

# IEEE SDN Initiative :: Outreach: Towards a comprehensive, sustainable wiki catalogue of testbeds and open source toolkits

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Internet: <http://www.sdn-os-toolkits.org/>

 @ieeesdn

 Fraunhofer  
FOKUS

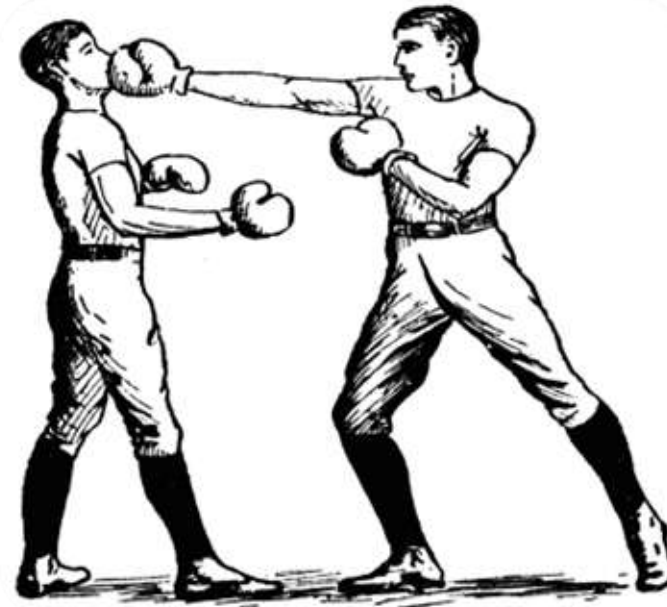
 Technische  
Universität  
Berlin

  
UNICAMP

 IEEE  
SOFTWARE  
DEFINED  
NETWORKS

 Open Source  
Toolkits & Testbeds

# Network Softwarization



## Existing

- CLIs
- Closed Source
- Vendor Lead
- Classic Network Appliances

## New

- APIs
- Open Source
- Customer Lead
- Network Function Virtualization (NFV)

## Why Open Source in Networking?

- Higher reliability, more flexibility
- Faster, lower cost, and higher quality development
- Collaborative decisions about new features and roadmaps
- A common environment for users and app developers
- Ability for users to focus resources on differentiating development
- Opportunity to drive open standards

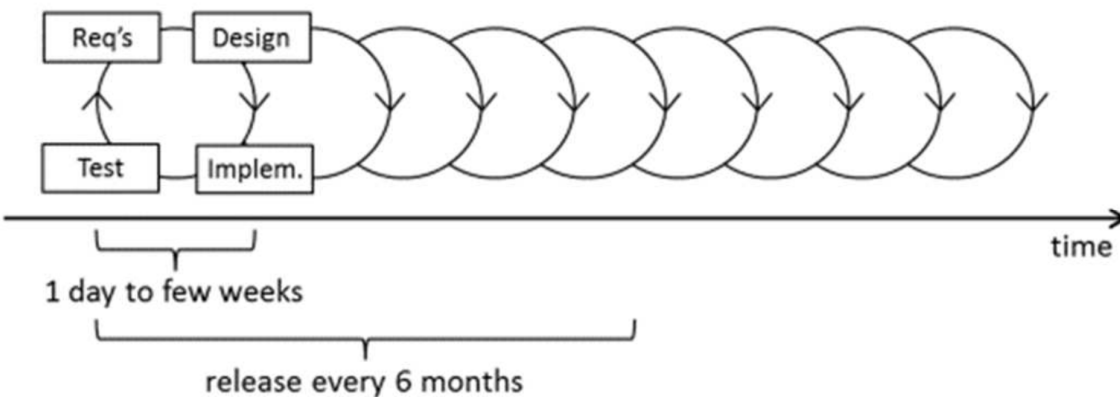
**Bottom Line:** The open source model significantly accelerates consensus, delivering high performing, peer-reviewed code that forms a basis for an ecosystem of solutions.



