BASELINE TO HELP WITH NETWORK MANAGEMENT

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Keywords: Computer network management, baseline, traffic characterization.

Abstract: This paper presents a model for automatic generation of a baseline which characterizes the traffic of network segments. The use of the baseline concept allows the manager to: identify limitations and crucial points of the network; learn about the actual status of use of the network resources; be able to gain better control of the use of network resources and to establish thresholds for the generation of more accurate and intelligent alarms, better suited to the actual characteristics of the network. Moreover, some results obtained with the practical use of the baseline in the management of network segments, are also presented. The results obtained validate the experiment and show, in practice, significant advantages in their use for network management.

1 INTRODUCTION

Computer networks are of vital importance nowadays for modern society, comparable to essential services like piped water, electricity and telephone. Extensive work has been done to improve ways to implement quality of services and traffic management along the Internet backbone (Duffield, 2001). Several existing tools and network management systems (NMS) aim to help with the network management and controls to reduce costs and improve resource utilization. However, the construction of a baseline suitable for the characteristics of each segment of a network backbone is an important task that is not usually found in the network management systems.

The Baseline can be defined as the set of basic information that shows the traffic profile in a segment of the network, through minimum and maximum thresholds about volume of traffic, quantity of errors, types of protocols and services that flow through this segment along the day. The real forecast or even an approximate one in a determined instant about the characteristics of the traffic of the segments that make up the network backbone, make the management decisions on problems that might be happening, more reliable and safer (Thottan, 2003).

The use of the baseline can help the network manager to identify limitations and control the use of resources that are critical for services that are latency-sensitive such as Voice over IP and video transport, because they can’t take retransmission or even network congestion. Besides improving the resources control, its use also facilitates the planning on the network increase, for it clearly identifies the real use of resources and the critical points along the backbone, avoiding problems of performance and fault that might happen.

The use of the baseline also offers the network manager advantages related to performance management, by means of the previous knowledge of the maximum and minimum quantities of traffic in the segment along the day. This enables the establishment of more effective and functional alarms and controls, because they are using thresholds that suit the baseline, respecting the variations of traffic along the day instead of using the linear thresholds that are set based on the expertise of the human network manager (Hajji, 2003). Deviations in relation to what is being monitored real-time and what the baseline expresses must be observed and analyzed carefully, and can or can not be considered as problems. In order to do

Lemes Proença Jr. M., Coppelmans C., Bottoli M. and de Sousa Mendes L. (2004).
BASELINE TO HELP WITH NETWORK MANAGEMENT.
In *Proceedings of the First International Conference on E-Business and Telecommunication Networks*, pages 152-160
DOI: 10.5220/0001395501520160

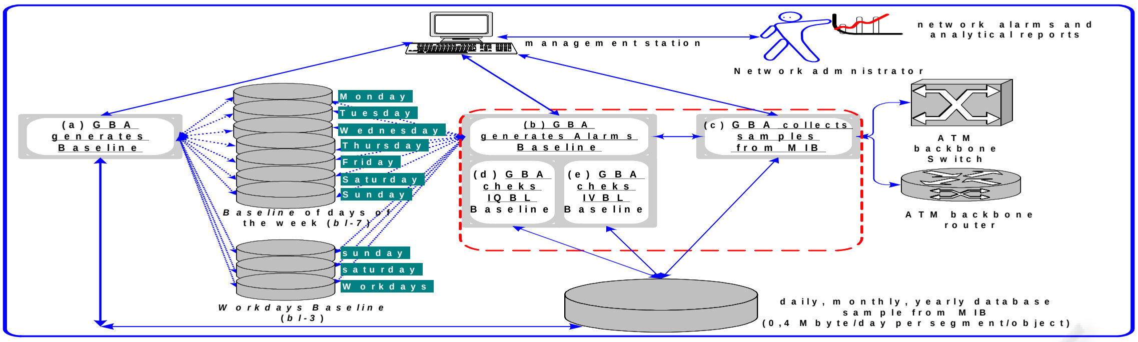

Figure 1: Operational functioning diagram for the generation of baseline and alarms.

that, the use of an alarms system integrated to the baseline and to the real-time monitoring will deal with these problems, warning the network manager when it is necessary.

