InfoTech Conference
2023 IEEE International Conference on Information Technologie
20-21 September 2023
BULGARIA

Analytical approach to evaluating the performance of the OpenFlow protocol on Software Defined Networks

by
Ilias Bobotsaris, Ioannis Koulouras, Spiridoula V. Margariti, Eleftherios Stergiou and Chrysostomos Stylios
Department of Informatics and Telecommunications
University of Ioannina

Conference site:
http://infotech-bg.com/

Software Defined Networks (SDN)

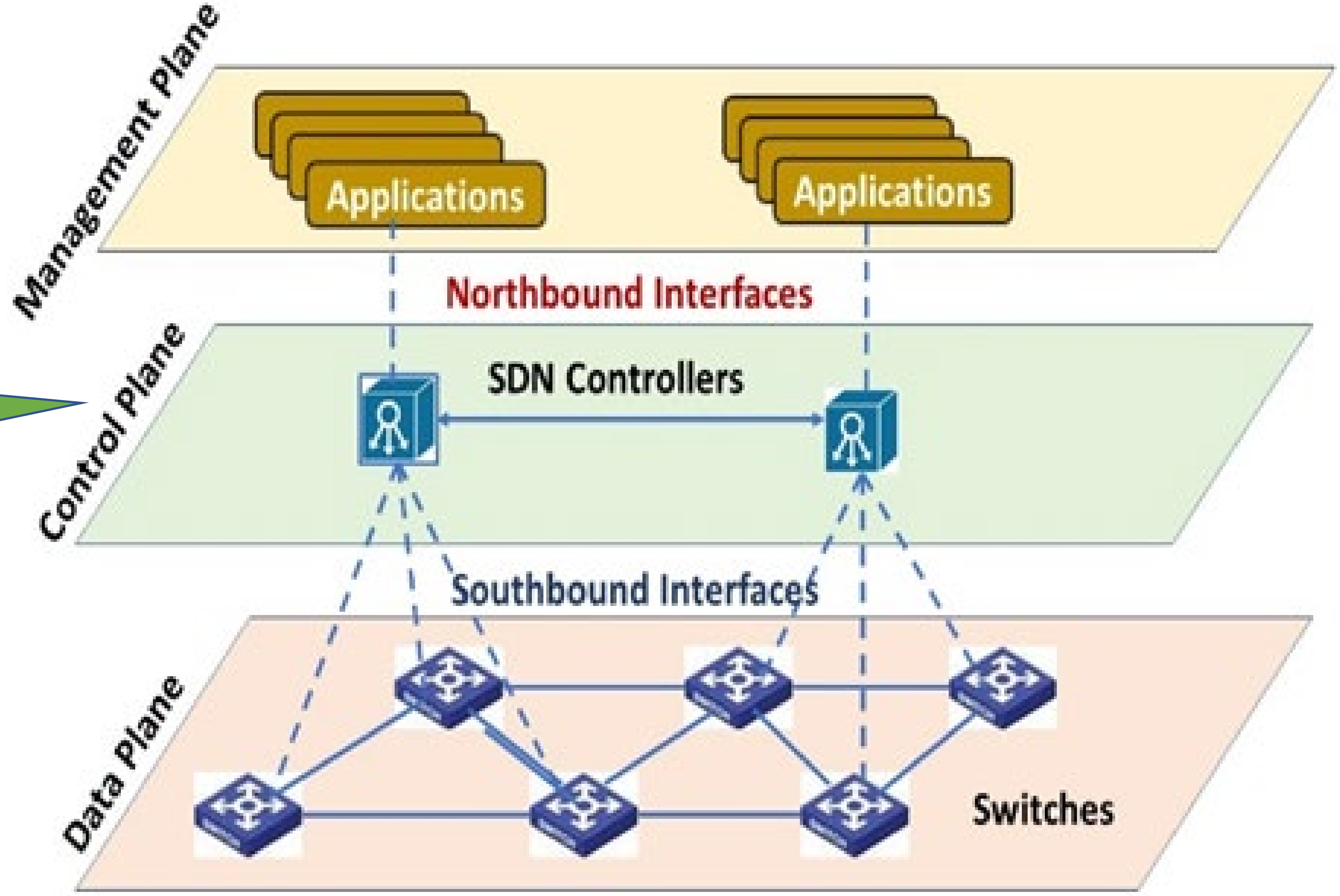
The SDN technology is a software-based idea that the control plane is physically separate from the data plane.
This technology leads to **flexible** and **programmable** networks and allows them to be **centrally managed**.

