Part I: Fundamentals (con’t)

Outline

- Goals
- Essentials
- Primers
  - Wired world
  - Wireless world
  - Emulator
  - Utilities

ns Primer – Wireless World

- Ad hoc routing
- Mobile IP
- Satellite networking

Ad Hoc Routing – An Example

- Scenario
  - 3 mobile nodes
  - moving within 670mX670m flat topology
  - using DSDV ad hoc routing protocol
  - Random Waypoint mobility model
  - TCP and CBR traffic
- *ns-2/tcl/ex/wireless-demo-csci694.tcl*

An Example – Step 1

```
# Define Global Variables
# create simulator
set ns [new Simulator]

# create a topology in a 670m x 670m area
set topo [new Topography]
$topo load_flatgrid 670 670
```

An Example – Step 2

```
# Define standard ns/nam trace
# ns trace
set tracefd  [open demo.tr w]
$ns trace-all $tracefd
# nam trace
set namtrace [open demo.nam w]
$ns namtrace-all-wireless $namtrace 670 670
```

An Example – Step 3

```
# Create God
set god [create-god 3]
$ns at 900.00 “$god setdist 2 3 1”
```

- **God**: store an array of the smallest number of hops required to reach one node to an other
- Optimal case against which to compare routing protocol performance
- Automatically generated by scenario file

An Example – Step 4

```
# Define how a mobile node should be created
$ns node-config \
        -adhocRouting DSDV \
        -llType LL \
        -macType Mac/802_11 \
        -ifqLen 50 \
        -ifqType Queue/DropTail/PriQueue \
        -antType Antenna/OmniAntenna \
        -propType Propagation/TwoRayGround \
        -phyType Phy/WirelessPhy \
        -channelType Channel/WirelessChannel \
        -topoInstance $topo
        -agentTrace ON \
        -routerTrace OFF \
        -macTrace OFF
```

An Example – Step 5

```
# Create a mobile node, attach it to the channel

set node(0) [$ns node]
# disable random motion
$node(0) random-motion 0
```

- Use “for” loop to create 3 nodes:

```
for {set i < 0} {$i < 3} {incr i} {
    set node($i) [$ns node]
}
```

An Example – Step 6

```
# Define node movement model
source movement-scenario-files

# Define traffic model
source traffic-scenario-files
```

Scenario Generator: Movement

- Mobile Movement Generator

```
setdest -n <num_of_nodes> -p
  pausetime -s <maxspeed> -t
  <simtime> -x <maxx> -y <maxy>
```

- Random movement
  - `$node start`
  - Source: `ns-2/indep-utils/cmu-scen-gen/setdest/`

A Movement File

```
$node_(2) set Z_ 0.000000000000
$node_(2) set Y_ 199.373306816804
$node_(2) set X_ 591.256560093833
$node_(1) set Z_ 0.000000000000
$node_(1) set Y_ 345.357731779204
$node_(1) set X_ 257.046298323157
$node_(0) set Z_ 0.000000000000
$node_(0) set Y_ 239.438009831261
$node_(0) set X_ 83.364418416244
$ns_ at 50.000000000000 "$node_(2) setdest 369.463244915743
    170.519203111152 3.371785899154"
$ns_ at 51.000000000000 "$node_(1) setdest 221.826585497093
    80.855495003839 14.909259208114"
$ns_ at 33.000000000000 "$node_(0) setdest 89.663708107313
    283.494644426442 19.153832288917"
```

Scenario Generator: Traffic

- Generating traffic pattern files
  - CBR traffic

```
ns cbrgen.tcl [-type cbf|tcp] [-nn
  nodes] [-seed seed] [-mc connections]
  [-rate rate]
```

  - TCP traffic

```
ns tcpgen.tcl [-nn nodes] [-seed seed]
```

  - Source: *ns-2/indep-utils/cmu-scen-gen/*

A Traffic Scenario

```
set udp_(0) [new Agent/UDP]
$ns_ attach-agent $node_(0) $udp_(0)
set null_(0) [new Agent/Null]
$ns_ attach-agent $node_(2) $null_(0)
set cbr_(0) [new Application/Traffic/CBR]
$cbr_(0) set packetSize_ 512
$cbr_(0) set interval_ 4.0
$cbr_(0) set random_ 1
$cbr_(0) set maxpkts_ 10000
$cbr_(0) attach-agent $udp_(0)
$ns_ connect $udp_(0) $null_(0)
$ns_ at 127.93667922166023 "$cbr_(0) start"
…….
```

