

# ns-2: Overview and Examples

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Lecture № 11

# Outline

- 1 A bit of history
- 2 ns-2
- 3 Installation of Cygwin
- 4 Installation of ns-2
- 5 ns-2 and Ubuntu
- 6 Simulation workflow
- 7 Example
- 8 Bibliography

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- **Network Simulator (ns)** – a fork of the **REAL** simulator
- **ns-1** – network simulator v1
  - Project started: ~ 1989
  - Languages: C++ and Tcl (Tool command language)
  - Project status: closed
- **ns-2/NS2** – network simulator v2
  - Project started: ~ 1996
  - Languages: C++ and OTcl (Object Tcl)
  - Project status: **closed**
- **ns-3** – network simulator v3
  - Project started : ~ 2006
  - Languages: C++ and Python
  - Project status: active

## A Bit of History (cont'd)

- ns-2 was developed in the frame of the **Virtual InterNetwork Testbed (VINT)** project supported by:
  - Defense Advanced Research Projects Agency (DARPA)
  - National Science Foundation (NSF)
  - University of Southern California / Information Sciences Institute (USC/ISI)
  - Xerox Palo Alto Research Center (Xerox PARC)
  - etc.
- Application fields:
  - Research and development (R&D)
  - Education
- Software:
  - Open source
  - Freeware

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- Official site:
  - <http://www.isi.edu/nsnam/ns/>
  - [http://nsnam.isi.edu/nsnam/index.php/Main\\_Page](http://nsnam.isi.edu/nsnam/index.php/Main_Page)
- Last version:
  - **ns-allinone-2.35.tar.gz**, 2011, ~ 60 MB
  - <http://sourceforge.net/projects/nsnam/files/allinone/ns-allinone-2.35/>
- System requirements:
  - C++ compiler
  - UNIX (FreeBSD, Linux, SunOS, Solaris)
  - Windows with Cygwin

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# Installation of Cygwin

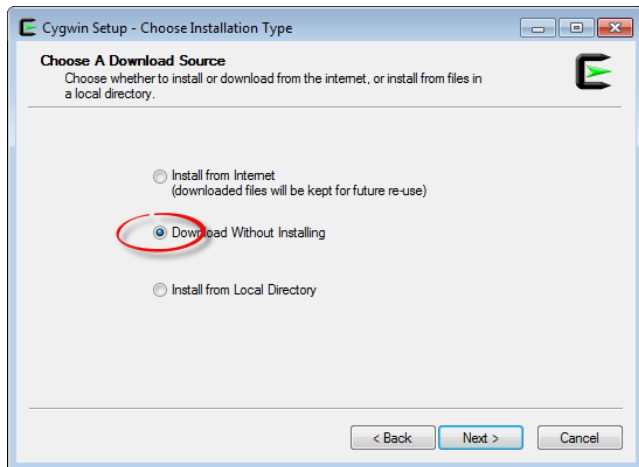
- **Cygwin** – a large collection of GNU and open source tools which provide functionality similar to a Linux distribution on Windows
  - <http://www.cygwin.com>
- Recent release:
  - **2.10.0**
  - setup-x86.exe (for 32-bit Windows) or setup-x86\_64.exe (for 64-bit Windows)
  - <http://www.cygwin.com/install.html>

# Installation of Cygwin (cont'd)

- 2 ways to install Cygwin:
  - Clean install from scratch
  - Update a previously installed version
- Recommended installation order:
  - Download **setup.exe** (~ 1 MB)
  - Run **setup.exe** and download all packages (~ 6 GB)
  - Re-run **setup.exe** and install Cygwin

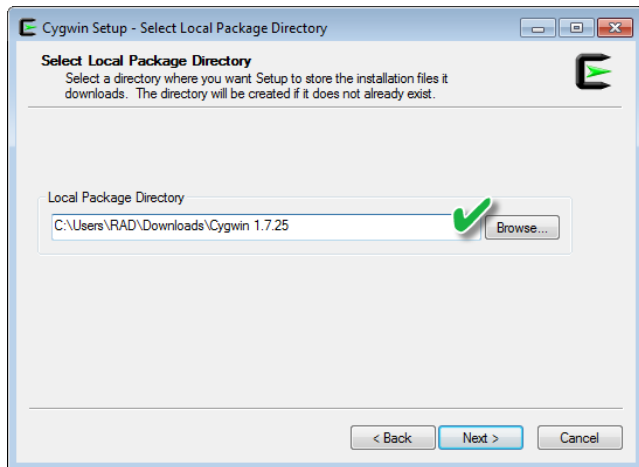
# Installation of Cygwin (cont'd)

- Download without installing



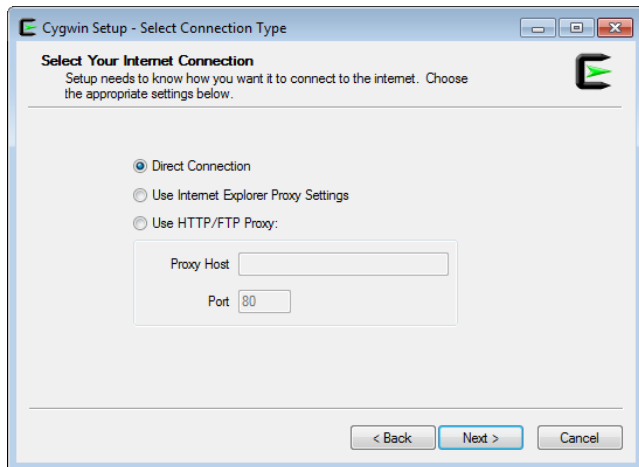
# Installation of Cygwin (cont'd)

- Select a local directory to store installation files



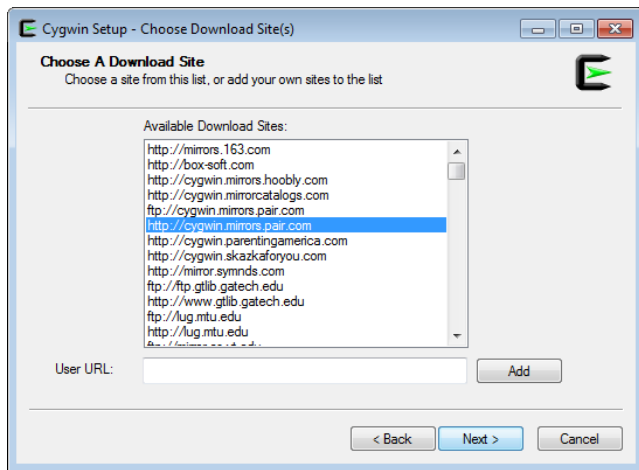
# Installation of Cygwin (cont'd)

- Select your Internet connection



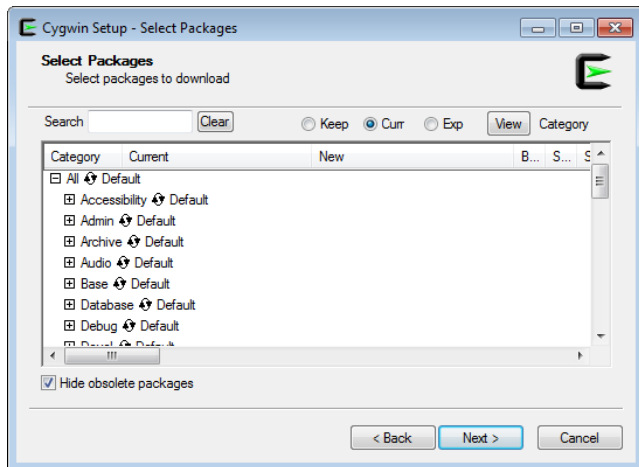
# Installation of Cygwin (cont'd)

