Results Showcase

Three main use cases are considered to demonstrate the main achievements of COHERENT.

1 RAN Sharing

- **Intra-RAT radio resource management control app**
  demonstrates the benefit of control plane programmability based on the COHERENT SDK to dynamically partition resources among multiple tenants/slices based on their service descriptor and their predicted short-term performance.

2 Load Balancing

- **Intra-RAT handover app**
  demonstrates the benefit of data-plane programmability using the COHERENT SDK to trigger an X2 handover of a User Equipment (UE) based on the actual network conditions.
- **Inter-RAT traffic steering app**
  shows how the traffic of users can be dynamically steered, balanced, and isolated between Wi-Fi and LTE networks based on their actual radio resource utilizations.

3 Spectrum Management

- **Inter-RAT spectrum management app**
  demonstrates how the knowledge base maintaining the information related to operators and shared spectrums, policies, and interference are stored, managed and shared across different RAT, namely LTE and Wi-Fi.
- **Intra-RAT spectrum sharing control app**
  shows how the spectrum information is retrieved and analyzed through the COHERENT SDK to find and reallocate the best available frequency, bandwidth, and power to a subset of cells that opportunistically make use of such spectrum to improve both users and network performance.

Dissemination

Wide dissemination of COHERENT outcomes is one of the key objectives of the project. COHERENT has published research papers in variety of high quality journals, workshops and conferences such as IEEE Communications Magazine, IEEE JSAC, IEEE Transactions on Wireless Communications, IEEE ICC, IEEE Globecom, EuCNC, IEEE PIMRC and IEEE NOMS.

Standardization

COHERENT has made over 80 contributions to the following standardization bodies and shaped the key ingredients of future 5G standards:

Electronic Communications Committee Project Team 1 – ECC PT1

✓ Presentation of COHERENT concepts related to flexible FDD duplexing; these concepts are reflected now in ECC/CEPT "Roadmap to 5G".

The 3rd Generation Partnership Project – 3GPP

✓ Contributions on application of Central Coordination and User plane/Control plane separation concepts in 3GPP standards related to the 5G NR, with main contributions to Requirements, Architecture, RRM functional split, functions and APIs for F1 interface.

ETSI Broadband Radio Access Networks – BRAN

✓ Contributions on application of Central Coordination in a 5GHz heterogeneous network, captured in the ETSI TR 103 494 initiated and led by COHERENT partner 4GC and supported by COHERENT partners Thales, VTT, Fairspectrum and CREATE-NET.

Project Facts

COHERENT is one of the 5G PPP research projects funded by the European Commission.

Duration:
July 2015 – March 2018

Coordinator:
Dr. Tao Chen, VTT Technical Research Centre of Finland LTD

Consortium:
15 partners from 9 countries with competence well balanced among industry companies, telecom operators, universities, research institutes and SMEs.

Budget:
6 M€ from the European Commission under the Horizon 2020 Programme

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Partners

Coherent

Coordinated Control and Spectrum Management for Heterogeneous Radio Access Networks

5G

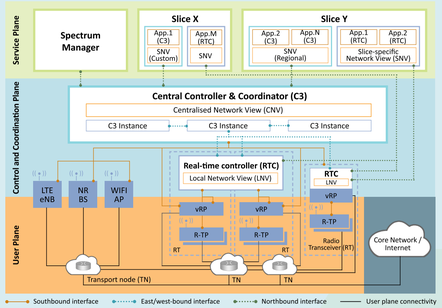
5G PPP

This project has received funding from the European Union's Horizon 2020 Programme under grant agreement No 671639.

Approach

COHERENT addresses the challenges of exponential mobile traffic growth, increase in network complexity, and need for inter-network coordination of wireless network resources by creating breakthroughs in control, coordination and flexible spectrum management in 5G networks. The project partners conducted research, development and validation of a novel control framework for 5G heterogeneous radio access networks (RANs) which combines software defined networking (SDN) for RAN programmability, efficient radio resource control and coordination, and flexible spectrum management.

COHERENT Architecture



The illustrated COHERENT system architecture specifies a programmable control and coordination framework that is responsible for monitoring the network, making control and coordination decisions and programming the behavior of the physical network. The architecture is designed for scalable real-time control and coordination. It facilitates the programming of RAN infrastructure and efficient handling of radio network resources.

Scalability and **timeliness** for control and coordination are capitalized on two mechanisms, namely the Central Controller and Coordinator (C3) as well as Real-Time Controller (RTC). 5G Network programmability is driven by **network abstraction**. By receiving status reports from low layer entities, C3 maintains a centralized network view of the governed entities, e.g. Radio Transceivers (RTs), such as legacy LTE eNodeBs, Wi-Fi Access Points (AP) or 5G New Radio Base Stations (5G NR BS), and physical transport nodes (TNs), such as switches and routers.

Network Abstractions

COHERENT uses network abstractions to expose network states and conditions to the logically centralized control entity, enabling SDN control principles for 5G RAN. Network graphs abstract the network states at the centralized control entity. A network graph is the aggregation of the data structure that contains the relevant parameters of network elements and the associated metrics between any pair of network elements. The most important aggregation categories are: clustering for combining similar nodes into a single entity, edge selection for grouping data storage only for related nodes, statistical representation by using probabilistic characterisation of instantaneous metrics, and functional synthesis by combining multiple related variables into a single parameter.

