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

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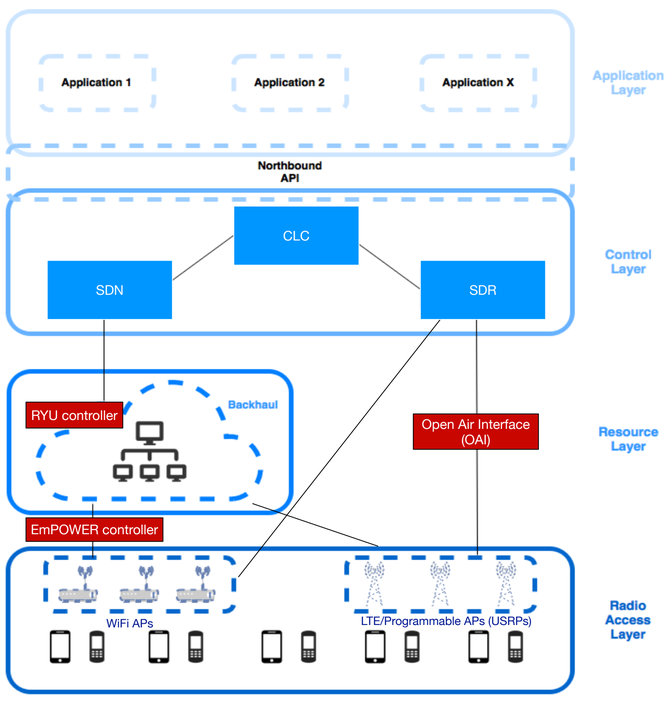
## Scope

- ✓ 5G networks introduce Ultra Dense Networks (UDN), comprising a plethora of coexisting 3GPP and non-3GPP Radio Access Technologies
- ✓ Gradual transition from the traditional cell/single access point concept, towards an *abstracted pool of network and radio resources (e.g. C-RAN)*
- ✓ The network operation will become more service/user oriented via end-to-end network slicing, for critical verticals, from the *Core Network to the Radio*
- ✓ SDN's programmable control plane with SDR's programmable data plane convergence will complement and enhance both scopes

## Challenges

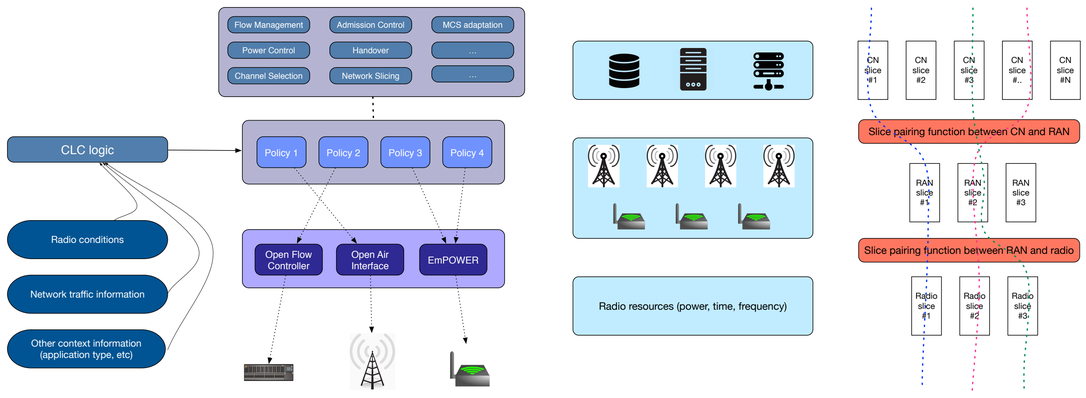
- ✓ Spectrum and network resources scarcity imposes a coordinated resource sharing scheme
- ✓ Besides the resource scarcity, ultra dense wireless deployments result in critical interference challenges
- ✓ By acquiring a global view of the network, via a Cross Layer Controller, we attempt to orchestrate the resource allocation mechanisms in an end-to-end manner, i.e., in the Core Network, the backhaul of the RAN, as well as the radio environment.