Control plane gathers up-to-date topology information from the **data plane** using *topology discovering protocols*.

Most common discovery protocol used by Controllers to obtain a global network view is the OpenFlow Discovery Protocol (OFDP).

Software Defined Networks (SDN)

A general architecture of SDN



Control Plane consists of one or more **Controllers**

Control plane gathers up-to-date topology information from the **data plane** using *topology discovering protocols*.

By this work:

Our contribution points are :

- ✓ A novel mathematical model is developed for a typical SDN domain controlled by OpenFlow controller.

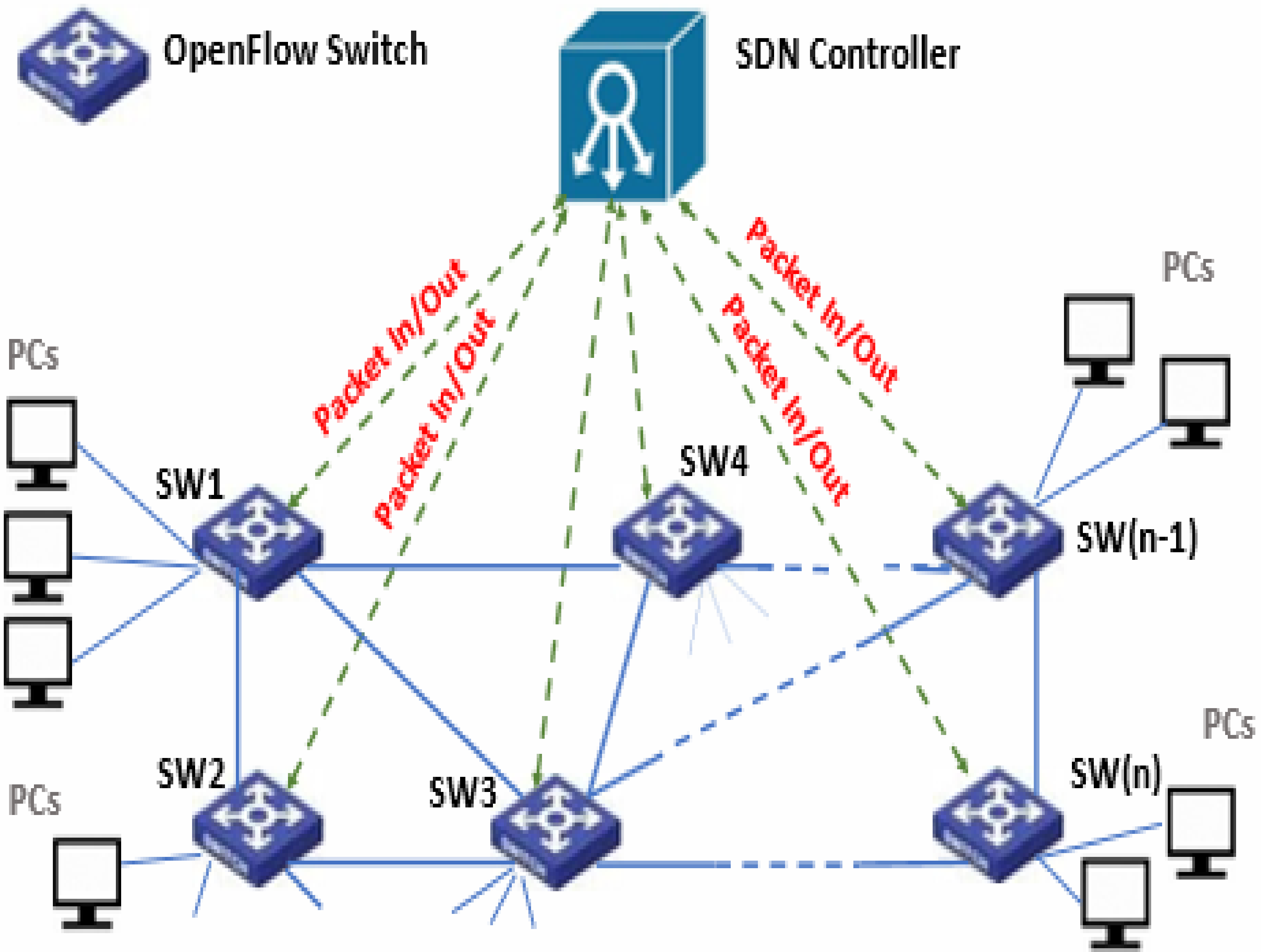
  This model helps basically to find

  the average value of the packet waiting time **from all switches** in and SDN network

Applying this mathematical model, we found:

- ✓ ***the packet's waiting times on switches of an SDN domain controlled by an OpenFlow controller for various values of offered load***
- ✓ ***the value of average stored data in switches' buffers of the same SDN domain for various values of offered load***

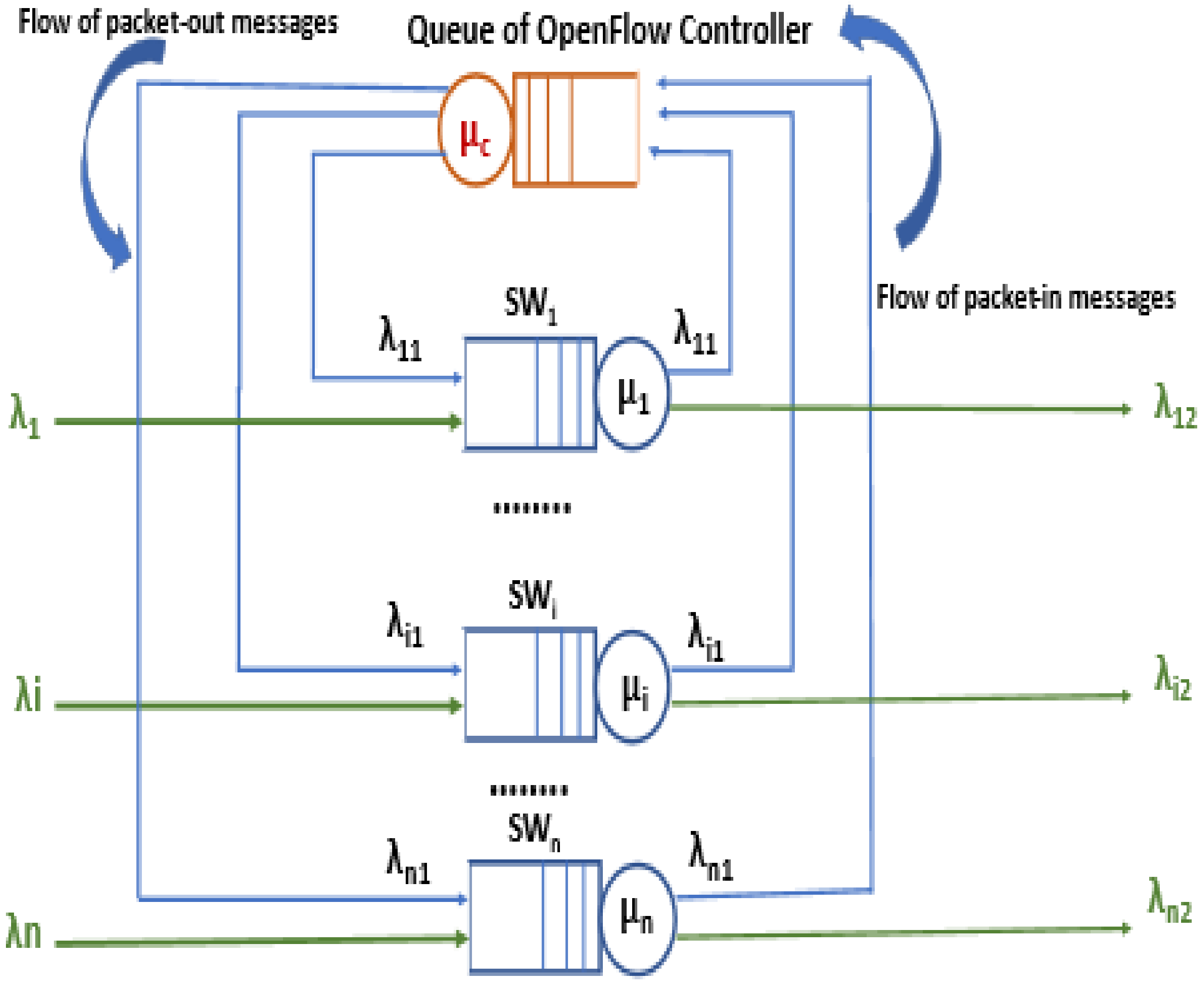
Software-Defined Networking (SDN) - Model development



