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Convergence of Decentralized Cloud Platforms and 5G Networks

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Introduction

- Our goal → to present a **Software Defined Radio** (SDR) approach for **5G networks** based on **Universal Software Radio Peripheral** (USRP) and **GNU Radio**

{ an open-source software that offers tool for developing software and provides modules for digital signal processing used for implementing radios defined virtually }

Technologies:

- 5G
- SDR
- Cloud Computing

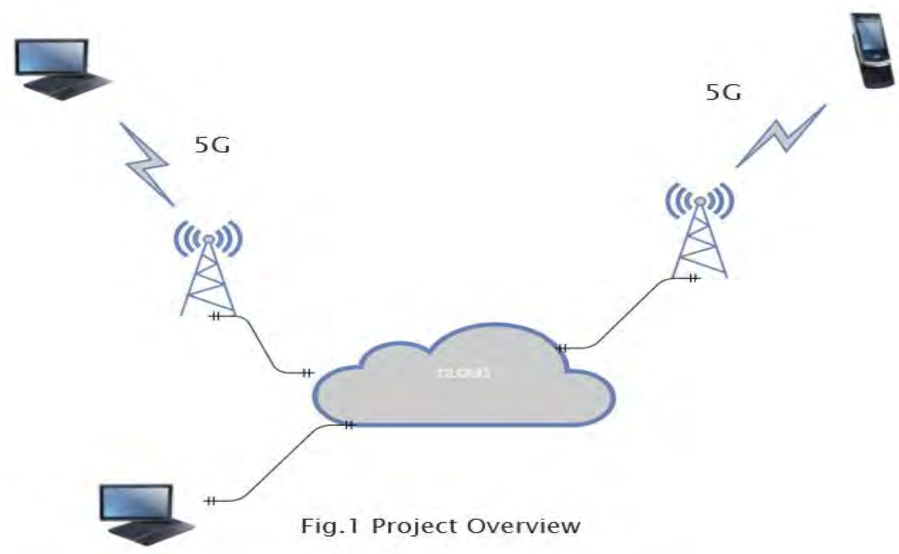

Fig.1 Project Overview

Short biography

Projects – www.beiaro.eu / www.mobcomm.pub.ro

- FP7 (2 on-going)
  - **REDICT** : Regional Economic Development by ICT
  - **eWALL** : Electronic Wall for Active Long Living
  - **NMSDMON** : Network Management System Development and Monitoring
  - **FAIR** : Friendly Application for Interactive Receiver
  - **Cloud Consulting** : Cloud-based Automation of ERP and CRM software for Small Businesses
  - **ACCELERATE**: A Platform for the Acceleration of go-to market in the ICT industry
- H2020 (3 on-going, 3 under review)
  - **SWITCH**: Software Workbench for Interactive, Time Critical and Highly self-adaptive Cloud applications (ICT-9)
  - **Power2SME**: Cloud Platform for intelligent energy use by SMES
  - **Speech2Platform** S2P: Smart, natural language semantic analyser platform to process oriented back-ends
- National (more than 10 past projects, 5 on-going)
  - **MobiWay**: Mobility Beyond Individualism: an Integrated Platform for Intelligent Transportation Systems of Tomorrow
  - **EV-BAT**: Redox battery with fast charging capacity as a main source of energy for electric autovehicles
  - **CarbaDetect**: Imuno-biosensors for fast detection of carbamic pesticide residues (carbaryl, carbendazim) in horticultural products
  - **SARAT-IWSN** : Scalable Radio Transceiver for Instrumental Wireless Sensor Networks
  - **COMM-CENTER** : Developing of a “cloud communication center" by integrating a call/contact center platform with unified communication technology, CRM system, “text-to-speech” and “automatic speech recognition” solutions in different languages (including Romanian)

5th Generation Mobile Network

Standards & Features

- **Provide mobility on demand** only to those devices and services that need it.
- **Data rates of up to 1 Gb/s**
- **10ms E2E latency**, 1ms E2E latency for special cases

