Università degli Studi di Catania

Dottorato di ricerca in
Ingegneria dei Sistemi, Energetica, Informatica e delle Telecomunicazioni – XXXII ciclo

Dipartimento di Ingegneria Elettrica, Elettronica e Informatica

Flexible SDN/NFV-based SON testbed for 5G mobile networks

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Tutor: Prof. Daniela Panno
Academic Year: 2018/2019

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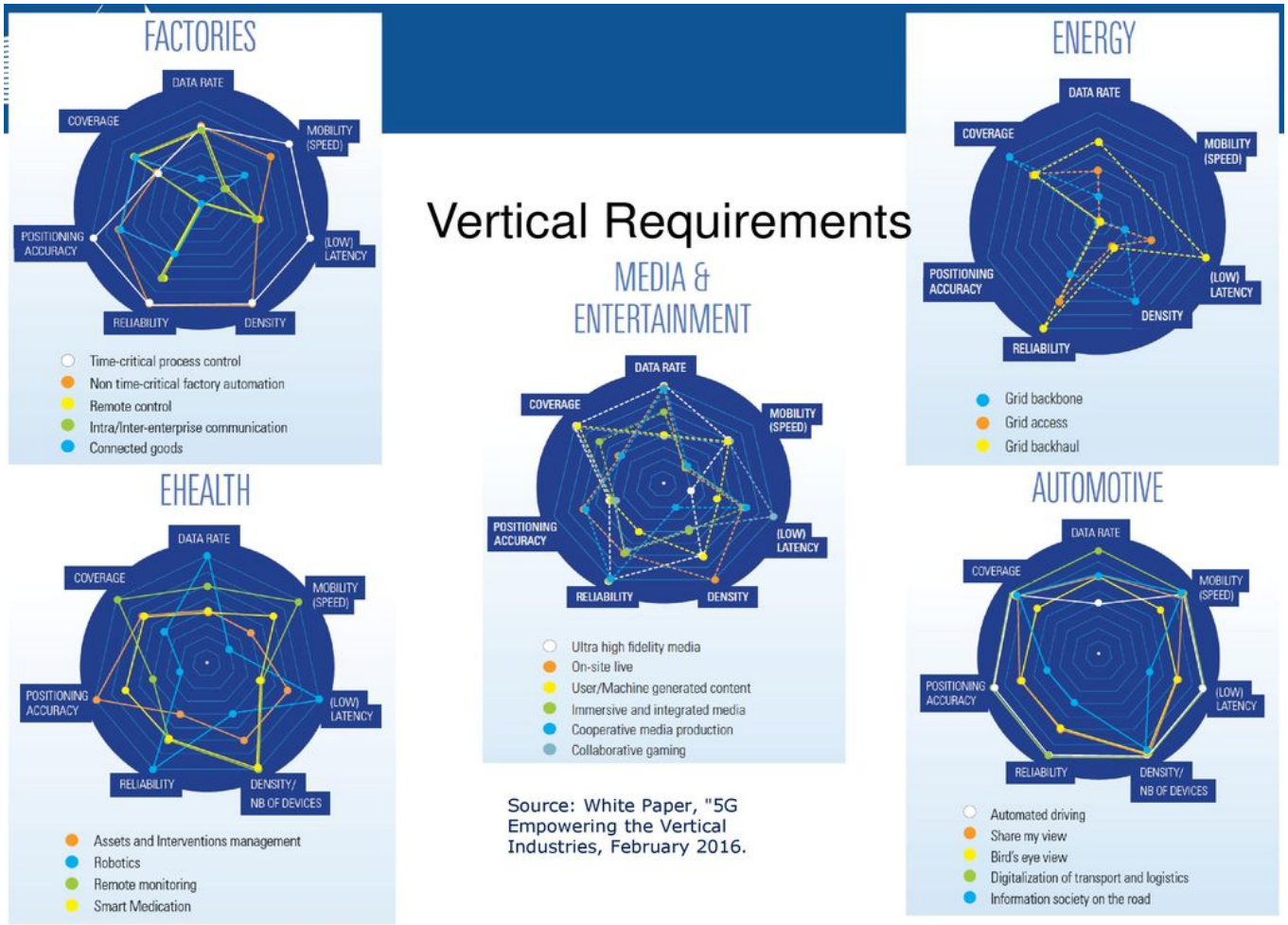
Outline

- 5G performances
- SDN, NFV, NG-SON as enabling technologies
- FlexRAN and OpenAirInterface software tools
- Proposed SDN/NFV-based SON testbed
- Considered use cases and developed strategies
- Work in progress and future works
- Publications, teaching and research activities

5G Performances

- 5G aims to address critical requirements of the vertical industries, such data rate, latency, density, mobility and reliability.
- The key capabilities that will enable these requirements are programmability, virtualization and flexibility.