# SDN/NFV & Open Source

## Evolving and accelerating the path to standardization

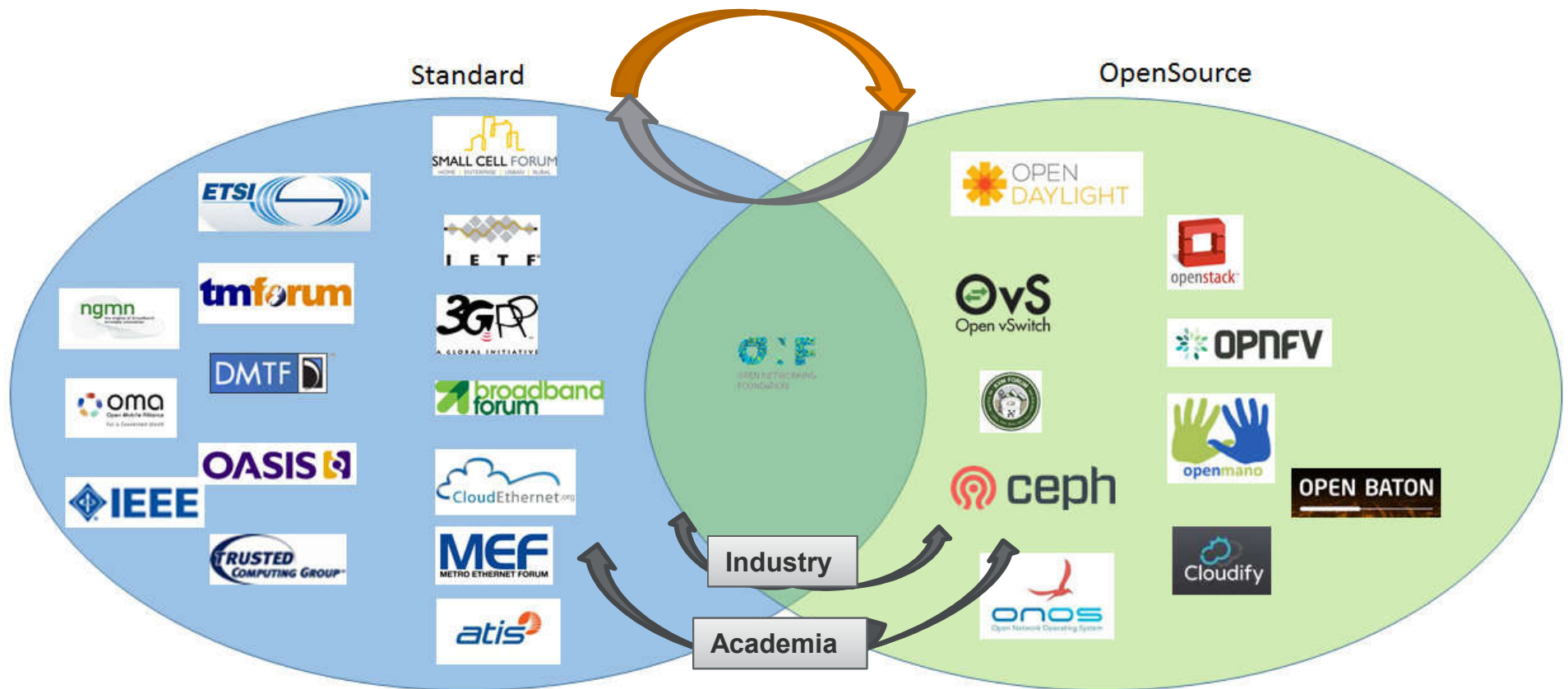
	Present with SDN	Past / Traditional
<b>Drivers</b>	Customer	Vendors
<b>Goals</b>	Address user / operator needs (customization)	Enable multiple solutions (interoperability)
<b>Deliverables</b>	Implementations & PoCs	Documents
<b>Quantity of Standards</b>	Less	More
<b>Timetable</b>	Few years	Many years
<b>Validation</b>	PoCs integral to the process	Products and deployments after release
<b>Point of Control</b>	Contribution to FLOSS codebase. Ability to understand codebase	Seat at standards committee table
<b>Parties Involved</b>	Anyone with domain expertise and coding ability	Vendors who can afford membership fees. Experts and academics with high standing in their fields



