Extending ns

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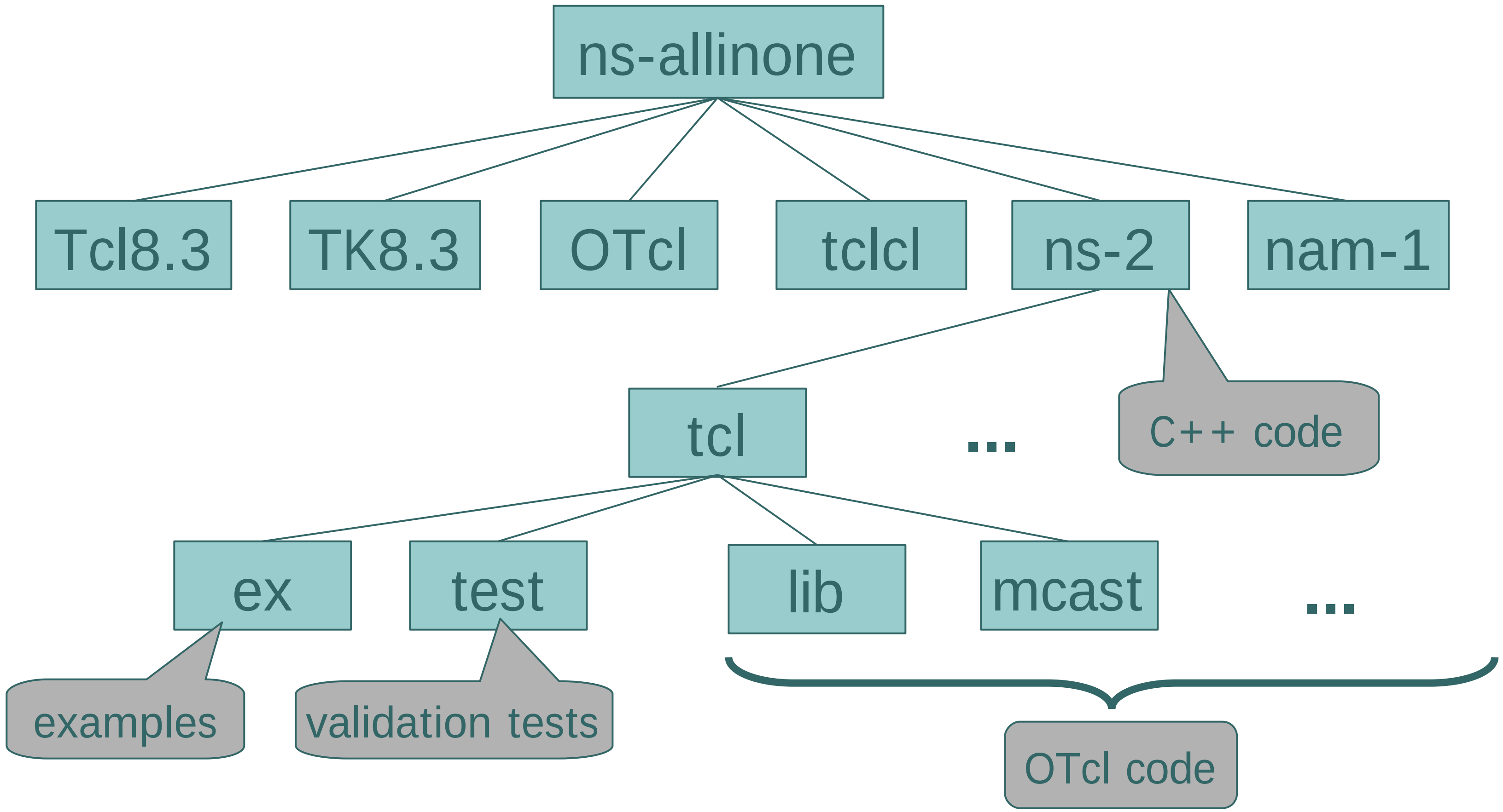
Outline