An Example – Step 7

```
# Define node initial position in nam
for {set i 0} {$i < 3 } { incr i} {
     $ns initial_node_position $node($i) 20
}

# Tell ns/nam the simulation stop time
$ns at 200.0 “$ns nam-end-wireless 200.0”
$ns at 200.0 “$ns halt”

# Start your simulation
$ns run
```

Energy Extension

- Node is energy-aware
- Define node by adding new options:

```
$ns_ node-config \
     –energyModel EnergyModel
     -initialEnergy 100.0
     -txPower      0.6
     -rxPower      0.2
```

nam Visualization

- Use nam to visualize:
  - Mobile node position
  - Mobile node moving direction and speed
  - Energy consumption at nodes (color keyed)

nam Visualization

- Replace

  ```
  $ns namtrace-all $fd
  ```

  with

  ```
  $ns namtrace-all-wireless $fd
  ```

  At the end of simulation, do

  ```
  $ns nam-end-wireless [$ns now]
  ```

- See an example: 🎥

Summary

- Mac Layer: IEEE 802.11
- Address Resolution Protocol (ARP)
- Ad hoc routing protocols: DSDV, DSR,TORA, AODV
- Radio Propagation Model
  - Friss-space attenuation at near distances
  - Two ray ground at far distances
- Antenna: an omni-directional antenna having unity gain

Summary

- Energy consumption model for sensor networks
- Visualization of node movement, reachability, and energy
- Validation test suites

Credit

- CMU
- UC Berkeley
- Sun Microsystem Inc.
- USC/ISI

A Brief on Satellite Networking

- Developed by Tom Henderson (UCB)
- Supported models
  - Geostationary satellites: bent-pipe and processing-payload
  - Low-Earth-Orbit satellites
- Example: `tcl/ex/sat-*.tcl`
- Much in-development

A Brief on MobileIP Support

- Developed by Sun
  - Require a different Node structure than the MobileNode
  - Co-exists with wired world in ns
- Standard MobileIP
  - Home Agent, Foreign Agent, MobileHosts…
- Example
  - `~ns/tcl/ex/wired-cum-wireless.tcl`

