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IP and 3G Bandwidth Management Strategies Applied to Capacity Planning

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1. Introduction

This chapter discusses the application of methodologies to plan and design IP Backbones and 3G access networks for today's Internet world. The recent trend of the multi-frequency band operations for mobile communication systems requires increasingly bandwidth capacity in terms of core and access. The network planning task needs mathematical models to forecast network capacity that match the service demands. As the nature of network usage changed, to explain and forecast the network growth, new methods are needed. In this chapter, we will discuss some strategies to optimize the bandwidth management of a real service provider IP/MPLS backbone and later we will propose a method for traffic engineering in a national IP backbone.

Currently, all telecommunications networks are using IP packets to transport several kind of services. The industry has called this integration as IMS (IP Multimedia Subsystem) in 3G technologies. One important challenge is how to implement this desirable integration with the lack of well known mathematical models to perform capacity planning and forecast the network needs in terms of growth and applications demands. In other way, the main question is how to deliver the required level of service for all kind of applications using the same structure but with different types of traffic and QoS (Quality of Service) requirements.

Due to the fact that many different services will use the same transport infrastructure, the Quality of Service can also be described as a result of traffic characterization because the traffic nature per service or at least per application shall be known. As demonstrated in some research papers (Leland et al., 1994; Carvalho et al., 2009), the Erlang model is not able to accurately describe the behavior of Ethernet and Internet traffic. Without the right model, scientific prediction becomes very difficult and therefore, the planning and forecasting tasks become almost impossible. The above research works verified that the Poisson traffic model is not able to explain the IP traffic dynamics and this implies that the capacity planning tasks for integrated services will need new methodologies. Some models have been used with superior performance to achieve these goals, the self-similar or mono-fractal model show acceptable results in several situations (Carvalho et al., 2007).

Several works show that the multifractal models are particularly promising for multimedia networks (Riedi et al., 2000; Abry, 2002; Fonseca, 2005; Deus, 2007). The traffic

engineering task is valuable to optimize the network resources such as links, routing and processing capacity. One important issue in the traffic engineering task is that the capacity planning forecasting may be for medium long periods (or more than one year), due the fact is not easy to increase long distance link capacities in small periods of time. This problem is much more valuable when the coverage area income is not proportional to the area, as in countries like Brazil, China, Russia in which large areas not necessarily economically attractive.

2. Network planning

The planning task is fundamental to optimize resource utilization. The Fig. 1 describes, from an industry point of view, a complete feasible telecommunications planning cycle. The inputs are the service demands, described as all type of products/services needs per region and also per customer. The physical and logical inventory are very important to be accurate in terms of transmission mediums such as fiber or radio, demographic dispersion, network elements complete description, management assets, and other important physical and logical information.

In terms of innovation, the approach is to use new technologies to achieve new degrees of service delivery; this function shall be used as a complement for planning and forecasting purposes. Other very important function is the economic variables to calculate the return of the investments (ROI) and all other related costs (fixed and variable). All information about traffic usage will be collected and sampled depending on the nature of the service and will have a fast track for immediate operations and decision-making, normally every 5 minutes. For long-term planning these samples will be aggregate in hours, days and weeks.

The functions in Figure 1, in terms of long term capacity will be used to achieve the capacity to deliver new services allowing network expansion related to the inputs, generating new routing and topology and other capacity needs, as described in Figure 1. The traffic engineering function is used in real-time, under human supervision, sometimes even when some modification in terms of routing is proposed by an algorithm. Sometimes, this could not be feasible in practice because network stability is more important in operational environments (Carvalho et al., 2009; Evans & Filsfils, 2007).

The peering agreements will be done as a function of the outputs and also observing the commercial issues. In this way, many service providers have a peering committee to approve new peering interconnections, which has not only a technical importance as well as a marketing approach. The capacity outputs will generate purchasing activities; this will be done by an engineering implementation function. The main objective is to have an operational network, providing all kind of facilities and desirable services.

Along with the massive growth of the Internet and other applications, an increasing demand for different kinds of services for packet switching networks is important. Nowadays, these networks are expected to deliver audio and video transmissions with quality as good as that of a circuit switching network. In order to make it possible, the network must offer high quality services when it comes to bandwidth provisioning, delay, jitter and packet loss.
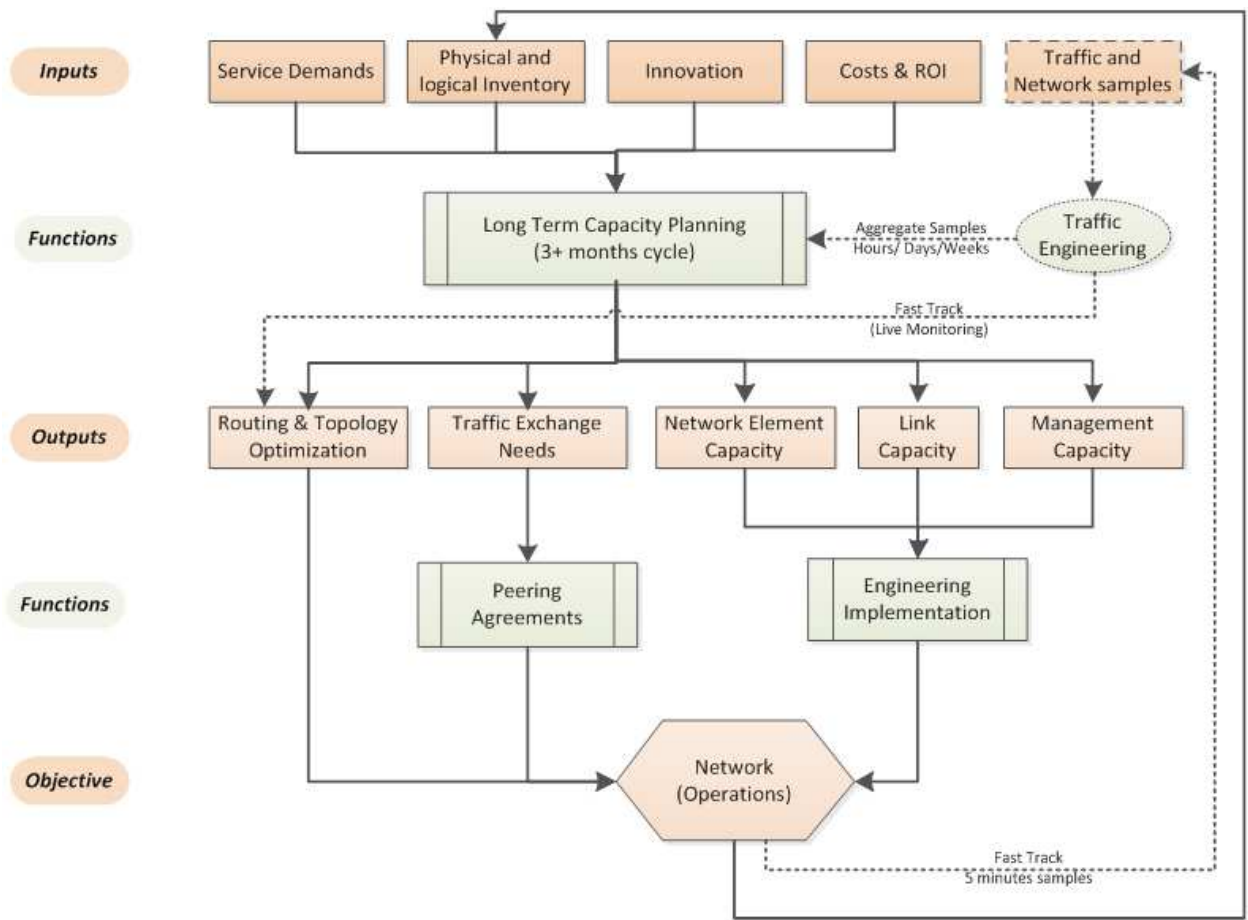
Fig. 1. Telecommunications Industry Planning Process. Adapted from (De Deus, 2007; Evans & Filsfils, 2007).

The processes of traffic characterization and modelling are very important points of a good network project. A precise traffic modelling may allow the understanding of a physical network problem as a mathematical problem whose solution may be simpler. For example, the use of traffic theory suggests that mathematical models can explain, at least for some confidence degrees, the relationship between traffic performance and network capacity (De Deus, 2007; Fonseca, 2005).

The next sections will provide an example on a 3G network using traffic samples to study the planning and project deployment phases. The network described in our study runs with more than 1 million attached 3G costumers with national coverage. In this network, we collected traffic in July 2009 in three different locations (Leblon, Barra da Tijuca and Centro) in Rio de Janeiro. In this way, the first step was to classify the traffic per application. The second step was to characterize the traffic using a procedure based on self-similarity (Clegg, 2005) or multifractal analysis (Carvalho et al., 2009). These results were used as basis for proposing a method to manage the traffic in the network.

