Πανεπιστήμιο Θεσσαλίας

ΔΙΠΛΩΜΑΤΙΚΗ

Σχεδιασμός και ανάπτυξη εργαλείων διαχείρισης ετερογενών πειραματικών υποδομών δικτύων

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in the

March 20, 2019

UNIVERSITY OF THESSALY

DIPLOMA THESIS

Design and implementation of control and management frameworks for heterogeneous experiment network infrastructure

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A thesis submitted in fulfillment of the requirements of Bachelor's degree

in the

March 20, 2019

Declaration of Authorship

I, Christos Kontomitros, declare that this thesis titled, "Design and implementation of control and management frameworks for heterogeneous experiment network infrastructure" and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a bachelor's degree at this University.
- Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
- I have acknowledged all main sources of help.
- Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself.

Signed:

Date:

"The thing that overcomes hard luck is hard work"

Harry Golden

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Abstract

Faculty Name
Department or Electrical and Computer Engineering

Bachelor's degree

Design and implementation of control and management frameworks for heterogeneous experiment network infrastructure

by Christos Kontomitros

Wireless technology has achieved a global revolution in a very short amount of time. New technologies emerge every day, opening a vast new field for experimentation and research. This in combination with the the increased growth of the market of Internet Of Things and high fidelity video streaming have highlighted the importance of such research. In my thesis I have developed an interface for managing and controling heterogenous experimental network infrastructrure on the 4G technology. This interface can be used by both researchers or hobbyist for the setup of their own 4G topologies. Each service of the interface will be throughtly examined and compared with the previous implementation. For our purpose I used the solutions provided by the Open Air Interface (OAI) open source ecosystem as well as the ip.access propertiary software and hardware, which consists an integral part of the equipment. These solutions are discussed along with the SiRRAN Communications technology, which is used as a Commercial Off The Shelf (COTS) Core Network solution. The developed solution provides a high level API for configuring the equipment, so that the experimenters are agnostic to all the low level configurations needed for setting up an experimental LTE equipment (hardware and Software Defined) in the testbed.. ...

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Σχεδιασμός και ανάπτυξη εργαλείων διαχείρισης ετερογενών πειραματικών υποδομών δικτύων

by Christos Kontomitros

Η ασύρματη τεχνολογία έχει εξελιχθεί δραματικά σε ένα μικρό χρονικό διάστημα. Νέες τεχνολογίες αναδύονται κάθε μέρα, ανοίγοντας ένα ευρύ πεδίο πειραματισμού και έρευνας. Η αυξανόμενη ανάπτυξη του Internet of Things και του βίντεο υψηλής ευκρίνειας επισημαίνουν τη σπουδαιότητα αυτής της έρευνας. Στην εξής διπλωματική αναπτύχθηκε μια διεπαφή για τη διαχείρηση και τον έλεγχο ετερογενούς πειραματικού εξοπλισμού δικτύων πάνω στη 4G τεχνολογία. Αυτή η διεπαφή μπορεί να χρησιμοποιηθεί τόσο απο ερευνητές όσο και από χομπίστες για το στήσιμο των δικών τους 4G τοπολογιών. Για αυτό το σκοπό χρησιμοποιήθηκαν λυσεις που παρέχει το Open Air Interface open source οικοσύστημα όπως και το ip.access λογισμικό και hardware.Αυτές οι λύσεις αναλύονται μαζί με τη τεχνολογία SiRRAN Communications, η οποία χρησιμοποιείται ως Commercial Off The Shelf (COTS) Core Network λύση. Το αποτέλεσμα που παράχθηκε παρέχει ένα υψηλού επιπέδου API για τη ρύθμιση του εξοπλισμού ώστε οι ερευνητές να μην χρειάζεται να γνωρίζουν χαμηλού επιπέδου ρυθμίσεις για το στήσιμο και το πειραματισμό πάνω στον LTE εξοπλισμό ...

Acknowledgements

I want to thank very deeply Nikos Makris, whose help made possible the completion of my master thesis.I want to thank also my supervisor Athanasios Korakis for entrusting me for this project as well as my family and friends, whose support all these years was necessary for finishing my degree.

Contents

Declaration of Authorship iii

Abstract vii

Περίληψη ix

Acknowledgements xi

1 Introduction 1
- 1.1 Increase in mobile traffic . . . 1
- 1.2 Increase in video streaming . . . 2
- 1.3 Chapter explanation . . . 2

2 4G LTE Components 3
- 2.1 Evolved NodeB (eNB) . . . 3
- 2.2 HSS (Home Subscriber Server) . . . 3
- 2.3 Mobility Management Unit (MME) . . . 4
- 2.4 Serving Gateway (SGW) . . . 4
- 2.5 Packet Data Network (PDN) Gateway (GW) . . . 5

3 Platforms for LTE experimentation 7
- 3.1 OAI ecosystem . . . 7
  - 3.1.1 Strategic roles . . . 7
  - 3.1.2 Large Scale Network Emulation . . . 7
  - 3.1.3 Heterogeneous 5G Networks . . . 11
- 3.2 Ip.access . . . 12
- 3.3 Sirran . . . 14

4 Experimentation testbeds 15
- 4.1 NITOS testbed . . . 15
  - 4.1.1 Introduction . . . 15
- 4.2 LTErf . . . 17
  - 4.2.1 LTErf purpose . . . 17
  - 4.2.2 Ip.access cell . . . 18
  - 4.2.3 OAI cells . . . 19
  - 4.2.4 OAI EPC . . . 19
  - SiRRAN LTEnet . . . 19
  - 4.2.5 Structure . . . 19
  - 4.2.6 Initialization . . . 20
  - 4.2.7 RRC-RRU EPC DEMO . . . 20

5 Services of the experimentation platform 23
5.1 OAI based services . . . 23
5.1.1 List all services . . . 23
5.1.2 Set eNB parameters . . . 23
5.1.3 Get eNB parameters . . . 23
5.1.4 Start eNB experiment . . . 23
5.1.5 Stop eNB experiment . . . 23
5.1.6 Check the status of the eNB . . . 23
5.1.7 List config files . . . 24
5.1.8 Save config file . . . 24
5.1.9 Load config file . . . 24
5.1.10 Load default config file . . . 24
5.2 EPC services . . . 24
5.2.1 Set plmid and operational key . . . 24
5.2.2 Set SPGW parameters . . . 24
5.2.3 Set MME parameters . . . 24
5.2.4 Run MME . . . 24
5.2.5 Run HSS . . . 25
5.2.6 Run SPGW . . . 25
5.2.7 Add subscriber . . . 25

A Parameters for eNodeB cell 27

Bibliography 29

List of Abbreviations

EPC	**E**volved **P**acket **C**core
OAI	**O**pen **A**ir **I**nterface
LTE	**L**ong **T**erm **E**volution
OMF	c**O**ntrol **M**anagement **F**ramework
4G	**4**th **G**eneration
EB	**E**xa **B**yte
API	**A**plication **P**rogramming **I**nterface
HSS	**H**ome **S**ubscriber **S**ervice

Chapter 1

Introduction

1.1 Increase in mobile traffic

It is forecasted that there will be a global increase in mobile traffic in the years to follow. This increase will be accompanied by the need for high bandwidth and low latency. The 4G LTE technologies are trying to keep up with this constant demand, researchers as well as big international companies are constantly improving the underlying algorithms and infrastructure. The following points, present some statistics of the growth observed during the years 2015-2016[1].

- It was observed a 63 percent growth in data exchanged over the network in 2016 from 4.4 EB in 2015 to 7.2 EB in 2016.
- The data increase from 2011 is fivefold, in the year 2011 the traffic was estimated in 400 petabytes.
- 4G is responsible for 69% of mobile traffic in 2016 in contrast with 3G networks which represent 29% of traffic
- The mobile network speed experienced a threefold increase in 2016 from 2MB/s in 2015 to 6.8 MB/s.
- The average smartphone in 2016 created 1,614 MB of traffic per month, up from 1,169 MB per month in 2015.
- 11 million wearables had embedded cellular connections
- Mobile connected tablets and PCs number have increased during the last years and they account for more traffic than smartphones (3,392 MB compared 1,614 MB).

