IEEE 5G and Beyond Testbed Workshop
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Towards a comprehensive, sustainable wiki catalogue of testbeds and open source toolkits

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

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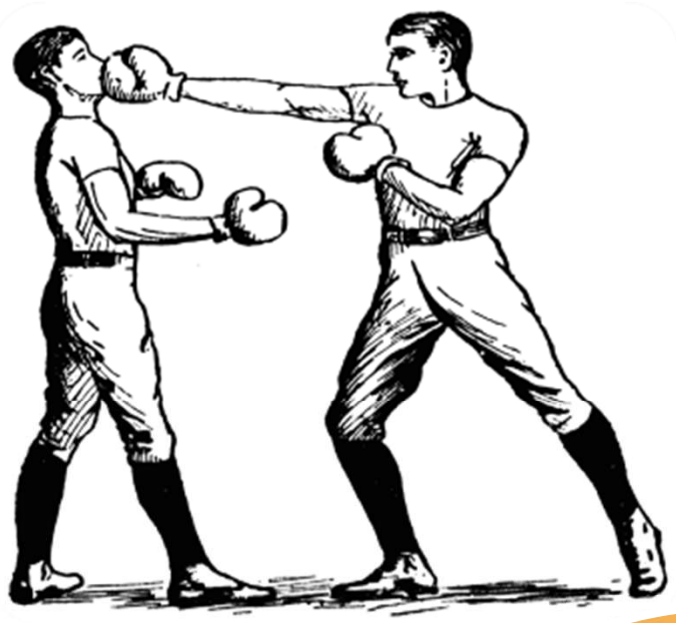
Open Source Toolkits & Testbeds

Network Softwarization



Existing

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

New

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

Adapted from: Kyle Mestery, Next Generation Network Developer Skills

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

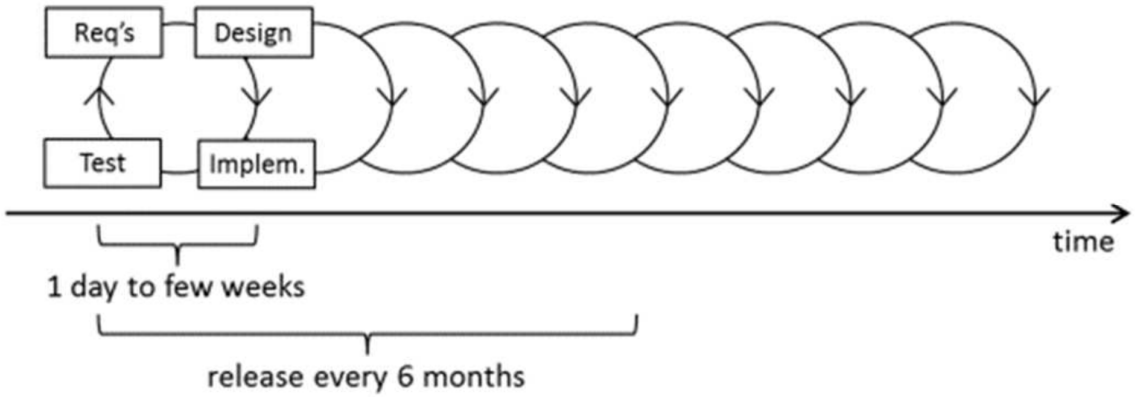
Bottom Line: The open source model significantly accelerates consensus, delivering high performing, peer-reviewed code that forms a basis for an ecosystem of solutions.

Source: Open Source in a Closed Network – Prodip Sen (OPNFV Summit 2015)

SDN/NFV & Open Source

Evolving and accelerating the path to standardization

	Present with SDN	Past / Traditional
Drivers	Customer	Vendors
Goals	Address user / operator needs (customization)	Enable multiple solutions (interoperability)
Deliverables	Implementations & PoCs	Documents
Quantity of Standards	Less	More
Timetable	Few years	Many years
Validation	PoCs integral to the process	Products and deployments after release
Point of Control	Contribution to FLOSS codebase. Ability to understand codebase	Seat at standards committee table
Parties Involved	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*"

