NS-3 NETWORK SIMULATOR

NS-3 Consortium Annual Meeting

Tom Henderson (University of Washington)

May 14, 2015

Agenda

- Introductions
- Consortium overview
- WNS3 and annual meeting
- Project status and discussion

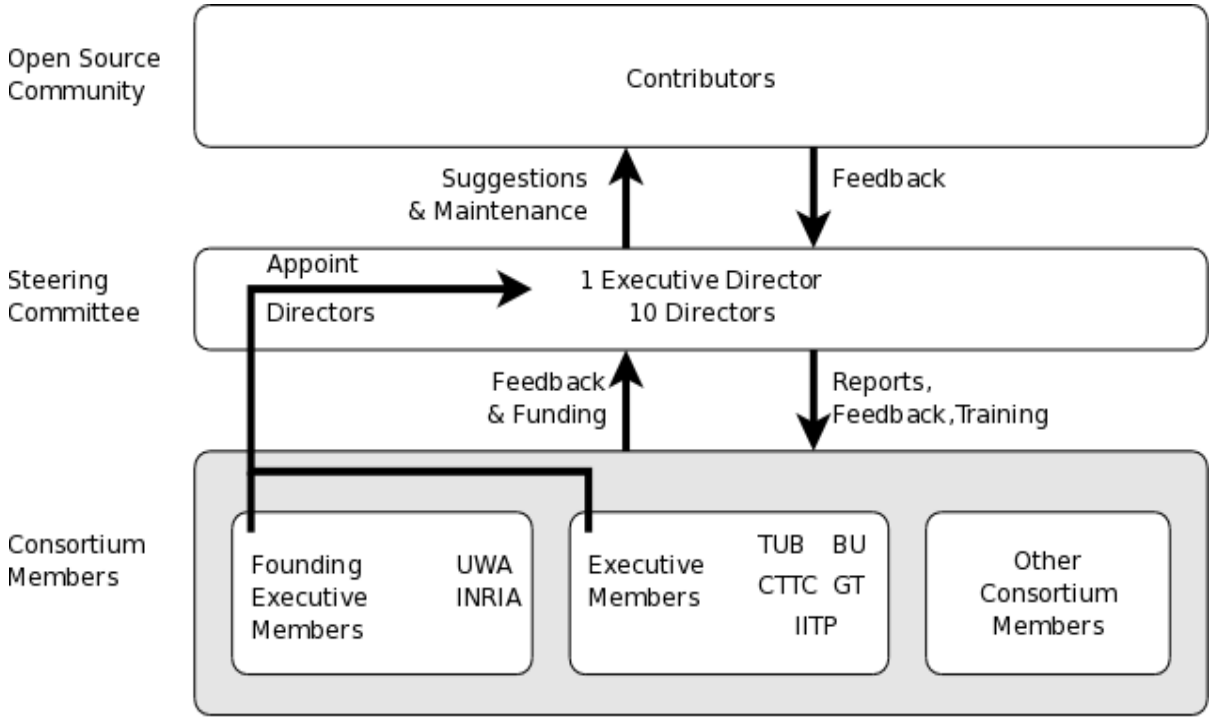
Consortium overview

- Established in 2012 to sustain the open source project

Kickoff meeting, March 2013, INRIA

Consortium organization

- Executive Members and Steering Committee
- Regular Members



More details at http://www.nsnam.org/consortium/about

Current Membership

- Founding Executive Members
  - INRIA, University of Washington
- Additional Executive Members
  - Bucknell, CTTC, Georgia Tech, INESCTEC
- Regular Members
  - Lawrence Livermore National Laboratory

Theory vs Practice

- **Theory:** Raise modest amounts of funding, primarily from several industrial users who become recurring members, to pay for full-time software engineers

- **Practice:** Raise small amounts of funding, primarily from annual meeting, to pay for annual meeting and low-cost activities.