## CLC high level architecture



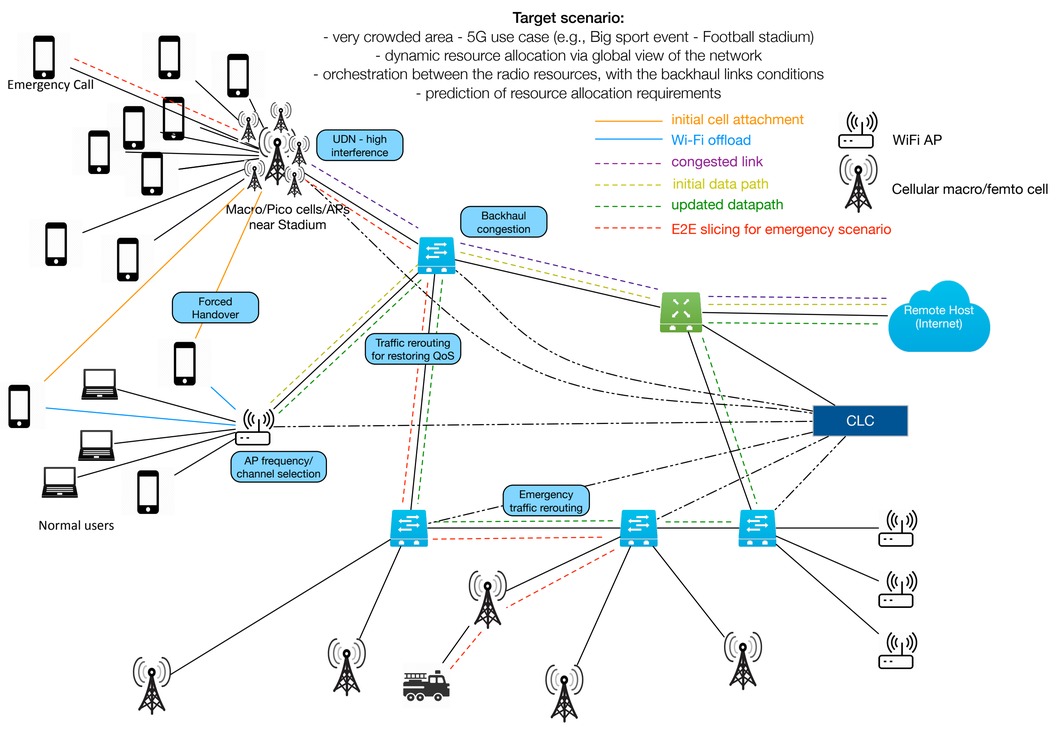

- ✓ CLC operates at the Control Layer, on top of the SDN and the SDR controllers
- ✓ The network and radio conditions (which are forwarded to CLC), as well as the network policies (which are forwarded from CLC to the network) are aggregated on a abstraction layer, which resides between the CLC and SDN/SDR controllers
- ✓ The main idea is to enable CLC operate in a controller-agnostic (e.g., diverse SDN controllers may be deployed)
- ✓ Applications can be built on top of CLC, providing additional functionality via the northbound interfaces

## Policies and Slicing

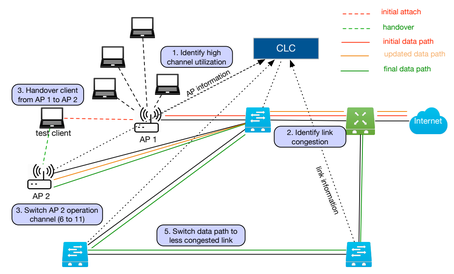



- ✓ Monitoring is applied either automatically (based on pre-defined threshold-based events) or manually via visual analysis, statistics, etc.
- ✓ Information about the radio conditions, the links of the backhaul network, the flow traffic, etc. is analyzed and the respective rules are created and forwarded to the sub-controllers
- ✓ CLC rules and actions are applied either automatically (on a per event basis), or manually via the CLC GUI
- ✓ The derived rules and actions are forwarded via the specific controllers (Ryu, OAI, etc.) and the southbound interfaces to the infrastructure (eNBs, Wi-Fi APs, switches, etc.)
- ✓ CLC is able to work with multiple tenants and create network/radio slices comprising specific Wi-Fi and LTE radio resources at the same time, for selected traffic types, users, etc.

