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SDN Controllers - A Comparative approach to Market Trends

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1. Introduction
2. SDN Controllers
3. TOP 6 SDN Controllers
4. Conclusion and Future Works

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INTRODUCTION

- SDNs is a **paradigm that introduces the separation of the control plane and data plane**. In this paradigm,routing/control Plane is centralized within in the SDN Controller. **Based on the Controller´s global network perspective, this component optimizes the behavior of the data plane, maximizing the possibilities of network management and control.**

- SDN is an emerging network paradigm that **allows to overcome the limitations of current network infrastructures**, being defined as a four pillars network architecture: **Data and Control Planes are decoupled**, the routing decisions are **flow-based instead of destination based**, **the control logics is executed by an external entity called SDN Controller**, and, the network is programmable through software applications running on the top of the SDN Controller.

INTRODUCTION

- ✓ The main contribution of this paper is the comparative review of the available SDN controllers and their main features, beyond technical, functional and market perspectives.

Related Works

Work	Characteristics
[1]	Kreutz et al conducted a generalized systematic review of the SDN paradigm and its several technological aspects. Nervertheless, this review was not oriented to a comparative study of controllers according to the market perspective.
[3]	Salman et al present a comparison among SDN controllers considering criteria such as programming language, documentation, modularity and performance, also not performing a market oriented comparison.
[4]	Gonçalo e Souza make a systematic review of the SDN controllers and a comparative approach was based on some criteria such as learning curve, supported APIs, documentation availability, Openflow version, among others technical points. Unfortunately, this work does not carry out a a market view perspective.

[1] KREUTZ, D. et al. Software-Defined Networking: A Comprehensive Survey. Oct. 2014. Available at: https://arxiv.org/pdf/1406.0440.pdf

[3] SALMAN, O. et al. SDN Controllers: A Comparative Study. Abr. 2016. Available at: https://www.researchgate.net/publication/304457462_SDN_controllers_A_comparative_study

[4] GONÇALO, J.S.P. , SOUSA, P. A comparative study of software defined networking (SDN) controllers (in portuguese). June. 2019. ISBN: 978-989-98434-9-3.

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SDN Controllers

We classify the main (key) characteristics of SDN controllers as 4 points (in addition to the availability of documentation and market acceptance):

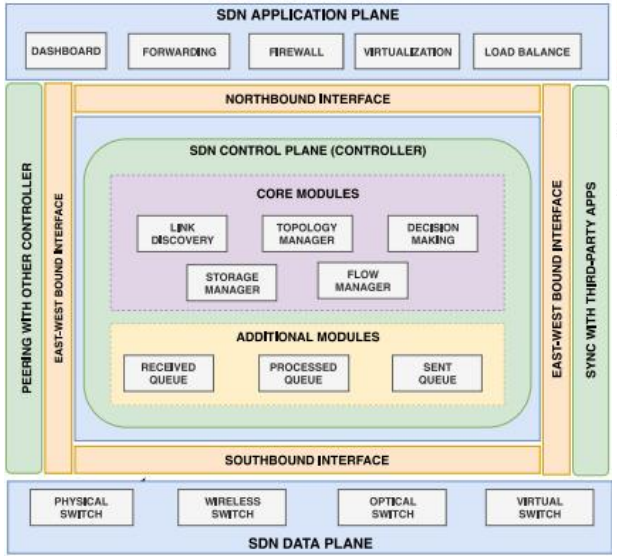
(1) **Architecture and Design Axes**, determining a centralized or distributed design providing a higher flexibility and performance to the traffic.

(2) **East/Westbound APIs**, which are essential components including functions such as importing and exporting data between controllers (**Federalization**), algorithms for data consistency models, monitoring and notification capability, etc.

