Proposal to Reduce the Computational Cost of Wireless Network Selection Process

Francirley Resendes Borges Costa and Claudio de Castro Monteiro
Network Computer Group - GREDES
IFTO Federal Institute of Education, Science and Technology of Tocantins
Palmas, Brasil
fborges@ifto.edu.br, ccm@ifto.edu.br

Abstract—**The network selection process has been widely studied in recent years as a result of technological evolutions which has been presented to the user with ease of access involving issues related to mobility and ubiquity of access to data. Thus, several proposals have already been presented, always showing a lot of variables that need to be considered for a good selection. However, these solutions presents a computational cost that grows with the complexity of the technique used, the number of variables involved and the ways of collecting these variables. The most common solutions, and still used in smart-phones and tablets, are those based on the signal level measured at the interface of the mobile, due there is no incremental computing cost to devices, maintaining these solutions as feasible. Therefore, this paper proposes a new metrics based on a mapping between the variables of network QoS (delay, jitter and packet loss) and the signal level, presenting, through experimental tests, prediction equations these variables based only on signal level measured at the device interface. The validation of the metrics is presented using a simple network selection algorithm, operating in an environment with two independent and overlapped WLANs and no distribution system, comparing the results obtained with the proposed metric and WLAN-First algorithm, present in most of smart-phones and tablets today.**

Keywords-WLAN; RSSI; QoS

I. INTRODUCTION

Nowadays, it is common the access to wireless networks, being those, the most diverse kinds. It is also increasing the popularization of devices, like smart-phones and laptops. Besides providing this technology with affordable prices, it offers an enormous mobility because the user can move it easily, keeping always best connected to the networks.

The access to multimedia content, like videos, songs and others, through the Internet is an example of services consumed by this increasing demand of users. These users do not want only to keep best connected, but also, to enjoy of a connection with quality of services.

To define what would be the best network for devices that use wireless networks, it is necessary several requirements analysis, what generate high computational cost. The network selection needs take in account the quality of experience of the users during a connection, without generate incremental computational cost. However, today, this is a big problem.

It is noticed that there is a challenge when we speak of network selection. Efficient Techniques to choose a better connection for these multiple devices are still are searched for researchers. This study looks for a solution with low computational cost, but efficient that could solve this challenge. Considering that the computational cost to measure the signal level information is minimum, the study seeks, through experiments, to relate such parameter with the QoS network, proposing in this way, a metric that can be used on the mobile devices as an alternative to the algorithm WLAN-First currently used.

The article is organized the following way. In Section II, we present some theoretical references for the work understanding. In Section III, we present the proposal, determining the objectives, beside of where and how the processing will be done. In Section IV, we present the "test bed" and methodology used for the realization of the study, like equipment and statistical studies about the data collected. In Section V, we present the results of the study and the models of network QoS prediction from the variables studied. In Section VI, we show the final considerations and some future work proposed.

II. RELATED WORKS

During the bibliographic survey done for the realization of this research, we found assignments [1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11] that show the signal level, measured on the mobile devices as a parameter to select networks.

Some of them use methods of artificial intelligence, by combining many networks variables (including signal level), determining which is the best network in a available group [3], [4]. Other authors use methods of decision making (MADM) to realize the same task [5], [6]. Other works present solutions for handover prediction based only in the signal level [7], [8]. Nevertheless, there is still a problem to solve in network selection scenario: How to establish what is possible to be done considering the computational cost added to the mobile device? Considering that the most efficient solutions for the networks selection has been focused on mobiles [1] and [2], the increasing of computational cost must be taken into account, in order to the applications can be feasible.

This way, even knowing that the level of the signal measured in a wireless interface of a mobile device, it not represent, in most cases, the quality of the service provided by a network [9] [10], this work was motivated by the fact that to measure the power of the signal on wireless interfaces, a device does not have increasing computational cost. This way, the study was conducted on an experimental basis, with a purpose to verify traces that could determine a relationship between the main network QoS variables (delay, jitter, and loss) and the signal intensity (RSSI) measured on the device [11].