The above parameters are summarized in Fig. 2

Use case category	User Experienced Data Rate	E2E Latency	Mobility
Broadband access in dense areas	DL: 300 Mbps UL: 50 Mbps	10 ms	On demand, 0-100 km/h
Indoor ultra-high broadband access	DL: 1 Gbps, UL: 500 Mbps	10 ms	Pedestrian
Broadband access in a crowd	DL: 25 Mbps UL: 50 Mbps	10 ms	Pedestrian
50+ Mbps everywhere	DL: 50 Mbps UL: 25 Mbps	10 ms	0-120 km/h
Ultra-low cost broadband access for low ARPU areas	DL: 10 Mbps UL: 10 Mbps	50 ms	on demand: 0-50 km/h
Mobile broadband in vehicles (cars, trains)	DL: 50 Mbps UL: 25 Mbps	10 ms	On demand, up to 500 km/h
Airplanes connectivity	DL: 15 Mbps per user UL: 7.5 Mbps per user	10 ms	Up to 1000 km/h
Massive low-cost/long-range/low-power MTC	Low (typically 1-100 kbps)	Seconds to hours	on demand: 0-500 km/h
Broadband MTC	See the requirements for the Broadband access in dense areas and 50+Mbps everywhere categories		
Ultra-low latency	DL: 50 Mbps UL: 25 Mbps	<1 ms	Pedestrian
Resilience and traffic surge	DL: 0.1-1 Mbps UL: 0.1-1 Mbps	Regular communication: not critical	0-120 km/h
Ultra-high reliability & Ultra-low latency	DL: From 50 kbps to 10 Mbps; UL: From a few bps to 10 Mbps	1 ms	on demand: 0-500 km/h
Ultra-high availability & reliability	DL: 10 Mbps UL: 10 Mbps	10 ms	On demand, 0-500 km/h
Broadcast like services	DL: Up to 200 Mbps UL: Modest (e.g. 500 kbps)	<100 ms	on demand: 0-500 km/h