These data have enabled us to make a good forecast about the future of cellular mobile environment. The key point remains the same, speed bandwidth and latency is expected to improve in the years to come. The predictions are summarized in these key points:

- Mobile traffic is expected to reach 49 EB,one fith of the total IP traffic
- More people will own a connected device in a rate of 1.5 devices per peson
- 4G technologies will occupy 53% of the total mobile connections
- It is estimated that about 80% of modern traffic will be in the form of video, which increases the need for higher speeds and overall bandwidth

1.2 Increase in video streaming

Video streaming plays a huge role in the evolution of mobile networks. As streaming services attract more clients, the demand for better cellural mobile archictectures increases. It is estimated that 43% of the US population uses a streaming service. This creates a huge amount of traffic that must be handled by the existing 4G technologies. Inability to do so increases dissatisfaction. High quality visual content ,which is more bandwidth demanding, is the most important factor in viewing experience [2].

1.3 Chapter explanation

To advance in the new world of telecommunications and cover the huge demand for internet traffic that will be created in the following years researchers should be able to experiment with new algorithms and topologies.These experiments must be conducted in real world environments due to the inefficiency of simulation tools to provide the same number of parameters .The interface we will create will help scientists from all over the world to test and obtain new data that will help them with the long term evolution of the mobile networks they are working on. In Chapter 2 we will explain the structure of the LTE components that our interface manipulates, what is their purpose and functionality. In Chapter 3 technologies and frameworks will be analyzed that will enable us to control the heterogeneous mobile equipment .Their differences are explained as well as why were they chosen for this project. Chapter 4 is dedicated in the explanation of the LTErf service, the initialization ,use and structure followed by a brief setup example. Chapter 5 includes the queries that can be issued for the experimenter to configure the equipment. Finally in Chapter6 a conclusion is drawn based of the future expansions of the project.

Chapter 2

4G LTE Components

2.1 Evolved NodeB (eNB)

The eNB connects with the S1 interface with the EPC and with the X2 interface with other eNB components. eNB does not have an intermediate control like the Radio Network Controller (RNC) [11] which was used in previous cellular mobile generations, so it supports all functions of Layer 1 and 2 protocols of the Open Systems Interconnection (OSI) [14] stack associated with the Evolved Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access (EUTRAN) Orthogonal frequency-division multiplexing (OFDM) interface. The result is a much simplified architecture and improved performance in the radio interface. Functions of the eNB are except modulation and demodulation or coding decoding are the following:

- Management of the Radio Resources
- Allocation of resources
- Encryption and compression of IP data packages
- Routing data to the Service gateway
- Trasmission of broadcast messages as well as paging messages
- Taking measurements and loging them

2.2 HSS (Home Subscriber Server)

The HSS is an integral part of Lte as well as of previous technologies. The general functionality of the HSS is the manipulation of the entries in the database, which contains the user subscriptions. It uses the diameter protocol to connect to the application center and the Call Session Control Function [4]. In detail the HSS is responsible for:

- IMSI (Internatonal Mobile Subscriber Identity and MSISDN (Mobile Subscriber ISDN Number) identification and adressing
- The user 's profile information such as QoS and information about the subscription
- mobility management, support of call and session establishment
- Data security guaranteed with radio encryption (protection against eavesdropping)
- Authenticaton of both parties in the network terminal

2.3 Mobility Management Unit (MME)

MME is a control unit in the LTE architecture which manages key functions in the Access Network as well as the Core Network [4, 7]. It has many roles some of which are :

- Non Access Stratum signaling
- Control over the trasmission power
- Selection of the Packet Data Network (PDN) Gateway (GW) as well as the Serving Gateway (SGW) for a given session
- Responsible for mobility between networks as well as handovers
- Management of both Tracking Area Code (TAC) and Tracking Area Identifier (TAI)
- Informing of timezone change to User Equipment UE
- Chooses the right service and PDN gateway SGW/PGW
- Authentication and authorization of users
- Roaming
- Uses HSS as a database from whitch takes information about the services to provide to subscribers, holds all the ids of UE subscribers of the network
- Lawful trasmission of warning messages

2.4 Serving Gateway (SGW)

The SGW (serving gateway) is a gateway from the MME network to the PGW. It is controlled by the MME and responsible of transferring data across the user plane.It checks the state of the UE in inactivity and creates paging requests when new data arrive [4, 12]. In detail the functons of the sgw are the following :

- Packet routing and forwarding
- eNBs will be served by one or more SGWs
- Anchor point for inter-eNB handover
- Transfers packets and signals between PGW and MME
- It is under the command of MME creating and destroying UE sessions
- Is acounted for inter-operator charging. For GPRS Tunneling Protocol (GTP) based S5/S8, it generates accounting data per UE and bearer
- Interfaces Offline Charging System (OFCS)

2.5 Packet Data Network (PDN) Gateway (GW)

PGW is the gateway after SGW that connects to the PDN.It is not necessary to be only one PGW for a UE, but only one SGW can be used. PGW is the connection between 3GPP and non-3GPP technologies.It enforces a given policy to packets and has a also a filtering role [4, 10].In detail PGW functions are the following :

- Filtering user 's packets
- Giving IP addresses to users
- Marks packets in the transport level in uplink and downlink
- Control of gates in uplink and downlink
- Rersponsible for charges of interoperator usage
- DHCP server/client functions
- Functions as IP router responsible for signaling and mobile tuneling
- Control of the service level rate in uplink and downlink .

Chapter 3

Platforms for LTE experimentation

3.1 OAI ecosystem

OSA Openairinterface Software Alliance was founded in 2014 and it is a French non profit organisation funded by corporate sponsors. Individual members can contribute to the development of the OSA software or to the projects run by other corporations which are also members. Goal of the alliance is also to help members collaborate better to innovate and work on future wireless technologies. The OSA offers an implementation of a subset of Release 10 LTE for UE, eNB, MME, HSS, SGW and PGW on standard Linux-based computing equipment.The software comes with the OSA license model. This software can be used on top of standard RF hardware equipment for the implementation of the LTE functions for allowing real-time interoperation with propertiary devices. The future objective of the organisation is the provided software to comply with 3GPP standards starting from Rel-13 to evolve towards 5G and of course to stay free and available for experimentation on common laboratory equipment[9].

