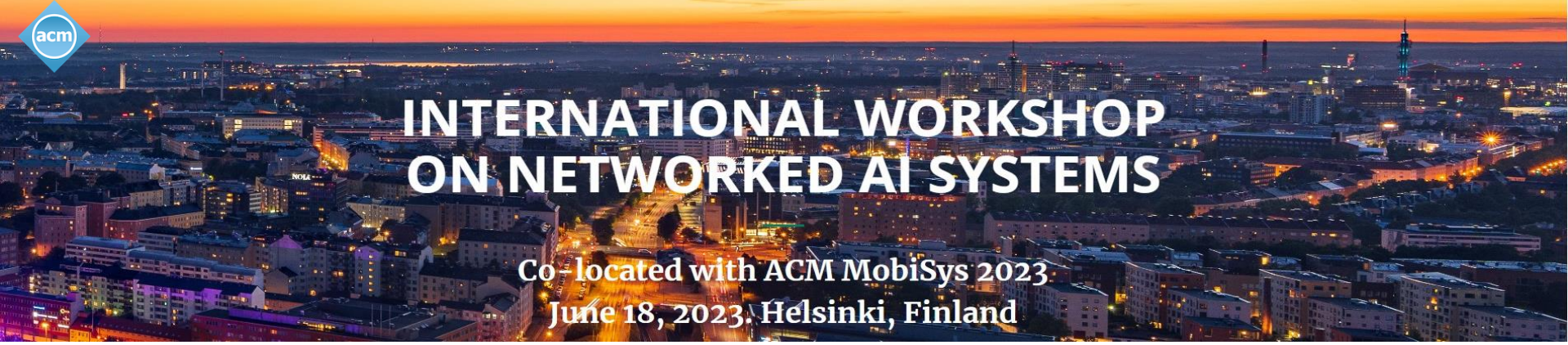


Improving the quality of Federated Learning processes via Software Defined Networking

A. Mahmod, G. Caliciuri, **P. Pace**, A. Iera

DIMES - University of Calabria, ITALY

UNIVERSITÀ DELLA CALABRIA
DIPARTIMENTO DI INGEGNERIA INFORMATICA, MODELLISTICA, ELETTRONICA E SISTEMISTICA
DIMES

TITAN LAB
Telecommunication & Information Theory for Advanced Networking LABoratory

Outline

- Motivation and Key contributions
  - FL limitations from the networking point of view
- The proposed SDN-based Framework
  - FL orchestrator + SDN Controller
- Testbed for performance evaluation
  - Implementation choices
  - FL platform and tools
  - HD platform
- Results
  - Accuracy and Loss of the FL process with different neural networks
  - Overhead due to additional control data packets
- Conclusions
- Ongoing and future works

