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Study and systematic Review of Computer Network Simulation with NS-3

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ABSTRACT

Complexity of current computer networks, including e.g., local networks, large structured networks, wireless sensor networks, datacenter backbones, requires a thorough study to perform analysis and support design. Simulation is a tool of paramount importance to encompass all the different aspects that contribute to design quality and network performance (including as well energy issues, security management overheads, dependability), due to the fact that such complexity produces several interactions at all network layers that is not easily model able with analytic approaches. In this study we aim to analyze, basing our investigation on available literature, the adoption of a popular network simulator, namely NS-3, and its use in the scientific community. More in detail, we are interested in understanding what are the impacted application domains in which authors prefer NS-3 to other similar tools and how extensible it is in practice according to the experience of authors. The results of our analysis, which has been conducted by especially focusing on more than 200 papers published between 2009 to 2021, reveals that 10% of the evaluated papers were discarded because they represented informal literature; most of the studies presented comparisons among different network simulators, beyond NS-3 and conceptual studies related to performance assessment and validation and routing protocols. Only about 30% of considered studies present extensions of NS-3 in terms of new modules and only about 10% present effective case studies demonstrating the effectiveness of employing network simulator in real application, except conceptual and modeling studies.

***Keywords:* computer networks; simulation; ns-3; wireless sensor networks; network performance; systematic review.**

1. INTRODUCTION

Computer networks are currently a cornerstone not only in traditional computing or business environment, but also in many different application fields, such as cloud facilities, Industry 4.0, Wireless Sensor Networks (WSN), Cyber Physical Systems (CPS), 5G communication systems, critical infrastructures protection, automotive, railways, military applications such as ground support, Command, Control, Communications and Intelligence (C3I), modern military air force systems, and many other possible examples. Computer networking took the place of other traditional technologies with the aim of providing richer services, adaptation to different conditions, repeat configuration, system-wide and node-wide intelligence, flexibility, interoperability, thanks to the fact that network architectures are layered, scalable, evolvable and adaptable, and to the intrinsic advantages of digital data orientation. The modularity of network technologies allows the independent development of standards that focus on individual problems and allow reuse of solutions and concurrent design of different layers for the same architecture or for different architectures to be made compatible or interoperable.

Modern networking technologies include hardware and software components. The availability of more reliable and faster computing hardware is changing the balance between hardware and software and the structure of network devices as well ,currently both embedded, mainly hardware-based nodes may coexist with mainly software-based nodes, in which analogous functions are provided with different tools, and Software Defined Networks (SDN) are spreading aside conventional hardware-based infrastructures, basically reducing the logical portion of a network that is necessarily implemented in hardware to the essential components that ensure the connection. This evolution, mainly pushed by the needs of cloud infrastructures and large computing infrastructures in general, such as warehouse scale computers, to allow easier deployment, control and management of complex networks, in turn enables a change of paradigm from distributed network control and logic to a centralized approach, including the ability of a nearly complete reconfiguration of all network nodes in a large installation by a single control and management node. In some scenarios, moreover, the higher levels of the network stacks might be completely implemented in the cloud, such as in the case of 5G technologies that blur the communication and computing portions of the system, or, less extremely, 4G technologies that delegate some functions from the cell antenna to the terminals.

When analyzing or integrating a computer network, this heterogeneity in hardware and software and the wide transparency in the interoperability of components results in a potentially lower knowledge of non-controllable nodes. The higher the number of vendors, the number of interacting technologies, the dimension and extension of the network, the amount of numbers, the heterogeneity in the services and layers, the security requirements, the survivability requirements, the more difficult is to model and understand faithfully the dynamics of the network. A low fidelity impacts significantly the results of assessments when the complexity of the network is not trivial, so the availability of modular simulation-based tools to support the process is a real need to avoid dramatic underestimation of network problems or erroneous assumptions on network behavior that may have serious consequences: for example, in evaluating the extension of the attack surface in a IoT system, the reliability of an Industry 4.0 installation or the performance of multimedia delivery systems.