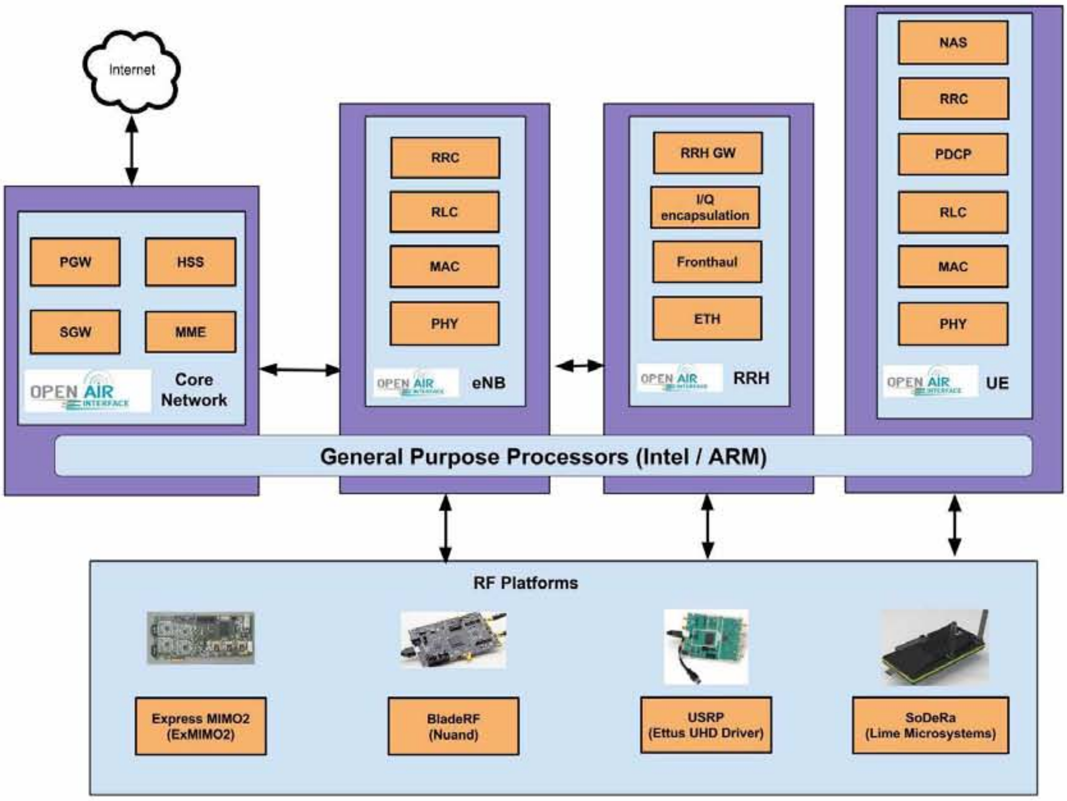
3.1.1 Strategic roles

OpenAirInterface (OAI) Software Alliance broadly focuses on the evolution of 3GPP Cellular stack (eNB + UE + Core Network) on general purpose processor architectures (Intel/ARM) with the goal of establishing generic interfaces with 3rd party RF platforms like EURECOM Express MIMO [3], National Instruments/Ettus Research USRP [15], Nuand BladeRF [8], SoDeRa Lime SDR platforms [5]. The alliance also ensures that several projects conducted within the framework of the alliance are capable of running on Commercial-Off-The-Shelf (COTS) hardware platforms, for example Intel x86 and ARM. The figure below shows the conceptual architecture of OAI and how it relates to several hardware RF platforms.

The Alliance engages itself in projects that enhances the core software (eNB/UE and Core Network) with the goal of running it across several platforms, while at the same time evolving towards future 3GPP standards.

3.1.2 Large Scale Network Emulation

The prototyping methodology of current and future generations pose complex challenges as there are stringent requirements on both data rates and overall latency of the cellular stack. There is a clear need that future prototyping platforms also have a software framework to validate the stack in both emulation and simulation. This allows to run the entire stack in a controlled laboratory setting for realistic system validation and performance evaluation (see Figure: OAI Emulation Platform).



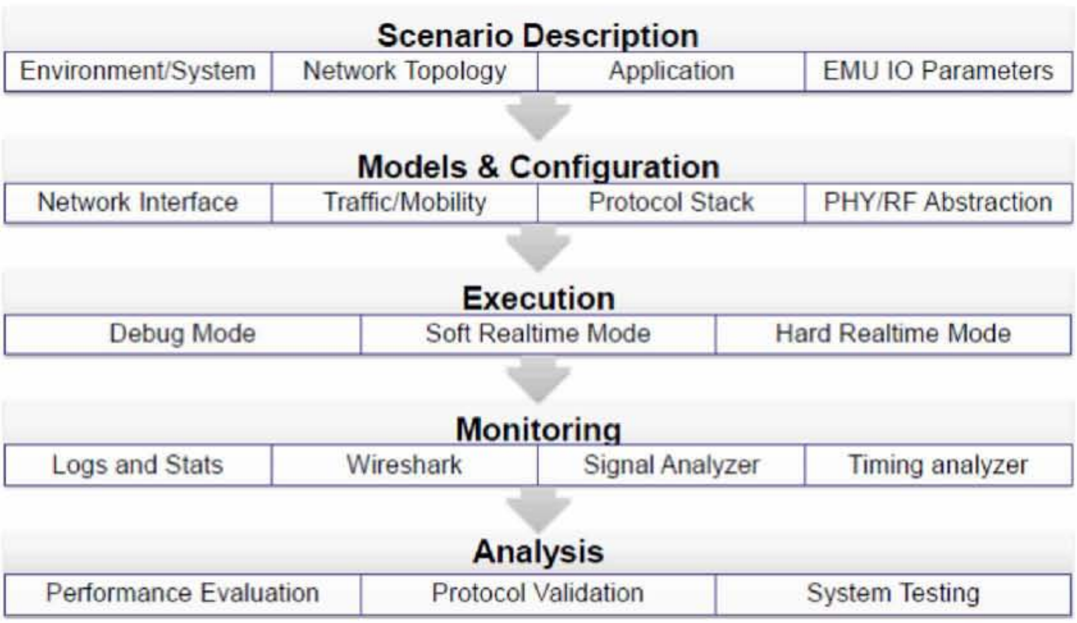
The platform is designed to represent the behavior of the wireless access technology in a real network setting, while obeying the temporal frame parameters of the air-interface. The behavior of the wireless medium is obtained (a) using a PHY abstraction unit which simulates the error events in the channel decoder, and (b) using (real) channel convolution with the PHY signal in real-time. The platform can be run either with the full PHY layer or with PHY abstraction. The remainder of the protocol stack for each node instance uses the same implementation, as would be in the full system. Each node has its own IP interface that can be connected either to a real application or a traffic generator. The emulator also implements the 3GPP channel models comprising three components, path loss, shadow fading and stochastic small scale fading, and interacts with the mobility generator to perform different channel realization over time with interference. The platform targets large-scale repeatable experimentation in a controlled laboratory environment with various realistic test-cases and can be used for integration, performance evaluation and testing.

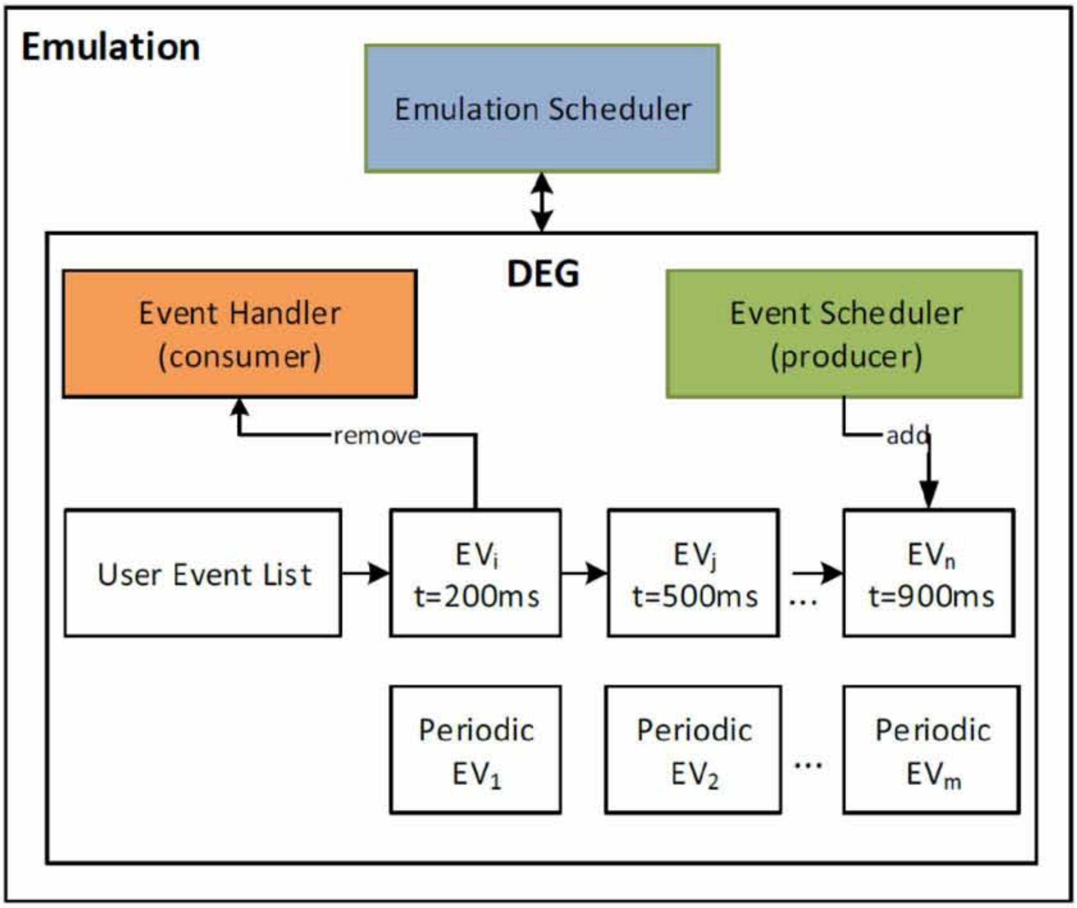
Here is the brief description of the design principles of the emulation platform:

- Experiment Design Workflow: A sequential experiment workflow, where the output of each step will be the input of the next, is employed to allow an experiment to be reproduced. Five consecutive steps are defined: scenario description, configuration, execution, monitoring, analysis, where each step is split into several sub-steps (see Figure: Experiment design workflow). Test-cases and can be used for integration, performance evaluation and testing.

- Discrete Event Generator: The discrete event generator (DEG) is one of the main building block of simulation/emulations allowing high-level control over

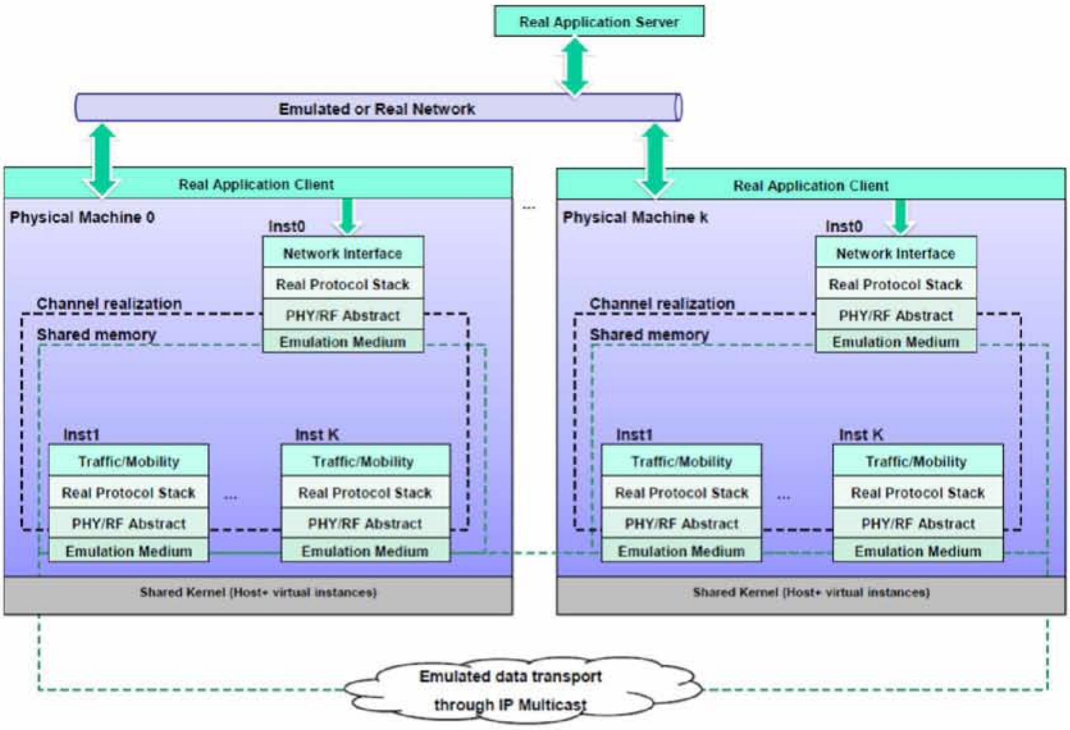

Emulation
Field trail
Experimentation & Innovations
Simulation
OPEN AIR 5G INTERFACE
5G SOFTWARE ALLIANCE
Simulation/ Emulation
• Link-level
• System-level
Soft Modem Target: x86 arch
• EXMIMO 2
• USRP
FPGA Modem
• FPGA Based PHY


Scenario Description
Environment/System
Network Topology
Application
EMU IO Parameters
Models & Configuration
Network Interface
Traffic/Mobility
Protocol Stack
PHY/RF Abstraction
Execution
Debug Mode
Soft Realtime Mode
Hard Realtime Mode
Monitoring
Logs and Stats
Wireshark
Signal Analyzer
Timing analyzer
Analysis
Performance Evaluation
Protocol Validation
System Testing



a user experiments. This is important to meet different experiment requirements and use cases, in particular when targeting large scale scenarios. They allow simulation/emulation configuration and monitoring as well as scheduling user-defined events over time and space. A typical DEG consists of an event producer, an event list, a scheduler, and an event consumer (see Figure: Discrete Event Generator).est-cases and can be used for integration, performance evaluation and testing.

- Protocol Vectorization and Emulation Data Transport: Protocol vectorization (or virtualization) of the entire protocol stack within the same physical machine is one the key requirements to increase the scalability of the emulation platform (c.f. Fig. 1.7). Protocol vectorization consists of sharing the same operating system instance and Linux IP protocol stack for independent emulated node instances. It allows networks nodes to coexist in the same execution environment. Note that, protocol virtualization offers the same functional properties (i.e. services) and the same non functional properties (i.e. performances) than that of a real protocol. To further increase the platform scalability and allow complex network experimentation, two or more emulated data flows may coexist between emulated nodes (see Fig: Protocol vectorization and network experimentation). Either nodes communicate via direct memory transfer (shared memory) or via IP multicast (over Ethernet) depending on whether they are part of the same physical machine or not. From the point of view of

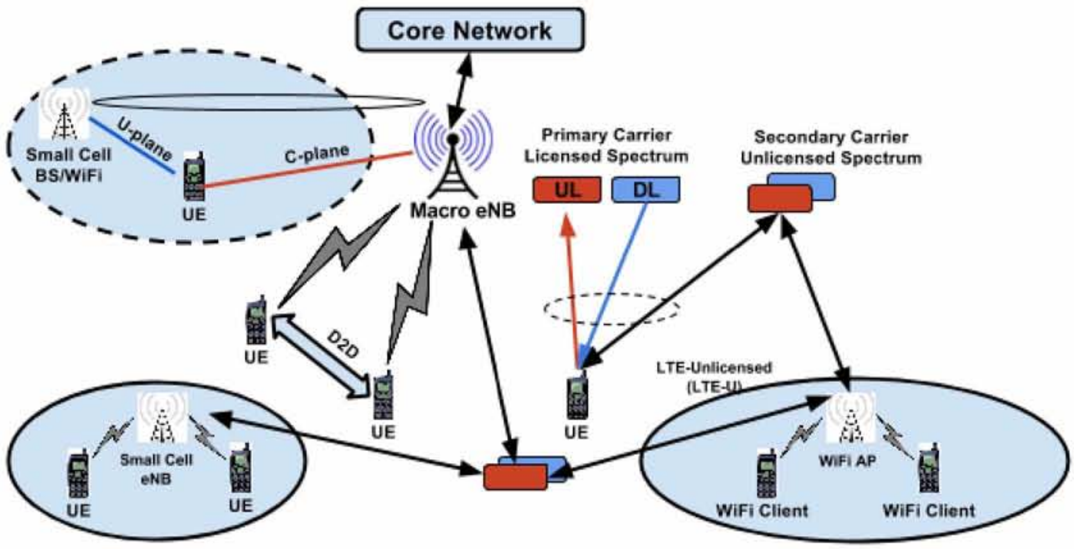


the protocol stack, the data flow is transparent and that the network connectivity is independent from the node distribution on a physical machine.est-cases and can be used for integration, performance evaluation and testing.