Basic assumption for modeling the SDN network architecture

- The OpenFlow works through the Ports
- The controller is modeled with a queue.
- Each switch is modeled with a queue.
- Each switch (SW_i) accept packets with rate λ_i (Poison) and service with rate μ_i (exponential)
- Each switch may send messages to controller with probability ρ.

Software-Defined Networking (SDN) - Model development



- of the input stream distributed by law:

$$a(t) = \rho\lambda_i e^{-\lambda_i t} + (1-\rho)\lambda_{i1} e^{-\lambda_{i1} t}$$

- the service time – follows the law:

$$b(t) = \rho\lambda_{i2} e^{-\lambda_{i2} t} + (1-\rho)\lambda_{i1} e^{-\lambda_{i1} t}$$

So, both the above services follow the **Hyperexponential-2 (M/H2/1 queue**) service probability density function.

Software-Defined Networking (SDN) - Model development

Suppose, $\boldsymbol{\pi_k^{(i)}}$ represents the probability that there are ***k*** packets in the ***i**^th^* switch. Then:

$$\pi^{(i)} = \left(\pi_0^{(i)}, \pi_1^{(i)}, \pi_2^{(i)}, \dots., \pi_k^{(i)}, ..\right),$$

A vector shows all the possible states (number of packets) of an arbitrary queue (***i***):

However, each states in the ***i**th* switch can be written as follows:

$$\pi_0^{(i)} = 1 - \frac{\lambda}{\mu} = 1 - \rho$$

$$\pi_1^{(i)} = (1-\rho)\rho$$

$$\pi_2^{(i)} = (1-\rho)\rho^2$$

…………… …….

$$\pi_k^{(i)} = (1-\rho)\rho^k$$

So, the **average number of packets** in the ***i**th* queue (switch) can be calculated based on queuing theory:

$$E_{(i)} = \sum_{k=0}^{\infty} k \cdot \pi_k^{(i)} = \sum_{k=0}^{\infty} k \cdot (1-\rho) \cdot \rho^k = (1-\rho) \cdot \rho \sum_{\kappa=0}^{\infty} k \cdot \rho^{k-1}$$

Calculating the series, the average number of packets are:

$$\boldsymbol{E_{(i)} = \frac{\rho}{1-\rho} = \frac{\lambda}{\mu-\lambda}},$$

Because, $\rho = \frac{\lambda}{\mu}$

Software-Defined Networking (SDN) - Model development

Apply the Little formulae: $\overline{E} = \lambda \cdot \overline{W}$

The average packet waiting time at the i^{th} switch is: $$\overline{W}_{(i)} = \frac{\overline{E}_{(i)}}{\lambda} = \frac{1}{\mu - \lambda}$$

The average value of the packet waiting time from all n switches served by a controller is:

$$\overline{W}_{avg} = \sum_{i=1}^{n} \frac{\lambda_i}{\sum_{i=1}^{n} \lambda_i} \cdot \overline{W}_{(i)}$$

