Network Simulator 2: Introduction

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NS-2 Overview

NS-2

- Developed by UC Berkeley
- Maintained by USC
- Popular simulator in scientific environment
- Other popular network simulators
  - QualNet: based on GloMoSim
  - Others: GloMoSim, OPNET, etc

NS2 Goals

- To support networking research and education
  - Protocol design, traffic studies, etc.
  - Protocol comparison;
  - New architecture designs are also supported.
- To provide *collaborative* environment
  - Freely distributed, open source;
  - *Increase confidence* in result

Two Languages: C++, OTcl

OTcl: short for MIT Object Tcl,
an extension to Tcl/Tk for object-oriented programming.

- Used to build the network structure and topology
  which is just the surface of your simulatoion;

- Easily to configure your network parameters;

- Not enough for research schemes and protocol architecture adaption.

Two Languages (Con't)

C++: Most important and kernel part of the NS2

- To implement the kernel of the architecture of the protocol designs;
- From the packet flow view, the processes run on a single node;
- To change or "comment out" the existing protocols running in NS2;
- Details of your research scheme.

Why 2 Languages?

- **2 requirements of the simulator**
  - Detailed simulation of Protocol: Run-time speed;
  - Varying parameters or configuration: easy to use.
- C++ is fast to run but slower to code and change;
- OTcl is easy to code but runs slowly.

Protocols/Models supported by NS2

- Wired Networking
  - Routing: Unicast, Multicast, and Hierarchical Routing, etc.
  - Transportation: TCP, UDP, others;
  - Traffic sources: web, ftp, telnet, cbr, etc.
  - Queuing disciplines: drop-tail, RED, etc.
  - QoS: IntServ and Diffserv Wireless Networking
- Ad hoc routing and mobile IP
  - Routing Protocol: AODV, DSDV, DSR, etc.
  - MAC layer Protocol: TDMA, CDMA(?), IEEE Mac 802.x, etc.
  - Physical layers: different channels(?), directional attena
- Sensor Networks

Researches based on NS2

- Intserv/Diffserv (QoS)
- Multicast: Routing, Reliable multicast
- Transport: TCP Congestion control
- Application: Web caching Multimedia
- Sensor Networks: LEACH, Directed Diffusion, etc.
- etc.

NS2 research actions

- NS2: the simulator itself, now version: ns-2.29
  We will work with the part mostly.

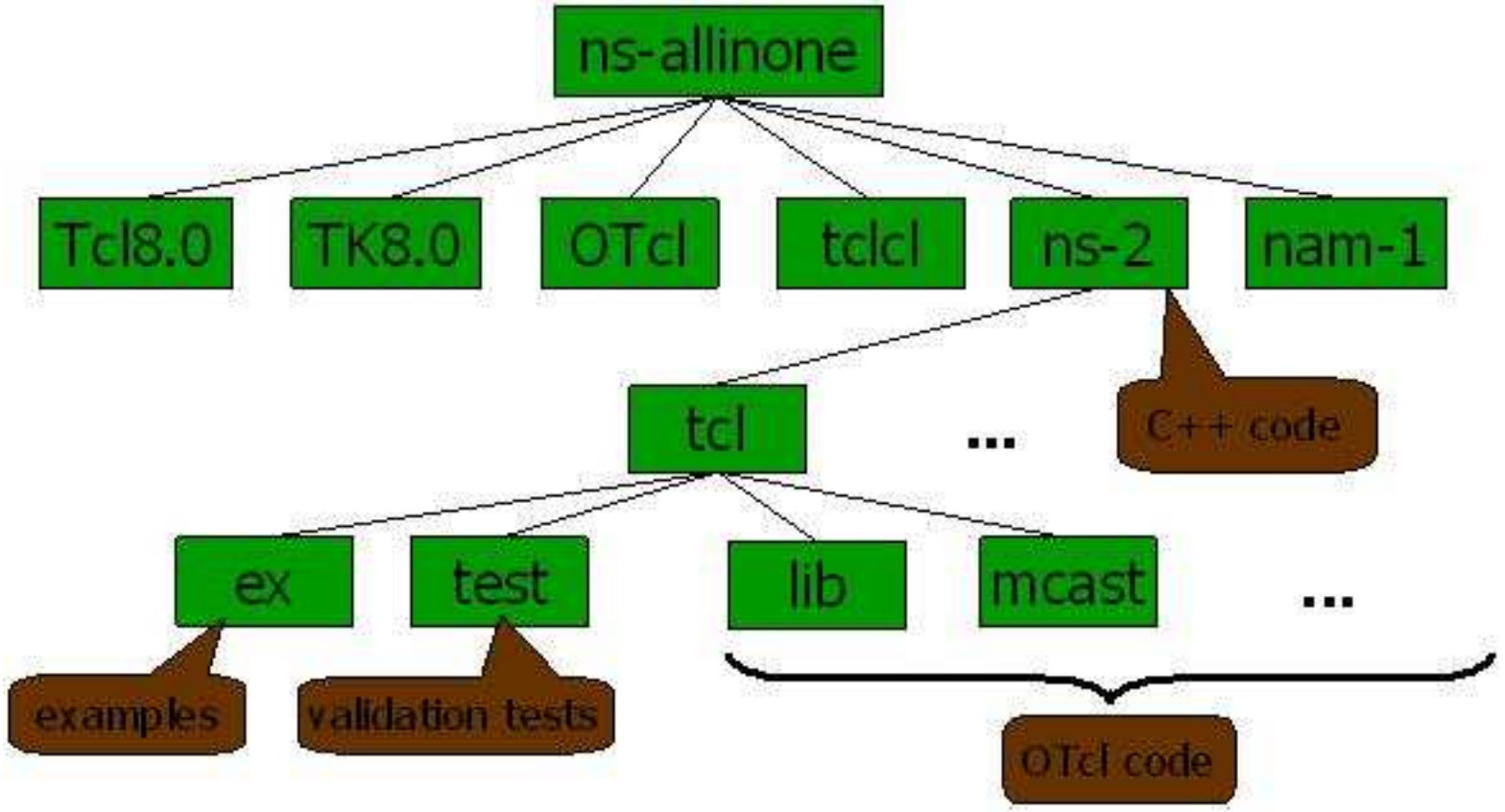
- NAM: Network animator. Visualized trace tool(not really).
  My recommendation is that ”Don’t use nam at all”.