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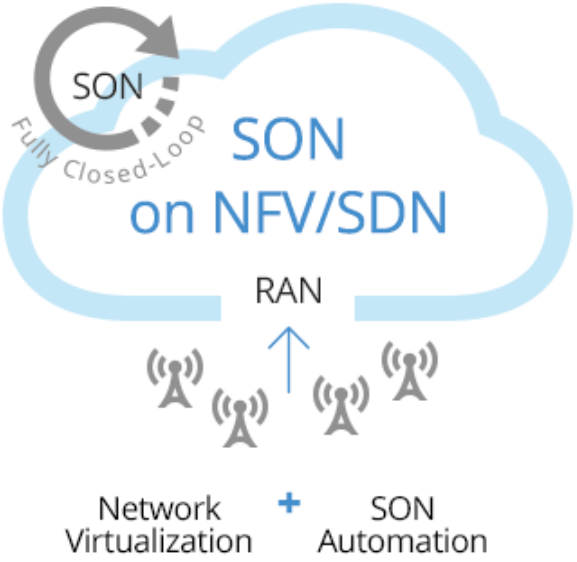
5G Performances

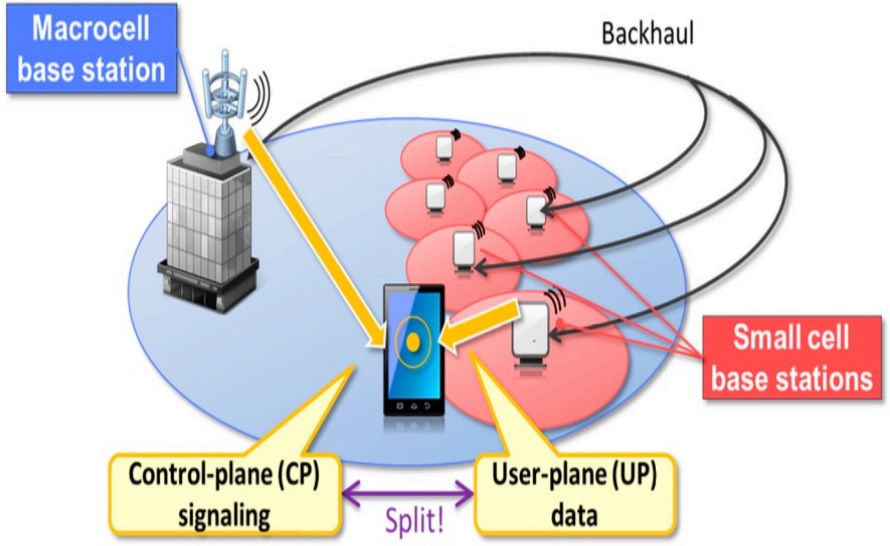
In the next few years, a considerable innovation concerning the design of the future 5G mobile networks will be a concrete step in order to enable different type of services related to different verticals

- Software Defined Networking (**SDN**)
- Network Function Virtualization (**NFV**)
- Self Organizing Network (**SON**)

are considered the enabling technologies to achieve these goals.

5G SON Testbed: Purposes and use cases





- SDN, NFV and NG-SON concepts
- Several other areas of system-level research

CONSIDERED USE CASE

- Manage RAN entities lifecycle in 5G CDSA deployment

The research activity is conducted in the context of a research collaboration between the University of Glasgow and the University of Catania, both participating to the Mosaic5G Research Project as contributor members.

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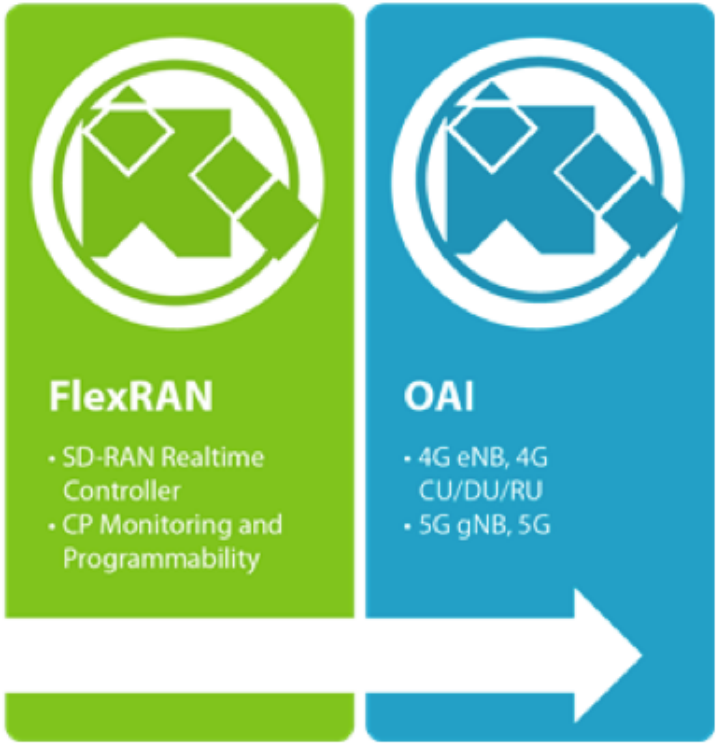
5G SON Testbed: Mosaic5G Research Project

