

## SDN Performance

Raising the bar on SDN control plane performance and scalability

This white paper describes an effective set of metrics to evaluate the “carrier-grade quotient” of SDN Control Planes/Controllers and provides performance evaluation of ONOS Blackbird using these metrics.

**April 6th, 2015**

## **The promise of SDN**

Software-Defined Networking (SDN) has become one of the hottest topics in the industry, and for a good reason. SDN is about separating the control plane from the data plane. As a result, SDN disaggregates proprietary closed boxes into the SDN control plane (SDN Network Operating System), the data plane and the applications and services. SDN gives users centralized control, greater visibility, greater choice because they can mix and match technologies at different layers. It also enables greater innovation because each layer can evolve at its own pace. The end benefit for the user is an ability to provide new services easily while lowering costs and this essentially is the real promise of SDN.

## **Lack of performance- a significant barrier to SDN adoption**

As service providers start deploying SDN solutions not only to test their labs networks but also to control and manage their carrier-scale networks, high performance, scalability and availability become key architectural requirements for these solutions. Carrier-grade SDN platforms and solutions need to demonstrate these attributes and measure and qualify them with effective metrics.

Building a “carrier-grade” SDN control plane is a challenging design problem that requires thoughtful technical analysis of the tradeoffs between high availability, performance and scale as all three are closely related. In fact, the lack of a high performance SDN control plane platform has been a big barrier to SDN deployment and adoption. Quantifying the SDN Control plane performance with effective metrics is yet another unaddressed challenge because simplistic performance metrics such as “Cbench” do not provide a complete or accurate view of the control plane’s performance and scale-out capabilities.

This white paper describes an effective set of metrics to evaluate the “carrier-grade quotient” of SDN Control Planes and provides an evaluation of ONOS Blackbird using these metrics. These proposed metrics are equally applicable for evaluating other SDN Control Planes/Controllers in addition to ONOS.

## **“Carrier-grade quotient” of SDN control plane- which metrics matter?**

SDN brings about the separation of the control plane from the data plane. This logically centralized control plane needs to provide high performance, scalability and availability to be considered for deployment in service provider and mission critical networks.

The SDN control plane supports a diversity of northbound applications and southbound devices and protocols. In carrier-scale networks, the SDN control plane has to support high throughput to deal with scale and size. This capability of the SDN control plane can be evaluated by measuring its “throughput” under high and increasing workloads at the northbound and southbound interfaces. Furthermore, the requirements and number of applications as well as the network will continue to grow requiring the SDN control plane to have the ability to scale up to support this growth. This important attribute is referred to as “scalability” or “scale-out”. Finally, failures are a fact of life and the SDN control plane needs to be able to swiftly detect and react to these failures to ensure seamless operation. These attributes can be captured by measuring the “latency” of the SDN control plane in detecting and/or reacting to such events.

Measuring all these attributes of the SDN control plane provide an effective way to gauge the “**carrier-grade quotient**” of the SDN control plane.

## **ONOS approach to performance, scalability and availability**

ONOS is architected as a logically centralized but physically distributed SDN control plane. ONOS comprises a cluster of instances that work together to manage the applications and the network. As demands on the SDN control plane grow, either due to an increase in the size of the network or due to an increase in the number of network control applications, ONOS can scale by adding additional instances to the cluster. ONOS automatically offloads a portion of the work to these new instances.

Architecting a distributed but logically centralized SDN control plane such as ONOS is a true technical challenge. ONOS’ ability to successfully provide and demonstrate high performance, scale and high availability together is what differentiates it from other open source SDN controllers available today. ONOS measurements that validate the benefits of its distributed architecture including providing high performance and scalability are highlighted in subsequent sections.

## **Measuring the performance and scale of the SDN control plane**

This section describes a comprehensive set of metrics to evaluate the performance and scale of the SDN control plane/SDN controllers. It also provides a comprehensive evaluation of ONOS Blackbird release performance using these metrics. Detailed information about the evaluation set-up, test methodology and detailed ONOS Blackbird evaluation is available at [ONOS wiki - Blackbird release evaluation](#).

## Summary of metrics

The ONOS Blackbird release defines the following set of metrics to effectively measure performance and other carrier-grade attributes of the SDN control plane.

### Performance Metrics:

- ❑ Topology – Switch change latency
- ❑ Topology – Link change latency
- ❑ Flow installation throughput
- ❑ Intent (Northbound) install latency
- ❑ Intent (Northbound) withdraw latency
- ❑ Intent (Northbound) reroute latency
- ❑ Intent (Northbound) throughput

Target numbers for metrics-

- ❑ Flow Throughput: 1 Million flow operations/sec
- ❑ Latency: Less than 100ms latency (ideally under 10ms)

