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EVALUATION OF THE QOS OF A MOBILE NETWORK BY MARKOV MODELING

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Abstract:

Assessing the quality of the mobile network, whether 2G, 3G, 4G or 5G, in a specific area by measuring throughput, network coverage, bandwidth, by a mobile operator is of paramount importance to ensure a high-quality user experience. A summary of the network quality dynamics in a travel area is necessary for decision makers and in developing mobile network dependent applications for users. This paper therefore proposes a Markov model as a mathematical solution to predict the network evolution by probability laws that summarise the dynamics of network qualities in a travel area. The Markov model has thus allowed to evaluate the qualities of the network dynamics and to summarize the dynamics by transition laws and dwell times in the different network qualities in a travel area. A result that leads to decisions on the quality of the networks and suggested application adapted to the network environment.

Keywords:

INTRODUCTION

Digital services have become an emerging value chain in Telecommunication and this has resulted in the proliferation of communication via the Internet at all points[1]. This situation has led to an increasing evolution of wireless networks, mobile equipment and terminals.

These developments foreshadow widespread user mobility.

Digital services will then be extremely diffuse, mobile and heterogeneous, at least at the periphery, i.e. where the users will be located[2]. The horizon that is thus taking shape is that of an ambient access through which:

- Users will be mobile and therefore likely to use resources in different places, without having to consider their current environment;
- Communication will be available everywhere but with different characteristics (in terms of throughput, loss rate, . . .) depending on the resources available;
- The network and its services will be able to satisfy, or even anticipate, the needs of users, making the most of the capacities of the environment, including the users themselves, in which they will evolve.

The quality of service will then depend on the performance of the available mobile network[3], [4]. It is therefore necessary to summarize the law of network state dynamics to help decision-makers decide on the use of mobile networks in a travel zone. Several methods and studies have been carried out to assess the quality of mobile networks in an area. The modeling and analysis of network dynamics has already been studied several times using statistical models, as in Cornillet's thesis, which used a mathematical model to evaluate the performance of mobile networks[5]. Salhani has also contributed to research into mobile network simulation models[6]. But in this study, we're interested in the dynamics of network quality on the move. In the following, we will use the Markov chain for a discrete analysis of network state dynamics to evaluate and propose a model that predicts network state dynamics. First we present the method for collecting network state data, then we present the theoretical framework of Markov models, followed by results and discussion.

MATERIALS AND METHODS

1) Drive Test

To assess network performance, several QoS measurement techniques have been implemented[3], [7]. The Drive Test is one of these techniques, its advantage is that it reflects the quality of service as perceived by the user. Test drives capture accurate real-world data of the RF environment when placed under a certain set of environmental and network conditions. Modern network simulation techniques of the new era have enabled network engineers to create a mathematical model to evaluate network performance[4]. Although this is true to some extent, the driving test in telecommunications remains at the heart of the network assessment process to continuously assess how the user experiences the network environment.

To carry out a drive test, a team travels in a car equipped with a digital measurement chain consisting essentially of:

- Mobile terminal and SIM card: also called mobile test is a terminal capable of communicating the measurements taken to a microcomputer. The track rover looks like a mobile station but incorporates many other features. Using the Hyper Terminal and a serial cable, it is possible to send commands that allow you to turn off the mobile or to call. But its real usefulness lies in the fact that it makes it possible to recover the frames and other information which circulates between the mobile and the network. It is thus possible to know the power level of the signal received by the mobile station, as well as other functionalities[8].
- GPS (Global Positioning System): allowing determine the geographical position of each measurement point.
- Laptop and drive test software: allowing the acquisition and processing of data retrieved from the tracker and GPS receiver. By viewing on the screen of the computer the various measurements carried out, it allows the engineer to check the state of the network on site. This tool offers the possibility save these measurements in special files, the engineer can thus replaying the sequences of measurements to better draw out the adequate conclusions.

Figure 1 : Steps followed during a drive test

During measurement campaigns, the technician tests:

- Call establishment (no failure)
- Maintaining communication for a certain period (no interruption)
- The quality of communication

Thus, drive test is the best solution for mobile network operators to collect signal strength, mobile network latency as well as GPS coordinates to constantly improve the network[9].