Fig.2 Parameters

5G Roadmap

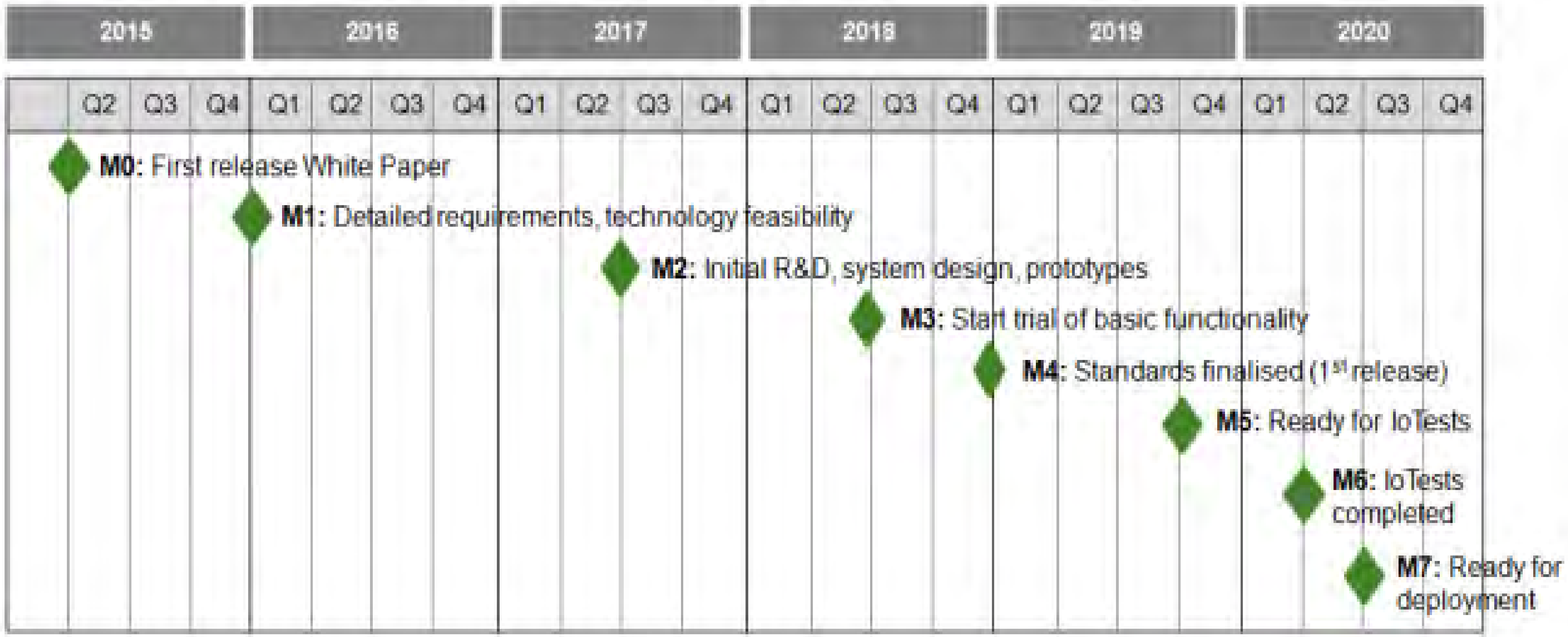

Fig.3 5G Roadmap

- Orange – first trial in January 2016 in Belfort (France)
- Verizon – United States 2016

5G Architecture

The Network architecture of 5G can provide the following capabilities:

- **Integrates the Radio Access Network (RAN)** in various frequency bands, that vary from 6Ghz up to100Ghz
- **Flexible deployments** using wireless and relying on optical technologies
- HetNet Implementation
- Cloud Computing can be applied to the (RAN)
- Full usage of SDN capabilities
- Internet of Things (IoT) **integration**

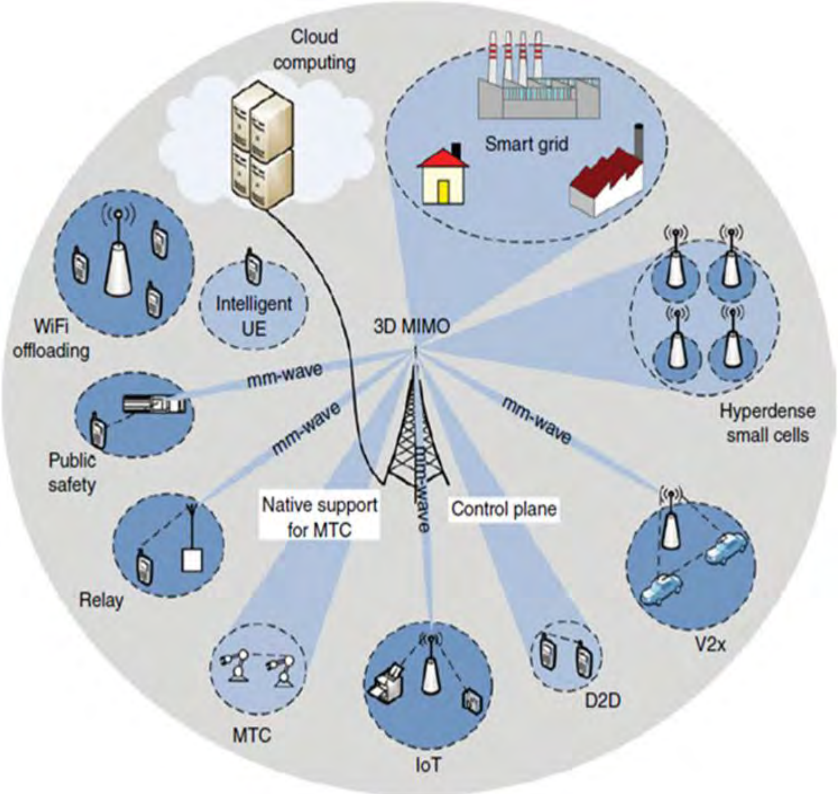

Fig. 4 5G Architecture

„Networks will become self-aware, cognitive, and implement extensive automation and continuous and predictive learning." [6]

HetNet

HetNet is an evolution of a mobile access network in which an operator can add macro cell capacity as demanded

- Multiple radio access Technologies (e.g. GSM, WCDMA, and LTE)

- HetNet* Access Nodes:

  1, Macro/Micro Cells

  2, Small Cells →

  - Pico Cells
  - Femto Cells
  - Distributed Antenna System
  - Relay Nodes

* Heterogeneous networks

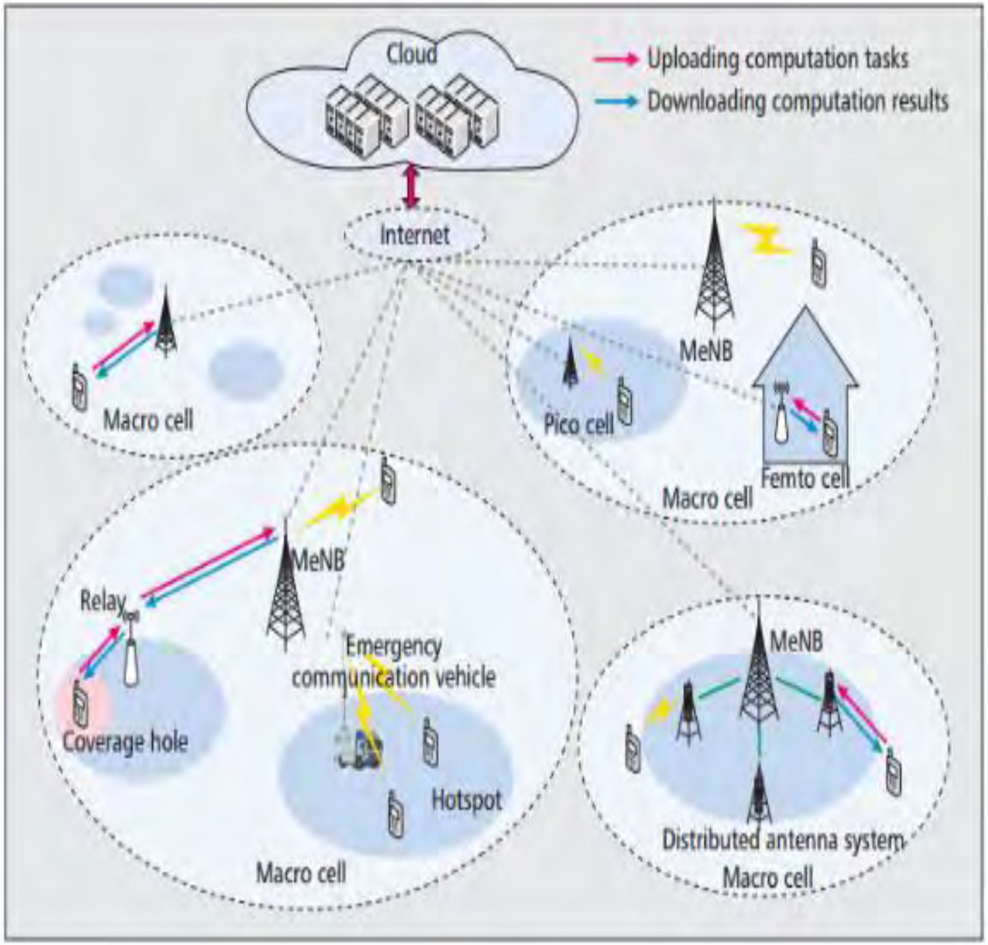

Fig.5 HetNet Architecture

Cloud Computing

Cloud computing
is a model for enabling
ubiquitous, convenient,
***on-demand** network*
access to a
***shared pool** of*
configurable computing
***resources** that can be*
rapidly provisioned and
***released** with minimal*
***management** effort or service*
provider interaction."