### Scalability

- ❑ Ability to scale control plane by adding capacity

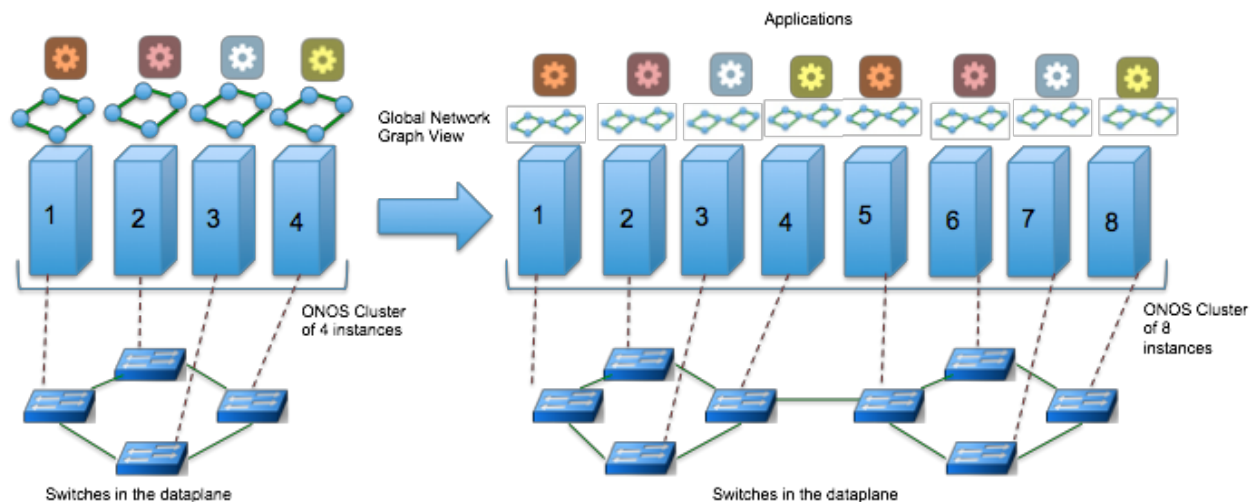


Figure 1. Add ONOS instances to handle growth in size of network

## High Availability

- ❑ Uninterrupted operation in the wake of failures, maintenance and upgrades (outside the scope of this white paper, detailed results are available on the [ONOS wiki](#))