3.1.3 Heterogeneous 5G Networks

Next generation 5G wireless networks will run applications requiring high demand for data rates. One of the solution to solve the data rate requirement is to allow densification of network by deploying small cells. Such densification results in higher spectral efficiency and can also reduce the power consumption of mobile due to its communication with nearby pico-cell. This solution significantly improves network coverage. However, this solution requires innovation in hardware miniaturization and cost reduction in the design of small cell base-station. Such small cell base-stations can be deployed as low powered femtocells typically used in enterprise/residential deployments or higher powered pico cells for improving outdoor coverage of macro cells. The concurrent operation of Macro-, micro-, pico- and femto-cells is termed as heterogeneous networks (HetNets). Interference management is one of the most critical challenges due to the uncoordinated nature of HetNet deployments. However, 3GPP has identified various scenarios and requirements in for the enhancements of small cells.

There has been recent push from both the academia and industry (3GPP) to enhance the operation of small cells by splitting control and data plane. The main idea here is that control plane provides connectivity and mobility, whereas user plane provides the data transport. This results in the fact that user equipment (UE) is connected to multiple base-stations, viz. macro and small cell. Such a definition of new carrier type in 3GPP (Rel 8-10), results in improved spectral efficiency as data transport is



handled by small cell. There is also significant gain in energy efficiency of network infrastructure as small cells can be switched off in case of lightly loaded scenarios.
LTE/WiFi Coexistence

5G wireless network design will see lot of convergence happening between LTE/WiFi networks. There has already been push from the industry to operate LTE in unlicensed bands. Such an approach will allow easier offloading of traffic from LTE to unlicensed bands. However, such offloading poses quality of service (QoS) issues for end users due to unmanaged and over-crowded nature of today's WiFi deployments. IEEE 802.11 Working group has also initiated a study group on High Efficiency WLANs (HEW) to address the densification of access points and terminals.
Device to Device Communications

Device to Device (D2D) communications is an approach where terminals close by discover themselves automatically and interact with each other without the base-station. Such an approach is highly efficient from power control standpoint and can also reduce interference in unlicensed frequency bands.

Conventional cellular architecture does not allow for user equipments (UEs) to communicate directly. However, when the devices are close by, this can be very inefficient and D2D can be especially useful in machine-type-communication (MTC) scenarios where there are large number of devices operating closely with each other. D2D when combined with the fact that it can be coordinated with base-stations can bring significant advantages to the existing cellular architecture in terms of both energy efficiency and spectral efficiency. D2D is currently an active topic of discussion within 3GPP.

3.2 Ip.access

Ip.access is responsible for creating solutions for all generations of mobile networks. The ip.access LTE 245 F femtocell has many utilities and is dual band capable, available in 3GPP Bands 1/13, 4/13, 2/5 or 7/13. Supporting 2x2 MIMO with an output power of +10dBm per port, the 245 provides comprehensive LTE operation in a compact form factor.

The 245 offers dual band LTE capability within a single hardware SKU. Operation is on one band at a time (i.e. not simultaneous dual band operation) as configured by via the OAM interface. A reboot is currently required when changing the

Feature	Details
3GPP Compliance	Compliant to 3GPP Rel 8.9.0
Number of RF Carriers	Single Carrier
3GPP Band Support	3GPP Band Support Dual Band 1/13, 4/13, 2/5 or 7/13
Bandwidth	10MHz
MIMO	2x2 MIMO-Single User Downlink only
RF Average Output Power	2 x 10dBm
Modulation/Coding	16QAM U/L and D/L
Max Data Rate Throughput	13Mbps
Simultaneous Active Users	4
Simultaneous Idle Users	64
Network Interfaces	S1 over IP
Electrical Supply	12V @ 5.5A from external power brick

OAM configuration. The RF subassembly used in the 245 has a maximum rating of 2 x 13dBm. However, for normal and continuous operation, the 245 should be configured such that RF output power does not exceed 2 x 10dBm unless additional heat-sinking measures have been applied.

Throughput Performance The 245 platform is capable of high speed data transfer to LTE capable devices. Currently specified performance of Air Interface data rate is 13Mbps, which can be achieved for a single active user with a small rate reduction when 2 users are active. Further rate reduction is to be expected when the cell is loaded with additional users. The platform is software upgradeable to support operation up to 100Mbps downlink aggregate throughput, using 64 QAM.

Mobility Idle mode mobility between the 245 and surrounding LTE or UMTS 3G cells is supported. The platform is software upgradable to support Active Mode handover.

Operational Range Useful cell radius depends on antenna types, number of users, throughputs and so on. The 245 is specified to support 900m range in terms of its baseband capability.

GPS The 245 is equiped with integrated GPS hardware. It can support various functions such as location and synchronisation subject to appropriate software support (not currently supplied).

Network Interfaces The 'S1' network interface is presented via two 1Gbps Ethernet ports.

Physical Interfaces

Figure XX: LTE245 LTE femto cell

The following physical interfaces are presented on the enclosure panel:

- DC power jack
- 2 off RJ45 Ethernet
- Micro USB
- 2 off SMA female RF
- 9-way RS-232 serial Console port
- GPS receptacle (not used)
- Telephony/modem port (not used)

3.3 Sirran

SiRRAN Communications LTEnet [13] founded in 2009 is a leading provider of 2G, 3G, 4G, network technologies. The software provided by the SiRRAN NetCore is able to create a private mobile network of the same functionality as a commercial one with the ability to use any SIM, whithout abandoning complex and distributed elements. The SiRRAN multi technology offers solutions from high-speed data, voice and SMS to mobile broadband including 2G, 3G, and 4G LTE. Small cells deployments can be installed on any computer, laptop or server creating large scale EPC/Node deployments. SiRRAN technologies come with an intuitive user-friendly dashboard, which function as monitor,configuration mangager and real-time analytics provider. The assisting radio configuration optimises the performance of the devices in use. The whole system is extendable with the use of the provided APIs. The software can run on many type of hardware platforms and user equipment as well as support the connectivity wiht external voice, SMS and data services. At the end the SiRRAN platform follows international mobile telecommunitcation standards.

Chapter 4

Experimentation testbeds

4.1 NITOS testbed

4.1.1 Introduction

NITOS Future Internet Facility is an integrated facility with heterogeneous testbeds that focuses on supporting experimentation-based research in the area of wired and wireless networks. NITOS is remotely accessible and open to the research community 24/7. It has been used from hundreds of experimenters all over the world. It is comprised of three different deployments, the Outdoor Testbed, the Indoor RF Isolated Testbed and the Office Testbed. NITOS facility currently consists of over 100 operational wireless nodes and is designed to achieve reproducibility of experimentation, while also supporting evaluation of protocols and applications in real world settings. NITOS facility is geographically separeted in 3 deployments. The Outdoor one at the exterior of the University of Thessaly (UTH) campus building, the Indoor one at the basement of the UTH's building and the Office testbed deployed at CERTH's office building in Volos. The control and management of the facility is done using the cOntrol and Management Framework (OMF) open-source software. Users can perform their experiments by reserving slices (nodes, access points, base stations or frequency spectrum) of the testbed through the NITOS scheduler that together with OMF support ease of use for experimentation and code development. The NITOS platform is open to any researchers who would like to test their protocols in real-world settings. They are given the opportunity to implement their novel protocols and study their behavior in a custom tailor-made environment. NITlab is constantly in the process of extending its Testbed capabilities.