Membership

- Membership is a way for an organization to sponsor recurring investment in the open source project

Inria's dues and overhead for Inria-based Consortium Members:

	Dues Before Overhead	Overhead (15%)*	VAT	Total Dues
Universities and non-profit	€1 000	€176	VAT will be applied pursuant to territoriality rules.	€1 176 + VAT
Very small companies	€1 000	€176		€1 176 + VAT
Small companies	€5 000	€882		€5 882 + VAT
Large companies	€10 000	€1 765		€11 765 + VAT

*For Inria, overhead is assessed on total payment.

University of Washington's dues and overhead for University of Washington-based Consortium Members:

	Dues Before Overhead	Overhead (20%)**	Taxes	Total Dues
Universities and non-profit	$1,250	$250	Taxes will be applied pursuant to U.S. rules.	$1,500 + Taxes
Very small companies	$1,250	$250		$1,500 + Taxes
Small companies	$6,250	$1,250		$7,500 + Taxes
Large companies	$12,500	$2,500		$15,000 + Taxes

**For the University of Washington, overhead is assessed on expenditures.

Current operations

- Steering Committee organizes annual meeting, WNS3, and training
- Accepts payments from Google Summer of Code for project mentors
- Members (e.g. Georgia Tech and University of Washington servers) provide services
- Still experimenting with ways to engage industrial users
- Budget/revenue: Net income of $4000 in 2014; net income of $2000-$3000 forecast for 2015

Revised goals for industrial activities

Membership still welcome, but also...

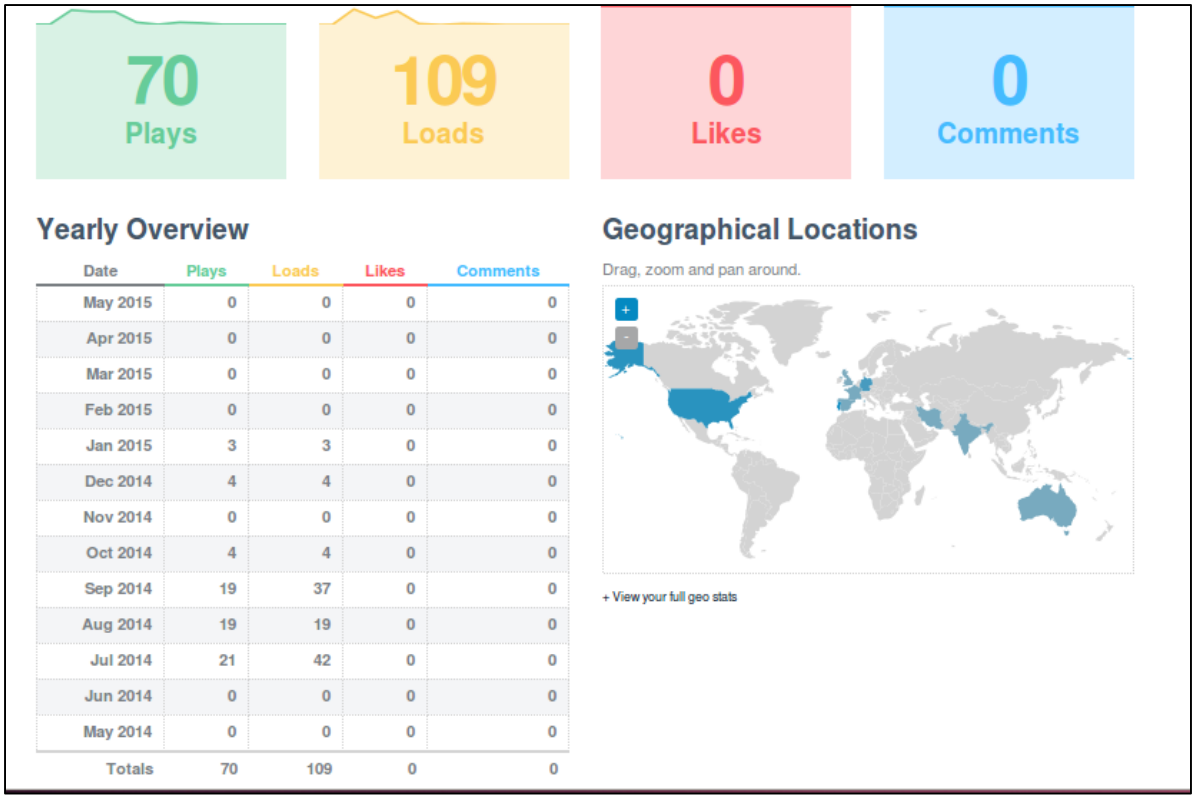
- One-time contributions (unrestricted gifts) also welcome
- Endorsements/letters of support can support future efforts to fund "research infrastructure" proposals (e.g. NSF)
- Encourage industrial users to upstream patches
- Encourage maintainers from industry

