NS2 Tutorial

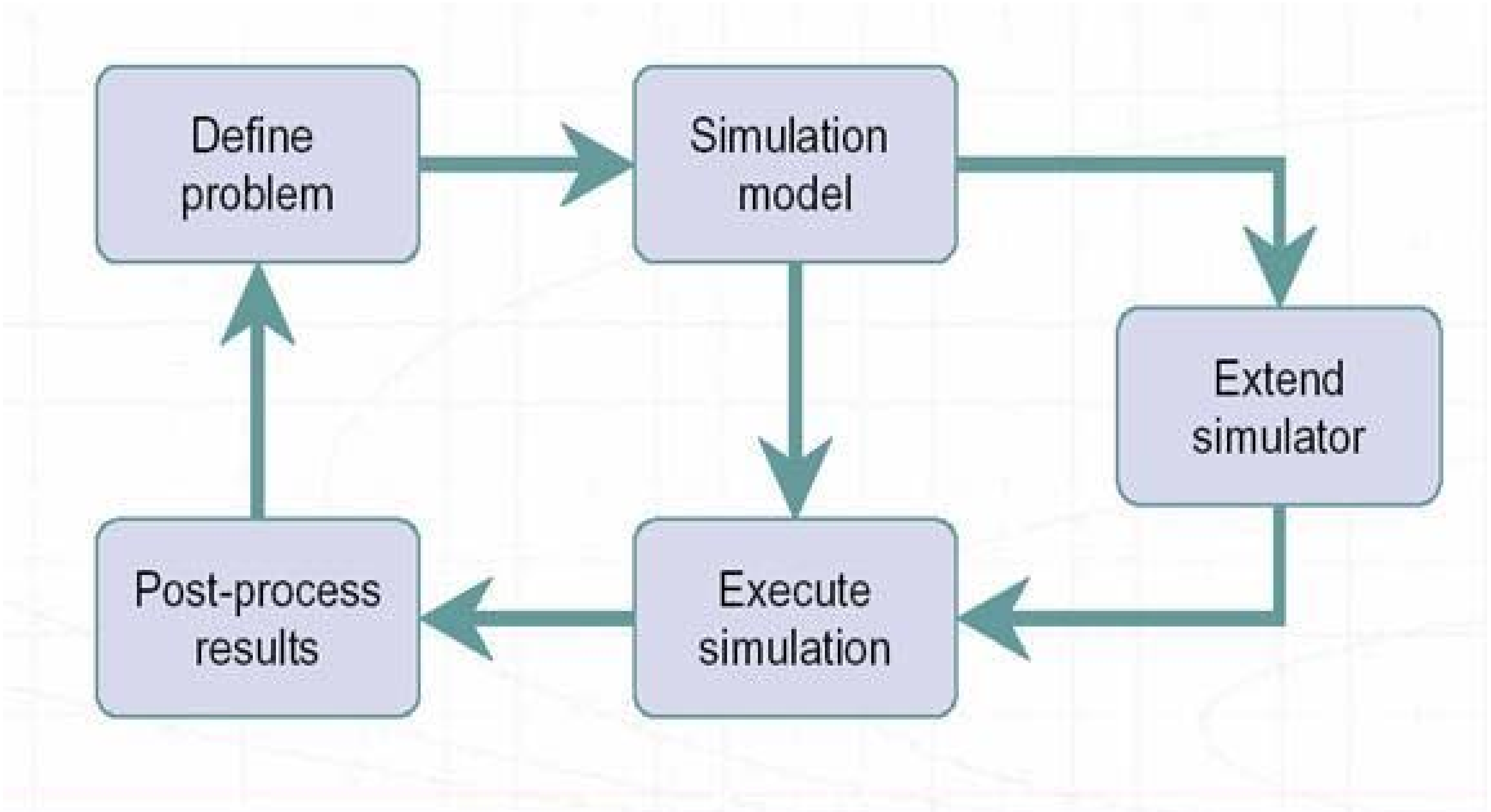
What is a simulation

- Simulation
  - Imitation of the operation of a facility or process
  - Facility being simulated is called a system
  - Assumptions/approximations, both logical and
  - mathematical, are made about how the system works
  - These assumptions form a *model* of the system
- Simulation allows you
  - To quickly & inexpensively acquire knowledge concerning a problem
  - That is usually gained through experience (that is often time consuming)

When to use simulations?

- Simulations can be used
  - To study complex systems i.e. systems where analytic solutions are infeasible
  - To compare design alternatives for a system that doesn't exist
  - To study the effect of alterations to an existing system
  - To reinforce/verify analytic solutions
- Simulations should not be used
  - If model assumptions are simple such that mathematical methods can be used to obtain exact answers (*analytical* solutions)

Simulation Flow



Types of Simulation

- Variety of types, but main are
  - Monte Carlo Simulations
  - Trace Driven Simulations
  - Discrete-event Simulations
    - A simulation using discrete-event (also called discrete state)
    - model of the system
    - Widely used for studying computer networks

Components of Discrete-Event Simulation

- Typical components:
  - 1. Event scheduler
  - 2. Simulation clock
  - 3. System state variables
  - 4. Event routines
  - 5. Input routines
  - 6. Report generator

What is ns-2?

