Establishment of Private Wireless Network Using Open-source Software Magma

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***Abstract*—In spite of Wi-Fi being fast, dependable and simple to use, if you need to cover a more extensive region or many gadgets it rapidly becomes inefficient and costly.To reduce the cost, the best way is to set up a Private network that are substantially more secure than Wi-Fi.Private Networks in enterprises enhances scalability, effectiveness and competitiveness.Hence, it demands establishment of private Networks, but building a private network can be costly.Open-source platform not only reduces the cost factor but provides a well controlled environment set-up for testing and experimentation of scalable and adaptive network.With the advancement of 4G/5G, testing for such advanced features needs experimentation set-up for both indoor and outdoor environments, which can be achieved by open-source platforms.This paper presented the established of end-to-end 4G/5G setup using OAI eNodeB/gNodeB protocol stack, USRP (B210),Magma Core Network (CN), Data Server and COTS 4G Smartphones.**

***Index Terms*—Private Network, Magma, OpenAirInterface (OAI).**

I. Introduction

Private Network as the name suggests is dedicated to private organization or enterprises that is configured to support activities like production, assembling, energy utilities, operations.Private Network term may be quite new, but it is evolving. Commercially, private LTE networks are quite popular, and theirs uses have become a reality in businesses [1].

Establishment of Private Network in any organization enhances adaptability, security, effectiveness.With the establishment of Private Network, enterprises can have control and choice to make modifications on the network based on their requirements like reach of a network, quick network failure recoveries, maximum limit of a network and more.

Wi-Fi being the popular solutions for Private Network has some drawbacks. Wi-Fi doesn't uphold huge Internet of Things (IoT) administrations because of the restricted association per channel, Wi-Fi also has security concerns which is not favourable for any defence organizations [2]. Table I list the differences between Wi-Fi 6 and Private 5G. Wi-Fi also have

TABLE I
Differences between Wi-Fi 6 and Private 5G

	Spectrum	Security	Reliability	Coverage
Wi-Fi 6	Low	Low	Low	Low
Private 5G	High	High	High	High

restricted facilities when it comes to new technologies like self-driven car, smart cities etc. In contrast to that, Private 4G/5G networks can fulfil all such advance needs in recent times and also in near future.

With advancement of technologies in telecommunications, many companies need secure, reliable and fast private network which covers large areas and allows secure voice and data communications in the organization.Some enterprises also depends on Private Network environment for carry their experiment and research need.Hence, open-source platforms can fulfil such requirements.

Some of the use-cases for Private networks are smart factory, medical services, campus environments like colleges, schools and military bases.In smart factory it provides dedicated network for customer specific requirement.In military bases, it can provide security services and further develop military activity efficiency. [3].

Private Networks can be established with the help of licensed mobile network operator.In this paper we have presented on how we can build enterprise grade private mobile network using open-source platforms like Magma(CN) ,OpenAirInterface (OAI) eNodeB/gNodeB protocol stack.After establishment of Private 4G/5G network, below test-cases were also verified:

1) Attachment of Base station (eNodeB ,gNodeB) to the Core Network(Magma).
2) UE (COTS 4G Smartphones) attachment to Base Station and Core Network (CN).
3) Uplink/Downlink throughput for TCP/UDP traffic.

The paper contents are divided into 2.Literature Review ,3.Methodology provides in-depth details on how Magma and OpenAirInterace (OAI) is used for the set up private network 4.Test Results and finally we conclude with 5.Conclusion and Future work.

II. Literature Review

Like never before, Private Network is in huge demands with the advancement of AI technologies like robots ,self driving car,drones,sensors etc.Private Networks provides services to those devices that requires scalability, security, availability.Private Networks will assist with working on the worth of the venture by giving foundation that can keep on developing [2].