FIGURE 4.1: Nitos general facility

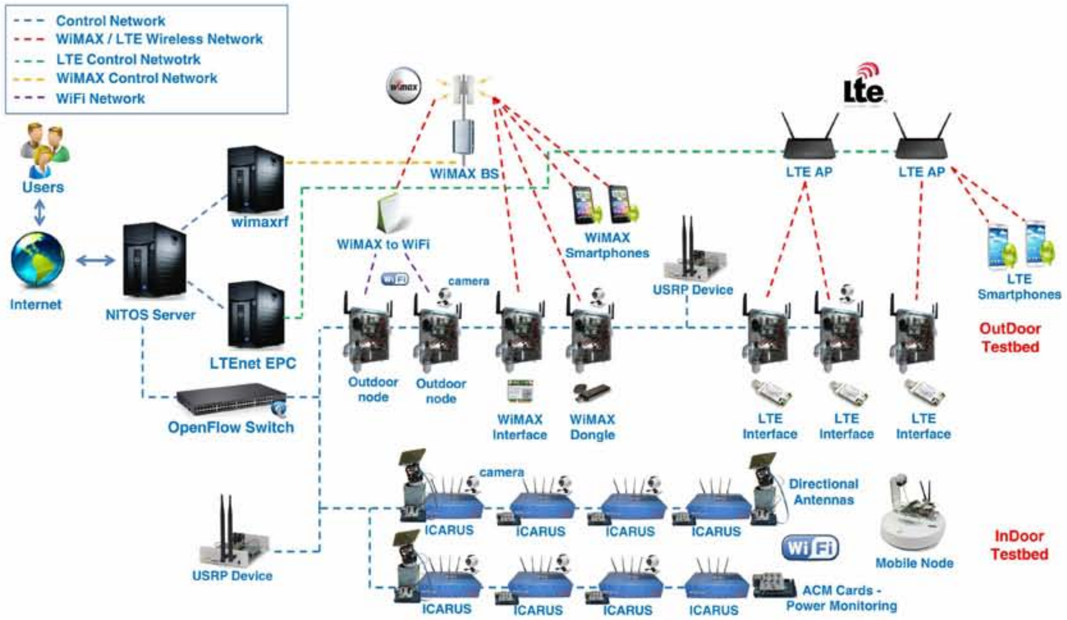


FIGURE 4.2: Nitos LTE configuration

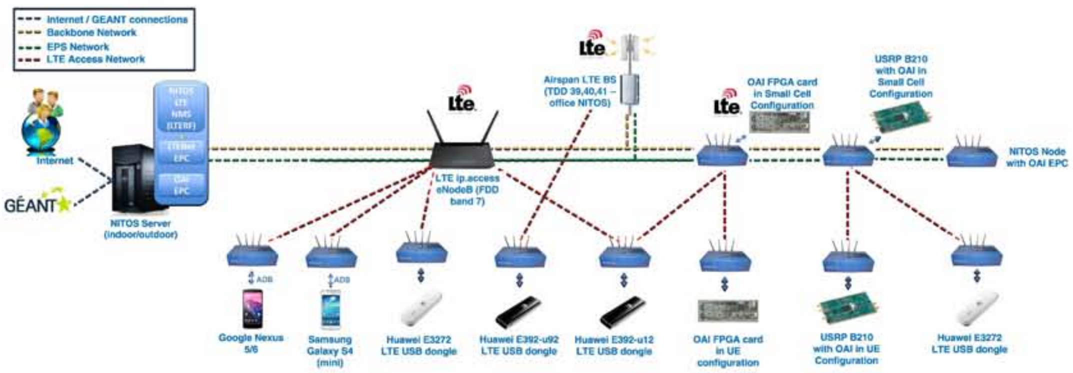


FIGURE 4.3: Outdoor LTE equipment

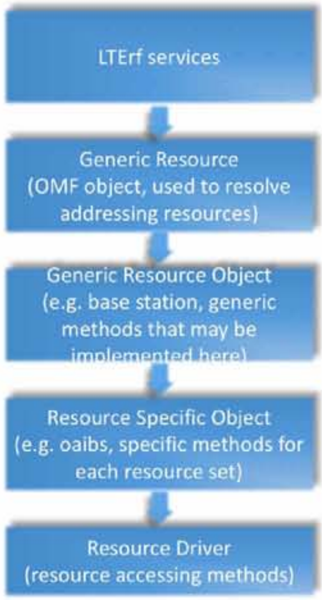
FIGURE 4.4: Outdoor LTE equipment

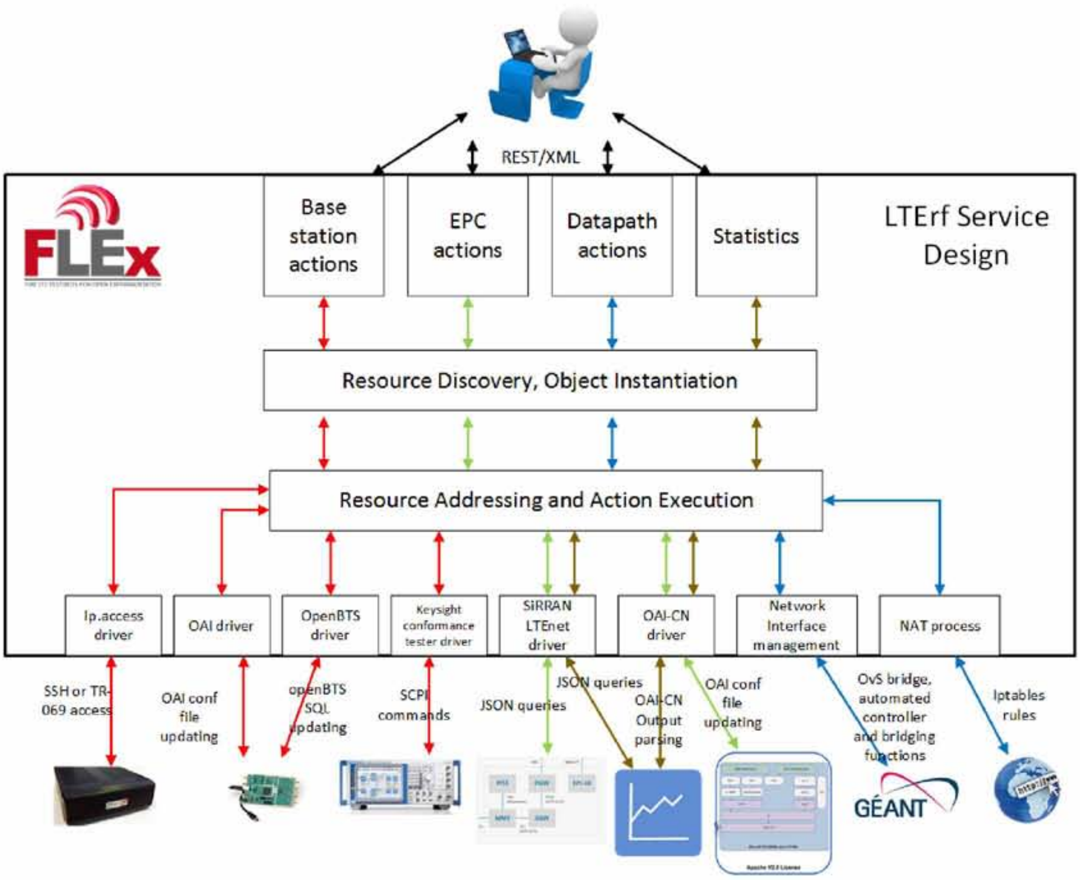
4.2 LTErf

4.2.1 LTErf purpose

The different LTE components(base stations and EPCs) are highly heterogeneous regarding their APIs, making it difficult for the experimenters to learn the documentation and handle the different resources.The LTErf service [6] brings a solution of these problems since it essentially builds a level of absraction for the testbed users making the connection and control of different type of components an easy task. LTErf provides an intuitive and easy to use api for the efficient deployment of services on top of any Linux box. The LTErf service is written in Ruby programming language utilizing several frameworks called rubygems or gems. The LTErf purpose is to configure these two basic components of the LTE infrastructure:

- The access network (ip.access femtocells and OpenAirInterface cells)
- The EPC network OpenAirInterface EPC (HSS,MME,S/PGW)





4.2.2 Ip.access cell

ThE ip.access LTE 245 femtocells are able to operate in two LTE bands the 7 and 13 but not concurrently. The API for configuring them, based on the latest releases 0.8 and 1.0 of their firmware, resides on aLTEring a database file located on each femtocell or by using a TR-069 client.Using a secure ssh connection to the femtocell the experimenter can access this database and issue an Sqlite update command in order to change the parameters or copy the entire database from his machine to the femtocell. It is necessary for the change to take effect the restart of the eNodeB node. This can be done easily by issuing a restart query which in return will invoke the restart function of the class responsible for this specific cell. In Chapter5 there is a reference to the the format of the queries that the experimenter can issue in order to do specific changes to the femtocell. Finally the ip.access node can be easily connected by the LTErf service with the OAI epc. The queries for the configuration are listed in 5.