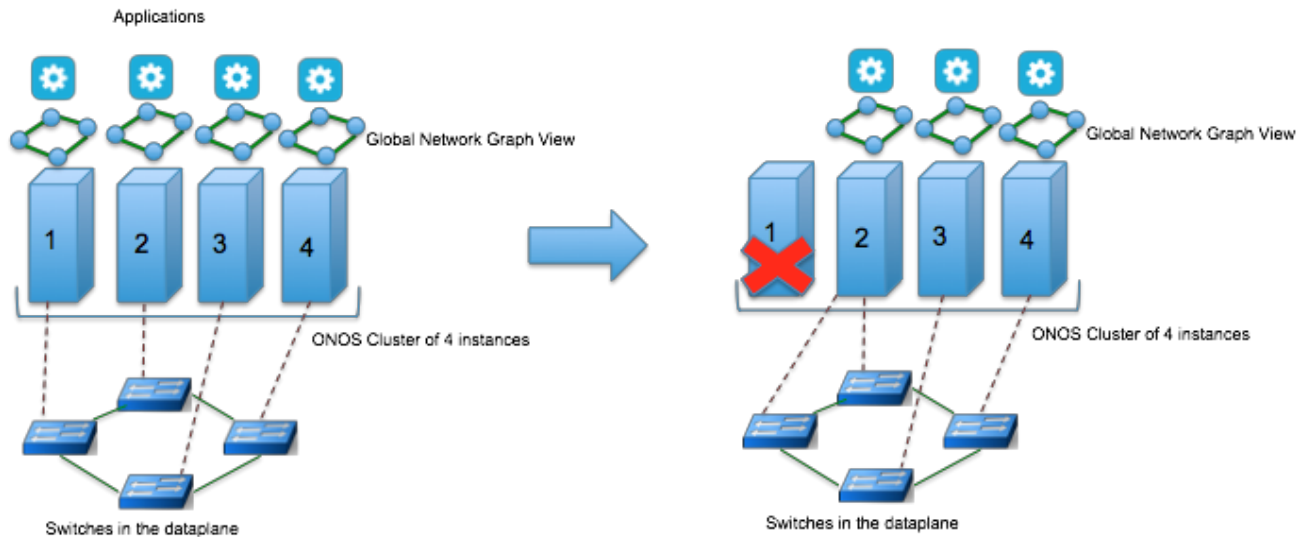


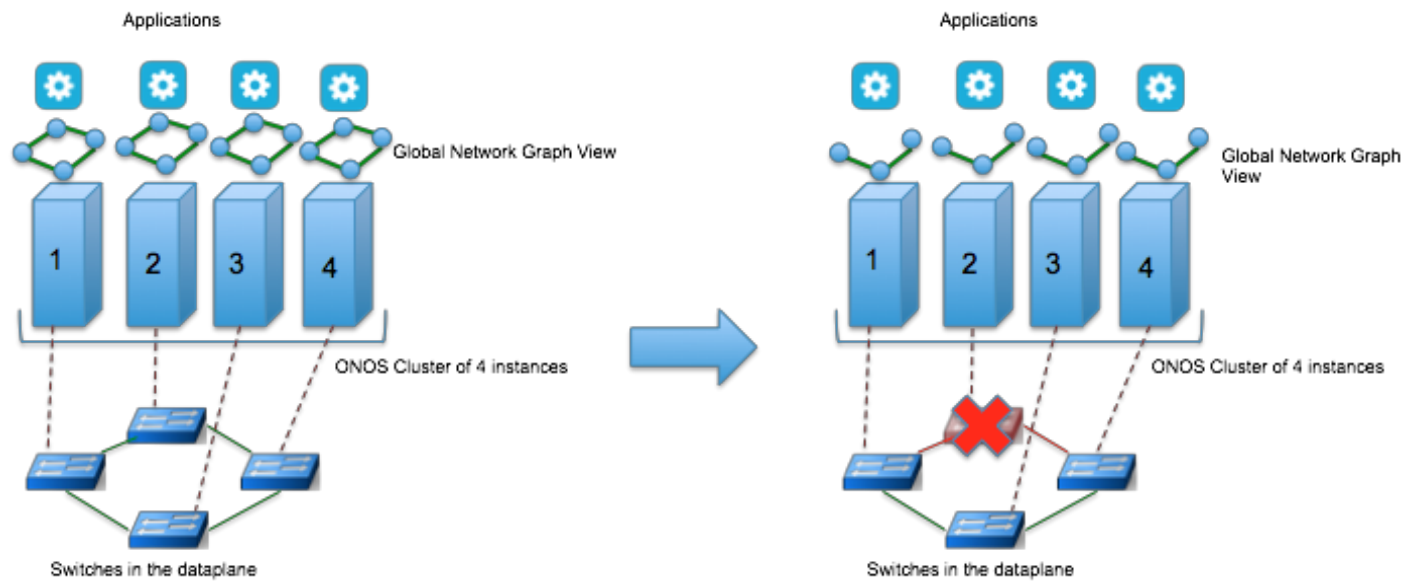
Figure 2. High Availability

## Detailed description of metrics

### ❑ Switch Latency

#### Definition of “Switch Latency” metric

This metric measures the latency of discovering and handling the switch up and switch down network events. A related goal is to measure the impact of distributed maintenance of the topology state on switch latency in a multinode ONOS cluster.



**Figure 3. Switch down latency metric**

### Importance of this metric

- This metric shows how quickly the SDN control plane can react to switch failures or introduction of new switches. A rapid response is especially essential to ensuring seamless operation in the wake of switch failures.

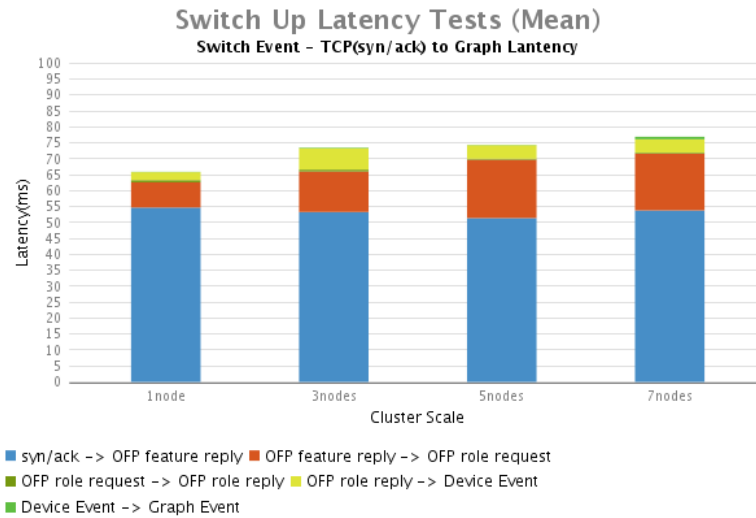
### Target numbers

- Under 100 ms latency and ideally under 10 ms

### Experimental setup

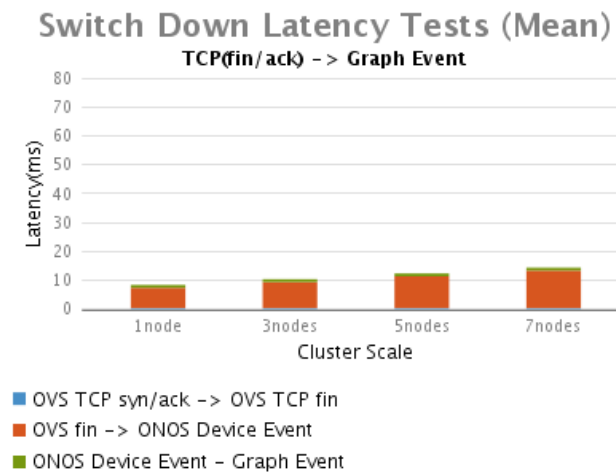
- Two OVS switches connected to each other.
- Events are generated from the switch
- Elapsed time is measured from the switch until ONOS triggers a corresponding topology event

## Actual results for ONOS



**Figure 4.**

- For all single and multi-instance setups, switch up latency ranges between **65 to 77 ms**.



**Figure 5.**

- For all single and multi-instance setups, switch down latency ranges between **8-13 ms**.
- Significantly faster because there is no negotiation with the switch. A terminating TCP connection unequivocally indicates that the switch is gone

## Key takeaways

- The latency numbers are well within 100 ms target.

## ❑ Link Latency

### Definition of “Link Latency” metric

This metric measures the latency of discovering and handling the link-up and link-down network events. A related goal is to measure the impact of distributed maintenance of the topology state on link latency in a multinode ONOS cluster.