Additionally, in this present reality where information breaks are quite common, high-innovation modern organizations require the utilization of their own modified security strategies and privately put away information, which may not be upheld by a portion of the customary public cell organizations. Because of these deficiencies, private organizations, which are likewise named non-public organizations in the third Generation Partnership Project (3GPP) [4], have drawn in huge interest.

Magma open-source platform has evolved as a community, and with major collaborations it provides its community to build advance networks [5] which supports Wi-Fi,LTE,5G communications. It can deftly uphold a radio access network with negligible turn of events and arrangement exertion, and incorporates three significant parts:Access Gateway,Orchestrator,Federation Gateway.

OpenAirInterface (OAI) provides flexible open-source platform for 4G/5G research. OAI delivers continuous and expandable research platforms that can be easily controlled in a lab set-up.OAI provides the 3GPP- adaptable LTE stack and LTE-A functionality which contributes to a real-time research and experimental set-up for both indoor and outdoor environments [5].OAI can be lead the 5G innovation by providing a quick prototyping and testing atmosphere, with which new advancements can be accomplished through experimentation. [6].

III. Methodology

To establish our Private Network, Fig 1. gives an overall schematic of how the private 4G/5G network will look.

Basic private Network consists of 1.UE's(User Equipment), 2.RAN (Radio Access Network), 3.EPC (Evolved Packet Core), 4.Micro Cloud.

1) UE's - *UE's* can be anything like mobile phones, robots, IOT-devices, autonomous car.We have used COTS 4G Smartphones.
2) RAN - *RAN* consists of base stations and antenna which connects devices like mobile phones to core network using radio frequency.Here we have used OpenAirInterface (OAI-eNodeB) to do the same.

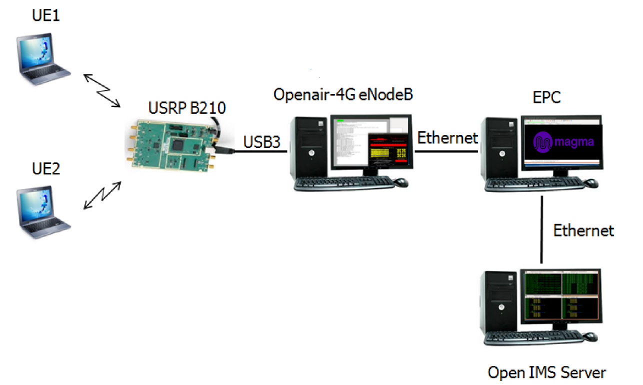


Fig. 1. Schematics of a Private 4G/5G Network

3) EPC - Provides important framework like MME, HSS, SGW, PGW for providing data and voice LTE services.Magma an Open-source platform is used to replicate the above services.Magma includes Access Gateway (AGW), Orchestrator and Federation gateway (FEG).
4) Micro Cloud-Advance technology which can be used for edge computing.

Overall software/hardware plaftforms used for End to End private 4G/5G Test Bed setup:

1) Commercial 4G smartphones
2) eNodeB RF front-end:B210.
3) eNodeB -OpenAirInterface (OAI) protocol stack.
4) Magma Core Network (CN)

A.*OpenAirInterface(OAI-eNB)*

The OpenAirInterface Radio Access Network (OAI- RAN) gives programming based executions of LTE base stations (eNBs), UEs and EPC.OAI presently oversaw by the OpenAirInterface Software Alliance (OSA)that gives open-source programming and apparatuses for 4G and 5G remote exploration.The OpenAirInterface (OAI) programming gives an open-source, norms consistent execution of a 3GPP 4G LTE stack that sudden spikes in demand for a product x86 CPU and a USRP radio gadget. The OAI programming traverses the full convention heap of the 3GPP LTE norms, and incorporates executions of EUTRAN (both eNB and UE).