- ns-2 stands for Network Simulator version 2.
- ns-2 is a discrete event simulator for networking research
- Work at packet level.
- Provide substantial support to simulate bunch of protocols like TCP, UDP, FTP, HTTP and DSR.
- Simulate wired and wireless network.
- It is primarily Unix based.
- Use TCL as its scripting language.
- ns-2 is a standard experiment environment in research community.

NS-2 Features

- NS-2: network simulator version 2
  - Discrete event simulator
  - Packet level simulation
- Features
  - Open source
  - Scheduling, routing and congestion control
  - Wired networks: P2P links, LAN
  - Wireless networks:
  - terrestrial (ad-hoc, cellular; GPRS, UMTS, WLAN, Bluetooth)
  - satellite

NS-2 Features: cont…

- Modeling Network Components
  - Traffic models and applications
    - Web, FTP, telnet, audio, sensor nets
  - Transport protocols
    - TCP (Reno, SACK, etc), UDP, multicast
  - Routing and queueing
    - static routing, DV routing, multicast, ad-hoc routing
    - queueing disciplines: drop-tail, RED, etc
  - Link layer
    - wired, wireless, satellite
- Providing Infrastructure for
  - tracing, visualization, error models, etc
  - modify or create your own modules

NS components

- NS, the simulator itself
- NAM, the Network Animator
  - visualize NS (or other) output
- pre-processing:
  - traffic and topology generators
- post-processing:
  - simple trace analysis, often in Awk, Perl, or Tcl

NS Software Structure: C++ and OTCL

- Uses *two* languages:
  - 1. C++ for the core of NS simulator
    - per packet processing
    - fast to run, detailed, complete control
  - 2. OTCL for control
    - (object Tool command Language)
    - A scripting (interpreted) language
    - simulation setup, configuration
    - fast to write and change

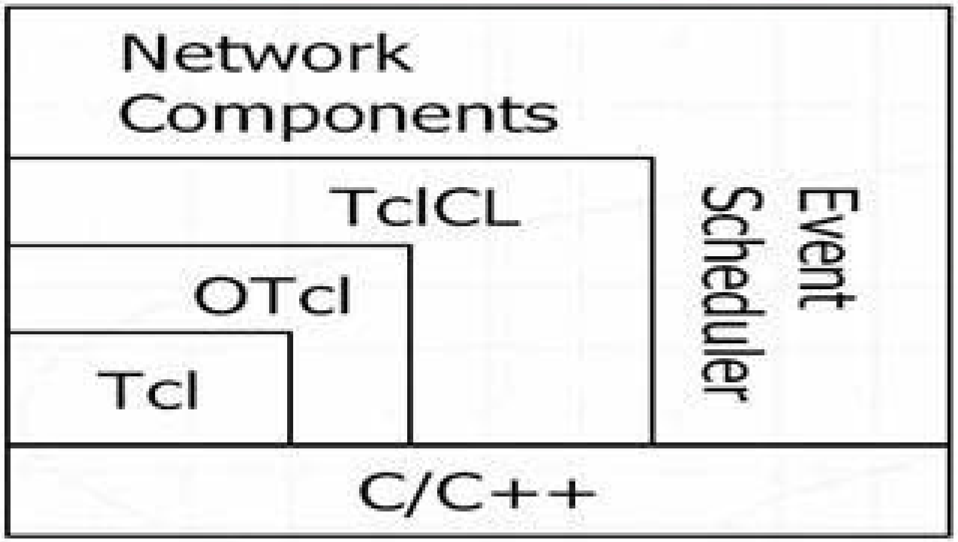
Why two language? (Tcl & C++)

- C++: Detailed protocol simulations require systems programming language
  - byte manipulation, packet processing, algorithm implementation
  - Run time speed is important
  - Turn around time (run simulation, find bug, fix bug, recompile, re-run) is slower
- Tcl: Simulation of slightly varying parameters or configurations
  - Quickly exploring a number of scenarios
  - iteration time (change the model and re -run) is more important

Steps when using NS

- Create OTCL script for your network model
  - nodes, links, traffic sources, sinks, etc.
- Parameterize simulation objects
  - Links: queue sizes, link speeds, ...
  - Transport Protocols: TCP flavor and parameters (more than 30), ...
- Collect statistics
  - dump everything to trace, post process it
  - gather stats during simulation within OTCL script
  - modify Ns source code
- Run NS multiple times
  - confidence intervals

NS-2 architecture



ns-2 Architecture

Designing and running simulations in Tcl using the simulator objects in the OTcl library. The event schedulers and most of the network components are implemented in C++ and available to OTcl through an OTcl linkage that is implemented using tclcl. The whole thing together makes NS, which is a OO extended Tcl interpreter with network simulator libraries.