- Select a server



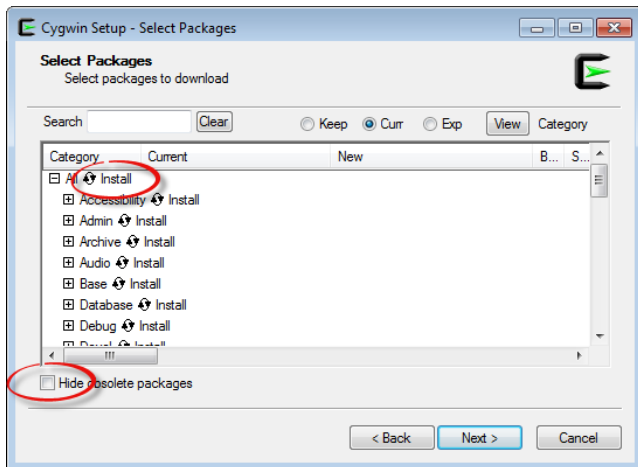
# Installation of Cygwin (cont'd)

- Select packages



# Installation of Cygwin (cont'd)

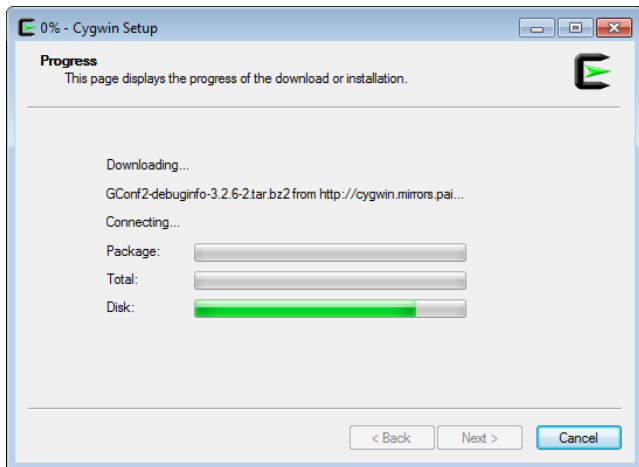
- Select all packages





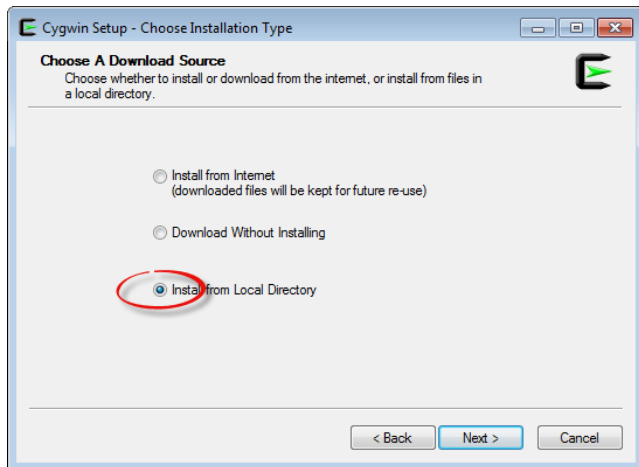
# Installation of Cygwin (cont'd)

- Downloading



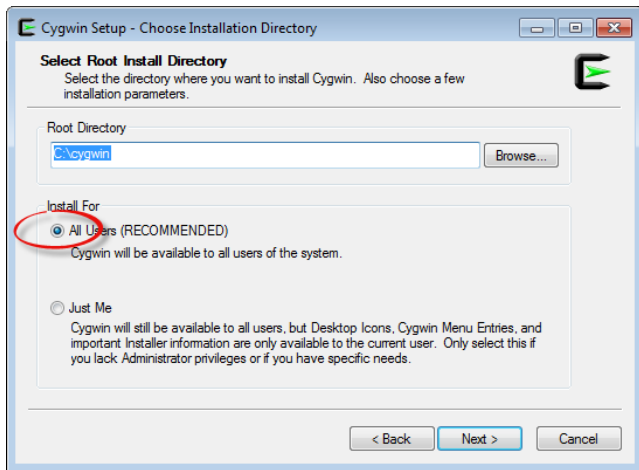
# Installation of Cygwin (cont'd)

- Install from the local directory



# Installation of Cygwin (cont'd)

- Select the installation directory
  - Size of **c:/cygwin** ~ 14 GB

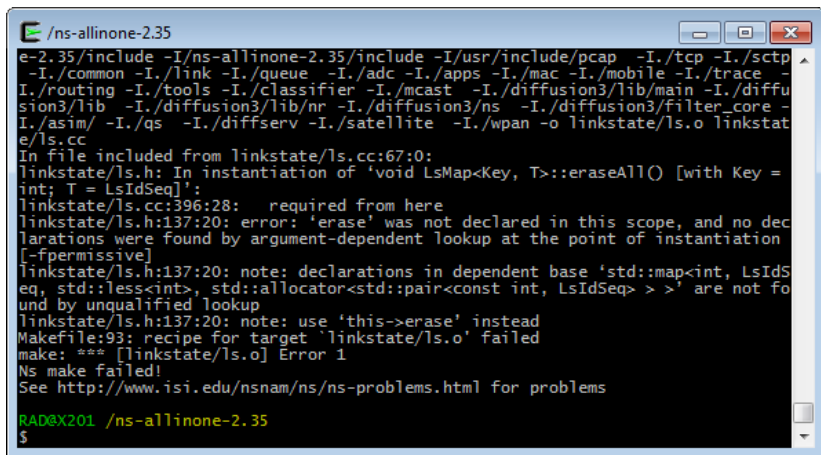


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# Installation of ns-2

- Ns make failed...



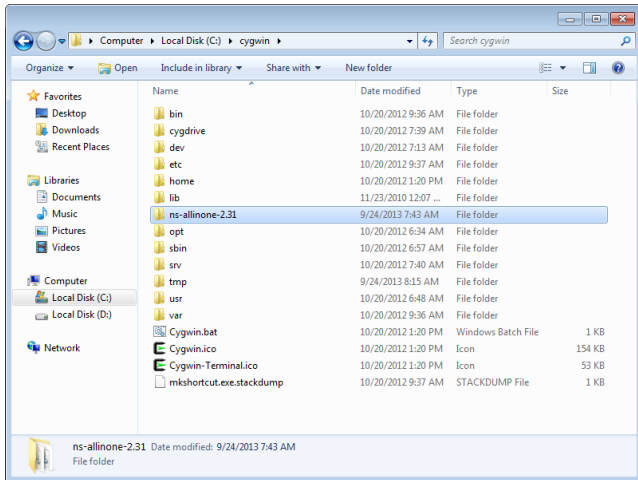
```
/ns-allinone-2.35
e-2.35/include -I/ns-allinone-2.35/include -I/usr/include/pcap -I./tcp -I./sctp
-I./common -I./link -I./queue -I./adc -I./apps -I./mac -I./mobile -I./trace -
I./routing -I./tools -I./classifier -I./mcast -I./diffusion3/lib/main -I./diffu
sion3/lib -I./diffusion3/lib/nr -I./diffusion3/ns -I./diffusion3/filter_core -
I./asim/ -I./qs -I./diffserv -I./satellite -I./wpan -o linkstate/ls.o linkstat
e/ls.cc
In file included from linkstate/ls.cc:67:0:
linkstate/ls.h: In instantiation of 'void LsMap<Key, T>::eraseAll() [with Key =
int; T = LsIdSeq]':
linkstate/ls.cc:396:28:   required from here
linkstate/ls.h:137:20: error: 'erase' was not declared in this scope, and no dec
larations were found by argument-dependent lookup at the point of instantiation
[-fpermissive]
linkstate/ls.h:137:20: note: declarations in dependent base 'std::map<int, LsIdS
eq, std::less<int>, std::allocator<std::pair<const int, LsIdSeq> > >' are not fo
und by unqualified lookup
linkstate/ls.h:137:20: note: use 'this->erase' instead
Makefile:93: recipe for target 'linkstate/ls.o' failed
make: *** [linkstate/ls.o] Error 1
Ns make failed!
See http://www.isi.edu/nsnam/ns/ns-problems.html for problems
RAD@X201 /ns-allinone-2.35
$
```

## Installation of ns-2 (cont'd)

- **Win7 Enterprise SP1 x64 + Cygwin 1.7.25 + ns-2.35 = fail** ☹
  - Cygwin mirrors usually include one version previous to the current one
  - Unfortunately, there is no complete archive of older packages
- **Win7 Enterprise SP1 x64 + Cygwin 1.7.16-1 + ns-2.31 = win** ☺
- **Win7 Enterprise SP1 x64 + Cygwin 2.10.0 + ns-2.35 = ???**