To manage the traffic demands, we deployed a traffic engineering concept that divides the traffic across the network through tunnels. The bandwidth was monitored and in the observed period, we collected metrics that were used as inputs to decide how to configure new parameters that may fit the incoming needs. An ILEC (incumbent local exchange

carrier) service provider of IP traffic was used to collect real network traces and we simulated a similar architecture of this network using the OPNET Modeler tool.

A 3G with a Metro Ethernet access was also analysed. The analysis considered a per application separation of traffic. The statistical analysis was done using a self-similarity approach, calculating the Hurst parameter using different calculation methodologies (Abry et al., 2002). Some multifractal analysis was also done as a tool to better choose the time scale.

The results show that the proposed method is able to generate better results in terms of an on-line traffic engineering control and also to provide key information to long term capacity planning cycles. The Traffic Engineering function is detailed using some network simulations examples. Finally, some long term forecasting and short term traffic engineering proposal was done in a 3G networks.

2.1 Traffic modelling in multimedia networks

The traffic modelling and its application to real traffic in operational networks, allows the implementation of research platforms that simulate future or real network critical conditions, which is particularly interesting for huge service providers. Injecting traffic series generated accordingly to mathematical models may help to evaluate several conditions in a network and certainly this may help to develop more accurate capacity planning models regarding specific QoS requirements. Such procedures also facilitate the creation of management strategies. A large number of tools on the Internet provide traffic analysis, like TG (TG), NetSpec (NetSpec), Netperf (Netperf), MGEN (MGEN) and D-ITG (D-ITG) and GTAR, Gerador de Tráfego e Analisador de QoS na Rede (Carvalho et al., 2006), FracLab (FracLab, 2011).

To model the traffic in integrated networks is necessary the use of mathematical models that allow, from its base, to infer the impact of traffic on network performance. The efficient characterization of traffic will be given by the degree of accuracy of the model in comparison with the real traffic statistical properties.

In our work, the characterization of the traffic is used as a key element in the design of complex telecommunications systems. Once characterized, the traffic on different time scales can be used in network simulations. The simulation process can reproduce the behaviour of traffic by application type, for parts of the network, by customer group or interconnections with other networks, opening the possibility to increase the knowledge of the network and making possible a better control of resources.

2.2 Poisson and erlang model

The use of the Internet to transmit real-time audio and video flows increases every day. Some of these applications are transmitted at a constant rate. This kind of traffic results by sending one packet every $1/Tx$ seconds, where Tx is the rate of transmission in packets per second, defined by the type of the application.

In circuit switched networks, a very successfully model is based on the Poisson distribution. The Poisson traffic is characterized by exponentially distributed random variables to

represent the inter-packet times. The Erlang model, broadly used in telephony systems has been successfully used for capacity planning for many years and is based in the premise that a Poisson distribution describes the traffic in this type of network.

The Poisson model was considered accurate in the early years of the packet switched networks and was heavily used for capacity planning. In the early 90's, the work of Leland(Leland et al., 1994) proved that the behavior of the Ethernet traffic was considerably different than Poisson traffics mainly regarding self-similar aspects with long-range dependence, which is not well described by short memory processes. In practice, the packet switched networks that were planned using the Poisson model, normally had an overprovision in links capacity to comply with the lack of accuracy of the model. Considering the different works about capacity planning following the work of Leland, the heavy-tail models were considered more accurate to describe the traffic in packet switched networks and consequently, they appeared as a better choice.

2.3 Self-similar

One kind of traffic that appears often in wideband networks is the burst traffic. It can be generated by many applications such as compressed video services and file transfers. This traffic is characterized by periods with activity (on periods) and periods without activity (off periods). Moreover, as proved in (Perlingeiro & Ling, 2005), (Barreto, 2007), it is possible to generate self-similar traffic by the aggregation of many sources of burst traffics that presents a heavy-tailed distribution for the on period.

The self-similar model defines that a trace of traffic collected at a time scale has the same statistical characteristics that an appropriately scaled version of the traffic to a different time scale (Nichols et al., 1998). From the mathematical point of view, the self-similarity of a stochastic process in continuous time is defined as shown in Equation 1, which defines a process in continuous time X (*t*) as exactly self-similar.

$$X(t) \overset{d}{=} a^{-H} X(at), a > 0 \qquad (1)$$

The sample functions of a process X(*t*) and its scaled version of the a^{-H}X(*at*) obtained by compressing the time axis by the factor amplitudes "a" , can not be distinguished statistically. Therefore, the moments of order n of X(*t*) are equal to the moments of order n of X (*at*), scaled by a-Hn. The Hurst parameter, H is then a key element to be identified in the traffic. For self-similar traffic, the H is greater than 0.5 and less than 1. For a Poisson traffic this value is close to 0.5. Experimental results show that this same parameter in operational networks (Perlingeiro & Ling, 2005; Carvalho et. Al., 2007) has values between 0.5 and 0.95. Then, the parameter H may be a descriptor of the degree of dependence on long traffic (Zhang et al.; 1997).

The aforementioned Hurst parameter plays a major role on the measurement of the self-similarity degree. The closer it is of the unity, the greatest the self-similarity degree. One of the most popular self-similar processes is the fractional Brownian motion (fBm), which is the only self-similar Gaussian process with stationary increments. The increments process of the fBm is the fractional Gaussian noise (fGn). To generate the traffic, we first create a fGn

sequence based on the method presented in (Norros, 1995). Each sample of the sequence represents the number of packets to be sent on a time interval of size T. The size of the time interval and the mean of the sequence generated will depend on the traffic rate.

2.4 Multifractal traffic

As self-similar models, multifractals are multiscale process with rescaling properties, but with the main difference of being built on **multiplicative** schemes(Incite, 2011). In this way, they are highly non-Gaussian and are ruled by different limiting laws than the additive CLT (Central Limit Theorem). Therefore, multifractals can provide mathematical models to many world situations such as Internet traffic loads, web file requests, geo-physical data, images and many others. The Hölder function is defined by the h(t) function.

In the self similar model, also called as monofractal, the Hurst parameter is a global property that quantifies the process changes according to changes in the scale. For multifractal traffic, however, the Hurst parameter becomes less efficient in this characterization and another metric is needed to perform the scaling analysis of the sample regularity.

There are several ways to infer the scaling behavior of traffic, one way is widely used by local singularities of the function. A singular point is defined as a point in an equation, curve, surface, etc., which have transitions or becomes degenerate (Ried et al., 2000). It is quite common that the singular points of the signal containing essential information on network traffic packets.

In order to identify the singularities of a signal, it is necessary to measure the regularity of the same point, which will reflect in burst periods occurring at all traffic scales. In (Gilbert & Seuret, 2000) some examples can be found about the point and the exponents of the local Hölder values making possible to check the degree of uniqueness of network traffic.

According to Veira, (Veira et al., 2000) the Hölder exponent is capable to describe the degree of a singularity. Considering a function $f : R \rightarrow R$, with x_0 as real number, and α a stricted real positive number. It can be assumed that f belongs to $C_\alpha(x_0)$ if a polynomial P_m with degree $n < \alpha$, as shown in (2).

$$\left| f(x) - Pm(x - x_0) \right| \leq C \left| x - x_0 \right|^\alpha \tag{2}$$

As described in (Ludlam, 2004) a multifractal measure P can be characterized by calculating the distribution f (α) , known as the multifractal, or singularity, spectrum where α is the local Hölder exponente (Clegg, 2005 ; Castro e Silva, 2004 ; Vieira, 2006). This measure can be also shown as a probability density function P (x), in this case, the local Hölder exponente (; Gilbert & Seuret, 2000) is defined ad in (7).

$$\alpha (x) = \lim l \rightarrow 0 \log P (\mathcal{B} (1 , x)) \log l \tag{3}$$

where $\mathcal{B} (1 , x)$ is a box centred at x with radius l, and $P (\mathcal{B})$ is the probability density integrated over the box $\mathcal{B}$. It describes the scaling of the probability within a box, centred on a point x , with the linear size of the box.

Each point x of the support of the measure will produce a different $\alpha(x)$, and the distribution of these exponents is what the singularity spectrum $f(\alpha)$ measures. The points for which the Hölder exponents are equal to some value α form a set, which is in turn a fractal object. The fractal dimension of this set can be calculated, and is a function of α, namely $f(\alpha)$.

