Experimental Networking

Lab 2, Network Simulator ns2

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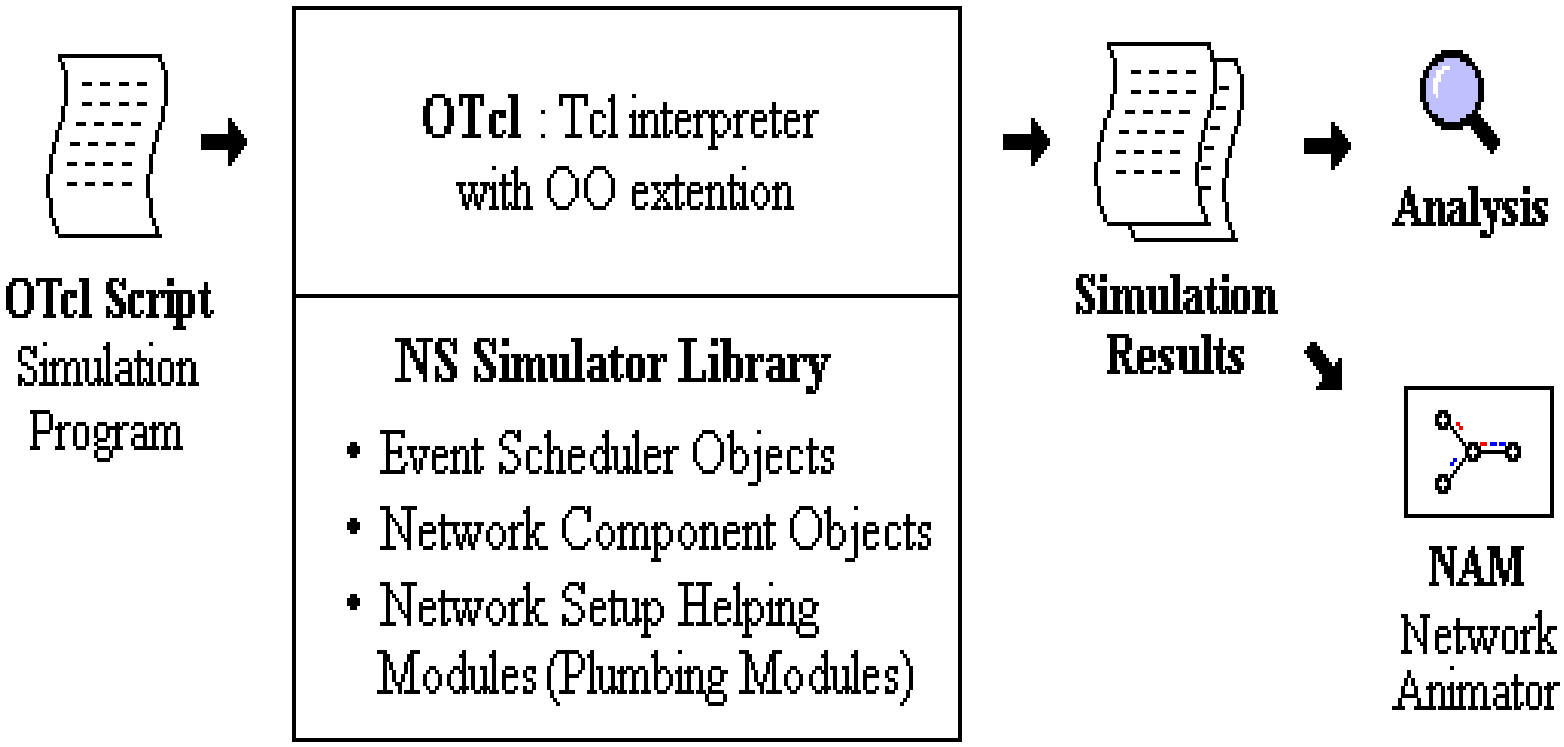
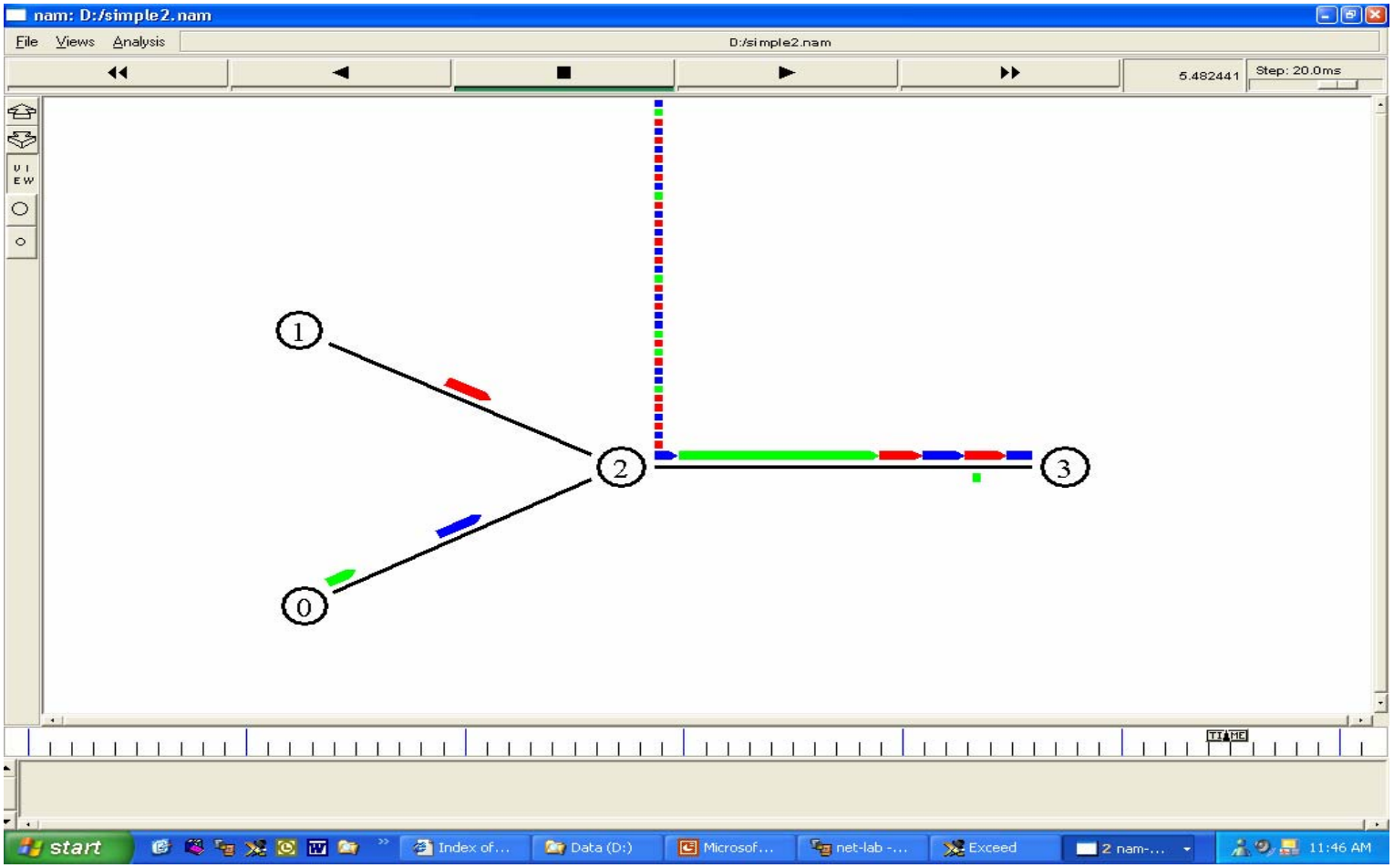
How ns2 works