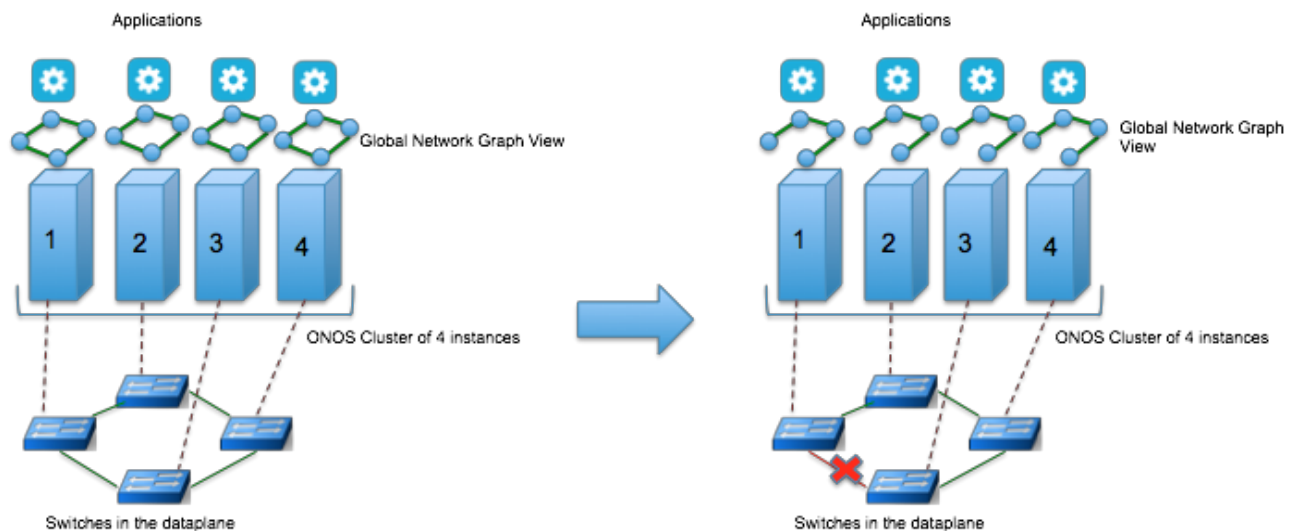


Figure 6. Link down latency metric

### Importance of this metric

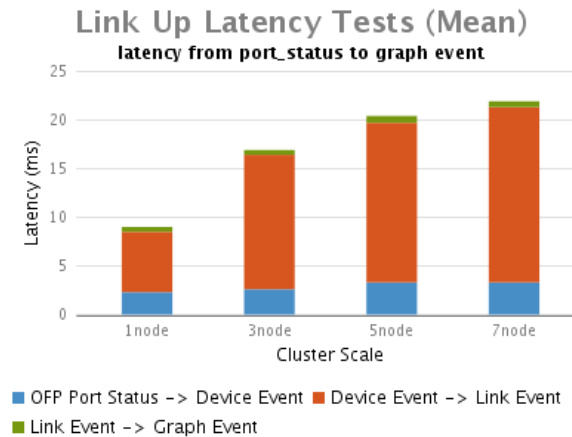
- This metric shows how quickly the SDN control plane can react to link failures, addition of, or state change of links. A rapid response is especially critical to ensuring seamless operation in the wake of link failures.

### Target numbers



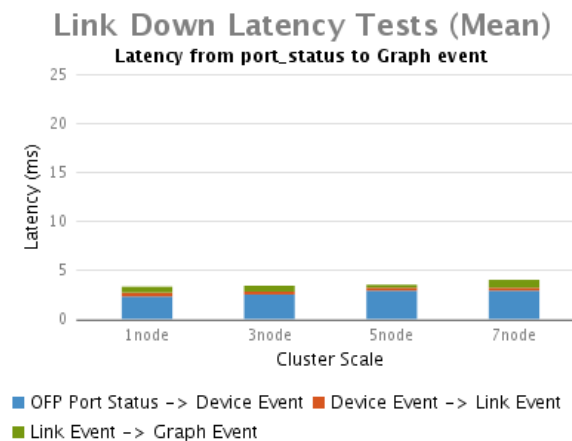
- Under 100 ms latency and ideally under 10 ms

## Actual results for ONOS



**Figure 7.**

- For a single instance, the latency is **8 ms**.
- For multi-node cluster, the latency ranges from **17 to 22 ms**.
- Since LLDP is used to discover links, it takes longer to discover a link coming up than going down



**Figure 8.**

- For a single instance, the latency is **3 ms**.
- For multi-node cluster, the latency is **3 - 4 ms**.

## Key takeaways

- The latency numbers are well within 100 ms target. Most of these are under 10 ms.

## ❑ Flow installation throughput

### Definition of the “Flow installation” throughput metric

This metric measures the number of flows that can be set up by the SDN control plane in response to application requests or to network events.