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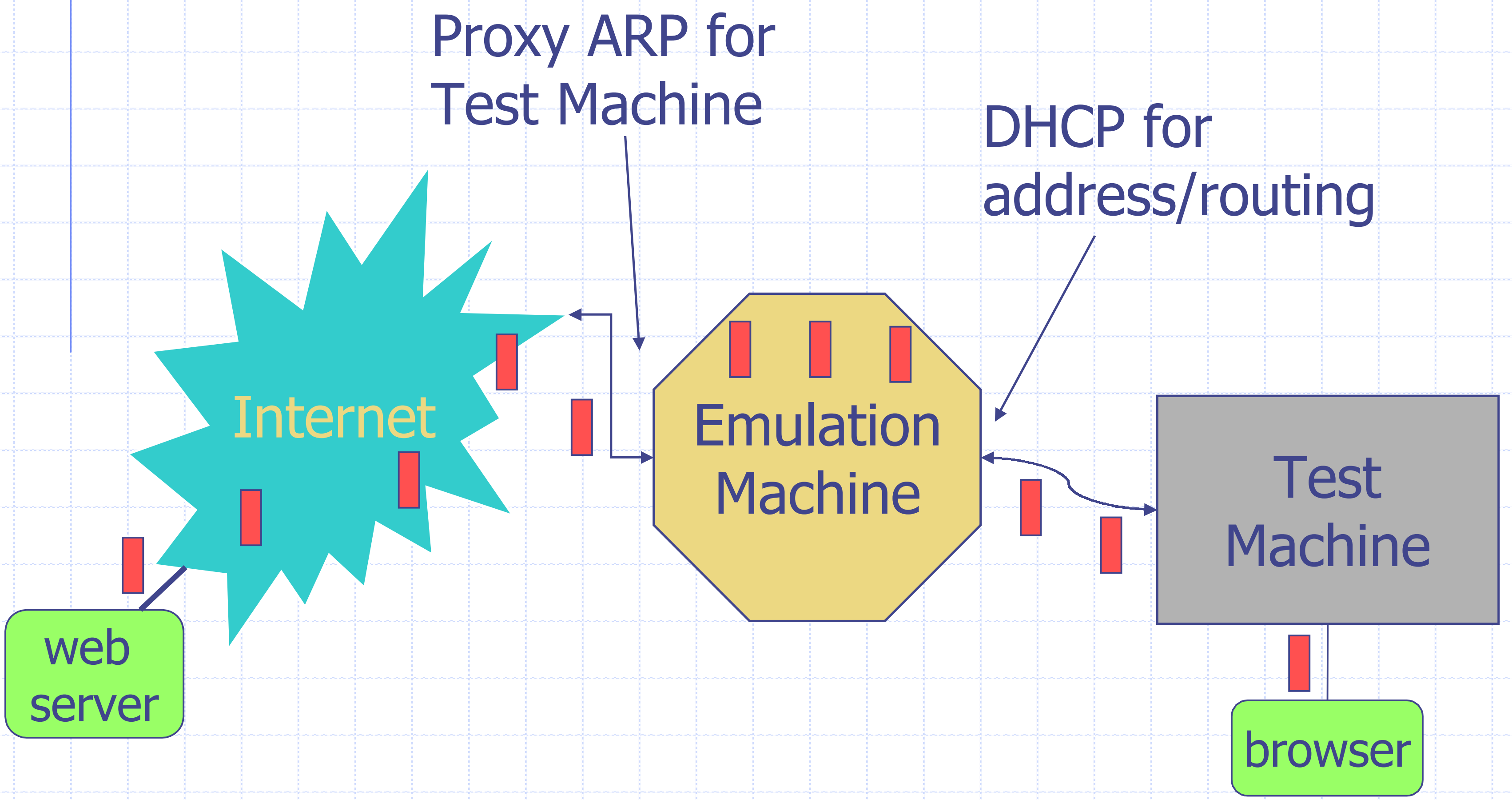
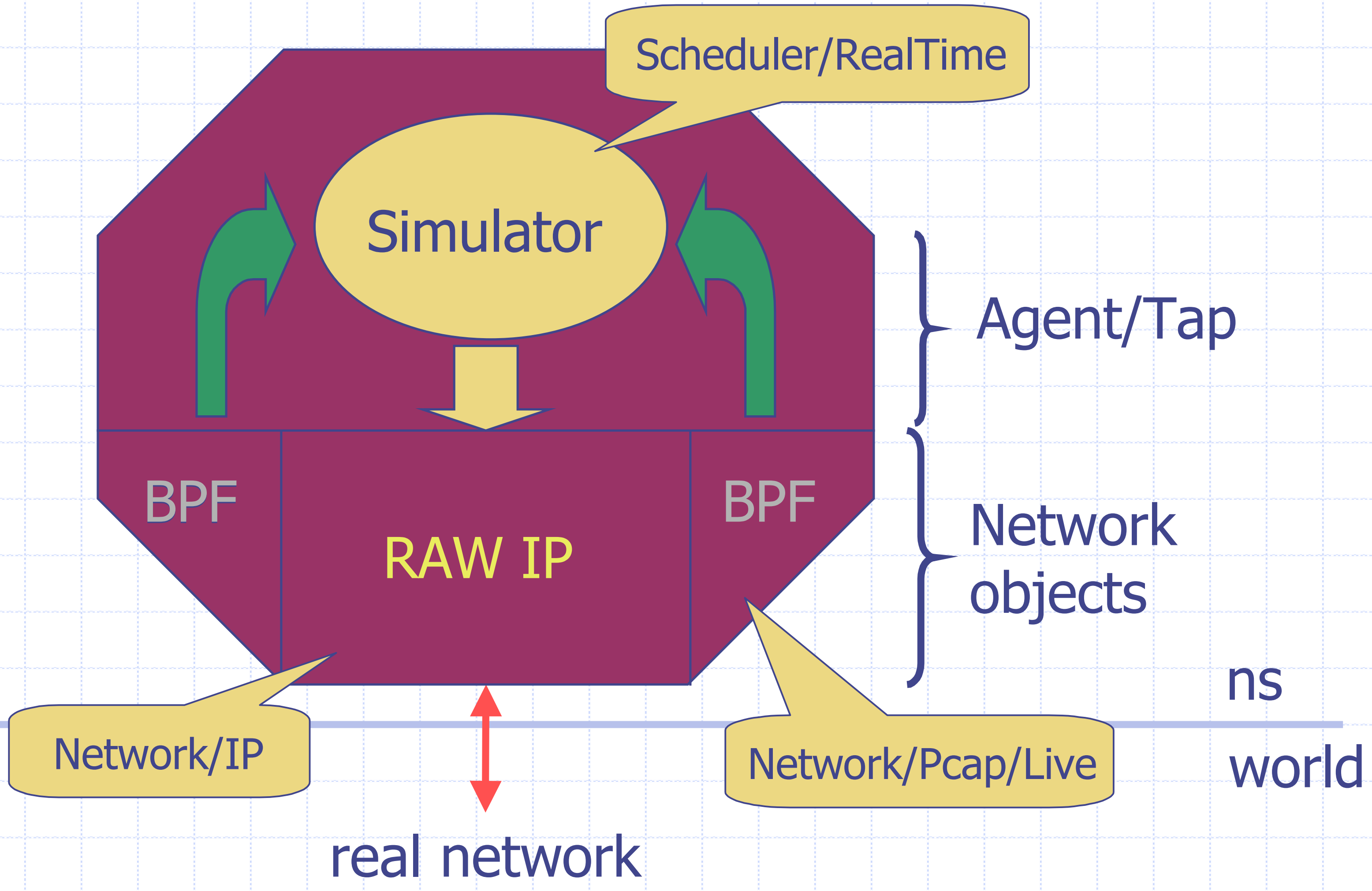
Emulation in ns