As described in (2), a function $f(x)$ satisfies the Hölder condition in a neighborhood of a point, where c and n are constants, as in (4).

$$x_0 \text{ if } |f(x) - f(x_0)| \leq c|(x-x_0)|^n \tag{4}$$

And a function $f(x)$ satisfies a Hölder condition in an interval or in a region of the plane, for all x and y in the interval or region, where c and n are constants, as in (5).

$$|f(x) - f(y)| \leq c|x - y|^n \tag{5}$$

3. Traffic characterization

The process of traffic characterization is a preponderant point of a feasible network project. In this section a traffic characterization framework is described. The characterization intends to describe a step by step procedure, which may be useful to understand the behavior of traffic in large networks using a mathematical model as a tool to achieve good planning. One difficult issue to characterize traffic in IP networks is the changing environment due to new applications and new services that are appearing constantly. This implies that the
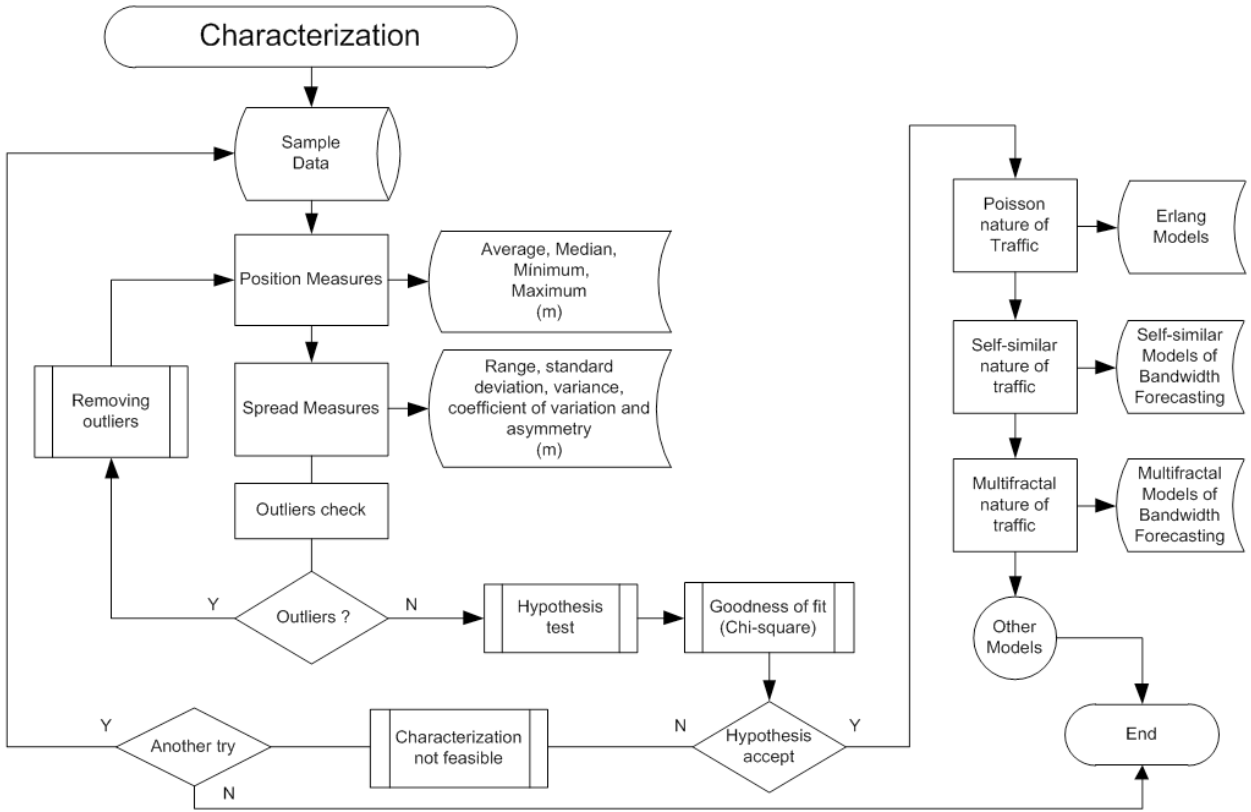

Fig. 2. Characterization process.

characterization used in real environments shall considerer the evolution and the amount of variation in the types of services, including not well known agents as social behavior and emerging applications.

The efficiency in traffic characterization is given by the model accuracy when compared with real traffic measures. As said by (Takine et al., 2004) a traffic model can only exist if there is a procedure for efficient and accurate inference for the parameters of the same mathematical structure. The traffic characterization is the main information source for the correct mathematical interpretation of network traffic. Once characterized, the traffic may be reproduced in different scales and periods and inserted into network simulators.

Figure 2 shows a complete characterization flow to optimize planning. This procedure was implemented in the GTAR (Barreto, 2007) simulator, developed within our research.

4. Experimental analysis

4.1 Analysis of an IP network

The first network to be evaluated is a Brazilian Service Provider in Brazil, with more than ten million PSTN (Public Switched Telephone Network) subscribers and more than one million ADSL as well. The IP network is shown Figure 3 each access layer is a PPPoX router capable called BRAS(Broadband Router Access Server).
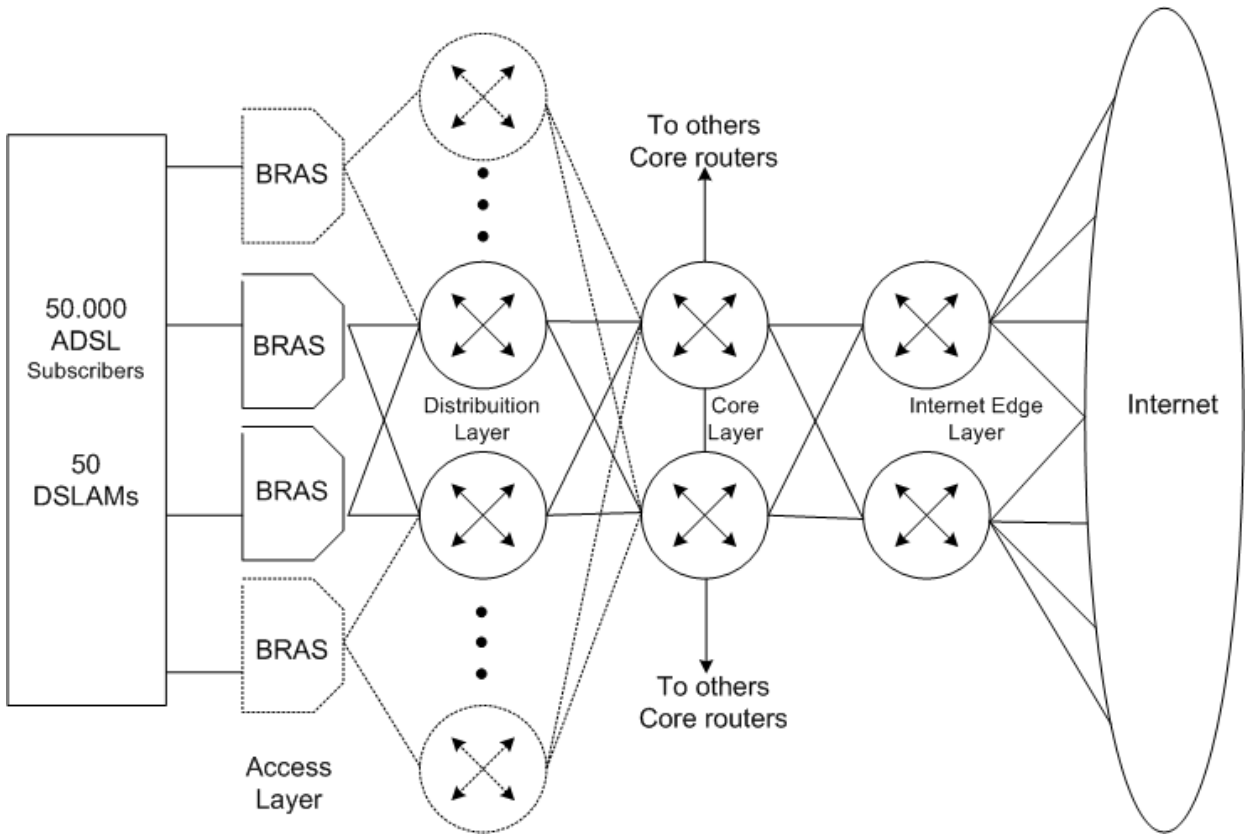