4.2.3 OAI cells

OAI cells can provide a complete full working LTE stack compatible with Rel 13 features. The cells can be accomodated in a simple commodity PC (e.g. a testbed node) and are responcible for the configurations of the EXMIMO2 FPGA platforms by EURECOM and the USRP B200/X300 platforms by Ettus Research.The class which is responsible for the OAI node uses a config file which is defined on initialization in order to to pass all the LTE parameters to the platform. The config file is prepared locally before the experimenter chooses to start the eNodeB node based on the experimenters queries and sends the file through a secure shell connection, when the experimenter decides to run the experiment or a change in the config file is issued. The user involvement is restricted in only changing some parameters in the config file at the same time the service is responsible for launching the OAI application depending on the existing equipment, this makes it easier for the experimenters, hiding a lot of complex configurations. There is also the option to save a configuration file for future use as well as loading an existing config file. The queries for the configuration are listed in 5.

4.2.4 OAI EPC

The OAI EPC is responsible of the MME, HSS, S/PGW components of an evolved packet core network. It is hosted also on a commodity PC and the configuration follows the same rules as the OAI cells. Each component is handled by a separate class, which is responsible for the creation and customization of the config file of each EPC application. The parameters for the config file can be set through the experimenter 's queries to the service. The service enables the EPC components to run on different machines and handles the connection with each other and with the OAI or ip.access cells. The queries for the configuration are listed in 5.

SiRRAN LTEnet

The testbeds host a commercial EPC network made by SiRRAN. It is running as a service over a single box machine. The LTEnet has been extended to provide a JSON based web interface for configuring the LTE parameters. The change of the parameters by the experimenter is executed by the same way as the other LTE components, through queries.

4.2.5 Structure

T he LTErf service is structured on the Sinatra gem. Sinatra is a Ruby web framework ,which is responsible for handling the queries sent to the server and responding with the suitable messages in XML format. On top of the sinatra gem exist other gems. The yaml gem is responsible to extract data from configuration files in yaml format. This functionality is usefull for extracting information from the lterf.yaml configuration file. The REXMl gem is another usefull module resposinble for formatting the responses to the client in XML format. The net-ssh, net-scp gems enable the service with the remote configuration of the respected nodes. Finally the sequel gem is utilized for remote calls to the mysql database of the node.

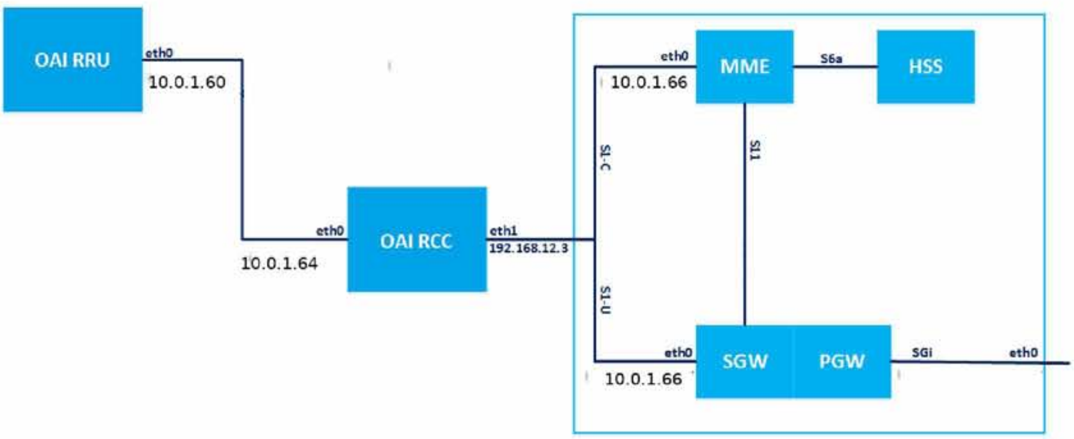
4.2.6 Initialization

In the startup of the LTErf the service learns the type (oai, oai-rcc, ip.access) and the ip address of each node in order to access it from the configuration file, which is provided. The file provides also information about the default configuration files for OAI nodes, or the location of the reset Sqlite database for ip.access nodes. The versions of the ip.access databases are provided and also the ssh RSA keys in order to access it. For each node a seperate class is created depending on the type provided. Then the created classes are initialized with the information in the lterf.yaml file. Each class holds the basic parameters for each node and is responsible for basic functions such as run/stop/restart. A demo follows for creating a rrc-rru epc topology

4.2.7 RRC-RRU EPC DEMO

The type of queries used to configure the equipment is better described in 5 The topology of the example is better understood in the following figure :

FIGURE 4.5: RRU/RCC - EPC



We have set the values in lterf.yaml file, such as the EPC will reside in node 66 the RRU in node 60 and RRC in node 64. First we start by configuring the EPC part of the equipment.The sinatra service is also running in node 66. We start with running the HSS with the following query:

```
curl "http://10.0.1.66:4567/epc/hss/run?node=1&run"
```

FIGURE 4.6: HSS run response

Then we configure the MME with the following query:

```
curl "http://10.0.1.66:4567/epc/mme/set?node=1
&MME_INTERFACE_NAME_FOR_S1_MME=eth0&MME_IPV4_ADDRESS_FOR_S1_MME=10.0.1.66/24&
MME_INTERFACE_NAME_FOR_S11_MME=lo&MME_IPV4_ADDRESS_FOR_S11_MME=127.0.8.11/8"
```

FIGURE 4.7: MME configure response

```
<Lterf>
  <Epc>
    <node1 MME_INTERFACE_NAME_FOR_S11_MME="lo" MME_INTERFACE_NAME_FOR_S1_MME="eth0" MME_IPV4_A
DDRESS_FOR_S11_MME="127.0.8.11/8" MME_IPV4_ADDRESS_FOR_S1_MME="10.0.1.66/24"/>
  </Epc>
</Lterf>
```

And run :

```
http://10.0.1.60:4567/epc/mme/run?node=1&run"
```

FIGURE 4.8: MME run response

```
MME is running
```

The same with SPGW with the following queries:

```
curl "http://10.0.1.66:4567/epc/spgw/set?node=1
&SGW_INTERFACE_NAME_FOR_S11=lo&SGW_IPV4_ADDRESS_FOR_S11=127.0.11.2/8&
SGW_INTERFACE_NAME_FOR_S1U_S12_S4_UP=eth0&SGW_IPV4_ADDRESS_FOR_S1U_S12_S4_UP=10.0.1.66/24&
PGW_INTERFACE_NAME_FOR_SGI=eth0&PGW_IPV4_ADDRESS_FOR_SGI=10.0.1.66/24
curl "http://10.0.1.60:4567/epc/spgw/run?node=1&run"
```

FIGURE 4.9: SPGW conf response

```
<Lterf>
  <Epc>
    <node1 PGW_INTERFACE_NAME_FOR_SGI="eth0" PGW_IPV4_ADDRESS_FOR_SGI="10.0.1.66/24" SGW_INTER
FACE_NAME_FOR_S11="lo" SGW_INTERFACE_NAME_FOR_S1U_S12_S4_UP="eth0" SGW_IPV4_ADDRESS_FOR_S11="1
27.0.11.2/8" SGW_IPV4_ADDRESS_FOR_S1U_S12_S4_UP="10.0.1.66/24"/>
  </Epc>
</Lterf>
```