RF command test tools are also used to verify the coverage criteria of installed cell towers and to assess whether cell tower sectors are providing the intended coverage area as designed by operators. In the rest of our study, we will focus exclusively on the multi-site drive test by analyzing the results provided by the mobile operator Telma[1], [10].

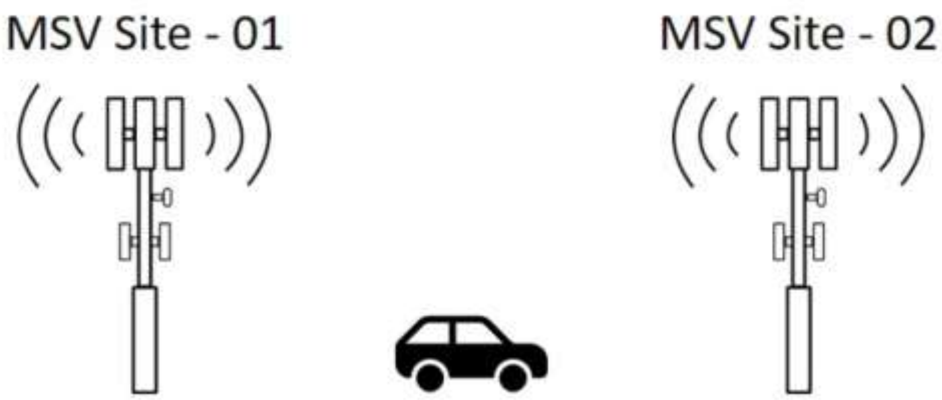


Figure 2: Multiple Site Verification (MSV drive test)

a) Data : Ambohimasina-Arivomamo drive test report

The data collected during a drive test is stored in log files and then evaluated on RF log post-processing tools, which usually have GIS-based visualization capabilities.

Figure 3: Travel zone 1 for dynamics analysis

Table 1: Statistical summary of data collected in dBm

Minimum	**1st quartile**	**Median**	**Average**	**Standard Deviation**	**3rd Quartile**	**Maximum**
-140.0	-118.9	-11.8	-112.4	8.89	-105.8	-83.2

