

WI-FI NETWORKS IN HFC CABLE NETWORKS - HOW TO UNDERSTAND AND MEASURE USER QUALITY PROBLEMS IN A WIRELESS ENVIRONMENT

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An initial effort to try to bring the quality of service of our carrier grade high speed data node based service from cable network, to a cell wireless network, presenting the concept of WUEQi (Wireless User Experience Quality index).

ABSTRACT

In this paper, is presented the concept of WUEQi, an index like a MOS index, to give ability for cable operators that are deploying Wi-Fi networks to have better control of this technology to deliver services. Looking basically to give to the users a better user experience and to the operator a good way to plan the expansion of the Wi-Fi network.

Keywords

Wi-Fi, Wireless networks, CATV, Strand mount AP, average power, EIRP, antennas, user experience, DOCSIS.

1. INTRODUCTION

Today with the dissemination of a new generation of very powerful mobile devices such as smartphones and tablets the way of our society communicate and consume information is changing, creating an exponential rise in the importance of mobility services, with the anything, anytime, anywhere concept. With this in mind a lot of cable MSO are dealing with a new and different ways to deliver mobile services to their customers with the deployment of wireless networks over the cable HFC plant.

With the proliferation of mobile devices the bandwidth requirements in the traditional mobile networks has also change pushing these mobile operators to find new ways of deliver these services with adoption of new technologies and that search can be a very good opportunity for the cable industry as well, since the deployment of this networks over the cable HFC plant can be very fast and efficient.

One technology that is getting a very big attention of the market right now is Wi-Fi. The

Wi-Fi standard today is undoubtedly the most heavily used wireless technology in terms of number of devices that is capable of use the technology and as the amount of data traffic transmitted over networks using this wireless technology. The technology is very mature and in any report that you have access to, it is set that around the world, millions and millions of devices such as smartphones, tablets, netbooks, notebooks, TVs, STBs, home gateways, even cars and refrigerators has embedded and certified chipsets with this technology and this number is growing, actually skyrocketing each day. That is why deploy a Wi-Fi network is a very attractive option to any convergent operators to give fixed broadband customers the mobility that they look forward.

But unlike from the common sense thinking that says the Wi-Fi technology is a very mature technology, this standard is not mature yet to deploy a service provider type of network. This is very easily pointed by the fact that to gain the scale of number of devices, this standard utilizes non license frequencies and since it is inherent to a wireless network (different to a cable HFC that is confined cable network) this type of solution deals with devices that are moving, unstable customer demands and different device power transmission that changes the way of get to know, understand and solve the problems that affect the most important thing at the end that is the user experience.

Since motivators of this deployments, in cable could be retention and churn reduction, 3G offload to traditional mobile operators and

location based services, user quality experience is became very important to the SP to provide the service and the use of analytics, throughout the WUEQi, could be the answer to try to have a little control to the chaos of delivering Wi-Fi mobile services to a customer that is used to have the quality of service of our carrier grade high speed data node based service from cable network.

This paper is organized as follows. In the next section we present the advantages of deploy a Wi-Fi network over cable HFC plant. In section 3. Important concepts about Wi-Fi networks deployment (Link budget calculation). Section 4. Show the challenges to deliver good and control user experience to the chaos of a non-license frequency wireless network, the problems about different link budgets with different devices and the concept of WUEQi.

2. ADVANTAGES OF WI-FI NETWORK IN A CABLE ENVIRONMENT

There are three big obstacles that service providers which intend to deploy a Wi-Fi network will probably face, named: reliable powering the access point units, make the backhaul link with Internet traffic to the APs and acquiring mounting sites. These three obstacles can make a huge difference in deploying big networks more efficient. HFC cable networks are already design and build with reliable power supply that can feed the Wi-Fi access point, of course if the access point is capable of handle the power from HFC plant and there is some units at the market that can not only handle but also being mounted in strand, solving the second issue. Also in a cable network the IP connectivity can be delivered in the same cable that is connected to feed the AP throughout the high-speed data DOCSIS network that is already in place. With this issues solved in HFC networks, cable operators will can quickly and easily deploy this wireless networks in the existing plant.

So as shown above, the implementation of a Wi-Fi network in an HFC plant is faster, easier and more efficient but something that we are not used to work and it is a big problem to control is the wireless access part mainly in deal with average transmitted power (TX power from a device) that is going to be translate to coverage and differ from the DOCSIS very much since the cable modem is easily controlled and does not move around. This problem is going to reflect in a bad user experience

3. IMPORTANT CONCEPTS ABOUT WI-FI NETWORKS DEPLOYMENT

3.1 Link Budget

A lot of questions are important when designing a Wi-Fi network such as:

1. What type of devices I want to provide the service?
2. What type of services I want to deliver?
3. What type of environment I am going to deploy the network?