- Pre-processing:
  Traffic and topology generators

- Post-processing:
  Simple trace analysis, often in Awk, Perl(mostly), or Tcl

Living under NS2

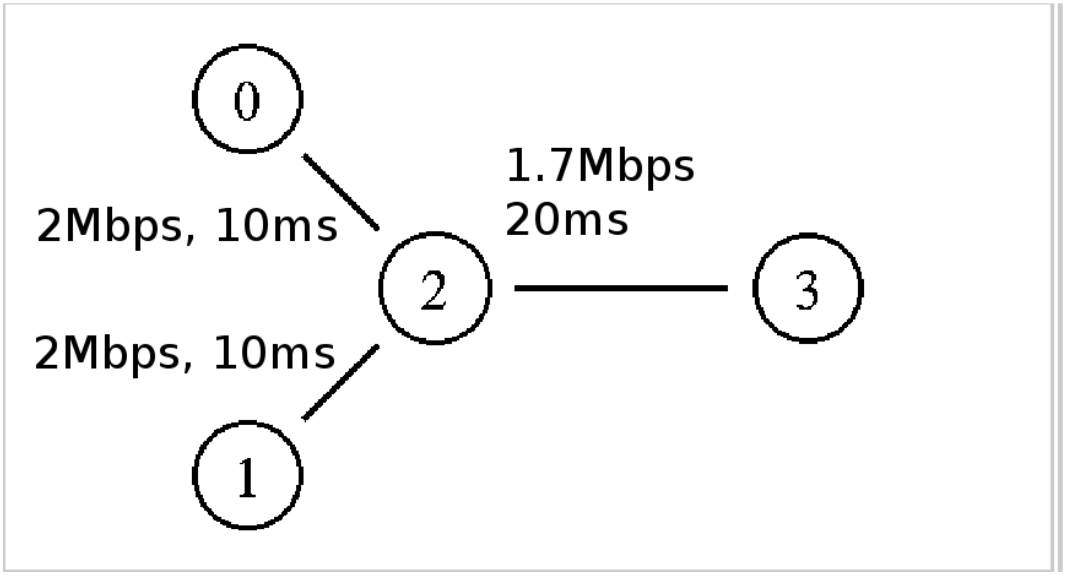
The NS2 Directory Structure



Warning

- Try to avoid using ns2 with version before 2.27
- DO NOT use gcc 4.x, suggestion: gcc3.3
- If you work with MAC layer protocols, please be careful for the versions

A Simple Simulation



We just need one Tcl script to do so.

A Simple Simulation, part 1: set up

```
set ns [new Simulator]                  ;#Create a simulator object

$ns use-scheduler Heap                  ;#Specify the scheduler, default: List Scheduler

                                        ;#Define different colors for data flows (for NAM)
$ns color 1 Blue
$ns color 2 Red


                                        ;#Create trace files for simulation
set nf [open out.nam w]
$ns namtrace-all $nf
set tf [open trace.tr w]
$ns trace-all $tf


                                        ;#Define a 'finish' procedure
proc finish {} {
        global ns nf tf
        $ns flush-trace

        #Close the NAM trace file
        close $nf

        #Close the ns2 trace file
        close $tf

        exit 0
}
```

A Simple Simulation, part 2: n/w structure

```
#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

#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 the queue for link (n2-n3). (for NAM)

$ns duplex-link-op $n2 $n3 queuePos 0.5
```

A Simple Simulation, part 3: Transport and Traffic

```
#Setup a TCP connection: from node 0 to node 3

set tcp [new Agent/TCP]
$ns attach-agent $n0 $tcp
set sink [new Agent/TCPSink]
$ns attach-agent $n3 $sink
$ns connect $tcp $sink
$tcp set fid_ 1

#Setup a FTP over TCP connection

set ftp [new Application/FTP]
$ftp attach-agent $tcp
$ftp set type_ FTP                ;#for Nam

#Setup a UDP connection: from node 1 to node 3

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
```

A Simple Simulation, part 4: traffic

```
#Setup a CBR over UDP connection

set cbr [new Application/Traffic/CBR]
$cbr attach-agent $udp $cbr
set type_ CBR $cbr            ;#used by Nam

set packet_size_ 1000 $cbr
set rate_ 1mb $cbr
set random_ false             ;#generating traffic periodically

#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"


#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"

#Run the simulation

$ns run
```

Steps in writing a simulating script

- Create the event scheduler
- Turn on tracing
- Create network
- Setup routing
- Insert errors
- Create transport connection
- Create traffic
- Transmit application-level data

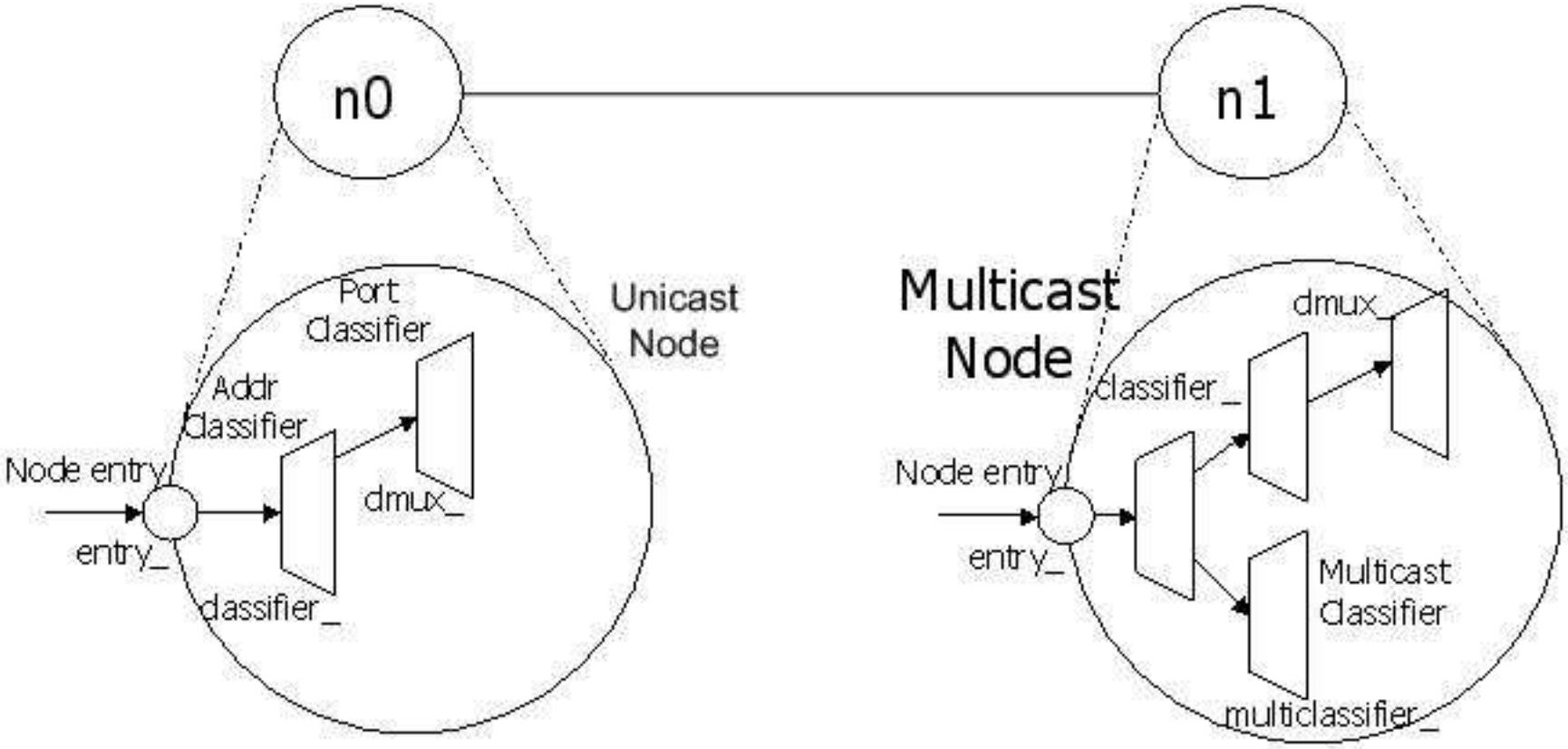
The trace file

- Turn on tracing on specific links
  `$ns_ trace-queue $n0 $n1`
- Each line in the trace file is in the format:
  $< event >\ \ < time >\ \ < from >\ \ < to >\ \ < pkt-type >$
  $< pkt-size >\ \ < flags >\ \ < fid >\ \ < src.port >\ \ < dst.port >$
  $< seq >\ \ < unique\ pkt\ id >$
- Trace example:

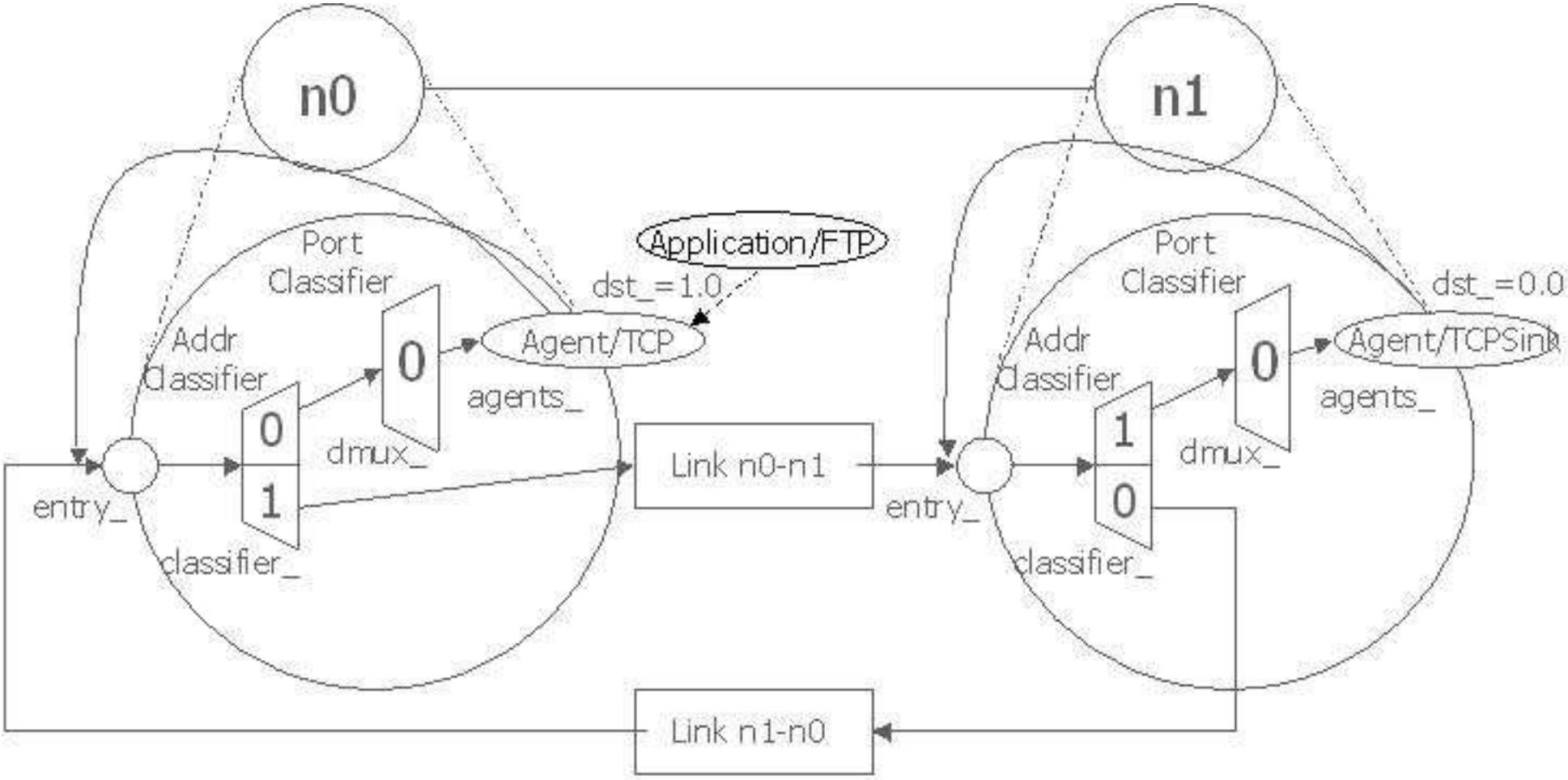
```
+ 1 0 2 cbr 210 ------- 0 0.0 3.1 0 0
- 1 0 2 cbr 210 ------- 0 0.0 3.1 0 0
r 1.00234 0 2 cbr 210 ------- 0 0.0 3.1 0 0
```