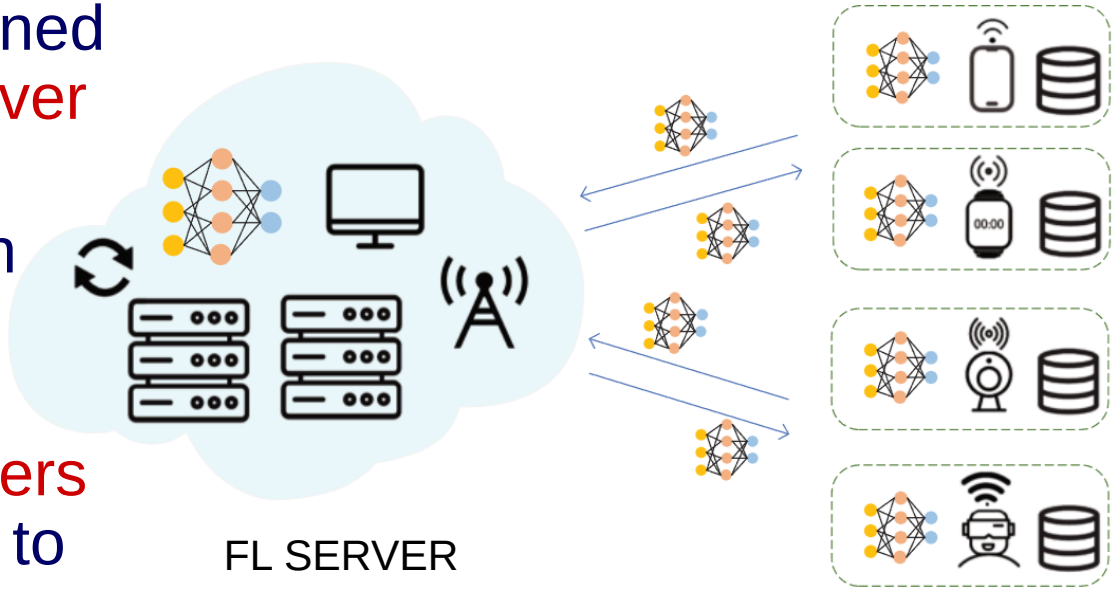
Motivations and Key contributions

- We are interested in investigating how to use the emerging "network for AI" paradigm, because of…
  - not enough attention to address FL efficiency enhancement from the perspective of the networking research community
    - effective methods for managing the network resources
  - congestion on different network segments between the clients and the server due to background traffic which could have a variable nature
  - some clients involved, despite having excellent performance in terms of computational capacity and memory, complete the training tasks but their data arrives late to the server due to the bad conditions of the underlying network segments.

We evaluate the potential of a framework in which a SDN network explicitly supports FL clients in dealing with issues related to the load conditions of the links to improve the QoS of the entire FL process.