Benefits to membership

- Send attendees to (annual) Consortium meetings for training
  - Gain access to training videos
- (Optionally) place a logo on the website as a member/supporter of ns-3

Video experiment results

- Discuss future video access



Statistics on tutorial views, Vimeo site

Future membership

- May want to expand/rotate the executive membership (steering commitee)
  - Organizations (not individuals) must join by invitation
  - If interested, please discuss with an existing member
- Need a new Executive Director for 2016 (from among existing Steering Committee)

Agenda

- Introductions
- Consortium overview
- WNS3 and annual meeting
- Project status and discussion

WNS3 status

Participation roughly doubled since 2014 for key metrics

- Paper submissions (27 in 2015)
- Poster submissions (10 in 2015)
- Attendance (50-60 in 2015)

WNS3 papers

- Publication fee of $500 was paid to place papers in ACM Digital Library
  - Others have inquired "Why not arXiv.org, in the spirit of open source?"
  - Terms of ACM "In Cooperation With" do not allow a-la-carte approach to submission

Current issues to discuss

- Site selection for future editions
- TPC co-chair for 2016-17
- Paper review guidelines
- Paper review processes
- Providing multiple tracks (industrial, repeatable, regular)?
- Video recording and streaming
- Remote participation?
- Sponsorship?
- Training proposals?

Paper review processes

- what defines a conflict of interest in reviewing a paper?
- how to deal with accusations of plagiarism?
- overall process/criteria for accepting papers
- where to draw the cutoff line? Is it better to be more selective or more inclusive?
- how to reconcile drastically different reviews (we have had 'strong accept' and 'strong reject' recommendations on the same paper)
- can papers be conditionally included (included if quickly revised) and what is the process for that
- process for late arrivals and deadline extensions
- handling contested reject decisions
- guidelines for setting up sessions (paper talk length, session chairs, etc.)

Agenda

- Introductions
- Consortium overview
- WNS3 and annual meeting
- Project status and discussion

Travel grants for 2016

Propose to continue travel stipend program for all 2015 ns-3 mentored summer projects:

- If student from summer project is able to publish his or her work from that project in WNS3, the Consortium will provide a $400 travel grant to attend WNS3 (if travel is necessary)

2015 Google Summer of Code projects

- Melchiorre Danilo Abrignani, "Carrier Aggregation support for the LTE module"
- Matthieu Coudron, "Implementing multipath TCP (MPTCP) in ns3"
- Natale Patriciello, "TCP layer refactoring with automated test on RFC compliance and validation"
- Vishwesh Rege, "802.15.4 realistic MAC and Energy Model"