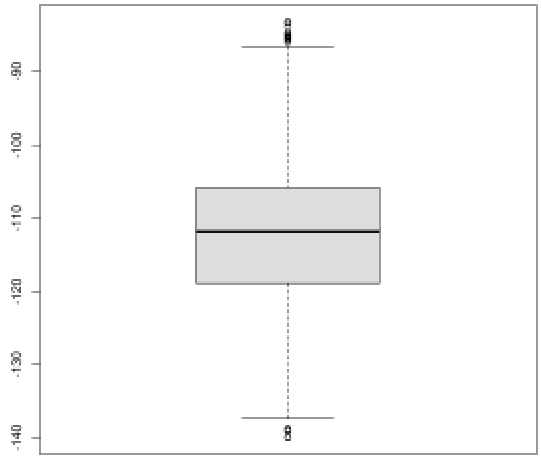


Figure 4 : Boxplot statistical summary of RHSP 4G of Ambohimasina-Arivomamo

b) Data: Drive test report Mantasoa zone

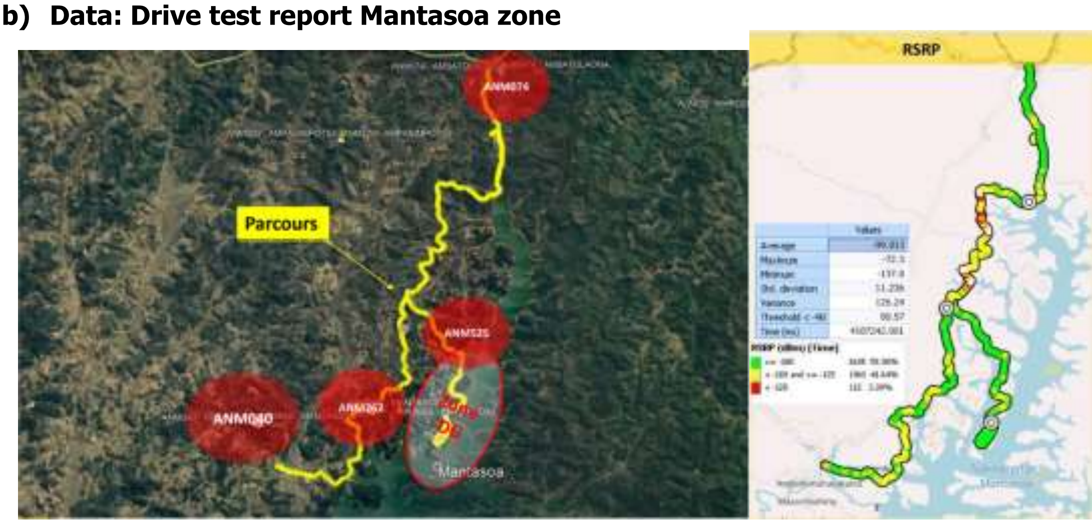


Figure 5 : Travel zone 2 for dynamics analysis

Table 2: Statistical summary of data collected in dBm

Minimum	1er quartile	Median	Average	Standard Deviation	3rd Quartile	Maximum
-137.80	-106.30	-98.90	-99.76	11.14	-92.20	-72.60

