

Make change on: ● Selected ○ ALL

□ Use FREEBSD by default

□ Computers/Hosts 10 % Vulnerable

□ Link Bandwidth 100000 kbps

Experiment Duration: 60 Seconds

Node Startup Command Directory:

/proj/worm/e1k/

Figure 2.A. Global component and script property configuration dialog

In the dialog, there are some other parameters that affect the TCL script generation:

- The "Experiment Duration" value will be one command-line parameter for the start-up commands or scripts, which can be utilized by user application to control the duration of the experiment.
- By default, user does not need to specify OS for test-bed node and test-bed will assign LINUX as the node operation system. If "Use FREEBSD by default" checkbox is checked, the script will add a additional line for every node "tb-set-node-os $n(##) FBSD-STD", except VM nodes which use special "pvcm" OS.

4.3. Virtualized LAN segment information file

When generating a virtualized network segment, the GUI generates another separate file named ***map.001*** which includes information regarding that sub-network. Upload this file to the DETER test bed computer so that the experimental programs can access it. The following lines are part of an example map.001 file.

```
#node & virtual node map file
#n-#### TYPE(B/I/V/R) S/N #####(GUI node index) #####(Last segment of IP)
n-208   V N 75    254
n-208   V N 69    253
n-208   V N 65    252
n-208   V N 61    251
n-208   V N 56    250
n-208   V N 59    249
```

Each line of the map.001 file represents one virtualized/real host node. The fields of each line are: node name, node type or line type (B for Bandwidth, I for Internet node, V for virtual node, R for real node), node susceptibility (S for susceptible, N for not susceptible), node GUI internal index and last byte of node IP address.

Note: the GUI will override map.001 if there is map.001 file in the directory.
Note: Map.001 file format may be slightly different in example above than in other GUI versions.

4.4. Internet Worm Simulation File format

For Internet scale-down worm experiment, use **NS2/Emulab->[Topology Format Conversion]->Read Internet topology from file (SLAMMER)** to read the topology file. A sample of the scale-down topology file is shown below.

```
*******************************************************
network 0.0.0.0/17 3
worm 0.0.72.101
worm 0.0.85.214
worm 0.0.123.42
network 0.0.128.0/17 1
********************************************************
```

4.5. Import Topology from GT-ITM

To import a scale-free topology generated by GT-ITM topology tool, use **NS2/Emulab->[Topology Format Conversion]->Read GT-ITM Format** to read the topology file. This operation takes some time to finish and user may need substantial editing after the import is done.

5. Visualization (Overview)

5.1. Log files preparation

To use the visualization feature of the GUI, all log files are required to be placed in the same directory. The log files are shown below:

1) *HOSTLIST file*: This is the /etc/hosts file of any experimental node and is renamed to 'hostlist'. The GUI uses the hostlist file to obtain a mapping between the internal index number (node, LAN, and link number in the script file) and the assigned IP address of a corresponding node.
2) *TCPDUMP log file:* The name of log file is tcplog_NN.NN.NN.NN. The log file can be in either binary format (default, TCPDUMP switch -w) or plain text format. Note for text format that the timestamp on each dump line has to be an unformatted number (using –tt option when running TCPDUMP program).
3) *Worm infection file*: The name of worm infection file can be either log_XXXX or log_NN.NN.NN.NN, where XXXX is a node index number and NN.NN.NN.NN is an IP address of node. The following is an example of a worm infection file:
   3 by n-8-link6 10.1.5.3 at:1074366335.249722
   Note: These files are only for WORM experiment.

5.2. Starting visualization

After collecting traffic and worm infection log files from an experiment, the GUI can visualize the result with the following steps:

1) Change the step time: Choose **NS2/Emulab->Change Step Time**. Specify an integer value between 1 and 60000 milliseconds.
2) Load the data: Choose **NS2/Emulab->DETER/EMULAB visualization (V node)**. When the dialog box named “Please locate the file directory” appears, go to the directory that contains all the necessary files (HOSTLIST file, Worm infection files, and TCPDUMP log files) and click the **Open** button (with or without clicking on any file in the directory).