- Extending ns
  - In OTcl
  - In C++
- Debugging

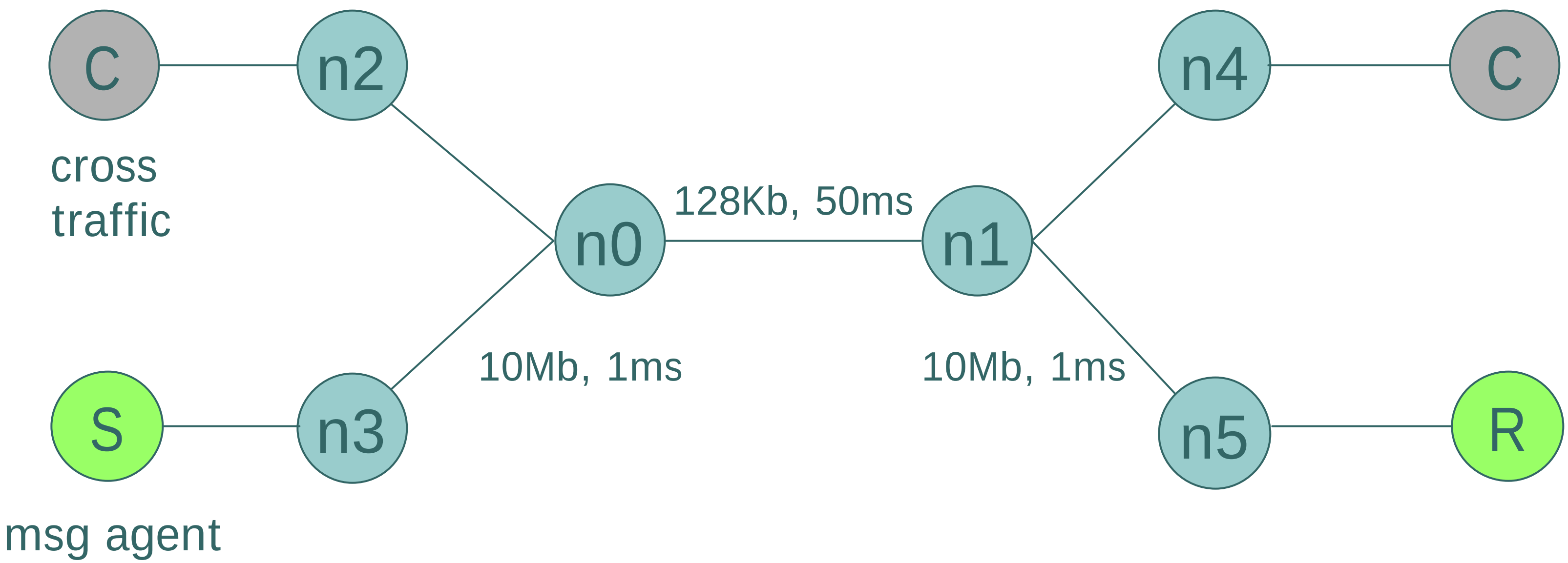
ns Directory Structure



Extending ns in OTcl

- If you don’t want to compile
  - `source` your changes in your sim scripts
- Otherwise
  - Modifying code; recompile
  - Adding new files
    - Change Makefile (NS_TCL_LIB), tcl/lib/ns-lib.tcl
    - Recompile

Example: Agent/Message



Agent/Message

pkt: 64 bytes of arbitrary string

Receiver-side processing

- A UDP agent (without UDP header)
- Up to 64 bytes user message
- Good for fast prototyping a simple idea
- Usage requires extending ns functionality

Agent/Message: Step 1

- Define sender

```
class Sender –superclass Agent/Message

# Message format: “Addr Op SeqNo”
Sender instproc send-next {} {
    $self instvar seq_ agent_addr_
    $self send “$agent_addr_ send $seq_”
    incr seq_
    global ns
    $ns at [expr [$ns now]+0.1] "$self send-next"
}
```

Agent/Message: Step 2

- Define sender packet processing

```
Sender instproc recv msg {
    $self instvar agent_addr_
    set sdr [lindex $msg 0]
    set seq [lindex $msg 2]
    puts "Sender gets ack $seq from $sdr"
}
```

Agent/Message: Step 3

- Define receiver packet processing

```
Class Receiver –superclass Agent/Message
Receiver instproc recv msg {
    $self instvar agent_addr_
    set sdr [lindex $msg 0]
    set seq [lindex $msg 2]
    puts “Receiver gets seq $seq from $sdr”
    $self send “$addr_ ack $seq”
}
```

Agent/Message: Step 4

- Scheduler and tracing

```
# Create scheduler
set ns [new Simulator]

# Turn on Tracing
set fd [new “message.tr” w]
$ns trace-all $fd
```

Agent/Message: Step 5

- Topology

```
for {set i 0} {$i < 6} {incr i} {
    set n($i) [$ns node]
}
$ns duplex-link $n(0) $n(1) 128kb 50ms DropTail
$ns duplex-link $n(1) $n(4) 10Mb 1ms DropTail
$ns duplex-link $n(1) $n(5) 10Mb 1ms DropTail
$ns duplex-link $n(0) $n(2) 10Mb 1ms DropTail
$ns duplex-link $n(0) $n(3) 10Mb 1ms DropTail

$ns queue-limit $n(0) $n(1) 5
$ns queue-limit $n(1) $n(0) 5
```

Agent/Message: Step 6

- Routing

```
# Packet loss produced by queueing

# Routing protocol: let’s run distance
vector
$ns rtproto DV
```

Agent/Message: Step 7

- Cross traffic

```
set udp0 [new Agent/UDP]
$ns attach-agent $n(2) $udp0
set null0 [new Agent/NULL]
$ns attach-agent $n(4) $null0
$ns connect $udp0 $null0

set exp0 [new
Application/Traffic/Exponential]
$exp0 set rate_ 128k
$exp0 attach-agent $udp0
$ns at 1.0 “$exp0 start”
```

Agent/Message: Step 8

- Message agents

```
set sdr [new Sender]
$sdr set seq_ 0
$sdr set packetSize_ 1000

set rcvr [new Receiver]
$rcvr set packetSize_ 40

$ns attach-agent $n(3) $sdr
$ns attach-agent $n(5) $rcvr
$ns connect $sdr $rcvr
$ns at 1.1 “$sdr send-next”
```