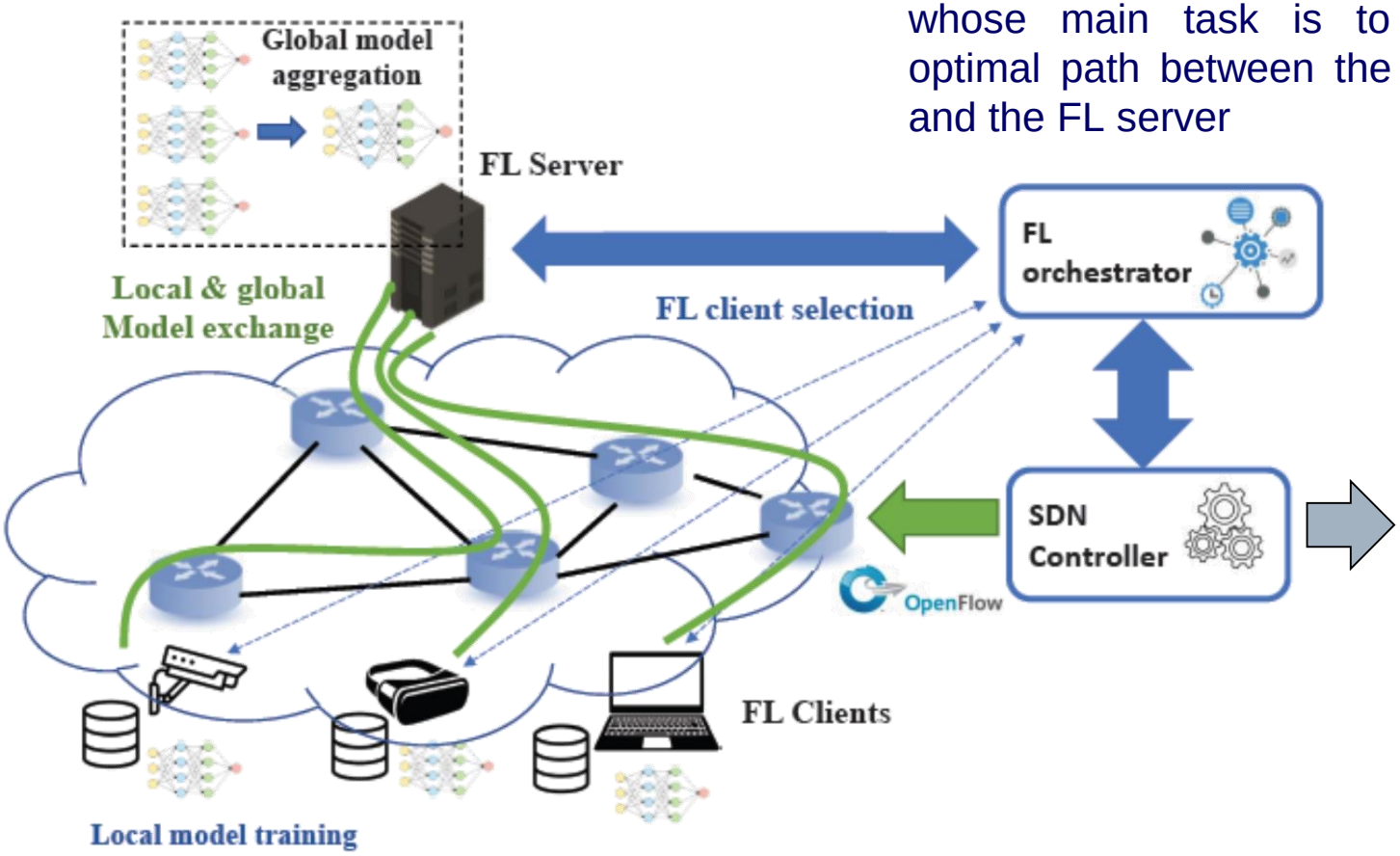
Federated Learning: a quick recall

1. Global Model to be trained forwarded from the server to the clients
2. Local model training on distributed clients
3. Transmission of the updated hyperparameters from distributed clients to the server
4. Hyperparameters aggregation and global model updated for the next training round



The reference Framework

- The FL Orchestrator will continuously exchange data with the SDN Controller whose main task is to guarantee the optimal path between the selected clients and the FL server



continuously monitoring and contrasting any dynamic overload of the network connections.

Testbed for perfomance evaluation

- Three levels of Open vSwitches (OvS) providing multiple choices of paths between the server and the clients using GNS3
- The CONTROLLER periodically implements a quick and easy load balancing strategy, based on the *Dijkstra Algorithm*
- Hardware platform HP Enterprise Proliant DL560 Gen10 equipped with 2 Intel Xeon-Gold 6225N processors (2.3GHz and 24core) and 256GB of RAM.

Table 1: Client categories

Client Performance	HD Characteristics	
	RAM (GB)	♯ of core
Cat 1 - Low	1	1
Cat 2 - Medium	4	2
Cat 3 - High	8	4