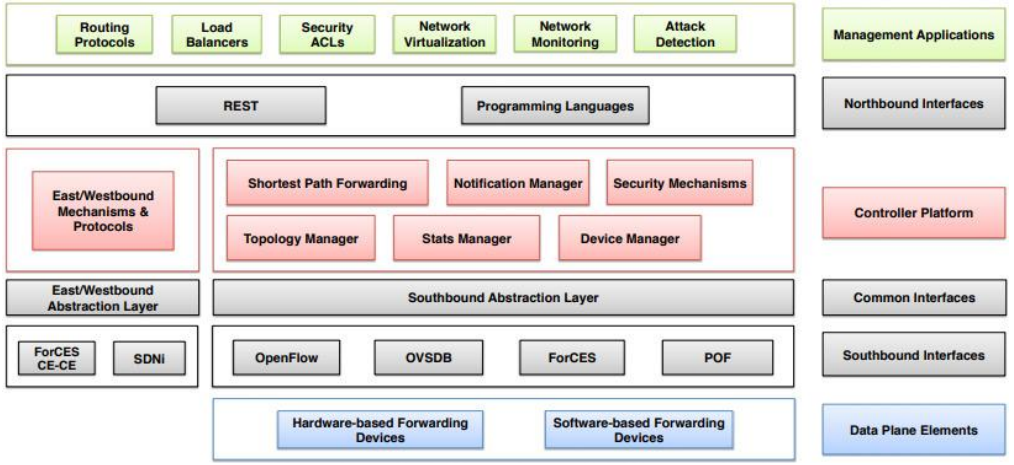
(3) **Programming languages**, providing interoperability, multithreading, low learning curve, fast access to memory and good memory management are taken into account

(4) **Support to Openflow and other protocols in the Southbound interface and network programmability.**