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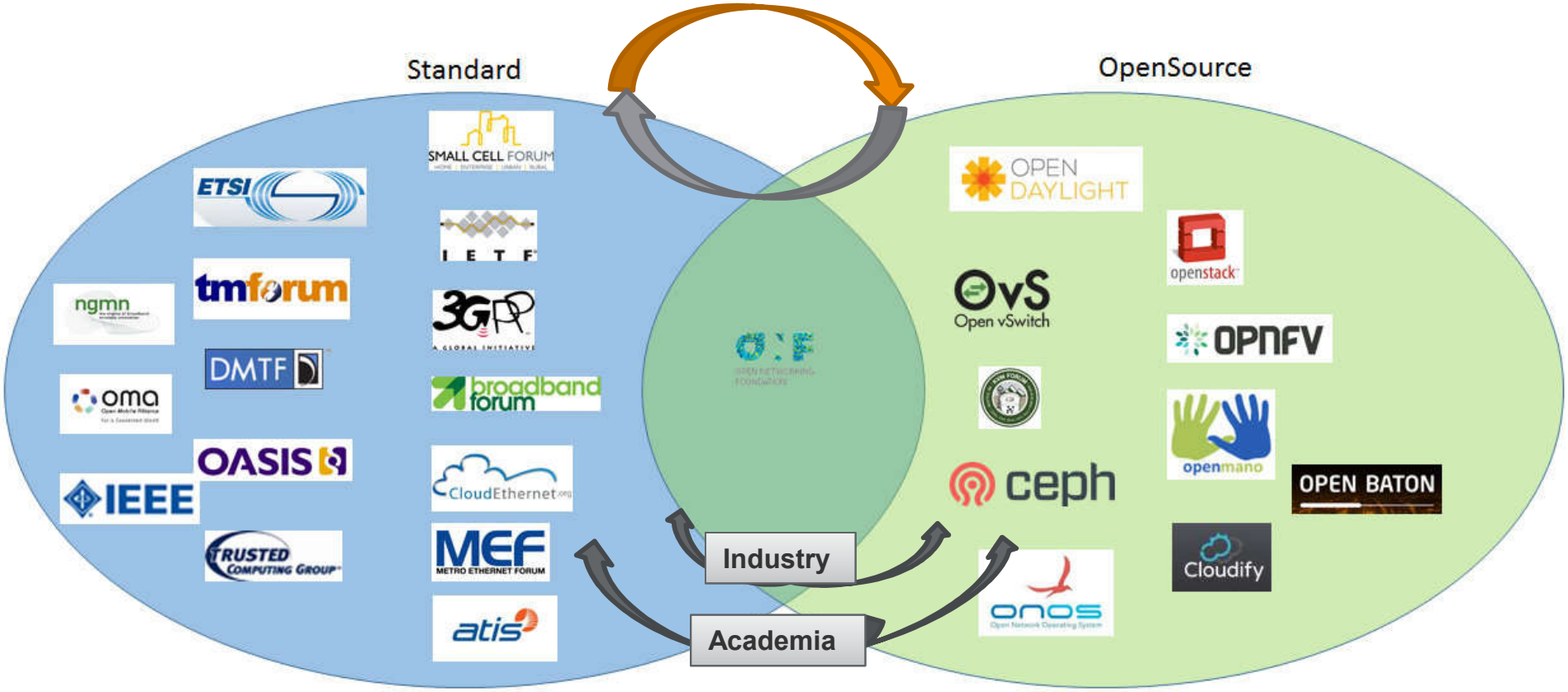
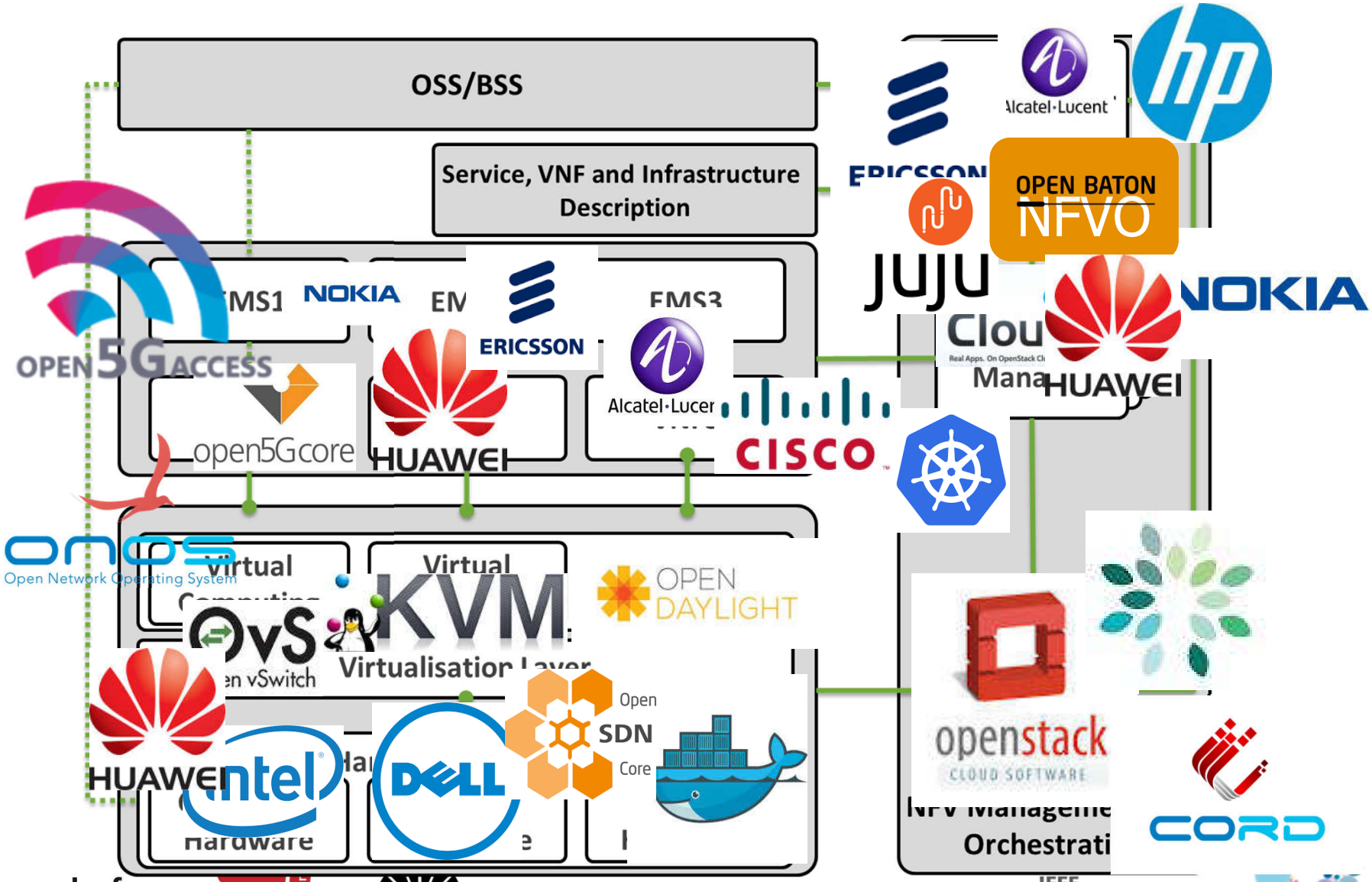
Standard Development & Open Source Organizations