If we assume that all switches are the same, then the above equation can be written as:

$$\overline{W}_{avg} = \sum_{i=1}^{n} \frac{\lambda_i}{n \cdot \lambda_i} \cdot \frac{1}{\mu_\iota - \lambda_\iota} = \frac{1}{n} \cdot \sum_{i=1}^{n} \frac{1}{\mu_i - \lambda_i}$$

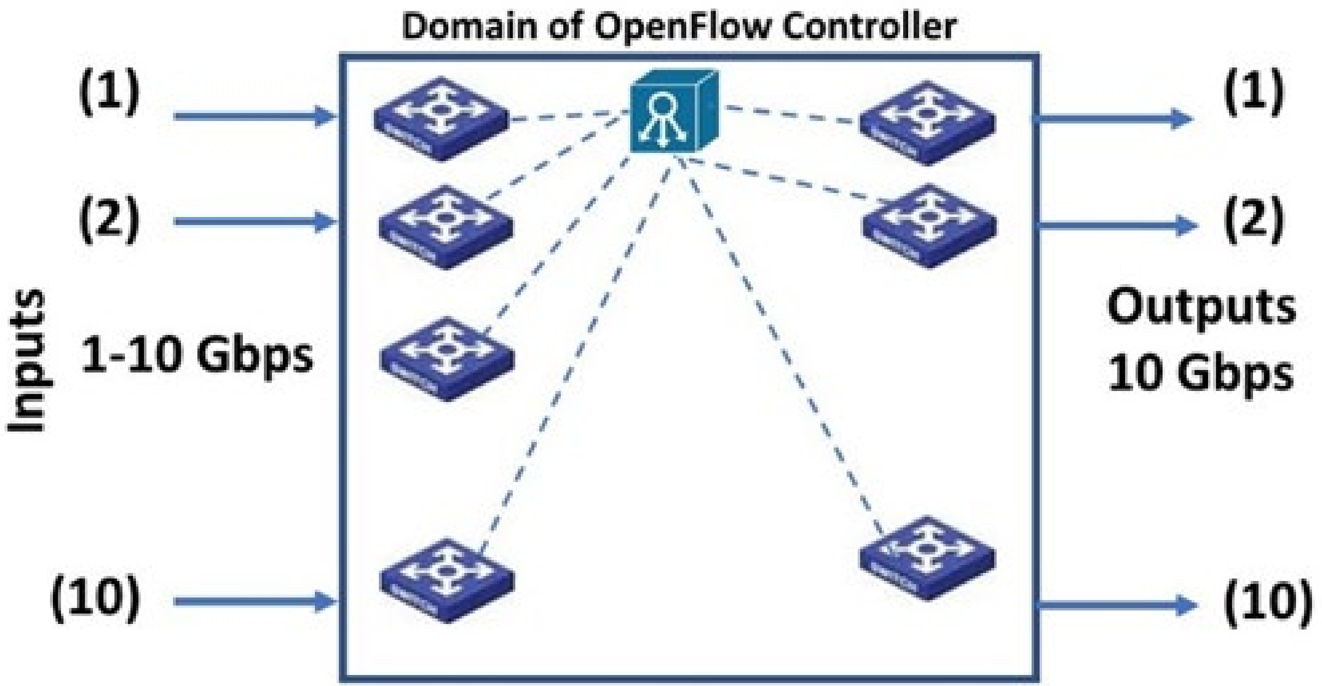
Application of the model
and
Results

Software-Defined Networking (SDN)