Ns2 Tutorial

- Languages
- Ns2
- Nam
- Assignment #2

Nam View


nam: D:/simple2.nam
File
Views
Analysis
D:/simple2.nam
5.482441
Step: 20.0ms
VIEW
1
2
3
0
TIME
start
Index of...
Data (D:)
Microsof...
net-lab -...
Exceed
2 nam-...
11:46 AM

Languages

- System language: C, C++, Java
  - Build data structures and algorithms from scratch
  - Strongly typed to manage complexity
  - Compiled, high efficiency, 10~20x faster

- Scripting language: Perl, Tcl(OTcl), Unix shell
  - Rapid high level programming: to “glue” applicatons
  - Typeless to simplify connections btwn components
  - Interpreted, less efficient
  - Sacrifice execution speed for development speed (5~10x faster than system language for gluing dev)

Ns2

- NS is a “Network Simulator”
  - Can setup network topologies
  - Generate packet traffic similar to Internet and measure various parameters
- NS is needed because:
  - Need to verify utility / feasibility of new algorithms / architectures
  - Actual topologies Expensive / Error prone / Time consuming to setup

Ns2 status

- Source code
  - C++ for packet processing, Otcl for control
  - 100K lines of C++; 70K lines of OTcl; 50K+ lines of test suite, examples, docs
  - http://www.isi.edu/nsnam/ns/
  - Current version 2.26, (v2.1-b5 installed)
- Platforms
  - Most UNIX systems (FreeBSD, Linux, Solaris)
  - Window 9x/NT/2000

Ns2

- Most of the NS2 source code is in C++
  - http://www.cplusplus.com/doc/tutorial/
  - http://www.isi.edu/nsnam/ns
  - http://www.isi.edu/nsnam/ns/ns-documentation.html
- Tcl is a simple scripting language used in conjunction with Otcl to setup simulation topologies and scenarios.
  - http://dev.scriptics.com/man/tcl8.2.3/
- OTcl adds Object orientation to Tcl
  - http://bmrc.berkeley.edu/research/cmt/cmtdoc/otcl/tutorial.html
- NAM – Network Animator is used to visualize simulations
  - http://www.isi.edu/nsnam/nam

Tcl

- expr 20 + 10
- set x 32
- set cmd expr; set x 11; $cmd $x*$x
- set a 44; set b [expr $a*4]
- set x 24; set y 18; set z "$x + $y is [expr $x + $y]"
- set x 24; set y 18; set z {$x + $y is [expr $x + $y]}
- proc power {base p} {

```
    set result 1
    while {$p > 0} {
            set result [expr $result * $base]
            set p [expr $p - 1]
        }
        return $result
    }
```

- Further: http://www.beedub.com/book/2nd/tclintro.doc.html

Anatomy of a simple Tcl Script

- Examine “simple.tcl”

```
# This is a simple Tcl script to illustrate
# basic operations
puts “Executing simple tcl script”
# Open a file for writing
set f1 [open “try” “w”]
# Write something into the file and close it
puts $f1 “Writing a sentence into file”
close $f1
# Read the sentence
set f1 [open “try” “r”]
set l1 [gets $f1]
puts “Read line: $l1”
```

A Simple Tcl Script (contd.)

- You can run the Tcl script using the program "tclsh" as:

```
~> tclsh simple.tcl
Executing simple tcl script
Read line: Writing a sentence into file
~>
```

- Let us observe the syntax:
  - Lines beginning with "#" are treated as comments
  - The symbol "$" is used to obtain the *contents* of a variable
  - The "set" method is used to assign values to variables. Note that the "$" does not appear when something is being assigned to the variable
  - The effect of parentheses in math is obtained by using [] – e.g., [open …] indicates that the code in the brackets is evaluated first and then assigned to f1
  - "puts", "gets", "open" are all Tcl commands. "puts $f1 …" indicates that we are passing contents of f1 as a parameter to puts
- Simple.tcl thus opens a file called "try", writes a sentence and reads from it