- **Open Air Interface (OAI)**
  - Open source software platform for 3GPP full protocol stack implementation, running on Linux OS
  - OAI RAN (gNB and UE entities)
  - OAI CN entities

- **FlexRAN Controller**
  - First Open-source Implementation of a Flexible and Programmable Platform for SD-RAN
  - Extension of OAI
  - FlexRAN Master Controller and FlexRAN agents for eNB



MOSAIC 5G

EURECOM Sophia Antipolis

OPEN AIR INTERFACE

FlexRAN

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5G SON Testbed: Testbed deployments

Phase one (prior Testbed deployment)

- Preliminary installation, configuration, debugging and testing of several HW/SW entities
- mutual compatibility test for stable configuration
- Deployed two simple use cases (I and II)

Phase two (TestbedCT)

- NFV-based 3GPP network emulated setup
  - VM for the NFV concept
  - Full PHY Layer mode for the emulation concept

Phase three (TestbedGLA)

- SDR-based 3GPP network real setup
  - Real network deployment with SDRs, USB Dongles and Smartphones

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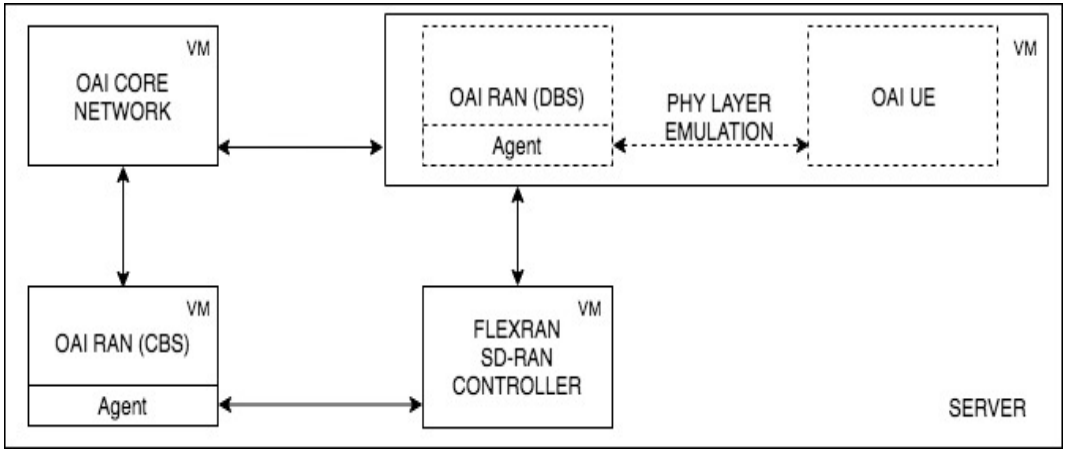
5G SON TestbedCT - Remote case

- **NFV-based 3GPP network emulated setup**
  - Docker Container and VM tested
  - **VM-based** deployment.
- **Remote case implementation, each entity runs on a dedicated VM**:
  - **OAI RAN** with agent support, tag 2018w41
  - **OAI CN** v 0.5
  - **FlexRAN Master Controller** v2.0
  - Wireless medium obtained using **Full PHY Layer Mode**
  - **eNB, RF front end and UEs emulated**



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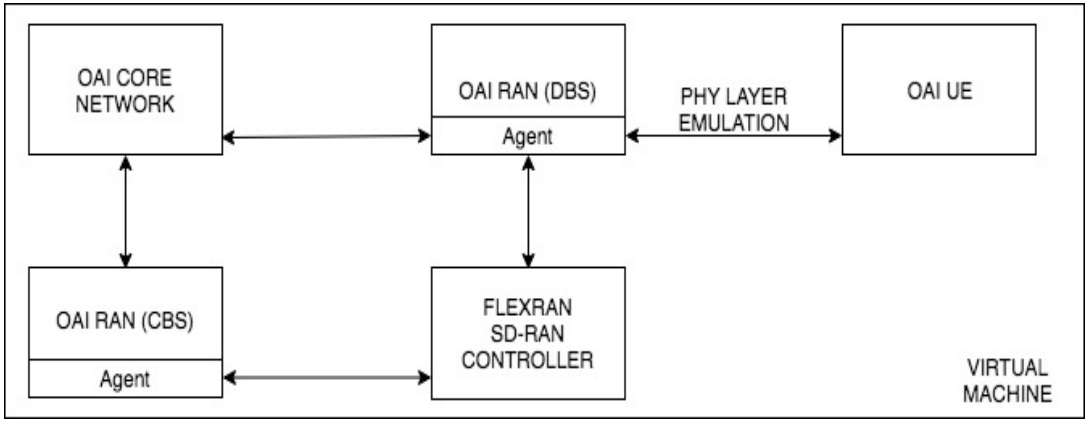
5G SON TestbedCT - Local case