Tcl: Overview

- Tcl: Tool command language
- Tcl is extensible and embeddable
  - NS-2 is also a Tcl interpreter (tclsh or ns)
- Tcl is a scripting language
  - Ideal for network configuration
- A Tcl script consists of commands
- To write Tcl scripts, you need to learn
  - Tcl command
  - Tcl syntax (how commands are parsed)

Tcl: Command

- A command consists of words
  - *cmdName arg1 arg2 …*
  - *cmdName*: core command or procedure
    - set, puts, expr, open, if, for, …
  - All words are considered as strings
  - White space (space/tab) separates arguments
  - Newline or semicolon (;) terminates a command
- Command evaluation: parsing and execution
  - The interpreter does "substitution" and "grouping"
  - (parsing) before running a command
  - Every command returns a result string after execution

TCL Overview:

- Similar to other programing languages with some peculiarities
  - variables not declared and are all of generic type
    - **set a 3** instead of a=3
  - mathematical operations cumbersome
    - **[expr 3+4]**
      returns the value 7
  - use "$" to read from a variable
    - **set a $b** instead of set a b or a==b
      equates a with b's value
  - write output
    - **put "hello world"**
      outputs hello word
    - **put $a**
      outputs a's value

NS2 installation

```
Download source code ns-allinone-2.29.tar.gz
[root@localhost Desktop]mkdir test
[root@localhost test]cp ns-allinone-2.29.tar.gz /root/Desktop/test
[root@localhost test]tar -xzvf ns-allinone-2.29.tar.gz
[root@localhost test]cd ns-allinone-2.29
[root@localhost test]./install
[root@localhost test] vi /root/.bash_profile
PATH=$PATH:/home/bin:/root/Desktop/test/ns-
    allinone/bin:/root/Desktop/test/ns-allinone-2.29/tcl-
    8.4.14/unix:/root/Desktop/test/ns-allinone/tk-8.4.14/unix
Export PATH
Press Esc and Shitt ZZ
Also Export LD_LIBRARY_PATH
Export TCL_LIBRARY according to your system paths
```

Writing First Procedure (Example 1)

```
# Writing a procedure called "test"
proc test {} {
    set a 43
    set b 27
    set c [expr $a + $b]
    set d [expr [expr $a - $b] * $c]
    for {set k 0} {$k < 10} {incr k} {
     if {$k < 5} {
        puts "k < 5, pow = [expr
     pow($d, $k)]"
     } else {
        puts "k >= 5, mod = [expr $d %
     $k]"
     }
    }
}
```

- **proc** is used to define a procedure
- **$** is used with the variable name
- **puts** prints out the following string within double quotation marks

Example 2

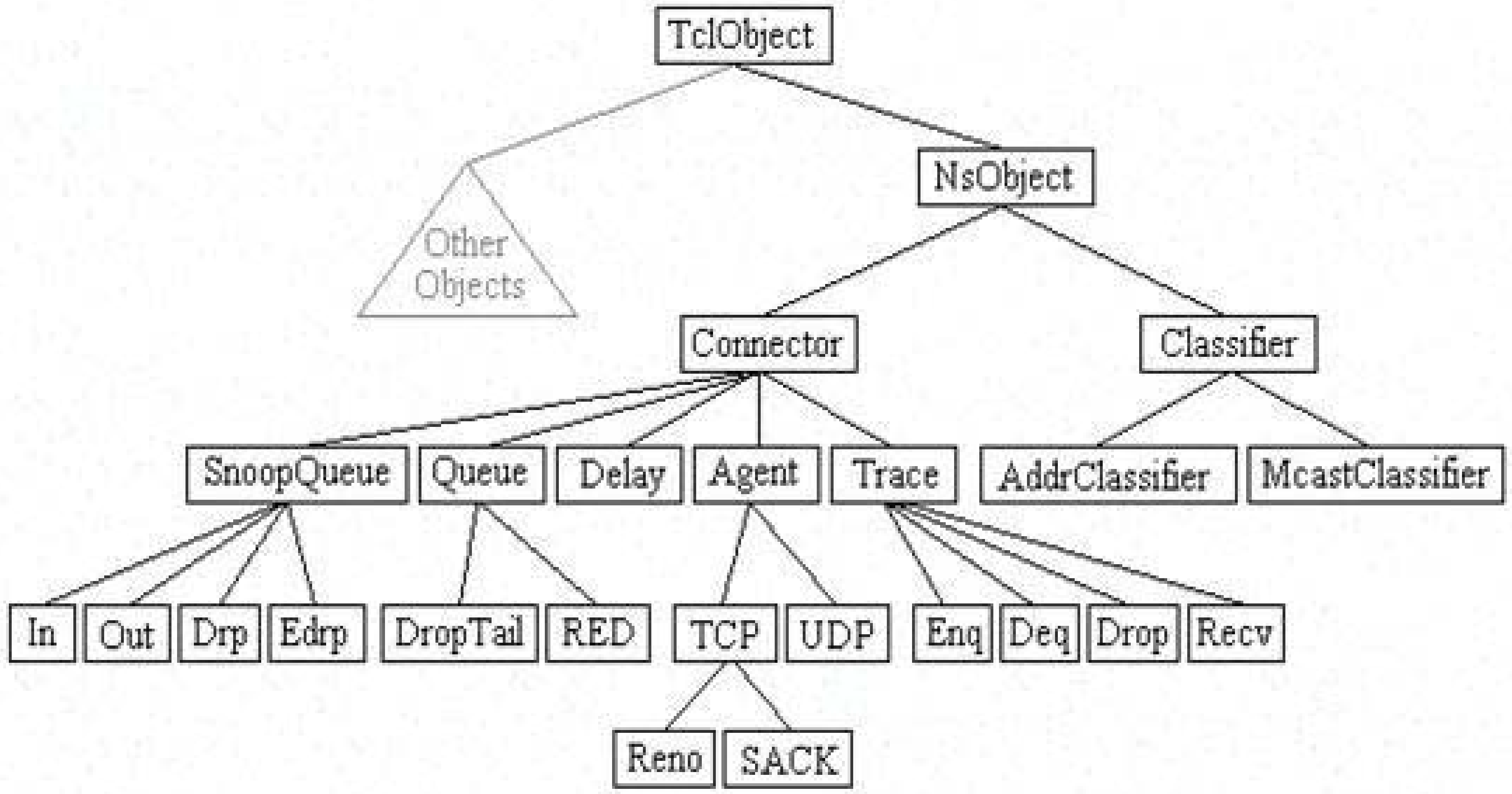
```
Class mom
mom instproc greet {} {
   $self instvar age_
   puts "$age_ years old mom say:
   How are you doing?"
}
Class kid -superclass mom
kid instproc greet {} {
   $self instvar age_
   puts "$age_ years old kid say:
   What's up, dude?"
}
set a [new mom]
$a set age_ 45
set b [new kid]
$b set age_ 15
$a greet
$b greet
```