- Event: s send, r receive, $+$ enqueue, $-$ dequeue, d drop, f forward,

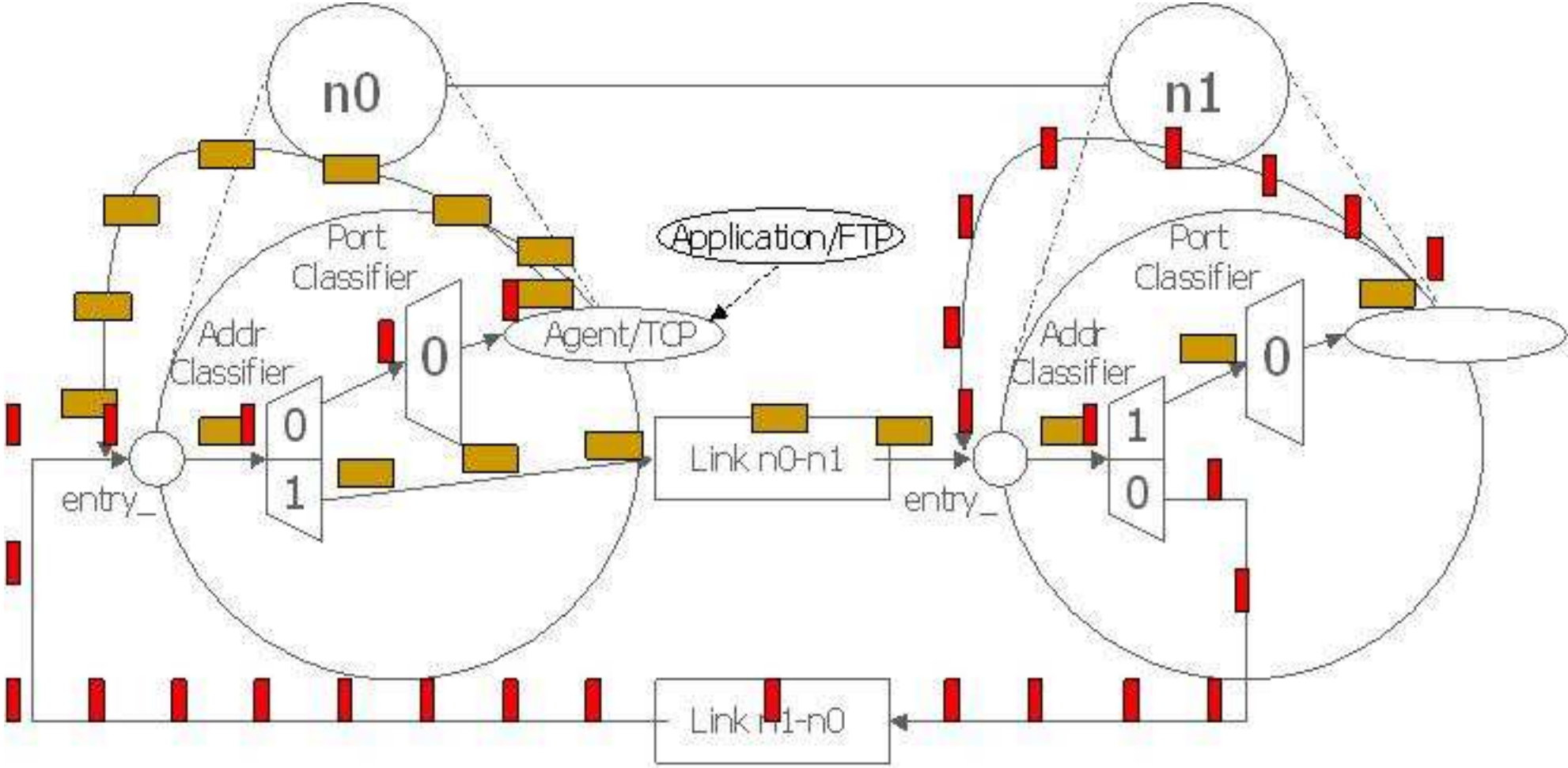
The network Topology



The Node Architecture

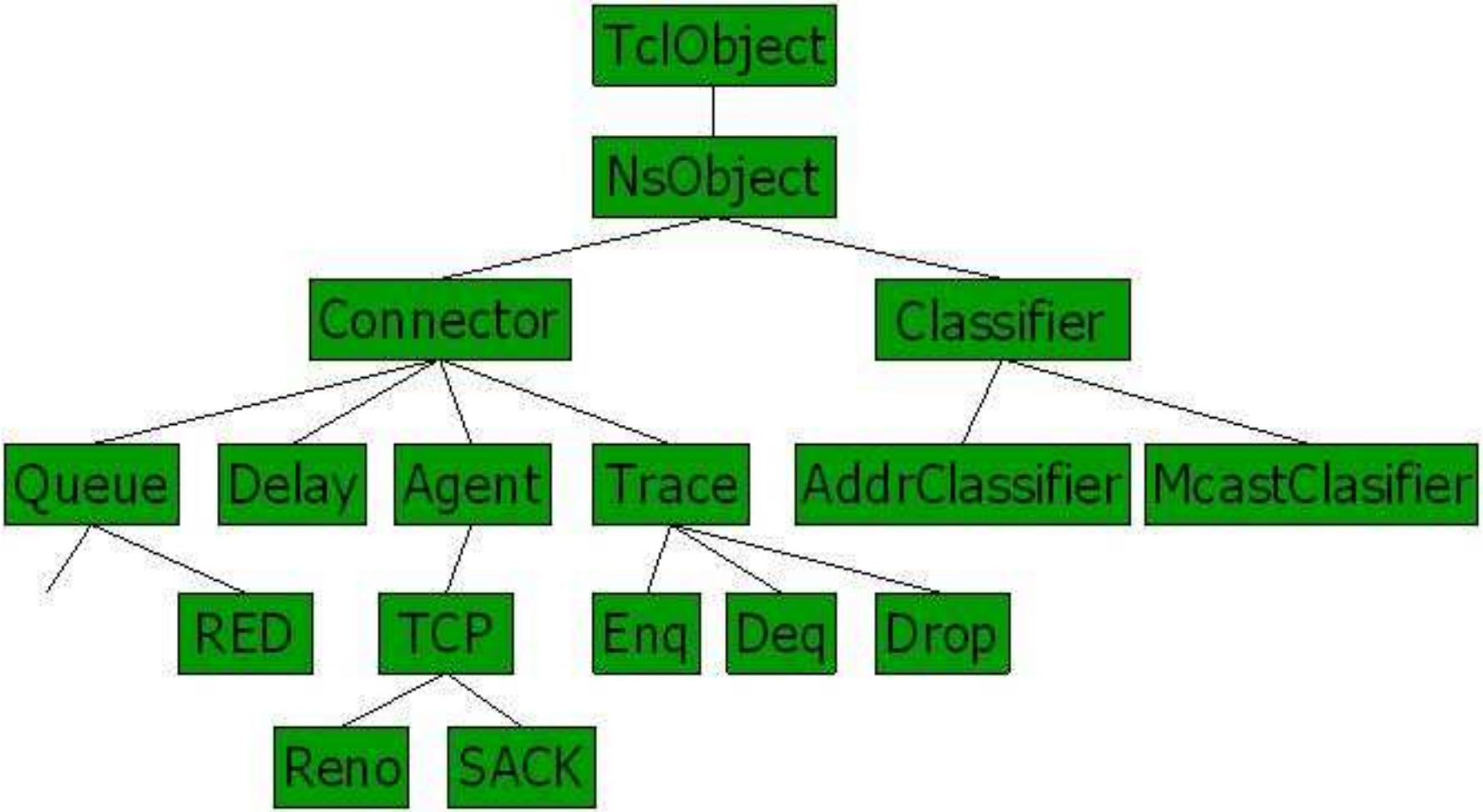


The Packet Flow



Extending to NS2

Class Hierarchy in NS2(Partial, C++ code)



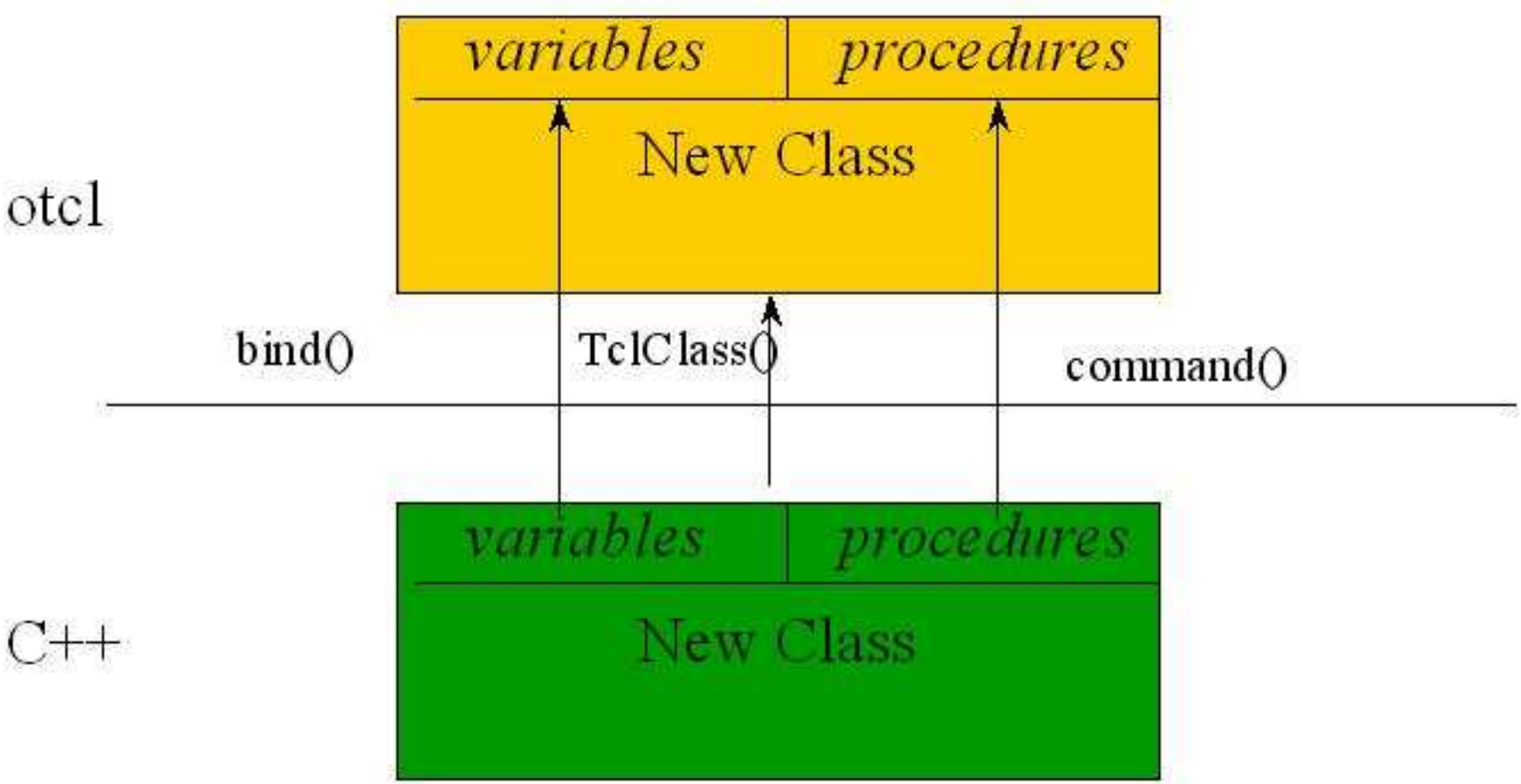
Create New Component for NS2

Your research needs you to do so, no escaping(crying!!!).