For the establishment of Base Station (eNodeB/gNodeB), setup, we have installed and configured open-source OpenAirInterface(OAI) software for Intel x86 based platform and connected to the USRP B210 hardware for OTA transmission and reception.OAI also has interoperability with USRP (B210,X300,N310) for OTA transmission.OAI can be installed on Ubuntu 18.04 or RHEL/CentOS 7.4, but preferred to be installed on Ubuntu as it provides smooth work flow and also convenient with the UHD-driver.

Steps, we have followed to install and configure OAI software for Intel x86 based platform to implement a 4G/5G cellular basestation (eNodeB/gNodeB):

1) *Installation of Ubuntu 18.04*:After downloading and installing Ubuntu 18.04, installation of low-latency kernel

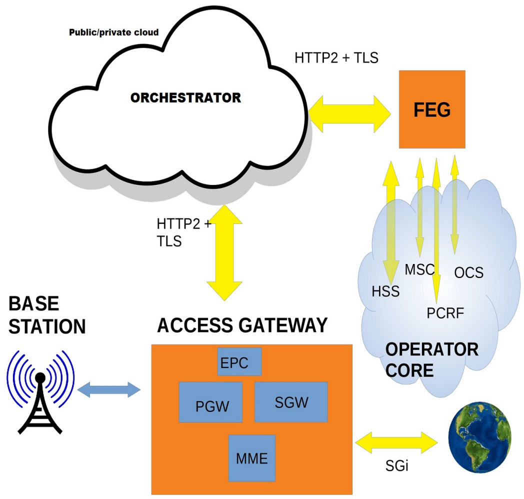


Fig. 2. Magma Architecture

TABLE II
HARDWARE CONFIGURATION FOR DEPLOYMENT OF ACCESS GATEWAY

FACET	VALUES
Magma Tag	v1.6
OS	Ubuntu 18.04
vCPU	4
RAM	(16 GB)
Memory	(90 GB)

TABLE III
HARDWARE CONFIGURATION FOR DEPLOYMENT OF ACCESS GATEWAY

FACET	VALUES
Magma Tag	v1.6
AGW IP	192.168.60.150
AGW OS	Ubuntu 18.04
Controller IP	192.168.60.248
Bootstrapper IP	192.168.60.248
Fluentd IP	192.168.60.247

was done.

2) *Installation and Configuration of UHD-driver*:using OAI build scripts it can be installed, but we built it manually from the source [7].
3) *OAI-eNB Installation and Configuration*:OAI-eNB was downloaded from the GIT repository [8]and was included in an environment for running and building OAI-eNB software.Configuration parameters of OAI-eNB were configured:
   a) Duplex Mode: FDD
   b) Frequency Band: 7
   c) Bandwidth: 5 MHz
   d) Antenna Scheme: SISO
4) Running OAI-eNodeB software.

For monitoring and diagnosing, the OAI-eNodeB software WiresharK was used for reviewing the network.

B.*Magma*

Magma contrasts from popular 3GPP implementations, especially in the manner in which it accomplishes freedom of the radio access innovation.Magma is an open-source platform which provides scaleable, flexible Mobile core.Magma's main components are Access Gateway (AGW), Orchestrator, Federation Gateway (FEG). Fig 2. provides the detailed Magma Architecture.

The aim of Magma was to give Mobile core solutions that are cost-effective, reliable, scalable and feasible for operators providing accessibility in remote areas.

Magma's main advantage over conventional 3GPP execution is that in 3GPP we have to configure every individual module separately, but in with the help of Magma component Orchestrator we can centrally configure those tasks.One flexible point in Magma is that the execution is to a great extent free of the radio access innovation (4G/LTE/5G or others like Wi-Fi).

Magma followed the basic principle of SDN that is separation of control plane from date plane, Access Gateway stores the run-time states at the edges, whereas Orchestrator stores the configuration states which allows UE's like mobile phones to connect to the network.

The EPC functionality are configured in Magma's Access Gateway (AGW) which relays the run-time functionality to the Orchestrator. Access Gateway's control plane functionality (MME) tracks and maintains the movements of UE's and user plane functionality (SGW,PGW) relays IP packets to and from RAN to external Internet.