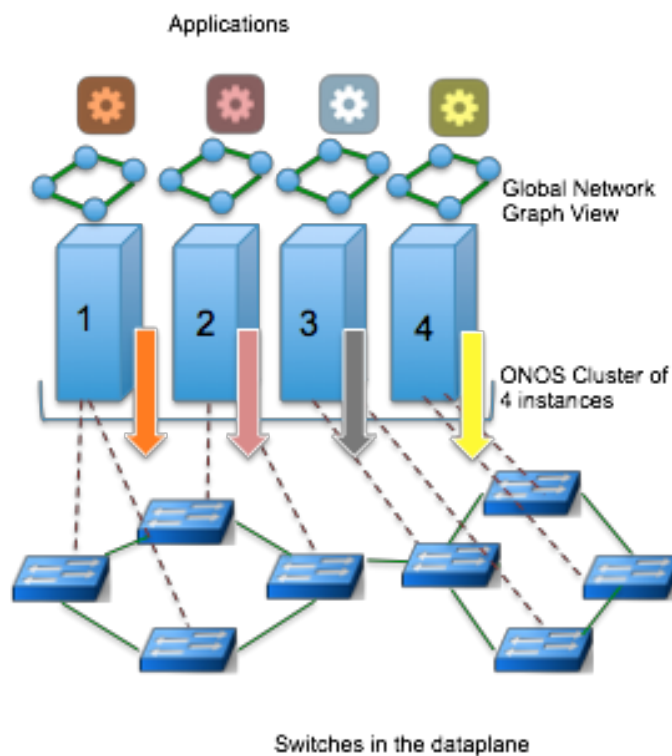
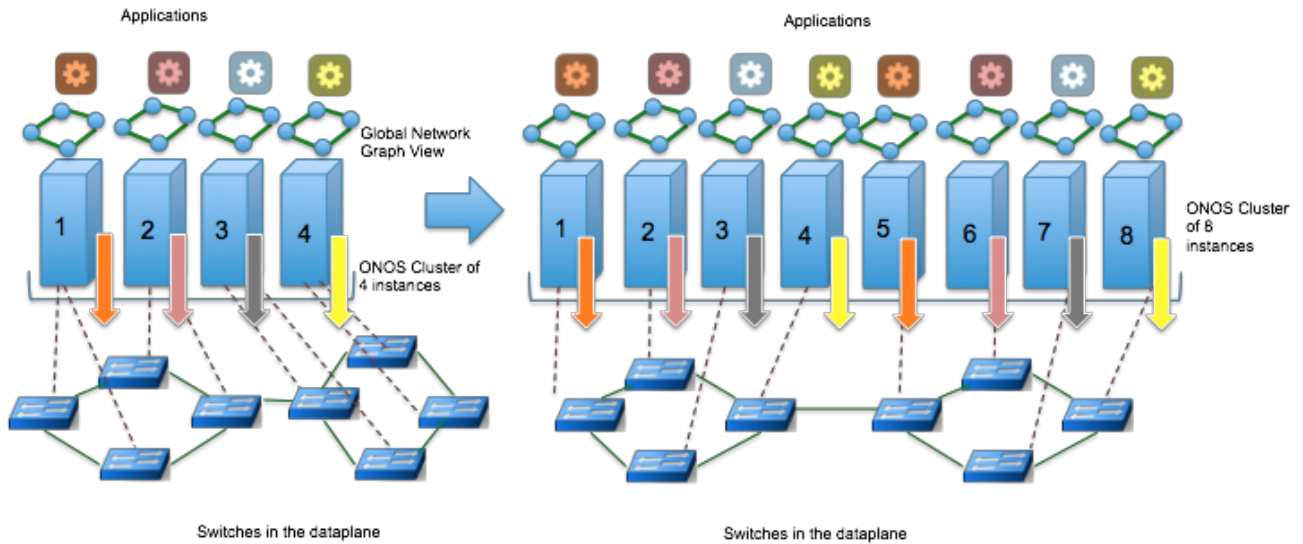


Figure 9. Flow installation throughput



**Figure 10. Flow throughput scale-out: Add ONOS instances to support higher throughput requirements and network growth**

#### Importance of this metric

- This metric evaluates the horsepower of the SDN control plane to install flows as well as its ability to scale-up as the number of flow installations needed increases.

#### Target numbers

- 1 million flow installations/sec

#### Experimental setup:

- Constant number of flows
- Constant number of devices attached to cluster
- Mastership evenly distributed
- Variable number for flow installers
- Variable number separate device masters traversed.

## Actual results

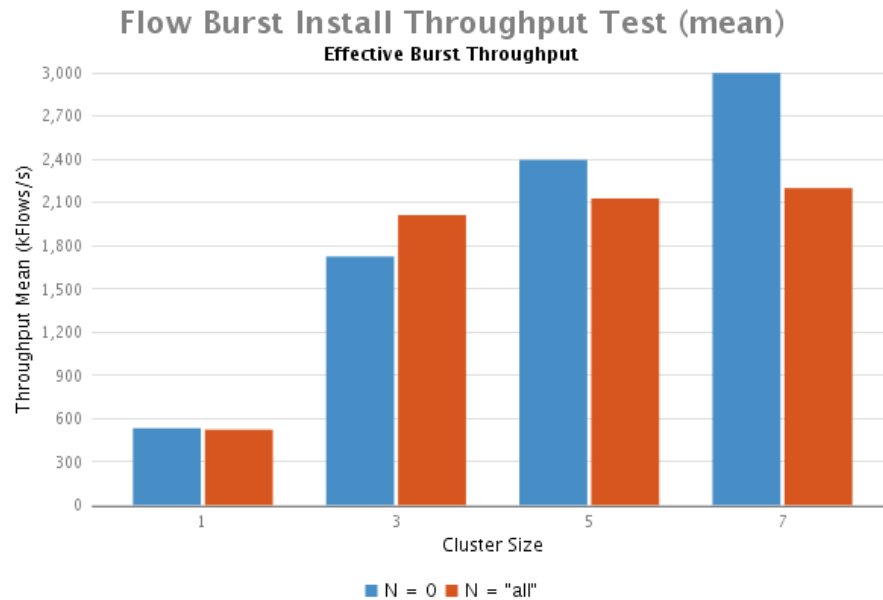


Figure 11.

- A single ONOS instance can install just over **500K local flow setups** per second.
- An ONOS cluster of seven can handle **3 million local, and 2 million non-local flow setups per second**.

(Note- local refers to installations generated and installed by same node in multi-node ONOS cluster, non-local refers to installations generated by one node and installed by other nodes in a multi-node ONOS cluster. Detailed description available [here](#)).