- The keyword **Class** is to create an object class and **instproc** is to define a member function to an object class
- Class inheritance is specified using the keyword **-superclass**
- **$self** acts same as the "this" pointer in C++,
- to create an object instance, the keyword **new** is used

Components

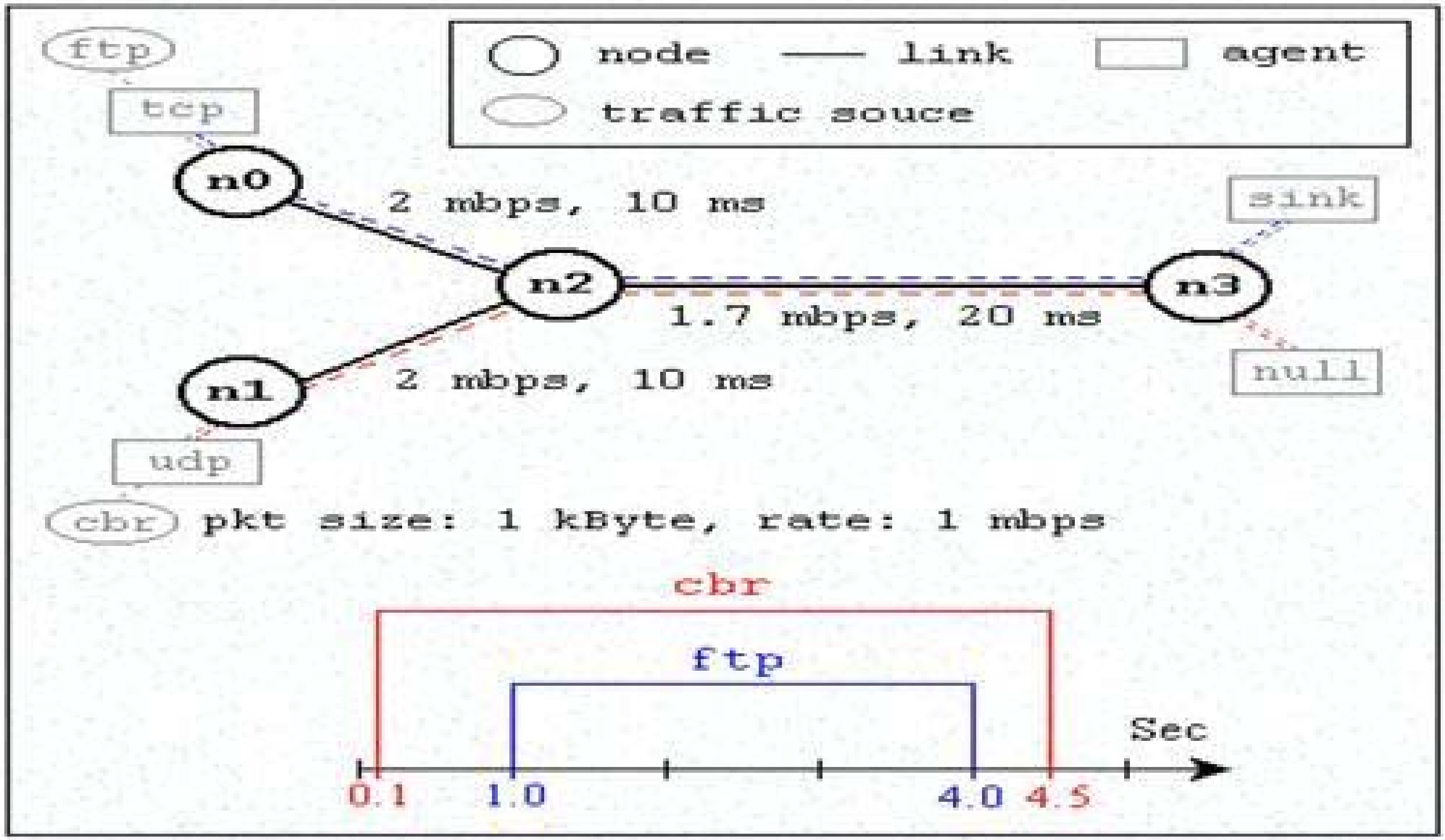
- Four major types
  - Application
    - Communication instigator
  - Agent
    - Packet generator/consumer
  - Node
    - Addressable entity
  - Link
    - Set of queues