So, with this in mind you can find out how to calculate the link budgets to provide services to the devices that you chose taking in consideration the environment and the services that you want to provide.

In our case we are going to consider 3 devices to provide the services, a typical notebook, a typical table and a typical Smartphone. Of course in a real scenario we are not going to see typical devices but real information that can be get from devices providers, FCC test and in our case ANATEL(Brazil Telecom Agency). Our environment will be a very dense and populated metropolis with a lot of buildings and reflections.

To determine the link budgets we should consider the usage of some models. For a free space, line of sight environment, the propagation law would result in square law decay. i.e. for each doubling

of distance the power drops by 6dB. The free space model is only an idealized model and the real world is not line of sight. There are objects in the environment such as trees, buildings, poles that signals reflect from and with this, the signal can add and subtract to produce a signal that decays faster than the square law.

Below we show a typical configuration of some device that we are going to consider calculating the link budgets.

	AP	Typical Notebook	Typical Tablet	Typical Smartphone
Average Power (A) dBm	21	16	17.5	16.0
Antenna Gain (B) dBi	5	6	2.0	0.0
EIRP (A+B) dBm	26	22	19.5	16.0

Table 1. Typical power of devices

Using some models we can show below the link budget in an urban and very dense city environment.

Link Budget between an AP and a typical notebook:

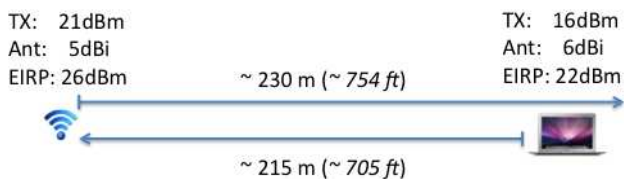


figure 1. Link budget – AP and notebook

So in this case the link budget is limited in 215 meters from the notebook to the AP.

Link Budget between an AP and a typical tablet:

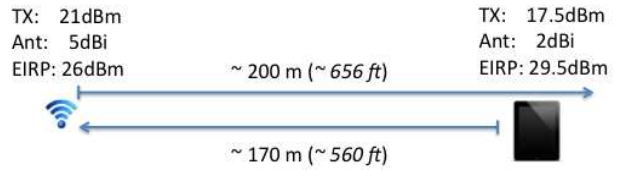


figure 2. Link budget – AP and tablet

So in this case the link budget is limited in 170 meters from the tablet to the AP.

Link Budget between an AP and a typical smartphone:

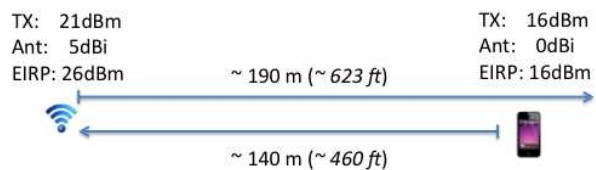


figure 3. Link budget – AP and smartphone

So in this case the link budget is limited in 140 meters from the smartphone to the AP.

This will show to us that the limit of the link budget will be defined by the transmission from device to the AP in upstream direction rather than in downstream direction since the average power transmitted in a downstream direction is bigger than the upstream direction.

3.2 Relation between type of services and SNR

Since the Wi-Fi is a system that uses adaptive modulation, the modulation nominal rate is dependent of the SNR of the link budget that is the difference from the noise floor (typically -90dBm in our city) to the signal that are receive by the device and the access point. Of course this SNR will make our user experience better or worse so we have to consider this in our index.

Below we show a table of typical SNR versus the type of service that is possible to use.

Service	SNR
Video 99% success	≥ 35 dB
Voice 99% success	≥ 25 dB
Web surfing 99% success	≥ 20 dB
Voice 90% success	≥ 20 dB
Email – Web surfing 90% success	≥ 7 dB

Table 2. Tested Services vs. SNR

	Rate (Mbps)	SNR (dB)	Signal Level (dBm)
802.11b (DSSS)	1	4	-81
	2	6	-79
	5,5	8	-77
	11	10	-75
802.11g Data Rate (OFDM)	6	4	-81
	9	5	-80
	12	7	-78
	18	9	-76
	24	12	-73
	36	16	-69
	48	20	-65
	54	21	-64

Table 3. Theoretical table data rate vs. SNR

4. THE CHALLENGES TO DELIVER GOOD USER EXPERIENCE

Since the limit of the link budget will be defined mainly by the transmission from the device to the AP some situations can occur like a smartphone see the network and could not associate (getting a fail association status at the system) or have a small SNR, having a bad user experience, in a place where a notebook can associate.