## Key takeaways

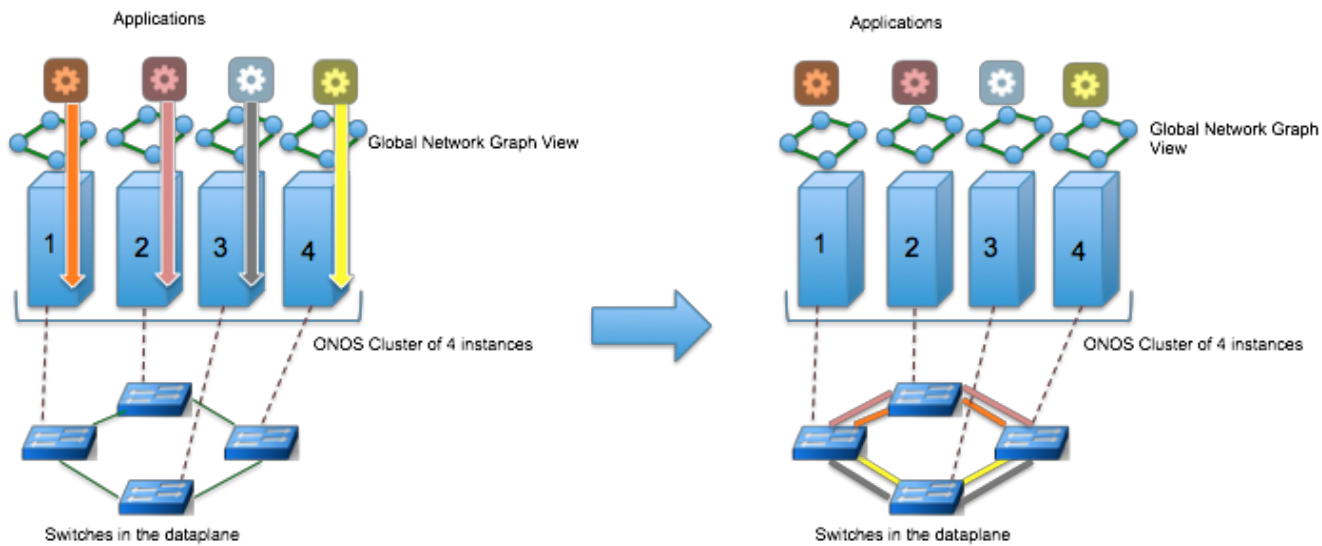
- Numbers show performance leadership and ONOS' ability to scale to meet service provider use case requirements
- Results show scale without jeopardizing throughput, latency or HA
- Industry's first demonstration of scale-out for flow installation throughput for an open source SDN control plane

## ❑ Intent install/withdraw/reroute latency

### Definition of “Intent latency” metrics

#### ❑ Intent installation/withdraw latency -

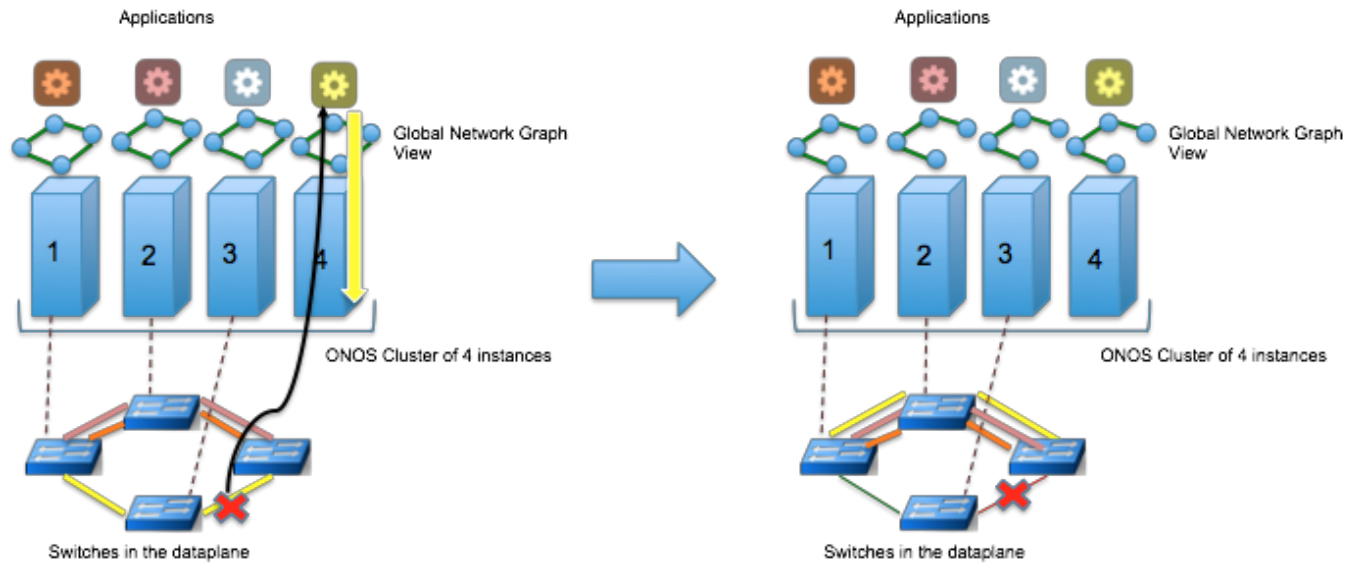
This metric measures the latency of adding and withdrawing intents. A related goal is to measure the impact of distributed architecture on intent add/withdraw latency in a multinode ONOS cluster.



**Figure 12. Intent add latency**

#### ❑ Intent reroute latency -

This metric measures the latency of rerouting an intent in the wake of failures and other adversities. A related goal is to measure the impact of distributed architecture on intent reroute latency in a multinode ONOS cluster.



**Figure 13. Intent reroute latency**

### Importance of these metrics

- The install/withdraw metric shows how quickly the SDN control plane can install and withdraw intents submitted by the northbound applications. A low latency is essential to being able to handle high rate of requests from applications as well as instantiating these requests rapidly on the actual network.
- The re-route metric shows how quickly ONOS/application can detect and reroute against failures. A rapid response is essential for ensuring seamless operation in the wake of failures and other adversities.