### Further Reading:

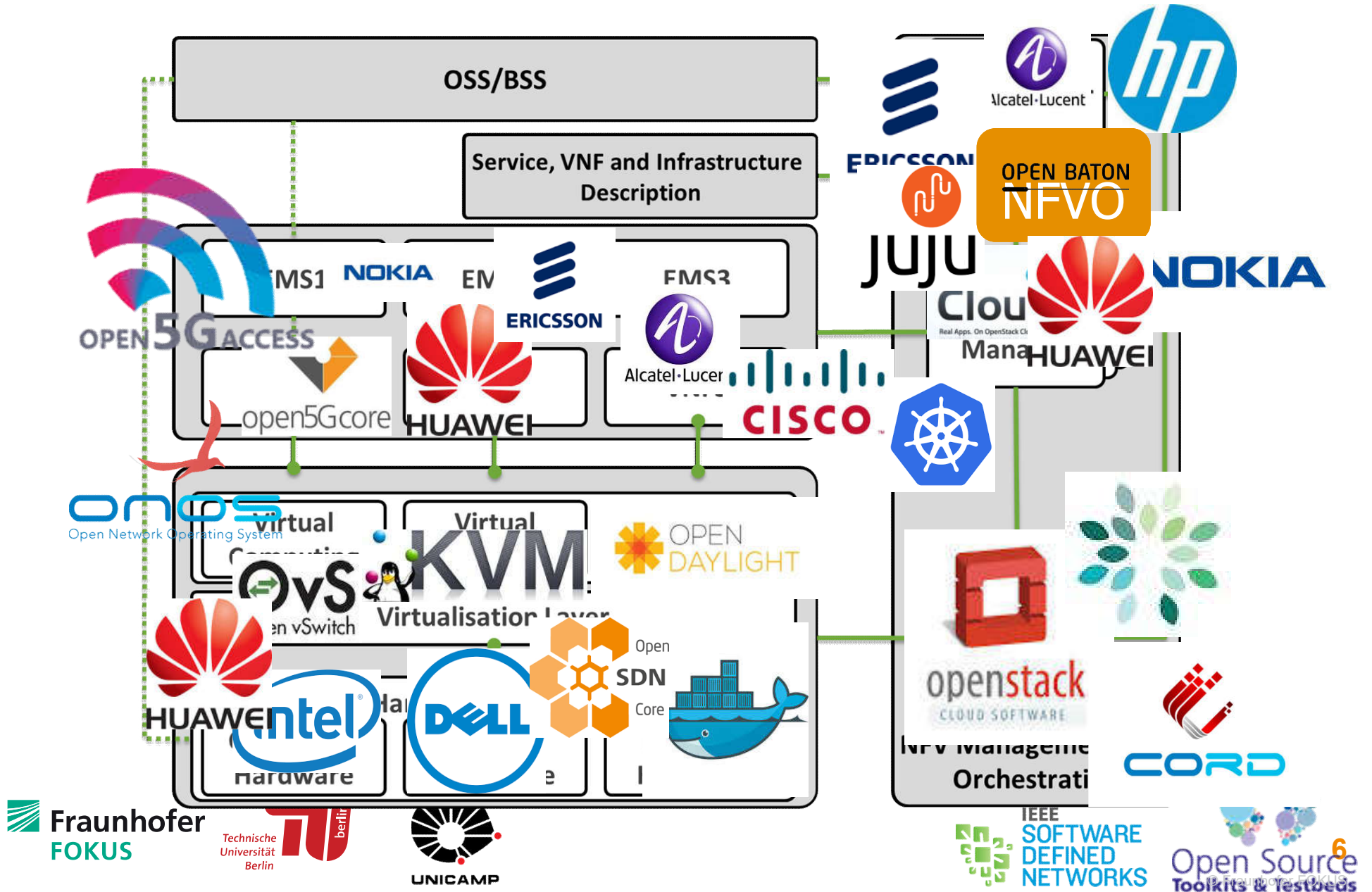
- IETF Trends and Observations [draft-arkko-ietf-trends-and-observations-00](#)
- Source of table: "[When Open Source Meets Network Control Planes](#)." In IEEE Computer (Special Issue on Software-Defined Networking), vol.47, Nov. 2014.
- Source of figure: A. Manzalini et al., "[Towards 5G Software-Defined Ecosystems](#)"