Agent/Message: Step 9

- End-of-simulation wrapper (as usual)

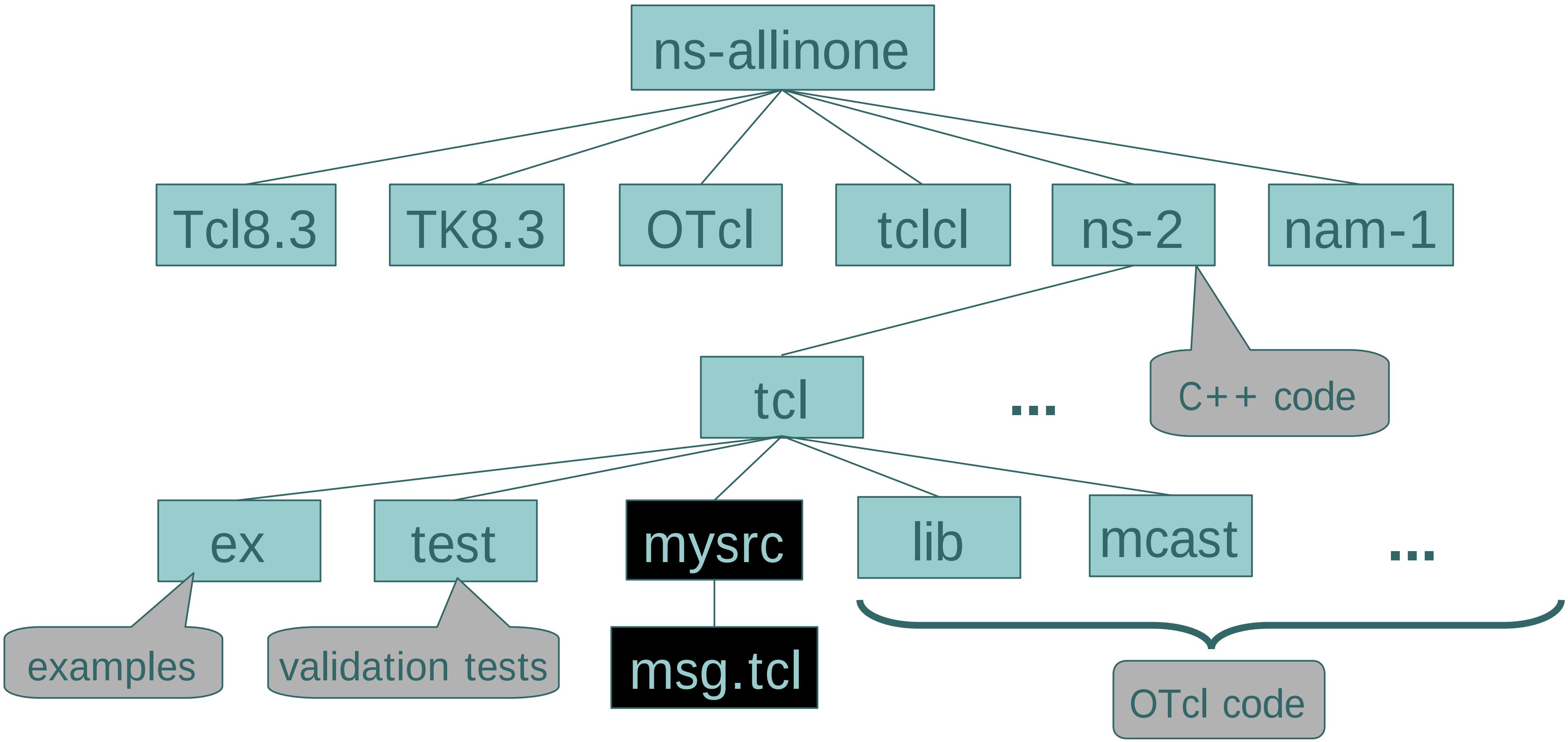
```
$ns at 2.0 finish
proc finish {} {
    global ns fd
    $ns flush-trace
    close $fd
    exit 0
}
$ns run
```

Agent/Message: Result

- Example output

```
> ./ns msg.tcl
Receiver gets seq 0 from 3
Sender gets ack 0 from 5
Receiver gets seq 1 from 3
Sender gets ack 1 from 5
Receiver gets seq 2 from 3
Sender gets ack 2 from 5
Receiver gets seq 3 from 3
Sender gets ack 3 from 5
Receiver gets seq 4 from 3
Sender gets ack 4 from 5
Receiver gets seq 5 from 3
```

Add Your Changes into ns



Add Your Change into ns

- tcl/lib/ns-lib.tcl

```
Class Simulator
…
source ../mysrc/msg.tcl
```

- Makefile

```
 NS_TCL_LIB = \
   tcl/mysrc/msg.tcl \
   …
```

  - Or: change Makefile.in, `make distclean`, then `./configure --enable-debug` , `make depend` and `make`

Outline

- Extending ns
  - In OTcl
  - In C++
    - New components

Extending ns in C++

- Modifying code
  - make depend
  - Recompile
- Adding code in new files
  - Change Makefile
  - make depend
  - recompile

Creating New Components

- Guidelines
- Two styles
  - New agent based on existing packet headers
  - Add new packet header