OTCL hierarchy



Example 03

- Network Diagram



Example 03 cont…

```
#Create a simulator object
set ns [new Simulator]
#(set ns [new Simulator]: generates an NS simulator object instance, and assigns it to
     variable ns )
#Define different colors for data flows (for NAM)
$ns color 1 Blue
$ns color 2 Red
#open nam trace file(This member function tells the simulator to record simulation traces
     in NAM input forma)
set nf [open out.nam w]
$ns namtrace-all $nf
#Define a finish procedure
Proc finish ()
{ global ns nf
$ns flust_trace
```

Example 03 cont…

```
#close the namtrace file
close $nf
#Execute nam on the trace file
Exec nam out.nam  &
exit 0
#create four nodes
set n0 [$ns node]
set n1 [$ns node]
Set n2 [$ns node]
Set n3 [$ns node]

 #create links between the nodes
$ns duplex-link $n0 $n2 2Mb 10ms DropTail
$ns duplex-link $n1 $n2 2Mb 10ms DropTail
$ns duplex-link $n2 $n3 1.7Mb 20ms DropTail
```

Example 03 cont…

```
#Set Queue Size of link (n2-n3) to 10
$ns queue-limit $n2 $n3 10
#Give node position (for NAM)
$ns duplex-link-op $n0 $n2 orient right-down
$ns duplex-link-op $n1 $n2 orient right-up
$ns duplex-link-op $n2 $n3 orient right
# Monitor queue for link n2-n3 for NAM
$ns duplex-link-op $n2 $n3 queuePos 0.5
#setup a tcp connection
set tcp[new Agent/TCP]
tcp set class_ 2  # marking tcp flow
$ns attach-agent $n0  $tcp
Set sink [new Agent/TCPSink]
$ns attach-agent $n3  $sink
$ns connect $tcp $sink
$tcp set fid_ 1  #identifying it in flow 1
```

Example 03 cont…

```
#Setup a FTP over TCP connection
set ftp [new Application/FTP]
$ftp attach-agent $tcp
$ftp set type_ FTP

#Setup a UDP connection
set udp [new Agent/UDP]
$ns attach-agent $n1 $udp
set null [new Agent/Null]
$ns attach-agent $n3 $null
$ns connect $udp $null
$udp set fid_ 2
```

Example 03 cont…

```
#Setup a CBR over UDP connection
set cbr [new Application/Traffic/CBR]
$cbr attach-agent $udp
$cbr set type_ CBR
$cbr set packet_size_ 1000
$cbr set rate_ 1mb
$cbr set random_ false

#Schedule events for the CBR and FTP agents
$ns at 0.1 "$cbr start"
$ns at 1.0 "$ftp start"
$ns at 4.0 "$ftp stop"
$ns at 4.5 "$cbr stop"
```