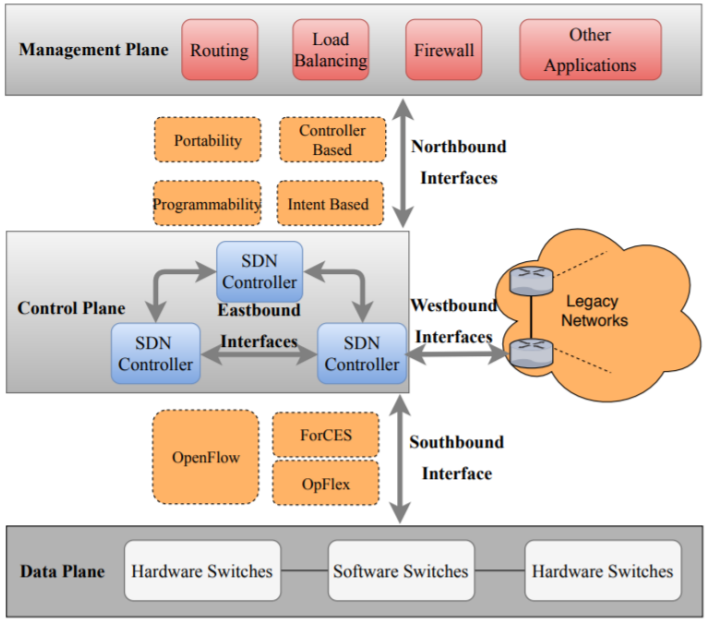
SDN Controllers



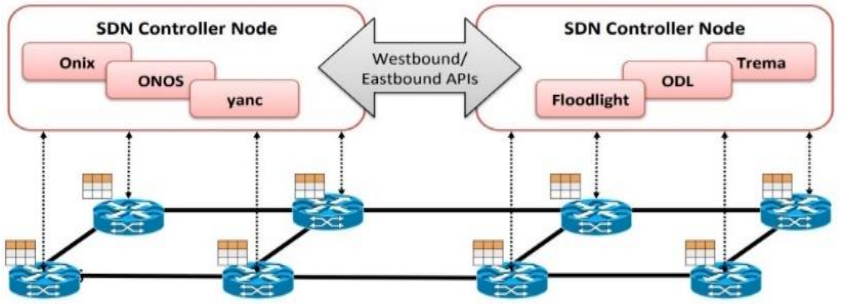
SDN controller architecture overview



SDN control platform Overview



SDN interface placement and properties



Simplified View of Distributed Design for SDN Controllers

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TOP 6 SDN Controllers

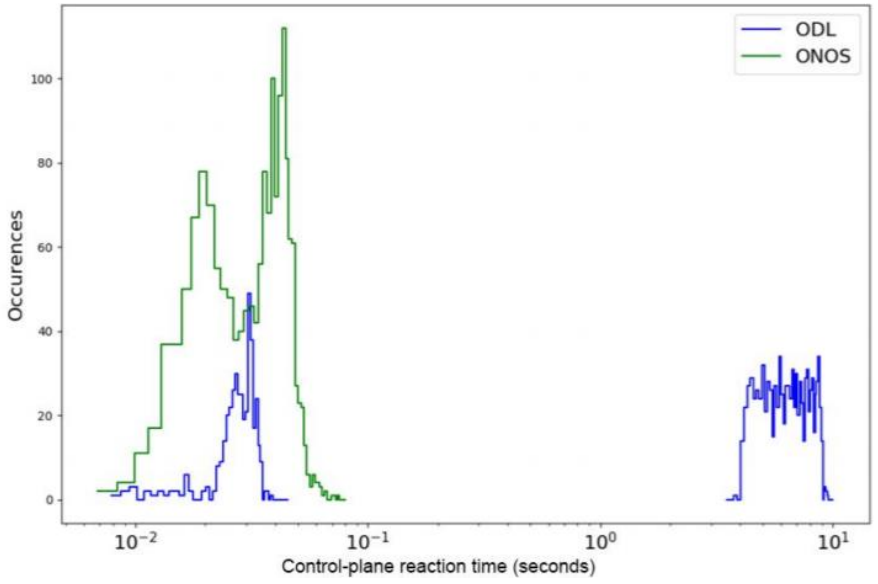
- **Classify SDN controllers is a challenge**, since there are several criteria that can be applied and some of them are mutually exclusive.

- The classification of each controller depends on factors such as the controller's citation in the literature and **use in industry/Market acceptance.**

- Regarding proprietary controllers, one of the main decision actors is the controller´s market value concerning SDN and virtualization solutions, and/or its citation as a reference in the SDN market, in addition to the documentation availability and the extension of its northbound API, connoting its extensibility and your marketplace for SDN NBI APPs.

TOP 6 SDN Controllers

In 2019, Secci et Al, in 2019 published in the ONF a comparative report (also not exhaustive) between the **TWO MOST USED CONTROLLERS (ONOS AND ODL)**, until now the ONF reference comparison considering security and performance aspects. **ONOS was better** in (***Path restoration behavior / control-plane reactivity to topology***), ***Cibersecurity Aspects*** (MITER CVE 2014 ~ 2018) ONOS 12 vs 22 ODL (16 is in a core OLD code and applications, DoS is a common trend reported) and ***Code Maturity*** (Code version and Bugs)



Project	Bugs	Commits	LOC	Density [bugs/kLOC]
ONOS	2.072	13.254	852.570	2,43
ODL	9.060	98.084	3.920.556	2,31

Git code version and Jira Bugs Reported

	ONOS	ODL
2014	0	2
2015	1	9
2016	0	2
2017	6	7
2018	5	2

MITRE CVE per Year

TOP 6 SDN Controllers

CONTROLLER	COMMENTS	STRONG POINTS	WEAK POINTS	MINIMAL HW SPECS
HUAWEI AGILE CONTROLLER	Component of its Cloudfabric Solution solutions, Based on ONOS.	Interoperate with third-party platforms like Vmware and Openstack. Support to several protocols for SBI besides Openflow (up to 1.4).	Large HW specs	CPU 32 cores@2.4 Ghz, 32G memory, 4*1200GB storage
HP VAN SDN CONTROLLER	Component of HP's SDN solutions, based on ODL.	Very rich API with excellent RSDoc documentation available and a marketplace to expand functions via NBI	It only supports Openflow in SBI	intel Core2/Xeon 8-core with 16gb ram and 64gb Storage.
JUNIPER CONTRAIL	Component of Juniper SDN Solutions for end-to-end dynamic configuration and control for any infrastructure.	Extensive documentation, broad support in both SBI and NBI and large integration (Kubernets, Openshift and Mesos).	Very high acquisition cost	2.2ghz quad-core processor, 12gb RAM, 2 tb storage
CISCO ACI APPLICATION CENTRIC INFRASTRUCTURE)	That supports Vxlan as an extensible overlay/network logic protocol and NFV using GRE (NV-GRE), based on ODL.	Extensive case documentation (except for the little NBI documentation) and a huge marketplace to provide extensions.	Very high acquisition cost	8vCPUs 2.1 Ghz Xeon, 32gb memory, 300gb SSD storage
ODL - OPENDAYLIGHT SDN CONTROLLER	Linux Foundation opensource controller, is the basis for several proprietary controllers such as the Ericsson SDN Controller, Fujistu Virtuora, Cisco ACI and others.	Its extensive protocol support in SBI as a service abstraction layer (Openflow, OVSDB, NETCONF, BGP, P4, LISP, SNMP, PCEP among others), and good NBI support.	Small/outdated documentation of the project .	8-cores CPU, 20gb memory (recommended 3gb memory for each CPU core), 40gb storege
ONOS (Open Network Operating System) SDN CONTROLLER	Is a Linux Foundation project and a leading open source SDN controller for building next generation SDN/NFV solutions and is the basis for several proprietary controllers like Huawei and a very good market acceptance (NTT, AT&T, China Unicom, Ciena, Cisco, Comcast, D-TAG, Ericsson, Google, Fujitsu, Intel, NEC, Nokia, Samsung, Verizon, Nokia, Telefonica, ZTE, Dell, Alibaba).	A good documentation and a large adopt in market (Opensource Community and Telcos). Due to a very rich SBI support to Openflow, P4, NETCONF, TL1, SNMP, BGP, RESTCONF and PCEP protocols, ONOS places itself as one of the controllers with a wider range of SBI coverage. Another Strong point is a low hw specs.	The fact that ONF still maintains two controllers (ODL and ONOS). [Not a ONOS specific weak point]	2x1.8 ghz CPU, 2 GB RAM, 10 GB hdd.