The use of modular simulation allows building a coherent model of a network with different levels of detail. The level of detail may, in principle, vary between high-level, behavioral modeling and emulation. The availability of modular, extensible, programmable, open, open-source, community-supported and community-driven simulation tools or simulation frameworks gives the modeler the possibility of producing simulation scenarios with any desired level of detail, even with an heterogeneous level in different simulated nodes, portions of network or subsystems, provided that a component for the simulation tool is available or autonomously developed by the modeler for the purpose. The extensibility allows the definition of new components for experimental or future real-world networks components, as well as the implementation of different versions of the same real-world networks component with a different inner complexity to manage with the duration of large simulation runs or to interface, in case, real-world networks components with simulated components. Modularity and extensibility enable component reuse, thus empowering the modeling process with well-tested, well-documented third-party components with little effort by the modeler, faster model development, incremental modeling strategies, comparative simulation for cross-validation by means of alternative modules, parameterization of models, definition of semi finished models or model portions, up to the support for structured modeling and analysis processes, including standardized processes in the framework of industrial certifications. Openness guarantees the legal rights needed for extension, while open-sourceness guarantees inspect ability of code for debug, verification or certification of simulations, or easy refactorization of components to evolve them with the simulation software infrastructure, and portability between versions. Community-supportedness fosters the collective effort to produce or improve new components, to augment the usefulness of the simulation tool and to strengthen the effectiveness of its use into simulation processes, or, together with open-sourceness, the implementation of third-party tools to support or automate simulation campaigns, simulation generation, model-based simulation development or other useful tools that ease or empower the management of simulation and its application in structured development and assessment processes and methodologies.

Many alternatives exist for computer network simulation: in this Systematic Literature Review (SLR) we focus on NS-3 (www.nsnam.org/), a modular, programmable, extensible, open, open-source, community-supported simulation framework for computer networks. Our choice is due to the fact that the technical characteristics of NS-3 match the needs of our research activities, and to the increasing popularity that this tool is gaining among the computer networks research community and, slowly, among professionals.

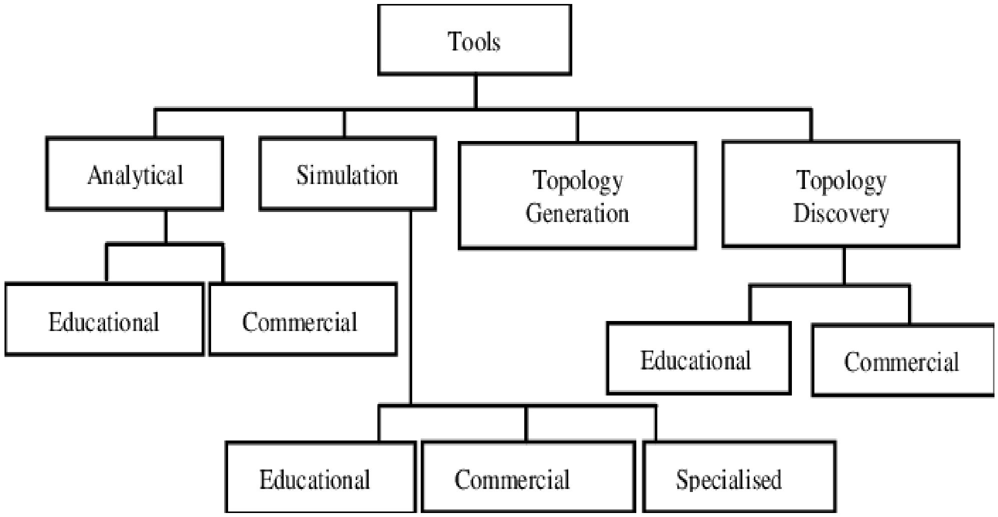

Fig -1 Classification of network design and simulation tools

NS-3 is an open computer networks simulation environment that is based on discrete-event simulation. In such a simulator, each event is associated with its execution time and the simulation proceeds by executing events in the temporal order of simulation time. When an event is processed, it may generate zero, one or more events. As a simulation executes, events are consumed, but more events may (or may not) be generated. The simulation will stop automatically when no further events are in the event queue, or when a special "Stop" event is found [1].