The Orchestrator also plays an important part in setting up a network. It manages the overall configuration and control of the mobile core centrally.On top of Orchestrator, sits Network Management System (NMS) which provides GUI for management of the Network.NMS provides a user-friendly interface which allows adding subscriber and policies to the network with ease.

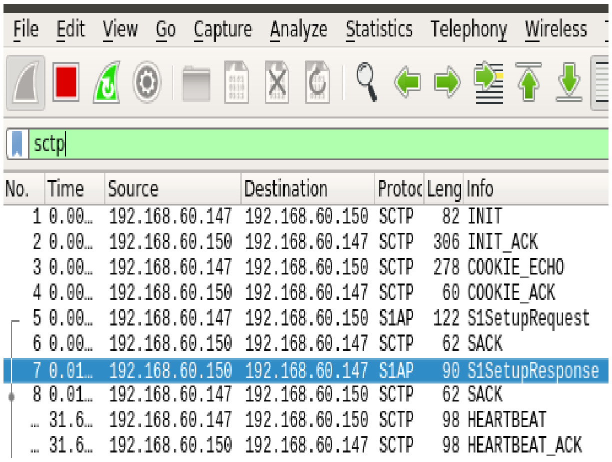
Magma Access Gateway (AGW)can be deployed on Ubuntu 20.04 and also can be deployed using Vagrant and VirtualBox [9]. We have deployed AGW using Vagrant and VirtualBox on Ubuntu 18.04 LTS using configuration mentioned in TABLE II.

Following every step for deployment of Access Gateway using Vagrant and VirtualBox in Ubuntu 18.04 [9] we have installed our Magma Mobile core.

The Orchestrator functionality can be implemented as a private or a public cloud.Here we have deployed Orchestrator using Docker and have registered it in Docker hub account using scripts provided in Magma repository.

By accepting the self-assigned certificate provided by the Magma [10] we used NMS for controlling and Management of the Network.NMS was used to configure our gateways and related eNodeBs.

After proper deployment of AGW and Orchestrator, using the NMS, configuration was made for AGW connection. TABLE III shows the characteristics for Orchestrator and AGW.



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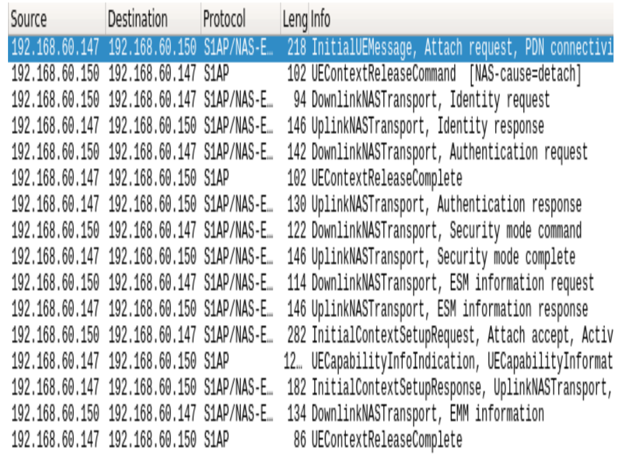
sctp

No.	Time	Source	Destination	Protoc	Leng	Info
1	0.00…	192.168.60.147	192.168.60.150	SCTP	82	INIT
2	0.00…	192.168.60.150	192.168.60.147	SCTP	306	INIT_ACK
3	0.00…	192.168.60.147	192.168.60.150	SCTP	278	COOKIE_ECHO
4	0.00…	192.168.60.150	192.168.60.147	SCTP	60	COOKIE_ACK
5	0.00…	192.168.60.147	192.168.60.150	S1AP	122	S1SetupRequest
6	0.00…	192.168.60.150	192.168.60.147	SCTP	62	SACK
7	0.01…	192.168.60.150	192.168.60.147	S1AP	90	S1SetupResponse
8	0.01…	192.168.60.147	192.168.60.150	SCTP	62	SACK
…	31.6…	192.168.60.147	192.168.60.150	SCTP	98	HEARTBEAT
…	31.6…	192.168.60.150	192.168.60.147	SCTP	98	HEARTBEAT_ACK

Fig. 3. Magma(CN) and OAI(eNodeB) attachment.