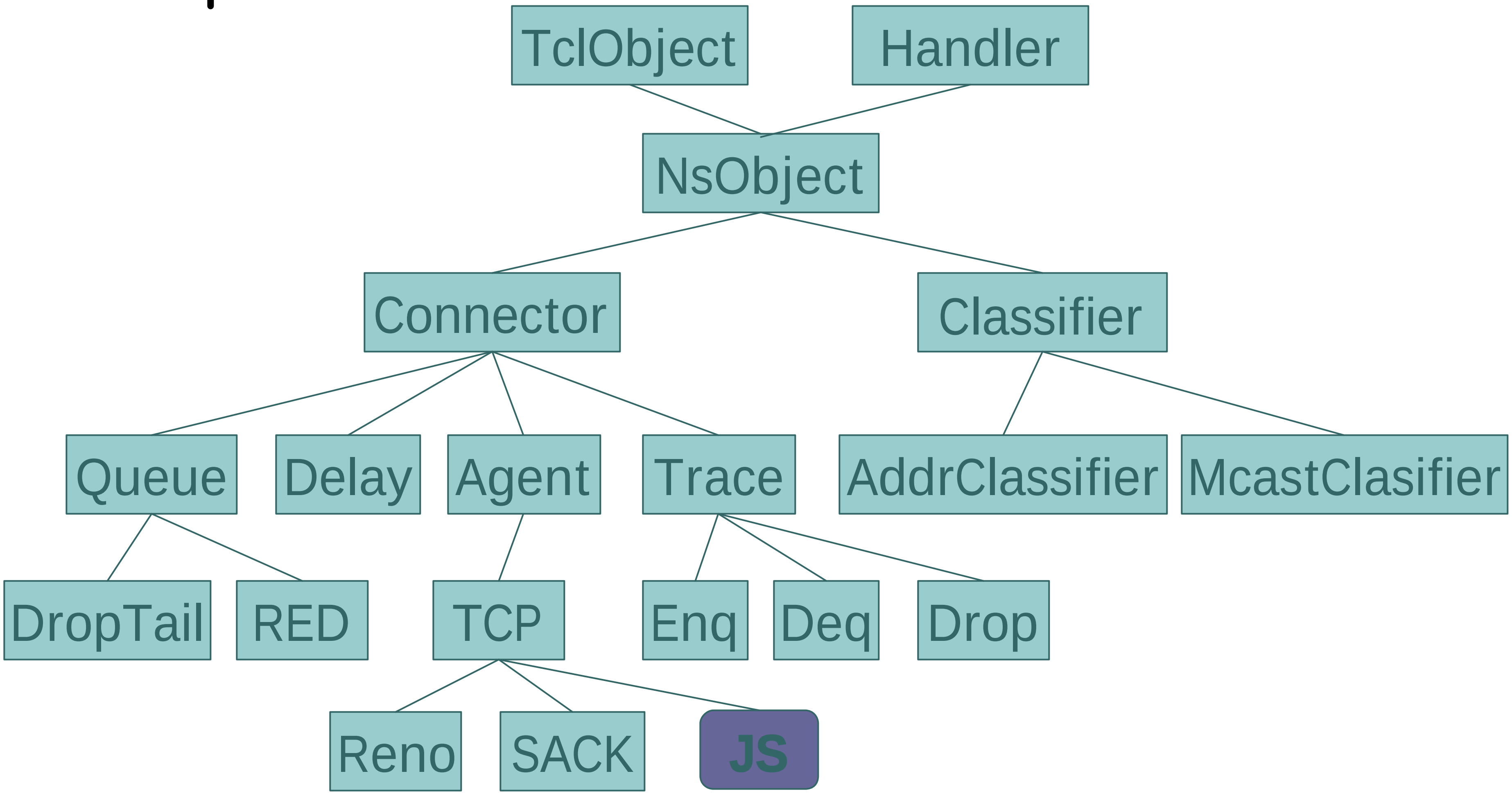
Guidelines

- Decide position in class hierarchy
  - I.e., which class to derive from?
- Create new packet header (if necessary)
- Create C++ class, fill in methods
- Define OTcl linkage (if any)
- Write OTcl code (if any)
- Build (and debug)

New Agent, Old Header

- TCP jump start
  - Wide-open transmission window at the beginning
  - From `cwnd_ += 1` To `cwnd_ = MAXWIN_`