## Target Use Case

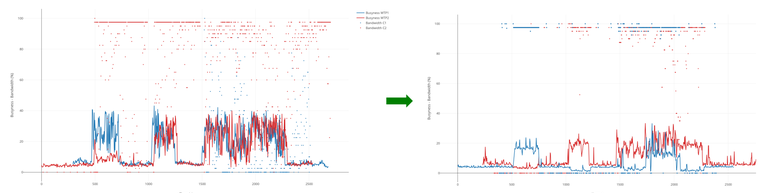



## Experimentation & Results



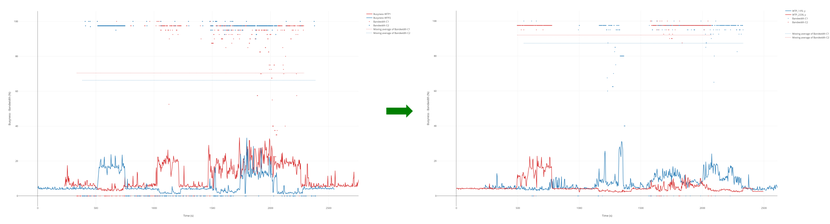

- ✓ Extensive experimentation took place in *NITOS Indoor RF Isolated Testbed* and involved scenarios comprising *OAI*-enabled B210 USRPs, an EPC node and *OAI* UEs (for the LTE experiments), as well as custom *EmPOWER*-enabled ICARUS nodes for the Wi-Fi part. *OpenFlow / Ryu* Controller – enabled switches were deployed locally for supplementary experiments

*Radio slicing in high interference environment*

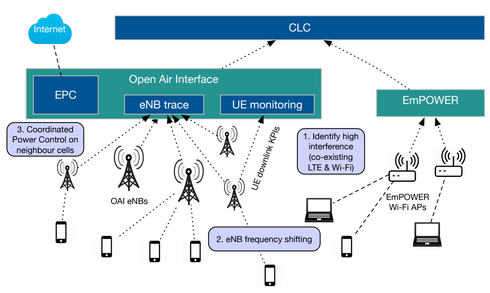


- ✓ By monitoring key network metrics, such as RSSI, throughput and jitter, we apply policies and rules in order to improve specific KPIs in scenarios, primarily related to interference mitigation and link congestion avoidance

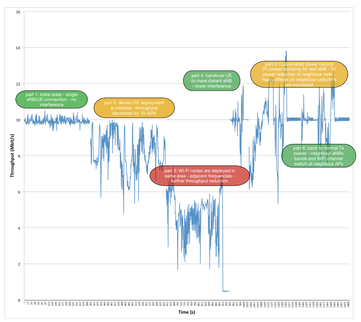
*Backhaul network slicing via OpenFlow-enabled flow management (2nd action)*

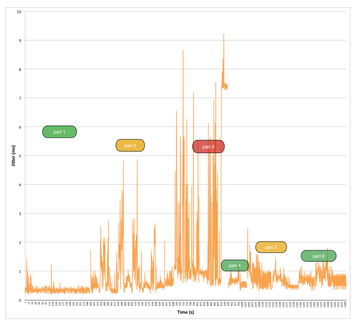


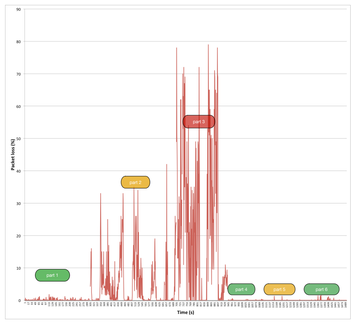
## Experimentation & Results




- ✓ Experiments with co-existing LTE (USRP-based) and custom Wi-Fi nodes (federated by *EmPOWER* radio controller) were carried out (e.g. emergency dense deployment and real-time radio resource planning)
- ✓ Power control, eNB frequency shifting, UE handover enforcement are some of the policy types, which were evaluated
- ✓ CLC forwards policies to the LTE part of the deployment via the *Open Air Interface* and to the Wi-Fi part via *EmPOWER* framework




## Conclusions – Next steps

- ✓ The management of dense wireless deployments towards 5G requires a holistic view of the available resources, comprising backhaul infrastructure (switches, links, etc.), RAN infrastructure (eNBs, LTE femto cells, Wi-Fi APs, etc.), as well as spectrum condition
- ✓ 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
- ✓ As part of our next steps, we plan to evaluate CLC's performance on more sophisticated scenarios, in an end-to-end manner and in a much more holistic context, based on automated policies and rules enforcement.