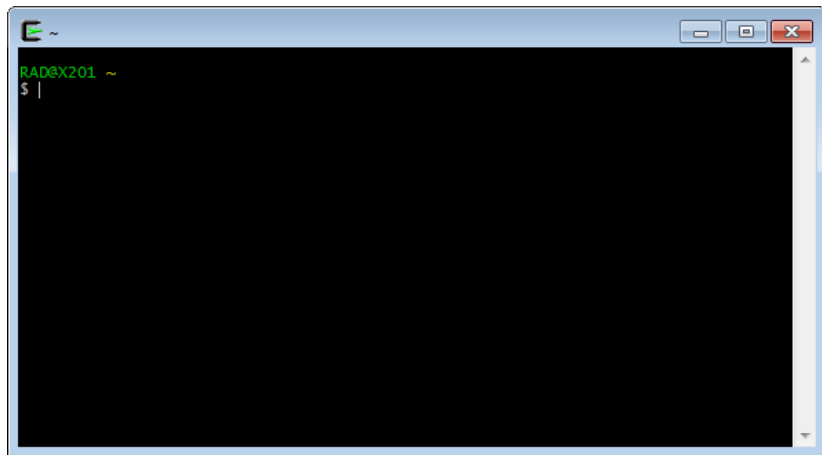
# Installation of ns-2 (cont'd)

- Unpack **ns-allinone-2.31.tar.gz** to **c:/cygwin**
  - <http://sourceforge.net/projects/nsnam/files/allinone/ns-allinone-2.31/>



# Installation of ns-2 (cont'd)

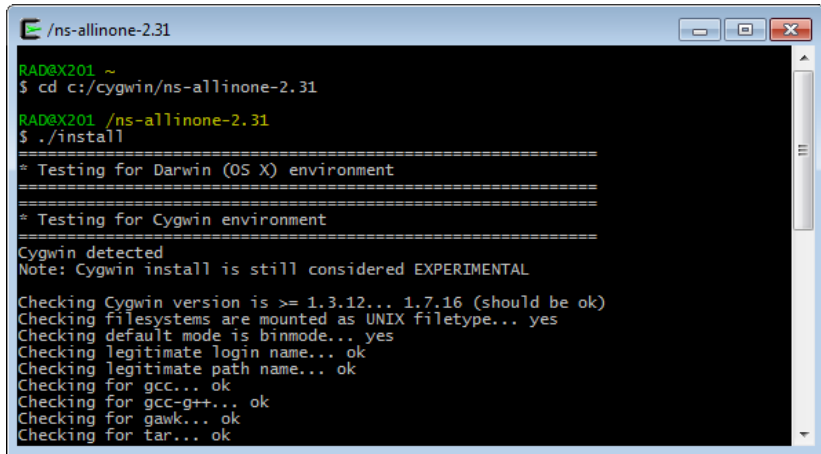
- Run Cygwin Terminal





# Installation of ns-2 (cont'd)

- Go to `c:/cygwin/ns-allinone-2.31` and type `./install`



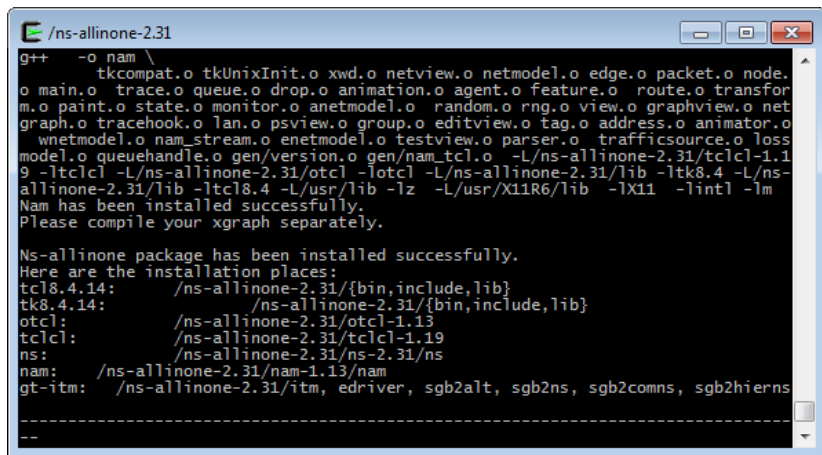
```

/ns-allinone-2.31
RAD@X201 ~
$ cd c:/cygwin/ns-allinone-2.31
RAD@X201 /ns-allinone-2.31
$ ./install
=====
* Testing for Darwin (OS X) environment
=====
* Testing for Cygwin environment
=====
Cygwin detected
Note: Cygwin install is still considered EXPERIMENTAL

Checking Cygwin version is >= 1.3.12... 1.7.16 (should be ok)
Checking filesystems are mounted as UNIX filetype... yes
Checking default mode is binmode... yes
Checking legitimate login name... ok
Checking legitimate path name... ok
Checking for gcc... ok
Checking for gcc-g++... ok
Checking for gawk... ok
Checking for tar... ok
```

# Installation of ns-2 (cont'd)

- Done!



```
/ns-allinone-2.31
g++ -o nam \
tkcompat.o tkUnixInit.o xwd.o netview.o netmodel.o edge.o packet.o node.
.o main.o trace.o queue.o drop.o animation.o agent.o feature.o route.o transfor
m.o paint.o state.o monitor.o anetmodel.o random.o rng.o view.o graphview.o net
graph.o tracehook.o lan.o psview.o group.o editview.o tag.o address.o animator.o
wnetmodel.o nam_stream.o enetmodel.o testview.o parser.o trafficsource.o loss
model.o queuehandle.o gen/version.o gen/nam_tcl.o -L/ns-allinone-2.31/tclcl-1.1
9 -ltclcl -L/ns-allinone-2.31/otcl -lotcl -L/ns-allinone-2.31/lib -ltk8.4 -L/ns-
allinone-2.31/lib -ltcl8.4 -L/usr/lib -lz -L/usr/X11R6/lib -lX11 -lintl -lm
Nam has been installed successfully.
Please compile your xgraph separately.

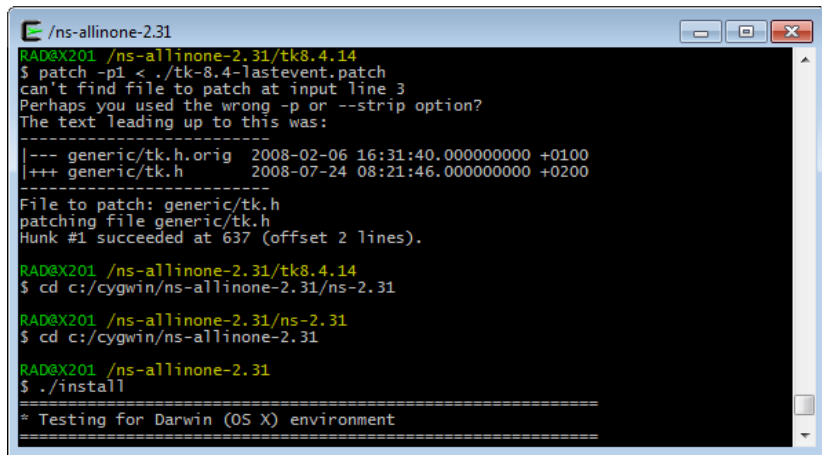
Ns-allinone package has been installed successfully.
Here are the installation places:
tk8.4.14:      /ns-allinone-2.31/{bin,include,lib}
tk8.4.14:      /ns-allinone-2.31/{bin,include,lib}
otcl:         /ns-allinone-2.31/otcl-1.13
tclcl:        /ns-allinone-2.31/tclcl-1.19
ns:           /ns-allinone-2.31/ns-2.31/ns
nam:          /ns-allinone-2.31/nam-1.13/nam
gt-itm:       /ns-allinone-2.31/itm, edriver, sgb2alt, sgb2ns, sgb2comns, sgb2hierns
-----
--
```