TCP Jump Start – Step 1



TCP Jump Start – Step 2

- New file: tcp-js.h

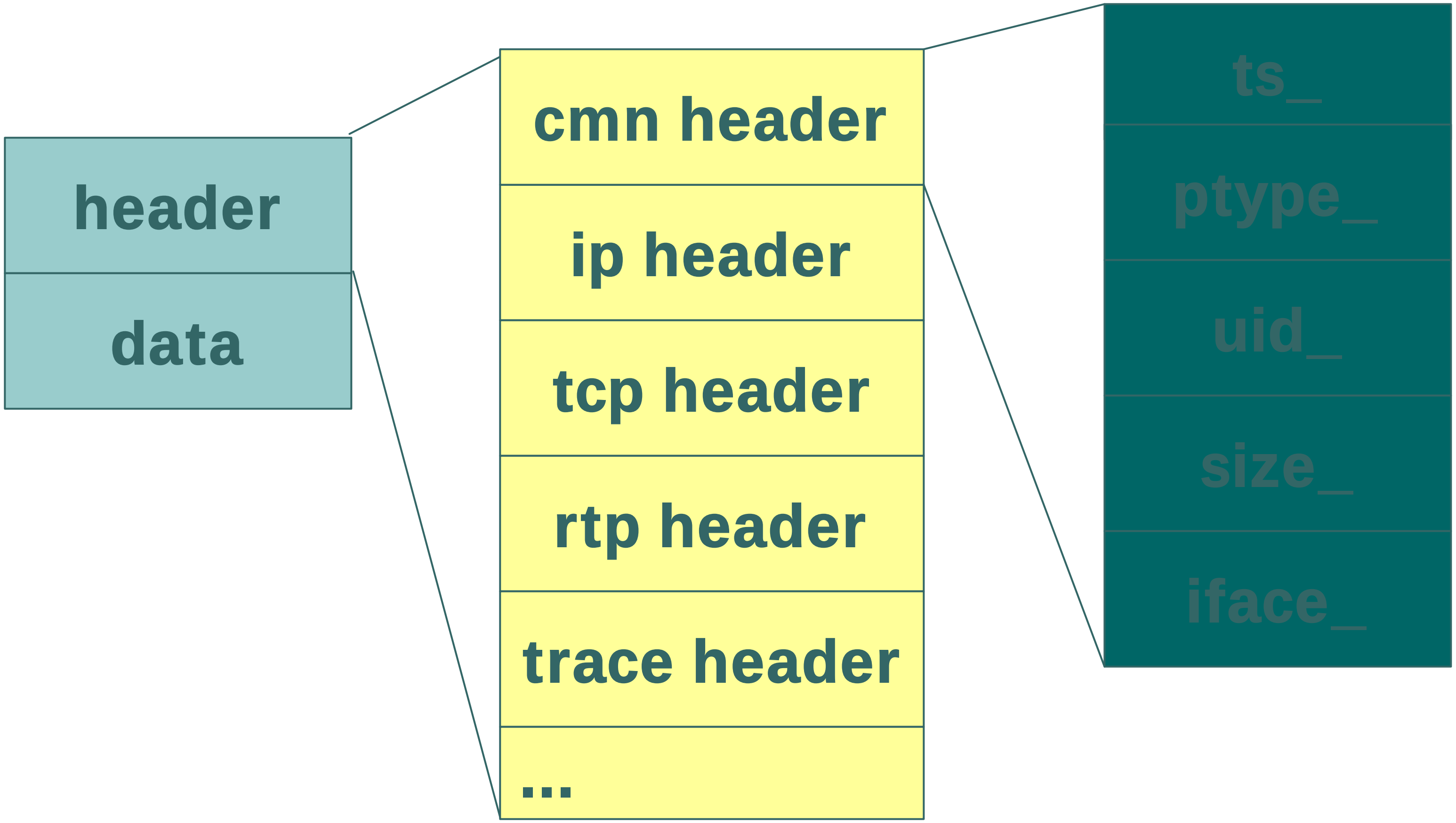
```
class JSTCPAgent : public TcpAgent {
public:
    virtual void set_initial_window() {
        cwnd_ = MAXWIN_;
    }
private:
    int MAXWIN_;
};
```

TCP Jump Start – Step 3

- New file: tcp-js.cc

```
static JSTcpClass : public TclClass {
public:
    JSTcpClass() : TclClass("Agent/TCP/JS")
{}
    TclObject* create(int, const
char*const*) {
            return (new JSTcpAgent());
    }
};
JSTcpAgent::JSTcpAgent() {
    bind(“MAXWIN_”, MAXWIN_);
}
```

