

# Softwarization of Radio and Wireless Networks

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While SDR and SDN initially were parallel evolutions happening in isolated research communities, several European projects, more specifically the H2020 projects WiSHFUL, eWINE and ORCA are currently developing enablers to bridge the gap between SDR and SDN. These projects offer advanced software and hardware platforms in open state-of-the-art large-scale wireless test facilities that can be used and further extended by academic researchers and wireless developers.

## Motivation

During the past decades we have witnessed the **explosive emergence of wireless technologies and standards**, covering different ranges and different licensed and unlicensed spectral bands.

Some trends observed are (1) the ever-increasing number and diversity of wireless devices (2) running applications that become more critical and bandwidth-hungry, and having very diverging QoS requirements, and (3) the presence of multiple heterogeneous wireless technologies, often integrated in the same device, sharing the same physical environment and in many cases also sharing the same spectral bands. Unfortunately, as the wireless radio spectrum is a scarce resource, the **available spectral bandwidth does not scale** with the increasing bandwidth demands from wireless devices and applications. There is hence a need to introduce new sophisticated techniques for accessing and sharing the wireless medium in a highly efficient manner. Such techniques are expected to either improve the **coordination** within a given spectral band (horizontal spectrum sharing), or explore the possibilities of **opportunisticly** using unused spectrum in underutilized and potentially licensed spectral bands (vertical spectrum sharing, also called dynamic spectrum sharing or DSS).

## The problem

Wireless networks have become extremely **complex systems** that cannot be optimized anymore following traditional approaches such as design-time planning and simple one-size-fits-all configuration strategies after deployment. Instead there is an increasing need for more intelligent techniques, being **cognitive radio networking** solutions, that can monitor the dynamic behaviour of the network, for instance the dynamics of the wireless environment and the varying application demands, and based on that autonomously adapt the network and radio parameters to maximize network performance and QoS. In many cases different applications have to share the same wireless infrastructure and the same spectral bands, making it really challenging to meet the **very diverging QoS requirements** simultaneously. The basic control mechanisms that are provided today in wireless technologies are not adequate to deal at the same time with extreme (ultra-low latency, ultra-high throughput, ultra-high reliability) and diverging (low AND high data rate, time-critical AND non-time critical) communication needs.

## Interesting evolutions

Interesting **softwarisation evolutions** are happening at different levels and enable sharing of wireless infrastructure and spectrum:

- At the networking level **Software-Defined Networking (SDN)** decouples the network control and data plane forwarding functions, enabling directly programmable network control offering diverse network services to a variety of applications. Such an approach allows virtualizing a single physical network into multiple logical network domains, each domain serving a certain category of traffic flows in the most appropriate way.
- At the radio level, we have observed the emergence of **Software-Defined Radio (SDR)**. An SDR is a radio communication system where transceiver components that are typically implemented on hardware (in an ASIC) are instead implemented by means of software on a host computer, or an embedded system equipped with programmable hardware like ASIP or FPGA.

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## WiSHFUL project

The WiSHFUL project<sup>1</sup> adopts the general idea of software defined networking (SDN), implemented in core IP networks, and applies it to the domain of heterogeneous wireless access networks. WiSHFUL offers several **software platforms** that comprise data plane and control plane functionality for advanced radio and network control supporting different wireless platforms (such as standard Linux and Wireless Mac Processor [1] for IEEE 802.11, Standard Contiki, TAISC [2] and GITAR [3] for IEEE 802.15.4, ip.access and Airspan for LTE, and Iris [4] for SDR). Although different wireless technologies and platforms can be very heterogeneous in terms of memory and processing capabilities, and supported operating systems, protocols and tools, the software platforms offered by the WiSHFUL project come with a **unified, technology-agnostic interface**, called UPI or Unified Programming Interface (see Figure 1) [5]:

- The **radio interface (UPI\_R)** consists of a set of functions that ensure uniform control of the radio hardware and lower MAC behaviour across heterogeneous devices. The lower MAC directly interacts with the radio hardware for radio transmission and reception, which involves time-critical operations.
- The **network interface (UPI\_N)** parallels the UPI\_R with a set of functions that provides uniform control over the upper MAC and higher layer protocol behaviour across various devices. The upper MAC is responsible for inter-packet states, where inter-device coordination required, and is not time-critical.
- The **global interface (UPI\_G)** extends the reach of the control provided by both the UPI\_R and the UPI\_N across several devices in a coordinated manner.
- The **hierarchical control interface (UPI\_HC)** enables hierarchical control between control programs (inter-control communication and management).
- The generic functions of UPI\_R, UPI\_N, and UPI\_G are supported by **Monitoring and Configuration Engines (MCEs)** that contain and manage the platform specific implementations of UPIs. Naturally, the UPI\_R and UPI\_N are supported by a local MCE, while the UPI\_G employs a global MCE.
- **Control Programs** are user-defined software that implements the controlling logic for a wireless solution and makes use of the UPI\_R and/or UPI\_N for radio/network control. Local Control Programs use the local information and abilities of a single device, while Global Control Programs interact with a group of devices.