[5] NIST Official Definition

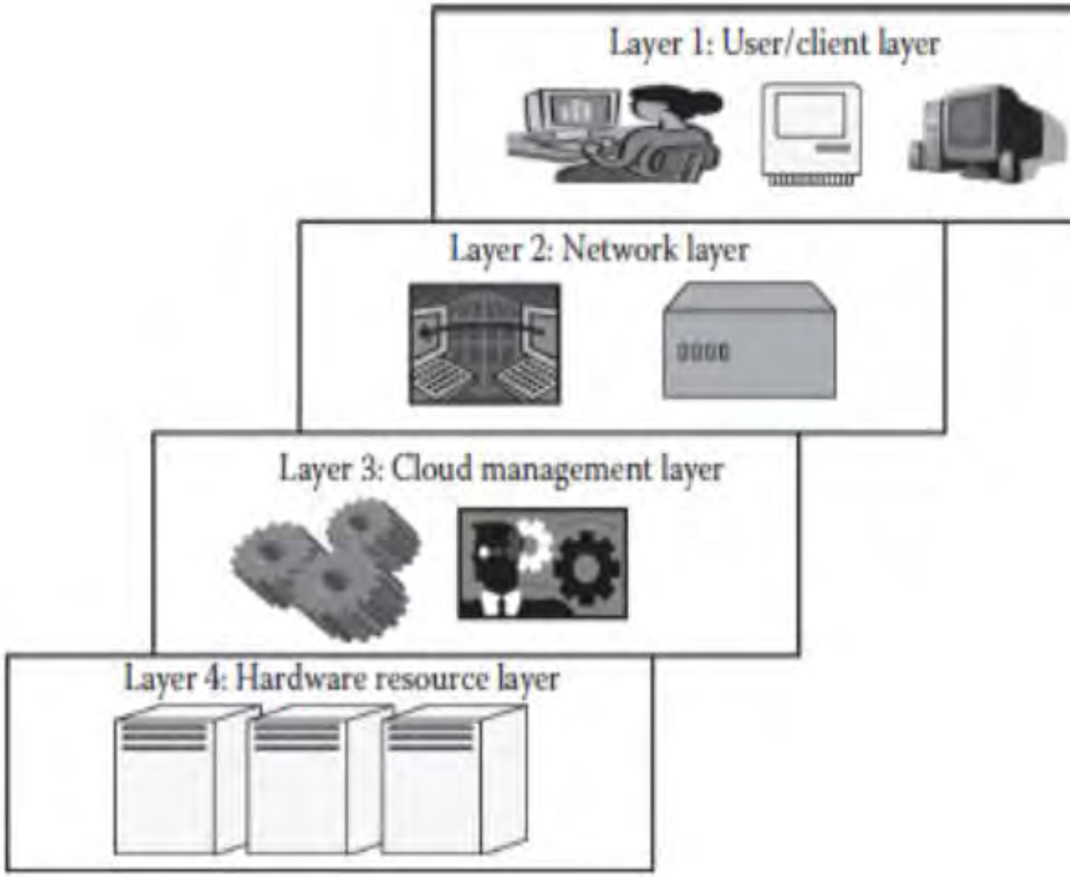

Fig. 6 Cloud Computing Architecture

5G & SDN Convergence (a)

The 5G technology can benefit from the programmability and scalability of SDN and NFV (Network Function Virtualization) technologies

- The **Software Defined Networking** approach is composed of a logically centralized entity called the Controller which manages the associated network data plane using an Application Programming Interface (API) that allows configuratio[n] of parameters such as forwarding tables of network equipment. (E.g. router, switch),

A **comparison** between traditional network architecture and the SDN approach is presented in Figure. 7.