# Standard Development & Open Source Organizations



Source: SDN IEEE Outreach, <http://sdn.ieee.org/outreach>

# A Growing ecosystem



# Testbeds around the globe

Title	location	owner organization	short description	website
<a href="#">5G Center for Innovative Networks</a>	Turkey	NETAS	5GNET based in Istanbul focuses on wireless access technologies and performs combined functionalities with a wide function equipped laboratory and venture capital.	N/A
<a href="#">5G Experimental Facilities</a>	UK	University of Bristol	The facility aims to create a unique, fully flexible, programmable and open experimental platform for all networks and IT technologies.	N/A
<a href="#">5G haus</a>	Germany	Deutsche Telekom	DT has set-up a European wide program for the coordination, planning, and carrying out of 5G related experiments, tests, and field trials.	<a href="https://www.telekom.com/5ghaus">https://www.telekom.com/5ghaus</a>
<a href="#">5G Lab Germany</a>	Germany	TU Dresden	It is an interdisciplinary team with more than 500 researchers and aims to deliver key technologies for enabling 5G. The 5G Holistic Testbed consists of several connected test-beds which enable holistic research approaches for areas from silicon, wireless, networks, edge clouds and applications.	<a href="http://5glab.de">http://5glab.de</a>
<a href="#">5G Playground</a>	Germany, Berlin	Fraunhofer FOKUS	5G playground encompasses a comprehensive, highly customizable and re-configurable network environment, based on commercially available components and the Fraunhofer own toolkits	<a href="http://5GPlayground.org">5GPlayground.org</a>
<a href="#">5G Wireless Innovation Center, Argela</a>	Turkey	Istanbul	5GWiN based in Istanbul and Silicon Valley focuses on software defined future radio access technologies. Current projects listed as ULAK to develop 4G base station, short and long range Small Cell, programmable C-RAN.	<a href="http://www.tinvestorrelations.com/turk-telekom-group/group-companies/argela.aspx">http://www.tinvestorrelations.com/turk-telekom-group/group-companies/argela.aspx</a>
<a href="#">5G-EmPOWER testbed</a>	Italy	Create-Net	5G-EmPOWER developed by Create-Net is a unique and open toolkit for SDN/NFV research and experimentation over wireless and mobile networks.	<a href="https://github.com/5g-empower/5g-empower.github.io/wiki/Overview">https://github.com/5g-empower/5g-empower.github.io/wiki/Overview</a>

And many more: <http://networld2020.eu/wp-content/uploads/2015/12/5G-experimentation-Whitepaper-v10.pdf>



## Research challenges (1/2)

Research and development around Software Defined Networking (SDN) and Network Function Virtualization (NFV) is vast and testbeds and related toolkits in academia addressing SDN, NFV, Mobile Edge Computing (MEC) and 5G technologies are being set-up

- A strong impact on the industry is anticipated

Many open source initiatives with high potentials are not known by other researchers due to the lack of visibility

- Scientific publications are a good mean for those researchers to get some visibility, but that's not enough





## Research challenges (2/2)

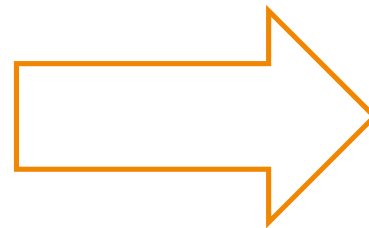
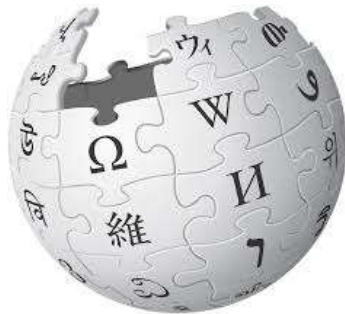
Many researchers, students, product developers have no idea how to get started