III. PROPOSAL

Normally, modern equipments of wireless access, have the possibility to access and/or migrate between various networks at any moment. However, there is a diversity of parameters that influences the networks selection, mainly, when the focus is QoS. Due to complexity of this process, variables and context to consider, such techniques have not become yet, a pattern adopted by the industry, that continues to insert on its mobile devices, algorithms of network selection, based on methods/criteria not efficient [12].

Through statistic methods, this work seeks to predict the value of the other variables that affect the network quality. Thus, the primary objective of this work is to propose a metrics to be used in a mechanism of network selection that presents low computational cost (resulting also in energy saving). The hypothesis is based mainly on the relationship between signal level and QoS variables (delay, jitter and packet loss), that affect directly the QoS of the networks in general.

This way, a practical scenario was mounted for measuring the involved variables and a collector algorithm was proposed and validated with an implementation. This algorithm can be seen in Figure 1.

A. Sample Collector

The first stage of the work was to develop a software to make the automatized collect of the necessary variables for the studies. In this case, we develop a program in C, receiving as parameters: i) the destination IP address (Host); ii) the quantity of ICMP requests; iii) the output interface, and iv) the number of iterations that it will be realized in each point. The number of iterations indicates how many times the group of requests will be executed at the point's collect.
After the execution of the routines, a file with the following data for each iteration is generated:

- Average delay: variable that stores the mean delay of the requisitions;
- Average jitter: variable that stores the mean jitter of the requisitions;
- Quantity of packet loss: variable that stores the quantity of requisitions ICMP that did not achieve its destination;
- Average network signal: variable that stores mean level of the wireless network signal over iteration.

When the program executes the ICMP requests, it creates a new process, in order to verify and store the signal level, until the end of every the set of ICMP requests. The algorithm follows the steps illustrated in Figure 1.

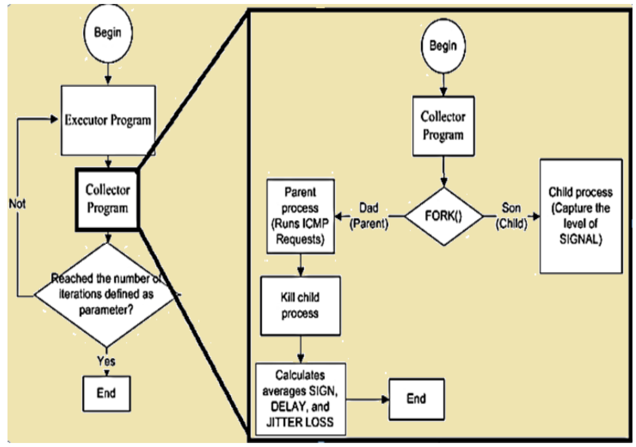

Figure 1. Collector algorithm.

In Figure 1, it is noticed that the algorithm uses two programs, one named **executor** and the other named **collector**. The first makes the call of the second according to the number of iterations defined via parameter. On the other hand, the second, divides its processing into two processes where one realizes the ICMP requests and the other stores the signal level. When the father process finishes its execution, it finishes the process son itself, calculating the averages of the collected values. The program verifies if the number of iterations was achieved. If yes, the program is finished; otherwise, the executor program calls the collector until it achieve the number of iterations established.

B. Environment Used

We define ten points, at ten meters from each other one. Every points were defined as illustrated in Figure 2. The set of points and the distance between each one of them, were defined following a straight line from the wireless network (Access Point – AP).

Figure 2. Collection Points

The coordinates of the points were collected using a GPS (Global Position System) data test. The location of each point is shown on Table I.

TABLE I. COORDINATES

POINT	COODINATES	
0	10°11'58.95"S	48°18'48.13"W
1	10°11'58.60"S	48°18'48.14"W
2	10°11'58.28"S	48°18'48.15"W
3	10°11'57.96"S	48°18'48.15"W
4	10°11'57.62"S	48°18'48.14"W
5	10°11'57.31"S	48°18'48.15"W
6	10°11'56.99"S	48°18'48.15"W
7	10°11'56.65"S	48°18'48.15"W
8	10°11'56.30"S	48°18'48.15"W
9	10°11'55.95"S	48°18'48.15"W

We try to avoid obstacles like walls, uphills, downhills, among others. The point 0 (zero), showed in Figure 2, is where the AP is located, but also, it is the first point's collect.