Open source project status

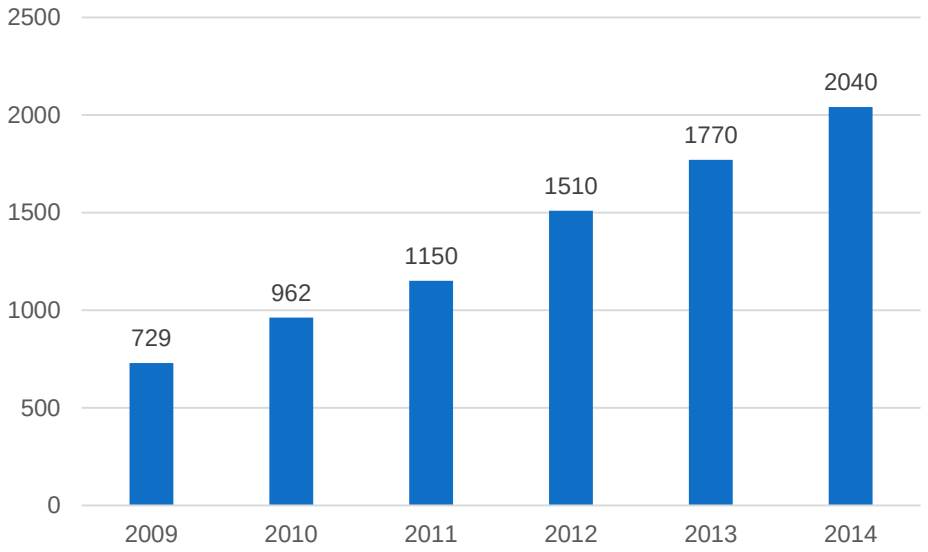
- Recent and future releases
- Usage statistics
- Maintainer status
- Google Summer of Code
- Windows Port

Usage statistics

- ns-3 use continues to grow, measured by activity on mailing lists, contributed code, and anecdotally
- ns-3-users members:
  - Feb. 2013: 2392, Feb. 2014: 3425, Feb 2015: 4603
- ns-3-users posts in past 12 months:
  - Feb. 2013: 6888, Feb. 2014: 7770, Feb 2015: 10,738
- ns-3 AUTHORS
  - Feb 2013: 113, Feb. 2014: 146, Feb 2015: 175

How many ns-3 publications?

- Google Scholar search of keyword 'ns-3 simulator'
  - Advanced search filters: English only, excluding patents and citations, custom date range
- Results by year (searched March 2, 2015):



Validating Google Scholar searches

- Google Scholar returns at most 1000 entries per search
- Offers time-based search granularity of calendar year only
- Therefore, no way to individually validate greater than 1000 entries
- For this talk, manually examined first 100 entries for 2013 by relevance; how many actual publications 'using ns-3'?

2013 search results for 'ns-3 simulator'

- Of the first 100 entries for Google Scholar (2013)
  - 50% (49/100) were using ns-3
  - 10% (10/100) were about ns-3
  - 40% (41/100) referenced ns-3 only, or were false positives

- Search results from other digital libraries
  - ACM Digital Library 2013: 503 results
    - "ns3" or "ns-3", searched April 1 2015
  - IEEE Digital Library 2013: 715 results
    - "ns3" or "ns-3", IEEE journals and conference pubs, full text and metadata, searched April 1 2015

Sample Google Scholar output

Scholar Alert: [ns-3 simulator]

Interface and Results Visualization of WMN-GA **Simulation** System: Evaluation for Exponential and Weibull Distributions Considering Different Transmission Rates
A Barolli, V Loia, T Oda, L Barolli, F Xhafa, M Takizawa - Computer Standards & ..., 2015
... Log-distance path loss model and constant speed delay model are used for the **simulation** and other parameters are shown in Table 2. We consider the connectivity between mesh routers and conduct simulations using **ns-3 simulator**. **...**

DOA Acoustic Source Localization in Mobile Robot Sensor Networks
R Levorato, E Pagello - ... Robot Systems and Competitions (ICARSC), 2015 ..., 2015
... Fig. 7. Variance Distance Error over the number of sensors **Ns** ∈ [**3**, 20] [m]. 74 Page 5. B. **Simulation** 2 - DOA Angle Error Comparing the results of the approaches with different maximum errors of the angle of the DOA sensors reveals that GP-DOA Fast 2 always outperforms the **...**