- The large number of existing activities makes very difficult the selection process of the tools needed for supporting their requirements



## How to get started???

# Towards a “Wikipedia” of Toolkits & Testbeds



# Phase 1: Collaborative Data Collection

## Toolkits:

- <http://bit.do/oss-sdn-nfv>
- From initial 90 to current 170+ projects

Name	Organization	Main Contribution / Focus [SHORT DESC: 160 char.]	Link-Project	Link-Repo-Code	OpenSource-License	Mailing-list
OpenSwitch (OVS)	Linux Foundation	Production quality, multilayer virtual switch designed to enable massive network automation through programmatic extension, while still supporting standard management interfaces and protocols.	<a href="http://openvswitch.org/">http://openvswitch.org/</a>	<a href="https://github.com/openvswitch/ovs">https://github.com/openvswitch/ovs</a>	Apache 2.0	<a href="mailto:announce@openvswitch.org">announce@openvswitch.org</a>
OpenSwitch (OSP)	Linux Foundation	OpenSwitch is a network operating system for disaggregated switches that are built around OCP compliant hardware and that utilize the ONOS tool leader to install and uninstall network operating systems.	<a href="http://www.openvswitch.net/">http://www.openvswitch.net/</a>	<a href="https://github.com/openvswitch/ovs">https://github.com/openvswitch/ovs</a>	Apache 2.0	<a href="mailto:osp-dev@lists.openvswitch.net">osp-dev@lists.openvswitch.net</a>
Indigo	Big Switch Networks	The Indigo agent includes core libraries aimed at enabling support for OpenFlow on physical and hypervisor switches.	<a href="http://www.projectfloodlight.org/indigo/">http://www.projectfloodlight.org/indigo/</a>	<a href="https://github.com/floodlight/indigo">https://github.com/floodlight/indigo</a>	Edgex Public License version 1	<a href="mailto:indigo-announce@openvswitch.org">indigo-announce@openvswitch.org</a>
Dataplane (DP)	CPQ	Research-friendly User-space OpenFlow 1.0 software switch forked from Stanford's original reference switch design used for prototyping and experimentation. Integrated into Mininet. Used for open source implementation of new OpenFlow features by CNF members.	<a href="https://github.com/CPQ/dataplane">https://github.com/CPQ/dataplane</a>	<a href="https://github.com/CPQ/dataplane">https://github.com/CPQ/dataplane</a>	BSD license	<a href="mailto:openflow-discuss@openvswitch.org">openflow-discuss@openvswitch.org</a>
LINC switch	FlowForwarding	LINC is a pure OpenFlow software switch written in Erlang.	<a href="https://github.com/flowforwarding/flowforwarding">https://github.com/flowforwarding/flowforwarding</a>	<a href="https://github.com/flowforwarding/flowforwarding">https://github.com/flowforwarding/flowforwarding</a>	Apache 2.0	<a href="mailto:inc-dev@flowforwarding.org">inc-dev@flowforwarding.org</a>
Protocol Oblivious Forwarding (POF)	Hussein	SDN southbound protocol designed for high flexibility.	<a href="http://www.poforwarding.org/">http://www.poforwarding.org/</a>	<a href="https://github.com/poforwarding/poforwarding">https://github.com/poforwarding/poforwarding</a>	BSD license	<a href="mailto:poforwarding@hussein.com">poforwarding@hussein.com</a>
Lagopus	NTT	High-performance software OpenFlow 1.3 switch leveraging DPDK.	<a href="https://github.com/ntt-lab/lagopus">https://github.com/ntt-lab/lagopus</a>	<a href="https://github.com/ntt-lab/lagopus">https://github.com/ntt-lab/lagopus</a>	Apache 2.0	<a href="mailto:lagopus-devel@lists.sourceforge.net">lagopus-devel@lists.sourceforge.net</a>
Berkley Extensible Software Switch (BES)	Berkley University	Modular framework for high-performance software switches allowing to configure custom packet processing datapath by composing small "modules".	<a href="https://github.com/berkeleylab/bes">https://github.com/berkeleylab/bes</a>	<a href="https://github.com/berkeleylab/bes">https://github.com/berkeleylab/bes</a>	BSDv3	
ClickOS	NEC	A minimalist, table-made, virtualized operating system to run Click-based middleboxes.	<a href="https://github.com/nec-lab/clickos">https://github.com/nec-lab/clickos</a>	<a href="https://github.com/nec-lab/clickos">https://github.com/nec-lab/clickos</a>	BSDv2	<a href="mailto:click@listserv.netlab.nec.de">click@listserv.netlab.nec.de</a>