After the GUI finishes calculating the starting time (the earliest TCP/UDP packet time minus two step times) and the traffic data of each link, it will visualize the data immediately and show the status of the network.   Note that the calculation time will vary according to the performance of your machine and size of the log file.

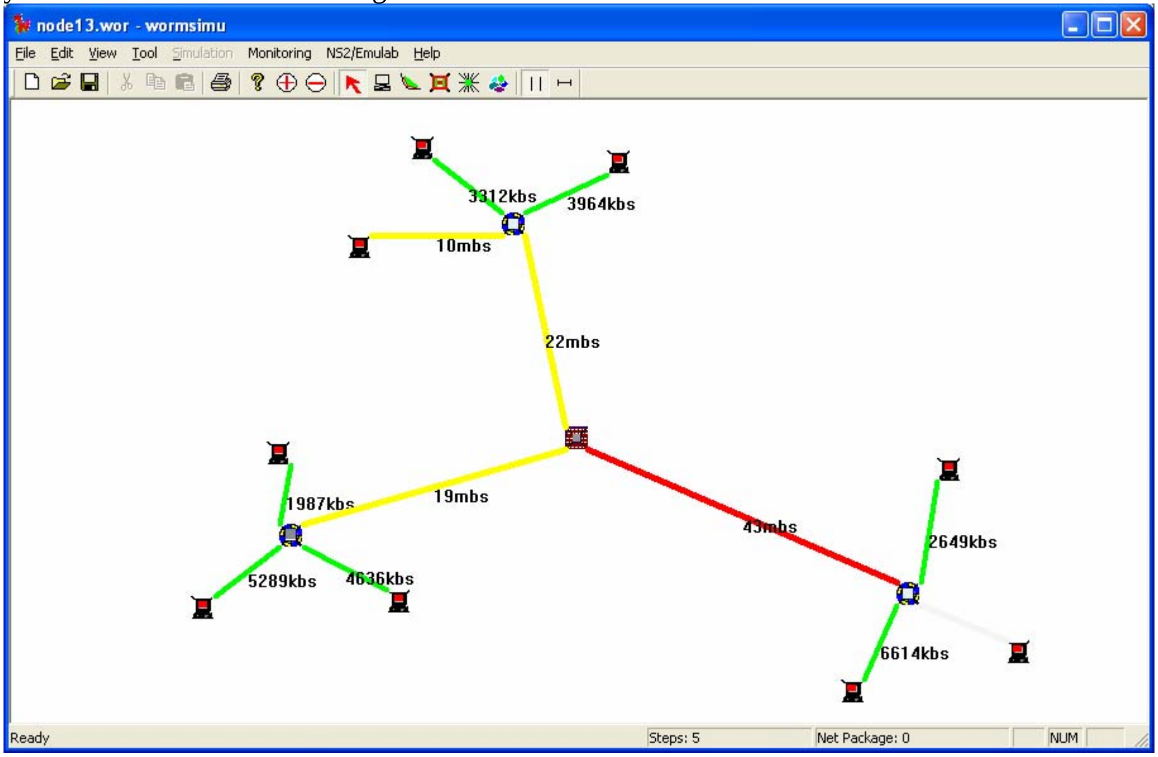


Figure 3: Worm propagation animation

5.3. Interpreting the animation

The color of a link represents the traffic volume on that link (in KBps and in Mbps). The color of a host indicates the host status.

Link color
1) Light Gray: less than 1 percent of bandwidth
2) Green: more than 1 percent of bandwidth
3) Yellow: between green and red
4) Red: more than 30 percent of bandwidth

Host color (Varied by experiment. The following example is for worm experiment.)
1) Red: Infected node.
2) Green: Vulnerable node but not infected
3) Gray: Non-vulnerable node

5.4. Controlling animation

The GUI provides the following two buttons on the right-most side of the toolbar to allow users to control the animation.

| |: Toggle between pause and resume animation
|—|: Move to a specific point in entire simulation time

5.5. Charts and other views

1) Bar chart: Shows the change in traffic on a particular link. **Right-click** on a particular link to show a pop-up menu and choose **Bar Chart** to switch to this view.