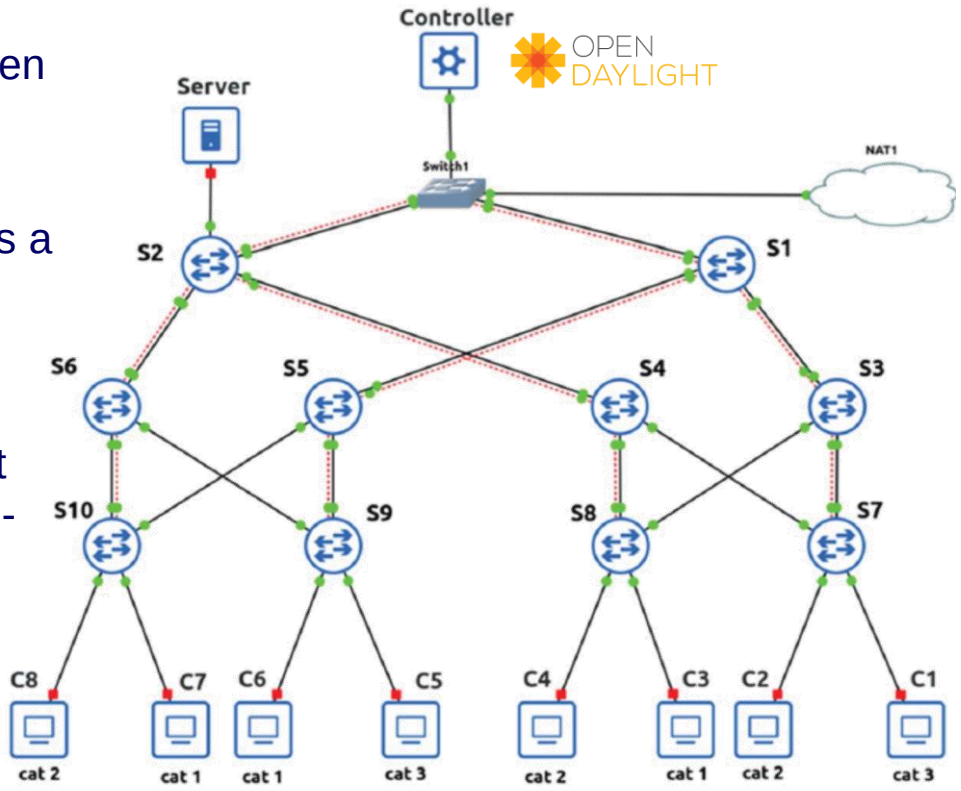


Figure 2: Network topology implemented in GNS3.

Testbed for perfomance evaluation

Flower https://flower.dev/

- CIFAR-10 dataset with 2 different neural networks:
  - MobileNetV2 with a size of 14MB with 3.5 million hyper-parameters.
  - DenseNet121 with a size of 33MB with 8.1 million hyper-parameters
- 20 rounds of evolution for the federated learning process

Table 1: Client categories

Client Performance	HD Characteristics	
	RAM (GB)	♯ of core
Cat 1 - Low	1	1
Cat 2 - Medium	4	2
Cat 3 - High	8	4