[PDF] Trapping in irradiated p-on-n silicon sensors at fluences anticipated at the HL-LHC outer tracker
W Adam, T Bergauer, M Dragicevic, M Friedl... - arXiv preprint arXiv: ..., 2015
... The effective trapping rates are extracted by comparing the results to **simulation**. The electric field is sim- ulated using Synopsys device **simulation** assuming two effective defects. **...** 2Hamamatsu webpage: http://www.hamamatsu.com/ Page 5. 3 3 **Simulation** of charge collection **...**

[PDF] Proposed Method to Enhance the Performance of AOMDV under DDOS Attack
KK Waraich, ESP Singh - 2015
... 13, (2011). [5] A. Bandyopadhyay, S. Vuppala and P.Choudhury, "A **Simulation** analysis of flooding attack in MANET using **NS-3**, IEEE", 2nd **...** [19] T. Issariyakul and E. Hossain, "Introduction to Network **Simulator** NS2", Springer Science and Business Media, LLC, (2009). **...**

Findings from a small survey

- Reviewed 139 paper results from 2013-14 search of IEEE library (top relevant results)
- Some papers matched multiple categories
- Hot topics:
  - LTE/cellular networks (15)
  - Wireless routing protocols (14)
  - Sensor networks (13)
  - Wireless MAC and PHY protocols (11)

Detailed paper counts by topic

Topic	Count		Topic	Count
LTE/Cellular	15		Network coding	4
Wireless routing protocols	14		Datacenter networks	4
Wireless sensor networks	13		Distributed systems	4
Wireless MAC/PHY	11		Optical links	3
Wireless QoS	9		Misc. physical links	3
Vehicular networks	9		Multicast	3
TCP/congestion control	9		Misc. security	2
Wireless security	9		Wired routers	2
About ns-3 itself	8		Wireless QoS	2
Wifi/mesh networks	7		WiMAX	1
Voice/video apps	6		Mobility	1
Energy/resource consumption	6		Misc. routing	1
DTN and space networks	5		Miscellaneous	1
Misc. wireless	5			

Traditional simulation usage dominates

Traditional usage: Single simulation process running in simulation time using native ns-3 models

- Published work using *ns-3 advanced features* (distributed, direct code execution, emulation) is less common
- Published work using *ns-3 frameworks* (co-simulation, etc.) authored by others is hard to find

However, many interesting papers using the advanced features have been published!

ns-3 relative popularity

- How many citations for other leading network simulators and emulators?
  - ns-2 (ns-3's predecessor)
  - OmNET++
  - OPNET
  - QualNet/Exata
  - mininet

ns-3 relative popularity (2014)

- ACM Digital Library

Search term	Count
ns-2 OR ns2	765
ns-3 OR ns3	299
OmNET++ OR OmNET	216
OPNET	164
QualNet or Exata	83
mininet	68
simulation	25,128

ACM Guide to Computing Literature, search performed 1 April 2015

IEEE Digital Library

Search term	Count
ns-2 OR ns2	836
ns-3 or ns3	351
OPNET	249
OmNET++ or OMNET	189
QualNet or Exata	90
mininet	75
simulation	54,979

Full text and metadata search, IEEE journals and conferences, search performed 1 April 2015

Findings from selective conferences

- Simulation is used in about one quarter to one third of papers at highly selective networking conferences (2014 NSDI, 2014 SIGCOMM, 2014 INFOCOM)
- General purpose network simulators are not overwhelmingly cited (vs. use of unspecified simulators)
  - 4/9 for NSDI, 6/15 for SIGCOMM
- Publicly available research testbeds (NSF GENI, European OneLab, PlanetLab, etc.) are seldom cited
- General purpose/open source hardware is more commonly cited (USRP, WARP, NetFPGA, Amazon EC2)
- Reproducibility or repeatability of published simulation results is still the exception, not the rule

