Netkit: Easy Emulation of Complex Networks on Inexpensive Hardware

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Netkit in a Nutshell

- software integration project
- based on user mode linux
- tools to set up virtual labs
- ready to use labs & teaching material
Overview

- Architecture
- Supported technologies
- Virtual network setup
- Applications
- Related work
- Scalability
Architecture

- Guest OS
  - User-Mode Linux
- Virtual hub
- Host OS
- Host kernel
- TAP
  - forwarding
- NIC

Emulation

NIC

Host kernel

User-Mode Linux

Guest OS

Guest OS

User-Mode Linux
foo@host$ ./uml-kernel modules=/home/foo/kernel/modules
name=vhost1 title=vhost1 umid=vhost1 mem=260M
ubd0=/home/foo/vhost1.disk,/home/foo/fs/fs.img root=98:1
uml_dir=/home/foo/uml/mconsole
eth0=daemon,,,/home/foo/hubs/vhub_foo_A.cnct
eth1=daemon,,,/home/foo/hubs/vhub_foo_tap.cnct quiet
con0=xterm con1=null SELINUX_INIT=0
manage a single user mode linux instance (virtual machine)
customizable hardware & net configuration
Architecture

- manage a single user mode Linux instance (virtual machine)
- customizable hardware & net configuration

vtools

```
foo@host$ vstart vhost1 --eth0=A
foo@host$ vstart router --eth0=A --eth1=tap,10.0.0.1,10.0.0.2
foo@host$ vstart vhost2 --eth0=tap,10.0.0.1,10.0.0.3
```
configure multiple virtual machines
set up a virtual lab

Architecture

- User-Mode Linux
- Guest OS
- NIC
- Virtual hub
- Quagga
- vtools
- ltools

configure multiple virtual machines
set up a virtual lab
configure multiple virtual machines
set up a virtual lab

host machine

foo@host$ lstart
Supported Technologies

- virtual machine
- virtual hub software
- virtual machine running appropriate software...
Supported Technologies

- Ethernet 802.3, 802.1d Bridging and Spanning Tree, 802.1Q VLAN tagging
- MPLS forwarding
- IPv4, IPv6, IP filtering and mangling (NAT, etc.), IPsec (transport and tunnel mode, ESP and AH), ARP, ICMP
- UDP, TCP, GRE tunnels, Equal cost multipath load balancing, PIM-SM
- ...

- DHCP, PPP, DNS, HTTP(S), Web proxy, MTA
- FTP, NFS, Samba
- Telnet, SSH
- RIP, OSPF, IS-IS, BGP, SNMP
- RADIUS, PAM, IKE, Snort, Traffic capturing and forging
- Scripting languages
- ...
Supported Technologies

• Ethernet 802.3, 802.1d Bridging and Spanning Tree, 802.1Q
• IPv4, IPv6, IP filtering and mangling (NAT, etc.), IPsec
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• Scripting languages
• ...
Supported Technologies

Compile time configurations provided

More can be added

Debian package manager
1. Define nodes
   mkdir as20r1 as20r2 as200r1 as100r1
Setting up a Lab

1. Define nodes
   
   ```
   mkdir as20r1 as20r2 as200r1 as100r1
   ```

2. Define topology

   ```
   as20r1[0]="A"
   as20r1[1]="F"
   as20r1[2]="C"
   as20r2[0]="E"
   as20r2[1]="C"
   as200r1[0]="A"
   as200r1[1]="B"
   as200r1[2]="J"
   as100r1[0]="E"
   as100r1[1]="F"
   as100r1[2]="J"
   ```
1. Define nodes
   mkdir as20r1 as20r2 as200r1 as100r1

2. Define topology

   \[
   \begin{align*}
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   as100r1[2]="J"
1. Define nodes
   `mkdir as20r1 as20r2 as200r1 as100r1`

2. Define topology

3. Populate configuration files using native syntax

   `as100r1/etc/quagga/bgpd.conf`

   ```
   router bgp 100
   network 100.1.0.0/16
   neighbor 11.0.0.2 remote-as 20
   neighbor 11.0.0.2 description Router as20r2 (primary)
   neighbor 11.0.0.2 prefix-list defaultIn in
   neighbor 11.0.0.2 prefix-list mineOutOnly out
   !
   ip prefix-list defaultIn seq 5 permit 0.0.0.0/0
   ip prefix-list mineOutOnly seq 5 permit 100.1.0.0/16
   ```
1. Define nodes
   `mkdir as20r1 as20r2 as200r1 as100r1`

2. Define topology

3. Populate configuration files using native syntax

4. Tell nodes to self configure

   `/sbin/ifconfig eth0 11.0.0.1 netmask 255.255.255.252 up`
   `/sbin/ifconfig eth1 11.0.0.5 netmask 255.255.255.252 up`
   `/sbin/ifconfig eth2 100.1.0.1 netmask 255.255.0.0 up`
   `/etc/init.d/quagga start`
Setting up a Lab

- as100r1
  - etc
    - zebra
      - bgpd.conf
      - daemons
  - as100r1.startup

- as200r1
  - etc
    - zebra
      - bgpd.conf
      - daemons
  - as200r1.startup