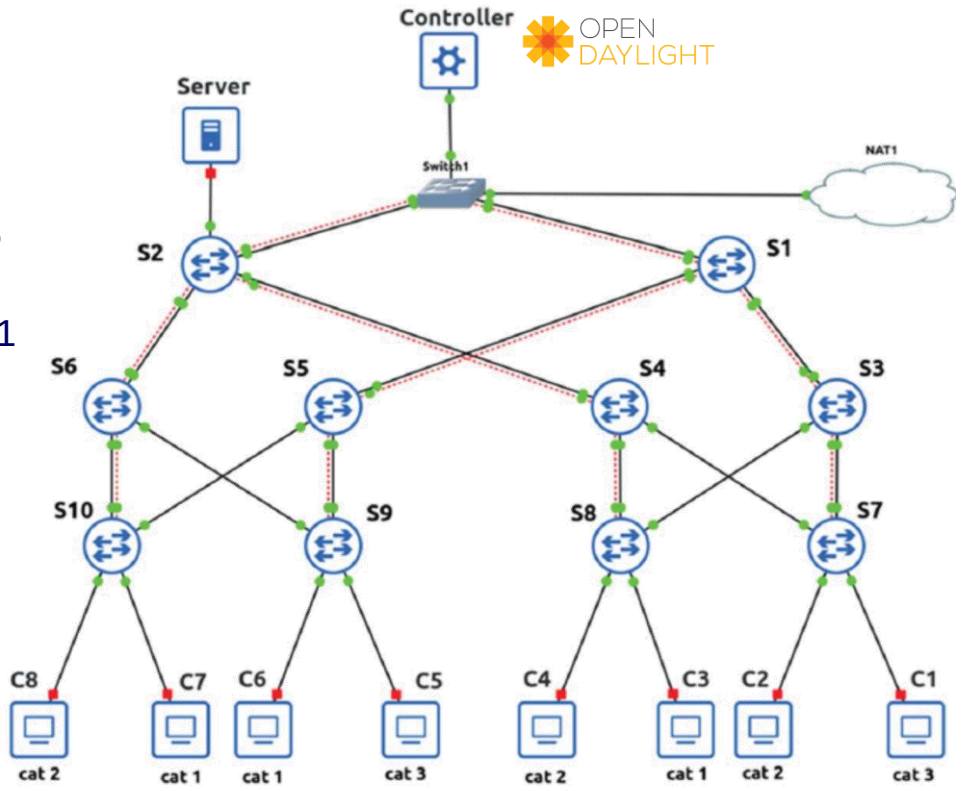
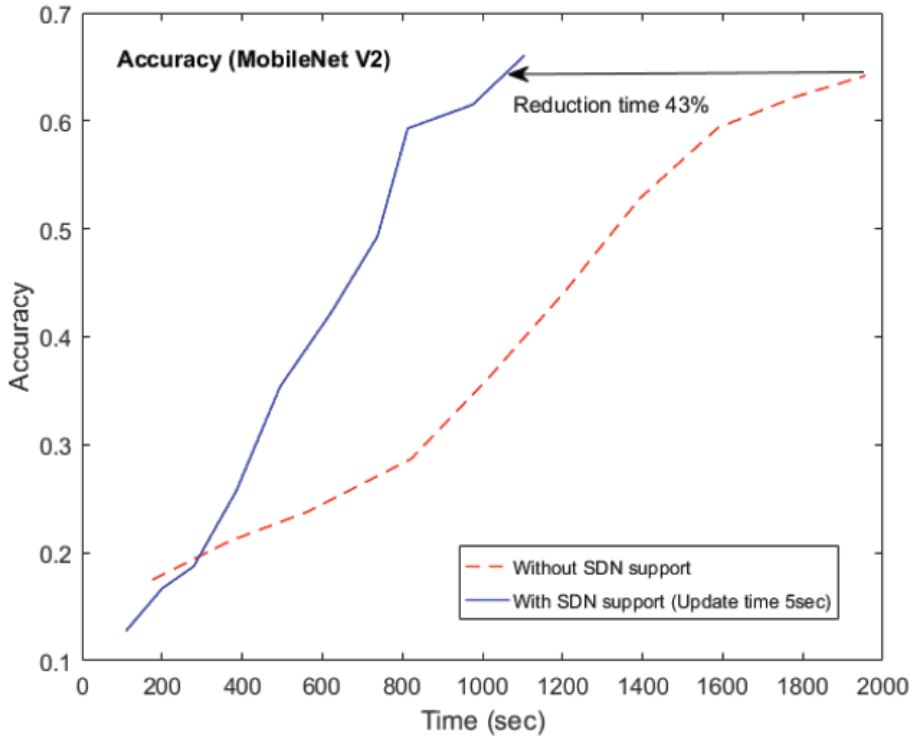