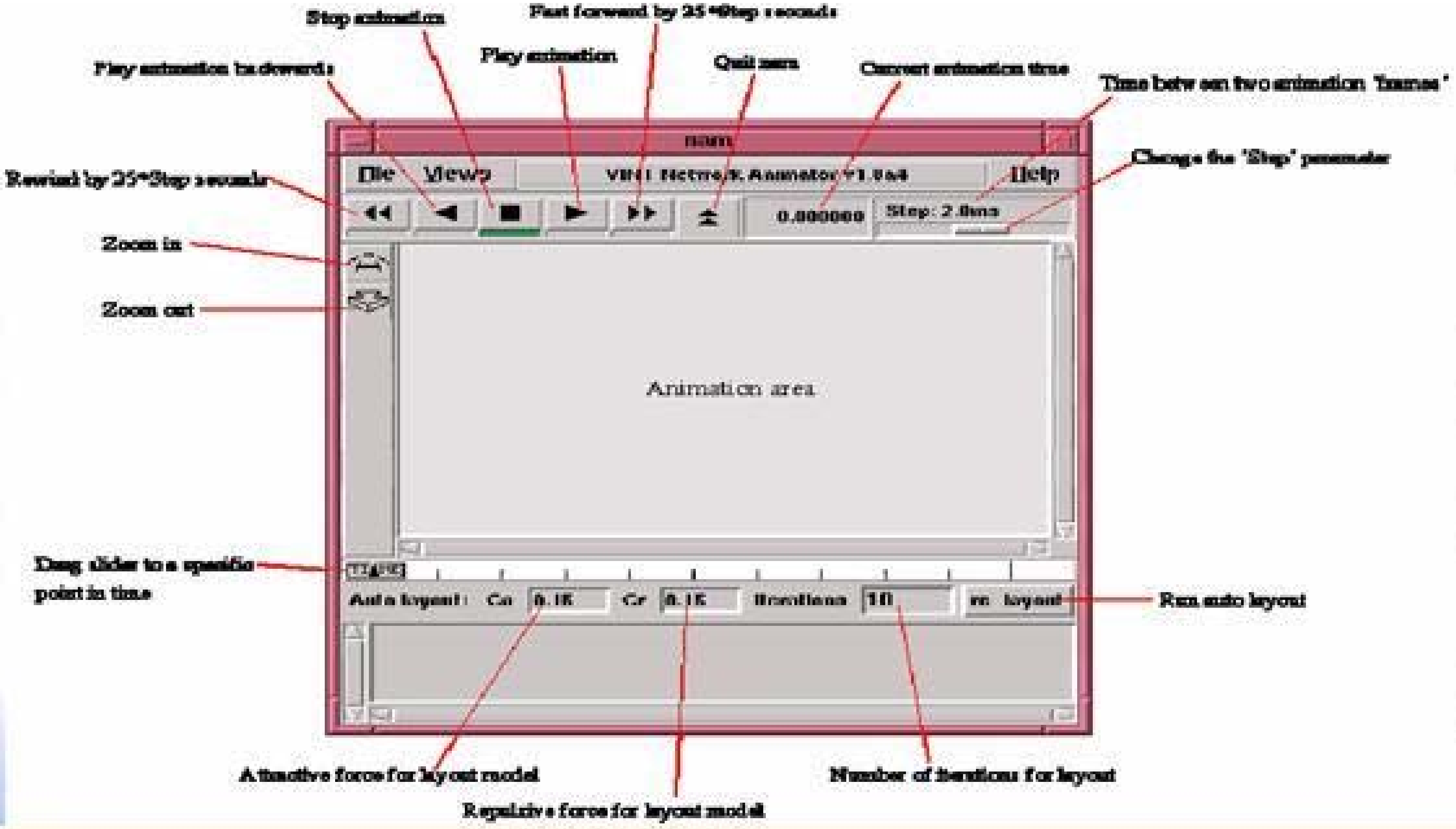
Example 03 cont…

```
#Detach tcp and sink agents (not really necessary)
$ns at 4.5 "$ns detach-agent $n0 $tcp ; $ns detach-agent $n3$sink"

#Call the finish procedure after 5 seconds of simulation time
$ns at 5.0 "finish"

#Print CBR packet size and interval
puts "CBR packet size = [$cbr set packet_size_]"
puts "CBR interval = [$cbr set interval_]"

#Run the simulation
$ns run
```

Executing Script

```
[root@localhost Desktop]cd test
[root@localhost test]ls
ns-simple.tcl
[root@localhost test] ns  ns-simple.tcl
#here simulation will start and nam will appear on screen. Two files will also
    appear in present working directory with the  name of out.nam and out1.tr.
    out.nam is network amulation file and out1.tr is a trace file  containing data
    about simulation
[root@localhost test]ls
ns-simple.tcl        out.nam                out1.tr
[root@localhost test]] kedit out.nam  out1.tr
```

