

Advanced LTE Network Deployment Methodology: A case Study for Dakar Region

Antoine Gnansounou*, Samuel Ouya*, Raïmy Abd. Toure*

*ESMT-DETIC-LTI, ESMT, Dakar Senegal

Antoine.gnansounou@esmt.sn, samuel.ouya@ucad.sn, raïmy.toure@ucad.sn

Abstract — This work describes the dimensioning process of LTE access network for an ISP, its models, methods and the tool used to dimension the network.

LTE is a system with larger bandwidths (up to 20 MHz), low latency and Packet optimized radio access technology having peak data rates of 100 Mbps in downlink and 50 Mbps in the uplink. Radio access technology for LTE is OFDM (Orthogonal frequency division multiplexing) that provides higher spectral efficiency and more robustness against multipath and fading, as compared to CDMA (Code division multiple access). In order to offer the operators increased flexibility in network deployment, the LTE system supports bandwidth scalability and both FDD and TDD duplexing methods. The main objectives of our research was the identification of LTE features relevant for the dimensioning, to define the basic models for Access Network Dimensioning to estimate Coverage needs of the infrastructure, the Network Element Count Estimation and the Capacity Evaluation.

Keywords – LTE; 4G; ISP; Network; Dimensioning.

I. INTRODUCTION

In this new era of information and communication well underway and growing, Wireless broadband technology is now in motion to provide higher data rate, wider coverage and improved mobility. We are now at the verge of high speed mobile Internet with nationwide coverage; all made possible by Long-Term Evolution (LTE) technology. LTE is commonly marketed as 4G LTE.

The 4G technology is being developed to meet Quality of Service (QoS) and rate requirements that involve prioritization of network traffic to ensure good quality of services. A Wireless Internet Service Provider (WISP) or an operator who intends deployed a LTE network to provide services to clients in a given region, should be interested in the engineering of the planning and sizing a network.

In our research approach to study and to propose a strategy to design and implement an 4GLTE for the region of Dakar, we devote the first section to justify needs and to prove the feasibility of the project, in the second, we mentioned the methodology of study and deployment, the third section is dedicated to the the planning and the proposition of synoptic architecture of the LTE network. Section five focused on sizing of the coverage according to the surface and the capacity. Before

last section which concludes the paper and outlines our future work, we have proposed a deployment strategy and coverage of rural areas.

II. CONTEXT AND JUSTIFICATION OF LTE TECHNOLOGY FOR THE DAKAR REGION

A new Internet Service Provider (ISP) aims to give an access to 1Mb/s minimum to its customers of Dakar.

Dakar is a dense city of more 5404 inhabitants per km² and a population of more than 3,000,000 inhabitants. With a penetration rate of broadband Internet service of 40% and a flow of minimum 1Mb/s, there is a need for a global traffic of minimum $3,000,000 * 0.4 * 1\text{Mb/s} = 1,2\text{Tbit/s}$. This flow rate is quite high and justifies the choice of the 4G LTE.

The city center of Dakar is full of small and medium-sized enterprises which will need more of 1Mbit/s as Internet flow, because the shares of videos and heavy files in a short period of time, quality of service requires, consume a lot of bandwidth. It is necessary for this technology 4GLTE.

To ensure a easy scalability and a compatibility with the previous networks (2.5G, 2.75G and 3G), the 4GLTE is needed as optimal choice.

The WiMax 802.16.m would have been able to make object of preference but, when we see already that the operators of the place choose to deploy the LTE for their evolution to the 4G, it must defend a homogeneity of network, source of bit of gymnastics of interconnection. Also the LTE Advanced provides more flow that the WiMax 802.16.m.

In conclusion we accompany without hesitation the new supplier of Internet access to study the deployment of its mobile network with its choice of technology: "4G LTE".

III. METHODOLOGY OF STUDY AND DEPLOYMENT

The main goal of this research is to study the needs and the feasibility of the deployment of the mobile technology LTE in the region of Dakar.

