ns-3 Waf build system

ns-3 Annual Meeting

June 2017

Software introduction

- Download the latest release
  - `wget http://www.nsnam.org/releases/ns-allinone-3.26.tar.bz2`
  - `tar xjf ns-allinone-3.26.tar.bz2`
- Clone the latest development code
  - `hg clone http://code.nsnam.org/ns-3-allinone`

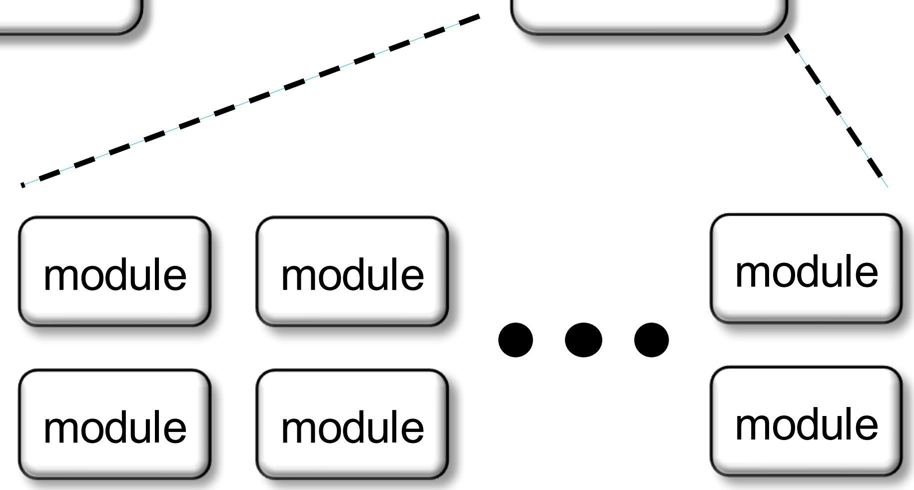
Q. What is "**hg clone**"?
A. Mercurial (http://www.selenic.com) is our source code control tool.

Software building

- Two levels of ns-3 build

1) bake (a Python-based build system to control an ordered build of ns-3 and its libraries)

2) waf, a build system written in Python



3) build.py (a custom Python build script to control an ordered build of ns-3 and its libraries) **<--- may eventually be deprecated**

ns-3 uses the 'waf' build system

- Waf is a Python-based framework for configuring, compiling and installing applications.
  - It is a replacement for other tools such as Autotools, Scons, CMake or Ant
  - http://code.google.com/p/waf/
- For those familiar with autotools:
- `configure` → `./waf configure`
- `make` → `./waf build`

waf configuration

- Key waf configuration examples

```
./waf configure
    --enable-examples
    --enable-tests
    --disable-python
    --enable-modules
```

- Whenever build scripts change, need to reconfigure

Demo: `./waf --help`

```
./waf configure --enable-examples --enable-tests --enable-modules='core'
```

Look at: `build/c4che/_cache.py`

wscript example

```
## -*- Mode: python; py-indent-offset: 4; indent-tabs-mode: nil; coding: utf-8; -*-

def build(bld):
    obj = bld.create_ns3_module('csma', ['network', 'applications'])
    obj.source = [
        'model/backoff.cc',
        'model/csma-net-device.cc',
        'model/csma-channel.cc',
        'helper/csma-helper.cc',
        ]
    headers = bld.new_task_gen(features=['ns3header'])
    headers.module = 'csma'
    headers.source = [
        'model/backoff.h',
        'model/csma-net-device.h',
        'model/csma-channel.h',
        'helper/csma-helper.h',
        ]

    if bld.env['ENABLE_EXAMPLES']:
        bld.add_subdirs('examples')

    bld.ns3_python_bindings()
```

waf build

- Once project is configured, can build via `./waf build` or `./waf`
- waf will build in parallel on multiple cores
- waf displays modules built at end of build

Demo: `./waf build`

Look at: `build/` libraries and executables

Running programs

- `./waf shell` provides a special shell for running programs
  - Sets key environment variables

```
./waf --run sample-simulator
./waf --pyrun src/core/examples/sample-
  simulator.py
```

Build variations

- Configuring a build type is done at waf configuration time
- debug build (default): all asserts and debugging code enabled

```
./waf -d debug configure
```