TOP 6 SDN Controllers

TOP 6 RANK	NAME	CLASSIFICATION COMMENTS	DOCUMENTATION AVAILABILITY	OF VER.	NBI/SBI/W-E API PROTO	LICENSE
1°	**ONOS**	Large number of telecom solution providers apply it as a basis to develop own proprietary solutions. Large community adopt. ONF/Linux Foundation standard and reference. Basis for several commercial solutions.	Extensive documentation available. northbound API well documented. its enabling programmability. Well documented and available project portal	yes (1.5)	In NBI gRPC, REST and a lot of abstractions (that simplify the creation, deployment, and operation of configuration, management and controlapplications). SBI with Plug-in Architecture, with extensive and growing list of southbound support including P4, OpenFlow, NETCONF, TL1, SNMP, CLI, BGP, RESTCONF and more. YANG tool-chain. W-EBI (SDN-i) with Raft protocol.	Apache 2.0
2°	ODL	Opensource reference in SDN controllers, being the basis for several commercial solutions.	Relative documentation difficulty. No updated documentation. API not well documented.	yes (1.3)	API Rest/Java , OSGi and a lot of SBI protocols. W-EBI (SDN-i) with BGP.	Eclipse (epl 1.0)
3°	CISCO ACI	Reference in the telecommunications and internet market.	Good documentation available, however northbound API documentation is not widely available.	No	API Rest, BGP and a lot of SBI protocols. No have public documentation about W-EBI API.	Proprietary License
4°	JUNIPER CONTRAIL	Reference in the telecommunications and internet market.	Good documentation available, however NBI docs is not.	No	API Rest, BGP and a lot of SBI protocols. No have public documentation about W-EBI API	Proprietary License
5°	HP VAN SDN CONTROLLER	HP's approach in the SDN market. extensive available documentation. RSDoc documentation API is very broad	Comprehensive documentation available and open. Well documented NBI and SBI .	Yes (1.3)	API Rest. No have public documentation about W-EBI API	Proprietary License
6°	HUAWEI AGILE CONTROLLER	Huawei's approach to SDN marking, huawei is a reference in telecommunications.	There is no open availability of extensive documentation. Public documentation is limited	Yes (1.4)	gluon, api rest, webservices. No have public documentation about W-EBI API	proprietary license

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Conclusion and Future Works

- **The comparative study of SDN controllers reveals that there are many options available, between free and proprietary software.** The acceptability of SDN controllers was analyzed according to their support to multiple protocols in the SBI, support to different applications at NBI and wide documentation availability

- As future work, **the context of this article indicates a constant update of comparative data due to the dynamic evolution of the related technologies and also of the market oscillations**. Opensource projects can oscillate in criteria, requirements and functionalities as well as proprietary designs may also be simply for market reasons of project decision.

- Also as future work we can include the criterion of adoption of SDN controllers in 5G projects (In Core, Edge, Access/RAN) that size also has the same issues of temporality and technological paradigms mentioned above

I hope everyone is safe, healthy and well

The full version of this article with all the details will be published , news about this in my Linkedin social network and on the CAARF-SDN group profile at Researchgate

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