As for security management, the use of the baseline can offer information related to the analysis of the users behavior, because the previous knowledge of the behavior and the traffic characteristics of a determined segment is directly related to the profile users manipulation, using this as information to prevent intrusion aspects or even network attacks, by means of the intrusion detection software (Northcutt, 2002) (Cabrera, 2001).

Another application for the baseline is related to the monitoring of a network segment which is normally performed manually by means of visual control, based on empirical knowledge with the network acquired by the manager. An example of this can be seen with the utilization of tools like GBA (Automatic Backbone Management) (GBA, 2004) and MRTG (Multi Router Traffic Grapher) (MRTG, 2004) that generate graphs with statistical analysis which consist of averages along a determined period of time about an analyzed segment or object. However, the simple use of these graphs establishes limitations for the network manager concerning to discovery and solution of problems. The limitations are caused especially by the non-automation of this task, where the monitoring of these graphs is performed visually, depending exclusively on the empirical knowledge about the functioning of the network acquired by the manager and due to the large quantity of graphs that have to be analyzed continuously. It only allows the detection of the problems and unusual situations in a reactive way.

Networks with a great number of segments turn their management more complex, considering the great quantity of graphs to be analyzed. The graphs usually present information on the volume of input and output of traffic of a certain segment, not aggregating information that could help the manager more efficiently in his decision-making with the purpose of solving problems that might be happening or that might have already happened.

Extensive work has been done in traffic characterization (Rueda, 1996), traffic measurement (Dilman, 2002) and anomaly detection (Hajji, 2003) (Thottan, 2003) (Papavassiliou, 2000), that is related to the proposal in this work. In (Rueda, 1996) is presented a survey of the main research done for traffic characterization in telecommunication networks. However these models intend to traffic modeling in a generic way, while the proposal presented in this paper intends to a traffic characterization generated from collected real data of each segment of analyzed network.

In (Hajji, 2003) is presented a proposal that is close to ours presented in this work, they proposed a baseline for automatic detection of network anomalies that uses asymptotic distribution of the difference between successive estimates of a model of network traffic. One problem that exists in this model is that it assumes that the training data is pure with no anomalies. In our case we calculate the baseline based on real data gathering from the network segment. Our baseline is generated based on statistical analyses of these data.

Thottan *et al* (Thottan, 2003), presents a review about anomaly detection methods and a statistical signal processing technique based on abrupt change detection that uses analysis of SNMP MIB variables for anomaly detection. They use a 15s sampling frequency, and it assumes, like an open issue, that there exist some changes in MIB data that don't correspond to network anomalies. The use of an effective and real baseline can help to solve this problem for knowing the real behavior of the traffic.

Papavassiliou *et al.*(Papavassiliou, 2000), presents a tool with intend to facilitate the network management, reducing costs and minimizing the human errors. They use a similar approach to ours for the construction of baselines, when they separate workdays from weekends.

In the rest of this paper it will be presented a description about the model proposed for the construction of the baseline, the way it was implemented and the results that show practical gains for the network management. At last, in section 3 we conclude and mention suggestions for future works.

2 BASELINE IMPLEMENTATION

The main purpose to be achieved with the construction of the baseline is the characterization of the traffic of the segment it refers to. This characterization should reflect initially the profile expected for the traffic along the day as well as other existing characteristics such as: types of protocols, types of applications, types of services. These characteristics are used to create a profile of the users. The baseline was initially developed to analyze the quantity of input and output of octates development, helping with the management as well as with the understanding about the networks functioning. Further information on the GBA can be found at http://proenca.uel.br/gba or in (Proença, 2001).

As for the tests and validation of the model, the data gathered by the GBA have been used since 2002 up to the present. The use of the data from the last two years was considered an important sample, characterized by periods of winter and summer vacations as well as holidays which contributed to the tests and validations of the ideas presented in this work. The analyzed data is related to the network segments with traffic TCP/IP based on Ethernet and ATM with LAN Emulation. The tests of the proposed model were carried out in three segments of the network *backbone* of UEL which are described below:

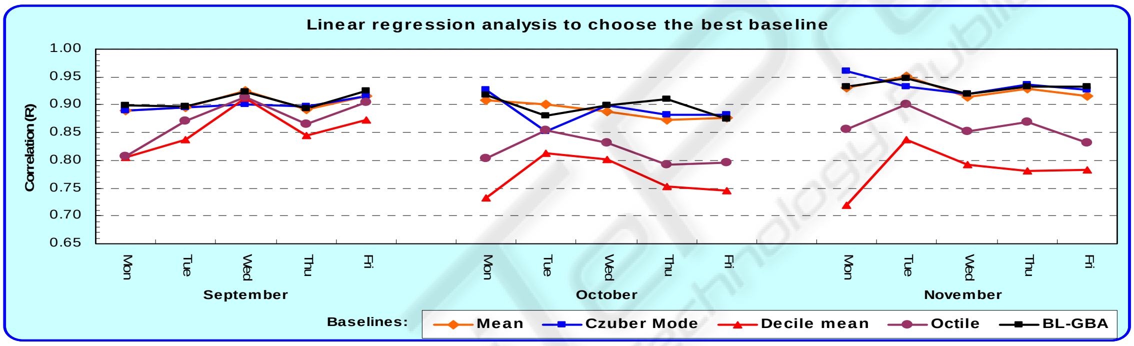

Figure 2: Linear regression analysis aiming at evaluating which is the best method for *baseline* generation.

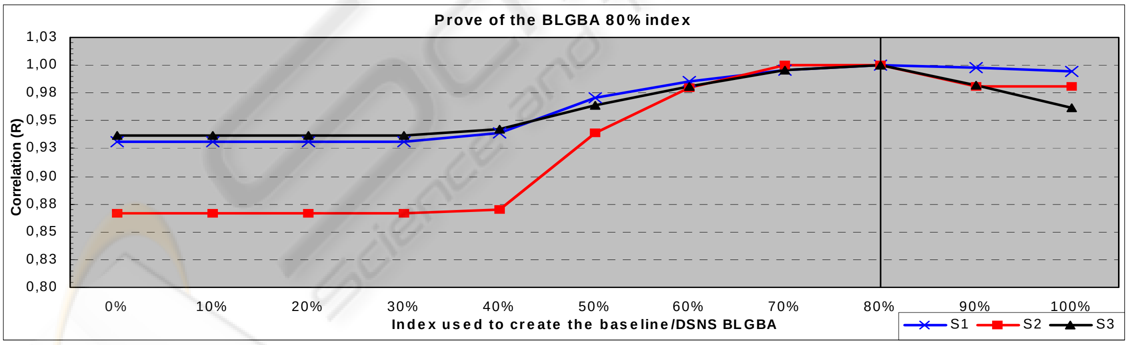

Figure 3: Linear regression analysis aiming at validating the choice for the index of 80% for the BLGBA.

stored in the *ifInOctets* and *ifOutOctets* objects which belong to the *Interface* group of the MIB-II (RFC-1213, 1991).

The use of the GBA tool (Automatic Backbone Management) was chosen as a platform for the development of the baseline due to the great quantity of historical information related to monitoring carried out along the last years in the main network segments of UEL. The GBA was initially developed to help with the network management with ATM backbone and it performed its duty as it became a platform of learning and

1. The first one which is called segment S_1 is responsible for interconnecting its ATM router to the other *backbone* segments; it gathers a traffic of approximately 2500 computers;
2. The second one which is called S_2 interconnects its office for undergraduate studies of academic affairs; it gathers a traffic of 50 computers;
3. The third one which is called S_3 interconnects State University of Campinas UNICAMP network to academic network at São Paulo (ANSP), it gathers a traffic of

all UNICAMP (about 5000 computers) to Internet.

For the generation of the *baseline* a model was developed based on statistical analyses that we call BLGBA. The analyses were carried out for each second of the day, each day of the week. Figure 1 illustrates the operational diagram used in the implementation of the baseline, which is carried out by the GBA generated baseline module. This module reads information from the database with data gathered daily and generates the baseline based on a period requested by the network manager.

Two types of baseline were created, one called ***bl-7*** which consists of seven baseline files, one for each day of the week, and the other one called ***bl-3*** which consists of three baseline files, one for the workdays from Monday to Friday, one for Saturday and another one for Sunday, as shown in Figure 1. The choice for generating the baseline separating the workdays of the week from Saturday and Sunday, was in order to minimize the margin of error in the final result, concerning the alterations in the volume of traffic that occur between the workdays and the other days. The results showed that it was the right choice, because the variation that was found in the volume of traffic between the workdays was of 10% and over 200% comparing workdays and weekends, as can be seen in figure 4.