A. Calculating packet's waiting times

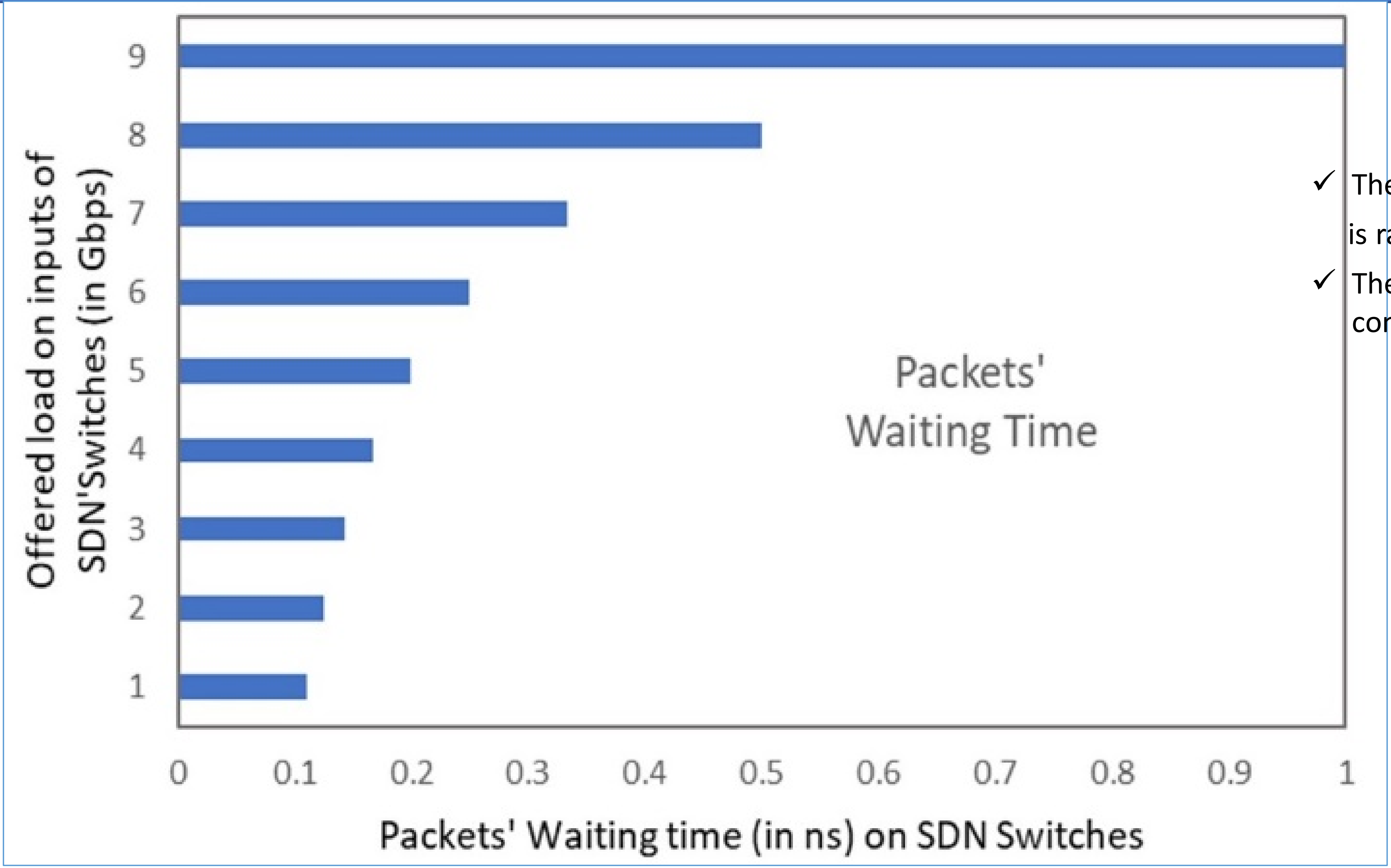
Scenario 1:

Let's an SDN domain (consists of 10 SDN Switches) controlled by an OpenFlow controller that has maximum output rates (~10 Gbps) while the offered load ranging from 1 to 9 Gbps.



?
the packet
waiting times
on
SDN Switches

Software-Defined Networking (SDN)