It is designed for research use, thinking of the needs of the research community, and fosters a community-based collaboration model both to support the development of new modules and to perform validation or peer review activities across different groups. NS-3 is distributed under an open-source model and a free software paradigm. The simulation environment is designed to allow its use as a real-time emulator as well, integrating simulated portions and physical portions in the same network. This level of integration is provided by a real-time scheduler, besides the simulation support, to enable simulation-in-the-loop. The simulator is intended to be used by means of its API inside programmatic descriptions of users' scenarios and configurations, which may be developed following usual workflows and processes. The API is used to produce outputs in terms of traces that are coherent with the traces that may be obtained by observing traffic in real-world networks with tools like Wire shark (https://www.wireshark.org/) or TCP dump (https://www.tcpdump.org/), so that they may be analyzed by the same tools that are already in use for experimental setups or diagnostics. The authors of NS-3 explicitly state that they aim at allowing the reuse of real-world implementation of protocols in NS-3, so that the effort for the design and production of very detailed simulation components is reduced as much as possible. The goal is to provide a very realistic simulation support for a large number of different types of network infrastructures, communication and routing protocols, technologies, layers, allowing network-enabled software to run on top of the simulation with minimal effort (e.g., virtual machines).

NS-3 is the result of a long experience that evolved through two previous simulators (namely NS-1 and NS-2): however, the development team decided to completely restart from scratch the design and development process with NS-3 on different premises, with no backward compatibility, actually giving birth to a completely new artifact but keeping and leveraging the experience from previous versions. NS-3 simulations may be written in C++ and Python, and their basic setup and execution is guided by a process suggested by the development team. NS-3 has been designed to be scalable.

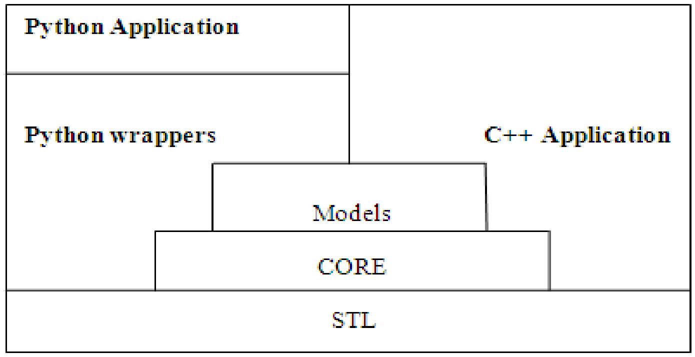

Fig -2 Architecture of NS-3

We believe that NS-3 has a significant potential and we expect its community to grow. We compared it against alternatives, and our internal evaluation led us to choose NS-3 over them. However, after a test period on several scenarios that are in the scope of our research activities, I decided to corroborate our evaluation with a SLR before using it to support the activities of a research project. Our investigation aims to study and understand what are the actual diffusion and the actual use of NS-3 in the research community, also to leverage literature to individuate possible weaknesses and limits of the tool that may affect the progress and the result of our research activities, and to classify the application areas in which adoption is wider and potential community support is stronger, more reactive and more intense, as well as the practically available modules and extensions that have been published and integrated.