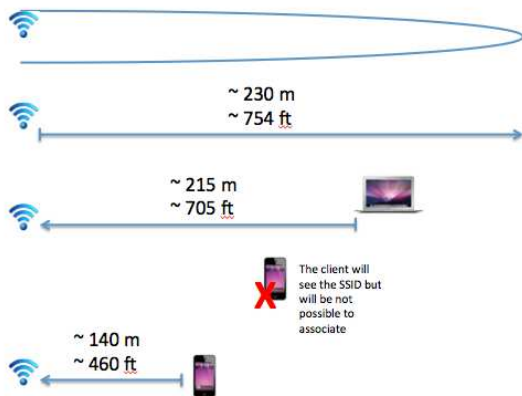


figure 4. Association problem

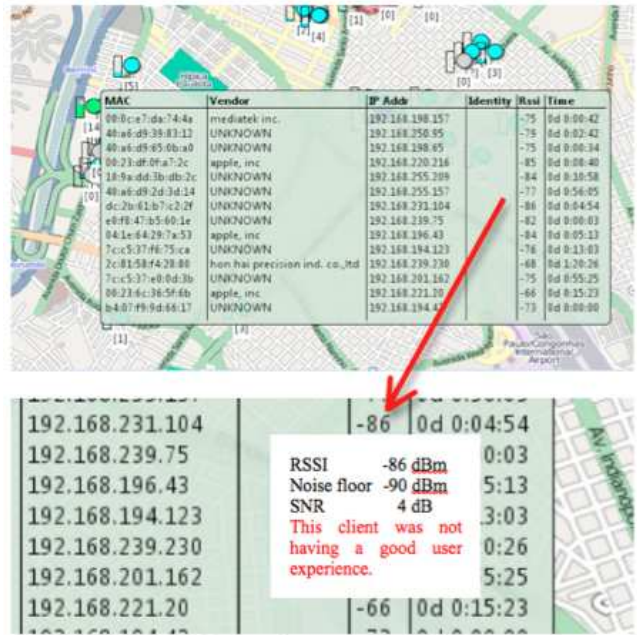


figure 5 – Real network management with customers

The figure 5 above show a particularly customer that was not having a good user experience, what we notice was that this customer could associate, was able to get an IP address (192.168.231.104) but he was not having a good throughput. In this example, we noticed that in most cases the algorithm of the device shown at the screen two of three bar of signal giving the erroneous impression to the user that it has sufficient signal strength to associate or have a good user experience but unfortunately this is not true.

In other cases we also notice another customers with less SNR was not be able to get an IP address because the throughput was too low and another that could not accomplish to associate and generate a trap registering that he had a fail association.

Because of this less control of the CPE and the type of the business models delivered where the product is offered free of charge to the subscriber as an extension of their fixed broadband service, there is a natural tendency to think that if the client can not connect to the Internet in a place where the Wi-Fi network is broadcast, there is no problem because the customer will get another form of connection to solve their connection

issue. This will cause a bad user experience to the client and will surely threatened one of the most important asset that we have that is our brand and also cause a money issue in the project since one of the reason of deploying this network is to retain the customer.

Clearly we need to seek technical "thermometers" so we can monitor the user experience in the wireless network service, not only depending from customer surveys to measure the quality of the service, and try to deliver a wireless services at the same level of quality that our industry is providing carrier-grade services to our customers. That is the difference of being called a carrier grade Wi-Fi service provide

4.1 Wireless User Experience Quality index

Since this problems of low SNR and fail association could occurs, we need to find a way of get, register and understand this data to solve problems like user experience, find places where the signal coverage is not good enough, control the network and know if the network is getting better or worse in time and also with this understanding make the upgrade and make the coverage bigger with a more cost effective way because you with those information can understand better where your customers need coverage. That why we present the concept of WUEQi, that is a index that is a scale of 1 (bad) to 5 (excellent) user quality of experience, similar to a MOS type index.

Variable #1 – SNR of the connection – S
The SNR variable has a weight of 2 in the total.

Margins	S
< 7 dB	1.0
7 dB < S < 15 dB	4.5
15 dB < S < 25 dB	4.9
> 25 dB	5.0

Table 4. "S" variable

Variable #2 – Fail Association - FA
The Fail Association variable has a weight of 3 in the total.