IV. METHODOLOGY

The equipments used were two notebooks model ASUS EEE PC 1001PX, considering that one had the Access Point function and the other had the client station function. The wireless devices on the notebooks are ATHEROS AR9285 model. Every the tests were realized, exclusively, with these equipments. The operating system used was LINUX UBUNTU version 11.04. The wireless network model used was the Ethernet 802.11g.

Then, with the collector program, five iterations of six thousand requests were performed at three point's collect, constituting the pre-sample of data. These parameters were chosen randomly, using the statistical calculations to define the ideal set of the collect.

The studies were realized to define how many iterations and how many requests per iteration should be done at each point's collect. Through the normal distribution, we can calculate the size of set of tests.

First, it was necessary to define the number of ICMP requisitions for each iteration. For this, through the pre-sample of data, cited previously, and with only the data of one iteration of each one of the three points, we obtain the following results, shown in the Tables II and III:

TABLE II. STANDARD DEVIATIONS AND QUANTITY OF LOSS OF THE COLLECTION POINTS

Variable	Point 1	Point 2	Point 3
Packet loss (dgram)	74	102	91
Delay (ms)	16,61	11,56	19,8
Signal level (db)	1,94	1,49	1,11
Jitter (ms)	23,11	15,55	27,51

a. dgram = Datagrams;
b. ms = Miliseconds;
c. db = Decibels.

TABLE III. IDEAL QUANTITIES PER VARIABLE REQUISITIONS

Variable	Point 1	Point 2	Point 3
Packet loss (dgram)	384	784	476
Delay (ms)	5270	2806	4568
Signal level (db)	3136	2401	1739
Jitter (ms)	6147	5270	9604

In Table II, there are the results from the standard deviations of the points 1, 2 and 3. In Table III, the quantities of requests necessary for each iteration are presented, by considering the observation of each variable analyzed. The biggest value found was of the jitter analysis (9604); therefore, the value adapted for the number of the test was rounded to 10,000 requests. With these data it was possible to estimate the Confidence Intervals (C.I.).

In previous studies, we notice that even collecting the data at the same point, some factors can change the values of the variables studied, therefore, it was necessary to estimate how many iterations should be done at each point. To define the number of ideal iterations, we used the same method previously described. The results are exposed in Table IV.

TABLE IV. IDEAL QUANTITIES OF ITERATIONS PER VARIABLE.

Variable	Averages (AVG)	Standard Deviation	Error	Ideal Sample
Delay	3,98477	0,826	0,194	69,575
Signal	62,07 %	0,998	0,235	69,347
Jitter	4,13384	1,040	0,250	66,515
Packet loss	130,2	122,328	29	68,355

In this case, we use the averages of the five iterations, instead of one. Another information that also must be quoted, is the error considered. The value of the error was defined through diverse considerations to enable the feasibility of the study. Some example of this is: i) the time for collecting; ii) climate factors and iii) the capacity of the equipment's battery.

With the data analysis, we can observe the values in Table IV, are around to seventy (70). Therefore, we use this value as the ideal number of necessary iterations at each collection point. After the collect, we calculate the confidence interval, with a significance level of 95%. These values may be visualized in Table V. The delay information and jitter are presented in milliseconds (ms), while the signal, in decibels (db) and loss, in datagrams (dgram).