To achieve these goal we recorded the work methodology includes studying:

- proposal of a network architecture
- sizing of the coverage according to the surface

- ✚ sizing of the coverage according to the capacity
- ✚ proposal for a strategy to offset the interfaces
- ✚ what technology for remote areas?.

IV. PROPOSAL OF LTE NETWORK ARCHITECTURE

A. Network architecture

The new supplier of Internet access is positioned on the segment of access to the network. It must not deploy a network of transport. Several architectural variations are offered to it:

- ✚ it deploys only of ENodeBs and leased transmission capacity to connect with the SGW of operators 4existing GLTE, according to a diagram of the optimal connection which reduces the costs of transport.
- ✚ it deploys the ENodeBs and SGW, in which case it ensures by rental of Capacity The ENodeBs connections and SGWs and then the connections SGWs and PGWs of operators LTE.
- ✚ it deploys the LTE network integer. It will ensure the interconnection of all its nodes of networks by rental of transmission capacities. It will connect her PGW to the station the submarine cable for Dakar or to the earth station of Gandoul or by satellite link dependent on a hub outside. But in this case it is no longer ISP but an operator 4GLTE rather.

It seems to us to be more optimal to make the first choice, that is to say deploy that ENodeBs and rent capabilities for the Connect to SGWs of LTE operators of the place. Depending on the location of the ENodeB, it chooses the SGW with which the connection will be of lesser cost. The operators will update the processing capabilities of the plans users and control of their equipment SGW, PGW and interfaces thereto. This induces a cost which they will take into account in the sale of capacity on the interface S1 to the ISP. The network architecture which derives from this choice then returns to the following:

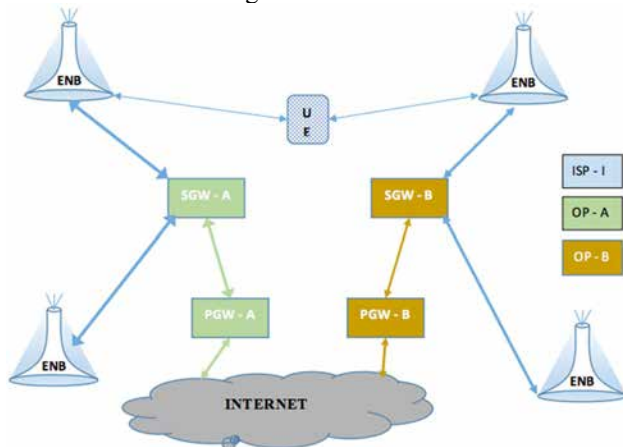


Figure 1. Synoptic diagram of the network architecture without ACE access

Otherwise, ISP can equip itself with a SGW and a PGW to make an Internet connection via the Africa Cost to Europe (ACE) submarine cable.

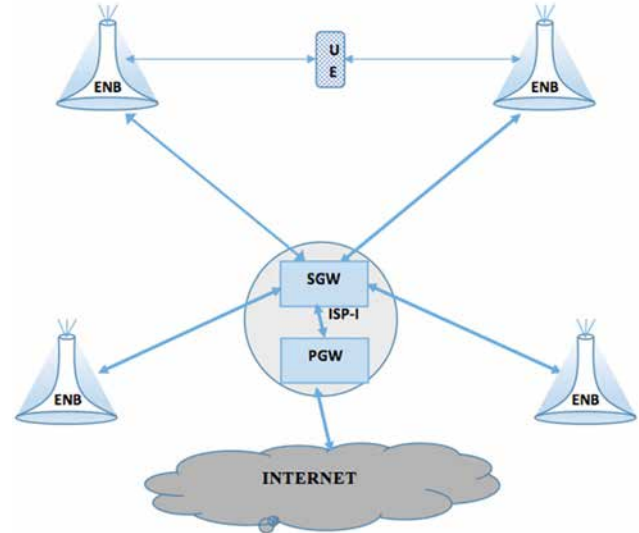


Figure 2. Synoptic diagram of the network architecture with ACE access

V. SIZING OF THE COVERAGE ACCORDING TO THE SURFACE

The sizing of the coverage according to the surface amounts to estimating the number of ENodeB necessary to cover the city of Dakar. To do this, it would be necessary