The model for baseline generation proposed and presented in this work, performs statistical analysis of the collected values, respecting the exact moment of the collection, second by second for twenty-four hours, preserving the characteristics of the traffic based on the time variations along the day. For the generation of the baseline, the holidays were also excluded due to the non-use of the network on these days. Moreover, the process of baseline generation also considered faults in the collected samples which occur along the day, eliminating these faults from the calculations for the baseline generation.

The GBA makes collections at each second at the MIBs of the network equipments. Along each day, 86400 samples are expected. Problems usually occur and may affect some of these samples due to the loss of package or congesting in the network. In this case, for the generation of the baseline, the exclusion of these samples was chosen in the calculation of the baseline related to that second. This problem occurs in less than 0.05% a day, for the analyzed samples.

The processing for the baseline generation is done initially in batch aiming at its creation through

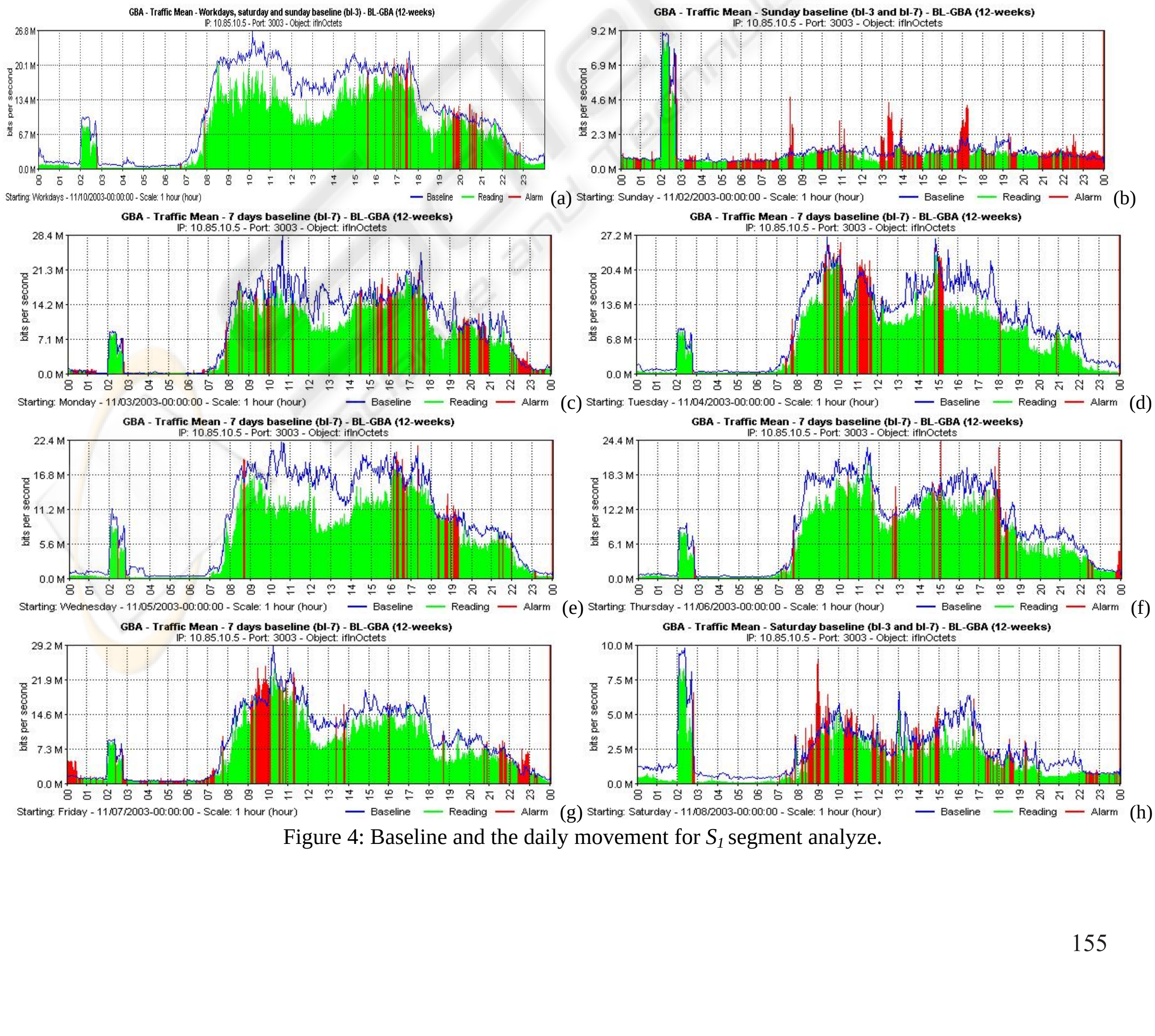

Figure 4: Baseline and the daily movement for S_1 segment analyze.

data related to a pre-established period. The baseline is generated second by second for a period of days represented by N which makes up the set n_j (j = 1, 2, 3, 4, ..., N); with the daily gathering there is a set of samples of the day represented by a_i (i = 0, 1, 2, ..., 86399). Then the bi-dimensional matrix is built with 86400 lines and N columns which must be previously sorted and that will be represented by M_{ij}.

The algorithm used for the calculation of the baseline (BLGBA) is based on a variation in the calculation of *mode*, which takes the frequencies of the underlying classes as well as the frequency of the modal class into consideration. The calculation takes the distribution of the elements in frequencies, based on the difference between the greatest G_{aj} and the smallest S_{aj} element of the sample, using only 5 classes. This difference divided by five, forms the amplitude h between the classes, $h = (G_{aj} - S_{aj})/5$. Then the limits of each L_{Ck} class are obtained. They are calculated by $L_{Ck} = S_{aj} + h*k$, where Ck represents the k class (k = 1...5).

The proposal for the calculation of the baseline of each Bl_i second has the purpose of obtaining the element that represents 80% of the analyzed samples. The Bl_i will be defined as the greatest element inserted in class with accumulated frequency equal or greater than 80 %. The purpose is to obtain the element that would be above most samples, respecting the limit of 80%. This process is used for the generation of baselines models ***bl-7*** and ***bl-3.***