Fig. 3. Testbed Network Architecture with 40% of simultaneous attached subscribers at least, all IP/MPLS interface 1 or 10 Gigabit Ethernet, also for long distance. (De Deus, 2007).
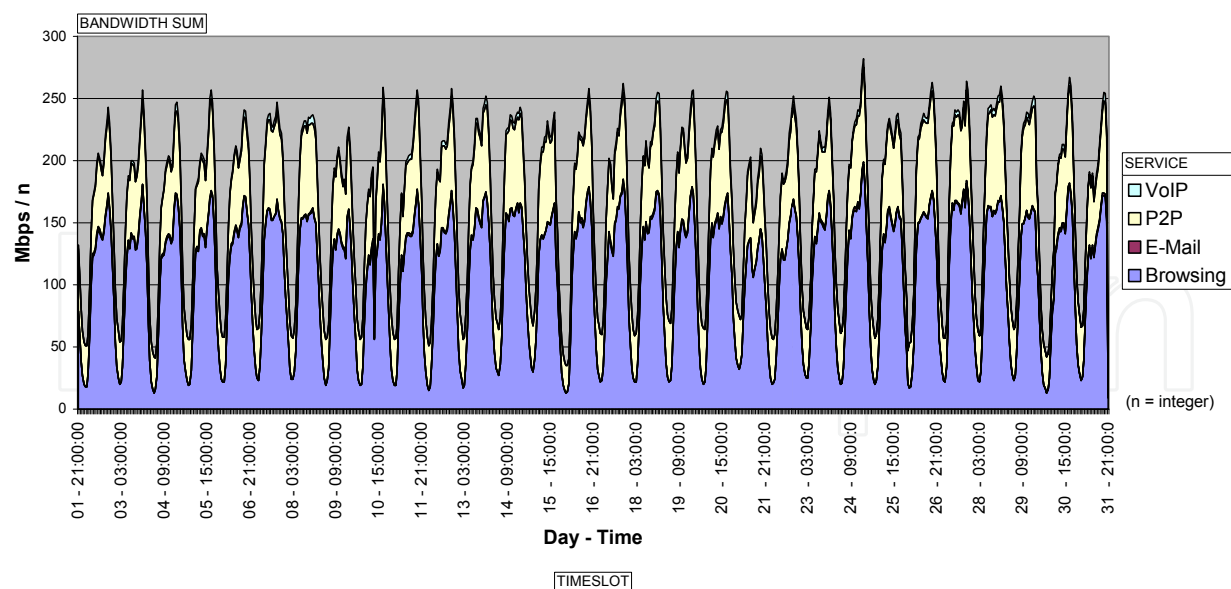
Fig. 4. Downstream traffic "on peak" and "off peak". The rate is normalized, 31 days sampled (De Deus, 2007).

Figure 4 and 5 shows the downstream traffic collection results for a 31 days period. The most important source of traffic is the HTTP(Browsing) following by P2P applications(e-Donkey, Bitorrent, Kazaa). In Figure 10, the same analysis is made for a 24 hours period.
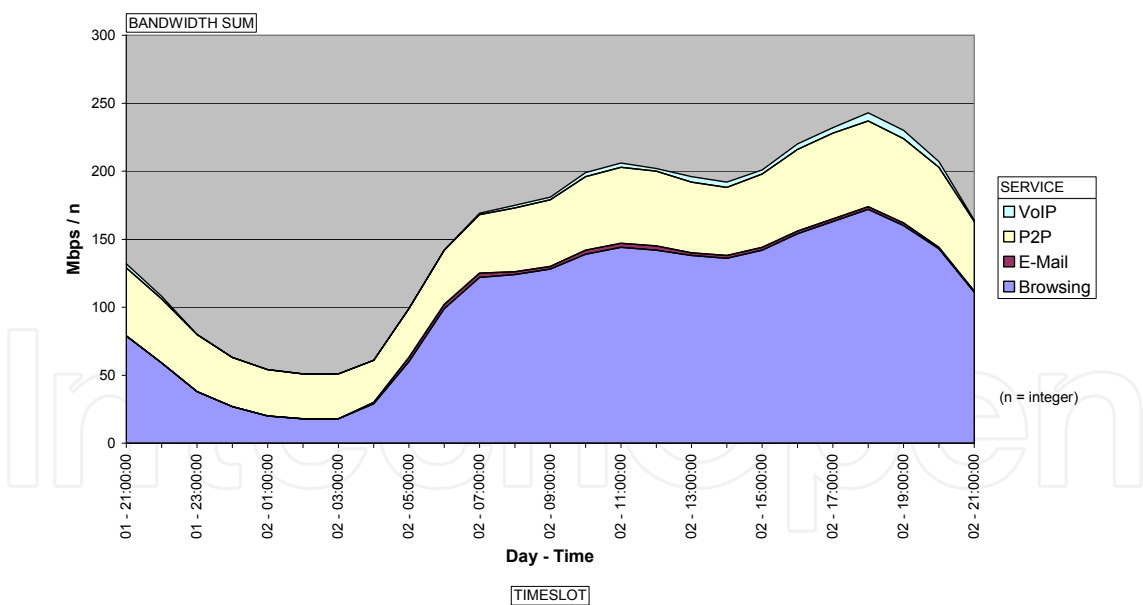

Fig. 5. Downstream traffic "on peak" and "off peak". Traffic rate is normalized, 24 hours sampled (De Deus, 2007).

Figure 6 shows the packet size probability distribution. Less than 100 Bytes packets have 50% of probability. These samples are from a real network with Internet traffic of 4 million xDSL subscribers, demonstrating the very large use of voice packets even when using http flows. This happens mainly because of applications such as SKYPE.
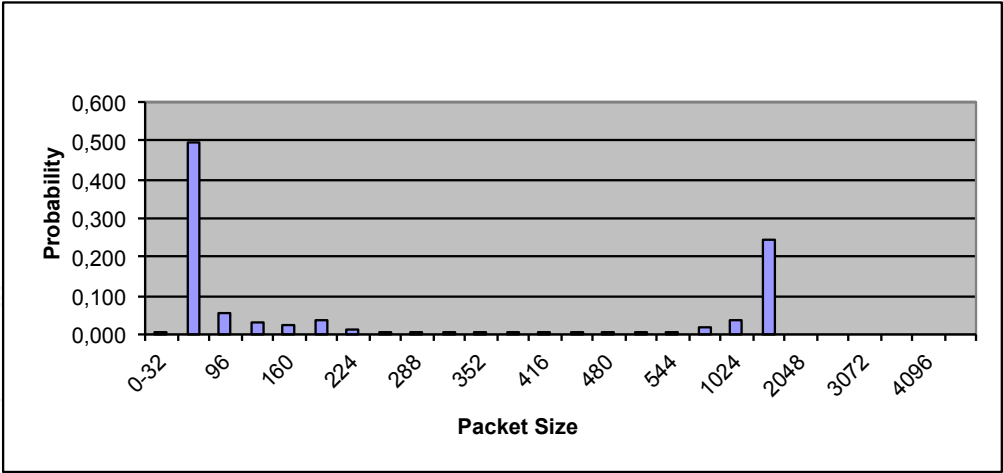
Fig. 6. Packet Size Probability Distribution (De Deus, 2007).

Table 1 shows and per application anaylis of traffic in which the Hurst parameter was calculated with two different methods (De Deus, 2007). For real time traffic, the Hurst parameter calculation demands attention because in some cases if statistical process does not have a representative long range dependence characteristic the parameter may be wrongly interpreted. Another issue is the trend present in the periodic traffic. For a more accurate estimation, the cycle regularity is removed to delete all observed trends.

Day	Hurst (*Variance-Time Plot*)	Hurst (Kettani-Gubner)	Chi-Square (Gaussian Distribution)
1	0,843	0,895	31,042
2	0,812	0,878	71,299
3	0,901	0,926	38,146
4	0,9	0,934	52,569
5	0,815	0,879	32,549
6	0,816	0,904	62,042
7	0,865	0,906	17,91
8	0,87	0,916	39,653
9	0,907	0,935	28,028
10	0,867	0,919	21,785
11	0,869	0,906	27,167
12	0,671	0,861	35,778
13	0,878	0,909	36,208
14	0,839	0,894	44,604
15	0,874	0,907	30,611
16	0,753	0,85	23,292
17	0,851	0,914	40,299

Day	Hurst (*Variance-Time Plot*)	Hurst (Kettani-Gubner)	Chi-Square (Gaussian Distribution)
1	0,915	0,948	63,549
2	0,942	0,962	49,771
3	0,937	0,963	45,25
4	0,902	0,935	28,243
5	0,902	0,928	20,708
6	0,901	0,942	30,181
7	0,939	0,964	43,258
8	0,932	0,964	52,354
9	0,937	0,968	39,007
10	0,922	0,948	38,576
11	0,86	0,926	37,5
12	0,904	0,942	33,84
13	0,937	0,965	55,799
14	0,922	0,958	46,972
15	0,935	0,963	46,757
16	0,935	0,967	49,986
17	0,933	0,964	37,285

Table 1. HTTP and P2P Hurst parameter estimation for 5 minutes average.

In Table 1 is shown the estimation of the H parameter for the HTTP (Hyper Text Transfer Protocol) applications. As can be seen, the H relies value between 0.67 and 0.93, which also shows a higher degree of self-similarity, considering that the lower value appears just in one day. For the P2P applications, the H parameter relies between 0.86 and 0.96.