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

A Growing ecosystem



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Open Source Toolkits & Testbeds

Testbeds around the globe

Title	location	owner organization	short description	website
5G Center for Innovative Networks	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
5G Experimental Facilities	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
5G haus	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.	https://www.telekom.com/5ghaus
5G Lab Germany	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.	http://5glab.de
5G Playground	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	5GPlayground.org
5G Wireless Innovation Center, Argela	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.	http://www.ttinvestorrelations.com/turk-telekom-group/group-companies/argela.aspx
5G-EmPOWER testbed	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.	https://github.com/5g-empower/5g-empower.github.io/wiki/Overview

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

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Open Source Toolkits & Testbeds

Source: the SDN Catalogue

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)

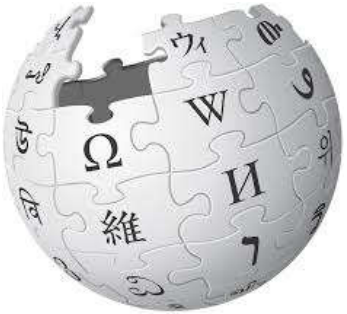
Many researchers, students, product developers have no idea how to get started

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

How to get started???

Image Source:
https://www.linkedin.com/pulse/how-technology-has-become-blessing-curse-paul-hollington

Towards a “Wikipedia” of Toolkits & Testbeds



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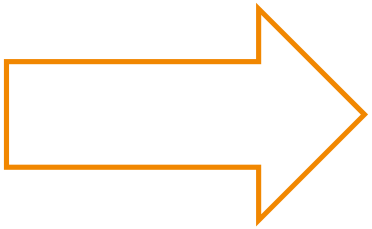

Open Source Toolkits & Testbeds

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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
OpenvSwitch (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.	http://openvswitch.org/	https://github.com/openvswitch/ovs/	Apache 2.0	announce@openvswitch.org
OpenSwitch (OSP)	Linux Foundation	OpenSwitch is a network operating system for disaggregated switches that are built around OCP compliant hardware and that utilizes the ONIE boot loader to install and uninstall network operating systems	http://www.openswitch.net/	https://archive.openswitch.net/artifacts/	Apache 2.0	ops-dev@lists.openswitch.net
Indigo	Big Switch Networks	The Indigo agent includes core libraries aimed at enabling support for OpenFlow on physical and hypervisor switches.	http://www.projectfloodlight.org/indigo/	https://github.com/floodlight/indigo	Eclipse Public License version 1	indigo-announce@openflowhub.
Ofsoftswitch13	CPqD	Research-friendly User-space OpenFlow 1.x 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 ONF members.	http://cpqd.github.io/ofsoftswitch13/	https://github.com/CPqD/ofsoftswitch1	BSD license	openflow-discuss@openflowswit
LINC-switch	FlowForwarding	LINC is a pure OpenFlow software switch written in Erlang	http://flowforwarding.github.io/LINC-S	https://github.com/FlowForwarding/LIN	Apache 2.0	linc-dev@flowforwarding.org
Protocol Oblivious Forwarding (POF)	Huawei	SDN southbound protocol designed for high flexibility.	http://www.poforwarding.org	http://www.poforwarding.org/pofdpdk/	BSD license	poforwarding@huawei.com
Lagopus	NTT	High-performance software OpenFlow 1.3 switch leveraging DPDK.	https://lagopus.github.io/	https://github.com/lagopus/lagopus	Apache 2.0	lagopus-devel@lists.sourceforge
Berkeley Extensible Software Switch (BES	Berkeley University	Modular framework for high-performance software switches allowing to configure custom packet processing datapath by composing small "modules".	https://github.com/NetSys/bess/wiki	https://github.com/NetSys/bess	BSDv3	
ClickOS	NEC	A minimalistic, tailor-made, virtualized operating system to run Click-based middleboxes.	http://cnp.neclab.eu/clickos/	https://github.com/cnp-neclab/clickos	BSDv3	cnplab@listserv.neclab.nec.de.
Click	MIT, UCLA, and others	The Click modular router: fast modular packet processing and analysis	http://www.read.cs.ucla.edu/click/	https://github.com/kohler/click	MIT	click@lists.list.com
Snabb Switch	Snabb	Snabb (formerly "Snabb Switch") is a simple and fast packet networking toolkit.	https://snabb.co/	https://github.com/snabb/snabb	Apache 2.0	snabb-devel@googlegroups.com