Click	MIT, UCLA, and others	The Click modular router: fast modular packet processing and analysis.	<a href="http://www.nec.ca/click-subjects/">http://www.nec.ca/click-subjects/</a>	<a href="https://github.com/nec-lab/click">https://github.com/nec-lab/click</a>	MIT	<a href="mailto:click@mit.edu">click@mit.edu</a>
Snabb Switch	Snabb	Snabb (formerly "Snabb Switch") is a simple and fast packet networking toolkit.	<a href="https://github.com/snabb">https://github.com/snabb</a>	<a href="https://github.com/snabb">https://github.com/snabb</a>	Apache 2.0	<a href="mailto:snabb-devel@googlegroups.com">snabb-devel@googlegroups.com</a>
OpenNetVM	GW, UCR	High-performance NFV platform for running service chains through Decider NF's	<a href="https://github.com/opennetvm">https://github.com/opennetvm</a>	<a href="https://github.com/opennetvm">https://github.com/opennetvm</a>	BSD	<a href="mailto:inwood@uci.edu">inwood@uci.edu</a>
Open Network Install Environment (ONIE)	Open Compute Project	Open Compute Project open source initiative contributed by Citrus Networks that defines an open "install environment" for bare metal network switches.	<a href="http://www.opencompute.org/">http://www.opencompute.org/</a>	<a href="https://github.com/opencompute/onie">https://github.com/opencompute/onie</a>	GNU GPL v2	<a href="mailto:opencompute-onie@lists.opencompute.org">opencompute-onie@lists.opencompute.org</a>
Open Network Linux (ONL)	Open Compute Project	Linux distribution for "bare metal" switches, that is, network forwarding devices built from commodity components.	<a href="http://opennetworklinux.org/">http://opennetworklinux.org/</a>	<a href="https://github.com/OpenComputeProj/onl">https://github.com/OpenComputeProj/onl</a>	GNU GPL v2	<a href="mailto:opennetworklinux@googlegroups.com">opennetworklinux@googlegroups.com</a>
Facebook Open Switching System (FOSS)	Facebook	Facebook's software stack (user-space applications, libraries, and utilities) for controlling and managing network switches.	<a href="https://github.com/facebook/foos">https://github.com/facebook/foos</a>	<a href="https://github.com/facebook/foos">https://github.com/facebook/foos</a>	BSD license	
OpenDaylight (ODL)	Linux Foundation	Production-ready open SDN platform containing features, protocols and plug-ins that can be integrated in a number of ways to deliver a broad set of SDN use cases.	<a href="http://www.opendaylight.org/">http://www.opendaylight.org/</a>	<a href="https://github.com/opendaylight">https://github.com/opendaylight</a>	Apache 2.0	<a href="mailto:controller-users@lists.opendaylight.org">controller-users@lists.opendaylight.org</a>
ONOS	Linux Foundation	Carrier-grade SDN network operating system designed for high availability, performance, scale-out.	<a href="http://onosproject.org/">http://onosproject.org/</a>	<a href="https://github.com/onosproject/onos">https://github.com/onosproject/onos</a>	Apache 2.0	<a href="mailto:onos-discuss@onosproject.org">onos-discuss@onosproject.org</a>
Floodlight	Big Switch Networks	Java-based OpenFlow 1.0 controller	<a href="http://www.projectfloodlight.org/floodlight/">http://www.projectfloodlight.org/floodlight/</a>	<a href="https://github.com/floodlight/floodlight">https://github.com/floodlight/floodlight</a>	Edgex Public License version 1	<a href="mailto:floodlight-dev@openvswitch.org">floodlight-dev@openvswitch.org</a>
Ryu	NTT	Python-based OpenFlow 1.0 controller	<a href="https://github.com/ntt-lab/ryu">https://github.com/ntt-lab/ryu</a>	<a href="https://github.com/ntt-lab/ryu">https://github.com/ntt-lab/ryu</a>	Apache 2.0	<a href="mailto:ryu-dev@lists.sourceforge.net">ryu-dev@lists.sourceforge.net</a>
Thema	NEC	Thema is a full-stack framework for developing OpenFlow controllers in Ruby and C.	<a href="https://github.com/nec-lab/thema">https://github.com/nec-lab/thema</a>	<a href="https://github.com/nec-lab/thema">https://github.com/nec-lab/thema</a>	GNU GPL v2	<a href="mailto:thema-dev@googlegroups.com">thema-dev@googlegroups.com</a>
OpenMIL	OpenMIL Foundation	Base SDN/OpenFlow controller platform written almost entirely in C (from scratch) and provides top performance in terms of flow handling (download rate and latency) as well as a very stable application development platform.	<a href="http://www.openmil.org/openmil-core/">http://www.openmil.org/openmil-core/</a>	<a href="https://github.com/openmil/openmil">https://github.com/openmil/openmil</a>	GNU GPL v2	