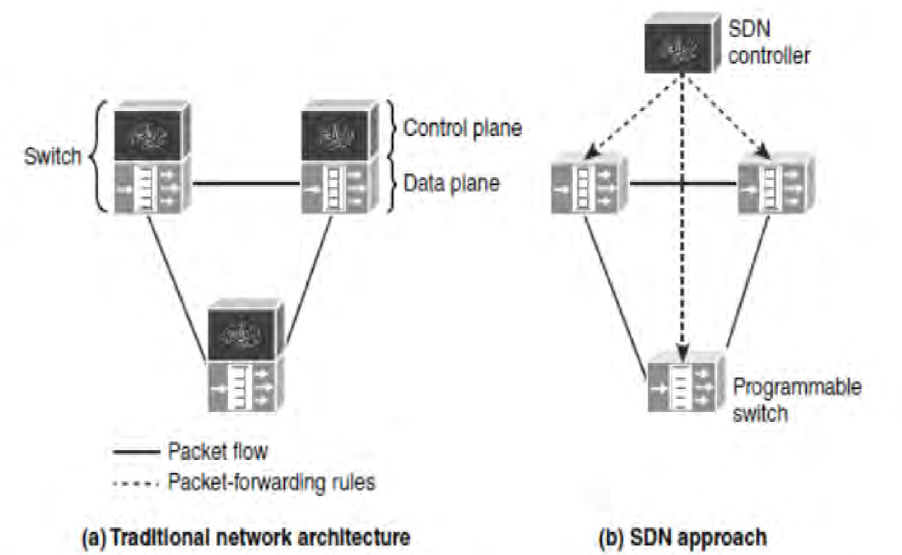

Fig. 7 Comparison between traditional networks and SDN Approach

5G & SDN Convergence (b)

The 5G architecture is a native SDN/NFV architecture covering aspects ranging from devices, (mobile/fixed) infrastructure, network functions, value enabling capabilities and all the management functions to orchestrate the 5G system.

APIs are provided on the relevant reference points to support multiple use cases, value creation and business models.