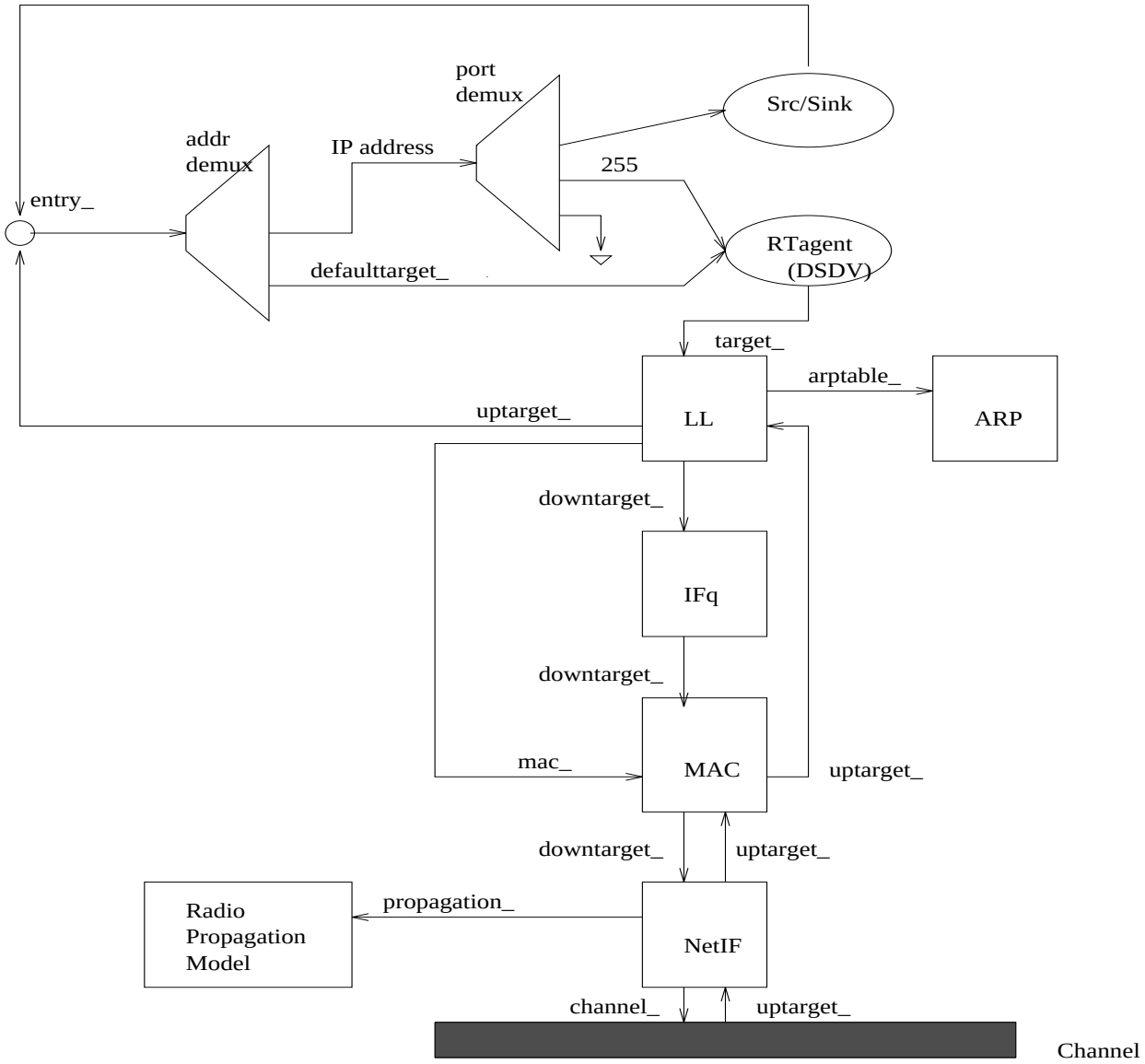
- Extending ns in Otcl
  source your changes in your simulation scripts

- Extending ns in C++
  - Change Makefile (if created new files)
  - make depend
  - recompile
  - Makefile is in the ”ns-2.29” directory

Adding New Class



C++ Code Architecture of a Mobile Node (DSDV)



A component at some layer of each node

- Up target: except the highest layer component
- Down target: even the lowest layer component
- Timers: triggering some actions
- Send: either to up or down neighbor
- Recv: from either up or down neighbor