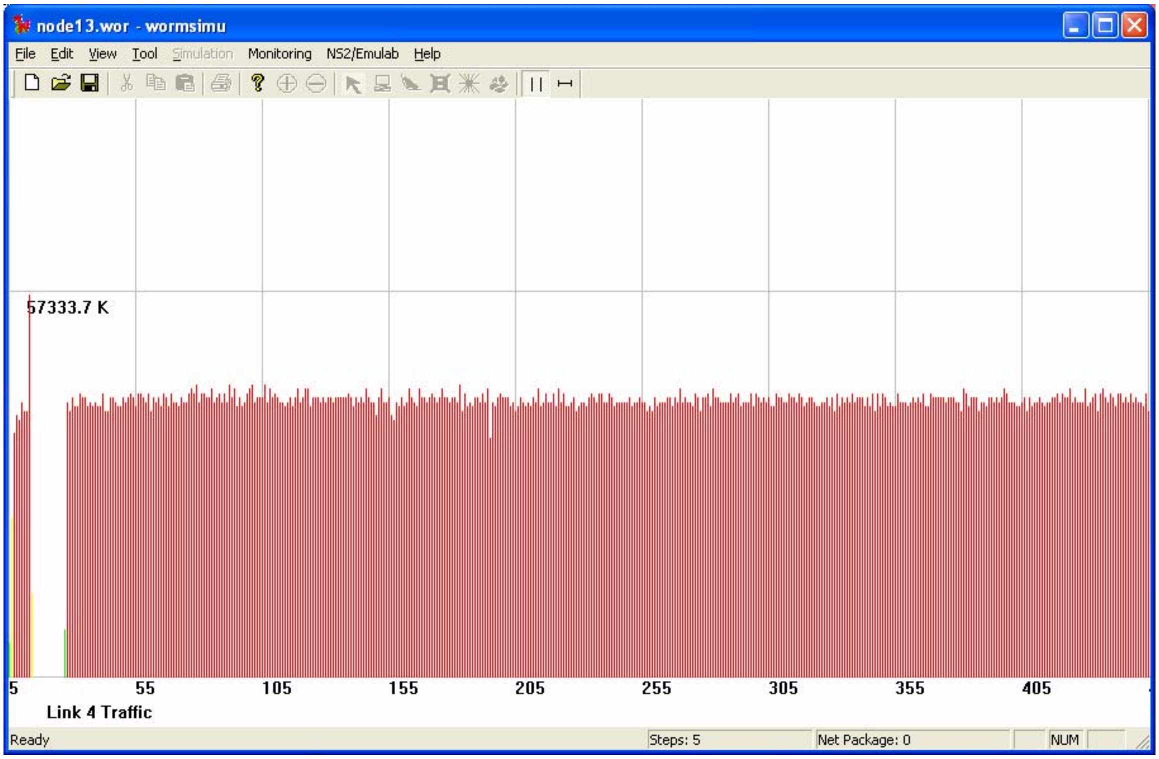


Figure 4. Link traffic bar chart

2) Worm traffic chart: Shows the traffic composition on a link. **Right-click** on a particular component to show a pop-up menu and choose **Worm Traffic** to switch to this view. The blue part of a bar represents the non-worm background traffic volume. The red part of a bar stands for worm traffic. Currently, this worm traffic chart feature can identify only SLAMMER worm traffic.

To return to the main animation view (main window) from a bar chart view or a worm traffic chart view, choose menu **View->Normal view**.