2. RELATED WORK

Simulation is a widely accepted tool in the field of computer networks. Literature offers both free and commercial simulation tools that aim at supporting, at different levels and with different purposes, design and analysis of computer networks. With no claim to completeness, this Section presents some relevant cases to provide a first reference to the readers. Within the category of open-source simulators, besides NS-3 literature reports NS-2, OMNET++ and SWANS as noticeable examples.NS-2 (https://www.isi.edu/nsnam/ns/), actually the previous version of NS-3, deserves to be mentioned as a different tool, because it is still widely used not with standing it is not maintained anymore and its last version has been released in 2011, since, as previously reported, NS-3 has been completely redesigned on a different basis. NS-2 implements discrete-event simulation. NS-2 is characterized by a separation between the approach to the definition of the simulated components and the approach to the definition of simulation management and setup, the first is based on a compiled software, programmed in C++, including the components defined by the user or third parties, if any, while the second is managed by interpreted code written in OTcl, an object-oriented extension of the popular Tcl language, to ease the process. NS-2 has a significant base of available simulation components, due both to its popularity and lifespan, including protocols, reusable simulation objects that represent real-world equipment or routing algorithms. Support exists for wired and wireless networks, mobile networks, generation of specific patterns of traffic and energy-oriented evaluation. Its wide adoption fostered the development of third-party tools that partially compensate its limited support for visual management and analysis. OMNET++ (https://omnetpp.org/) is an event-based simulator that aims to provide a generic support to all kind of networked systems, from mobile networks to on-chip networks. The core of the simulator is a C++-based kernel that provides several services on which different application areas are made available by additional third-party frameworks, including very different cases such as photonic networks or sensor networks, or more abstract system performance modeling tools such as queuing networks.

Table-1: Study and comparison of Simulators

Features	GloMoSim	NS-2	NS-3	OMNET++
Language support	Parsec C	C++/OTcl	C++	C++
GUI Support	Poor	Poor	Good	Good
Time taken to learn	Long	Long	Moderate	Moderate
Time spend in downloading and installation	Long Time to download.	Moderate Time	Long Time to download & install all necessary patches & supporting software	Very Easy takes very less time to install and easily available
Platform	Linux, Windows	Linus, Unix, Windows	Linus, Unix, Windows	Linux, Unix, Windows, Mac OS
Network Visualization tool	Yes	Yes	Yes	Yes
Create Trace file	Yes	Yes	Yes	Yes
Availability of analysis Tool	Yes	Yes	Yes	Yes
Redesigning & Modification	Possible	Possible	Possible	Possible
Interaction with Real Time system	Possible	NO	Possible	Possible
Fast Simulation Capability	Poor	Moderate	Moderate	Moderate
Design &Implementation Protocols	Support Only wireless Protocols	Support both wired and wireless	Support both wired and wireless	Support both wired and wireless

The official website reports a very comprehensive list of domains that have been covered by users and made publicly available under open-source licenses. OMNET++ provides a proprietary scripting language to describe topologies in model setups and can be used both from the command line and a rich graphical user interface. Models and components may be specified by an event-based paradigm and a process-oriented paradigm. The simulation kernel, designed for portability, allows distributed and parallel execution to support large simulation scenarios and speed up the runs. The simulation definition process is integrated in Eclipse to ease setup and management, and interactive simulation is provided. OMNET++ supports analysis of performance metrics by visual tools.

SWANS (http://jist.ece.cornell.edu/) is a simulator for wireless networks and sensor networks that has been designed with special attention to allow high simulation performance and larger simulation scenarios with respect to NS-2 and GloMoSim, the open-source version of the QualNet simulator described later in this section. A SWAN uses JiST, a Java-based high-performance discrete-event simulation engine, as simulation support. The main aim of SWANS is scalability. Its architecture is component-based, and it can run Java network applications over simulated networks. The last version has been released in 2005. Within the category of commercial simulators, the market offers tools such as NetSim and QualNet. NetSim (https://www.tetcos.com/) is a tool that can be licensed for professional, research or teaching use. It is reported by developers to be or have been used in different professional environments such as military and space organizations, utilities distribution companies, railways industry, network equipment manufacturers and services providers for the design, development and evaluation of a rich variety of computer and communication networks. NetSim provides user friendly tools to support the various activities and allows both simulation and emulation. It provides packet animation and a native analysis support. Simulations can be based on existing modules or user defined modules written in C. QualNet (https://www.scalable-networks.com/qualnet-network-simulation) is designed to allow users to test, be trained on or plan large realistic networks by means of simulation (the same company provides an emulation tool as well). QualNet is originally based on GloMoSim and supports operationally accurate contexts. It provides a suite of tools for the configuration, the tracing and the analysis of traffic events.