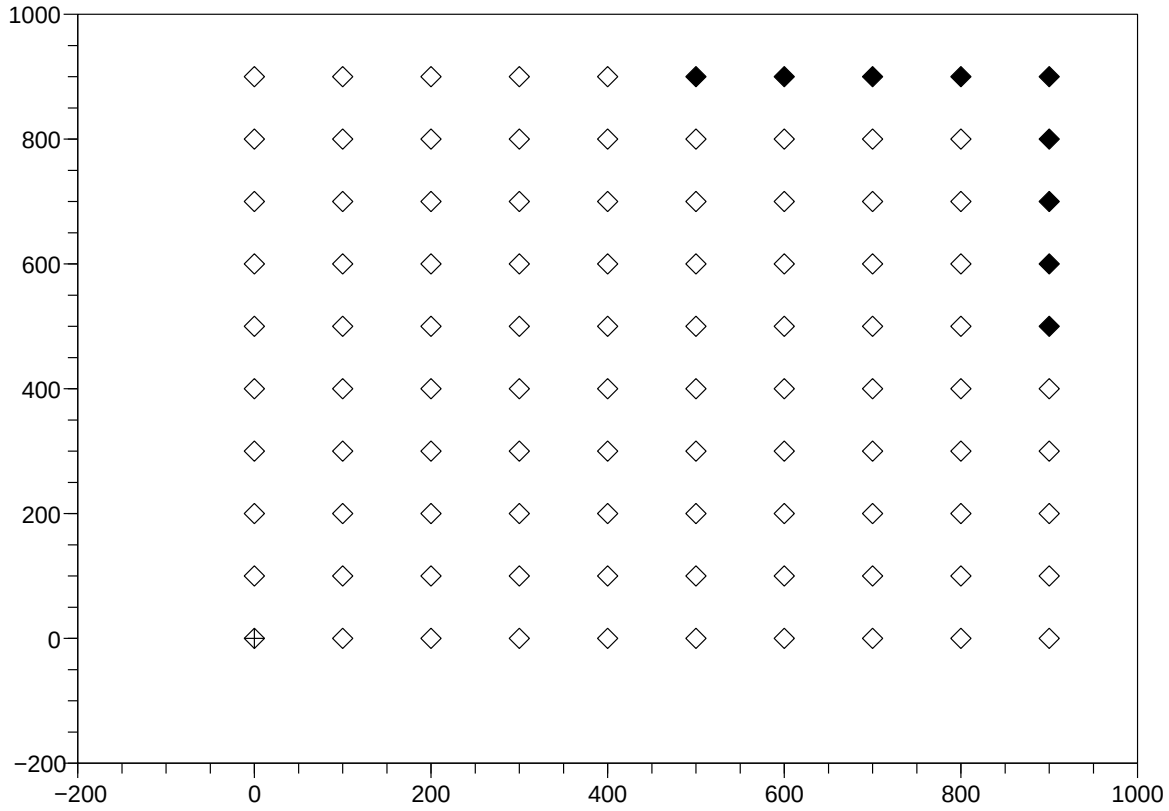
Assigments

- Finish the following sections of the tutorial on link http://nile.wpi.edu/NS/
  - Purpose
  - Overview
  - Basics
  - Post Simulation
  - Extending NS: where to Find What?

- Understand how to simulate the DSR and DSDV routing with ns2. You may use the NS2 manual.

- Optional: A document showing how to code a new routing agent http://masimum.dif.um.es/nsrt-howto/html/nsrt-howto.html

Project Assignment 1



Project Assignment 1: requirement

- Wireless simulation: using BOTH DSDV and DSR routing;
- You should trace Agent, Routing Agent, Mac;
- You DON'T need to create nam trace;
- Create 9 CBR flows upon UDP transportation to one node.
- CBR Packet Size: 1024 Bytes, interval 1.0 sec, Simulation(Traffic) Time: 120 sec;
- No other parameter's default value should be changed;
- All 9 flows start at the same time, so as end.

How to code a new Routing Agent

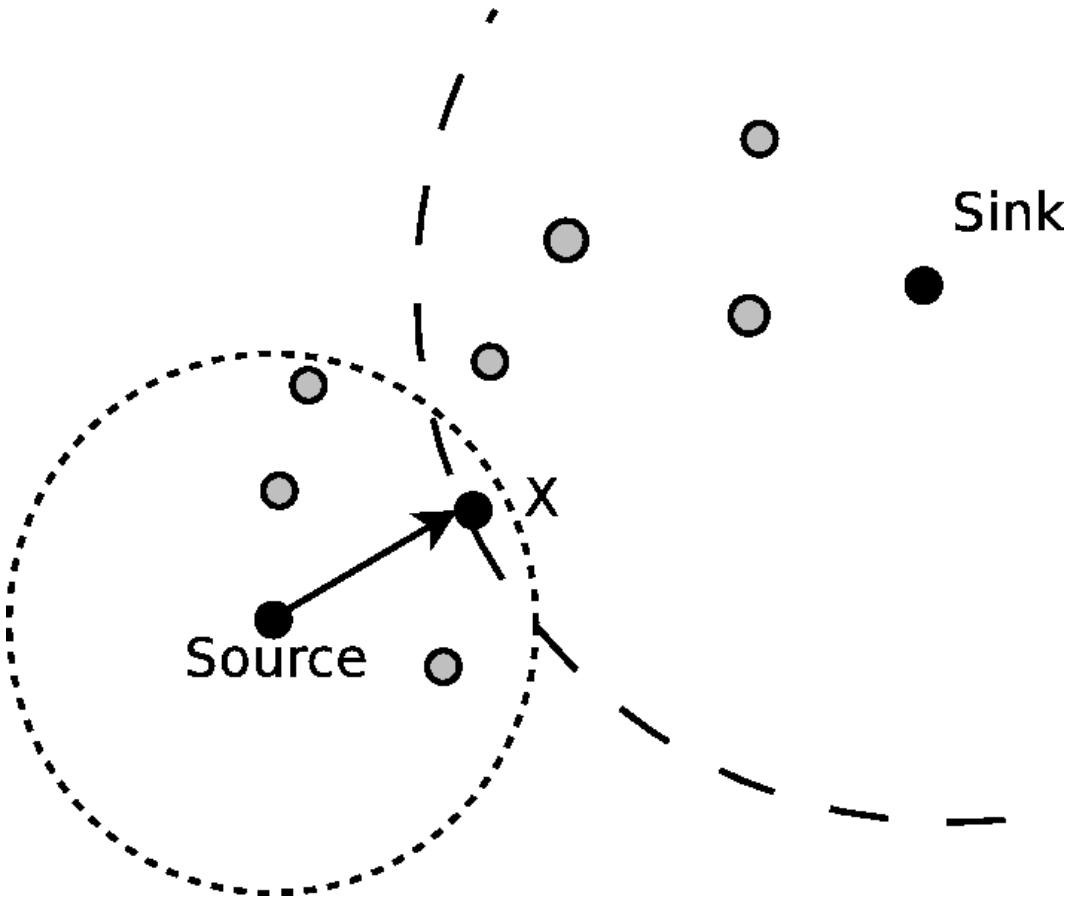
Steps

- Packet header design
- Packet header globalizing
- Routing Agent design
- Timer Design
- Tcl script commands Design
- Tcl linkage