Exercise 1- Loops and Lists

- This exercise will introduce you to *loops and lists* in Tcl.
- A file contains information about path in a network. The path is specified as a list of numbers: 1 15 7 25 3 25 2 10 5 … to indicate that node 1 is connected to node 7 with a link of 15Mbps, node 7 to node 3 with 25Mbps and so on. Write a tcl script to read this file and interpret its contents. Your output should look like:

```
Link 1: Node 1 to Node 7; Bandwidth: 15M
Link 2: Node 7 to Node 3; Bandwidth: 25M
```

- You might want to use the following functions:

```
# Create an empty list in l1
set l1 [list]
# Concatenate a list/string with another and assign to l2
set l2 [concat $l1 $s1]
# Access an element i from the list l2
set el1 [lindex $l2 $i]
# Execute a statement n times
for {set i 0} { $i < n } {incr i} {
...
}
```

Tcl

- Stop here, let students do Tcl program

Otcl Examples

- A “class” is like a struct with facilities for private and public variables, member functions and inheritance
- Lets examine the topology class:

```
Class Topology

Topology instproc init { } {
   $self instvar nodes ns
    set ns [Simulator instance]
   set nodes(1) [$ns node]
   set nodes(2) [$ns node]
   $ns duplex-link $nodes(1) $nodes(2) 10M 10ms DropTail
}

Topology instproc get-node { node-id } {
    return $nodes($node-id)
}
```

Otcl Examples (contd.)

- To understand all aspects in the above example you have to know the basics of Object oriented programming. I will assume that you know at least the meaning of these terms: member functions, static functions/variables, instances, constructors
- The first line is the declaration of "Topology" as a class
- The function "init" is the equivalent of constructor in C++ - it is the first function called when an instance of this class is created by "new" operator.
- $self is equivalent to the "this" pointer in C++. It refers to the present instance within which the function is executing – that is it refers to "itself"
- "instvar" is used to declare a member variable and similarly "instproc" is used to declare a member function. The syntax of a procedure is similar to that in Tcl except that the class name has to come first and the "proc" keyword is replaced by instproc. The empty braces ("{}") indicate that the procedure takes no parameters.

Otcl Examples (contd.)

- Note that the variable ns is being assigned "[Simulator instance]". "Simulator" is the name of a class. "instance" is a static function in the class which returns the instance of the Simulator class (already in memory)
- The general syntax to access member functions is

