FED4FIRE
Federation for FIRE Plus

Cross Layer Control (CLC) based on SDN and SDR towards 5G Ultra Dense Heterogeneous Networks

Sokratis Barmpounakis
George Tsiatsios
Nikolaos Maroulis

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Introduction – Motivation

- Our work focuses on scenarios where numerous wireless devices coexist in dense network deployments of heterogeneous access technologies
- In general, 5G networks introduce new challenging network environments:
    - numerous, heterogeneous wireless devices, things
    - numerous, heterogeneous access technologies: Ultra Dense Networks (UDN) use case, comprising a plethora of **coexisting 3GPP and non-3GPP** Radio Access Technologies

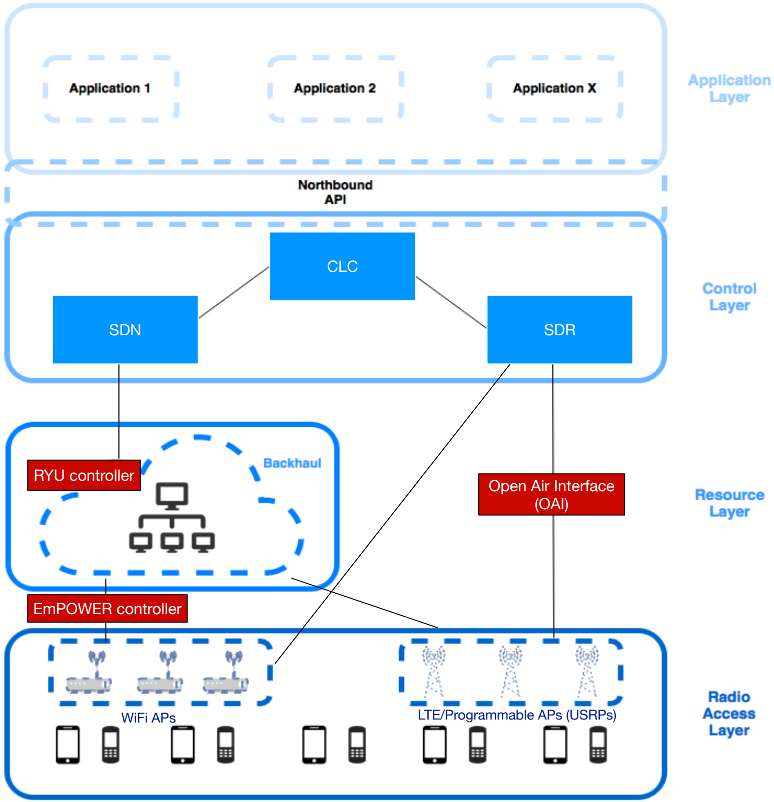
➢ limited resources must be allocated optimally

- In order to address some of the aforementioned requirements, we use Software Defined Networking and Software Defined Radio approaches

Concept and objectives

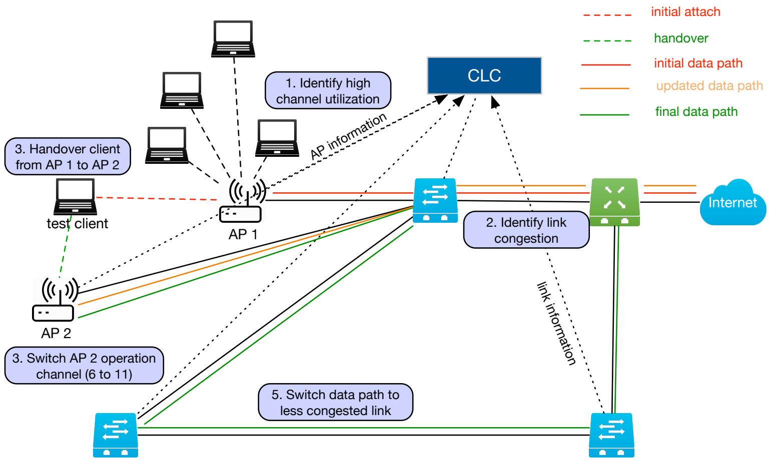
- In order to cope with such a **dynamic and challenging environment, holistic control frameworks must be applied, capable of sensing** the network conditions and applying rules and policies across the network
- Towards this end, by acquiring a **global view of the network at a single point**, via a cross layer controller, we attempt to **manage the resource allocation in an end-to-end manner**, i.e., in the Core Network, the backhaul of the RAN, as well as the Radio resources
- Radio-related information and policies, can improve backhaul network operations and conditions and vice versa