3. CONCLUSIONS AND FUTURE WORKS

In this paper, we study documented the large success of NS-3 as a network simulator, its popularity and its flexibility. Data show that the scientific community considers it a useful tool in different fields, and dedicate third-party resources to extend it and develop add-ons for new adjacent application domains. A further useful contribution may be provided by analogous analyses on literature on the main "competitors", e.g., NS-2 and OMNET++, based on the same research questions and an overall meta-analysis to obtain a general view on the topic, to spot what is still not covered and would be useful for the scientific community and practitioners and develop focused built-in extensions or design a new, comprehensive simulation tool.

4.REFERENCES

[1] Riley, G.F.; Henderson, T.R. The ns-3 Network Simulator. In Modeling and Tools for Network Simulation; Wehrle, K., Güne¸s, M., Gross, J., Eds.; Springer: Berlin/Heidelberg, Germany, 2010; pp. 15–34. doi:10.1007/978-3-642-12331-3_2.

[2] Prof. M S Shegokar;Prof. V R Tripathi MH; Analysis study and comparison of recent trends in simulators: 2019 JETIR April 2019, Volume 6, Issue 4; (ISSN-2349-5162).

[3] Piro, G.; Grieco, L.A.; Boggia, G.; Camarda, P. Nano-Sim: Simulating Electromagnetic-Based Nanonetworks in the Network Simulator 3. In Proceedings of the 6th International ICST Conference on Simulation Tools and Techniques, Cannes, France, 6–8 March, 2013; ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering): Brussels, Belgium, 2013; pp. 203–210.

[4] Raman, A.; Chou, K.; Mastorakis, S. A simulation framework for Peer-to-Peer file sharing in named data networking. In Proceedings of the 2019 Workshop on ns-3, Florence, Italy, 18–21 June 2019; pp. 57–64.

[5] Bakshi, S. and Tahiliani, M.P. Recent Acknowledgement Support for ns-3 TCP. In Proceedings of the 2019 Workshop on ns-3, Florence, Italy, 18–21 June 2019; pp. 9–16.

[6] Rohrer, J.; Mauldin, A. Implementation of epidemic routing with IP convergence layer in ns-3. In Proceedings of the 10th Workshop on ns-3, Mangalore, India, 13–14 June 2018; ACM: New York, NY, USA, 2018; pp. 69–76.

[7] Mittal, V., Jain,V., Tahiliani, M.P. Proportional Rate Reduction for ns-3 TCP. In Proceedings of the 10th Workshop on ns-3, Mangalore, India, 13–14 June 2018; ACM: New York, NY, USA, 2018; pp. 9–15.

[8] Fontes, H.; Campos, R.; Ricardo, M. A trace-based ns-3 simulation approach for perpetuating real-world experiments. In Proceedings of the Workshop on ns-3, Porto, Portugal, 13–14 June 2017; ACM: New York, NY, USA, 2017; Volume Part F128360, pp. 118–124.

[9] Franchi, M.; Pecorella, T.; Ridolfi, A.; Fantacci, R.; Allotta, B. Kinematic constraints and ns-3 mobility models: The AUV issue. In Proceedings of the Workshop on ns-3, Porto, Portugal, 13–14 June 2017; ACM: New York, NY, USA, 2017; Volume Part F128360, pp. 103–109.