- Simulator ⇔ real network
  - Inject received packets into simulation
  - Emit packets on to live network
- Usage
  - Subject real implementations to controlled conditions in the simulator
  - Subject simulations to real-world traffic
- Currently only works on FreeBSD

Sample Environment



Emulation Machine



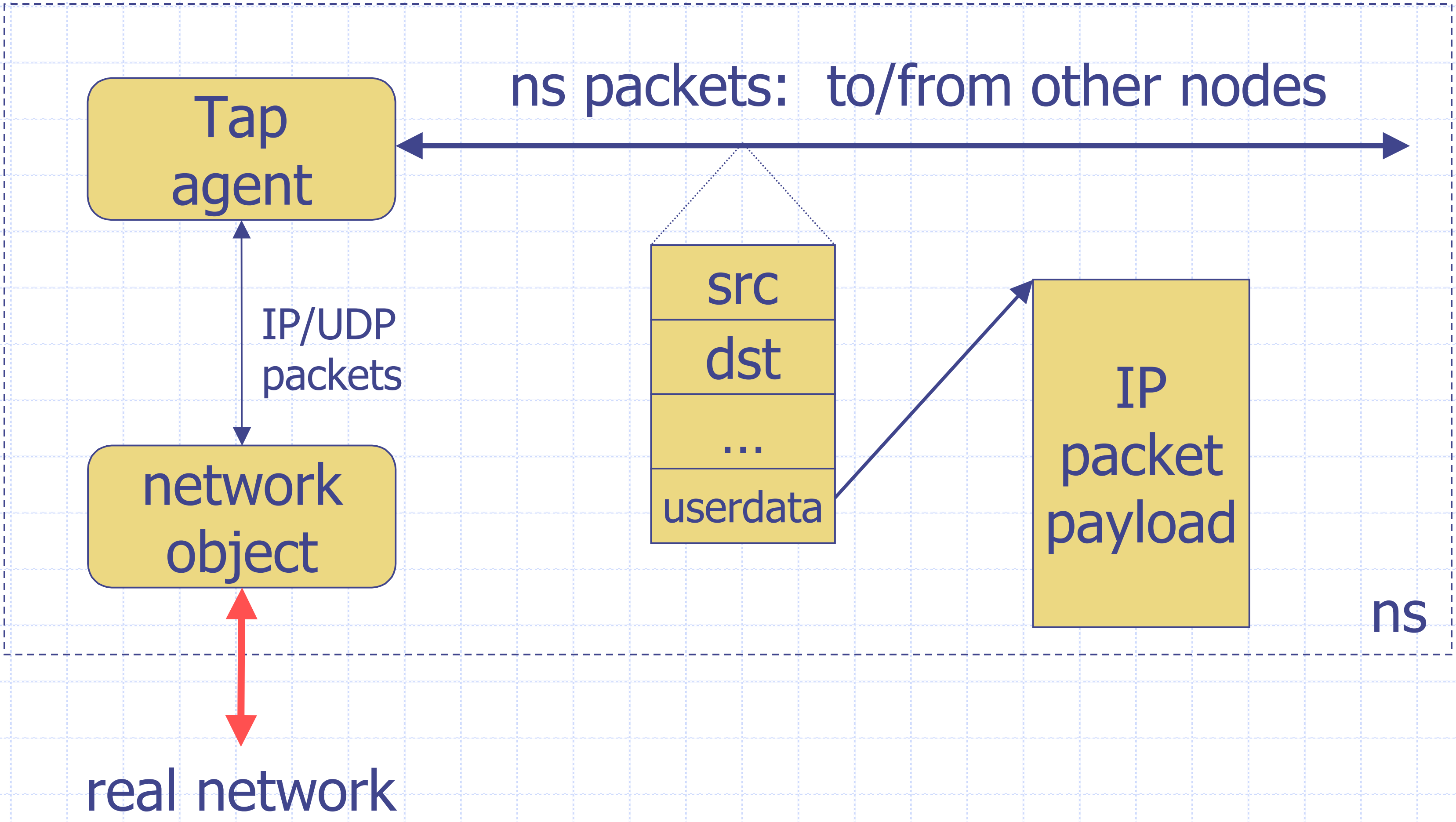
Realtime Scheduler

- Extended from Scheduler/List
- Synchronizes simulation time to real time
- Fails when simulation time falls behind
- `$ns use-scheduler RealTime`