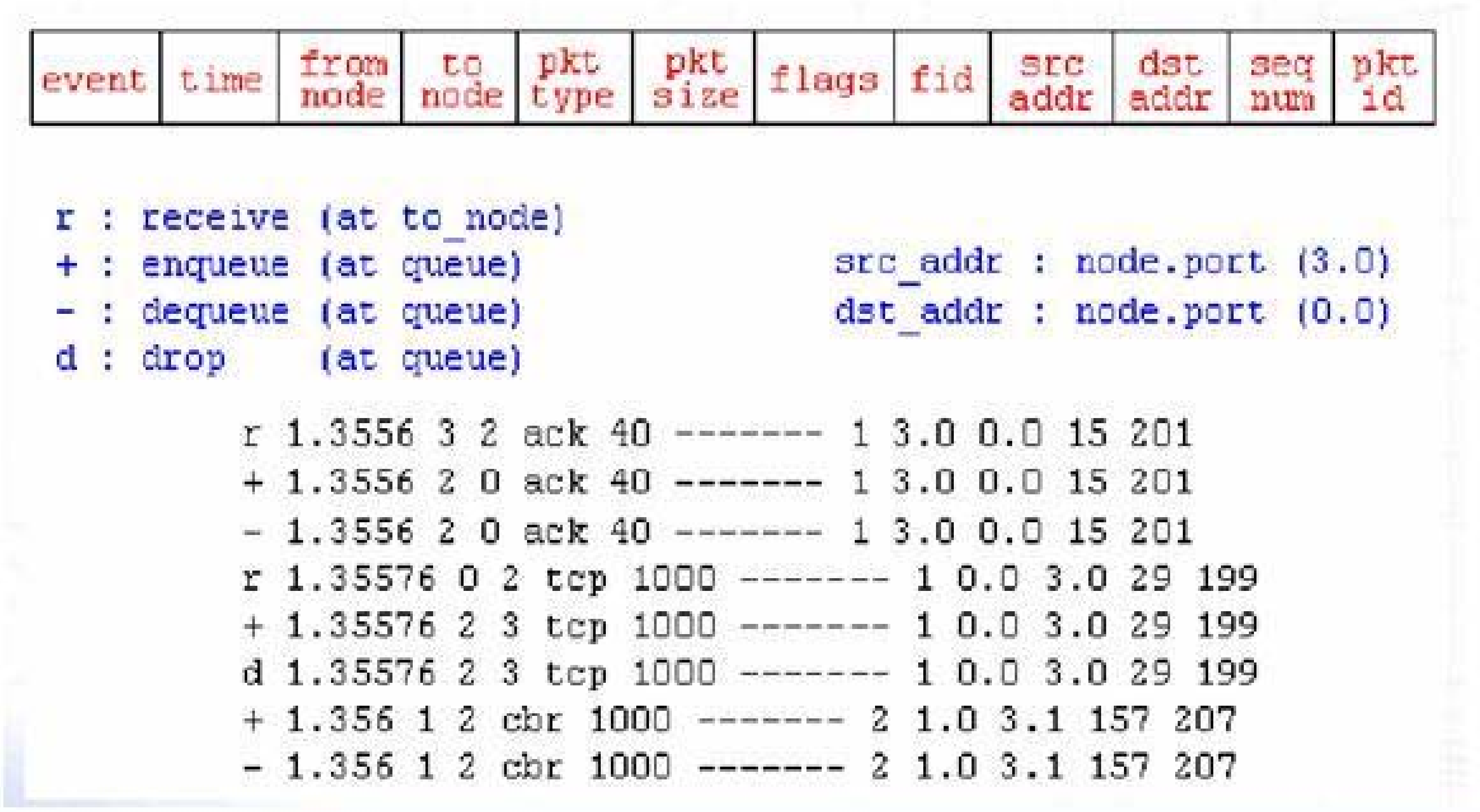
Network Amulator(NAM)


Stop animation
Fast forward by 25*Step seconds
Play animation backwards
Play animation
Quit nam
Current animation time
Time between two animation 'frames'
Change the 'Step' parameter
Rewind by 25*Step seconds
Zoom in
Zoom out
Drag slider to a specific point in time
Run auto layout
Attractive force for layout model
Repulsive force for layout model
Number of iterations for layout
nam
File
Views
VINT Network Animator v1.0a4
Help
0.000000
Step: 2.0ms
Animation area
Auto layout:
Ca
0.15
Cr
0.15
Iterations
10
re-layout

.tr Trace File

```
+ 0.1 0 2 cbr 1000 -----ÿÿÿÿ 0.0 3.0 0 0
- 0.1 0 2 cbr 1000 ------- 1 0.0 3.0 0 0
+ 0.1 1 2 tcp 40 ------- 2 1.0 3.1 0 1
- 0.1 1 2 tcp 40 ------- 2 1.0 3.1 0 1
r 0.10532 1 2 tcp 40 ------- 2 1.0 3.1 0 1
+ 0.10532 2 3 tcp 40 ------- 2 1.0 3.1 0 1
- 0.10532 2 3 tcp 40 ------- 2 1.0 3.1 0 1
r 0.113 0 2 cbr 1000 ------- 1 0.0 3.0 0 0
+ 0.113 2 3 cbr 1000 ------- 1 0.0 3.0 0 0
- 0.113 2 3 cbr 1000 ------- 1 0.0 3.0 0 0
r 0.115853 2 3 tcp 40 ------- 2 1.0 3.1 0 1
+ 0.115853 3 2 ack 40 ------- 2 3.1 1.0 0 2
- 0.115853 3 2 ack 40 ------- 2 3.1 1.0 0 2
+ 0.117857 0 2 cbr 1000 ------- 1 0.0 3.0 1 3
- 0.117857 0 2 cbr 1000 ------- 1 0.0 3.0 1 3
r 0.126387 3 2 ack 40 ------- 2 3.1 1.0 0 2
```

.tr Trace File Cont…



event	time	from node	to node	pkt type	pkt size	flags	fid	src addr	dst addr	seq num	pkt id

```
r : receive (at to_node)
+ : enqueue (at queue)                 src_addr : node.port (3.0)
- : dequeue (at queue)                 dst_addr : node.port (0.0)
d : drop    (at queue)
```

```
r 1.3556 3 2 ack 40 ------- 1 3.0 0.0 15 201
+ 1.3556 2 0 ack 40 ------- 1 3.0 0.0 15 201
- 1.3556 2 0 ack 40 ------- 1 3.0 0.0 15 201
r 1.35576 0 2 tcp 1000 ------- 1 0.0 3.0 29 199
+ 1.35576 2 3 tcp 1000 ------- 1 0.0 3.0 29 199
d 1.35576 2 3 tcp 1000 ------- 1 0.0 3.0 29 199
+ 1.356 1 2 cbr 1000 ------- 2 1.0 3.1 157 207
- 1.356 1 2 cbr 1000 ------- 2 1.0 3.1 157 207
```