- ✚ gather the necessary parameters to establish a radio link budget.
- ✚ Choose a model of radio propagation in adequacy with the environment of the city of Dakar (flat ground occupied by buildings with a strong density of population)
- ✚ Calculate the maximum allowable distance
- ✚ Calculate the radius of a cell according to the type of cell adopted (sectoral sorting, sectoral bi, mono sectorial)
- ✚ Calculate the surface of a cell
- ✚ Calculate the number of ENodeB

A. Calculation of the maximum distance (d_{max})

The coverage will be sized on the basis of a downlink link budget for a site covered by an ENodeB. To do this we need the following parameters:

- ✚ SINRmin (dB), the minimum signal-to-noise ratio required for the proper operation of the User Equipment (UE)

- ✚ N_r (dB) the average noise perceived by the EU
- ✚ P_e (dBm) the power emitted by the ENodeB
- ✚ G_e (dB) the gain of the transmit antenna of the ENodeB
- ✚ α_e (dB) transmission losses before the antenna
- ✚ G_r (dB) receive antenna gain at EU level
- ✚ α_r (dB) loss on reception

If PL_{max} denotes the maximum allowed pathloss for the good functioning of a UE - ENodeB radio link, we have the following equation (1):

$$PL_{max} = P_e + G_e + G_r - \alpha_e - \alpha_r - N_r - SINR_{min} - Marges \quad (1)$$

For the city of Dakar, the most appropriate radio propagation model is COST-HATA. Indeed the LTE operating band here is around 2GHz on a flat ground with a dense land use from the point of view of buildings and populations.

Since the $F > 400$ MHz so we will have:

$$a(h_{UE}) = 3.2(\log 11.75h_{UE})^2 - 4.97$$

Then equation (2):

$$PL_{max} = 46.3 + 33.9 \log(f) - 13.82 \log(h_{eN}) - (3.2(\log 11.75h_{UE})^2 - 4.97) + (44.9 - 6.55 \log h_{eN}) \log(d_{max}) \quad (2)$$

Equations (1) and (2) make it possible to find the maximum distance d_{max} as a function of the parameters: f , h_{eN} , h_{UE} , P_e , G_e , G_r , α_e , α_r , N_r and $SINR_{min}$. The usual values of these parameters to perform such a balance are recorded in the following table:

Parameters	Values
Antenna height eNodeB (h_{eN})	30 m
Terminal height (h_{UE})	1.50 m
Frequency	2100 Mhz
Emission	
Power emission (P_e)	46 dbm
Number of transmission antenna	4
Gain of emission (G_e)	17 db
Loss on emission (α_e)	1.8 db
Reception	
$SINR_{min}$	-3 db
Noise Power (N_r)	-104 dbm
Gain at the reception (G_r)	15 db
Loss on reception on UE	0 dB
Margins (Shadowing, interference, penetration)	40 bB

Table 1. Usual values to calculate d_{max}

According to these values, we finally calculated and found **$d_{max} = 2.29$ km.**

B. Calculation of the site area and the number of ENodeB

Type of Site	Area of Site	Number of eNodeB (N_{ENB})
Single Sector : $d_{max} = R_{cell}$	$S_{Site} = \frac{(3\sqrt{3} * d_{max}^2)}{2}$ $= 13.75 \text{ km}^2$	41 eNodeB
Two Sector : $R_{cell} = \frac{2\sqrt{13}d_{max}}{13}$	$S_{Site} = \frac{12\sqrt{3} * d_{max}^2}{13}$ $= 8.38 \text{ km}^2$	66 eNodeB
Three Sector : $R_{cell} = \frac{d_{max}}{2}$	$S_{Site} = \frac{9\sqrt{3} * d_{max}^2}{8}$ $= 10.21 \text{ km}^2$	54 eNodeB
Quad Sector : $R_{cell} = \frac{2d_{max}}{5}$	$S_{Site} = \frac{24\sqrt{3} * d_{max}^2}{25}$ $= 8,72 \text{ km}^2$	64 eNodeB