OpenNetVM	GW, UCR	High performance NFV platform for running service chains through Docker NFs	http://sdnfv.github.io/onvm/	https://github.com/sdnfv/openNetVM	BSD	timwood@gw.edu
Open Network Install Environment (ONIE)	Open Compute Project	Open Compute Project open source initiative contributed by Cumulus Networks that defines an open "install environment" for bare metal network switches	http://onie.opencompute.org/	https://github.com/opencompute/onie/	GNU GPL v2	opencompute-onie@lists.openco
Open Network Linux (ONL)	Open Compute Project	Linux distribution for "bare metal" switches, that is, network forwarding devices built from commodity components.	http://opennetlinux.org/	https://github.com/OpenComputeProje	GNU GPL v2	opennetworklinux@googlegroup
Facebook Open Switching System (FBOS	Facebook	Facebook's software stack (user-space applications, libraries, and utilities) for controlling and managing network switches.	https://github.com/facebook/fboss	https://github.com/facebook/fboss	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	http://www.opendaylight.org	https://github.com/opendaylight	Apache 2.0	controller-users@lists.opendayli
ONOS	Linux Foundation	Carrier-grade SDN network operating system designed for high availability, performance, scale-out	http://onosproject.org/	https://github.com/opennetworkinglab/	Apache 2.0	onos-discuss@onosproject.org
Floodlight	Big Switch Networks	Java-based OpenFlow 1.0 controller	http://www.projectfloodlight.org/floodl	https://github.com/floodlight/floodlight	Eclipse Public License version 1	floodlight-dev@openflowhub.org
Ryu	NTT	Python-based OpenFlow 1.x controller	http://osrg.github.io/ryu/	https://github.com/osrg/ryu	Apache 2.0	ryu-devel@lists.sourceforge.net
Trema	NEC	Trema is a full-stack framework for developing OpenFlow controllers in Ruby and C.	https://trema.github.io/trema/	https://github.com/trema/trema	GNU GPL v2	trema-dev@googlegroups.com
OpenMul	OpenMUL 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.	http://www.openmul.org/openmul.com	https://github.com/openmul/openmul	GNU GPL v2	
POX	Stanford University	Python-based OpenFlow 1.0 controller used for research and experimentation	https://github.com/noxrepo/pox	https://github.com/noxrepo/pox	Apache 2.0	pox-dev@lists.noxrepo.org
Beacon	Stanford University	Java-based OpenFlow 1.0 controller	https://openflow.stanford.edu/display/	git@gitolite.stanford.edu/beacon.git	BSD License	
SNAC	Stanford University	OpenFlow 1.0 controller with network access control application				
NOX	Stanford University	First OpenFlow 1.0 controller implementation	https://github.com/noxrepo/nox	https://github.com/noxrepo/nox	Apache 2.0	nox-dev@lists.noxrepo.org
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.	http://openiris.etri.re.kr/	https://github.com/openiris/IRIS		
ExaBGP	Exa Networks	ExaBGP provides a convenient way to implement Software Defined Networking by transforming BGP messages into friendly plain text or JSON, which can then be easily handled by simple scripts or your BSS/OSS.	https://github.com/Exa-Networks/exab	https://github.com/Exa-Networks/exab	BSD	exabgp-users@googlegroups.co
GoBGP	NTT	GoBGP is an open source BGP implementation designed from scratch for modern environment and implemented in a modern programming language, the Go Programming Language.	https://osrg.github.io/gobgp/	https://github.com/osrg/gobgp	Apache 2.0	gobgp-devel@lists.sourceforge.n
Bird	CZ.NIC	IP Routing Stack	http://bird.network.cz/	git@gitlab.nic.cz/bird.git	GNU GPL	bird-users@network.cz
Quagga	OpenSourceRouting	IP Routing Stack	https://www.opensourcerouting.org/	http://git.savannah.gnu.org/cgit/quagga	GNU GPL	quagga-users@lists.quagga.net
Calico	Tigera	Highly efficient vRouter in each compute node that leverages the existing Linux kernel forwarding engine without the need for vSwitches	https://www.projectcalico.org/	https://github.com/projectcalico/calico	Apache 2.0	calico-announce@lists.projectcal
XORP	XORP	IP Routing Stack	http://www.xorp.org/	http://github.com/greweb/xorp.ci	GNU GPL	xorp-users@xorp.org
Astara	Akanda	Orchestration platform based on Layer 2 agnostic and interfaces with the OpenStack Neutron REST APIs featuring sophisticated lifecycle management to monitor, configure, and manage 3rd party virtualized routers, load balancers and firewalls.	http://akanda.io/	https://github.com/openstack/astara	Apache 2.0	#openstack-astara channel on fr