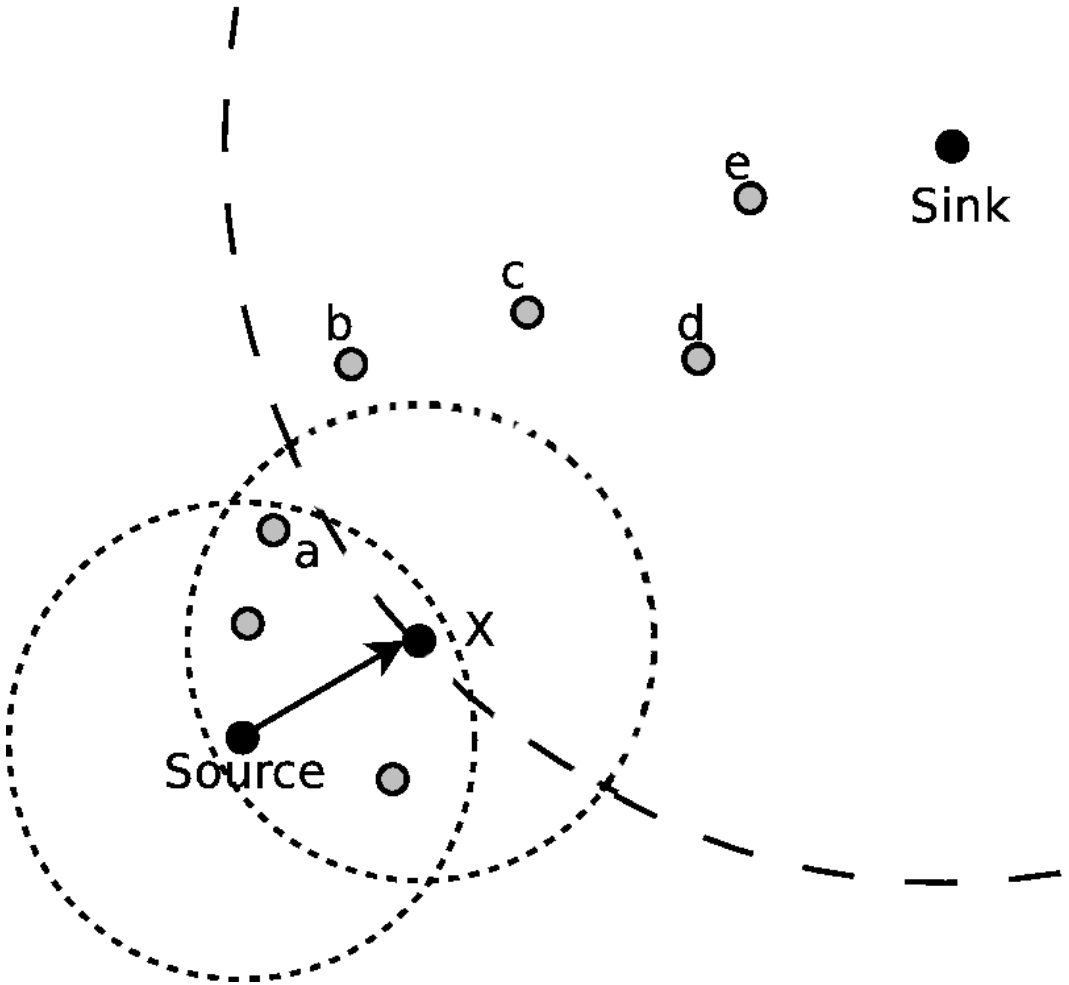
Objective: GPSR routing

- MobiCom 2000
- B. Karp and H.T. Kung, Harvard University
- *GPSR: Greedy Perimeter stateless Routing for Wireless Networks*
- Stateless Point-to-Point Routing based on Location information

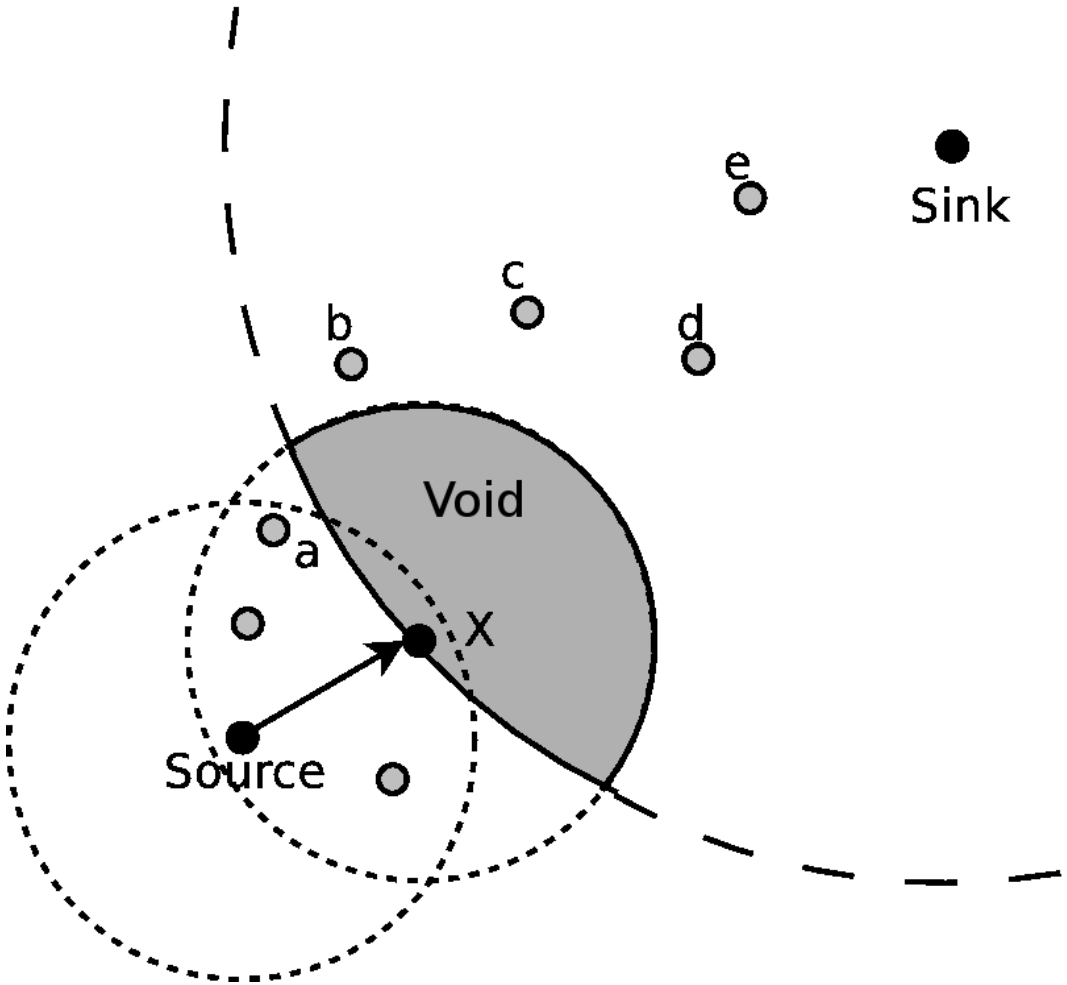
GPSR: Greedy Forwarding



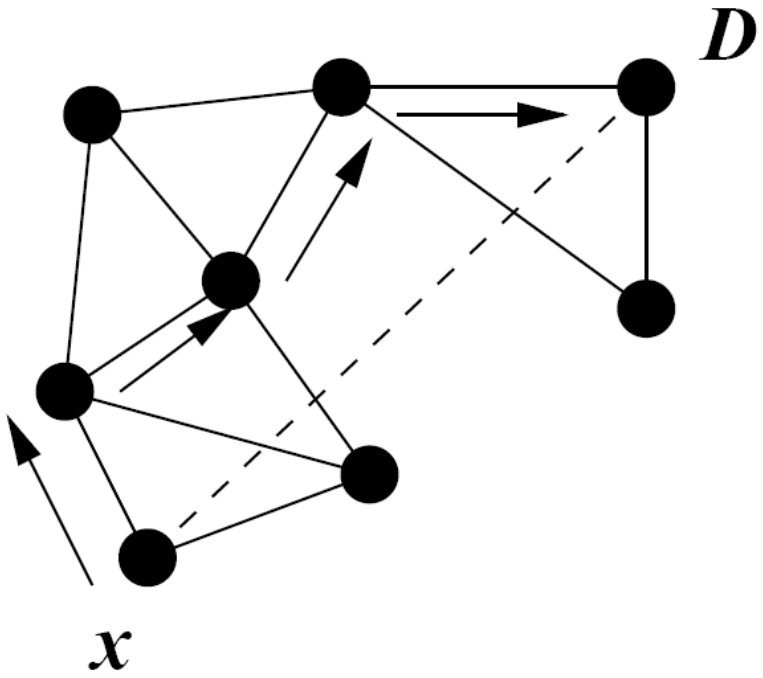
GPSR: GF Failure



GPSR: Void Problem



GPSR: Perimeter (Face) Routing



Planarizing the Graph (mapped from network), routing around faces to sink

Packet Header

```
struct hdr_gpsr {
  u_int8_t type_;

  static int offset_;
  inline static int& offset() {return offset_;}
  inline static struct hdr_gpsr* access(const Packet *p){
    return (struct hdr_gpsr*) p->access(offset_);
  }
};
```

Packet Header

```
struct hdr_gpsr_hello {
  u_int8_t type_;
  float x_;     //My geo info
  float y_;
  inline int size(){
    int sz =
      sizeof(u_int8_t) +
      2*sizeof(float);
    return sz;
  }
};
```