FIGURE 4.10: SPGW run response

```
SPGW is running
```

To connect them with the RRC and RRU the following queries must be issued :

```
curl "http://10.0.1.66:4567/bs/set?node=2&ipv4=10.0.1.66
&enbIpv4InterfaceS1MME=eth0&enbIpv4AddressS1MME=10.0.1.60/24&enbIpv4InterfaceS1U=eth0&
enbIpv4AddressS1U=10.0.1.60/24&remote_address=10.0.1.64&local_address=10.0.1.60"
```

FIGURE 4.11: RRU conf response

```
<Lterf>
  <BS>
    <node2 enbIpv4AddressS1MME="10.0.1.60/24" enbIpv4AddressS1U="10.0.1.60/24" enbIpv4Interfac
eS1MME="eth0" enbIpv4InterfaceS1U="eth0" ipv4="10.0.1.66" local_address="10.0.1.60" remote_add
ress="10.0.1.64"/>
  </BS>
</Lterf>
```

```
curl "http://10.0.1.60:4567/bs/soft_exec?node=2"
```

FIGURE 4.12: RRU run response

```
BS node2 has started execution
```

```
curl "http://10.0.1.66:4567/bs/set?node=4&enbIpv4AddressS1MME=192.168.12.3/24&enbIpv4Ir
&enbIpv4AddressS1U=192.168.12.3/24
&remote_address=10.0.1.60&local_address=10.0.1.64"
```

FIGURE 4.13: RCC conf response

```
<Lterf>
  <BS>
    <node4 enbIpv4AddressS1MME="192.168.123/24" enbIpv4AddressS1U="192.168.12.3/24" enbIpv4Int
erfaceS1U="eth1" local_address="10.0.1.64" remote_address="10.0.1.60"/>
  </BS>
</Lterf>
```

```
curl "http://10.0.1.60:4567/bs/soft_exec?node=4"
```

FIGURE 4.14: RCC run response

```
BS node4 has started execution
```

Chapter 5

Services of the experimentation platform

5.1 OAI based services

5.1.1 List all services

To get the list of all the services you must send the following query

```
curl "http://lterf:4567"
```

5.1.2 Set eNB parameters

This service enables the researcher to change the parameters to configure the eNB. The researcher must give the following send the following query where nodeid is the number of the node the experiment is going to execute and parameters are the parameters for configuration. The parameters can be found in A.1

```
curl "http://lterf:4567/bs/set?node=nodeid parameters"
```

5.1.3 Get eNB parameters

This service is usefull for checking the eNB paramters for or after the execution of the experiment, the query is the following

```
curl "http://lterf:4567/bs/get?node=nodeid&parameters"
```

5.1.4 Start eNB experiment

To start the eNB you must have first configured the parameters of the EPC components (details int the following sections) and the eNB. To start you must send the following query

```
curl "http://lterf:4567/bs/exec?node=nodeid"
```

5.1.5 Stop eNB experiment

To stop the eNB the following query must be given

```
curl "http://lterf:4567/bs/stopOAI?node=nodeid"
```

5.1.6 Check the status of the eNB

To check if the eNB is running or if it has stoped the following query must be given

```
curl "http://lterf:4567/bs/checkStatus?node=nodeid"
```

5.1.7 List config files

To list the already available configuration files for the eNB the following query must be given

```
curl "http://lterf:4567/bs/config/list?node=nodeid"
```

5.1.8 Save config file

To save a created eNB configuration file the following query must be given

```
curl "http://lterf:4567/bs/config/save?node=nodeid"
```

5.1.9 Load config file

To load a eNB config file for the already created the following query must be given

```
curl "http://lterf:4567/bs/config/load?node=nodeid"
```

5.1.10 Load default config file

To load the default eNB config file for the already created the following query must be given

```
curl "http://lterf:4567/bs/config/default?node=nodeid"
```

5.2 EPC services

5.2.1 Set plmid and operational key

To set the plmid and the operational key for the database in the hss config file the following query must be given

```
curl "http://lterf:4567/EPC/set?node=nodeid&op_key=xxxxxxxx$plmid=xxxxxxx"
```

5.2.2 Set SPGW parameters

To set the parameters for the sgpw config file the following query must be given

```
curl "http://lterf:4567/EPC/spgw/set?node=nodeid&parameters"
```

5.2.3 Set MME parameters

To set the parameters for the mme config file the following query must be given

```
curl "http://lterf:4567/EPC/mme/set?node=nodeid&parameters"
```

5.2.4 Run MME

To run, stop, restart the mme or just check the status of the process you must give the following query where the parameter is either start/stop/restart/status

```
curl "http://lterf:4567/EPC/mme/run?node=nodeid&parameter"
```

5.2.5 Run HSS

To run, stop, restart the hss or just check the status of the process you must give the following query where the parameter is either start/stop/restart/status

```
curl "http://lterf:4567/EPC/hss/run?node=nodeid&parameter"
```

5.2.6 Run SPGW

To run, stop, restart the spgw or just check the status of the process you must give the following query where the parameter is either start/stop/restart/status

```
curl "http://lterf:4567/EPC/spgw/run?node=nodeid&parameter"
```

5.2.7 Add subscriber

To add a new subscriber give the following query where the parameters include the table to change ie table = users and also the key and the imsi

```
curl "http://lterf:4567/EPC/mme/run?node=nodeid&parameter"
```

Appendix A

Parameters for eNodeB cell

Table of OAI NodeB parameters

freqBandIndicator	Setup of the LTE band (Supported bands are 7 and 13) - You will have to set the DL and UL EARFCN values (Band 7 -> 3100/21100)
earFcnDl	Setup the EARFCNDL (Downlink) parameter (Initial config: band 7 -> 3100)
earFcnUl	Setup the EARFCNUL (Uplink) parameter (Initial config: band 7 - 21100)
DlBandwidth	Setup the downlink bandwidth
UlBandwidth	Setup the Uplink bandwidth
PhyCellID	Physicall Cell ID which determines the PSS and SSS of the cell (default is 270)
PBCHPowerOffset	Setup the Power Offset of the Physical Broadcast Channel with respect to the Reference Signal Power in dB. Set the desired value multiplied by 10 (default is 0)
PSCHPowerOffset	Setup the Power Offset of the Primary Synchronisation Channel with respect to the Reference Signal Power in dB. Set the desired value multiplied by 10 (default is 30)
SSCHPowerOffset	Setup the Power Offset of the Secondary Synchronisation Channel with respect to the Reference Signal Power in dB. Set the desired value multiplied by 10 (default is 30)
RefSignalPower	Setup the Downlink Reference Signal Transmit Power in dBm. (default is -15 -> 13dBm)
NumOfRACHPreambles	Set the number of preambles to be used for contention based RACH
TxMode	Set the number of enabled antenna ports for transmission. In all cases
MCSDl	Set the DL MCS profile to use (available profiles are 0-28). CQI reporting must be disabled
MCSUl	Set the UL MCS profile to use (available profiles are 0-26). CQI reporting must be disabled
AdminState	Set the cell state to LOCKED (0 - Not Transmitting) or UNLOCKED (1 - Transmitting)
CQIReport	Enable or Disable periodic CQI reporting. (Enable -> 1)
UEReport	Enable or Disable periodic UE measurement reporting. (Enable -> 1)

PUSCHPowerControl	Enable or Disable PUSCH power control. (default is 1)
PDCCHPowerControl	Enable or Disable PDCCH power control and aggregation. (default is 1)
SINRPUCCHPowerControl	Enable or Disable SINR based PUCCH power control. (default is 0)
HARQPUCCHPowerControl	Enable or Disable HARQs BLER based PUCCH power control. (default is 0)
FreqPUSCHPowerControl	EnablAppe or Disable Frequency Selective PUSCH power control. (default is 0)

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