TABLE V. CONFIDENCE INTERVALS

P[i]	Variable	Standard Deviation	avg	C.I. α=95%	Min Margin	Max Margin
0	Signal (db)	0,01520852	69,99	0,004	69,992	69,999
	Delay (ms)	6,18539727	5,989	1,449	4,540	7,438
	Jitter (ms)	2,62774534	2,828	0,616	2,212	3,444
	Loss (dgram)	7,76973211	5,471	1,820	3,651	7,292
1	Signal (db)	1,51335227	42,94	0,355	42,586	43,295
	Delay (ms)	5,45189219	4,790	1,277	3,513	6,067
	Jitter (ms)	2,09261122	1,769	0,490	1,279	2,259
	Loss (dgram)	67,6242572	59,05	15,842	43,215	74,899
2	Signal (db)	1,91760654	33,40	0,449	32,952	33,850
	Delay (ms)	60,1989292	37,96	14,102	23,866	52,071
	Jitter (ms)	5,82958986	7,275	1,366	5,909	8,641
	Loss (dgram)	69,2890859	436,5	16,232	420,29	452,76
3	Signal (db)	0,85534434	39,41	0,200	39,213	39,614
	Delay (ms)	4,39566103	3,565	1,030	2,535	4,594
	Jitter (ms)	1,58620896	1,197	0,372	0,825	1,568
	Loss (dgram)	63,0608566	73,22	14,773	58,456	88,001
4	Signal (db)	1,22242838	37,44	0,286	37,156	37,729
	Delay (ms)	208,923603	131,2	48,943	82,308	180,19
	Jitter (ms)	21,9951686	18,47	5,153	13,326	23,631
	Loss (dgram)	81,6578087	200,7	19,129	181,59	219,85

5	Signal (db)	1,09617497	42,84	0,257	42,587	43,101
	Delay (ms)	32,0866230	19,27	7,517	11,759	26,793
	Jitter (ms)	4,88242644	6,525	1,144	5,381	7,669
	Loss (dgram)	47,5931711	98,18	11,149	87,037	109,33
6	Signal (db)	0,93811564	30,20	0,220	29,983	30,422
	Delay (ms)	2405,75533	682,7	563,57	119,16	1246,3
	Jitter (ms)	25,8061138	21,77	6,045	15,724	27,815
	Loss (dgram)	647,759259	469,9	151,74	318,22	621,71
7	Signal (db)	1,11200051	39,01	0,260	38,749	39,270
	Delay (ms)	33,9789006	16,58	7,960	8,628	24,548
	Jitter (ms)	5,42724717	4,583	1,271	3,312	5,855
	Loss (dgram)	79,0995925	119,5	18,530	100,99	138,05
8	Signal (db)	1,40141661	31,61	0,328	31,287	31,944
	Delay (ms)	144,401208	58,39	33,827	24,565	92,220
	Jitter (ms)	12,8705671	9,183	3,015	6,168	12,198
	Loss (dgram)	241,156497	323,9	56,493	267,42	380,4
9	Signal (db)	0,46778293	21,27	0,110	21,161	21,380
	Delay (ms)	7983,11352	7736	1870,1	5866,7	9607
	Jitter (ms)	85,1955070	136,2	19,95	116,30	156,21
	Loss (dgram)	2392,03947	3477	560,3	2916,7	4037,4

P[i] = Pont in Position i, from 0 to 9.

V. Results

With the ideal collect finished, the next step was to seek the QoS prediction models, through of relationship between the variables studied. For this, we use techniques of linear regression (multiple and simple); therefore the prediction model was determined like illustrated on the equation 1.

$$Y = b_0 + b_1.x_1 + b_2.x_2 + b_3.x_3 \qquad (1)$$

where:

- Y = Dependent variable;
- b_0 = Linear adjustment coefficient;
- $b1,2,3$ = Coefficients of the variables 1, 2 e 3.
- $x1,2,3$ = Average values of the independent variables 1, 2 e 3.

In this work, we study, always, four variables: signal level, delay, jitter and packet loss, with one of them is considered as dependent variable and the other three are considered as independent variable. In this context, four models of prediction were found, but only three of them have shown coefficient of determination to validate the prediction. These models are shown in Table VI.

TABLE VI. Models of prediction.

Depend variable	Prediction model equation	(R^2) coeficients of determination
Delay	$Y = 320,5642 -26,928925x_s + 47,1463341x_j +0,0127093x_p$	0,8822654429
Jitter	$Y = 23,3186 +0,0144121124x_a - 0,381432x_s +0,002428774x_p$	0,9843574233
Loss	$Y = 584,8607 + 0,3679054x_a - 1,12599x_j - 9,5240063x_s$	0,9739415504

a. Xa = Average delay;
b. Xj = Average jitter;
c. Xp = Average loss;
d.Xs = Average signal.