CLC high level set-up

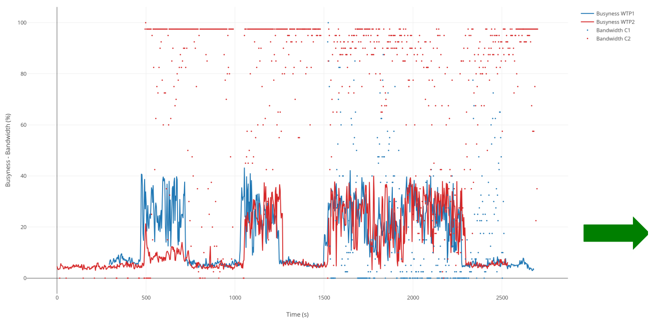


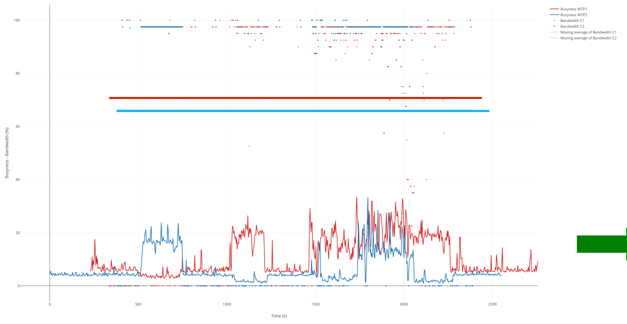
- CLC uses an abstraction layer, which aggregates:
  - the network and radio conditions, as monitored by the different controllers
  - the network policies (which are being pushed from CLC back towards the separate controllers)
- Experimentation took place in **NITOS Indoor RF Isolated Testbed** and involved scenarios comprising
  - OAI-enabled B210 USRPs in order to implement the LTE eNodeBs
  - an EPC node and OAI UEs (for the LTE experiments), as well as
  - custom EmPOWER-enabled ICARUS nodes for the Wi-Fi part.
  - OpenFlow / Ryu Controller – enabled switches were deployed locally for supplementary experiments

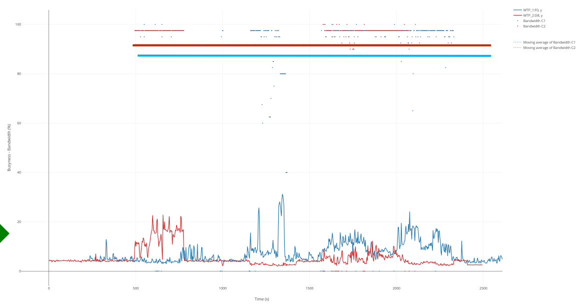
Experiment 1 results



- The main idea is to ameliorate specific network KPIs , such as the throughput, the latency and the experienced interference…
- …working with both layers of the network, and particularly, when there is an indirect relation between the radio and the backhaul link layers.
- Interference and High utilization of channel identification
- Congested link identification
- Phases: Blue active only, Red active only, simultaneous traffic
- Actions taken: Handover, AP2 Channel Switch (to non-congested channel) and re-routing of AP2's flows using SDN features optimize considerably the KPIs