# Installation of ns-2 (cont'd)

- Patch **tk.h** to make **nam** work correctly:
  - Download **tk-8.4-lastevent.patch** from [http://bugs.gentoo.org/show\\_bug.cgi?id=225999](http://bugs.gentoo.org/show_bug.cgi?id=225999)
  - Save it to **c:/cygwin/ns-allinone-2.31/tk8.4.14**
  - Go to **c:/cygwin/ns-allinone-2.31/tk8.4.14** and type **patch -p1 < ./tk-8.4-lastevent.patch**
  - In case of problems, replace **-p1** by **-p0**
  - Specify which files to patch, i.e. **generic/tk.h**
  - Go to **c:/cygwin/ns-allinone-2.31** and re-run **./install**

# Installation of ns-2 (cont'd)

- Apply the patch and re-run installation of ns-2



```
/ns-allinone-2.31
RAD@X201 /ns-allinone-2.31/tk8.4.14
$ patch -p1 < ./tk-8.4-lastevent.patch
can't find file to patch at input line 3
Perhaps you used the wrong -p or --strip option?
The text leading up to this was:
-----
|--- generic/tk.h.orig      2008-02-06 16:31:40.000000000 +0100
|+++ generic/tk.h          2008-07-24 08:21:46.000000000 +0200
-----
File to patch: generic/tk.h
patching file generic/tk.h
Hunk #1 succeeded at 637 (offset 2 lines).

RAD@X201 /ns-allinone-2.31/tk8.4.14
$ cd c:/cygwin/ns-allinone-2.31/ns-2.31

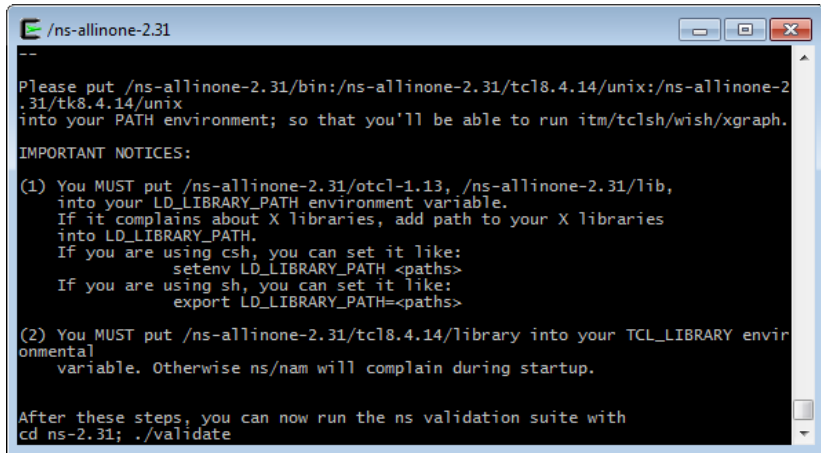
RAD@X201 /ns-allinone-2.31/ns-2.31
$ cd c:/cygwin/ns-allinone-2.31

RAD@X201 /ns-allinone-2.31
$ ./install

=====
* Testing for Darwin (OS X) environment
=====
```

# Installation of ns-2 (cont'd)

- Once the process is finished, add the environment variables



```
/ns-allinone-2.31
--
Please put /ns-allinone-2.31/bin:/ns-allinone-2.31/tcl8.4.14/unix:/ns-allinone-2.31/tk8.4.14/unix
into your PATH environment; so that you'll be able to run itm/tclsh/wish/xgraph.

IMPORTANT NOTICES:

(1) You MUST put /ns-allinone-2.31/otcl-1.13, /ns-allinone-2.31/lib,
into your LD_LIBRARY_PATH environment variable.
If it complains about X libraries, add path to your X libraries
into LD_LIBRARY_PATH.
If you are using csh, you can set it like:
    setenv LD_LIBRARY_PATH <paths>
If you are using sh, you can set it like:
    export LD_LIBRARY_PATH=<paths>

(2) You MUST put /ns-allinone-2.31/tcl8.4.14/library into your TCL_LIBRARY environmental
variable. Otherwise ns/nam will complain during startup.

After these steps, you can now run the ns validation suite with
cd ns-2.31; ./validate
```

# Installation of ns-2 (cont'd)

- Environment variables:

- ① **Path**

- /ns-allinone-2.31/bin;/ns-allinone-2.31/tcl8.4.14/unix;  
/ns-allinone-2.31/tk8.4.14/unix

- ② **LD\_LIBRARY\_PATH**

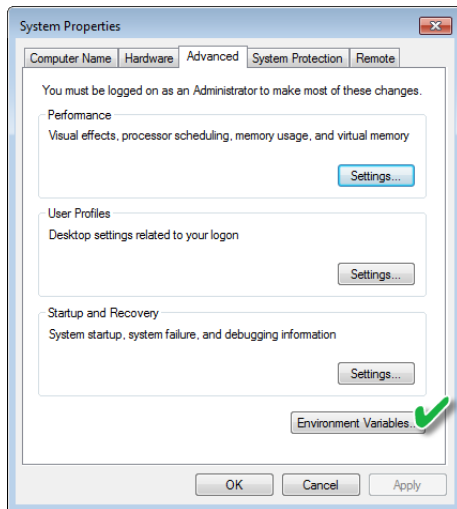
- /ns-allinone-2.31/otcl-1.13;/ns-allinone-2.31/lib

- ③ **TCL\_LIBRARY**

- /ns-allinone-2.31/tcl8.4.14/library

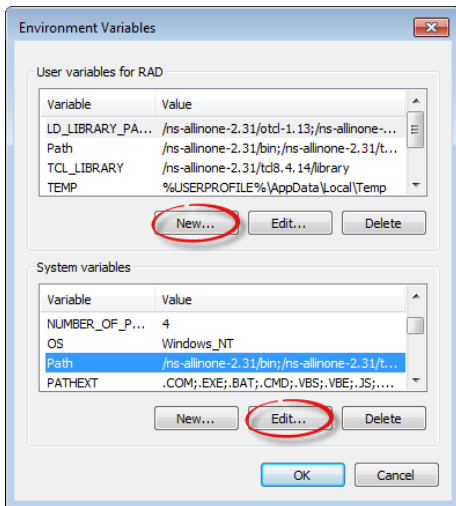
# Installation of ns-2 (cont'd)