5.6. Output traffic data to text file

You can save the traffic data of a link into a text-file format for, e.g., further statistical analysis using another software package. Click on the link and choose ->**Output traffic**. The following is a sample of a traffic data file in which each line shows traffic data on a link during one time-step interval.

```
Traffic(kps)    Packets   WormTraffic(kps) WormPackets
       0.000          0        0.000          0
       0.000          0        0.000          0
    2649.600          4        0.000          0
    2649.600          4        0.000          0
    3974.400          6        0.000          0
    5289.600          8        0.000          0
   23846.400         36        0.000          0
   36432.000         55        0.000          0
   39081.600         59        0.000          0
   38419.200         58        0.000          0
   41068.800         62        0.000          0
   39744.000         60        0.000          0
   39744.000         60        0.000          0
```

5.7. Internet scale-down worm experiment visualization

For Internet scale-down worm experiment, use **NS2/Emulab->Internet Simulation Visualization** to see the worm infection animation. Choose **View->Statistics/Traffic** to check the worm infection curve. The followings are samples of an infection log file, which must be named *gui_result*.

```
InfectedIP:    0.0.72.101 Time: 0.00 TotalScans:       4315 Scan/Worm:    4315
InfectedIP:  0.48.170.103 Time: 3.52 TotalScans:       8630 Scan/Worm:    4315
```

6. Data Management of traffic traces files using MySQL

ESVT supports experimental data storage and retrieval using database. If MySQL database is installed as required in the installation section, ESVT will automatically detect the installation and store the traffic traces on the link into database tables with necessary conversion when user chooses L**ink Visualization** and clicks the **plot** button.

ESVT reads and converts one TCPDUMP trace file into two separate database tables. One table holds the generated NETFLOW-like flow series, and another table stores the detailed packet records. The flow table is named with the fashion of topology name plus link index number plus "flow". E.G., if the topology file name is real2xx.wor, the flow table for the link 61 will be named with real2xx_wor_61_flow. The packet table is named similarly, e.g., real2xx_wor_61_packet. Data structures of two tables are listed below.

Flow table/list structure

Column Name	Data type	Note
Flow_id	Integer	
Src_ip	Char[16]	
Src_port	Smallint[6]	
Dst_ip	Char[16]	
Dst_port	Smallint[6]	
Protocol	Smallint[6]	1--tcp;2--udp;3--icmp
Start_time	Double	
Last_time	Double	
Total_bytes	Integer	
Total_packets	Integer	
Status	Smallint[6]	1--Just_Syn;

		5--Established;10--Closed

Packet table structure

Column Name	Data type	Note
Flow_id	Integer	
Packet_time	Double	
Packet_size	Smallint[6]	

Note: The same flow/packet data structure is also used in link/flow visualization purposes that will be introduced in the next section.

User can use MySQL query browser or any other database tools to inspect, import and export, manipulate the trace data after they are saved in database. Or you can load trace data from other sources into MySQL database and utilize the ESVT tools to visualize them.

SQL Example

```
"Select src_ip, src_port,dst_ip,dst_port,protocol,\
        start_time,last_time,total_bytes,total_packets,status from vm20_wor_9_Flow \
Union ALL \
Select src_ip, src_port,dst_ip,dst_port,protocol,\
        start_time,last_time,total_bytes,total_packets,status from vm20_wor_19_Flow \
where flow_id>=100 \
order by start_time"
```

The above SQL statement selects the flow records from two tables whose flow_id are equal or greater than 100 and orders them by the flow start time.

7. User defined visualization (Link/Flow Traffic)

7.1 Preparation

The same procedure as outlined in section 5.1 should be used to prepare for visualization