The estimation of the the Hurst parameter in Table 1 uses three different methods: the Variance-Time Plot Method, the Kettani-Gubner Method (Clegg, 2005), (Barreto, 2007). Also a Chi-squared analysis was made as a non-parametric test of significance (Perlingeiro, 2006), (De Deus, 2007), (Clegg, 2005) due to the fact that it is necessary to verify the distribution similarity. The statistical significance test allows, with a certain degree of confidence, the acceptance or rejection of a hypothesis, as shown in Figure 7. The sampled links had a load, in the worst case around 70%.

Figure 7 shows the Hölder calculation for the traffic. The conclusion in fact is that the traffic is self-similar and monofractal, when the measurement is done in a 5 minutes per sample.
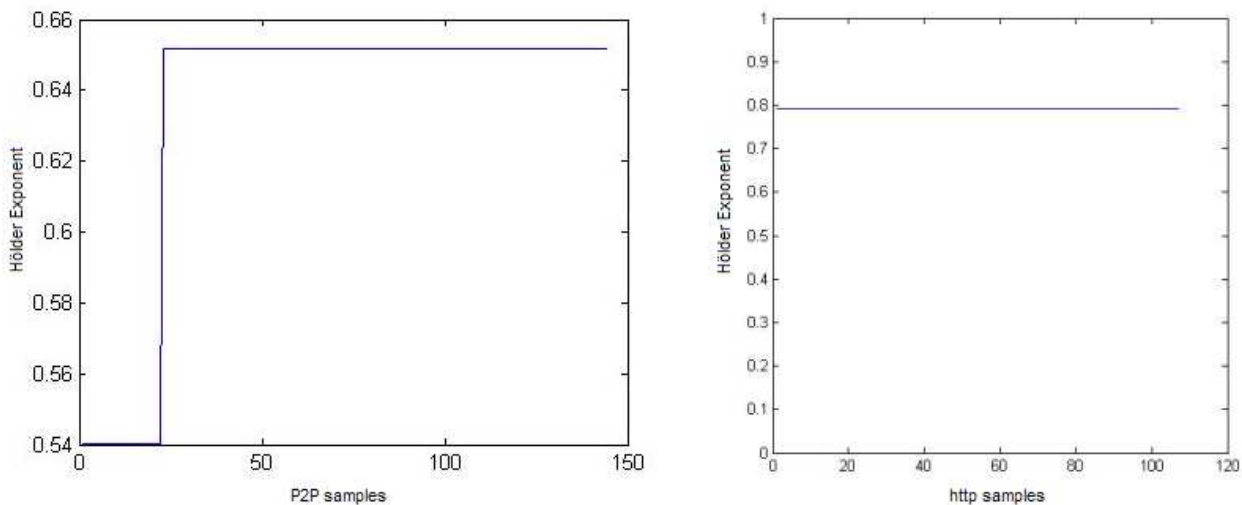
Fig. 7. P2P and http 5 minutes samples, Hölder exponent using the local Hölder Oscillation Based method [fraclab].

4.1.1 Bandwidth control strategies for the IP network

Figure 8 shows the proposal of a real-time network forecast. First, in the network the samples are collected. Then the traffic is classified per application. The estimation and a characterization of the parameters of collected samples are calculated. These parameters are used as input to a traffic forecast tool based on a mathematical traffic model which intends to find the sub-optimal capacity of the link for that traffic load, considering its self-similarity nature.

The objective is to use these parameters as inputs of a simulation tool to forecast the traffic and feedback in real-time the network to provide a new model to capacity plan in the backbone.

Following Figure 8, first the network samples are collected. Thenext step is the execution of classification procedure per application using tools based on protocols (Destination, Source, Port, Payload types). Next phase is to estimate the parameter (e.g. Hurst, Hölder) that will

be used as input to a traffic forecast tool based on valid models (Norros *at al.,* 2000). The next step is to insert the parameter to a tool that will take a decision of how the auto-configuration will be done and a configuration of the element abstracting the vendor (e.g. Juniper, Cisco, Huawei). In figure 7 the example of application of the feedback process is described using the auto configuration tool to change the tunnel characteristics, that will use the proposed framework in Figure 8, as an example of setting up an outstream traffic marked as Diffserv.

If the traffic can be characterized as asymptotical self-similar or monofractal or multifractal some ready prediction models based (e.g. fBm, MWM, MMW) can be used. The core idea is that using only some parameters the mathematical calculus can be feasible at real time, as shown in Figure 14.
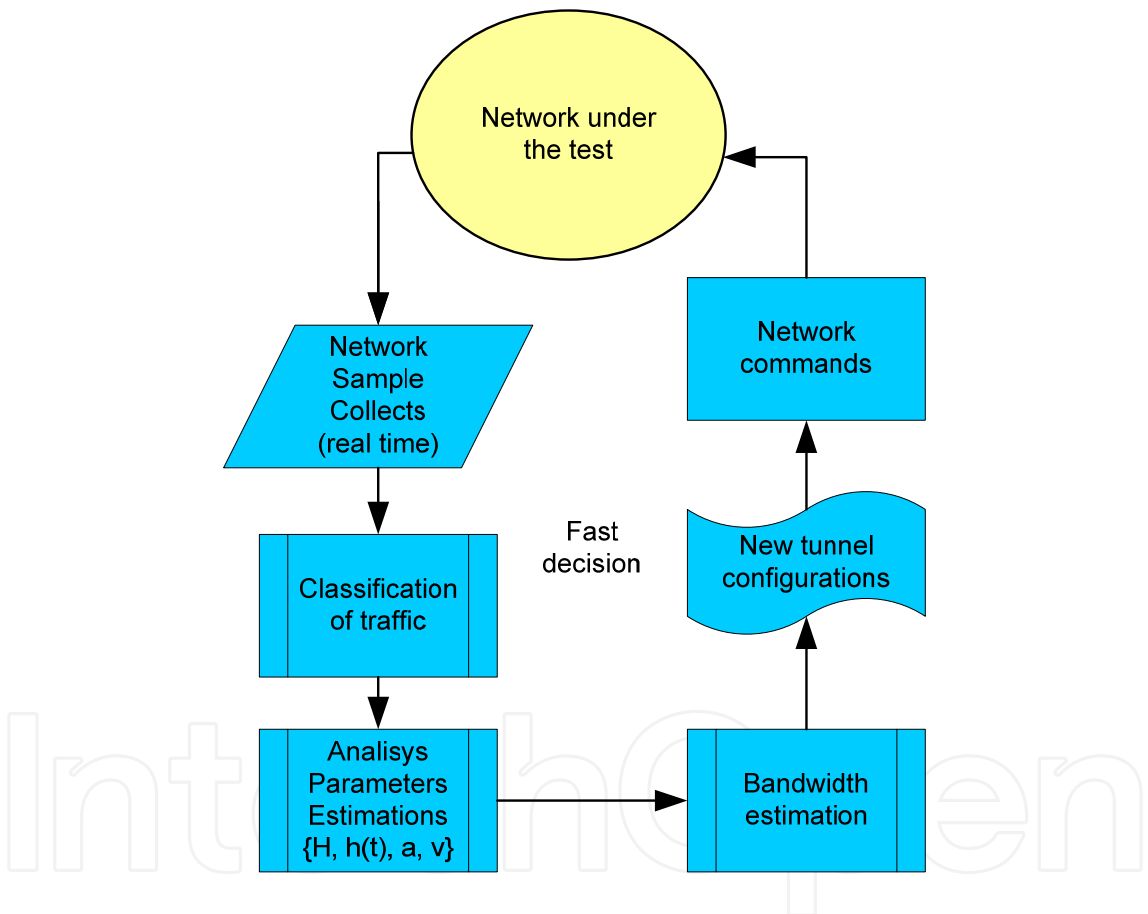
Fig. 8. Proposal of a network real-time forecast framework with bandwidth estimation.

In this case, the tunnels are configured using the self-similarity bandwidth estimators, as described in (Carvalho, 2007). The traffic needs to be marked as the DiffServ and will be injected per tunnel as the auto configuration tunnel selection.

There are several methods used to estimate bandwidth. The method used in our example is the FEP(Fractal Envelope Process). This model has a good performance for long range dependence with a high degree of confidence in the quasi-Real Time estimation (De Deus, 2007).
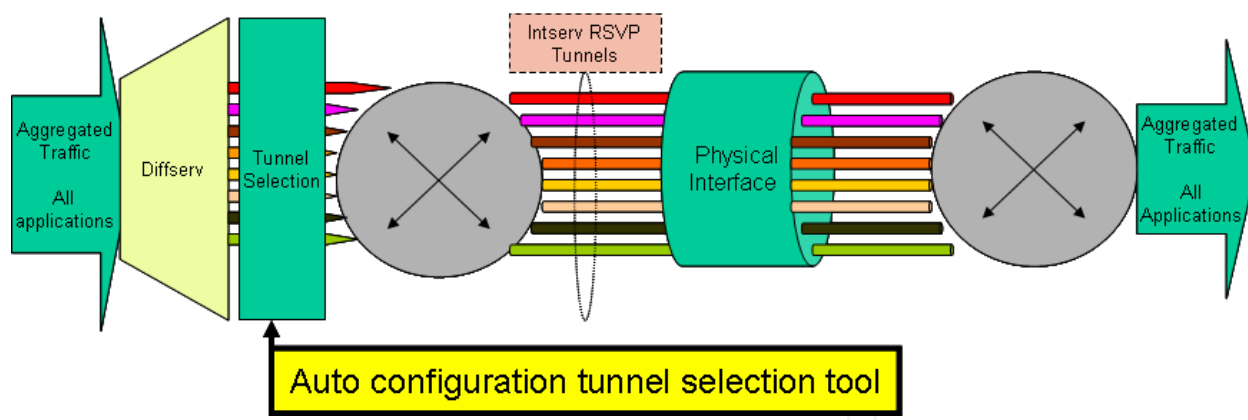
Fig. 9. Tunnel selection between two routers using Diffserv and Inteserv to select the specific tunnel.