Network Objects

- Abstraction of real traffic source/sink
- Base class for various network types
  - Opened read-only, write-only, or read-write
- Raw IP and UDP/IP network object
  - Send/receive raw IP packets or UDP/IP
  - IP multicast support
- Pcap network object
  - Send/receive link-layer frames
  - Use BPF/libpcap filtering language

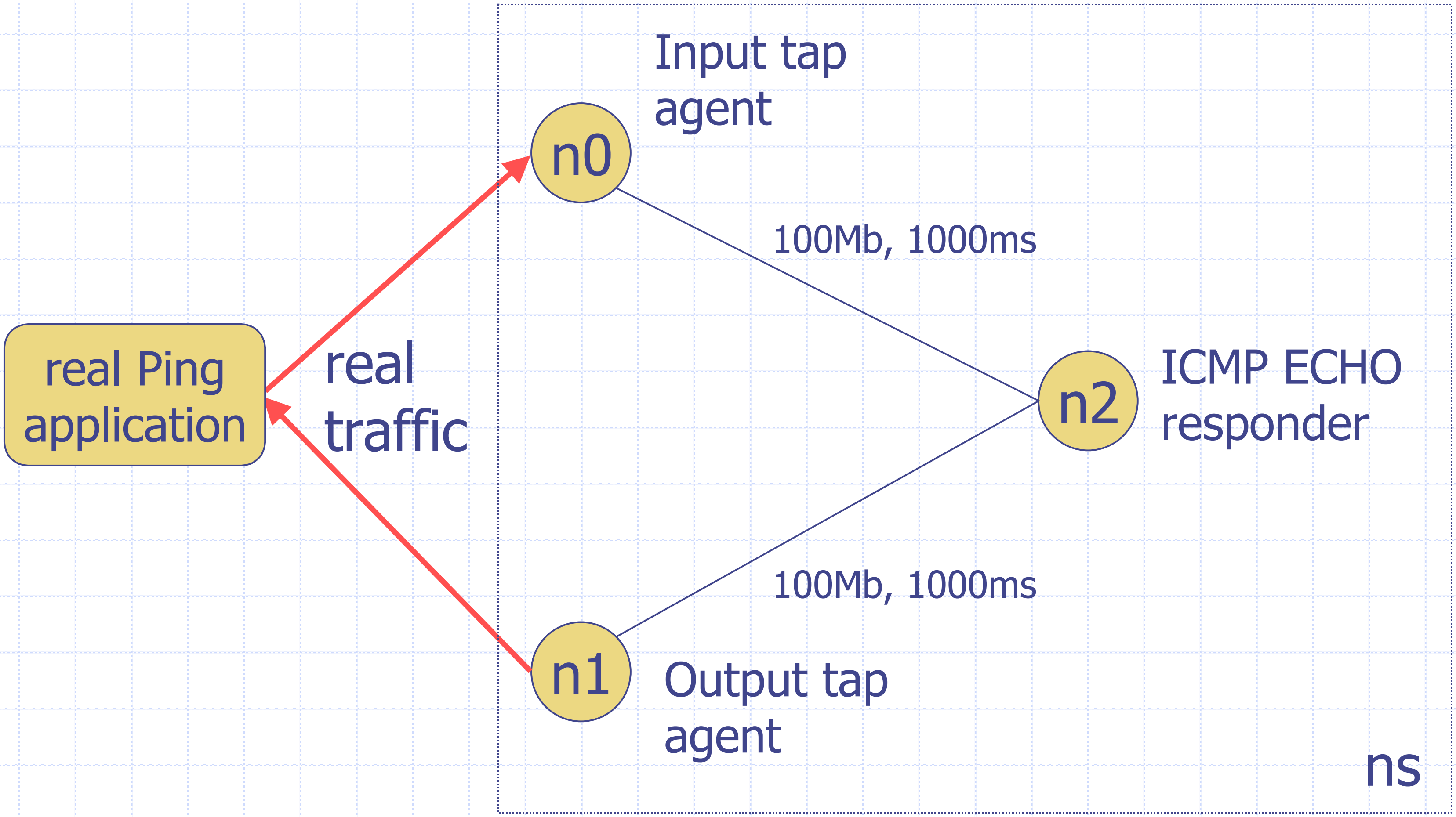
Tap Agents


Tap agent
ns packets: to/from other nodes
IP/UDP packets
network object
src
dst
…
userdata
IP packet payload
ns
real network