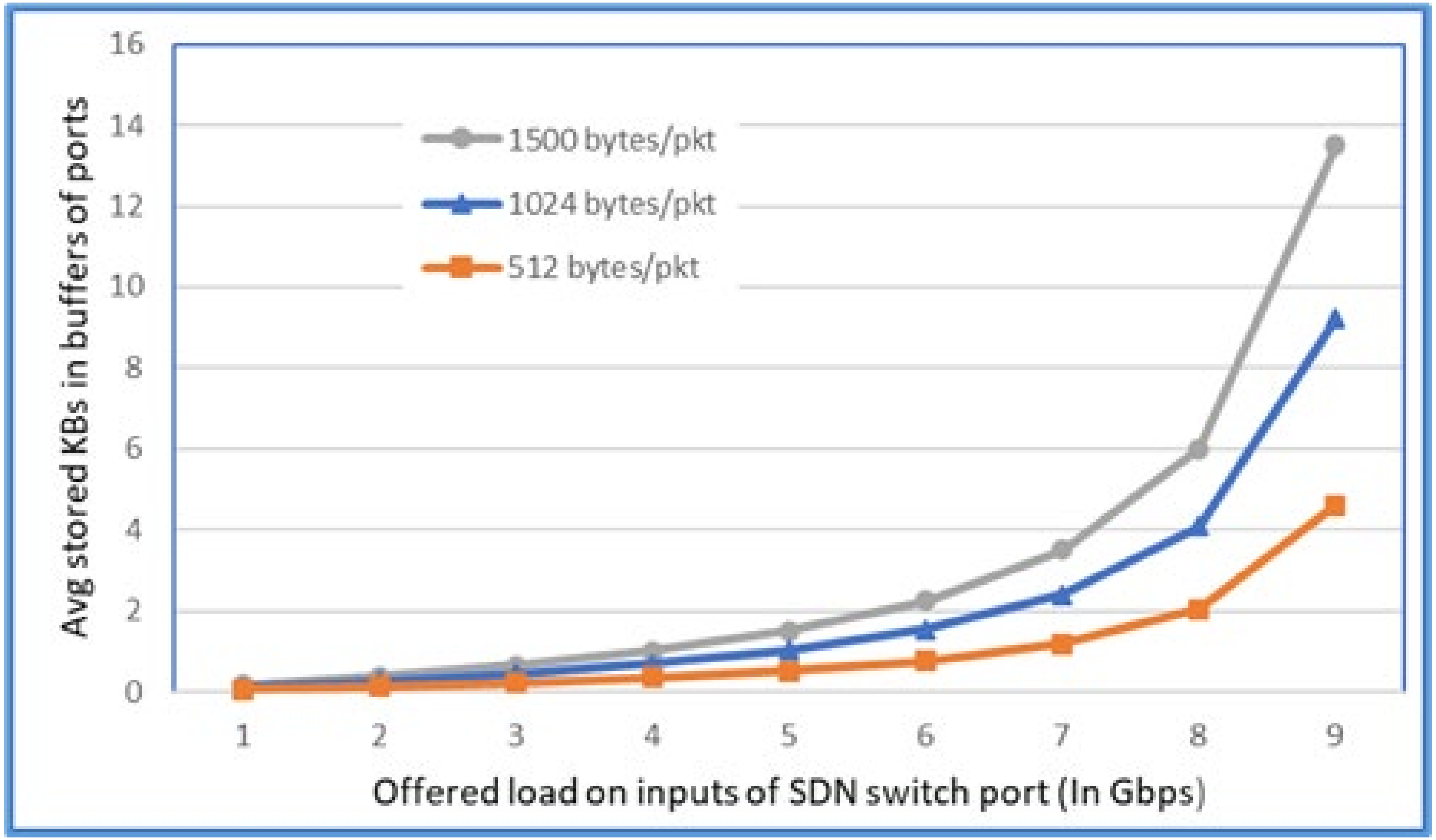
Assumptions

- ✓ The offered load on inputs is ranged from 1 to 9 Gbps.
- ✓ The outputs can service in constant rate of 10 Gbps

Software-Defined Networking (SDN)

B. Calculating the average stored data in buffer

Scenario 1: the same



.. as the packet size of transferred data increases, more storage space is required for the packets passing through.

CONCLUSION

In this work,

- An analytical approach for performance of OpenFlow SDNs is developed.
- Using this model:
    - The packet waiting time on SDN switches is calculated for a scenario of an SDN domain working with offered load from 1 to 9 Gbps. Also,
    - The average stored (in KBs) in buffers on ports is calculated for the same pattern of the offered load.

For future,
to investigate the optimal trade-off between performance characteristics and cost for SDN switches is planned.

Thank you for your attention!

Plovid, Bulgaria September 2023!