The bandwidth estimation most accepted definition, currently known, use a concept introduced by (Kelly et al.,1996), where there is a direct dependency on buffer size and time scales related to the buffer overflow possibility. The concept is shown in (6) where X[0, t] is the amount of bits that arrive in an interval [0, t], considering that X[0, t] has stationary increments. The letter b is the buffer size and t time or scale, BP is the capacity in bits per second.

$$BP(b,t) = \frac{\log E \left\lfloor e^{bX[0,t]} \right\rfloor}{bt} \quad 0 < b, t < \infty \tag{6}$$

Based on this theory, several bandwidth estimators have been proposed and evaluated for its effectiveness and complexity of evaluation. In (Fonseca et al., 2005) an evaluation of the FEP estimator model (Fractal Envelope Process) was developed with good results, for use in high speed networks.

Equation (7) represents the FEP process estimation where the K is the buffer, a is the average, H is the Hurst parameter, σ is the standart devitation and Ploss represents the probability of packet loss when a buffer overflow. This is only valid when 0.5 < H < 1.

$$EN = \overline{a} + K^{\frac{H-1}{H}} * \left(\sqrt{-2 * \ln(P_{loss})} * \sigma \right)^{\frac{1}{H}} * H \left(1 - H \right)^{\frac{1-H}{H}} \tag{7}$$

Using (7) and correcting with (8) and (9), some curves are plotted in different time scales in Figure 10 (FEP Estimator and FEP Model). The best results are with 5 and 1 minutes, achieving the most next to average but still providing a good service with no delay, jitter or packet loss. The "Modelo FEP" f_{op} means the dynamic calculation per hour, the "Tunel P2P constante" and "Tunel HTTP constant"means the estimation with a Poisson Distribution Estimator, the P2P and HTTP means the dynamic bandwidth calculation.

$$f_{op} = \frac{2}{5} \frac{EN}{\sqrt{b'L}} \quad if \ 0.5 < H \le 0.7 \tag{8}$$

$$f_{op} = \frac{2}{75} \frac{EN}{\sqrt{b'L}} \; if \; 0.7 < H < 1 \tag{9}$$

The f_{op} is calculated based on (Perlingeiro & Ling, 2005) study as shown in (8) and (9), where *EN* is from (7) and *b'* is the normalized buffer (*b'=b/b_0*), where *b* is the buffer and b_0 minimum possible buffer size, L is the burst factor.
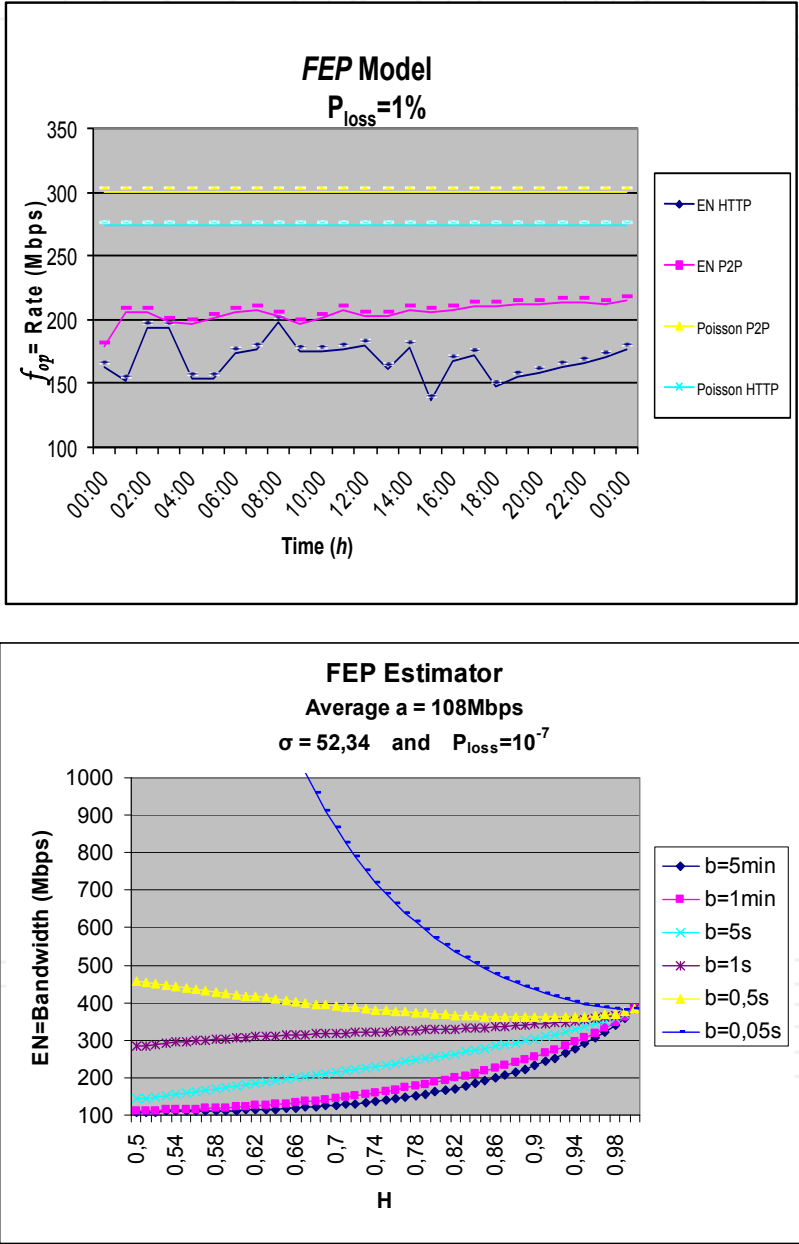

Fig. 10. Bandwidth estimation curves using the FEP method.

The FEP Model shown in Figure 10 uses a dynamic tunnel configurator as shown in Figure 9, denoting a better usage of the total available bandwidth. In the figures it appears that when a constant calculated bandwidth is used, more bandwidth is required. In the same way, the FEP Estimator shows that as much aggregated the traffic will be in any time scale,

the difference will be minimum. In the other hand, when going to small time scales .05, .5 or 1 seconds, there is a trend in super estimation, proportional to the diminishing of the Hurst parameter.

As shown in many works (Leland et al., 1994), (Abry et al., 2002), (Carvalho et al., 2009), the Hurst parameter can show an accurate and single way to determinate the self-similarity. The Erlang model is very useful because its simplicity. A traffic engineer only needs to have some little information about service demand such as Retention time, blocking Probability, Number of Calls in the maximum usage hour to have the traffic and number of channels or resource needed.

The curves in Figure 10 show the possibility to have something, not so easy as Erlang model, but also possible to be achieved as a traffic model when a self-similar characterization is feasible. Also, the multi fractal model can also help to understand this same traffic in smaller scales, or in some case depending the traffic nature.