Emulation Modes

- Protocol mode
  - Simulator interpret/generate live traffic
  - Existing agents: ICMP ECHO, ICMP Redirect, ARP, TCP NAT
- Opaque mode
  - Simulator does not interpret network data
  - Operations: packet drop/reordering/delay…

Protocol Mode: Ping Responder



Ping: Step 1

- Stage setup

```
# Create simulator
set ns [new Simulator]
$ns use-scheduler RealTime

# Emulator address
set me [exec hostname]
# Or an arbitrary one (may require ARP support)
# set me “10.11.12.13”
```

Ping: Step 2

- Create I/O network objects

```
# Packet input
set bpf0 [new Network/Pcap/Live]
$bpf0 set promisc_ true
set nd0 [$bpf0 open readonly fxp0]
set filt “(not ip host $me)”
$bpf0 filter $filt

# Packet output
set ipnet [new Network/IP]
$ipnet open writeonly
```

Ping: Step 3

- Agents

```
# Input agent
set pfa [new Agent/Tap]
$pfa network $bpf0

# Output agent
set ipa [new Agent/Tap]
$ipa network $ipnet

# ICMP ECHO agent
set echoagent [new Agent/PingResponder]
```

Ping: Step 4

- Create network topology

```
set n0 [$ns node]
set n1 [$ns node]
set n2 [$ns node]
$ns simplex-link $n0 $n2 100Mb 1000ms DropTail
$ns simplex-link $n2 $n1 100Mb 1000ms DropTail

$ns attach-agent $n0 $pfa
$ns attach-agent $n1 $ipa
$ns attach-agent $n2 $echoagent
$ns simplex-connect $pfa $echoagent
$ns simplex-connect $ipa $echoagent
```