- Environment variables in Windows 7



# Installation of ns-2 (cont'd)

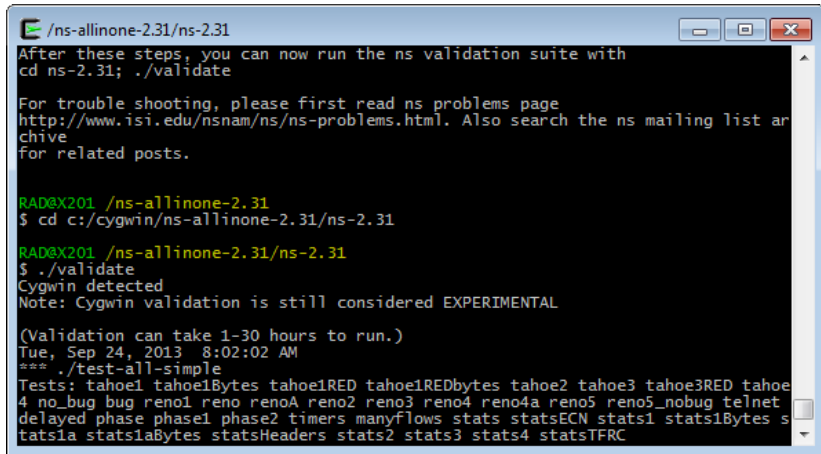
- Add/edit environment variables





# Installation of ns-2 (cont'd)

- Go to `c:/cygwin/ns-allinone-2.31/ns-2.31` and type `./validate`



```
ns-allinone-2.31/ns-2.31
After these steps, you can now run the ns validation suite with
cd ns-2.31; ./validate

For trouble shooting, please first read ns problems page
http://www.isi.edu/nsnam/ns/ns-problems.html. Also search the ns mailing list archive
for related posts.

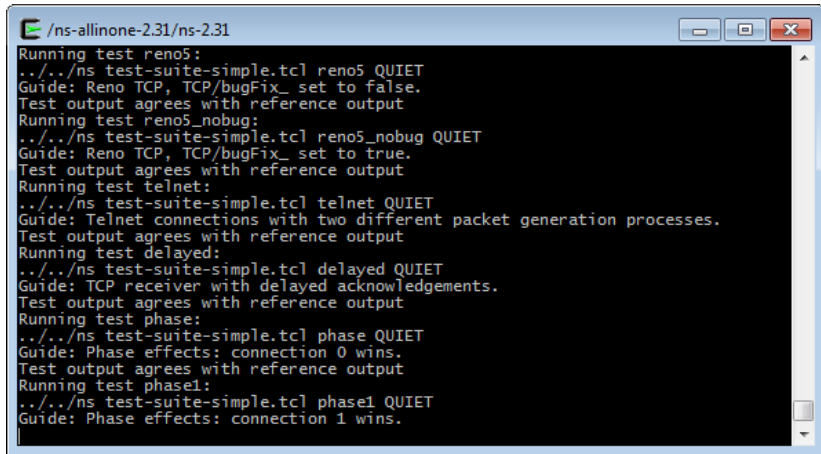
RAD@X201 /ns-allinone-2.31
$ cd c:/cygwin/ns-allinone-2.31/ns-2.31

RAD@X201 /ns-allinone-2.31/ns-2.31
$ ./validate
Cygwin detected
Note: Cygwin validation is still considered EXPERIMENTAL

(Validation can take 1-30 hours to run.)
Tue, Sep 24, 2013 8:02:02 AM
*** ./test-all-simple
Tests: tahoe1 tahoe1Bytes tahoe1RED tahoe1REDbytes tahoe2 tahoe3 tahoe3RED tahoe
4 no_bug bug reno1 renoA reno2 reno3 reno4 reno4a reno5 reno5_nobug telnet
delayed phase phase1 phase2 timers manyflows stats statsECN stats1 stats1Bytes s
tats1a stats1aBytes statsHeaders stats2 stats3 stats4 statsTFRC
```

# Installation of ns-2 (cont'd)

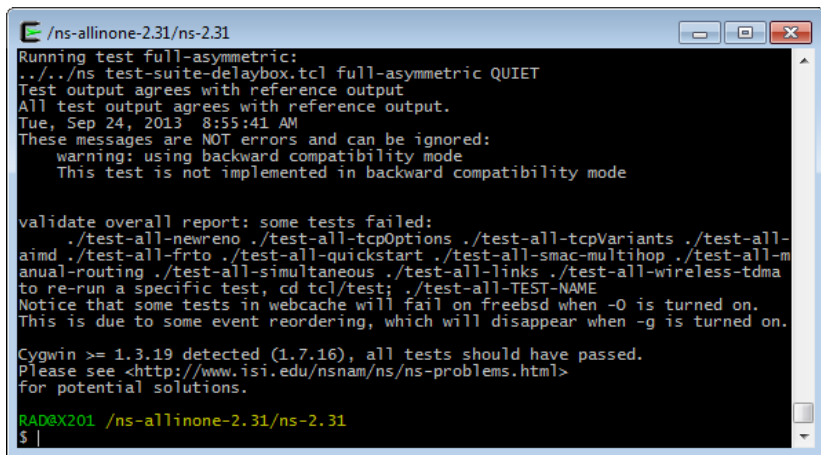
- Validating the installed ns-2 (takes a long time!)



```
/ns-allinone-2.31/ns-2.31
Running test reno5:
../ns test-suite-simple.tcl reno5 QUIET
Guide: Reno TCP, TCP/bugFix_ set to false.
Test output agrees with reference output
Running test reno5_nobug:
../ns test-suite-simple.tcl reno5_nobug QUIET
Guide: Reno TCP, TCP/bugFix_ set to true.
Test output agrees with reference output
Running test telnet:
../ns test-suite-simple.tcl telnet QUIET
Guide: Telnet connections with two different packet generation processes.
Test output agrees with reference output
Running test delayed:
../ns test-suite-simple.tcl delayed QUIET
Guide: TCP receiver with delayed acknowledgements.
Test output agrees with reference output
Running test phase:
../ns test-suite-simple.tcl phase QUIET
Guide: Phase effects: connection 0 wins.
Test output agrees with reference output
Running test phase1:
../ns test-suite-simple.tcl phase1 QUIET
Guide: Phase effects: connection 1 wins.
```

# Installation of ns-2 (cont'd)

- Done!



```
/ns-allinone-2.31/ns-2.31
Running test full-asymmetric:
../../ns test-suite-delaybox.tcl full-asymmetric QUIET
Test output agrees with reference output
All test output agrees with reference output.
Tue, Sep 24, 2013 8:55:41 AM
These messages are NOT errors and can be ignored:
warning: using backward compatibility mode
This test is not implemented in backward compatibility mode

validate overall report: some tests failed:
./test-all-newreno ./test-all-tcpOptions ./test-all-tcpVariants ./test-all-
aimd ./test-all-frto ./test-all-quickstart ./test-all-smac-multihop ./test-all-m
anual-routing ./test-all-simultaneous ./test-all-links ./test-all-wireless-tdma
to re-run a specific test, cd tcl/test; ./test-all-TEST-NAME
Notice that some tests in webcache will fail on freebsd when -O is turned on.
This is due to some event reordering, which will disappear when -g is turned on.

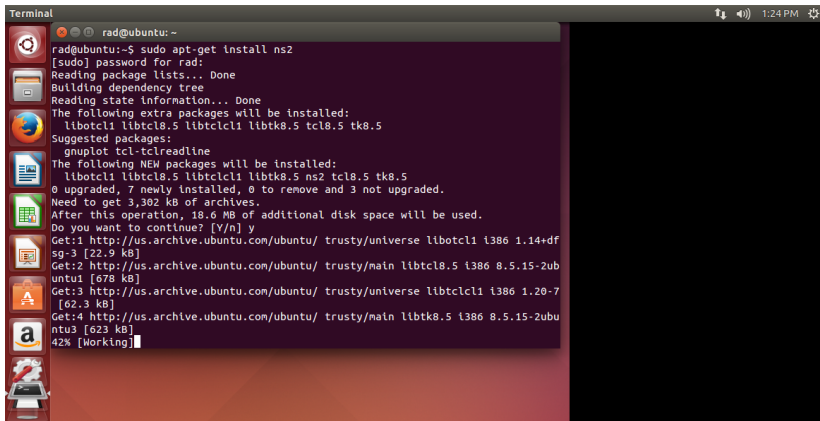
Cygwin >= 1.3.19 detected (1.7.16), all tests should have passed.
Please see <http://www.isi.edu/nsnam/ns/ns-problems.html>
for potential solutions.

RAD@X201 /ns-allinone-2.31/ns-2.31
$ |
```