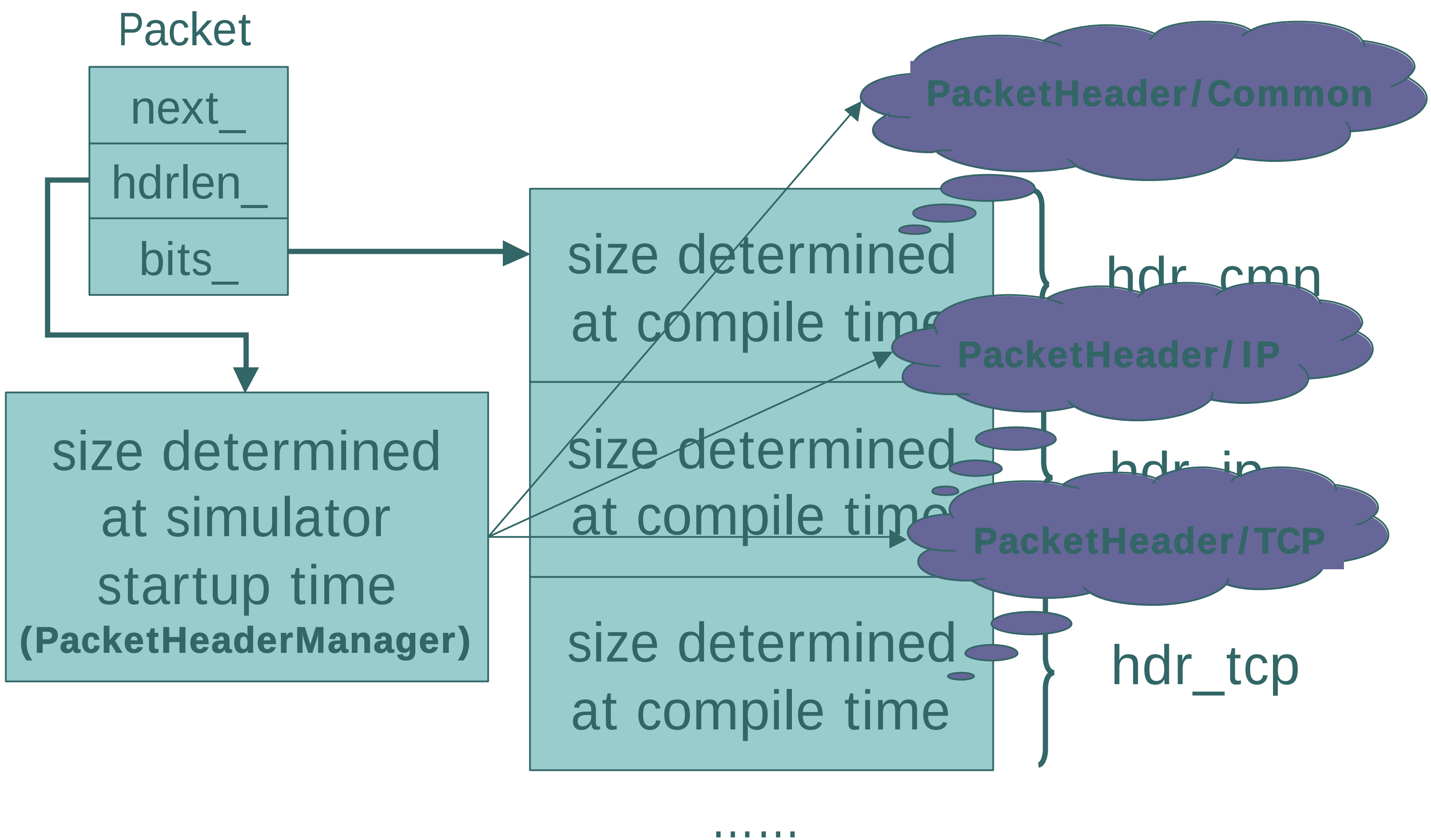
Packet Format



New Packet Header

- Create new header structure
- Enable tracing support of new header
- Create static class for OTcl linkage (packet.h)
- Enable new header in OTcl (tcl/lib/ns-packet.tcl)
- This does not apply when you add a new field into an existing header!

How Packet Header Works



Example: Agent/Message

- New packet header for 64-byte message
- New transport agent to process this new header

New Packet Header – Step 1

- Create header structure

```
struct hdr_msg {
  char msg_[64];
  static int offset_;
  inline static int& offset() { return
  offset_; }
  inline static hdr_msg* access(Packet* p) {
   return (hdr_msg*) p->access(offset_);
  }
  /* per-field member functions */
  char* msg() { return (msg_); }
  int maxmsg() { return (sizeof(msg_)); }
};
```

New Packet Header – Step 2

- PacketHeader/Message

```
static class MessageHeaderClass :
   public PacketHeaderClass {
public:
  MessageHeaderClass() :
  PacketHeaderClass("PacketHeader/Message
  ",

  sizeof(hdr_msg)) {
   bind_offset(&hdr_msg::offset_);
  }
} class_msghdr;
```

New Packet Header – Step 3

- Enable tracing (packet.h):

```
enum packet_t {
  PT_TCP,
  …,
  PT_MESSAGE,
  PT_NTYPE // This MUST be the LAST one
};
class p_info {
  ……
   name_[PT_MESSAGE] = “message”;
   name_[PT_NTYPE]= "undefined";
  ……
};
```

New Packet Header – Step 4

- Register new header (tcl/lib/ns-packet.tcl)

```
foreach pair {
  { Common off_cmn_ }
  …
  { Message off_msg_ }
}
```