Packet Header

```
struct hdr_gpsr_query {
  u_int8_t type_;
  float x_;      //The sink geo info
  float y_;
  float ts_;     //time stampe
  int hops_;
  u_int8_t seqno_;     //query sequence number
  inline int size(){
    int sz =
      2*sizeof(u_int8_t) +
      3*sizeof(float) +
      sizeof(int);
    return sz;
  }
};
```

Packet Header

```
struct hdr_gpsr_data {
  u_int8_t type_;
  u_int8_t mode_;  //Greedy forwarding or Perimeter Routing

  float sx_;      //the geo info of src
  float sy_;
  float dx_;      //the geo info of dst
  float dy_;
  float ts_;      //the originating time stamp
  inline int size(){
    int sz =
      2*sizeof(u_int8_t) +
      5*sizeof(float);
    return sz;
  }
};
```

Packet Header

```
union hdr_all_gpsr {
  hdr_gpsr       gh;
  hdr_gpsr_hello ghh;
  hdr_gpsr_query gqh;
  hdr_gpsr_data  gdh;
};
```

Routing Agent

```
class GPSRAgent : public Agent {
  MobileNode *node_;
  PortClassifier *port_dmux_;
    ...
  GPSRNeighbors *nblist_; //neighbor list (routing table)
    ...
  GPSRHelloTimer hello_timer_;
  double hello_period_;
  void hellomsg();
  void recvHello(Packet*);
    ...
  void GetLocation(double*, double*);
    ...
  void forwardData(Packet*);
```

Routing Agent

```
protected:
  void hellotout();
    ...
public:
  GPSRAgent();

  int command(int, const char*const*);
  void recv(Packet*, Handler*);
};
```

Routing Table

- Maintaining the routing information;
- Able to decide a next hop when required;
- It is a part of the routing agent;
- It may just a local object, not a global object (NsObject)

Initializing: variables binding

- The configuration of routing agent can be done through the tcl script by calling ”bind” function, which does not requiring re-compiling when we change the value of it (Example Later);

```
GPSRAgent::GPSRAgent() : Agent(PT_GPSR),
                         hello_timer_(this){
    ...
    bind("hello_period_", &hello_period_);
    ...
}
```

Packet forwarding: on Receiving

- According to the packet type, taking different actions

```
void GPSRAgent::recv(Packet *p){
  if(iph->saddr() == my_id_){//a packet generated by myself
    if(cmh->num_forwards() == 0){ //coming from higher layer
        ...    //append some routing information
        forwardData(p); //forward it
        return;
    }
    else if(cmh->num_forwards() > 0){//routing loop
        ...  //typically drop it
    }
```

Packet forwarding: Classifying

```
  ...
if(cmh->ptype() == PT_GPSR){
  struct hdr_gpsr *gh = HDR_GPSR(p);
  switch(gh->type_){
  case GPSRTYPE_HELLO:
    recvHello(p);
    break;
  ...
  }else { //Data packet coming from others
      iph->ttl_--;
      if(iph->ttl_ == 0){ //ttl expire
          drop(p, DROP_RTR_TTL);
          return;
      }
    forwardData(p);
  }
```

Packet forwarding: on forwarding

```
void GPSRAgent::forwardData(Packet *p){
  struct hdr_cmn *cmh = HDR_CMN(p);
  struct hdr_ip *iph = HDR_IP(p);

  if(cmh->direction() == hdr_cmn::UP &&
     ((nsaddr_t)iph->daddr() == IP_BROADCAST ||
      iph->daddr() == my_id_)){ //a packet sent to me !!
    port_dmux_->recv(p, 0);   //forward to higher layer
    return;
    }
```

Packet forwarding: on forwarding

```
else{
    ... //update the routing info in the packet header
    cmh->direction() = hdr_cmn::DOWN; //to lower layers
    cmh->addr_type() = NS_AF_INET;
    cmh->next_hop_ = nexthop; //change the next hop
    send(p, 0);
}
```

Agent Tcl script Commands

```
int GPSRAgent::command(int argc, const char*const* argv){
    ...
    if(strcasecmp(argv[1], "log-energy")==0){
      if(node_ && node_->energy_model()){
        //record the energy
      }
      return TCL_OK;
    }
    TclObject *obj;
    if ((obj = TclObject::lookup (argv[2])) == 0){
      fprintf(stderr, "%s: %s lookup of %s failed\n",
              __FILE__, argv[1],argv[2]);
      return (TCL_ERROR);
    }
```

Agent Tcl script Commands

```
    if (strcasecmp (argv[1], "node") == 0) {
      node_ = (MobileNode*) obj;
      return (TCL_OK);
    }
    else if (strcasecmp (argv[1], "port-dmux") == 0) {
      port_dmux_ = (PortClassifier*) obj; //(NsObject *) obj;
      return (TCL_OK);
    }
}
```

Globalizing

```
static class
GPSRHeaderClass : public PacketHeaderClass{
public:
  GPSRHeaderClass() : PacketHeaderClass("PacketHeader/GPSR",
                                        sizeof(hdr_all_gpsr)){
    bind_offset(&hdr_gpsr::offset_);
  }
}class_gpsrhdr;

static class GPSRAgentClass : public TclClass { public:
  GPSRAgentClass() : TclClass("Agent/GPSR"){}
  TclObject *create(int, const char*const*){
    return (new GPSRAgent());
  }
}class_gpsr;
```

Routing Protocol Control: Timers

```
class GPSRHelloTimer : public TimerHandler {
public:
  GPSRHelloTimer(GPSRAgent *a) : TimerHandler() {a_=a;}
protected:
  virtual void expire(Event *e);
  GPSRAgent *a_;
};
void GPSRHelloTimer::expire(Event *e){
  a_->hellomsg();
}
void GPSRAgent::hellomsg(){
    ...
    hello_timer_.resched(hello_period_);
}
```

Changes to NS2: Packet type: *common/packet.h*

```
enum packet_t {
    PT_TCP,
    ...
    PT_GPSR,  //add
    ...
};

class p_info{
    p_info(){
        name_[PT_TCP] = "tcp";
        ...
        name_[PT_GPSR] = "gpsr";   //add
        ...
};
```

Changes to NS2: Trace support *trace/cmu-trace.cc*

```
void CMUTrace::format(Packet *p, const char* why){
    ...
    case PT_TCP:
        break;
    ...
    case PT_GPSR:   //add
        break;      //add
    default:
    ...
}
```

Changes to NS2: Tcl Library *tcl/lib/ns-packet.tcl*

```
foreach prot {
    AODV
    DSR
    ...
    GPSR      ;# add
    ...
}
```

Make it running: *Makefile*

```
OBJ_CC =
    ...
    $(OBJ_STL)  \
    gpsr/gpsr.o   #add
```

Simulation: *wireless-gpsr.tcl*

```
    ...
Agent/GPSR set hello_period_   5.0 ;#Hello message period
    ...
for {set i 0} {$i < $opt(nn)} {incr i} {
    $ns_ at [expr $opt(stop) - 0.1] "$ragent_($i) log-energy"
}
```

Trace Analyzing

```
s 5.054902765 _54_ RTR  --- 112 gpsr 29 [0 0 0 0]
    [energy 999.975614] ------- [54:255 -1:255 32 0]

r 5.055969912 _44_ RTR  --- 112 gpsr 29 [0 ffffffff 36 800]
    [energy 999.975102] ------- [54:255 -1:255 32 0]
```

Thank You !

Any Questions?

My email: *kliu@cs.binghamton.edu*