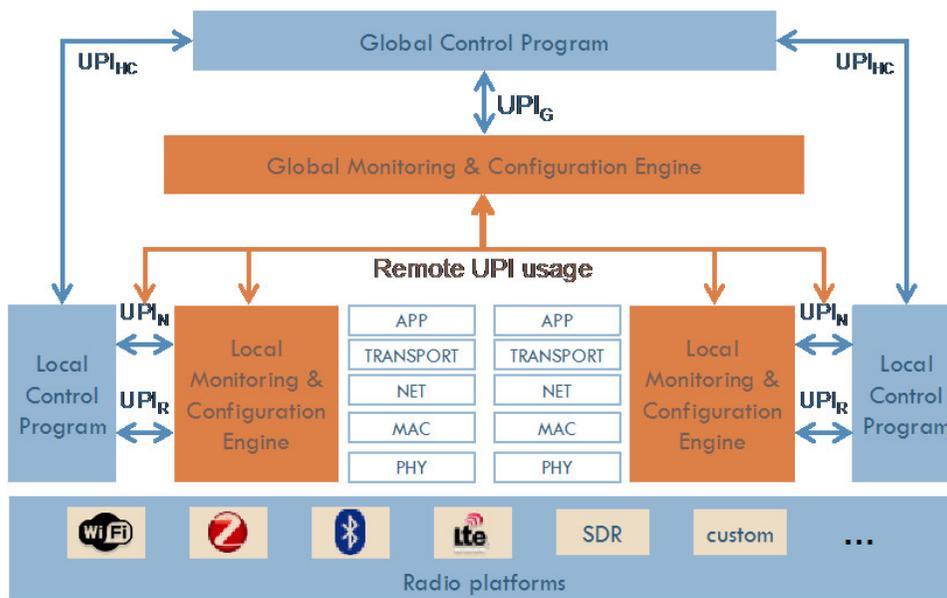


Figure 1: WISHFUL conceptual architecture for flexible and unified radio and network control

Using the WISHFUL software platforms, wireless network solution developers can focus on the network optimisation without the need to dig into complex hardware and software specifications for different technologies and platforms. They only have to write control program(s) that directly call the required UPI functions for monitoring and control.

**eWINE project**

The eWINE project<sup>2</sup> extends the WISHFUL software architecture with an *intelligence toolbox* (see Figure 2) for enabling intelligent network and radio control [6]. The connection between the WISHFUL software architecture for radio and network control and the intelligence toolbox is made by the WISHFUL UPIs. As the UPIs are unified abstractions that span across several wireless technology platforms, the components of the intelligence framework are generic. The *Data Collection* component is a generic software module that interacts with the WISHFUL UPIs, to retrieve data about radio and network operation, and with the Application API to retrieve information about the application requirements. The Data Collection Component also implements aggregation functionality to reduce the amount of data or to change the representation of data. The *Intelligence Composition* module offers support for composing and configuring several algorithms available in the *Intelligence Repository* into a self-contained intelligence engine that uses the data provided by the Data Collection component and triggers configuration of radio and network through the *Action* component. The Action component translates the intelligence decisions taken by the Intelligence Composition component in a sequence of UPI calls. The eWINE intelligence toolbox offers a common set of tools that enable the realization of intelligent approaches using the algorithms from the repository. Together with the UPIs the toolbox enables reasoning about the current network state and applying actions to change the configuration of radio and network, hence realizing true cognitive networking.