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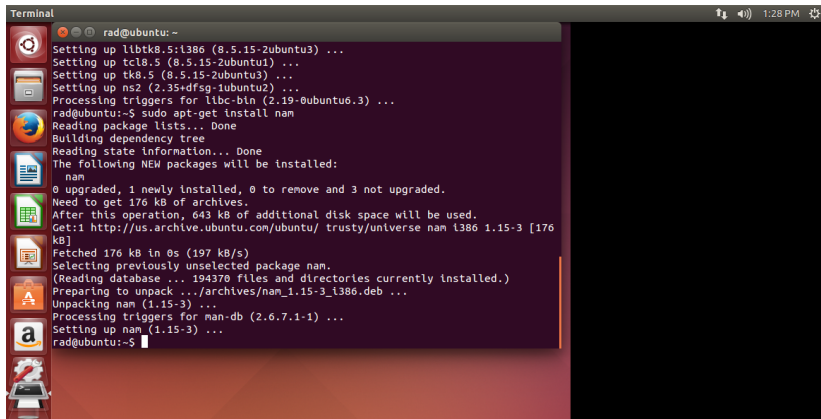
- Install ns-2: `sudo apt-get install ns2`
  - Run Terminal: `<Ctrl>+<Alt>+<T>`



```
rad@ubuntu:~$ sudo apt-get install ns2
[sudo] password for rad:
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following extra packages will be installed:
  libotcl1 libtcl8.5 libtclcl1 libtk8.5 tcl8.5 tk8.5
Suggested packages:
  gnuplot tcl-tclreadline
The following NEW packages will be installed:
  libotcl1 libtcl8.5 libtclcl1 libtk8.5 ns2 tcl8.5 tk8.5
0 upgraded, 7 newly installed, 0 to remove and 3 not upgraded.
Need to get 3,302 kB of archives.
After this operation, 18.6 MB of additional disk space will be used.
Do you want to continue? [Y/n] y
Get:1 http://us.archive.ubuntu.com/ubuntu/ trusty/universe libotcl1 i386 1.14+dfsg-3 [22.9 kB]
Get:2 http://us.archive.ubuntu.com/ubuntu/ trusty/main libtcl8.5 i386 8.5.15-2ubuntu1 [678 kB]
Get:3 http://us.archive.ubuntu.com/ubuntu/ trusty/universe libtclcl1 i386 1.20-7 [62.3 kB]
Get:4 http://us.archive.ubuntu.com/ubuntu/ trusty/main libtk8.5 i386 8.5.15-2ubuntu3 [623 kB]
42% [Working]
```

# ns-2 and Ubuntu (cont'd)

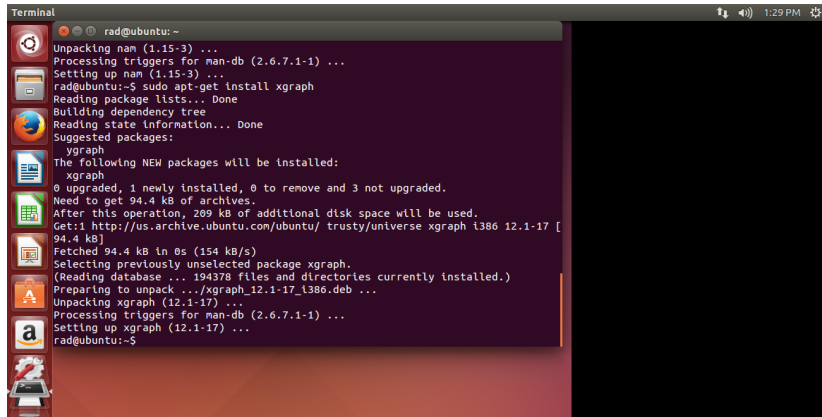
- Install nam: **sudo apt-get install nam**
  - See <http://askubuntu.com/questions/467901/segmentation-fault-core-dumped-in-ns2-ubuntu-14-04> ☹
  - Or use **ubuntu-12.04.5** instead of ubuntu-14.04.1



```
Terminal
rad@ubuntu: ~
Setting up libtk8.5:i386 (8.5.15-2ubuntu3) ...
Setting up tcl8.5 (8.5.15-2ubuntu1) ...
Setting up tk8.5 (8.5.15-2ubuntu3) ...
Setting up ns2 (2.35+dfsg-1ubuntu2) ...
Processing triggers for libc-bin (2.19-0ubuntu6.3) ...
rad@ubuntu:~$ sudo apt-get install nam
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following NEW packages will be installed:
  nam
0 upgraded, 1 newly installed, 0 to remove and 3 not upgraded.
Need to get 176 kB of archives.
After this operation, 643 kB of additional disk space will be used.
Get:1 http://us.archive.ubuntu.com/ubuntu/trusty/universe nam i386 1.15-3 [176
kB]
Fetched 176 kB in 0s (197 kB/s)
Selecting previously unselected package nam.
(Reading database ... 194370 files and directories currently installed.)
Preparing to unpack .../archives/nam_1.15-3_i386.deb ...
Unpacking nam (1.15-3) ...
Processing triggers for man-db (2.6.7.1-1) ...
Setting up nam (1.15-3) ...
rad@ubuntu:~$
```

# ns-2 and Ubuntu (cont'd)

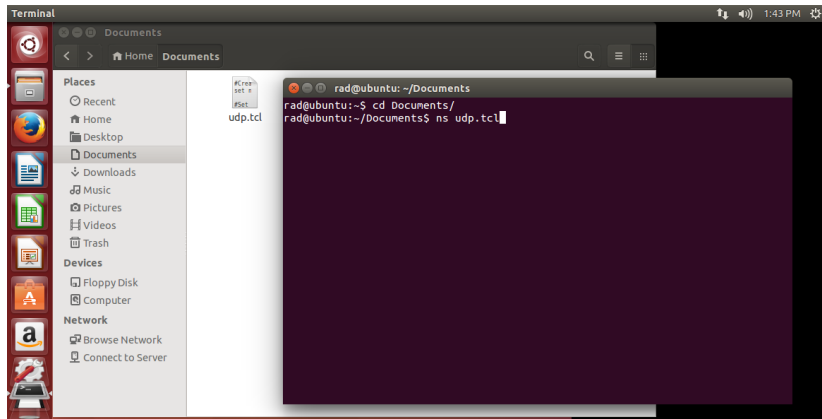
- Install xgraph: `sudo apt-get install xgraph`

A terminal window titled "Terminal" showing the installation of the xgraph package on Ubuntu. The prompt is "rad@ubuntu: ~". The output shows the installation of nam (1.15-3) and man-db (2.6.7.1-1) first. Then, the command "rad@ubuntu:~\$ sudo apt-get install xgraph" is entered. The terminal shows the process of reading package lists, building a dependency tree, and reading state information. It lists "ygraph" as a suggested package and shows that xgraph is the new package to be installed. It indicates that 94.4 kB of archives are needed and that 209 kB of additional disk space will be used. The source is identified as "http://us.archive.ubuntu.com/ubuntu/trusty/universe/xgraph\_1386\_12.1-17\_94.4\_kB". The package is fetched at 154 kB/s. It shows that xgraph (12.1-17) is selected and prepared for unpacking. The installation process for xgraph (12.1-17) is shown, including unpacking, processing triggers for man-db (2.6.7.1-1), and setting up xgraph. The prompt returns to "rad@ubuntu:~\$".

```
Terminal
rad@ubuntu: ~
Unpacking nam (1.15-3) ...
Processing triggers for man-db (2.6.7.1-1) ...
Setting up nam (1.15-3) ...
rad@ubuntu:~$ sudo apt-get install xgraph
Reading package lists... Done
Building dependency tree
Reading state information... Done
Suggested packages:
  ygraph
The following NEW packages will be installed:
  xgraph
0 upgraded, 1 newly installed, 0 to remove and 3 not upgraded.
Need to get 94.4 kB of archives.
After this operation, 209 kB of additional disk space will be used.
Get:1 http://us.archive.ubuntu.com/ubuntu/trusty/universe xgraph 1386 12.1-17 [
94.4 kB]
Fetched 94.4 kB in 0s (154 kB/s)
Selecting previously unselected package xgraph.
(Reading database ... 194378 files and directories currently installed.)
Preparing to unpack ../xgraph_12.1-17_1386.deb ...
Unpacking xgraph (12.1-17) ...
Processing triggers for man-db (2.6.7.1-1) ...
Setting up xgraph (12.1-17) ...
rad@ubuntu:~$
```