Testbeds:

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

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Phase 2: Initial version of the Wiki

https://wiki.sdn.ieee.org

- Some existing wiki toolkits have been analyzed:
  - Selected Atlassian Confluence directly supported by and integrated with the IEEE service infrastructure and used in related 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

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Image Source: Photographed by Lane Hartwell (http://fetching.net/) on behalf of the Wikimedia Foundation.
https://commons.wikimedia.org/wiki/File:Wikipedia_mini_globe_handheld.jpg

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

Image Source: Photographed by Lane Hartwell (http://fetching.net/) on behalf of the Wikimedia Foundation.
https://commons.wikimedia.org/wiki/File:Wikipedia_mini_globe_handheld.jpg

Lesson learnt

- Creating a live catalogue was more complex than expected:
  - A google doc was created for collecting inputs from different partners world-wide
- Content requires frequent updates:
  - Potential committed authors must be identified in order to keep the catalogue always inline with the state-of-the-art standards and technologies
- Different authentication policies must be put in place:
  - Define a set of reviewers (wikipedia style) before the content is actually put online
  - It needs to be explored whether Confluence is the appropriate tool for this

Potential outlook for future activities

- Improve the Wiki technologies
- Define Workflows for content management, user accounts, etc.
- Continue evolving the catalogue through the IEEE 5G initiative
- Extend the actual scope so that also 5G standards and existing open source projects are covered

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