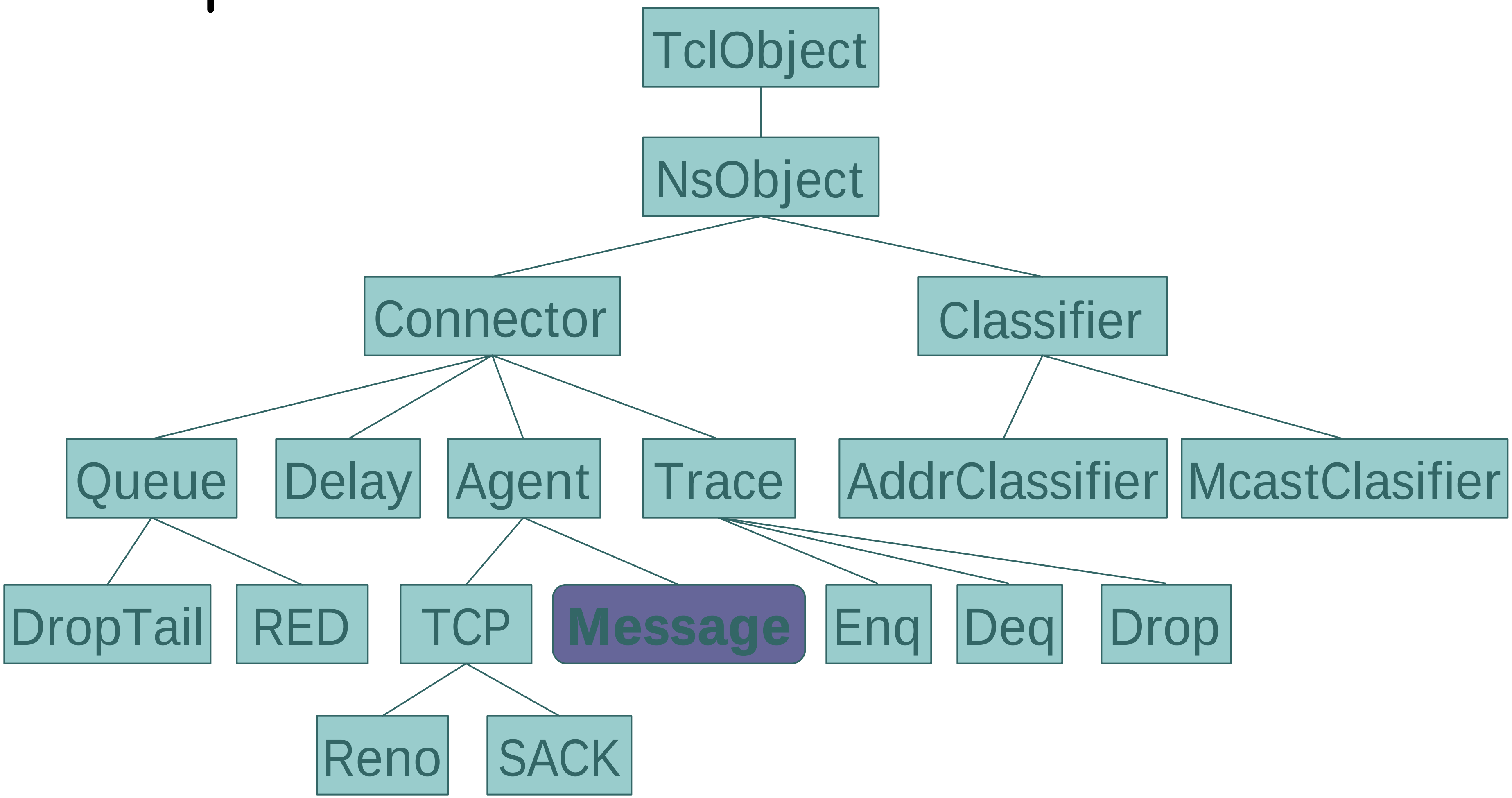
Packet Header: Caution

- Some old code, e.g.:

```
RtpAgent::RtpAgent() {
  ……
  bind("off_rtp_", &off_rtp);
}
……
hdr_rtp* rh = (hdr_rtp*)p-
  >access(off_rtp_);
```

- Don't follow this example!

Agent/Message – Step 1



Agent/Message – Step 2

- C++ class definition

```
// Standard split object declaration
static …

class MessageAgent : public Agent {
public:
  MessageAgent() : Agent(PT_MESSAGE) {}
  virtual int command(int argc, const char*const*
  argv);
  virtual void recv(Packet*, Handler*);
};
```

Agent/Message – Step 3

- Packet processing: send

```
int MessageAgent::command(int, const char*const*
   argv)
{
   Tcl& tcl = Tcl::instance();
   if (strcmp(argv[1], "send") == 0) {
    Packet* pkt = allocpkt();
    hdr_msg* mh = hdr_msg::access(pkt);
    // We ignore message size check...
    strcpy(mh->msg(), argv[2]);
    send(pkt, 0);
    return (TCL_OK);
   }
   return (Agent::command(argc, argv));
}
```

Agent/Message – Step 4

- Packet processing: receive

```
void MessageAgent::recv(Packet* pkt, Handler*)
{
  hdr_msg* mh = hdr_msg::access(pkt);

  // OTcl callback
  char wrk[128];
  sprintf(wrk, "%s recv {%s}", name(), mh->msg());
  Tcl& tcl = Tcl::instance();
  tcl.eval(wrk);

  Packet::free(pkt);
}
```

Outline

- Extending ns
  - In OTcl
  - In C++
  - Debugging: OTcl/C++, memory
  - Pitfalls

Debugging C++ in ns

- C++/OTcl debugging
- Memory debugging
  - purify
  - dmalloc

C++/OTcl Debugging

- Usual technique
  - Break inside command()
  - Cannot examine states inside OTcl!
- Solution
  - Execute tcl-debug inside gdb