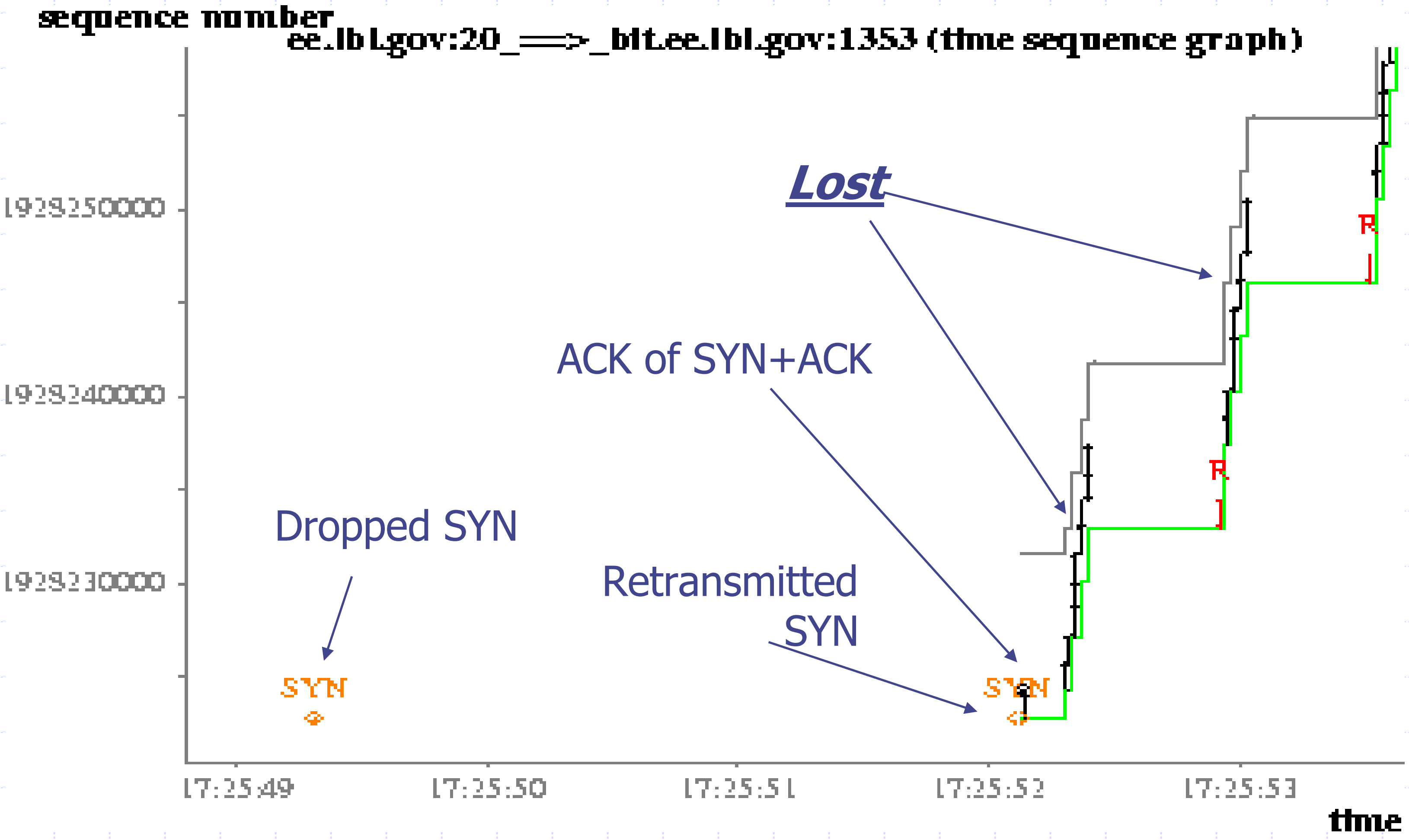
Ping: Step 5

- Start

```
# Wait for ping to come in...
$ns run
```

- Result
  - 2000.052ms ± 1.021ms

Opaque Mode (TCP: 10 packet periodic drop)



Lost

ACK of SYN+ACK

Dropped SYN

Retransmitted SYN

More Examples

- ~ns/emulate
- Example scripts
  - Protocol mode: ~ns/emulate/empaper.tcl
  - Opaque mode: ~ns/emulate/em3.tcl

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Utilities

- Tcl debugger
- Topology generation
- Scenario generation
- Web cache trace converter

Debugging Your ns Script

- tcl-debug 1.9
  - http://expect.nist.gov/tcl-debug/
  - Works with Tcl 8.0.4 and below
- Installation
  - [make distclean] in ns
  - ./configure --with-tcldebug=<dir>
  - make

Debugging Your ns Script

- Using tcl-debug
  - Insert "debug 1" into your scripts, e.g.:

```
set tcp [new Agent/TCP]
debug 1
$tcp set window_ 200
```

  - When "debug 1" is executed, ns drops to:

```
vint/ns-2(121): ./ns t.tcl
2: lappend auto_path $dbg_library
dbg2.0>
```

Debugging Your ns Script

```
dbg2.0> h
s [#]           step into procedure
n [#]           step over procedure
N [#]           step over procedures, commands, and arguments
c               continue
r               continue until return to caller
u [#]           move scope up level
d [#]           move scope down level
                go to absolute frame if # is prefaced by "#"
w               show stack ("where")
w -w [#]        show/set width
w -c [0|1]      show/set compress
b               show breakpoints
b [-r regexp-pattern] [if expr] [then command]
b [-g glob-pattern]   [if expr] [then command]
b [[file:]#]          [if expr] [then command]
                if pattern given, break if command resembles pattern
                if # given, break on line #
                if expr given, break if expr true
                if command given, execute command at breakpoint
b -#            delete breakpoint
b -             delete all breakpoints
```