4.2 Analysis of a 3G network

The second evaluated network is a brazilian 3G network. This network runs with more than 1 million attached 3G costumers with national coverage. The traffic samples were collected in July, 2009 in three different locations (Leblon, Barra da Tijuca and Centro) in Rio de Janeiro. Two monitors were located in the network to collect the traffic, as shown in Figure 11.
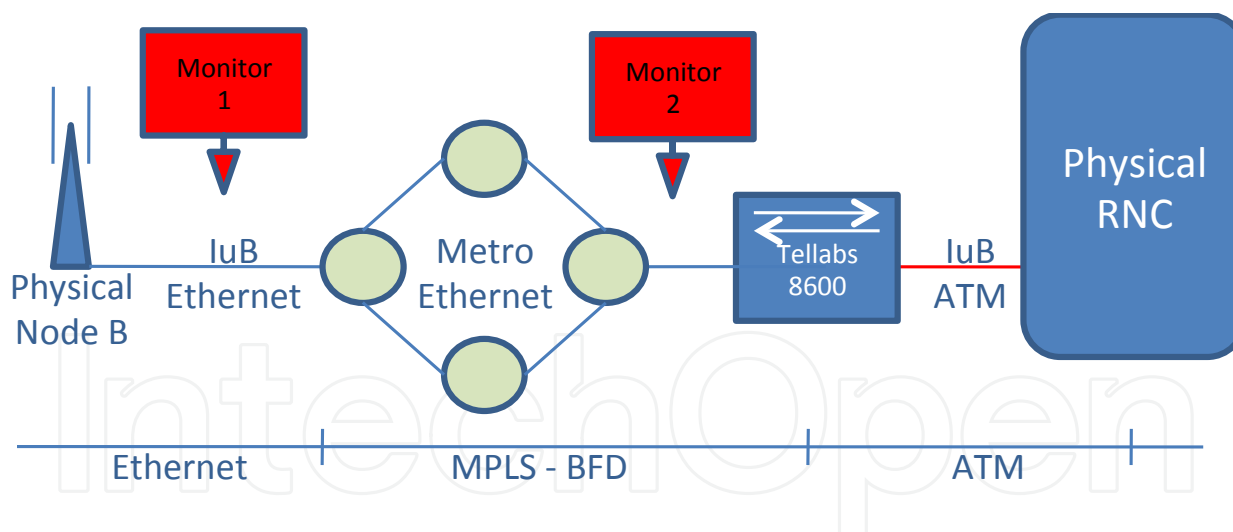

Fig. 11. 3G Network.

The main objective in this section is to investigate planning and project deployment phases based on traffic characterization. The first step is to classify the traffic per application. The second is to characterize the traffic using a procedure based on self-similarity (Clegg, 2005) or multifractal analysis (Carvalho *et al*, 2009).

Figure 12 shows the network topology for the Ethernet physical node B (ATM node) with an ATM-IP router which is responsible to convert ATM to Ethernet(IP). The same situation is found in RNC side where a Tellabs ATM-IP router aggregates all node B physical uplinks,

every one carried through a Metro Ethernet network, with more than 50km radius Rio de Janeiro metropolitan area coverage.
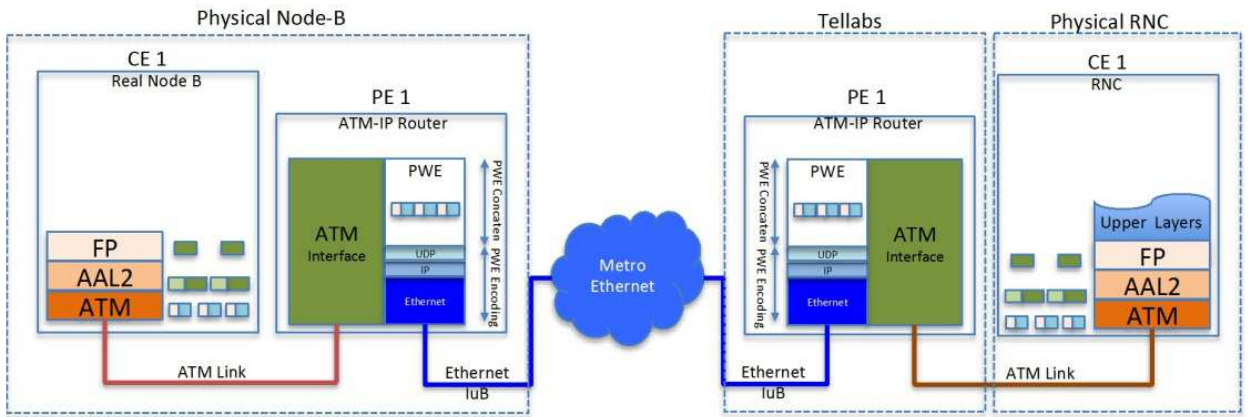

Fig. 12. 3G topology from Node B to RNC.

The first performance analysis of this network found some drawbacks in terms of latency and packet loss and jitter. In Figure 13 (before) is shown the first measures. One detected problem was the high level of broadcasting (ARP included) for this metro Ethernet network, in some periods, more than 80% of all IP traffic.
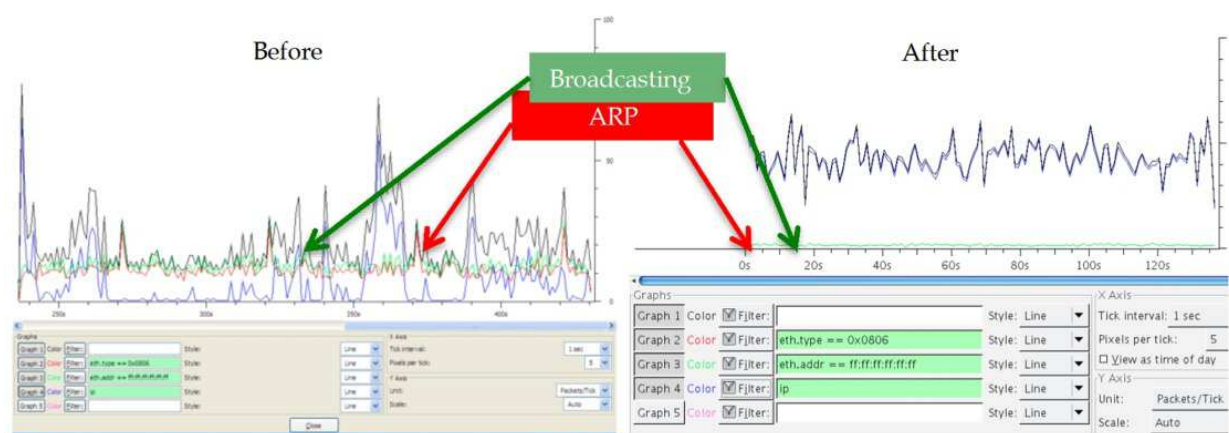

Fig. 13. 3G Traffic analysis (before and after).

As shown in Figure 12, the transport from Node-B to the RNC is performed by a MetroEthernet network that uses also a BFD protocol to track the availability of a Multiprotocol Label Switching (MPLS) Label Switched Path (LSP). In particular, BFD (Aggarwal et al., 2010) can be used to detect a data plane failure in the forwarding path of an MPLS LSP.

LSP Ping is an existing mechanism for detecting MPLS LSP data plane failures and for verifying the MPLS LSP data plane against the control plane, making possible the PseudoWire connections through a MPLS environment.

The problem, in this case, was an architectural design mistake because all Node B uplinks were configured in Level 2 VLANs (OSI Model), with more then 250+ 3G nodes B in the

same IP subnet. The solution for this architectural problem was divide the Node Bs in 20 per subnet, as shown in Figure 8 (after).

This division resulted in diminishing the broadcasting to less than 5%. This problem is very simple in a typical Ethernet topology, but not so easy to be detected when inserted in a 3G network. Ethernet is a protocol designed for local area purposes; the MEF (Metro Ethernet Forum) inserted some signalling standards as a way to simplify the application in metro and long-range use.

Figure 14 shows the traffic trace collected in the 3G network and Figure 15 and Figure 16 show the singularity spectrum and the Hölder function for the 3G samples, showing the possibility to use the multifractal model also to forecast purposes.

This information is important do show this traffic can be characterized as multifractal in small scales of time, but in other hands the bandwidth model for this type of traffic model is also hard to build, because the nature of the traffic. Other important thing to understand is how to insert modifications with make the system not stable. In small scales, huge systems will need a lot of information to compute the bandwidth between to distance nodes.