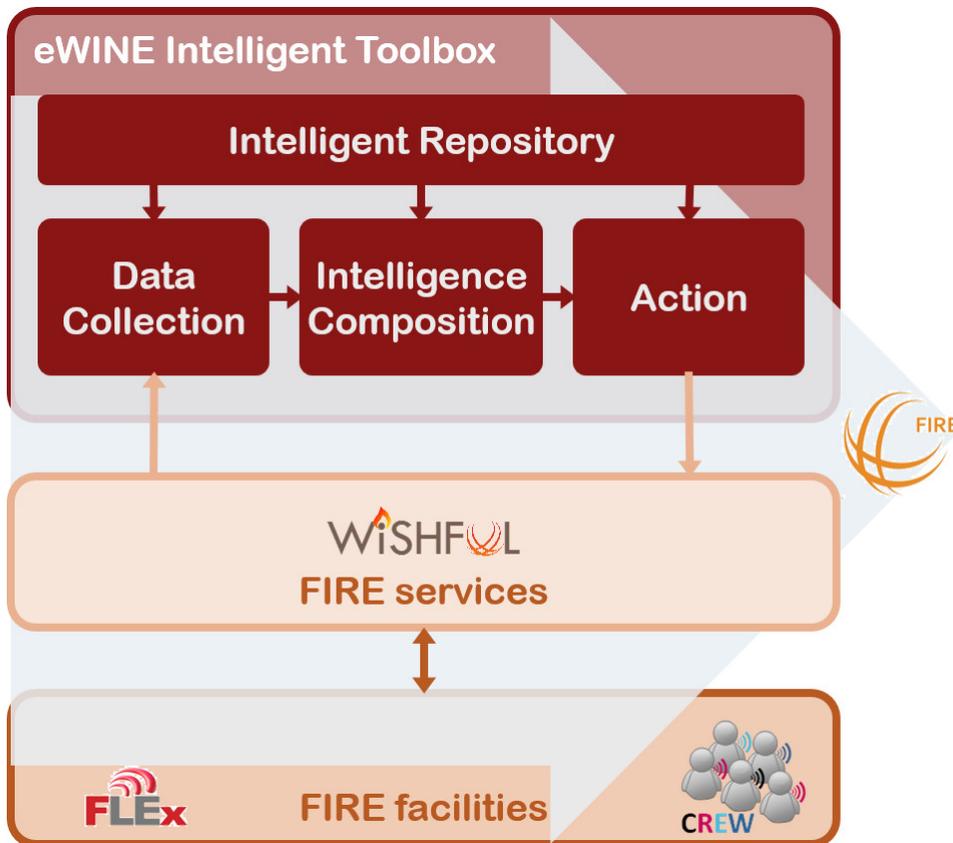
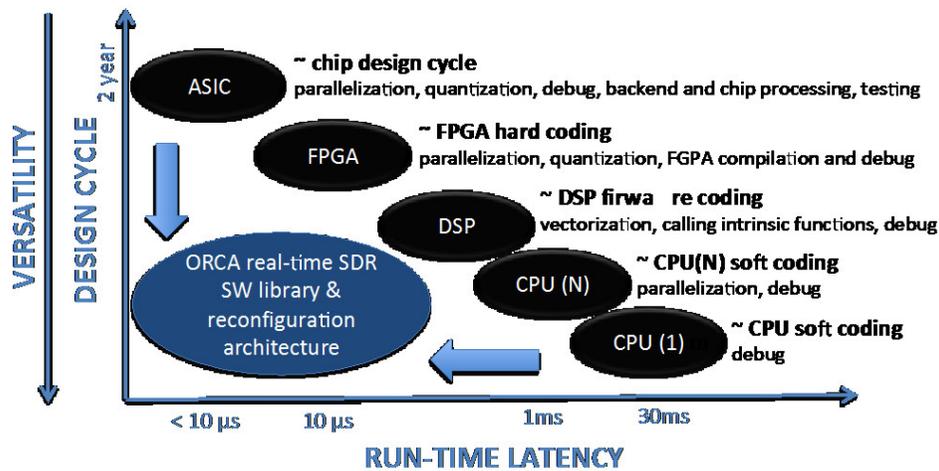


Figure 2: the eWINE intelligence toolbox

## ORCA project

The ORCA project<sup>3</sup> (starting in January 2017) will accelerate flexible **end-to-end experimental validation** by making open and modular software and hardware architectures available meeting the requirements in terms of runtime latencies, throughput, and versatility, the latter referring to the (re)configuration and (re)programming capabilities. Such architectures smartly use novel flexible radio technology, more-specifically **real-time Software Defined Radio (SDR)** platforms. ORCA will fill the gap between 1) **fast design cycle and high versatility**, but high runtime latency (typically offered by a CPU environment), and 2) **low runtime latency**, but slow design cycle and low versatility (as offered by an ASIC), which is illustrated in Figure 3. ORCA will provide a wireless SDN architecture by adding a high degree of flexibility at the radio level to adapt wireless networks to the dynamic nature of today's applications [7]. The main target of ORCA is offering appropriate interfaces to integrate network functionality with RF, PHY and medium access functionality in SDR devices, providing a data, control and management plane at all levels (radio and network).



(/images/files/newsletter/201701-moerman-figure3.jpg)

Figure 3: ORCA acceleration: filling the gap between high versatility and low latency with real-time SDR

<sup>1</sup><http://www.wishful-project.eu/> (<http://www.wishful-project.eu/>)

<sup>2</sup><http://www.ewine-project.eu/> (<http://www.ewine-project.eu/>)

<sup>3</sup><http://www.orca-project.eu/> (<http://www.orca-project.eu/>)

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