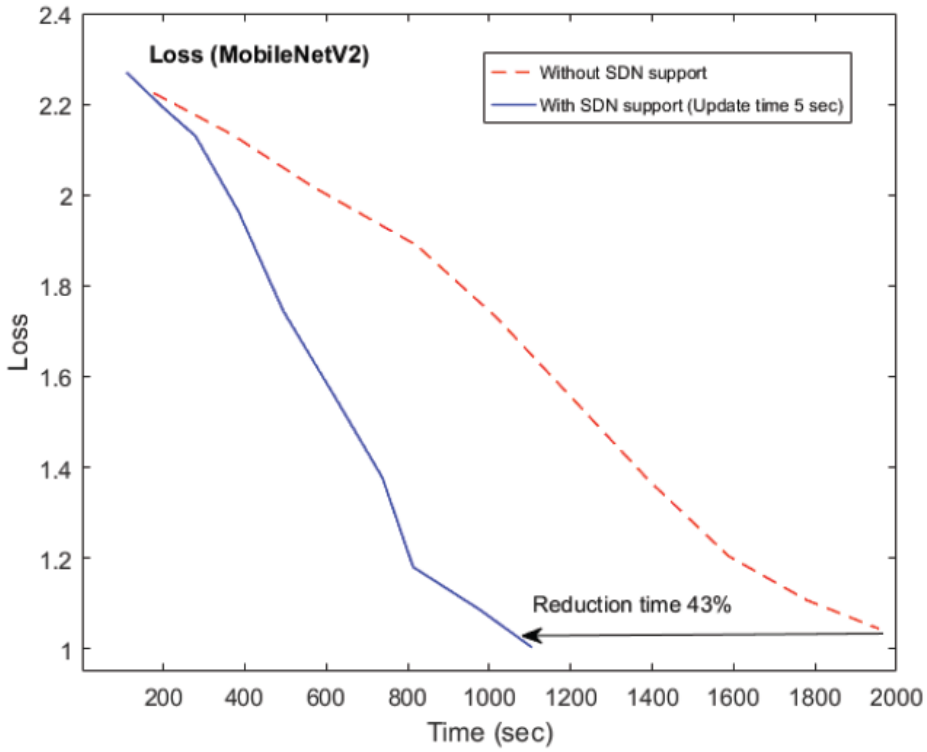