- **NFV-based 3GPP network emulated setup**
  - Docker Container and VM tested
  - **VM-based** deployment
- **Local case implementation, all the following entities run on a VM**:
  - **OAI RAN** with agent support, tag 2018w41
  - **OAI CN** v 0.5
  - **FlexRAN Master Controller** v2.0
  - Wireless medium obtained using **Full PHY Layer Mode**
  - **eNB, RF front end and UEs emulated**



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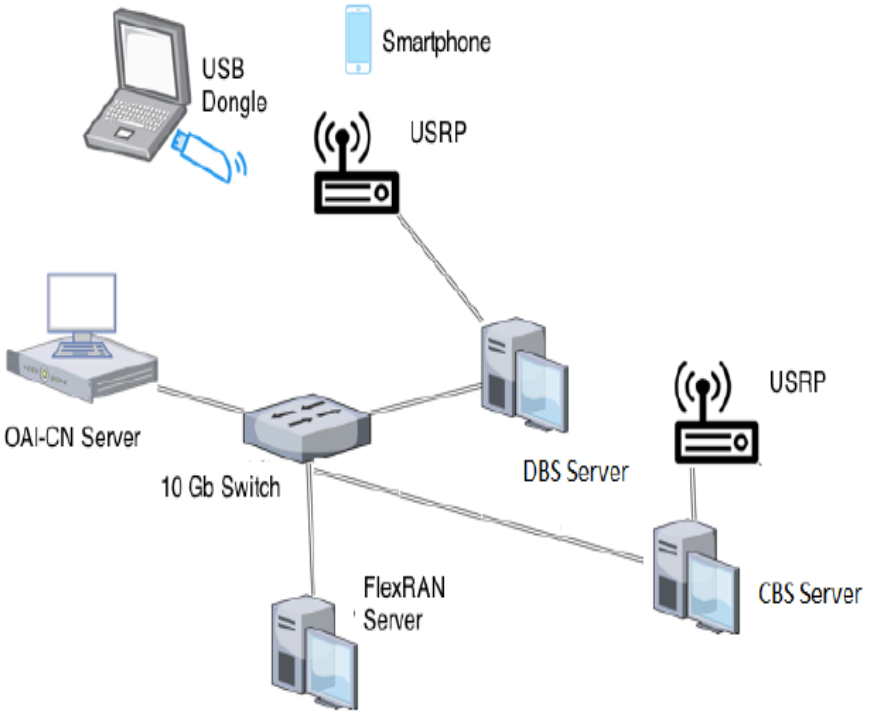
5G SON TestbedGLA - Remote Case

Remote case implementation, each entity runs on a dedicated Server or PC:

- Mini PC Kit NUC7i7 DNHE, **for OAI RAN** 2018.w36 tag
- Intel Server System R1304SPOSHBNR Intel Xeon E3-1220 v6 Quad-core @3 GHz, for **OAI Core Network** v.0.5.0
- Tower Desktop with the same processor model as the Server machine, for **FlexRAN Controller** v 2.0
- **USRP B205mini** for small cell acting as eNB (Radio Front End)
- B205 connected to the RAN through a USB 3.0 (LTE band 7 have been used)
- Huaweii E3372 LTE/4G 150 Mbps USB Dongles, acting as UEs
- Machines connected to "Netgear Prosafe XS716E 10Gigabit" **switch**, with 10Gigabit Ethernet cables



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5G SON TestbedGLA - Local case

All the following entities run a Server or a PC:

- Mini PC Kit NUC7i7 DNHE for:
  - **OAI RAN** 2018.w36 tag
  - **OAI Core Network** v.0.5.0
  - **FlexRAN Controller** v 2.0
- **USRP B205mini** for small cell acting as eNB (Radio Front End)
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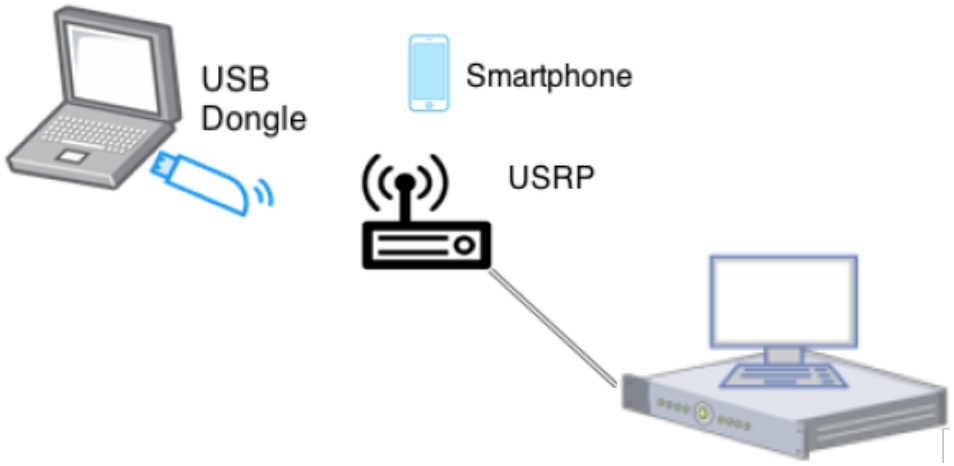

- OAI RAN
- OAI Core Network
- FlexRAN Master Controller and Agent

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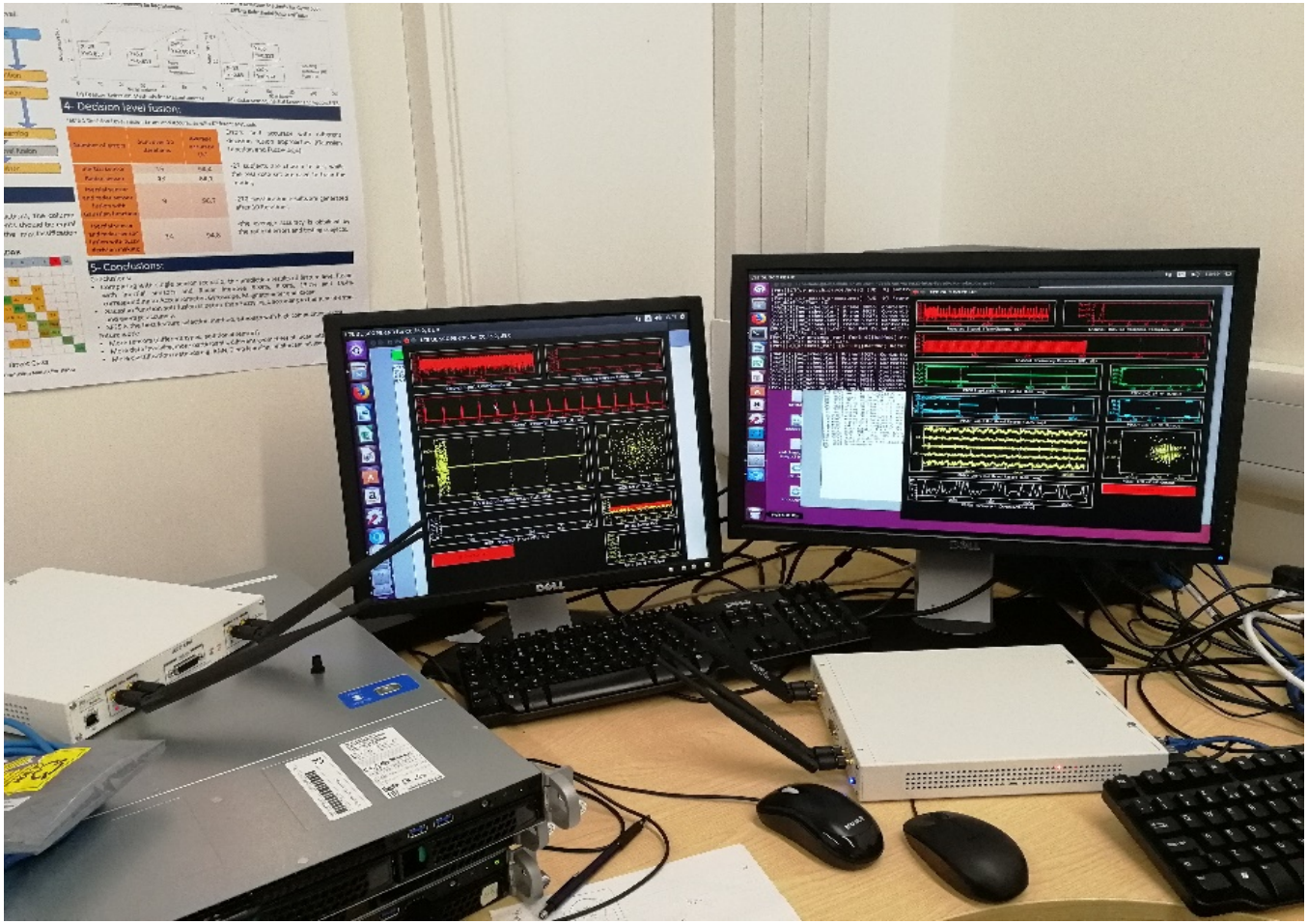
5G SON Testbed: Real view



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Stop&Restart strategy in 5G SON Testbed

We consider **three steps**:

1. **The application** - We create an application, in order to dynamically trigger the instantiation of a base station in terms of virtualized or real entities.