Table 2. Table and formula to calculate number of eNodeB

The penultimate line of this table represents the option of our choice of coverage for three reasons:

- ✚ Numbers of eNodeB (54) approximately equal to the average of the two extreme values 41 and 66.
- ✚ Offers network densification as adapted to the population density of the Dakar region.
- ✚ In the simulation software that we will use, the Quad Sector option does not exist.

VI. SIZING OF THE COVERAGE ACCORDING TO THE CAPACITY

We start on the basis of a minimum bit rate of 1Mb/s which represents approximately three data connections at 384 Kbps.

But based on a service policy defined by the types of services and the simultaneity of the services (multimedia dimension) we will be able to estimate the global traffic offered to the access network and then find the number of ENodeB on the basis of the Cell. throughput of each ENodeB.

We will take the greatest value of the two results obtained and a simulation will be done with an appropriate software tool to get an idea of the distribution of the ENBs.

A. Flow offered to an eNodeB

For this dimensioning the following data are needed:

P: the population of the coverage area;

Nuser: the number of users that can offer data traffic to the network

τ : the penetration rate of the LTE offer;

Nuser = $\tau * P$

Nmou/Si: the maximum number of bytes exchanged per user per service per day, of which 10% is brought back to the busy hour;

If: the list of services to be provided by the network;

Nuser_Si: the number of users per service If at the busy time and α_i , the corresponding percentage of β Nuser, where β is the reduction coefficient taking into account that at the busy time, all potential users are not connected to the network

Nuser_Si = $(\alpha_i * \beta * P * \tau) / 100$

Fu: the utilization factor that takes into account that not all subscribers are at maximum throughput.

PAR (Peak To Average Ratio): which connects the average number of bytes exchanged per user per service Si (Nmoy_ouSi) to the maximum number of bytes exchanged per user per service If per day (NmouSi).

$N_{mouSi} = PAR * N_{moy_ouSi}$

The maximum overall rate offered to the network is:

$$D_{gm}(bps) = \frac{\sum 8 * \alpha_i * \beta * P * \tau * N_{moy_ouSi} * PAR * Fu}{36 * 10^5}$$

This global bit rate will be supported by the number of ENodeB NENB given by the coverage, ie by eNodeB it will be necessary to support the following capacity:

$$D_{ENB}(bps) = \frac{\beta * \sum(\alpha_i * P * \tau * D_i)}{10^2 * N_{ENB}}$$

The coefficient β depends on the bandwidth BPENB (Mhz) deployed of each eNodeB.

B. Flow available by ENodeB

The number of NBR resource blocks corresponding to this bandwidth is:

$$N_{BR} = \frac{100 * BP_{ENB}}{20}$$

The symbol number for a resource block is: $12 * 7 = 84$, the modulation being $2^n QAM$

The information rate available at an eNodeB (Dinfo-ENB) is given by:

$$D_{info-ENB}(bps) = BP_{ENB} * 84 * n * 10^4$$

Assuming the charge of eNodeB at 80%, one can write

$$D_{ENB} = 0.8 * D_{info-ENB} = \frac{\beta(8 * BP_{ENB} * 84 * n * 10^3) * (10^2 * N_{ENB})}{\sum(\alpha_i * P * \tau * D_i)}$$

C. Capacity required by ENodeB

The capacity require by eNodeB is calculate as indicated on the table below:

Band width (BPENB) in Mhz	Number of bits per symbol (n)	Dinfo-ENB (Kbps)	DENB (Gbps)	β	Number of users simultanously connect ed to the busy time	Number of users simultanously connected to the time charged by eNodeB
5	6	25,2	35,1*(β)	0,0008	862	16
10	6	50,4	35,1*(β)	0,0015	1724	32
15	6	75,6	35,1*(β)	0,0022	2586	48
20	6	100,8	35,1*(β)	0,0023	2758	51
40	6	201,6	35,1*(β)	0,0046	5517	102

Table 3. Required capacity of eNodeB

VII. PROPOSAL FOR A STRATEGY TO OFFSET THE INTERFACES

On the basis of the service policy, the sizing of the S1 interface will be done for each ENodeB

Depending on the locations of ENodeBs confirmed by an adequate survey, we will produce a following connection table:

For remote areas, we offer a light infrastructure solution such as Gigabit WI-FI (802.11ac) for wireless connection spots to be implemented in locations subject to frequent groupings: markets, town halls, health center, schools, recreation centers, public services, community IT service center.

To do this, it will install Gbit WI-FI access points in these places and ensure solar power supply in case of non availability of SENELEC. It will then federate the access points around a router by a network MPR (Microwave Radio Package). The topology of this network can be star or ring according to the requirements of the field. The router will be multiport baseband and will have an optical interface to accommodate a leased fiber link from a transport operator. This link will connect the router to the Internet portal of a connection operator. The transport operator may be the same as the connection operator and this is desirable. The architecture is as below.

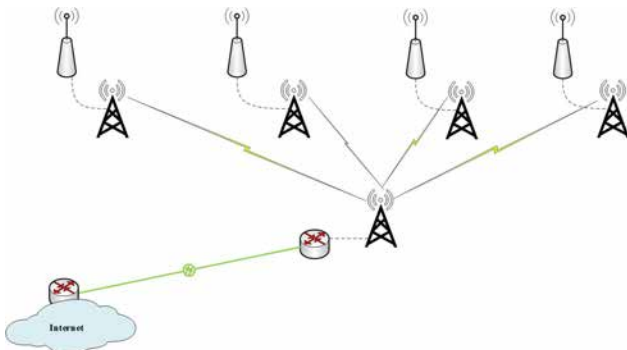


Figure 3. Architecture of network with connection to ISP

The MPR links will be at least 1 Gbit and with n baseband ports for the router, the leased link will have a capacity of N Gbit / s.

These links could be implemented in WI-FI long distance but we fear the lack of capacity, because there is the constraint of 1 Mbps at least per connection.

VIII. SIMULATION AND RECOMMENDATIONS

A. Simulation of coverage of the Dakar region

Tool: Atoll version 3.2.1.58.38

Parameters: ENodeB: 2100 Mhz frequency, 30m height, 4X2 MIMO antenna, 1.8dB antenna gain, 46dBm transmit power, 1.8dBm transmit loss. Propagation model: Cost Hata.

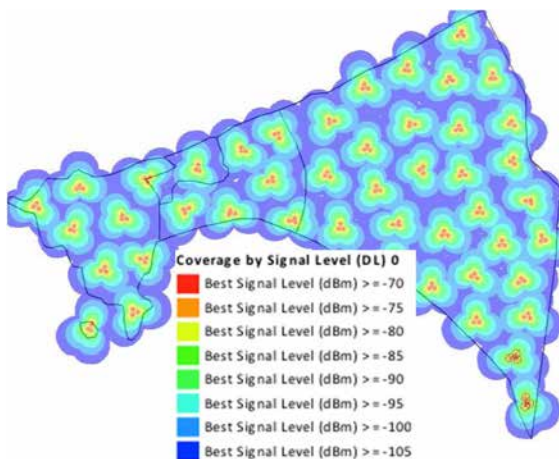


Figure 4. LTE Coverage area in Dakar

The simulation shows that 46 ENodeBs could be sufficient to cover the Dakar region, instead of 54 ENodeB provided by the calculations. It is necessary to justify this by the characteristic parameters of land are more complete in Atoll than in the calculation of balance made. All the time it would be necessary to foresee during the actual deployment that one could use more than 46 to 54 ENodeB