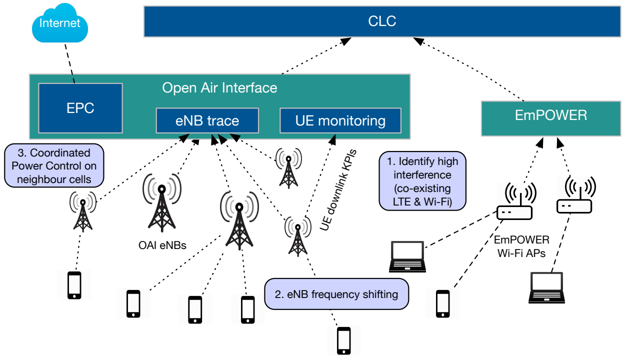


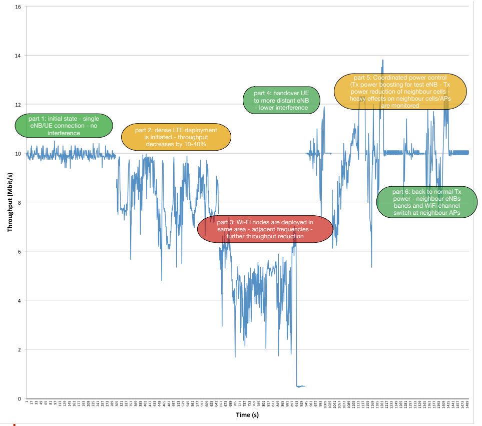


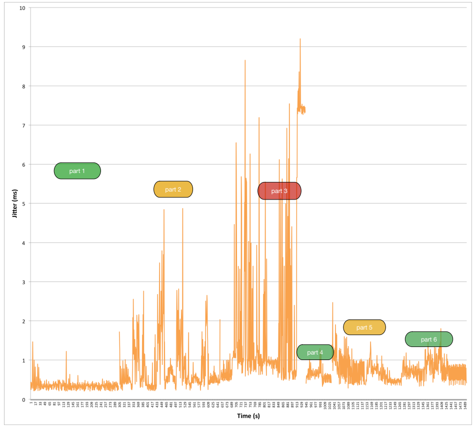


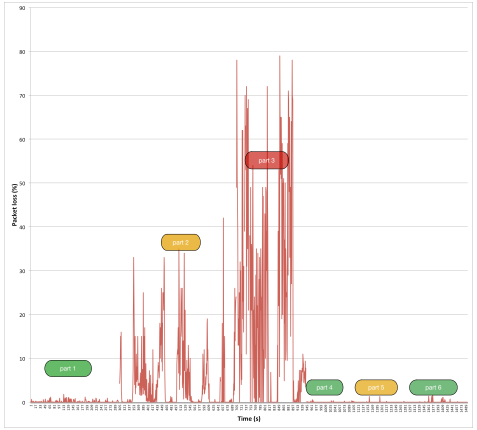
Experiment 2 results

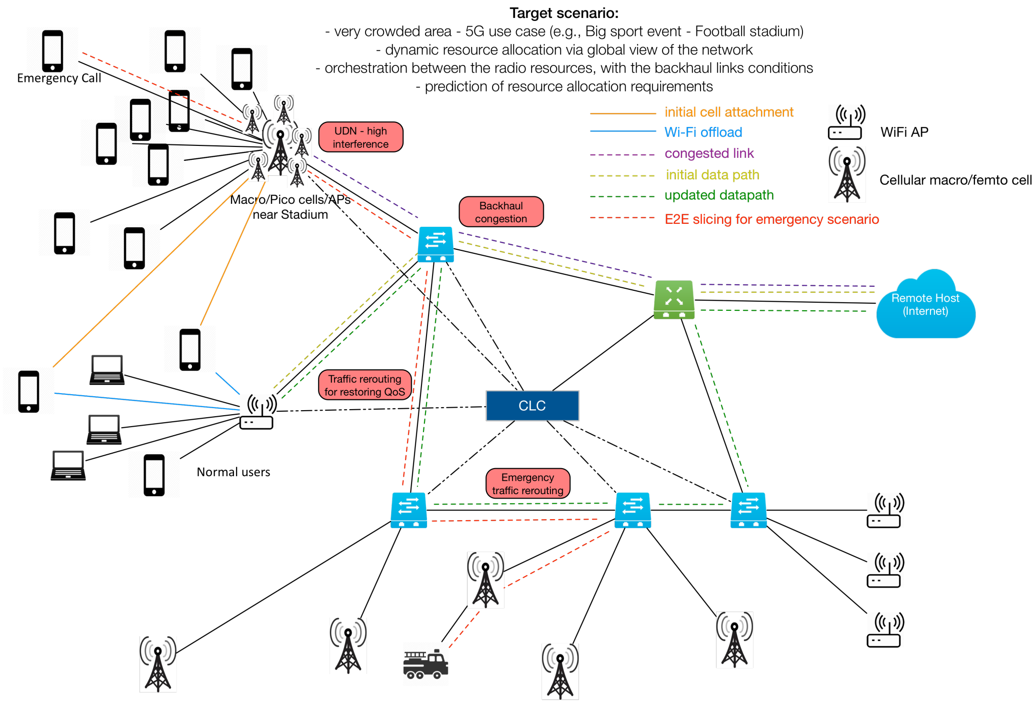
- Experiments with co-existing LTE (USRP-based) and custom Wi-Fi nodes (federated by *EmPOWER* radio controller)
- The main rationale behind this scenario is to demonstrate the feasibility of having a single point of control between heterogeneous coexisting Radio Access Technologies (RATs), at which all the information is aggregated and the policies are taken in a unified and holistic manner, considering the resources of both the LTE as well as the WiFI networks as part of the overall abstract resources pool.
- The experiment was carried out on NITOS Testbed, where we reserved nodes connected with USRP B210, hosting the OAI 5g Controller software, nodes connected with HUAWEI E3372 LTE Dongles with pre-defined 208 MCC and 93 MNC and one generic node to host OAI Evolved Packet Core (EPC). The CLC Platform was run on our public server in order to be visible from the Testbed.
- Actions taken: Power control, eNB frequency shifting, UE handover enforcement are some of the policy types, which were evaluated