R2 indicates how much of the variance of Y can be represented by the variance of the independent variables. The values of R2 are in the interval between 0 to 1, where 1 indicates that model is more accurate. For example, in Table VI, the variance of the depend variable delay presents values around 88.23%, considering the group of independent variables: signal, jitter and packet loss.

In real environments, these variables cannot exist separately. It is not possible to observe jitter without observing delay, besides of the loss of datagrams being inherent to network environments. Beside the multiple regression model is the most efficient to predict values, analyzing more than one variable, it is not indicated in this case. In this sense, due the needy to analyze the impacts caused by each one of the QoS variables, we use for analysis, the models of simple regression, considering only one variable at each time, in order to verify the relationship with the signal level variable.

A. QoS Models of Prediction with Simple Regressions.

The models of simple regressions relate only two variables, therefore, with the value of one of them, it is possible to predict the value of other one. This models are used, in this work, to obtain a model of prediction.

We use the collected data in some simple regression models and we notice that both exponential and potential models has been goods correlation coefficients. The Figures 3, 4 and 5 illustrate a graphic analysis of the data, showing relationship between the variables: loss, delay and jitter to the signal level. Tables VII and VIII present the coefficients of determination found.

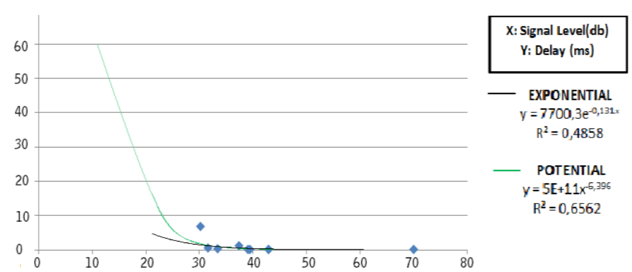

Figure 3. Relation signal level and delay.

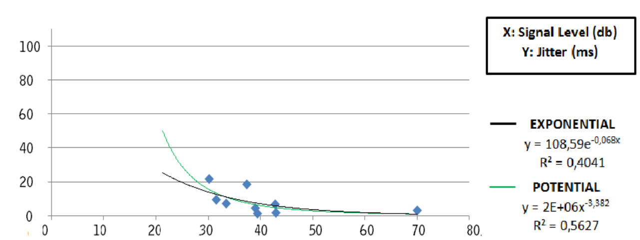

Figure 4. Relation signal level and jitter.

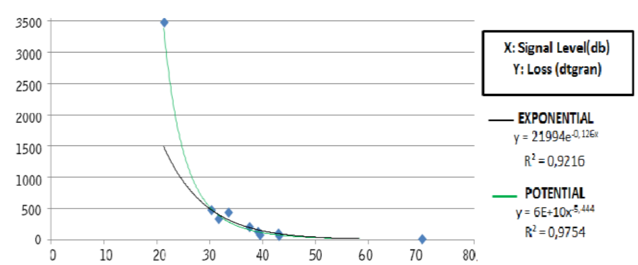

Figure 5. Relation signal level and loss.

TABLE VII. MODELS OF PREDICTION WITH EXPONENTIAL REGRESSION.

Depend variables	Prediction model equation	(R^2) coeficients of determination
Delay	$y = 7700{,}3e^{-0{,}131x}$	0,4858
Jitter	$y = 108{,}59e^{-0{,}068x}$	0,4041
Packet loss	$y = 21994e^{-0{,}126x}$	0,9216

TABLE VIII. PREDICTION MODELS WITH POTENTIAL REGRESSION.

Depend variables	Prediction model equation	(R^2) coeficients of determination
Delay	$y = 5e{+}11x^{-6{,}396}$	0,6562
Jitter	$y = 2e{+}6x^{-3{,}382}$	0,5627
Packet loss	$y = 6e{+}10x^{-5{,}444}$	0,9754

We notice, through Figure 5 and Tables VII and VIII, that the relationship between signal level and packet loss is the most explained by the regression models. In the exponential and potential models, the determination coefficients (R2) show more than 92.16% and 97.54% respectively, when predicting the values of the variable Y (loss). In other cases, Figures 3 and 4 and also through Tables VII and VIII, for both delay and jitter, the better results are obtained for the potential regression, respectively. The coefficients of determination achieve around 65.62% and 56.27%.