Abbreviation NS2

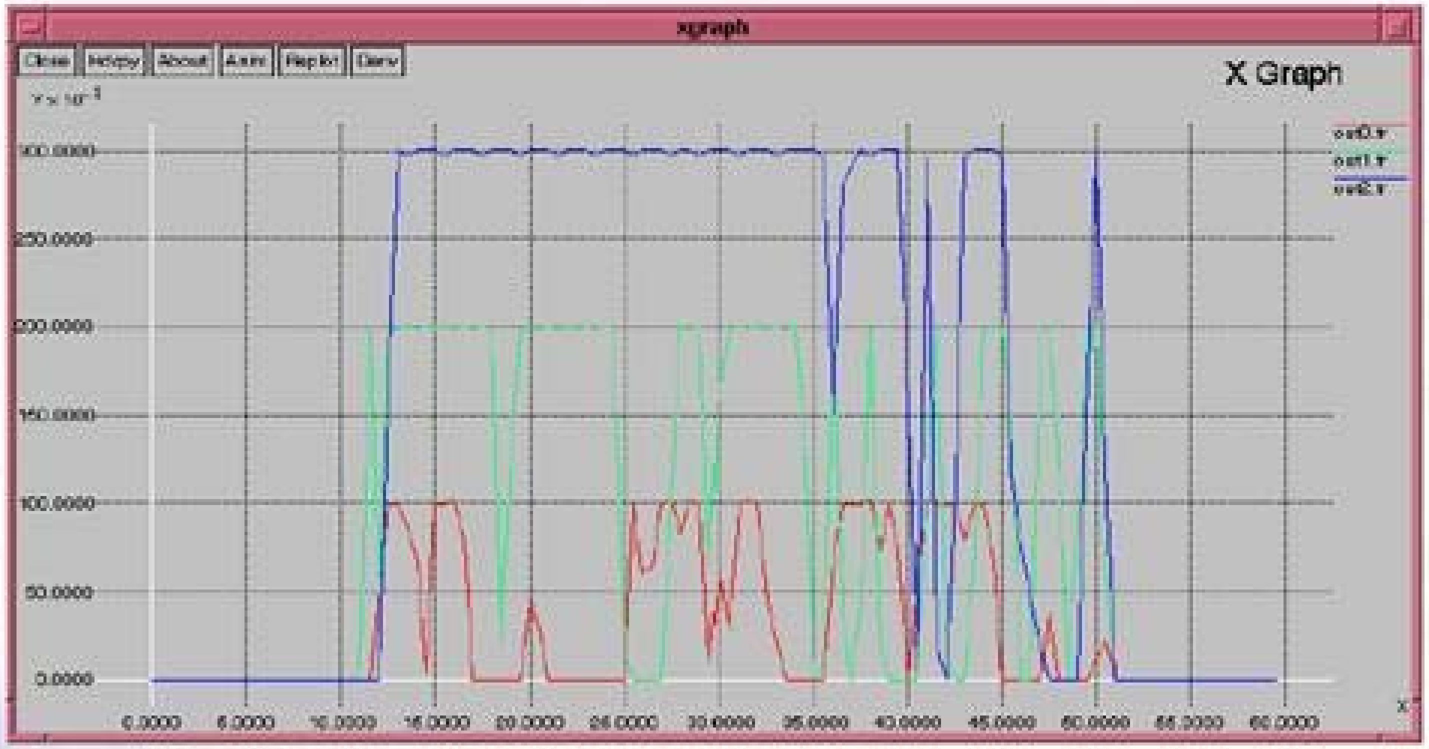
- Some abbreviations used:
- Event:
  - S=send
  - R=receive
  - D=drop
  - F=forward
- Trace level:
  - AGT=agent
  - RTR=router
  - MAC=MAC
  - IFQ=drop due to full buffer
  - ARP=drop by ARP

Acquiring useful data from .tr file

- cat out.tr | grep " 2 3 cbr " | grep ^r | column 1 10 | awk '{dif = $2 - old2; if(dif==0) dif = 1; if(dif > 0) {printf("%d\t%f\n", $2, ($1 - old1) / dif); old1 = $1; old2 = $2}}' > jitter.txt
- This shell command selects the "CBR packet receive" event at n3, selects time (column 1) and sequence number (column 10), and calculates the difference from last packet receive time divided by difference in sequence number (for loss packets) for each sequence number
- Data will be written to jitter.txt

XGraph:

- NS-2 relies on XGraph in order to displaysimulation results
- XGraph is a UNIX graphing application



NS2 Useful Links

- Network Simulator NS-2
  - NS-2 Homepage (http://www.isi.edu/nsnam/ns/)
  - NS-2 Manual (http://www.isi.edu/nsnam/ns/nsdocumentation.
html)
- Getting started with NS-2
  - Marc Greis's tutorial
(http://www.isi.edu/nsnam/ns/tutorial/index.html)
  - NS by example (http://nile.wpi.edu/NS/)
  - NS2 for beginners
(http://www-sop.inria.fr/maestro/personnel/Eitan.Altman/COURS-NS/n3.pdf)
  - OTcl (ftp://ftp.tns.lcs.mit.edu/pub/otcl/doc/tutorial.html)