Conceptual scenario

Lessons learned from the results

- ✓ The management of dense wireless deployments towards 5G requires a holistic view of the available resources
    - ✓ backhaul infrastructure (switches, links, etc.)
    - ✓ RAN infrastructure (eNBs, LTE femto cells, Wi-Fi APs, etc.)
    - ✓ radio conditions
- ✓ The experimentation that was carried out in NITOS proves that dynamic radio resource management using wireless SDN and SDR approaches has a direct effect on the measured performance KPIs
- ✓ When combined with coordinated actions related to the backhaul network (e.g., dynamic flow management using OpenFlow switches) a higher enhancement of these KPIs is reported

Business Impact

- Our lab acquired useful knowledge in relation to the **USRP programmable nodes**, which were used for the LTE part of our experiments.
- In addition, due to the remote control of the experiments and the very valuable cooperation we had with the NITOS experts' team, we gained additional useful network management experience **in real network environments (e.g. VLAN deployment)**

Business Impact

- CLC is a project, which began running **internally** in the context of the lab's activities, several months before joining the Fed4Fire+ experimentation team.
- **The overall vision is to build a mature framework for 5G resource management,** able to be applied in diverse contexts and 5G verticals.
- As a result, after its initial validation within Fed4Fire+ context, **we plan to continue developing CLC, extend its features (e.g., automatic policy generation based on Machine Learning techniques) and test it further in more projects**.

Business Impact

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- The main problem, which we faced before the experiments execution, **was the lack of real equipment in a real, scalable network environment.**
- Additionally, it was a big shortcoming for not being able to experiment with USRP equipment, which we finally used in NITOS testbed.
- If the Fed4Fire+ experimentation had not occurred, for sure this would have delayed considerably our activities due to lack of equipment

Business Impact

- Due to CLC's generic context, we plan to apply this solution to **different projects and 5G vertical domains**.
- CLC is one of our lab's current focuses in the domain of 5G. We have already started identifying a potential contribution of CLC technical solution in **a 5G proposal related to Connected Cars.**
- Using Fed4Fire facilities **again** in the future would be of great value for us too, for example, in order to **evaluate one of the next CLC releases**, in which novel features would need to be validated.

Feedback: Infrastructure used

- Infrastructure used:
    - NITOS Wireless testbed (Icarus nodes, USRP implementations, etc.)
    - NITOS OpenFlow testbed (OpenFlow Switches experimentation)
- Tools used
    - **OMF tool** for building custom OS images (including a custom OpenWRT format)
    - **NITOS VLANs** in order to extend the number of interfaces (NITOS built-in Ethernet slots) between the deployment's network elements (e.g. OpenFlow switches)
    - **OpenVPN** in order to connect in an efficient way our local deployment (e.g., CLC back-end) with the deployment in NITOS
    - **Open Air Interface (OAI)** –enabled USRP nodes in order to set-up the LTE deployment
    - **Minicom AT** for realizing the communication with the Huawei LTE Dongles

Feedback based on design/set-up/running the experiment on Fed4Fire

- There was high amount of time available **for working on the actual experiments** and **very few "distracting" administration/documents-related moments**. This was great, taking into account the relatively limited timeframe available for carrying out the experiments and producing results.
- **We had to address two prerequisites, which were not primarily met and were addressed with full success.**
    - First, the variety of Operation Systems available did not satisfy the needs of our deployment, because we needed OpenWRT to be installed in some nodes. With the great support and assistance from the Testbed team, everything was installed properly.
    - Secondly, for the purposes of our experiment, some nodes' Ethernet ports, needed to be connected directly to one another, in order to redirect the traffic, but with the Implementation of VLANs by the Testbed assistants, we easily managed to work around that.

Feedback on the service, support, Patron, etc.

- The role of the Patron is of utmost importance. Although having to deal with each testbed itself requires additional time, testbed-specific patrons are very significant, **in order to be able to discuss with specialised people on specialised hardware and deployments.**
- **Easy access to the testbed infrastructures:** we only had to book **a few hours in advance** our time slots in order to access the requested infrastructures easily.

Feedback: Added value of Fed4FIRE

- One of the most significant features of the federation **is the combination of diverse tools and infrastructures, which for a small/medium university lab is difficult to acquire**, i.e. SDN infrastructure, programmable wireless nodes (USRPs), Cloud Testbeds, Software Defined Radio platforms, etc., as a **single service**.
- Active expert support: It is also of high significance to have a **team of experts per each testbed** in order to set-up efficiently the experiments, make any required custom configurations, etc.

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