Topology Generation

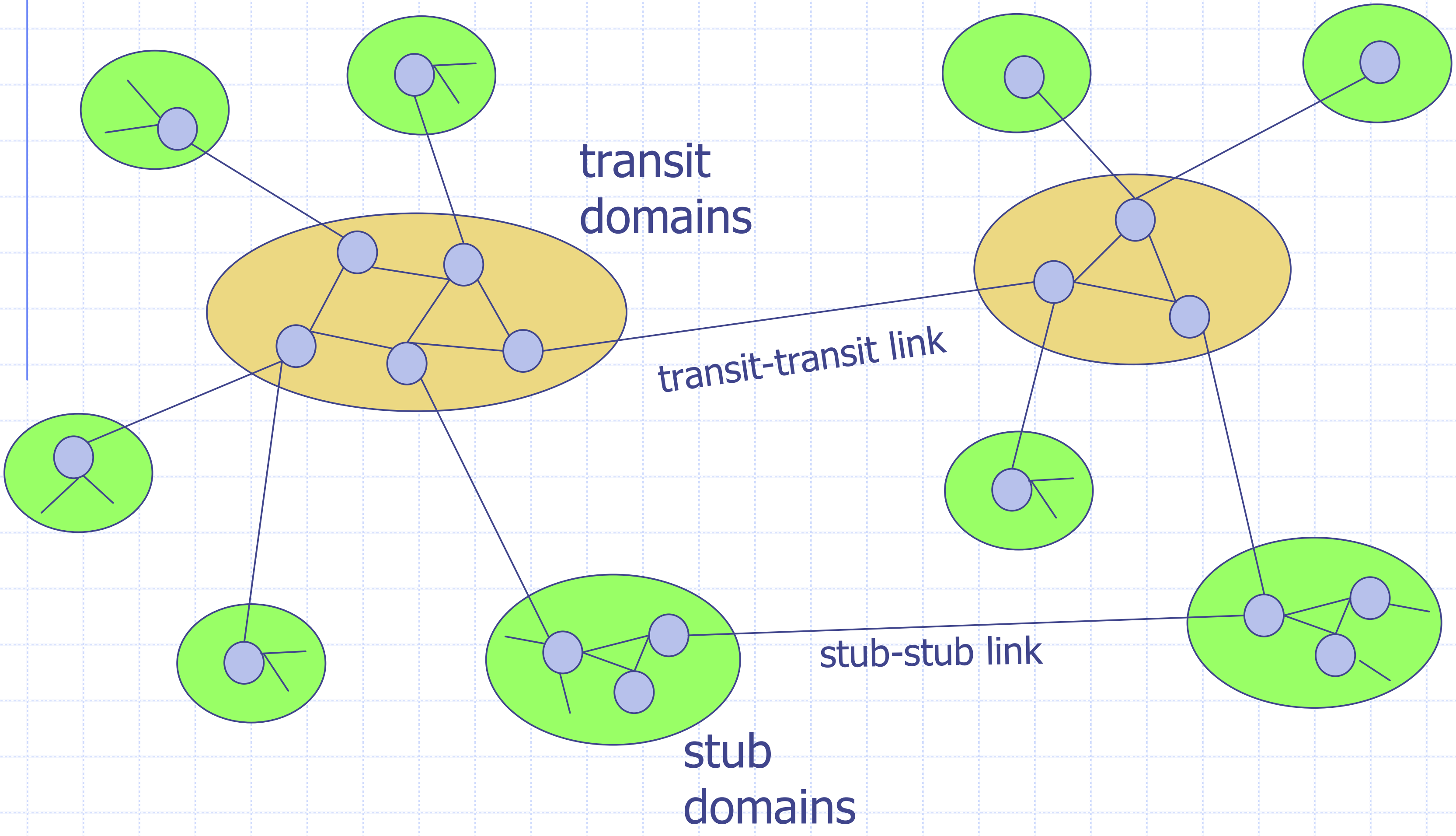
- http://www.isi.edu/nsnam/ns/ns-topogen.html

Packages	Graphs	Edge Method
NTG	n-level	probabilistic
RTG	Flat random	Waxman
GT-ITM	Flat random, n-level, Transit-stub	various
TIERS	3-level	spanning tree

GT-ITM

- Installation
  - Comes with ns-allinone
  - Require Knuth’s cweb and SGB
- Usage
  - itm <config_file>
- Three graph models
  - Flat random: Waxman
  - n-level hierarchy
  - Transit-stub

GT-ITM: Transit-Stub Model



GT-ITM: Example

- Transit-stub network
- Config file (e.g., ts1)

```
# <method keyword> <number of graphs> [<initial seed>]
# <# stubs/trans node> <#rand. t-s edges> <#rand. s-s
  edges>
# {<n> <scale> <edgemethod> <alpha> [<beta>] [<gamma>]}
# (average!) number of nodes = 1x2x(1+3x4) = 26
ts 10 47      # 10 graphs, init seed 47
3 0 0         # 2 stubs per transit nodes
1 20 3 1.0    # n. of transit domains (pure random)
2 20 3 0.5    # n. of nodes per transit domain
4 10 3 0.5    # n. nodes in each stub domain
```

GT-ITM: Example

- Run
  - `itm ts1`
  - Result: ts1-{0-9}.gb
- Result files in SGB format

Converters for GT-ITM

- sgb2ns
  - Convert SGB format to ns config file
  - `sgb2ns <SGB_file> <OTcl_file>`
  - `ts2ns`: output lists of transit and stub nodes
- sgb2hier
  - Convert transit-stub information into hierarchical addresses
  - `sgb2hierns <SGBFile> <TclFile>`

Converters for GT-ITM

- Format of generated ns config files

```
proc create-topology {nsns node linkBW} {
    upvar $node n
    upvar $nsns ns
    # Create nodes, links,
    ......
}
```

- Usage

```
 source <OTcl_file>
 create-topology ns nodes 1.5Mb
```

See Your Topology

- Create an ns wrapper

```
# Assume you’ve done “sgb2ns ts1-0.gb ts1.tcl”
source ts1.tcl
set ns [new Simulator]
$ns namtrace-config [open ts1.nam w]
create-topology ns node 1.5Mb
$ns at 1.0 “exit 0”
$ns run
```