The use of one model type can be very carefully choose because this could make the Operations Staff make wrong decisions that could result in many downtime.
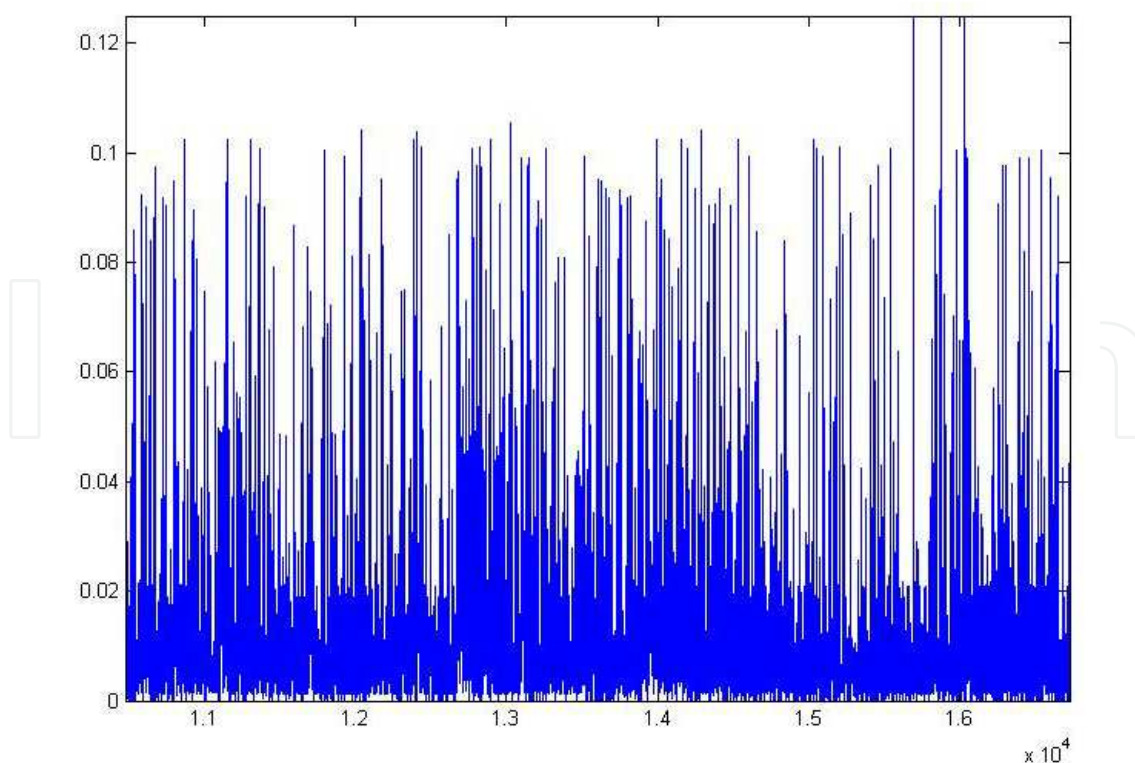

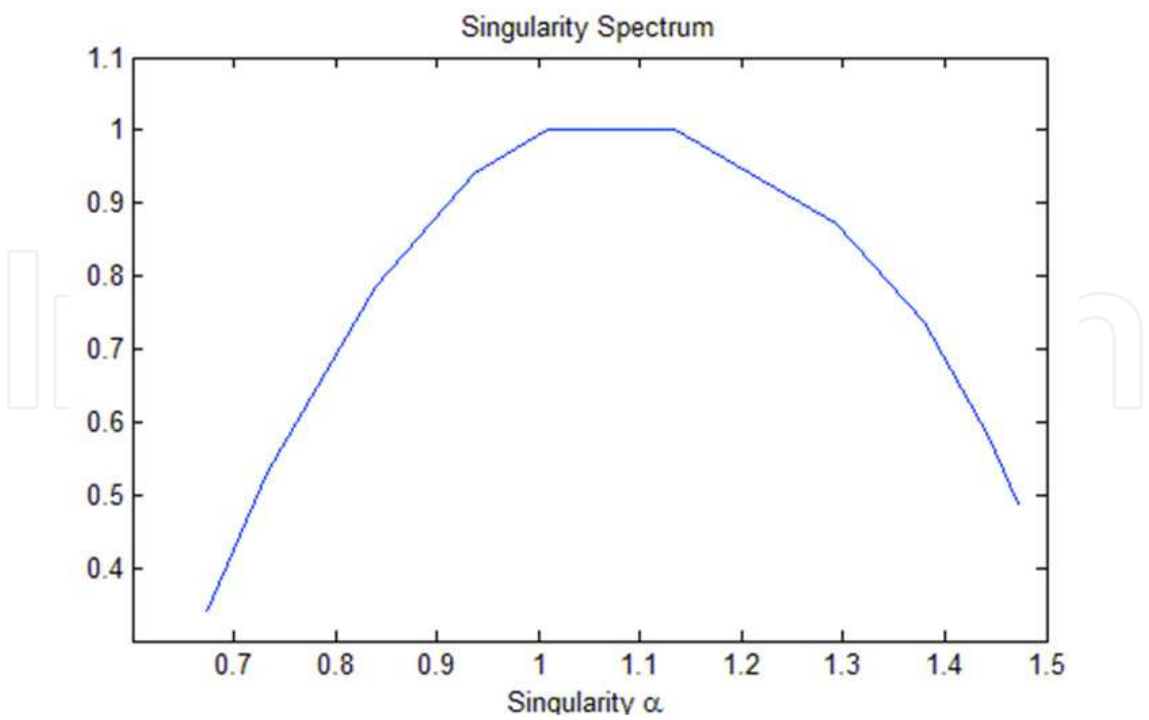Fig. 14. Normalized 3G Traffic samples (milliseconds time scale).

Fig. 15. 3G Traffic multifractal analysis – Singularity Spectrum (milliseconds time scale).
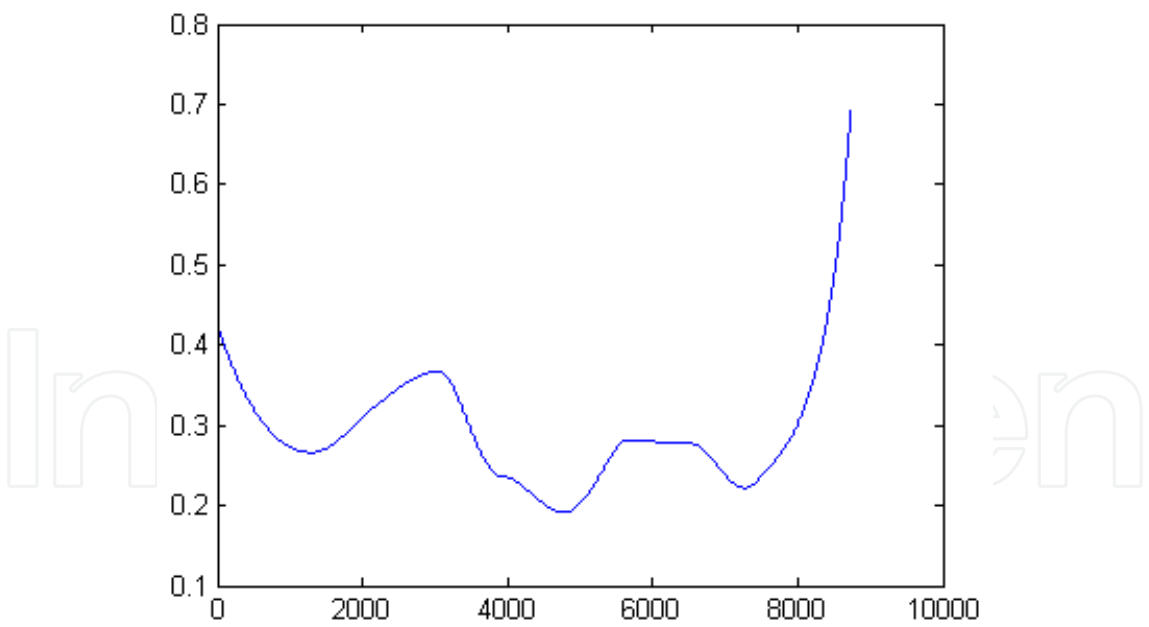

Fig. 16. 3G Traffic multifractal analysis – Hölder function. (milliseconds time scale).

5. Conclusion

This chapter presented an approach and a set of frameworks to characterize traffic and optimize network planning in IP and 3G networks. Based on real traffic measurements, we

characterized the traffic and showed examples of how to apply the proposed frameworks. An special interest of our work has a focus in real operating networks and the examples show the application of the proposed frameworks in these environments.

The traffic characterization procedures for mutilmedia traffic were explained. We provided analyses by collecting different types of traffic and measuring its self-similar or multifractal degrees. All of this work was done with some self-developed (Carvalho et al., 2006) tools and also with some other tools (FRACLAB, 2011; OPNET, 2011).

The traffic models give us a good idea of the traffic behavior. In fact, the models can be valuable tools to the conception, management and sizing of a telecom network, resulting on efficient use of its resources. The operator can plan the growth of the network just to fit the business model, guaranteeing at different moments the efficient use of network resources, guaranteeing, on the other hand, the users satisfaction. In this context, the traffic models can also be used to define alternative policies that, for example, promote the network adaptation in periods with different levels of congestion.

Some very important to considering is how to improve the planning function with a better forecasting (Zukerman et al., 2003)., in terms of long time period for new assets plan and also to implement new products.

Something also very important is how to manage the network resources to have the best optimization possible, this will provide costumer better experience when using and buying exactly their needs.

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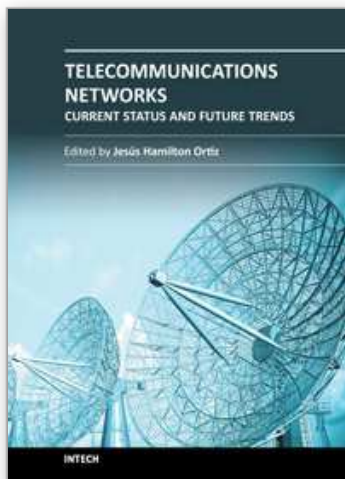
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