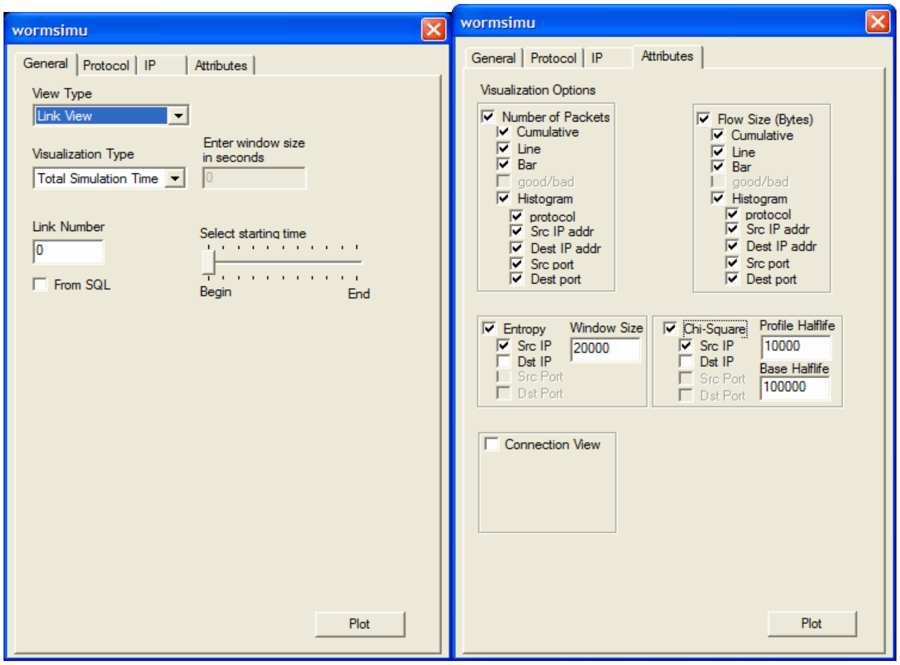
7.2 Starting the visualization

Two options are available for the user to visualize data on network link:

- Choose **View->Link Visualization**
- Right click on any link in the network topology and selection **Link Visualization**

Either of these options will bring up a dialog box which allows the user to select which visualization options are desired.

Note: When user chooses one link (link number editor box) to visualize, ESVT will do the data conversion from TCPDUMP format to flow/packet lists with the structures stated in section 6. One flow file will be generated and saved on the same directory with the original TCPDUMP file, with the name "flow_****" (**** is the IP part of TCPDUMP file). If the conversion has been done before and the data was saved in MySQL database, a YES/NO dialog will be displayed and user can choose to load data from database or re-do the conversion and database updates.



View Type: Link View

Visualization Type: Total Simulation Time

Enter window size in seconds: 0

Link Number: 0

□ From SQL

Visualization Options

☑ Number of Packets
☑ Cumulative
☑ Line
☑ Bar
□ good/bad
☑ Histogram
☑ protocol
☑ Src IP addr
☑ Dest IP addr
☑ Src port
☑ Dest port

☑ Flow Size (Bytes)
☑ Cumulative
☑ Line
☑ Bar
□ good/bad
☑ Histogram
☑ protocol
☑ Src IP addr
☑ Dest IP addr
☑ Src port
☑ Dest port

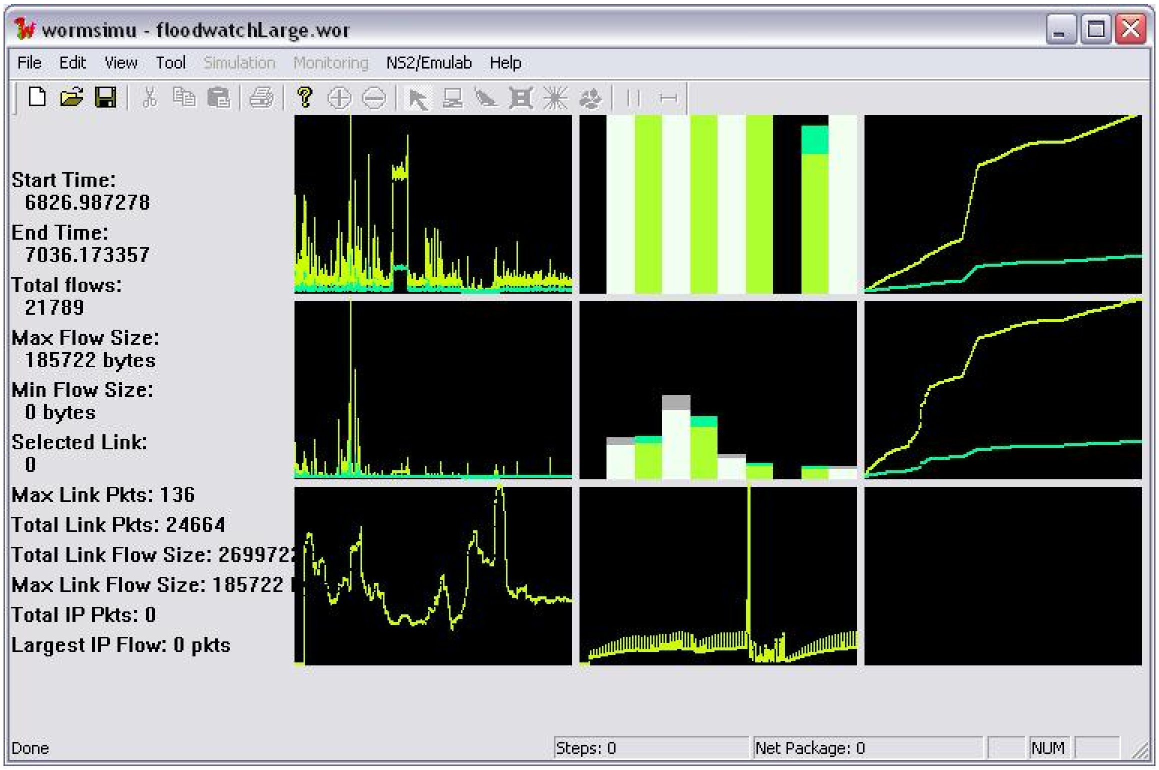
☑ Entropy
☑ Src IP
□ Dst IP
□ Src Port
□ Dst Port
Window Size: 20000