2. **The commands** - We implement specific commands by editing the native code, running on top of FlexRAN/OpenAirInterface, to dynamically manage the RAN entities life-cycle.

3. **The timing evaluations** - We perform time measurements, concerning the RAN entities activation/deactivation procedures.

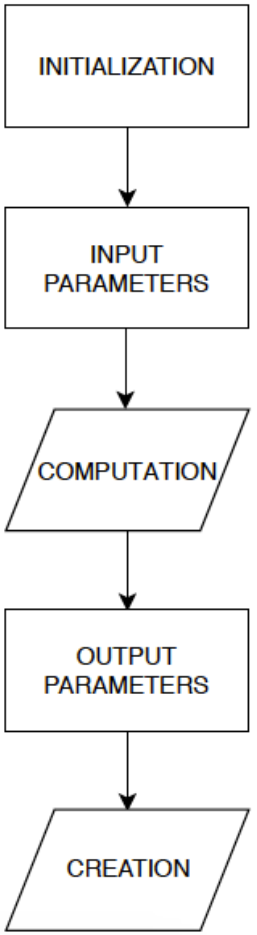
Stop&Restart strategy in 5G SON Testbed

- **First step – The application**

- The application is designed on the basis of the native FlexRAN/OpenAirInterface instructions.

- As shown in Figure, after the initialization step, properly issuing the specified instructions as input parameters, the application is able to dynamically trigger the creation of RAN and core network entities, exploiting the output parameters computed in the computation step.

- The creation step, depends on the considered testbed setup, it is executed by the creation of the related real or virtualized entities.



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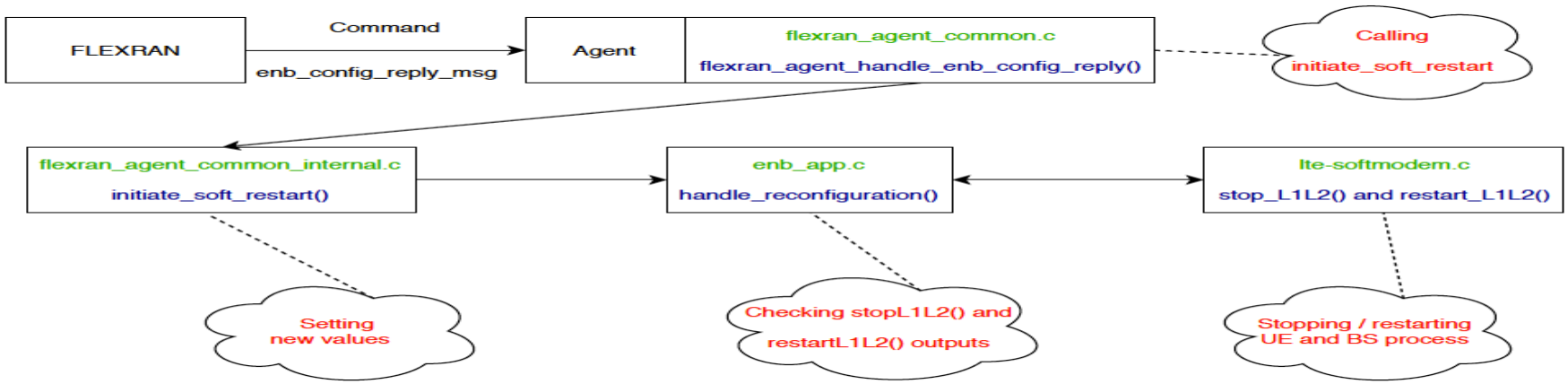
Stop&Restart strategy in 5G SON Testbed



- **Second step – The commands**
- Our main contribution comes with the creation of three different commands: stop, restart and Stop&Restart.
- The stop command triggers the deactivation of a given base station specifying its agent id.
- The start command triggers the activation of a specific base station given the specific agent id.
- The Stop&Restart command, as a mix of the two aforementioned commands, permits to dynamically control the life-cycle of a given base station.