The purpose of the study was achieved in potential model, because only with the value of the variable signal level was has been possible to predict the other 3 variables, independently.

B. *Validation of the proposed models*

To realize the validation of the models found for the prediction of each QoS variable, in function of the measured signal level, it was mounted an environment with two overlay WLANs, without distribution system. In a mobile device, model SAMSUNG P6200, it was implemented a simple algorithm based on the models presented in this work.

We use the described environment to transmit a video sequence known as highway, containing 2000 frames in the QCIF format, using a video server based on the VLC software. Beside this, we consider the threshold of 20 packets loss to be used by algorithm to choice between the networks.

By considering always a level of trust of 95%, we realize 10 groups of tests, each one with 100 transmissions of this video sequence, from the server to the mobile. During the transmissions, we capture, using ICMP requests, from the mobile to the gateway of the two WLAN networks available, the values of the datagrams loss. During every transmissions, the mobile was submitted to a movement that allowed a large variations at the signal level measured on each network, aiming to test of the model found. The results can be seen in Figures 6 and 7.

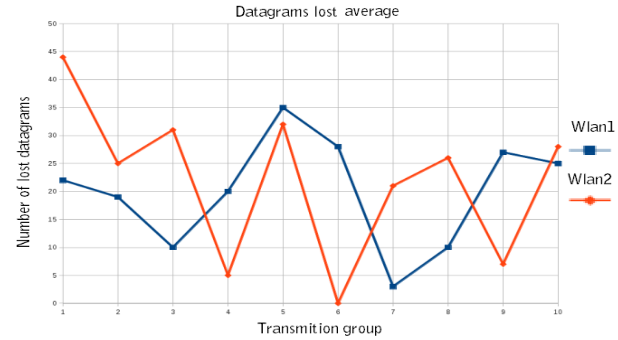

Figure 6. Average Datagram Loss Measured by the Mobile on WLAN1 and WLAN2.

Figure 7. RSSI measured on the Mobile of WLAN1 and WLAN2

As we can see in Figures 6 and 7, the algorithm of network selection, proposed based on the presented model, did the change of network whenever the datagrams loss was above the threshold, providing the user with a better experience in the reception of services on its own devices.

An example can be seen at the point referring to the sixth group of transmissions, where the average value of RSSI for WLAN1 was 60db and the loss for the same network was of 28 datagrams. Meanwhile, for WLAN2, RSSI was lower, 53db and the loss of datagrams was null. In this case, while WLAN-First didn't show sensibility, indicating to the mobile that it should remain in the same network (WLAN1), the algorithm based in the our proposal, had recommended to the mobile, the change of network to WLAN2. Even this network having a smaller RSSI, the proposed model for datagrams loss showed to be efficient, suggesting the change to a network with less loss. Meanwhile, using the traditional algorithm, native of the device (WLAN-First), the mobile remained in its origin network from the beginning until the end of the video sequence transmissions, not taking into consideration the losses of the network.

Similar results were found using the prediction models proposed for delay and jitter, characterizing that the proposed models can be used together or separated, depending of the traffic type considered by the network selection.

We notice that the results of this work do not increase the computational cost to the device, demonstrated by the battery consumption, if compared to the WLAN-First algorithm, as in Figure 8.

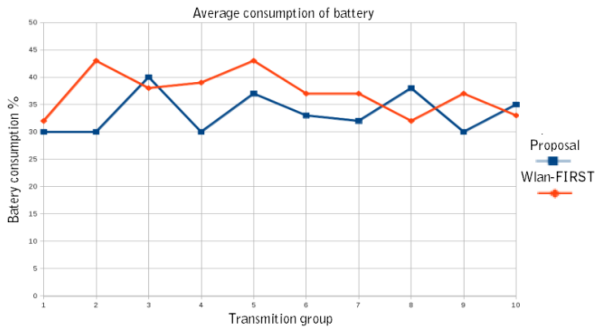

Figure 8. Percentage of consumed battery

In Figure 8, it is possible to observe that the battery consumption of our proposal did not change, if compared to WLAN-First algorithm. Considering that WLAN-First adopts the strategy of keeping the mobile always connected to a WLAN, without considering the QoS network, we can affirm that our proposal achieved better results, basically with the same battery consumption.