# ns-2 and Ubuntu (cont'd)

- Run simulation: `ns <file name>.tcl`



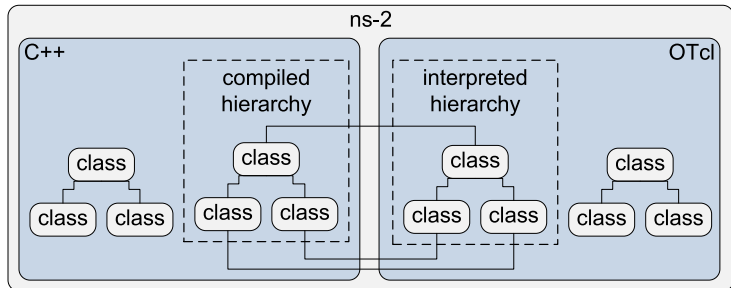


# Outline

- 1 A bit of history
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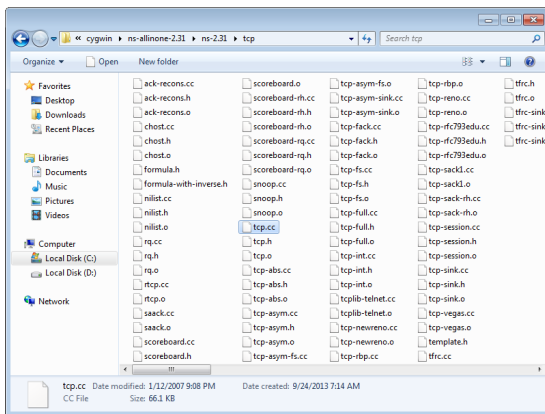
# Simulation Workflow

- ns-2 architecture:
  - C++ defines the internal mechanism of the simulation objects
  - OTcl sets up simulation by assembling and configuring the objects as well as scheduling discrete events
- ns-2 in Cygwin:
  - Run **XWin Server**
  - Go to the directory with your script **<file name>.tcl**
  - In **XWin Server** window type **ns <file name>.tcl**



# Simulation Workflow (cont'd)

- ns-2 features:
  - A wide range of communications protocols and algorithms
  - **xgraph** – statistical graphing tool
  - **nam** – visualization tool

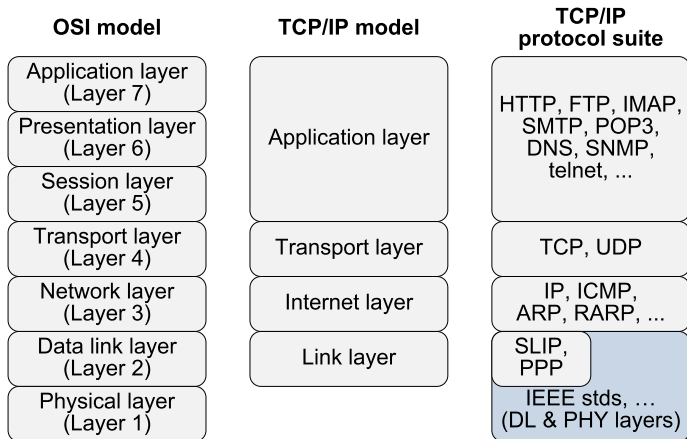


- **ns-2 simulation workflow**

- 1 Using a text editor, create a baseline script
  - Define the network topology (nodes, links, queues, etc.)
  - Attach transport layer protocols ('Agents') and applications ('Applications') to the end nodes
  - Create traffic
  - Choose statistics to be collected
  - Run the simulation
  - View the results
- 2 Duplicate the script
  - Make changes
  - Re-run the simulation
  - Compare the obtained results
- 3 Repeat №2 if needed

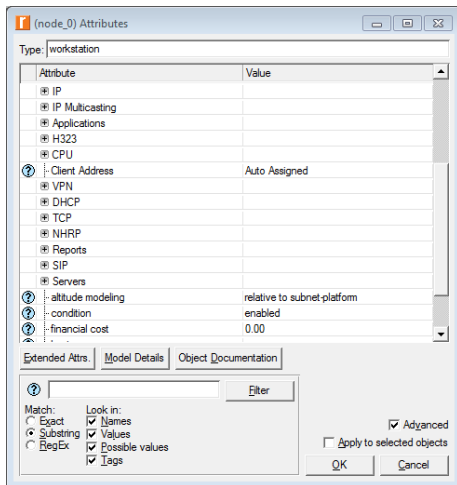
# Simulation Workflow (cont'd)

- TCP/IP protocol suite



# Simulation Workflow (cont'd)

- Compare with nodes in **OPNET/Riverbed Modeler**
  - **set node\_0 [Sns node]**



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# Example

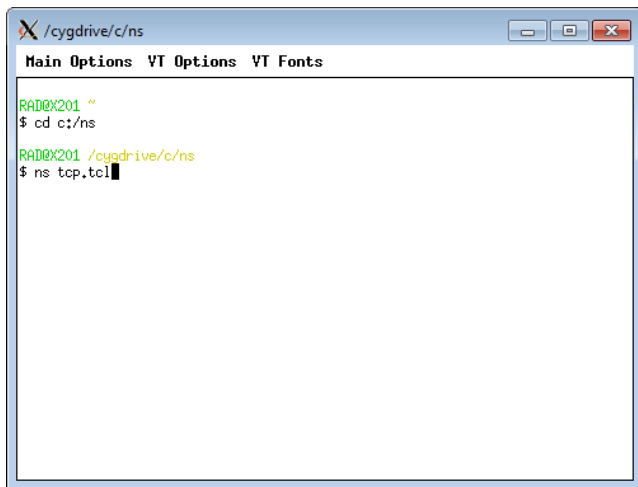
- UDP vs. TCP

UDP	TCP
Message-oriented	Byte-stream-oriented
Connectionless	Connection-oriented
Stateless	Stateful
Unreliable	Reliable
Unicast and multicast	Unicast only
Used by a few user applications (VoIP, multimedia streaming, etc.)	Used by many user applications (WWW, email, FTP, Telnet, etc.)
Used by many network services (RIP, SNMP, DNS, etc.)	Used by a few network services (e.g., DNS zone transfers)



## Example (cont'd)

- Run `c:/ns/tcp.tcl` in XWin Server

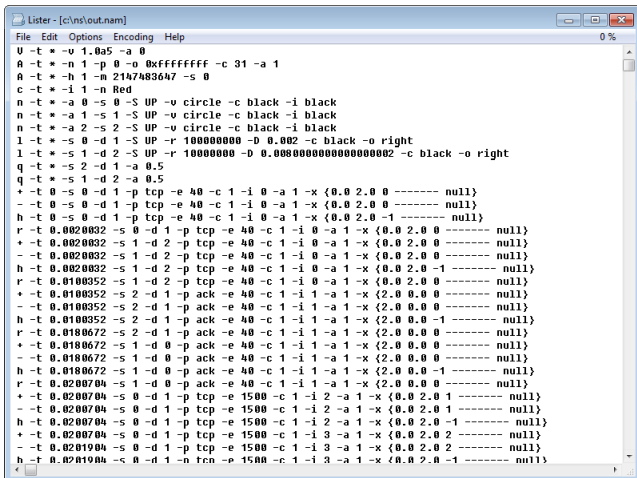


The screenshot shows a terminal window titled `/cygdrive/c/ns`. The window has a menu bar with `Main Options`, `VT Options`, and `VT Fonts`. The terminal content is as follows:

```
RAD@X201 ~  
$ cd c:/ns  
  
RAD@X201 /cygdrive/c/ns  
$ ns tcp.tcl
```