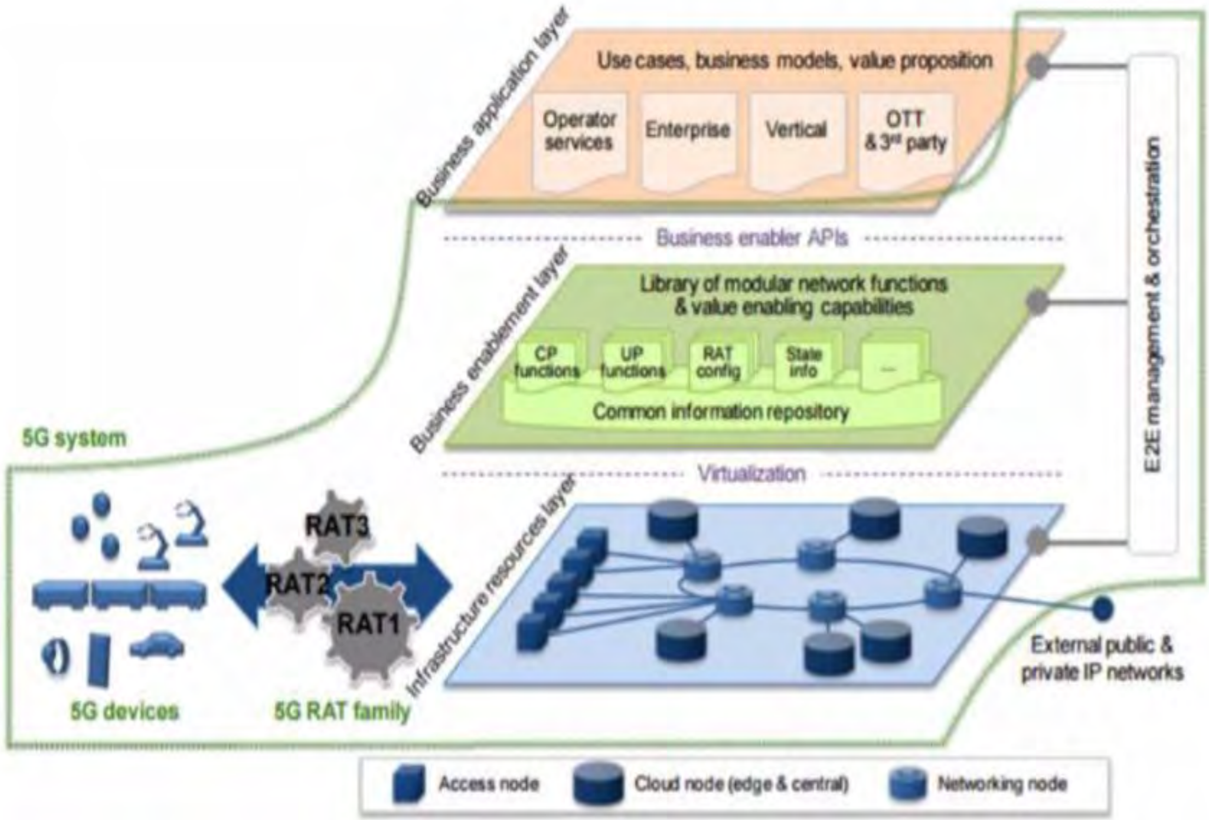

Fig. 8 5G and SDN convergence

Proposed measurements

- The purpose is to create a 5G Network using the USRP platform and implementing a cloud platform. The 5G Network will be implementing using a BPSK modulation for header and QPSK modulation for data transmission. In order to encode data on multiple carrier frequencies, OFDM (Orthogonal Frequency-divison multiplexing) will be used. **The performance of the Cloud platform will be evaluated by measurements done for the transmission of a UDP data stream.**

Proposed measurement environment (a)

Fig.9 USRP N210

USRP N210 Networked Series (Ettus Research)

- Used to implement software defined radio systems → **GNU Radio**, LabVIEW™ and Simulink™
- Up to 50 MS/s Gigabit Ethernet Streaming
- Fully-Coherent **MIMO** Capability
- **Gigabit Ethernet** Interface to Host
  2 Gb/s Expansion Interface
- Spartan 3A-DSP 3400 **FPGA** (N210)

Fig.10 VERT 2450

VERT 2450 Antenna

- **Omni-directional** vertical antenna
- Quad-band Cellular/PCS and ISM bands working at 3dBi gain.

Proposed measurement environment (b)

- **Open-source** software that contains a series of tools for implementing **software defined radios**

- Contains blocks for **signal processing** as well as virtual sources and virtual equipment in order to emulate real equipment

- Compatibility with external **hardware** (i.e. USRP) in order to create a software-defined radio

The measurement environment was used in the SaRaT-IWSN project

SaRaT-IWSN

Scalable Radio Transceiver for Instrumental Wireless Sensor Networks

Project details

- PCCA research project under the grant no. 20/2012 supported by UEFISCDI Romania [8]
- Project duration: 36 months
- Main objective: implement a **radio transceiver** that is capable of handling **multiple** communication requirements in a versatile manner.
- Very **flexible** platform, in which the implementation of physical layer protocols is object-oriented, flexible and easy to modify

Results (a)