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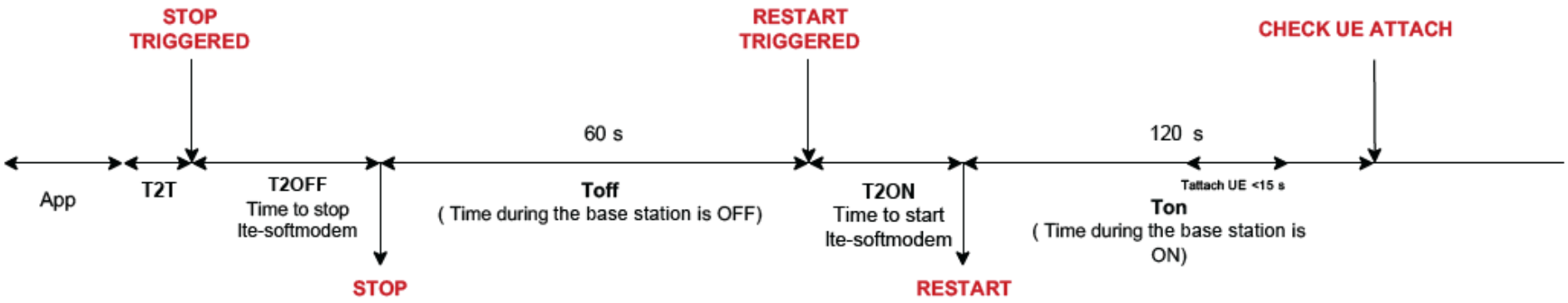
Timing evaluations - Time parameters



- **Third step – Timing evaluations**

We define the following time parameters:

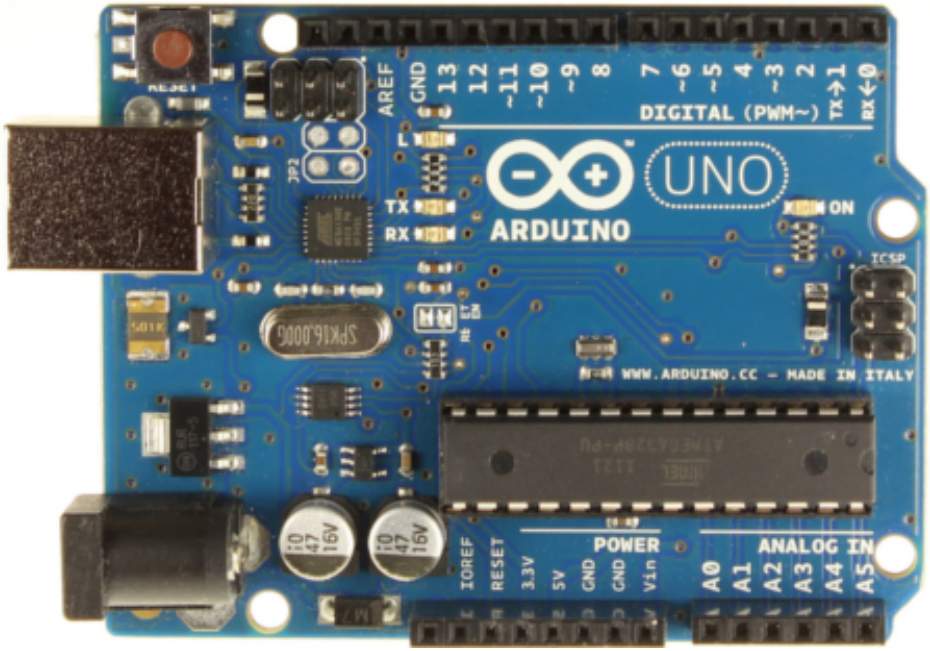
- **Toff**: Activation Time
- **Ton**: De-activation time
- **T2OFF** as the time needed to stop the lte-softmodem.
- **T2ON** as the time needed to start the lte-softmodem.
- **Time-to-Trigger (T2T)** , defined as the time between the FlexRAN command triggering and its effective reception performed by the specified agent.

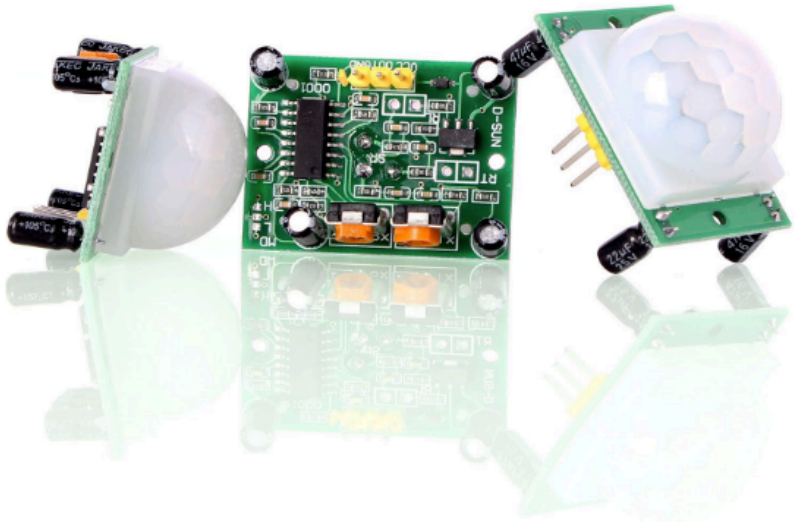
The figure shows an example of a specific execution of the Stop&Restart command. In this specific case, Toff is set to 60 seconds and Ton to 120 seconds .