POX	Stanford University	Python-based OpenFlow 1.0 controller used for research and experimentation	<a href="https://github.com/novonegro/pox">https://github.com/novonegro/pox</a>	<a href="https://github.com/novonegro/pox">https://github.com/novonegro/pox</a>	Apache 2.0	<a href="mailto:pox-dev@lists.sourceforge.net">pox-dev@lists.sourceforge.net</a>
Beacon	Stanford University	Java-based OpenFlow 1.0 controller	<a href="https://github.com/stanford/beamon">https://github.com/stanford/beamon</a>	<a href="https://github.com/stanford/beamon">https://github.com/stanford/beamon</a>	BSD License	
SNAC	Stanford University	OpenFlow 1.0 controller with network access control application	<a href="https://github.com/novonegro/snac">https://github.com/novonegro/snac</a>	<a href="https://github.com/novonegro/snac">https://github.com/novonegro/snac</a>	Apache 2.0	<a href="mailto:snac-dev@lists.sourceforge.net">snac-dev@lists.sourceforge.net</a>
NOX	Stanford University	First OpenFlow 1.0 controller implementation	<a href="https://github.com/novonegro/nxm">https://github.com/novonegro/nxm</a>	<a href="https://github.com/novonegro/nxm">https://github.com/novonegro/nxm</a>	Apache 2.0	<a href="mailto:nox-dev@lists.sourceforge.net">nox-dev@lists.sourceforge.net</a>
IRIS	ETRI	The Recursive SDN OpenFlow Controller by ETRI is an open source version of IRIS. IRIS is an OpenFlow-based SDN controller designed to solve scalability and availability issues of SDN.	<a href="http://openiris.etri.re.kr/">http://openiris.etri.re.kr/</a>	<a href="https://github.com/etri/iris">https://github.com/etri/iris</a>		
ExaBGP	Eva Networks	ExaBGP provides a convenient way to implement Software Defined Networking by transforming BGP messages into ready-to-run JSON, which can then be easily handled by simple scripts or your SDN/SD-WAN.	<a href="https://github.com/EvaNetworks/exabgp">https://github.com/EvaNetworks/exabgp</a>	<a href="https://github.com/EvaNetworks/exabgp">https://github.com/EvaNetworks/exabgp</a>	BSD	<a href="mailto:exabgp-users@googlegroups.com">exabgp-users@googlegroups.com</a>
GoBGP	NTT	GoBGP is an open source BGP implementation designed from scratch for modern workstation and implemented in a modern programming language, the Go Programming Language.	<a href="https://github.com/ntt-lab/gobgp">https://github.com/ntt-lab/gobgp</a>	<a href="https://github.com/ntt-lab/gobgp">https://github.com/ntt-lab/gobgp</a>	Apache 2.0	<a href="mailto:gobgp-dev@lists.sourceforge.net">gobgp-dev@lists.sourceforge.net</a>
Bird	CZ.NIC	IP Routing Stack	<a href="https://github.com/bird-network/bird">https://github.com/bird-network/bird</a>	<a href="https://github.com/bird-network/bird">https://github.com/bird-network/bird</a>	GNU GPL	<a href="mailto:bird-users@network.cz">bird-users@network.cz</a>
Quagga	OpenSourceRouting	IP Routing Stack	<a href="http://www.opensource-routing.org/">http://www.opensource-routing.org/</a>	<a href="https://github.com/opensourcerouting/quagga">https://github.com/opensourcerouting/quagga</a>	GNU GPL	<a href="mailto:quagga-users@lists.quagga.net">quagga-users@lists.quagga.net</a>
Calico	Tigera	Highly efficient vRouter in each compute node that leverages the existing Linux kernel forwarding engine without the need for switches	<a href="http://www.projectcalico.org/">http://www.projectcalico.org/</a>	<a href="https://github.com/projectcalico/calico">https://github.com/projectcalico/calico</a>	Apache 2.0	<a href="mailto:calico-announce@lists.projectcalico.org">calico-announce@lists.projectcalico.org</a>
XORP	XORP	IP Routing Stack	<a href="http://www.xorp.org/">http://www.xorp.org/</a>	<a href="https://github.com/xorp/xorp">https://github.com/xorp/xorp</a>	GNU GPL	<a href="mailto:xorp-users@xorp.org">xorp-users@xorp.org</a>
Atarix	Atarix	OpenFlow-based SDN Controller by Atarix is an open source version of IRIS. IRIS is an OpenFlow-based SDN controller designed to solve scalability and availability issues of SDN.	<a href="https://github.com/atarix/atarix">https://github.com/atarix/atarix</a>	<a href="https://github.com/atarix/atarix">https://github.com/atarix/atarix</a>	Apache 2.0	<a href="https://atariix.com/newsletter">https://atariix.com/newsletter</a>