Source	Destination	Protocol	Leng	Info
192.168.60.147	192.168.60.150	S1AP/NAS-E…	218	InitialUEMessage, Attach request, PDN connectivi
192.168.60.150	192.168.60.147	S1AP	102	UEContextReleaseCommand [NAS-cause=detach]
192.168.60.150	192.168.60.147	S1AP/NAS-E…	94	DownlinkNASTransport, Identity request
192.168.60.147	192.168.60.150	S1AP/NAS-E…	146	UplinkNASTransport, Identity response
192.168.60.150	192.168.60.147	S1AP/NAS-E…	142	DownlinkNASTransport, Authentication request
192.168.60.147	192.168.60.150	S1AP	102	UEContextReleaseComplete
192.168.60.147	192.168.60.150	S1AP/NAS-E…	130	UplinkNASTransport, Authentication response
192.168.60.150	192.168.60.147	S1AP/NAS-E…	122	DownlinkNASTransport, Security mode command
192.168.60.147	192.168.60.150	S1AP/NAS-E…	146	UplinkNASTransport, Security mode complete
192.168.60.150	192.168.60.147	S1AP/NAS-E…	114	DownlinkNASTransport, ESM information request
192.168.60.147	192.168.60.150	S1AP/NAS-E…	146	UplinkNASTransport, ESM information response
192.168.60.150	192.168.60.147	S1AP/NAS-E…	282	InitialContextSetupRequest, Attach accept, Activ
192.168.60.147	192.168.60.150	S1AP	12…	UECapabilityInfoIndication, UECapabilityInformat
192.168.60.147	192.168.60.150	S1AP/NAS-E…	182	InitialContextSetupResponse, UplinkNASTransport,
192.168.60.150	192.168.60.147	S1AP/NAS-E…	134	DownlinkNASTransport, EMM information
192.168.60.147	192.168.60.150	S1AP	86	UEContextReleaseComplete

Fig. 4. UE attached to Base Station and Core Network

After connection of AGW with the Orchestrator, we need to provision our enodeB in NMS.We have manually configured enodeB by enabling the "enodeB managed externally" option under RAN settings.Now, to add our subcriber to the network, we initially provisioned an Access Point Network(APN).APN can be easily added using the "ADD APN" under APN configuration.After adding APN, UEs was successfully attached and connected to the Magma AGWs.Once the AGW picks the APN information, the UE's were allocated IPs, under APN by the Magma.

IV. Test Results

In this section we come up with the results for the test-case mentioned above:

1) *Attachment of Base station (eNodeB, gNodeB) to the Core Network(Magma)*: Fig 3. verify that Magma core network was successfully attached to the OAI (eNodeB, gNodeB).S1SetupRequest and S1SetupResponse verifies the successful attachment.
2) *UE (COTS 4G Smartphones) attachment to Base Station and Core Network (CN)*:Fig 4. verify that UE attachment requested was successfully granted to Base Station and Core Network (CN).
3) Uplink and Downlink throughput for TCP/UDP traffic was also verified .

V. Conclusions and Future Work

This paper presented the establishment of End-to-End 4G setup using the OAI eNodeB, Magma CN, Data Server and COTS 4G Smartphones. The work aims to provide a realistic Over the Air (OTA) experimental setup using these open-source tools instead of commercial eNodeB and EPC. In future this setup will be extended for the evaluation of 5G Standalone Mode (SA) Mode using OAI gNodeB, Magma 5G Core and COTS 5G Smartphones.

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