### Target numbers

- Under 100 ms latency and ideally under 10 ms

## Actual results

### Intent Install/Withdraw/Re-route Latency (Mean)

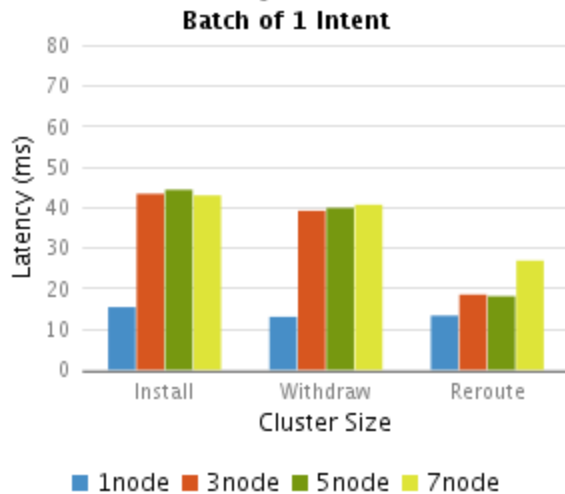


Figure 14.

### Intent Install/Withdraw/Re-route Latency (Mean)

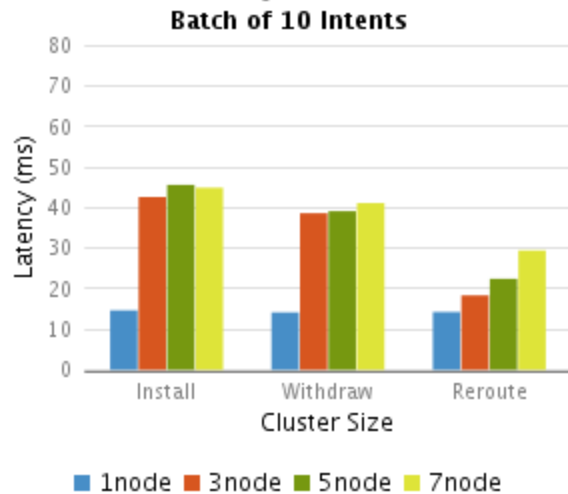


Figure 15.

- A single ONOS node reacts in **~15 ms** to all submit, withdraw or re-route triggers.
- Multi-node ONOS reacts in **~40 ms** to submit and withdraw requests and **~20 ms** to re-route requests.

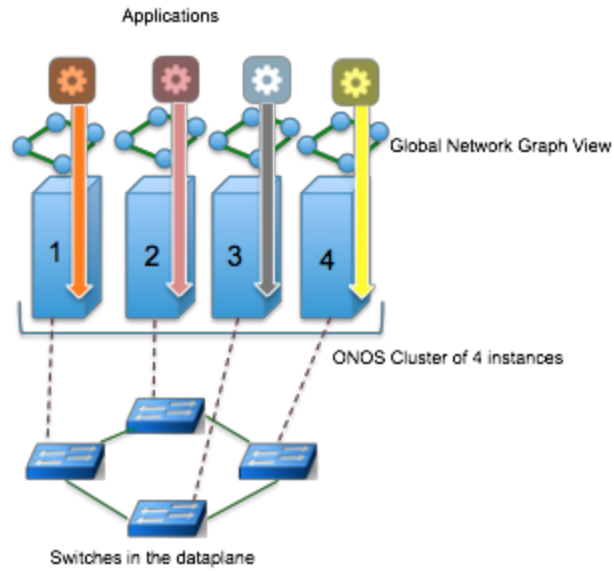
## Key takeaways

- The latency numbers are well within 100 ms target. These will be further optimized to meet the “10 ms or under” goal.