Margins	FA
< 3 fail association in a AP per hour	5.0
3 < Fail Association per hour < 10	2.5
10 < Fail Association per hour < 20	1.0
> 20 Fail Association per hour	0.5

Table 5. "FA" variable

Variable #3 – Get an IP address - I
The fail getting IP Address per hour variable has a weight of 3 in the total.

Margins	I
< 3 fail getting IP address in a AP per hour	5.0
3 < fail getting IP address in a AP per hour < 10	2.5
10 < fail getting IP address in a AP per hour < 20	1.0
> 20 fail getting IP address in a AP per hour	0.5

Table 6. "I" variable

Variable #4 – Medium throughput of the connection - M
The medium throughput of the connection has a weight of 2 in the total.

Margins	M
M < 6 Mbps	1.0
6 Mbps < M < 9 Mbps	2.5
9 Mbps < M < 12 Mbps	4.75
12 Mbps < M < 18 Mbps	4.8
18 Mbps < M < 25 Mbps	4.85
25 Mbps < M < 50 Mbps	4.9
50 Mbps < M < 75 Mbps	4.95
M > 75 Mbps	5.0

Table 7. "M" variable

Using the formulas show below we can find the WUEQi.

$$MT = \frac{\sum M}{\sum users(1h)}$$

$$ST = \frac{\sum S}{\sum users(1h)}$$

$$WUEWQi = \frac{2xMT + 2xST + 3xI + 3xFA}{10}$$

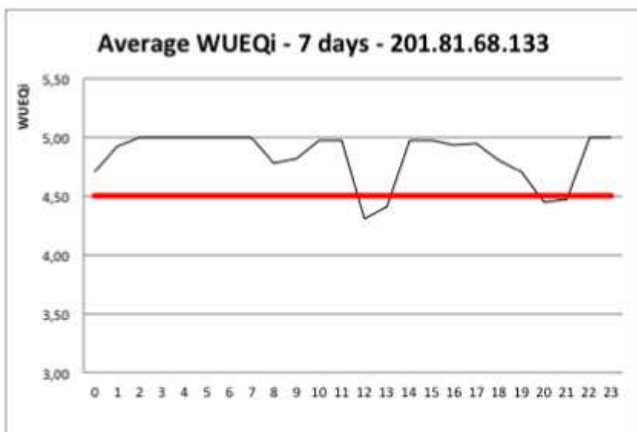
We can calculate from the WUEQi of an AP to the WUEQi of the network using a simple mean formula:

$$WUEWQi(network) = \frac{\sum WUEQi(allAP)}{\#AP}$$

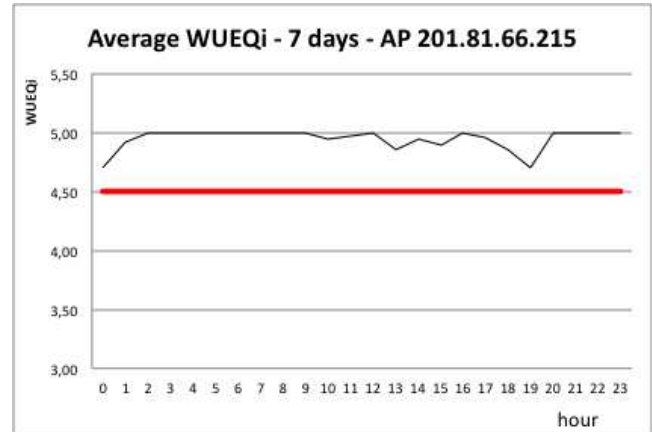
4.2 Using the index

With this index we can identify which access points are facing problems with bad user experience and make site surveys to implement more coverage in the places that the customer are demanding. With this data you can make better planning for the growth of the network, more efficient and cost effective. This index can also keep the track of changes of the network keeping history of the network grade.

The case showed below is an AP that was facing problems with a bad user experience and has to have a survey and make the coverage better.



The case showed below is an AP that has a good compartment



5. CONCLUSION

This work does not intend to be the final word in measuring the quality of service of a Wi-Fi network but a starting point of a more controlled network and a point of discussion. As a service provider, we must have the concern with the quality of any service that our companies are delivering. When we were deploying this network we faced with a lot of our users (testers) saying that in some places they could look the network and connect well, but in other places they found the network associate and could not use the Internet or found and could not associate, so with this concepts we could not only measure the network quality but more important get to know where to focus our effort to make expansion to grow our coverage and serve our customer better.

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