  `$obj member-func parameters`

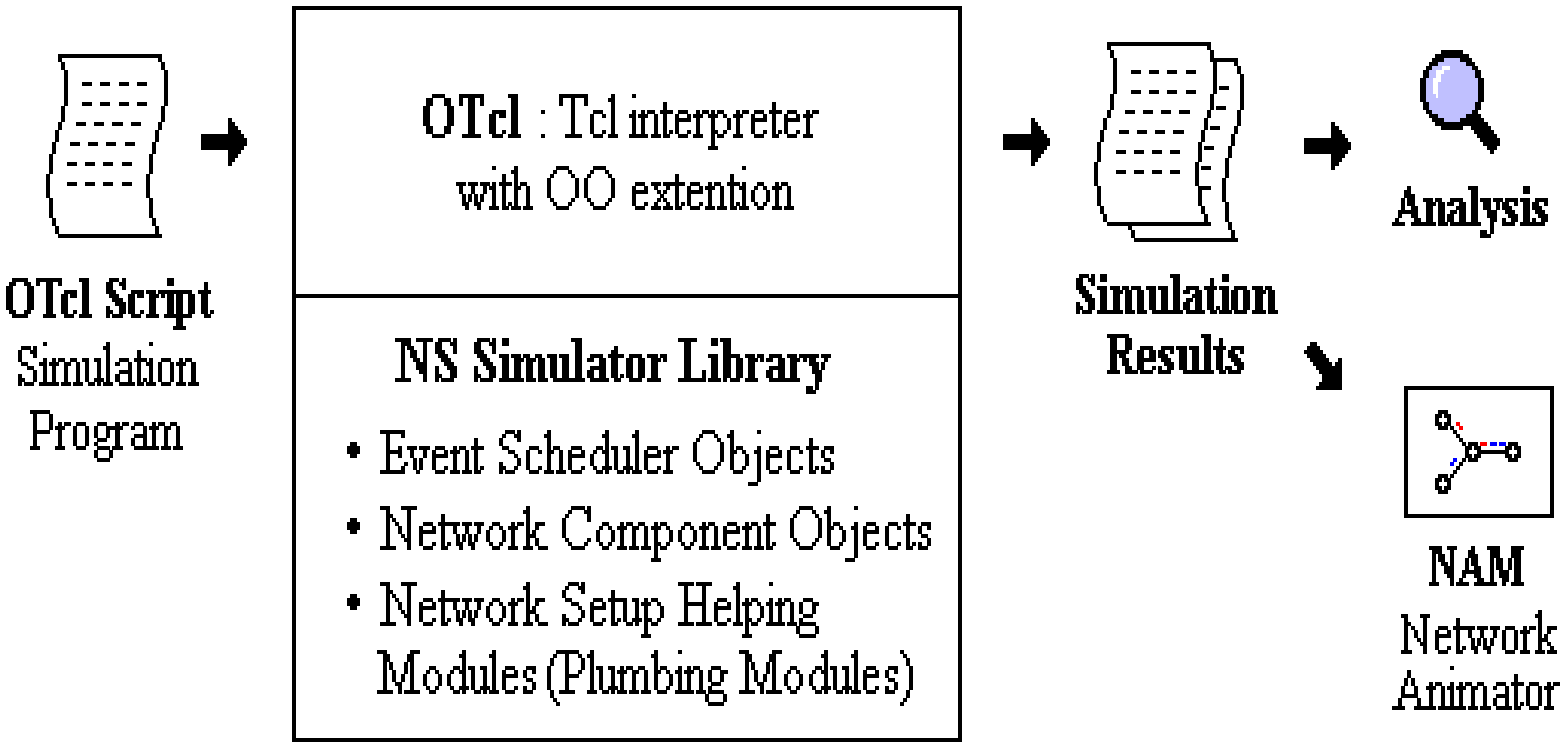
  This can be observed where the duplex-link function is called to create a link between nodes(1) and nodes(2).
- nodes() is an array. As noted in the example no special declaration is needed to use arrays.
- To use this class, we may write this code:

```
set ns [new Simulator]
set t1 [new Topology]
set n1 [$t1 get-node 1]
```

OTcl

- Stop here, let students do OTcl program

How ns2 works



An example: skeleton

- A ns-2 simulation script generally includes
  - Create the event scheduler
  - Turn on tracing, if needed
  - Create network topology
  - Setup routing
  - Create transport agent
  - Create traffic source/sink
  - Transmit application-level data

An example: how to start

- Create a event scheduler
  - set ns [new Simulator]
- Open a file for trace data
  - set nf [open out.nam w]
  - $ns namtrace-all $nf

An example: how to start

- A procedure to close file and start NAM
  - proc finish {} {
    ```
    global ns nf
    $ns flush-trace
    close $nf
    exec nam out.nam &
    exit 0
    }
    ```
- Schedule the procedure
  - $ns at 5.0 "finish"
- Start simulation
  - $ns run

An example: topology

- Node
  - set n0 [$ns node]
  - set n1 [$ns node]
  - set n2 [$ns node]

- Link
  - $ns duplex-link $n0 $n1 1Mb 5ms DropTail
  - $ns duplex-link $n1 $n2 400Kb 10ms DropTail