C++/OTcl Debugging

```
(gdb) call Tcl::instance().eval("debug 1")
15: lappend auto_path $dbg_library
dbg15.3> w
*0: application
 15: lappend auto_path $dbg_library
dbg15.4> Simulator info instances
_o1
dbg15.5> _o1 now
0
dbg15.6> # and other fun stuff
dbg15.7> c
(gdb) where
#0 0x102218 in write()
......
```

Memory Debugging in ns

- Purify
  - Set PURIFY macro in ns Makefile
  - Usually, put -colloctor=<ld_path>
- Gray Watson's dmalloc library
  - http://www.dmalloc.com
  - make distclean
  - ./configure --with-dmalloc=<dmalloc_path>
  - Analyze results: dmalloc_summarize

dmalloc: Usage

- Turn on dmalloc
  - alias dmalloc ’eval ‘\dmalloc –C \!*`’
  - dmalloc -l log low
- dmalloc_summarize ns < logfile
  - ns must be in current directory
  - Itemize how much memory is allocated in each function

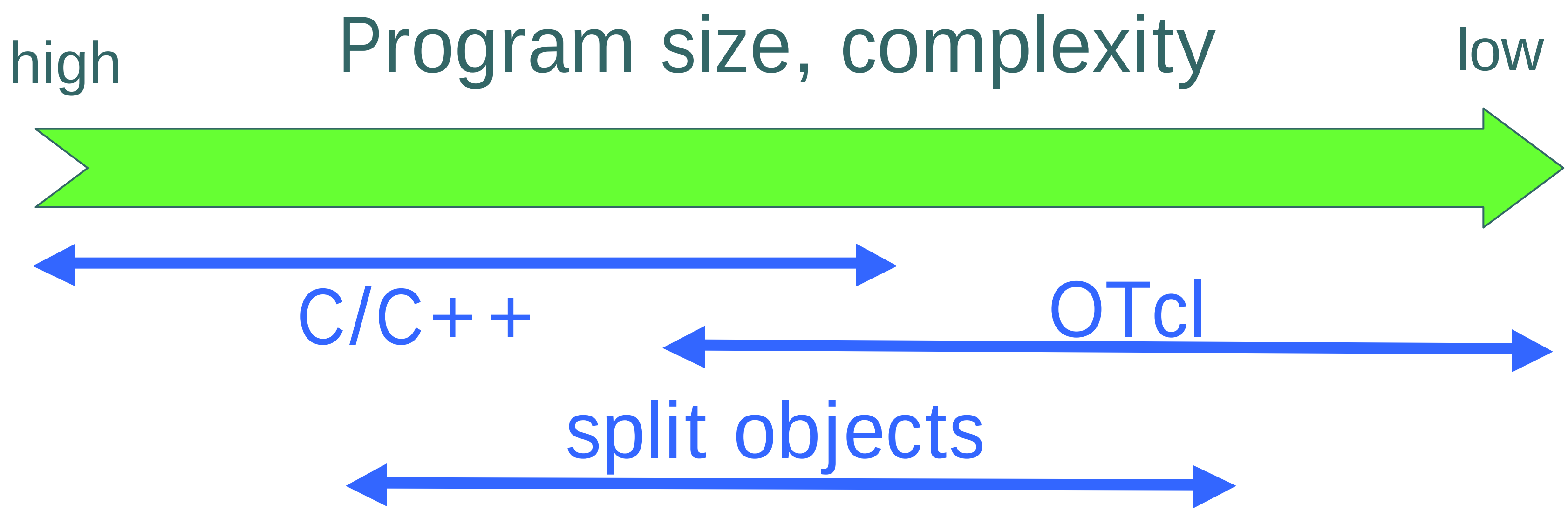
Pitfalls

- Scalability vs flexibility
  - Or, how to write scalable simulation?
- Memory conservation tips
- Memory leaks

Scalability vs Flexibility

- It’s tempting to write all-OTcl simulation
  - Benefit: quick prototyping
  - Cost: memory + runtime
- Solution
  - Control the granularity of your split object by migrating methods from OTcl to C++

THE Merit of OTcl



- Smoothly adjust the granularity of scripting to balance extensibility and performance
- With complete compatibility with existing simulation scripts

Object Granularity Tips

- Functionality
  - Per-packet processing → C++
  - Hooks, frequently changing code → OTcl
- Data management
  - Complex/large data structure → C++
  - One-time configuration variables → OTcl

Memory Conservation Tips

- Remove unused packet headers
- Avoid `trace-all`
- Use arrays for a sequence of variables
  - Instead of `n$i`, say `n($i)`
- Avoid OTcl temporary variables
- Use dynamic binding
  - `delay_bind()` instead of `bind()`
  - See object.{h,cc}
- See tips for running large sim in ns at `www.isi.edu/ns/nsnam/ns-largesim.html`

Memory Leaks

- Purify or dmalloc, but be careful about split objects:

```
for {set i 0} {$i < 500} {incr i} {
   set a [new RandomVariable/Constant]
}
```

  - It leaks memory, but can't be detected!
- Solution
  - Explicitly delete EVERY split object that was new-ed

Final Word

- My extended ns dumps OTcl scripts!
  - Find the last 10-20 lines of the dump
  - Is the error related to "_o*** cmd …" ?
    - Check your command()
  - Otherwise, check the otcl script pointed by the error message