☑ Chi-Square
☑ Src IP
□ Dst IP
□ Src Port
□ Dst Port
Profile Halflife: 10000
Base Halflife: 100000

□ Connection View

Figure 5: Example dialog box for user defined visualization.

Fig. 5 shows what the dialog box looks like. The tabs across the top allow the user to select different options, attributes, and view types. Once the user has selected the desired options, pressing **Plot** will bring up a dialog box so that the user may select the location of the data files. Select the location of the files and click **OK**. The visualization results are displayed in the main window. Clicking on a single plot will zoom-in and show further statistics related to the plot which was clicked on.



Start Time:
6826.987278
End Time:
7036.173357
Total flows:
21789
Max Flow Size:
185722 bytes
Min Flow Size:
0 bytes
Selected Link:
0
Max Link Pkts: 136
Total Link Pkts: 24664
Total Link Flow Size: 269972
Max Link Flow Size: 185722
Total IP Pkts: 0
Largest IP Flow: 0 pkts

Done
Steps: 0
Net Package: 0
NUM

Figure 6: Sample visualization output. Clicking on any plot will zoom-in and show further details.

7.3 Data sources

User can choose to visualize traffic data of one specific link by inputting **Link Number** (automatically filled if user right-clicks the link to start the link visualization dialog), or he/she can visualize and analyze flow data that results from a SQL query. To do this, user can check the **From SQL** box and input an appropriate SQL statement in the pop-out window. The system will report an error message if the SQL statement is not correct or not supported by the MySQL database.

7.4 Visualization Options

The dialog box provides the user with two features to better help visualize traffic data; attribute filtering, and view-type specification. *Attribute filtering* allows the user to filter out unwanted data. This allows the user to see only data related to the experiment. Filtering is accomplished by changing the view type. The available options are; link view, IP view, and protocol view. Each type allows the user to filter data specific to that type by selecting options given in the various dialog box tabs. *View-type specification* allows the user to specify which plots or views he or she desires to visualize. This includes line plots, bar plots, histograms, connection views, etc.

8. Important Parameters

For efficiency consideration, the tools are designed with upper limits for component number and flow/packet number in the link visualization.

Topology

Computer nodes	5000
Switch nodes	2000
Router nodes	1000
Network/Internet nodes	10
Links	5000
Links per Switch (Max)	120
Links per Router	10

Link visualization

Flow number	1,000,000
Packet number	5,000,000

9. Features in the next version

- Support of popular network topology formats: The GUI will support the output from popular scale-free topology generators (e.g., those of GA Tech and Umich) and will convert it to EMIST GUI format.
- Experiment and data management: The GUI will be an interface to the DHS data repository and will incorporate traffic traces of different formats into EMIST ESVT.
- Traffic source generation tool from TCPDUMP and NETFLOW traces.
- Trace file digestion tool.