## Testbeds:

- <http://networld2020.eu/wp-content/uploads/2015/12/5G-experimentation-Whitepaper-v10.pdf>

## Phase 2: Initial version of the Wiki

- Some existing wiki toolkits have been analyzed:
  - Selected Atlassian Confluence directly supported by and integrated with the IEEE service infrastructure and used in other open source initiative (OPNFV)
- Generation of the structure. Separation between:
  - toolkits and testbeds
- Tagging (labels) mechanism based on main functionalities / scope provided of each individual toolkit or testbed
  - It facilitates classification and navigation



## Phase 3: Open the Wiki to the public community

- Managed by the community
  - Open to any registered user
  - Scales nicely / cost-effective (effort/per-person)
  - Content updates, curation, etc.
- Area caretakers to validate updates



## Live demo



# Acknowledgements

Thanks to all volunteers that contributed to the realization of the catalogue

- INTRIG MSc and PhD students @ Unicamp
- See ~30 names under the “Contributors” tab:  
<http://bit.do/oss-sdn-nfv>
- Giuseppe Carella (TU Berlin)
  - Co-producer and leader of the testbed catalogue efforts



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Internet: <http://www.sdn-os-toolkits.org/>

 @ieeesdn

 Fraunhofer  
FOKUS

 Technische  
Universität  
Berlin

  
UNICAMP

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SOFTWARE  
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NETWORKS

  
Open Source  
Toolkits & Testbeds