Frequency: 5GHz, RX/TX Gain: 25dB

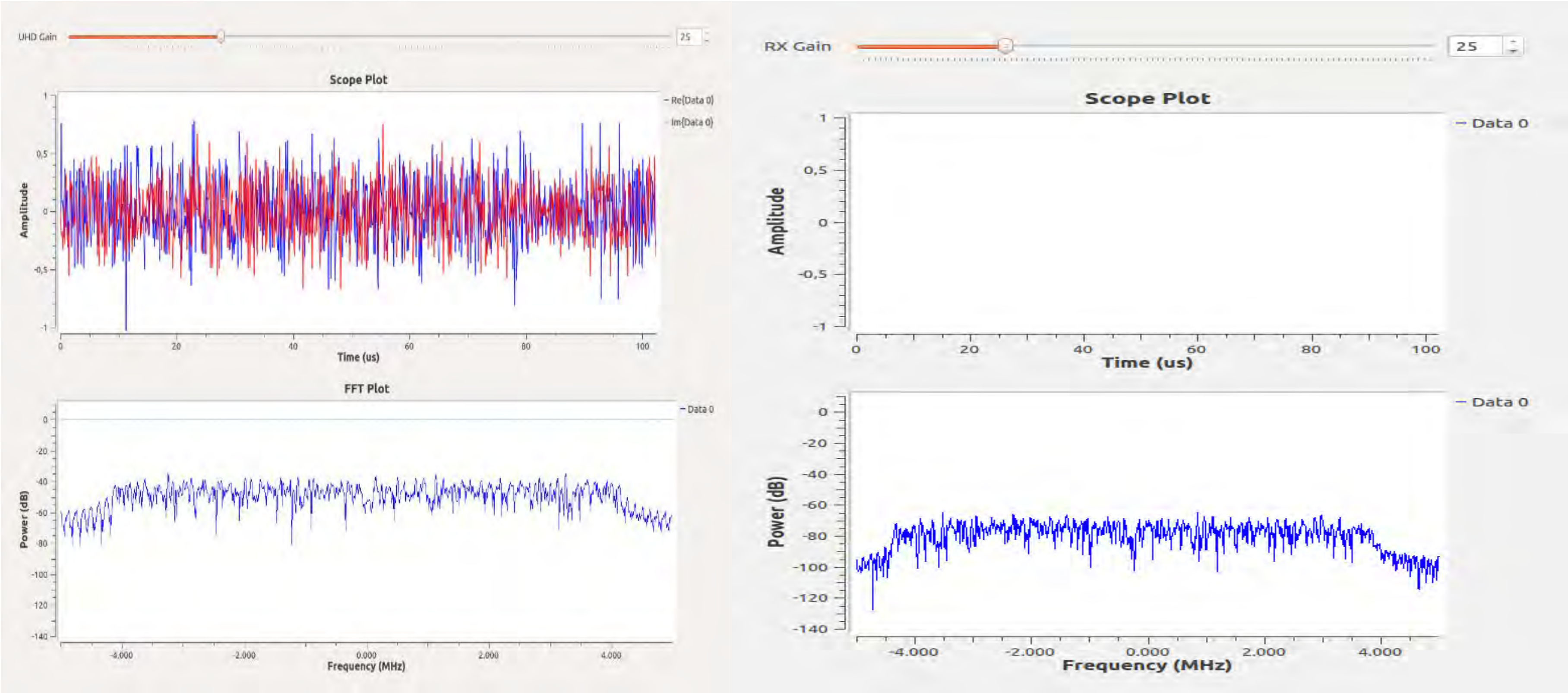

Fig. 11 Amplitude/Phase representation at emission/reception

Results (b)

test_tx

```
test message1
test message2
test message3
test message4
test message5
test message6
test message7
test message8
test message9
test message10
```

Fig. 12 Text file at emission
Error rate: 8%

test_rx

```
910 test message9
911 test message10
912 test message1
913 test message2
914 test message3
915 test message4
916 test message5
917 test message6
918 test message7
919 test message8
920 test message9
921 test message10
922 test message1
923 test message2
924 test message3
925 test message4
926 test message5
927 test message6
928 test message7
929 test message8
930 test message9
931 test message10
932 test message1
933 test message2
934 tetest message1
935 test message1
936 test message2
937 test message3
938 test message4
939 test message5
940 test message6
941 test message7
942 test message8
943 test message9
944 test message10
945 test message1
946 test message2
947 test message3
948 test message4
949 test message5
950 test message6
951 test message7
952 test message8
953 test message9
954 test message10
955 test message1
956 test message2
957 test message3
958 test message4
959 test message5
960 test message6
961 test message7
962 test message8
```

test_rx

```
958 test message4
959 test message5
960 test message6
961 test message7
962 test message8
963 test message9
964 test message10
965 test message1
966 test message2
967 test message3
968 test message4
969 test message5
970 test message6
971 test message7
972 test message8
973 test message9
974 test message10
975 test message1
976 test message2
977 test message3
978 test message4
979 test message5
980 test message6
981 test message7
982 test message8
983 test message9
984 test message10
985 test message1
986 test message2
987 test message3
988 test message4
989 test message5
990 test message6
991 test message7
992 test message8
993 test message9
994 test message10
995 test message1
996 test message2
997 test message3
998 test message4
999 test message5
1000 test message6
1001 test message7
1002 test message8
1003 test message9
1004 test message10
1005 test message1
1006 test message2
1007 test message3
1008 test message4
1009 test message5
1010 test message6
```

Fig.13 Text file at reception

Results (c)

The results for sending a text file using UDP protocol for different transmission and reception gain values are represented in Table 1.

Frenquency [GHz]	TX Gain [dB]	RX Gain [dB]	Error Rate [%]
5	25	25	8
5	25	20	11
5	25	15	22
5	25	10	28

Table 1. Results

Conclusions

- Powerful Cloud Platform
- 5G Data Rates
- Mobility
- Countless Applications – IoT, M2M, Cloud
- Easy integration

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Thank you for your attention!

Questions?

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