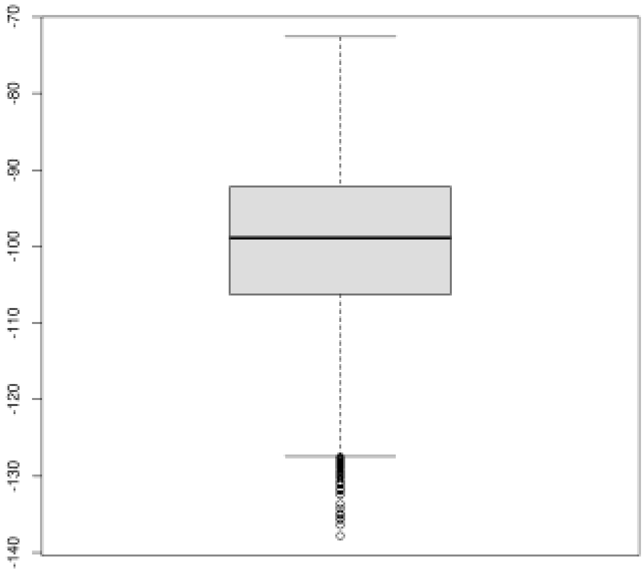


Figure 6 : Boxplot statistical summary of RHSP 4G of Mantasoa

c) Data: Report drive test 5G Antananarivo Zone - Tan_Analakely Site

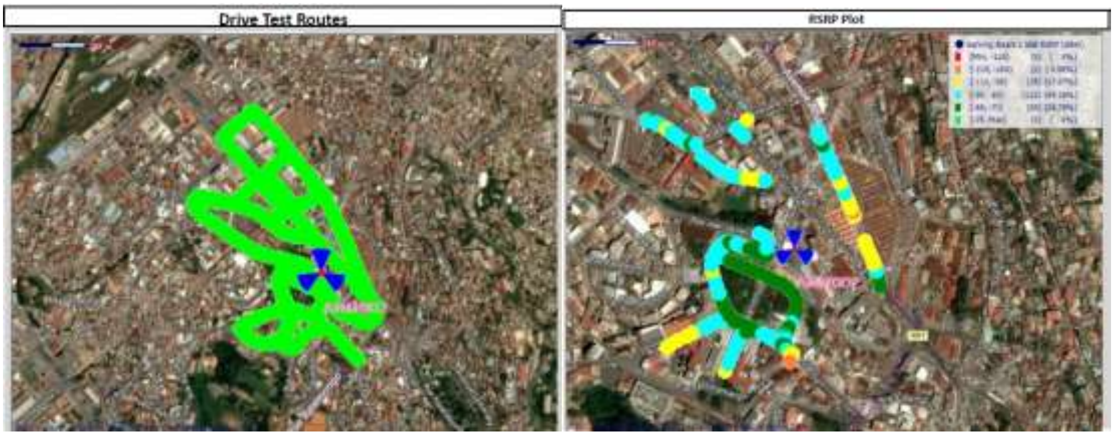


Figure 7 : Travel zone 3 for dynamics analysis

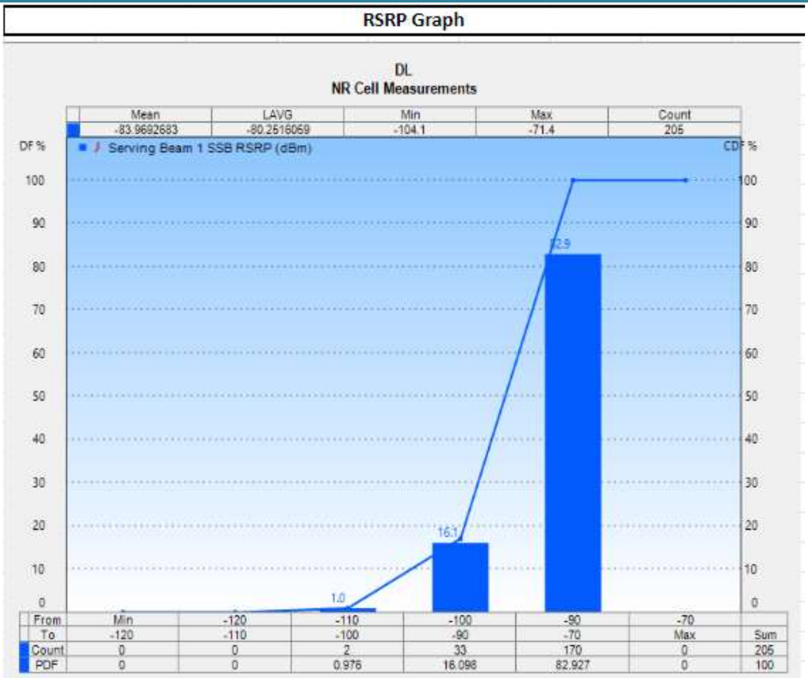


Figure 8 : Statistical summary of data collected Analakely

2) Markov modeling

a) Choice of the markovian model

A stochastic process represents a discrete or continuous-time evolution of a random variable. In cases where the future hazard depends on the present and not on the past, Markovian models can be used. These models have had multiple applications in plant ecology (succession of types of vegetation), in geology (succession of geological layers or sedimentary layers) and, if they have been applied to the dynamics of mangroves, they have not been applied up to now on the scale of a delta and in the joint dynamics of sediment and colonization by mangroves.

The Markov chain is a stochastic process allowing to model the dynamics of a system whose states evolve over time. In practice, we are interested in the Markov chain having the following properties: (1) Discrete-time Markov, described by a sequence of random variables $(X_t)_{t>0}$defined in a discrete state space E such that the transition from a state $X_t = i$at time t the next state $\{X_{t+1} = j\}$at time t+1 is determined by some conditional probability P_{ij}; (2) Markov of order 1, based on the assumption that the future evolution of the process X_{t+1}depends only on its present state X $_t$ which sums up its entire past[11].

$$P(X_{t+1} = i_{t+1}, X_0 = i_0, X_1 = i_1, \dots, X_t = i_t) = P(X_{t+1} = i_{t+1} \vee X_t = i_t) \qquad (1)$$

To construct a Markov chain, it is necessary to define:

- A finite n-dimensional state space E;
- A matrix of transition probabilities between the different states denoted P such that the sum of each row is equal to unity let $\sum Pij = 1$and Pij assumed to be homogeneous over time;
- An initial distribution made up of the initial probabilities of being in the different states, denoted by $\pi_0(i) = P(X_0 = i)$.

b) Markov chain properties

The interest of Markov lies in the possibility of summarising, by describing in a condensed way, the temporal successions of states using a matrix of transition probabilities. The average probability $P_{ij}$of going from state i to state j was estimated empirically by the ratio $p_{ij} = \frac{n_{ij}}{n_i}$(3) where $n_{ij}$is the number of transitions from state i to state j and ni is the number of landscape units (islands) in state i[12].
The most important characteristics of a Markov chain are the possibilities:

- To predict in time t a distribution by the recurrent formula: $\pi_{t+1} = \pi_t * P = \pi_0 P^t$, where π_t a vector of state probabilities at time t;
- To eventually converge to a stationary state π independently of the initial situation satisfying the equation: $\pi \ \ * P = \pi$ (2) under the ergodic hypothesis of the Markov chain.