Figure 2: Network topology implemented in GNS3.

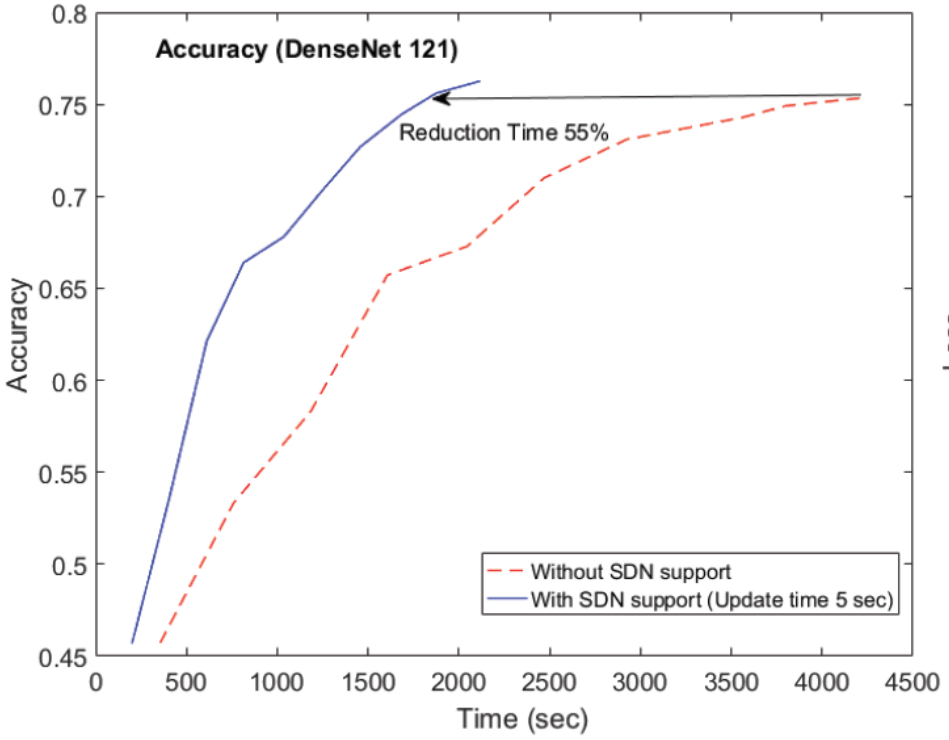
Results – MobileNet v2

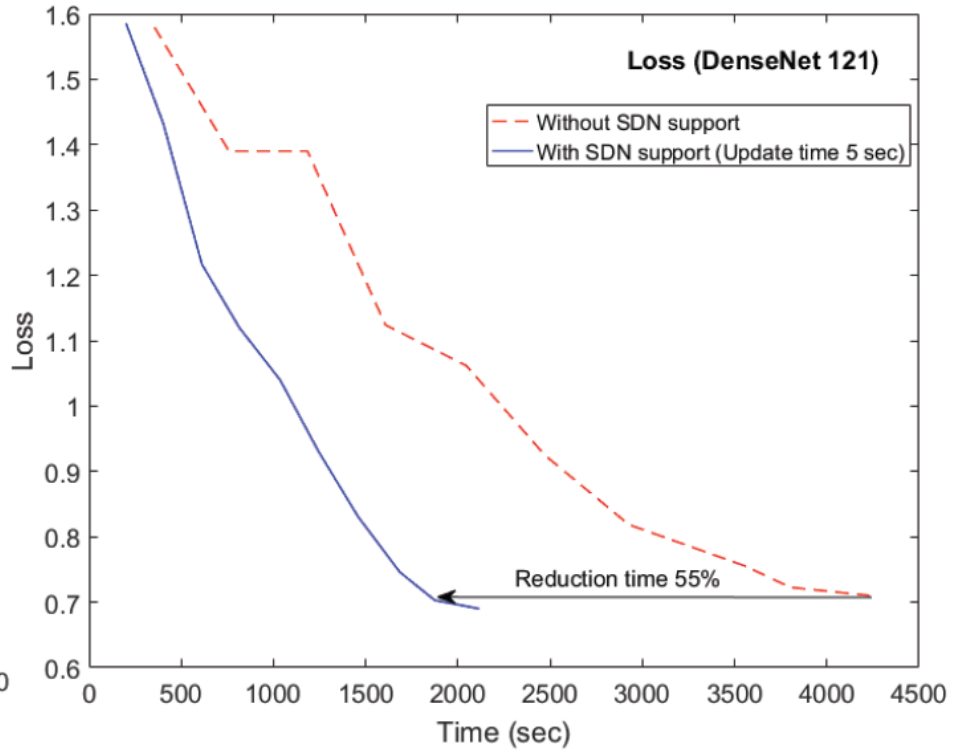




- The benefit of using SDN support is very clear and impressive in terms of time saved to reach an acceptable level of accuracy (i.e. 65%)