2014 SIGCOMM topics

Session	Papers	Simulation used	Named simulator
Dataplane	4	2	
Network Architecture	5	2	
Middleboxes	4	0	
Wireless	3	0	
Monitoring	4	1	ns-3
Datacenter design	4	2	mininet
Scheduling for Datacenter	**4**	**3**	
Wireless II	3	0	
Network Architecture II	3	0	
Network operations	5	2	
Transport/congestion ctl.	**3**	**3**	ns-2, OmNET++

Current issues

- Maintainers

Modularity

loss models for Teraherz channels

GPSR

LEAR extensions to DSR

WiFi WFQ queues

Mobility Service Interface

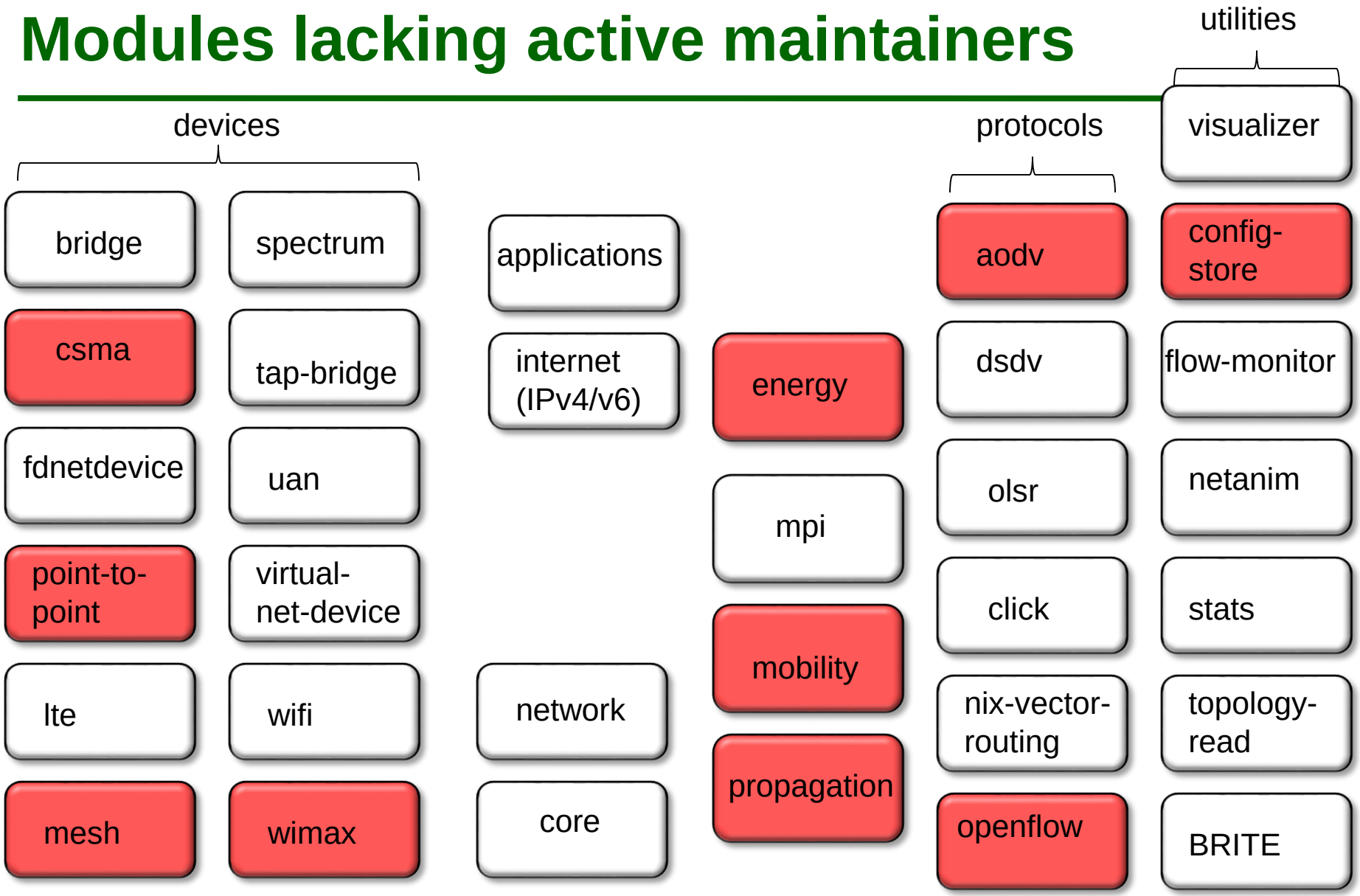
UAN WOSS framework

TCP Cubic

CLWPR

ns-3-dev

Modules lacking active maintainers

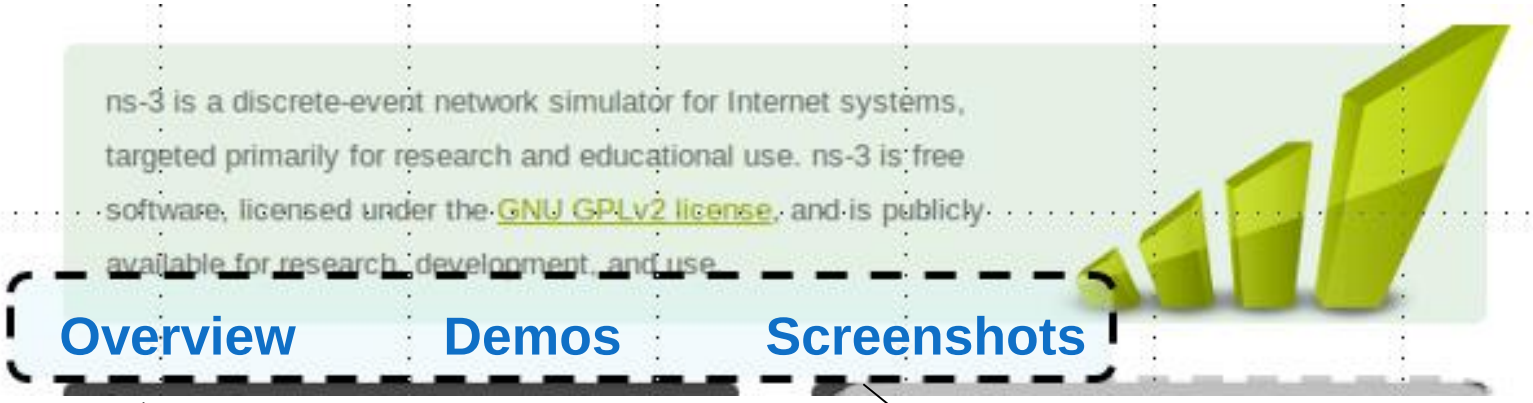


Other maintainers sought

- Help for ns-3 DCE
- ns-3 bibliography list
- contributed code curator
- website maintenance
- documentation translations
- etc.

Proposed website enhancements

Links to promotional material



- Maintain a master "data sheet" description of ns-3
- Links to "application notes" such as:
- "Vehicular simulations"
- "LTE simulations"
- "TCP testing"

- YouTube page for demo videos

- Screenshot page

Asking for help

- Per-module maintenance status and where help is requested
- List of ideas with suggested mentors and how to get started
- How to create and submit patches
- How to submit examples
- Options for submitting new modules

Contributed code

- Long-term goal is to split ns-3 into many packages (libraries) that may evolve independently, and provide tool to manage dependencies
  - ns-3 "core" shrinks to much smaller scope
- Need to accommodate binary packages
- Need to support easy discovery of modules and module status