Achievements

Network abstractions support network programmability across heterogeneous radio access technologies (RAT) in a scalable manner. COHERENT

- Introduced network abstraction methodologies for different RATs
- Developed network abstractions for the functional entities of the COHERENT architecture and defined control interfaces
- Reported performance evaluations of applying the network graph approach in different control scenarios, e.g. load balancing, multiconnectivity, device-to-device (D2D) communications
- Demonstrated suitability of network abstractions in emerging mobile network control applications.

Extensive evaluation results show the potential of the COHERENT approach as the flexible control solution for heterogeneous 5G RAN.

Flexible Spectrum Management

Flexible yet effective spectrum management is one of the key enablers for the success of 5G networks. Given that wireless spectrum is allocated to different operators, and due to increased deployment density, the traditional coexistence solutions within licensed bands may not provide the necessary isolation anymore. The classical interference mitigation approach based on orthogonal spectrum sharing among operators in licensed bands may be inefficient in small-cell scenarios with changing numbers of users, variable area coverage and variable load. A new vision for spectrum utilization is required. Various approaches were proposed by COHERENT as alternatives for licensed-only solutions.

Achievements

COHERENT contributed towards the practical implementation of flexible spectrum management by providing

- New approaches towards dynamic spectrum management with the use of network graphs, and the idea of virtual spectrum resources as a prospective future solution
- New ways for micro-area spectrum sharing, especially in the context of Frequency Division Duplex (FDD) flexible duplexing scheme and application of non-contiguous transmission
- New model for small-scale spectrum sharing in numerous contexts
- Real-time trials of spectrum sharing unitizing the Citizens Broadband Radio Service (CBRS) model on the existing network; the whole experiment assumes the protection of the incumbent networks by means of a remote database operating in CBRS mode
- Real-time implementation of the spectrum policy management and selection in the OpenAirInterface platform, allowing for dynamic frequency allocation for legacy eNodeBs.

RAN Sharing and Network Slicing

RAN sharing refers to the ability to share radio and spectrum resources efficiently among multiple operators or more generally tenants. The main objective of RAN sharing and network slicing in COHERENT is to maximize the utilization of RAN resources across tenants by exploiting the statistical multiplexing gain. Such resources can be described by type, either physical or virtual, and by abstraction. The common scheduler is developed in COHERENT to take charge of accommodating requests and resource mapping from different tenants to meet their service requirements.

Network slicing in COHERENT extends RAN sharing with resource and functional isolation, enabling a tenant to dynamically instantiate a virtual BS and a virtual AP on top of the physical RAN infrastructure and take full control of the slice. With network slicing, a slice owner can independently manipulate and adjust its allocated resources in a virtualized or physical form, and customize the user plane and control plane processing as per service need. Thus, network slicing enables the composition and deployment of multiple logical networks over a shared physical infrastructure presented to the network owner as a service or slices.

Achievements

COHERENT results include

- Devising algorithms for RAN sharing and spectrum sharing for both LTE and Wi-Fi
- Defining different type of resource and spectrum abstractions
- Designing and implementing a policy-based two level Medium Access Control (MAC) scheduler
- Designing and implementing a RAN sharing framework and extensions for RAN slicing
- Building a proof-of-concept demonstrator.

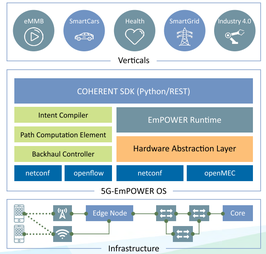
Software Development Kit

The COHERENT Software Development Kit (SDK) allows network programmers to deploy control and coordination policies as network "apps" running of top of a logically centralized controller. The SDK supports multi-tenancy, allowing apps to be executed in their own slice of resources with a customized view of the network resources.

5G-EmPOWER and FlexRAN platforms are two independent implementations of COHERENT C3 and COHERENT SDK. Both platforms are publicly available through their respective open source licences.

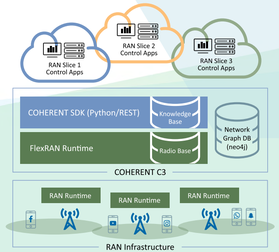
The COHERENT SDK operating on 5G-EmPOWER platform supports both commercial and open source solutions. 5G-EmPOWER supports Wi-Fi APs capable of running OpenWRT and popular open-source LTE stacks such as srsLTE. The SDK has been used by commercial LTE small cells produced by the project partner CommAgility.

5G-EmPOWER platform



The COHERENT SDK operating on the top of the FlexRAN platform, being designed RAT-agnostic, currenty supports OpenAirInterface LTE eNodeB with particular focus on control and programmability of the protocol stack for both realtime and non-realtime control apps, such as scheduling and mobility management.

FlexRAN platform



More information about the SDK can be found on the project website **www.ict-coherent.eu**.