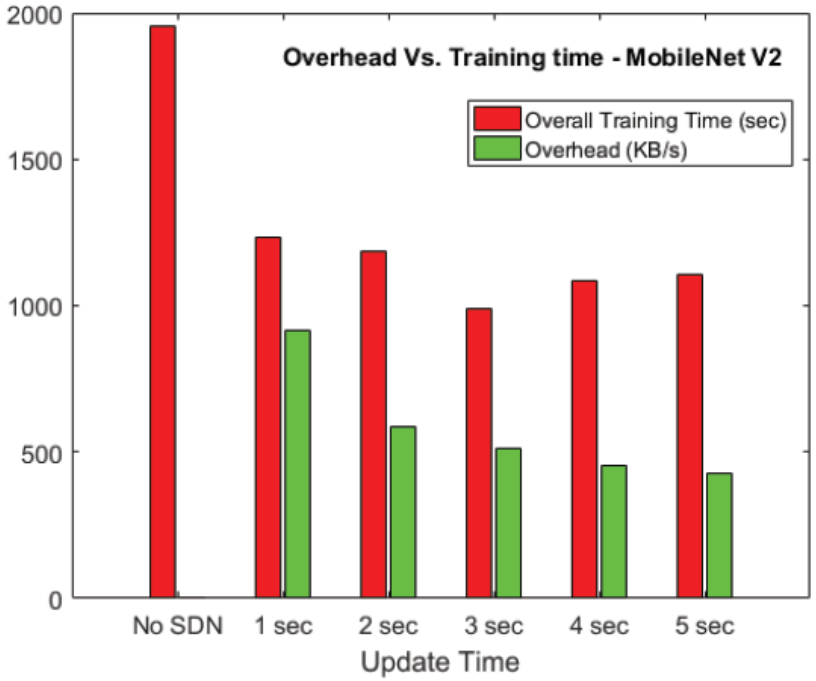
Results – DenseNet 121

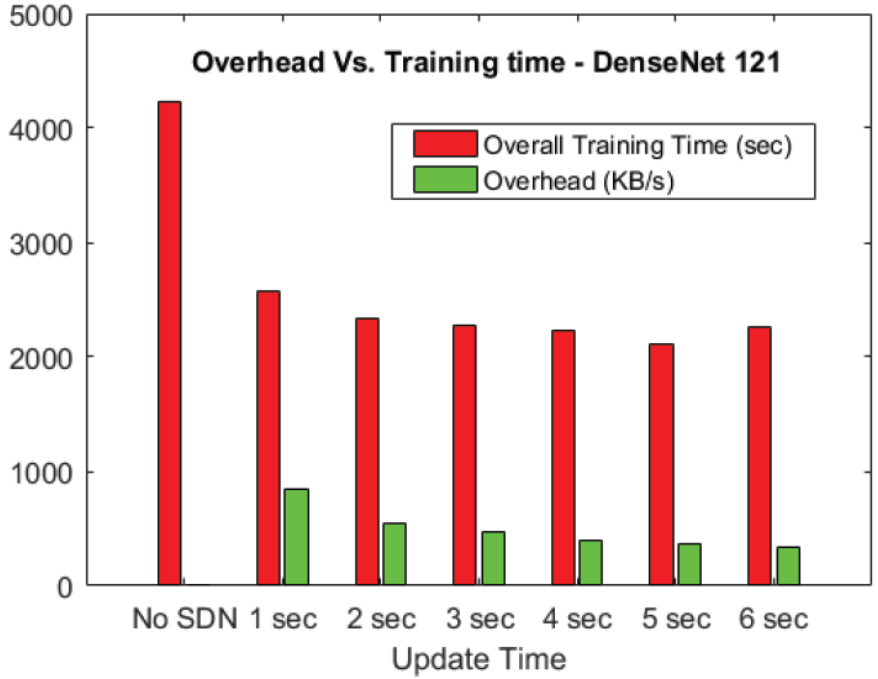




- The presence of SDN allows the system to work even better under more intense traffic load conditions, reaching the accuracy value of 75% and the loss value of 0.70 saving 55% of time.

Results – Additional control data packets





- the *"price to pay"* in terms of the amount of additional control data packets traveling to/from the SDN controller
- the overhead, in terms of control data packets, increases from 425KB/s when the update time is 5 seconds, up to 916KB/s when updating at a higher rate

Conclusions

- We designed a **SDN-based** communication architecture to support the quality of the FL process with particular attention to **reduce training times** at the same performance level.
- We implemented a sophisticated testbed and carried out a first set of tests for performance evaluations to provide a proof of concept for the proposal.

- **The first obtained results are encouraging and testify the effectiveness in guaranteeing high-quality levels of the FL process.**

Ongoing & Future works

- We are working on a wise *SDN-driven client selection* procedure implemented by the FL Orchestrator which takes into account the communication resources available at any stage of the process in addition to the *computational* and *memory resources* of the clients.

- We plan to use the SDN controller for the purpose of:
  - (i) intervening on the traffic load at the client side deriving from connections other than the one established with the FL server and active at the same time
  - (ii) implementing effective intrusion detection approaches by intervening at the network level.

THANK YOU FOR THE ATTENTION

Questions?

p.pace@dimes.unical.it