Considerations

- Benchmark for many 5G use cases with a significant closeness to real network deployment criticalities
- The results permit us to validate the NG-SON capabilities of our testbed.
- Strategy timings are remarkable feedbacks for real 5G deployments
- SDR, VM, FlexRAN controller and OpenAirInterface offer us the flexibility, programmability and high performance capabilities needed, making the testbed an ideal enabler for the development of various 5G use cases.
- The testbed is a starting point to enable design and comparison of more sophisticated control applications

EE with Motion Sensor/ Arduino optimization





- We propose a D-SON algorithm to minimize the energy consumption of SCs by utilizing a motion detection circuit.
- We utilize an Arduino Uno board and an HC-SR501 PIR motion sensor.

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EE with Machine learning optimization

- We developed an improved and more efficient version of the algorithm exploiting Machine-learning techniques.
- Exploiting network traffic pattern prediction to determine small cell switching on-off (URRP B205mini) based on datasets processed by machine learning.
- To this end, EE algorithm code has been optimized and input from machine learning included.
- Consequent additional power meter measurements showed a significant improvement as regards the energy saving compared to the no EE saving approach.

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Publications, teaching and research activities

- **Publications**

- G. C. Valastro, D. Panno, and S. Riolo, “A SDN/NFV-based C-RAN architecture for 5G Mobile Networks,” in IEEE MoWNeT 2018
- Y. A. Sambo, G. C. Valastro, G. M. M. Patanè, M. Ozturk, S. Hussain, M. A. Imran and D. Panno, “Motion Sensor-based Small Cell Sleep Scheduling for 5G Networks,” in IEEE CAMAD 2019
- G. M. M. Patanè, G. C. Valastro, Y. A. Sambo, M. Ozturk, S. Hussain, D. Panno and M. A. Imran, “Flexible SDN/NFV-based SON testbed for 5G mobile networks,” in DS-RT 2019
- M. Ozturk, G. C. Valastro, Y. A. Sambo, G. M. M. Patanè, S. Hussain, D. Panno and M. A. Imran, “Machine Learning based Predictive Cell Switching,” in IEEE Communication Letters Journal, IEEE, (Under Submission).
- G. C. Valastro, Y. A. Sambo, G. M. M. Patanè, M. Ozturk, S. Hussain, D. Panno and M. A. Imran, “SDN/NFV based RAN Slicing Application for 5G mobile networks,” in IEEE Journal (Under Submission).
- E. Catania, A. La Corte, D. Panno and G. C. Valastro, “IoT Privacy in Ultra-Dense Networks,” in Journal, (Under Submission).

Publications, teaching and research activities

- **Teaching activities**

- Teaching and Lab support in Reti e Servizi Mobili course
- Thesis support in Reti e Servizi Mobili course

- **Research activities**

- Technical coordinator in the context of the participation of the University of Catania to the Mosaic5G Research Project
- Active contribution, code uploading on top of Mosaic5G plaftorm (https://gitlab.eurecom.fr/), with related intellectual property and copyright
- Technical coordinator in the context of research collaboration with University of Glasgow
- Technical coordinator in the context of research collaboration with Bristol Is Open
- Technical coordinator in the context of research collaboration with Altran

Publications, teaching and research activities

- **Training activities**

- MATLAB Academic Tour 2018 – Stefano Olivieri (Mathworks) – 06/11/2018.
- Workshop Assistive Technology for the Independent Living: the NATIFLife Project – 05/06/2019.
- International School on Informatics&Dynamics in Complex Networks (ISI&DCN),15-19 October 2018.
- 5G Italy – The Global Meeting in Rome, 4 – 5 – 6 December 2018.
- International School on Data Science and IoT – 9 – 13 September 2019.
- IEEE/ACM DS-RT 2019 – The 23rd International Symposium on Distributed Simulation and Real Time Applications, 7 – 9 October 2019.

- **Presentations @ PhD Schools and Conferences**

- I presented the lecture "A SDN/NFV based C-RAN architecture for 5G mobile networks" at the International School on Informatics&Dynamics in Complex Networks (ISI&DCN), 15-19 October 2018.
- I presented the lecture "Flexible SDN/NFV-based SON testbed for 5G mobile networks" at the International School on Data Science and IoT – 9-13 September 2019.
- I presented the paper "Flexible SDN/NFV-based SON testbed for 5G mobile networks" at the IEEE/ACM DS-RT 2019 – The 23rd International Symposium on Distributed Simulation and Real Time Applications, 7 – 9 October 2019.

Thank you for your kind attention

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