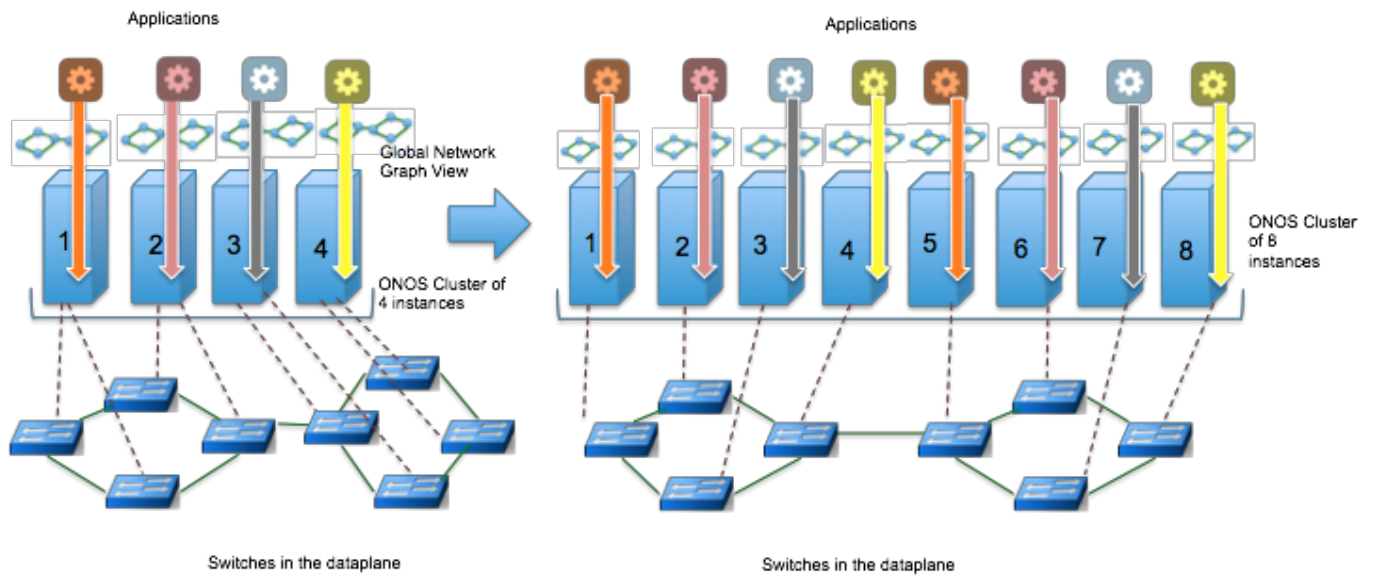
## ❑ Intent throughput

### Definition of “Intent throughput” metric

This metric measures how many intent requests by northbound applications can be handled and installed by ONOS.



**Figure 16. Intent throughput**



**Figure 17. Intent scale-out: Add ONOS instances to support higher intent throughput requirement**



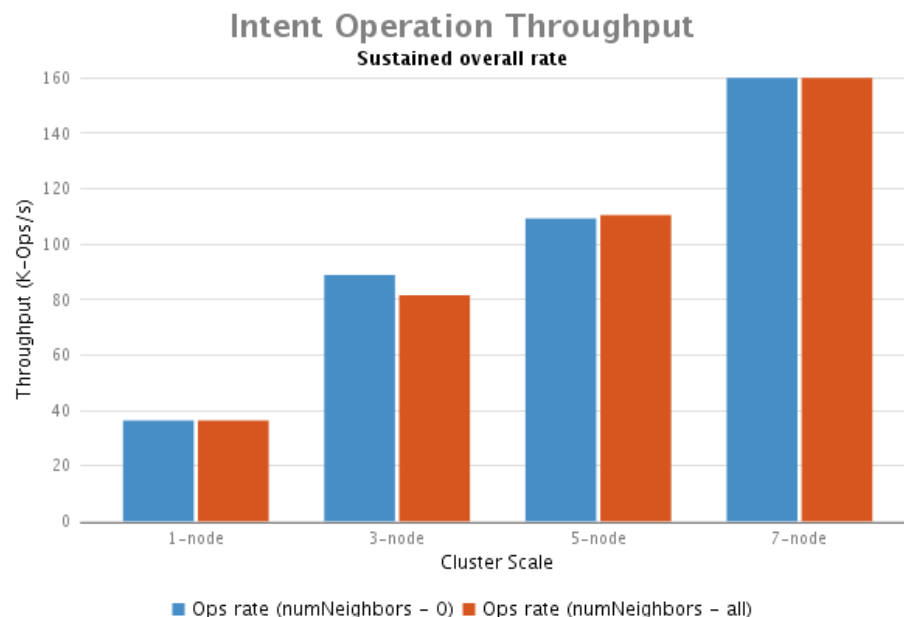
## Importance of this metric

- This metric evaluates the horsepower of the SDN control plane to install intents as well as its ability to scale-up as the number of intent installations needed increases. A high value ( in hundreds of thousands per sec) is necessary to be able to handle requests from a large number of applications in carrier-scale networks.

## Target numbers

- Benchmarking northbound throughput is an entirely new area of specification and there are no target numbers as of today. ONOS project will provide targets in the coming releases based on input from service providers and learnings from ONOS' real world use cases/solutions/deployments.

## Actual results



**Figure 18.**

- A single ONOS node can sustain more than **30K operations per second**.
- A 7-node ONOS cluster can sustain **160K operations per second**

## Key takeaways

- This metric is an effective way to measure northbound throughput for SDN control plane
- Numbers show ONOS' performance leadership and its ability to scale to meet service provider use case requirements
- Industry-first demonstration in open source of scale-out effect for intents-ONOS Intent throughput scales by increasing cluster size.

## What's next?

Lack of a resilient, high performance SDN control plane has been a key barrier to SDN deployment. ONOS is the first open source SDN Control Plane platform that has successfully demonstrated high availability, high performance and scale-out together, has defined a set of metrics to effectively evaluate and quantify these characteristics and published a comprehensive performance evaluation for its Blackbird release on the [ONOS wiki](#).

But ONOS Blackbird release is just the beginning. ONOS community will continue to optimize ONOS' performance and commits to publicly providing a comprehensive performance/scalability evaluation for each of its future releases. ONOS aims to raise the bar for SDN control plane performance and related measurement methodologies. Most importantly, it aims to launch an industry-wide movement towards openly providing similar performance measurements for all SDN control platforms/Controllers for the benefit of the end-users.



## About ONOS

ONOS is a SDN network operating system for service provider and mission critical networks, architected to provide a resilient, high performance SDN control plane featuring northbound and southbound abstractions and interfaces for a diversity of management, control, service applications and network devices. ONOS was open sourced on December 5th, 2014.

ONOS ecosystem comprises ON.Lab, organizations who are funding and contributing to the ONOS initiative including Tier 1 Service Providers - AT&T, NTT Communications, SK Telecom, and leading vendors including Ciena, Cisco, Ericsson, Fujitsu, Huawei, Intel, NEC; members who are collaborating and contributing to ONOS include ONF, Infoblox, SRI, Internet2, Happiest Minds, CNIT, Black Duck, Create-Net, KISTI, KAIST, Kreonet and the broader ONOS community. Learn how you can get involved with ONOS at [onosproject.org](http://onosproject.org).