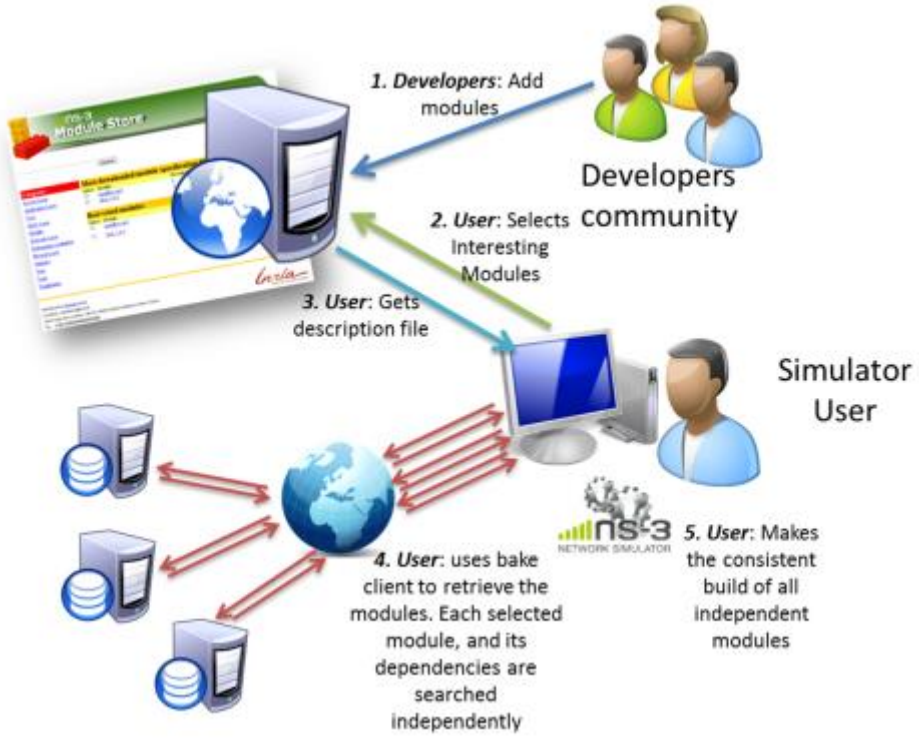
Contributed code status

- Objective or reputation-based systems to convey model status to users

module	ns-3 module name	module maintained by	maintainer	latest version	works with ns-3 version	external libraries needed	coding style	Doxygen	regression test coverage	validation test report	user's manual	send bug reports to
core	core	ns-3 project	Mathieu Lacage	3.9	3.9	GSL				RNG generator only		ns-3 Bugzilla "core" product
simulator	simulator	ns-3 project	Mathieu Lacage	3.9	3.9	none						ns-3 Bugzilla "simulator" product
...												
physim		KIT	Jens Mittag	1.0	3.9	IT++						Tracker at http://example.edu
underwater acoustic networking	uan	ns-3 project	Leonard Tracy	N/A	3.9	none						ns-3 Bugzilla "uan" product
abandoned model	abandon	none	none	0.8	3.5	none						mailto:example-research-group.edu

Module discovery

- Bake file (XML) for now
- Web-browsable service in future?



Initial step for ns-3.24

- Optional modules downloaded by bake into contrib/ directory
  - Waf builds as usual
- Bake extended to allow ns-3 module addition and subtraction from the download
- ./waf --enable-modules/--disable-modules will control the scope of the build

Example

- "Obstacle" module provided as source code somewhere (code.nsnam.org, github, bitbucket)
- Release manager works with contributor to extend bakeconf.xml (e.g. add CGAL support)
- bake extended to allow user to discover obstacle module availability
  - ./bake.py --list-modules
- bake extended to allow user to add obstacle module to the current configuration
  - ./bake.py --add-module=obstacles