We choose the first-order discrete-time Markov model because the sample is a set of temporal observations of successions of states in which the next state conditionally depends on the previous state.

RESULTS

To characterize the model, it is necessary to define the initial law and the transition matrix of the Markov chain.

Table 3: Statistical summary of data collected

Level	*4G coverage (dBm)*
Good	*Greater than -105*
Medium	*Between -105 and -115*
Bad	*Less than -115*

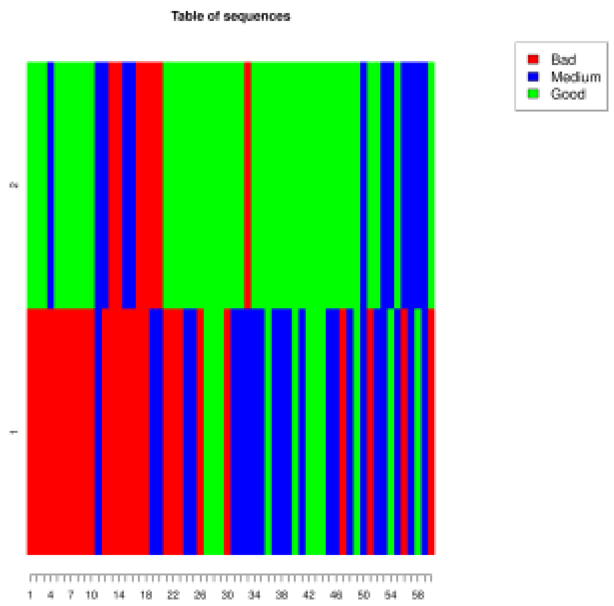


Figure 9: Network state sequence tables

We consider the dataset which represents the succession of quality status of the networks in two evaluation study sites of the "drive test" during 60 minutes of travel. Three qualities of networks have been identified: Good, Average and Bad.

The state space will then be:

E = {Good, Medium, Bad} (2)

We make the assumptions that the succession of lattice states is driven by a homogeneous Markov chain.

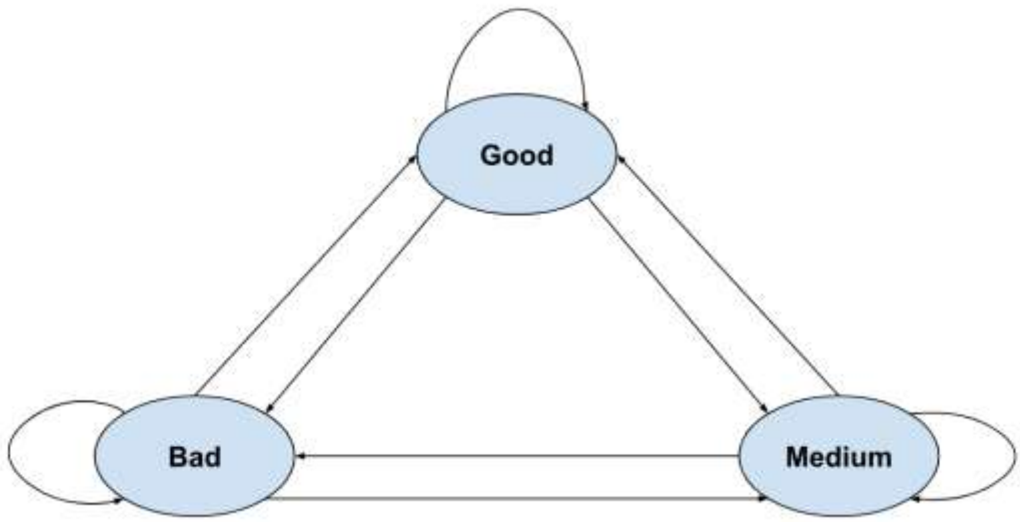


Figure 10: Transition graph between the different states

With the drive test sample, we were able to estimate the transition probability between the three different network states.