- as20r1
  - etc
    - zebra
      - bgpd.conf
      - daemons
  - as20r1.startup

- as20r2
  - etc
    - zebra
      - bgpd.conf
      - daemons
  - as20r2.startup
  - lab.conf

- Typical size: <200KB
- Email/Web friendly
Ready to Use Labs

- **Basic topics**
  - Routing with static routes and RIP
  - ARP
- **Application level**
  - DNS
  - Email
- **Advanced**
  - Bridging
  - STP
- **Interdomain Routing**
  - Prefix filtering
  - Stub & Multihomed AS
  - Transit AS
Applications

Prospective | Actual
### Applications

<table>
<thead>
<tr>
<th>Research</th>
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</tr>
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</table>
|          | • Routing instabilities  
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<td><strong>Teaching</strong></td>
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<tr>
<td>Basic/Advanced networking courses</td>
<td>University courses/exams</td>
</tr>
</tbody>
</table>
Other Network Emulators

- UMLMON
- VNUML
- Einar
- IMUNES
- ModelNet
- PlanetLab/VINI
- Emulab

Easy Emulation of Complex Networks on Inexpensive Hardware
Other Network Emulators

- **UMLMON**
  - User-Mode Linux
  - No kernel/filesystem image
  - System wide configuration
  - Targeted to sys admins

- **VNUMUL**
- **IMUNES**
- **Emulab**
- **PlanetLab/VINI**

Emulation of Complex Networks on Inexpensive Hardware
Other Network Emulators

- Einar
  - Live CD only
  - Xen based

- ModelNet

- PlanetLab/VINI

- Emulab

- VNUML

- UMLMON

- IMUNES

- Other Network Emulators

- Easy Emulation of...
Other Network Emulators

- Emulab
- ModelNet
- UMLMON
- Einar
- VNUML
- PlanetLab/VINI
- IMUNES
  - Live CD only
  - FreeBSD kernel

University of Zagreb

Other Network Emulators

- UMLMON
- VNUML
- Einar
- ModelNet
- PlanetLab/VINI
- Emulab

Easy Emulation of on

- Live CD only
- FreeBSD kernel
Other Network Emulators

- Einar
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Easy Emulation of Complex Networks on Inexpensive Hardware
Emulab

ModelNet

IMUNES

Einar

UMLMON

PlanetLab/VINI

Other Network Emulators

Easy Emulation of Complex Networks on Inexpensive Hardware

Communities started around 2002

Other Network Emulators

- Emulab
- ModelNet
- IMUNES
- Einar
- UMLMON
- VNUML

Other Network Emulators

- Large scale
- Server clusters
- Require affiliation & approval

Planet Emulab of Complex Networks on
Other Network Emulators

- Emulab
- VNUMEL
- IMUNES
- PlanetLab/VINI
- Einar
- UMLMON
- Other Network Emulators

Easy Emulation of Complex Networks on Inexpensive Hardware
Universidad Politécnica de Madrid

Other Network Emulators

- Emulab
- ModelNet
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- Other Network Emulators

VNUML

- User-Mode Linux
- XML
- Conceived to run as root

Easy Emulation of Complex Networks on Inexpensive Hardware
Scalability

Pentium 4 3.2GHz, 2GB RAM (~350 €)

Startup time

Current entry price: >400 €

VNUML

Netkit
Scalability

Pentium 4 3.2GHz, 2GB RAM (~350 €)

CPU load during 1GB HTTP transfer

1st setting
Inexpensive Hardware

Scalability

Pentium 4 3.2GHz, 2GB RAM (~350 €)

CPU load during 1GB HTTP transfer

2nd setting
Inexpensive Hardware

Scalability

Pentium 4 3.2GHz, 2GB RAM (~350 €)

CPU load during 1GB HTTP transfer

3rd setting
Scalability

Pentium 4 3.2GHz, 2GB RAM (~350 €)

CPU load during 1GB HTTP transfer

- VNUML
- Netkit
- Remote

Time (s)

%CPU

x1
Scalability

Pentium 4 3.2GHz, 2GB RAM (~350 €)

CPU load during 1GB HTTP transfer

- Load average (1 min)
- Time (s)

Graph showing scalability with different load average curves for VNUML, Netkit, and Remote.
Scalability

Pentium 4 3.2GHz, 2GB RAM (~350 €)

CPU load during 1GB HTTP transfer

VNUML
Netkit

Time (s)

%CPU

0 100 200 300 400 500 600 700 800

0 10 20 30 40 50 60 70 80 90

x5
Scalability

Pentium 4 3.2GHz, 2GB RAM (~350 €)

CPU load during 1GB HTTP transfer

Time (s)

Load average (1 min)

VNUML
Netkit

x5
So What?

▲ Take home
- Lightweight
- Easy
- Turn key (labs)
- Applications
- Good scalability

▲ What next?
- UI improvements (e.g., test procedure)
- More labs (e.g., ISP topologies)
- Better scalability by distribution (VDE?)
Where to Go Next

http://www.netkit.org/

- Releases & Documentation
  - Live CD
- Ready to use Labs
- Mailing list (138 subscribers) & FAQ
- Publications

Thanks to: You, Giuseppe Di Battista, Maurizio Patrignani, Stefano Pettini, ...