An example: agent / applicaiton

- Create a UDP agent and attach it to node n0
  - set udp [new Agent/UDP]
  - $ns attach-agent $n0 $udp
- Create a CBR traffic source and attach it to udp0
  - set cbr [new Application/Traffic/CBR]
  - $cbr attach-agent $udp
- Create a null agent to be traffic sink
  - set null [new Agent/Null]
  - $ns attach-agent $n2 $null

An example: agent / applicaiton

- Connect them
  - $ns connect $udp $null
- Schedule the event
  - $ns at 0.5 "$cbr start"
  - $ns at 4.5 "$cbr stop"

An example: agent / applicaiton

- Stop here, let students do UDP transmission simulation

An example: agent / applicaiton

- Create a TCP agent and attach it to node n0
  - set tcp [new Agent/TCP]
  - $ns attach-agent $n0 $tcp
- Create a FTP traffic source and attach it to udp0
  - set ftp [new Application/FTP]
  - $ftp attach-agent $tcp
- Create a TCPSink agent to be traffic sink
  - set sink [new Agent/TCPSink]
  - $ns attach-agent $n2 $sink

An example: agent / applicaiton

- Schedule the event
  - $ns at 0.5 "$ftp start"
  - $ns at 4.5 "$ftp stop"

Traces

- Traces in NS format
  - $ns trace-all [open tr.out w]

```
<event> <time> <from> <to> <pkt> <size> -- <fid> <src> <dst> <seq> <attr>
     + 1 0 2 cbr 210 ------- 0 0.0 3.1 0 0
     - 1 0 2 cbr 210 ------- 0 0.0 3.1 0 0
     r 1.00234 0 2 cbr 210 ------- 0 0.0 3.1 0 0
     d 1.04218 1 2 cbr 210 ------- 0 0.0 3.1 0 0
```

- Traces in NAM format
  - $ns namtrace-all [open tr.nam w]

- Turn on tracing on specific links
  - $ns trace-queue $n0 $n1
  - $ns namtrace-queue $n0 $n1

An example: agent / applicaiton

- Stop here, let students do TCP transmission simulation

More settings: event and queuing

- Schedule events
  - $ns at <time> <event>
  - <event>: any legitimate ns/tcl commands
- Links and queuing
  - $ns duplex-link $n0 $n1 <bandwidth> <delay> <queue_type>
  - <queue_type>: DropTail, RED, CBQ, FQ, SFQ, DRR

More settings: Routing

- Unicast
  - $ns rtproto <type>
  - <type>: Static, Session, DV, cost, multi-path
- Multicast
  - $ns multicast (right after [new Simulator])
    - or set ns [new Simulator –multicast on]
  - $ns mrtproto <type>
  - <type>: CtrMcast, DM, ST, BST (centralized,dense mode, shared tree

More settings: Traffic on Top of UDP

- UDP
  - set udp [new Agent/UDP]
  - set null [new Agent/Null]
  - $ns attach-agent $n0 $udp
  - $ns attach-agent $n1 $null
  - $ns connect $udp $null
- CBR
  - set src [new Application/Traffic/CBR]
- Exponential or Pareto
  - set src [new Application/Traffic/Exponential]
  - set src [new Application/Traffic/Pareto]

More settings: Traffic on Top of TCP

- TCP
  - set tcp [new Agent/TCP]
  - set tcpsink [new Agent/TCPSink]
  - $ns attach-agent $n0 $tcp
  - $ns attach-agent $n1 $tcpsink
  - $ns connect $tcp $tcpsink
- FTP
  - set ftp [new Application/FTP]
  - $ftp attach-agent $tcp
- Telnet
  - set telnet [new Application/Telnet]
  - $telnet attach-agent $tcp

Exploring further

- The slides till now have provided the basics of what is needed to run simulations in NS. To explore further, you can exploit the following sources:
  - The NS manual: http://www.isi.edu/nsnam/ns/doc/index.html
  - Example code in `tcl/test` directory of your NS distribution
  - NS Mailing lists: http://www.isi.edu/nsnam/ns/ns-lists.html

Assignment #2

- See assignment page