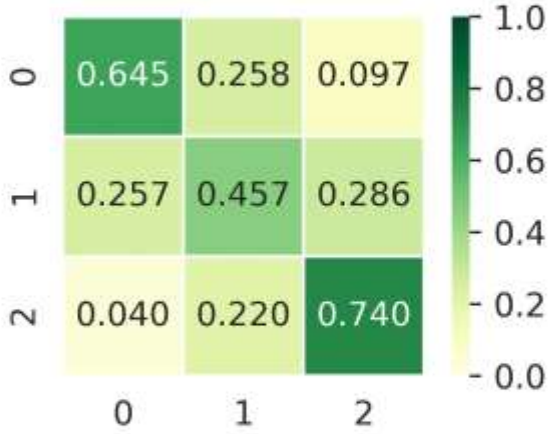
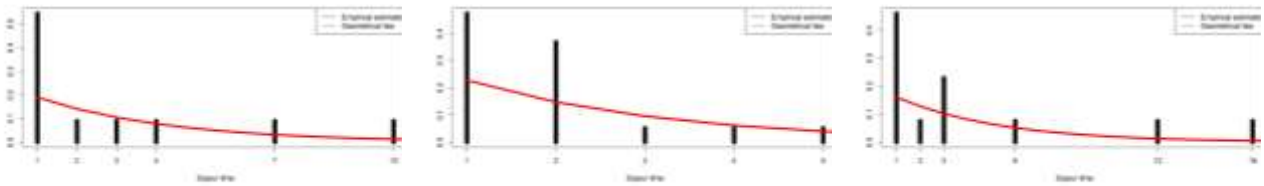


Figure 11: Transition probability matrix

In addition to the transition matrix, the temporal dynamics on the drive test sample will be used to find the residence time law in each network quality state.

Consider a Markov chain with transition matrix Q on a finite state space E. For a state i in E, the residence time S(i) is the time the chain spends in i before moving to another state.



a) Bad quality b) Medium quality c) Good quality

Figure 12 : Law of residence time in a state before transition to another state

On the move, the transition between users' network states is directed by the transition matrix. The drive test sample also allowed us to estimate the expected residence time in each network quality.

Table 4 : Expected law of residence times for each state

Network Quality	**Bad**	**Medium**	**Good**
Expected residence time (in minutes)	2.83 minutes	1.84 minutes	3.92 minutes

DISCUSSION

By applying a mathematical model to the drive, network qualities are tested in a travel zone. We can see that during a journey, the user is faced with a dynamic variation in network quality. The model was able to summarize the laws of dynamics, but also to measure network quality in a travel zone. On average, network quality remains good for only 4 minutes. This justifies the focus of our article on the need to adapt digital services for mobile network users on the move. Existing quality measurement methods are all based in one area, but here we've considered the fact that users may be on the move. But to improve the study, it's better to work in continuous time than in discrete time, which is the limit of this study. For application producers dependent on mobile networks, the challenge is "How to ensure continuity of service, whatever the quality of network coverage in the user's location and at all times".

CONCLUSION

The aim of this study is to model network state dynamics to summarize the law of dynamics and also to evaluate the network in a travel zone in Madagascar. Starting with a drive test carried out in a travel zone, we discretized the results to obtain three states: Bad, Medium and Good; then, we applied a Markov chain to obtain the transition probability laws between the three states; and finally, we obtained the laws that determine the residence times in each state. This method not only enabled us to summarize the dynamics, but also to evaluate the networks on the move. We can see that in Madagascar, the quality of moving networks is still poor. It is therefore appropriate to develop telephone applications adapted to the dynamics of network quality, which is a prospect in the face of these network dynamics in Madagascar.

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