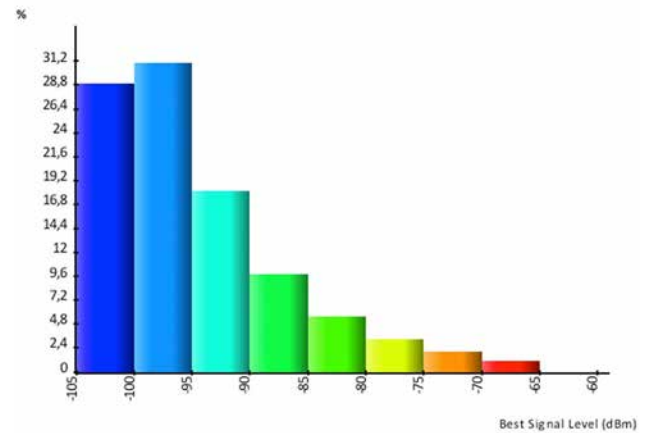


Figure 5. LTE signal levels

B. Recommendation

We recommend technically to the ISP the lease of a VCV (Virtual Concatenation Group) capacity of 6VC4 for each ENodeB on the optical network of the exchange point which certainly has a PGW. Thus, the exchange point will be the transport operator and the connection operator for the ISP. A flexible bit rate of $6 \times 149.76 \text{ Mb/s} = 898.56 \text{ Mb/s}$ will be made available to cope with upgrades due to changing capabilities.

Another alternative is to rent a capacity of 1Gb/s to transport the S1 interface data encapsulated in "Ethernet" frames.

According to the latest information obtained from stakeholders, the ISP is allowed to build its own transmission links. So an investment is to be made for the implementation of optical links and FH MPR links.

VI. CONCLUSION

To maintain their competitive edge in the world of mobile networks in the city of Dakar, many ISP has initiated work on LTE. As LTE is a packet optimized radio access technology with low latency and large bandwidths. This thesis work is based on the dimensioning of LTE Networks. During the course of this research work models and tools for LTE dimensioning have been developed. Both coverage and capacity estimation is carried out. Radio link budget is investigated for coverage planning and different factors affecting the performance of the network. Dimensioning tool is designed to keep the interface simple and to set the functional parts clearly distinguishable. The final product gives the number of sites (cells) needed in order to support a certain subscriber population with a given capacity.

Great effort has been made in order to make this work complete in all aspects. Currently, the simulation results for only a limited antenna configurations and scenarios are available. Using a more accurate simulator will yield better results for capacity planning exercise.

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Antoine GNANSOUNOU is a senior lecturer at Ecole Supérieure Multinationale des Télécommunications (ESMT) of Dakar (Senegal). He obtained a Master degree at Cheikh Anta Diop University of Dakar in the field of Mobile Network. He had made many training and expertise on telecommunications systems and mobile networks (2G, 3G, 4G, 5G, wireless, hertz). Elsewhere, he studied the planning and dimensioning mobile network and QoS.



Dr. Samuel OUYA is a researcher at the Laboratory of Information Processing (LTI), enrolled at the Graduate School of Mathematics and Computer Science, specializing in telecommunications, has supported a doctoral thesis on the theme "STUDY OF THE CONVERGENCE OF TELECOMMUNICATIONS SERVICES AND ITS APPLICATIONS TO VIRTUAL ORGANIZATIONS".

Dr. Raïmy Abd. TOURE is a researcher at the Laboratory of Information Processing (LTI), enrolled at the Graduate School of Mathematics and Computer Science, specializing in telecommunications, has supported a doctoral thesis on the theme "STUDY OF THE CONVERGENCE OF TELECOMMUNICATIONS SERVICES AND ITS APPLICATIONS TO VIRTUAL ORGANIZATIONS".