VI. Conclusion and Future Works

As we presented before, there are no efficient computational network selection techniques available. This study presents satisfactory results, showing that there is a relationship between the variables studied. Table VI shows satisfactory results, reaching coefficients of determination in the interval between 0 and 1.

With simple regressions, it was possible to determine R2 to each one QoS variables, noticing, that, in 97.54% of the cases, it is possible to predict the loss of datagrams on a network, through of the signal level measured. Even without having an expressive relationship between other QoS variables, delay and jitter present coefficients, in order to show that there is a relationship with the signal level.

We can notice, then, that it is possible to achieve success in the development a technique of network selection with low computational cost and efficient. Even that any data has presented values with a low relationship, it is possible to determine some variables, that affect directly the QoS of a network observing the signal level only.

However, the proposed environment shows only a portion of the possible environments, some aspects need to be better investigated and yet improved, facts that is being studied.

A study mixing both simple and multiple regressions can result in more accurate values. Besides this, the proposed model here can be expanded and generalized to other test beds, using mathematical tools more elaborated that can verify other non-linear relationship between the variables.

References

[1] C. C. Monteiro, "Um ambiente para apoio à integração de redes sem fio heterogêneas", Doctoral Thesis. Submitted to the Department of Electrical Engineering. University of Brasília, Brasília, June 2012.

[2] V. M. Rios, "Seleção de redes sem fio baseada em técnicas de apoio à decisão.", Master's thesis submitted to the Department of Electrical Engineering. University of Brasília, Brasília, June 2012.

[3] R. B. Ali and P. Samuel. "On the Impact of Soft Vertical Handoff on Optimal Voice Admission Control in PCF-Based WLANs Loosely Coupled to 3G Networks", IEEE Transactions on Wireless Communications 8, pp. 1356–1365, March 2009.

[4] S. Das, "et al", "IEEE 802.21: Media Independent Handover: Features, Applicability, and Realization", IEEE Communications Magazine 47 (1), pp. 112–120, January 2009.

[5] A. De La Oliva, "et al", "An Overview of IEEE 802.21: Media-Independent Handover Services", Wireless Communications, IEEE 15 (4), pp. 96–103, August 2008.

[6] M. Kim, T. Moon, and S. Cho, "A study on IEEE 802.21 MIH Frameworks in Heterogeneous Wireless Networks", 11th International Conference on Advanced Communication Technology-Volume 1, IEEE, pp. 242–246, South Korea, February 2009.

[7] C. Lim, D. Kim, O. Song and C. Choi, "Share: Seamless Handover Architecture for 3G-WLAN Roaming Environment", Wireless Networks 15, pp. 353–363, April 2009.

[8] P. Machan, S. Serwin, J. Wozniak, "Performance of Mobility Support Mechanisms in a Heterogeneous UMTS and IEEE 802.11 Network Offered Under the IEEE 802.21 Standard", 1st International Conference on Information Technology, IEEE, pp. 1–4, Nice, May 2008.

[9] E. Stevens-Navarro and V. W. S. Wong, "Resource Sharing in an Integrated Wireless Cellular/WLAN System", Canadian Conference on Electrical and Computer Engineering, CCECE, 2007, pp. 631–634, Vancouver, April 2007.

[10] Y. Wang, H. Lo, Y. Li, and W. Lee, "Seamless Handover with Buffer Prediction for Wireless Networks Based on IEEE 802.21" International Conference on Information Networking, LNCS, 2008, pp. 1–5, Tokio, January 2008.

[11] Y. Wei, Y. Hu, and J. Song, "Network Selection Strategy in Heterogeneous Multi-Access Environment", The Journal of China Universities of Posts and Telecommunications 14, pp. 16–20, China, October 2007.

[12] F. F. Silva, "Jornalismo live streaming: tempo real, mobilidade e espaço urbano", VI National Meeting of Journalism Researchers, pp. 1-4, Universidade Metodista, São Paulo, November, 2008 .