# Example (cont'd)

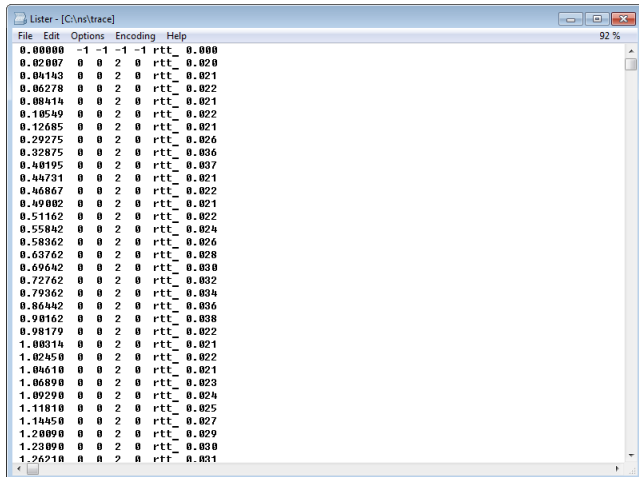
- View out.nam



```
Lister - [c:\ns\out.nam]
File Edit Options Encoding Help 0%
U -t * -v 1.0a5 -a 0
A -t * -n 1 -p 0 -o 0xffffffff -c 31 -a 1
A -t * -h 1 -m 2147483647 -s 0
c -t * -i 1 -n Red
n -t * -a 0 -s 0 -S UP -v circle -c black -i black
n -t * -a 1 -s 1 -S UP -v circle -c black -i black
n -t * -a 2 -s 2 -S UP -v circle -c black -i black
l -t * -s 0 -d 1 -S UP -r 10000000 -b 0.002 -c black -o right
l -t * -s 1 -d 2 -S UP -r 10000000 -b 0.008000000000000002 -c black -o right
q -t * -s 2 -d 1 -a 0.5
q -t * -s 1 -d 2 -a 0.5
+ -t 0 -s 0 -d 1 -p tcp -e 40 -c 1 -i 0 -a 1 -x {0.0 2.0 0} ----- null}
- -t 0 -s 0 -d 1 -p tcp -e 40 -c 1 -i 0 -a 1 -x {0.0 2.0 0} ----- null}
h -t 0 -s 0 -d 1 -p tcp -e 40 -c 1 -i 0 -a 1 -x {0.0 2.0 -1} ----- null}
r -t 0.0020032 -s 0 -d 1 -p tcp -e 40 -c 1 -i 0 -a 1 -x {0.0 2.0 0} ----- null}
+ -t 0.0020032 -s 1 -d 2 -p tcp -e 40 -c 1 -i 0 -a 1 -x {0.0 2.0 0} ----- null}
- -t 0.0020032 -s 1 -d 2 -p tcp -e 40 -c 1 -i 0 -a 1 -x {0.0 2.0 0} ----- null}
h -t 0.0020032 -s 1 -d 2 -p tcp -e 40 -c 1 -i 0 -a 1 -x {0.0 2.0 -1} ----- null}
r -t 0.0100352 -s 1 -d 2 -p tcp -e 40 -c 1 -i 0 -a 1 -x {0.0 2.0 0} ----- null}
+ -t 0.0100352 -s 2 -d 1 -p ack -e 40 -c 1 -i 1 -a 1 -x {2.0 0.0 0} ----- null}
- -t 0.0100352 -s 2 -d 1 -p ack -e 40 -c 1 -i 1 -a 1 -x {2.0 0.0 0} ----- null}
h -t 0.0100352 -s 2 -d 1 -p ack -e 40 -c 1 -i 1 -a 1 -x {2.0 0.0 -1} ----- null}
r -t 0.0180672 -s 2 -d 1 -p ack -e 40 -c 1 -i 1 -a 1 -x {2.0 0.0 0} ----- null}
+ -t 0.0180672 -s 1 -d 0 -p ack -e 40 -c 1 -i 1 -a 1 -x {2.0 0.0 0} ----- null}
- -t 0.0180672 -s 1 -d 0 -p ack -e 40 -c 1 -i 1 -a 1 -x {2.0 0.0 0} ----- null}
h -t 0.0180672 -s 1 -d 0 -p ack -e 40 -c 1 -i 1 -a 1 -x {2.0 0.0 -1} ----- null}
r -t 0.0200704 -s 1 -d 0 -p ack -e 40 -c 1 -i 1 -a 1 -x {2.0 0.0 0} ----- null}
+ -t 0.0200704 -s 0 -d 1 -p tcp -e 1500 -c 1 -i 2 -a 1 -x {0.0 2.0 1} ----- null}
- -t 0.0200704 -s 0 -d 1 -p tcp -e 1500 -c 1 -i 2 -a 1 -x {0.0 2.0 1} ----- null}
h -t 0.0200704 -s 0 -d 1 -p tcp -e 1500 -c 1 -i 2 -a 1 -x {0.0 2.0 -1} ----- null}
+ -t 0.0200704 -s 0 -d 1 -p tcp -e 1500 -c 1 -i 3 -a 1 -x {0.0 2.0 2} ----- null}
- -t 0.0201904 -s 0 -d 1 -p tcp -e 1500 -c 1 -i 3 -a 1 -x {0.0 2.0 2} ----- null}
h -t 0.0201904 -s 0 -d 1 -p tcp -e 1500 -c 1 -i 3 -a 1 -x {0.0 2.0 -1} ----- null}
```

# Example (cont'd)

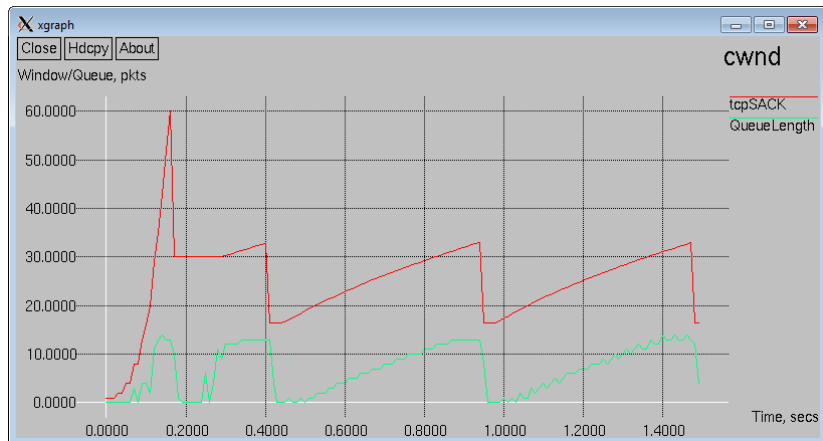
- View the results (RTT = Round-Trip Time)



```
Lister - [C:\ns\trace]
File Edit Options Encoding Help 92 %
0.00000 -1 -1 -1 -1 rtt_ 0.000
0.02007 0 0 2 0 rtt_ 0.020
0.04143 0 0 2 0 rtt_ 0.021
0.06278 0 0 2 0 rtt_ 0.022
0.08414 0 0 2 0 rtt_ 0.021
0.10549 0 0 2 0 rtt_ 0.022
0.12685 0 0 2 0 rtt_ 0.021
0.29275 0 0 2 0 rtt_ 0.026
0.32875 0 0 2 0 rtt_ 0.036
0.40195 0 0 2 0 rtt_ 0.037
0.44731 0 0 2 0 rtt_ 0.021
0.46867 0 0 2 0 rtt_ 0.022
0.49002 0 0 2 0 rtt_ 0.021
0.51162 0 0 2 0 rtt_ 0.022
0.55042 0 0 2 0 rtt_ 0.024
0.58362 0 0 2 0 rtt_ 0.026
0.63762 0 0 2 0 rtt_ 0.028
0.69642 0 0 2 0 rtt_ 0.030
0.72762 0 0 2 0 rtt_ 0.032
0.79362 0 0 2 0 rtt_ 0.034
0.86442 0 0 2 0 rtt_ 0.036
0.90162 0 0 2 0 rtt_ 0.038
0.98179 0 0 2 0 rtt_ 0.022
1.00314 0 0 2 0 rtt_ 0.021
1.02450 0 0 2 0 rtt_ 0.022
1.04610 0 0 2 0 rtt_ 0.021
1.06890 0 0 2 0 rtt_ 0.023
1.09290 0 0 2 0 rtt_ 0.024
1.11810 0 0 2 0 rtt_ 0.025
1.14450 0 0 2 0 rtt_ 0.027
1.20090 0 0 2 0 rtt_ 0.029
1.23090 0 0 2 0 rtt_ 0.030
1.26210 0 0 2 0 rtt_ 0.031
```

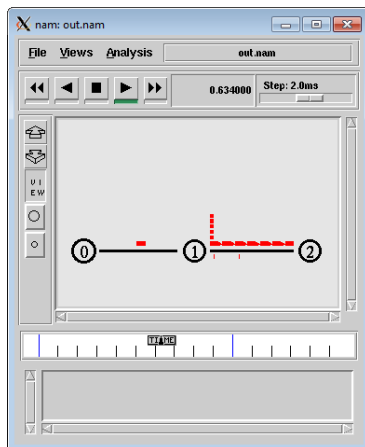
# Example (cont'd)

- View the results in **xgraph**



# Example (cont'd)

- View the network animation in **nam**



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# Bibliography

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