- optimized

```
./waf -d optimized configure
```

- static libraries

```
./waf --enable-static configure
```

Controlling the modular build

- One way to disable modules:
  - `./waf configure --enable-modules='a','b','c'`
- The `.ns3rc` file (found in utils/ directory) can be used to control the modules built
- Precedence in controlling build
  1) command line arguments
  2) .ns3rc in ns-3 top level directory
  3) .ns3rc in user's home directory

Demo how .ns3rc works

Building without wscript

- The scratch/ directory can be used to build programs without wscripts

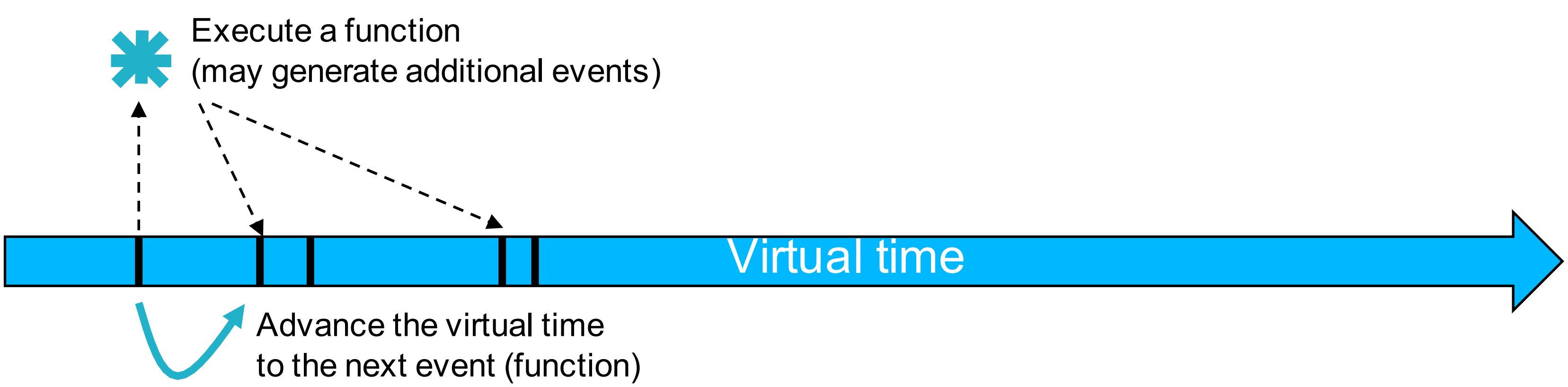
Demo how programs can be built without wscripts

ns-3 Training

ns-3 training, June 2017

Simulator core

- Simulation time
- Events
- Simulator and Scheduler
- Command line arguments
- Random variables



Simulator example

```
#include <iostream>
#include "ns3/simulator.h"
#include "ns3/nstime.h"
#include "ns3/command-line.h"
#include "ns3/double.h"
#include "ns3/random-variable-stream.h"

using namespace ns3;
```

```
int main (int argc, char *argv[])
{
  CommandLine cmd;
  cmd.Parse (argc, argv);

  MyModel model;
  Ptr<UniformRandomVariable> v = CreateObject<UniformRandomVariable> ();
  v->SetAttribute ("Min", DoubleValue (10));
  v->SetAttribute ("Max", DoubleValue (20));

  Simulator::Schedule (Seconds (10.0), &ExampleFunction, &model);

  Simulator::Schedule (Seconds (v->GetValue ()), &RandomFunction);

  EventId id = Simulator::Schedule (Seconds (30.0), &CancelledEvent);
  Simulator::Cancel (id);

  Simulator::Run ();

  Simulator::Destroy ();
}
```

Simulator example (in Python)

```
# Python version of sample-simulator.cc

import ns.core
```

```
def main(dummy_argv):

    model = MyModel()
    v = ns.core.UniformRandomVariable()
    v.SetAttribute("Min", ns.core.DoubleValue (10))
    v.SetAttribute("Max", ns.core.DoubleValue (20))

    ns.core.Simulator.Schedule(ns.core.Seconds(10.0), ExampleFunction, model)

    ns.core.Simulator.Schedule(ns.core.Seconds(v.GetValue()), RandomFunction, model)

    id = ns.core.Simulator.Schedule(ns.core.Seconds(30.0), CancelledEvent)
    ns.core.Simulator.Cancel(id)

    ns.core.Simulator.Run()

    ns.core.Simulator.Destroy()

if __name__ == '__main__':
    import sys
    main(sys.argv)
```

Simulation program flow

Handle program inputs

↓

Configure topology

↓

Run simulation

↓

Process outputs

Command-line arguments

- Add CommandLine to your program if you want command-line argument parsing

```
int main (int argc, char *argv[])
{
  CommandLine cmd;
  cmd.Parse (argc, argv);
```

- Passing --PrintHelp to programs will display command line options, if CommandLine is enabled

```
./waf --run "sample-simulator --PrintHelp"
```

```
--PrintHelp: Print this help message.
--PrintGroups: Print the list of groups.
--PrintTypeIds: Print all TypeIds.
--PrintGroup=[group]: Print all TypeIds of group.
--PrintAttributes=[typeid]: Print all attributes of typeid.
--PrintGlobals: Print the list of globals.
```

Time in ns-3

- Time is stored as a large integer in ns-3
  - Minimize floating point discrepancies across platforms
- Special Time classes are provided to manipulate time (such as standard operators)
- Default time resolution is nanoseconds, but can be set to other resolutions
  - Note: Changing resolution is not well used/tested
- Time objects can be set by floating-point values and can export floating-point values

```
double timeDouble = t.GetSeconds();
```

  - Best practice is to avoid floating point conversions where possible

Events in ns-3

- Events are just function calls that execute at a simulated time
  - i.e. callbacks
  - this is another difference compared to other simulators, which often use special "event handlers" in each model
- Events have IDs to allow them to be cancelled or to test their status

Simulator and Schedulers

- The Simulator class holds a scheduler, and provides the API to schedule events, start, stop, and cleanup memory
- Several scheduler data structures (calendar, heap, list, map) are possible
- "RealTime" simulation implementation aligns the simulation time to wall-clock time
  - two policies (hard and soft limit) available when the simulation and real time diverge

Random Variables

from src/core/examples/sample-rng-plot.py

- Currently implemented distributions
  - Uniform: values uniformly distributed in an interval
  - Constant: value is always the same (not really random)
  - Sequential: return a sequential list of predefined values
  - Exponential: exponential distribution (poisson process)
  - Normal (gaussian), Log-Normal, Pareto, Weibull, triangular

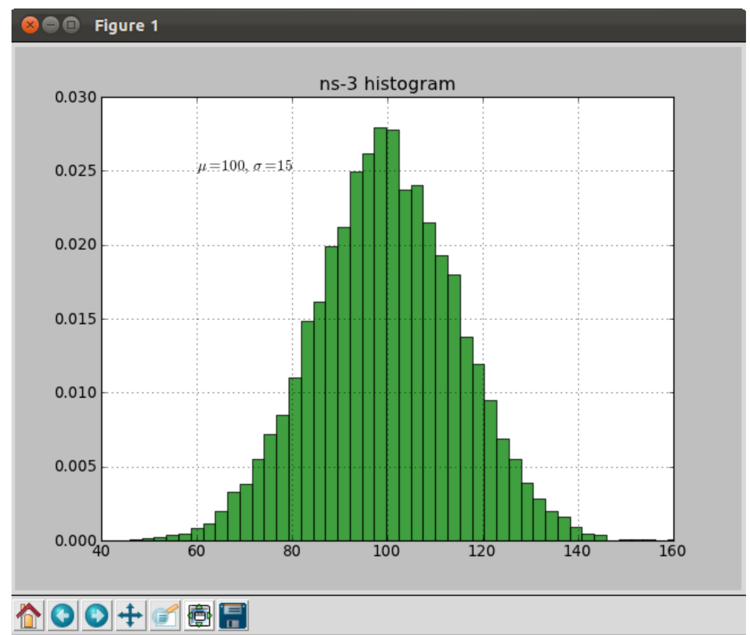
```
# Demonstrate use of ns-3 as a random number generator integrated with
# plotting tools; adapted from Gustavo Carneiro's ns-3 tutorial

import numpy as np
import matplotlib.pyplot as plt
import ns.core

# mu, var = 100, 225
rng = ns.core.NormalVariable(100.0, 225.0)
x = [rng.GetValue() for t in range(10000)]

# the histogram of the data
n, bins, patches = plt.hist(x, 50, normed=1, facecolor='g', alpha=0.75)

plt.title('ns-3 histogram')
plt.text(60, .025, r'$\mu=100,\ \sigma=15$')
plt.axis([40, 160, 0, 0.03])
plt.grid(True)
plt.show()
```



Random variables and independent replications

- Many simulation uses involve running a number of *independent replications* of the same scenario

- In ns-3, this is typically performed by incrementing the simulation *run number*
  - *not by changing seeds*