The BLGBA model used for the calculation of the *baseline* was chosen after the performance of tests with other statistical models based on the *mean, octile, decile average* and on the *mode* proposed by Czuber. The choice for the BLGBA model was based on:

1. Visual analysis of graphics containing the baseline and its respective daily movement, as illustrated in figure 4;
2. Deviation analysis proposed by Bland and Altman (Bland, 1986), takes into consideration the differences between the predicted and observed movements. Such differences must lie between an interval defined by $\overline{d} \pm 2 * s$, where $\overline{d}$ is the differences mean and s is the standard deviation of these differences. With this an upper and lower limit are set where the deviation must be contained. The model that presented better adjustment was the BLGBA, with 95% of the differences in these limits;
3. Residual analysis – the model which showed less residual index between the predicted and the occurred movements was the BLGBA;
4. Linear regression (Bussab, 2003) (Papouli, 2002) between the models aimed at evaluating which one showed a better correlation coefficient between the *baseline* and the daily movement. Figure 2 shows the result of the correlation tests for the segment S_1 related to the months of September to November 2003. In this figure it is possible to notice that the BLGBA shows a better correlation coefficient between the daily movement and the *baseline*.

The choice for the element that represents 80% of the samples for the calculation of the baseline Bl_i was done empirically. Analytical tests were carried out through linear regression 00 using baseline with this value ranging between 0 and 100%, with the purpose of verifying if 80% would be the best value to be used by the BLGBA, in the calculation of the Bl_i. Figure 3 shows the correlation coefficient R between the baseline and the samples for values of choice between 0 and 100 %. It is noticed that the *baseline* that uses 80%, shows a better correlation coefficient for BLGBA. These tests along with the visual analysis of the graphics with baseline and their respective daily movements showed that the value of 80% for the calculation of the ***Bl*** was the most satisfactory one

2.1 Baseline Results

The obtained results show the validity of the model for the generation of the baseline, bearing in mind the performed analyses and the comparison with the real movement that occurred. An example of that can be seen in figure 4 that illustrate in the form of a histogram, the daily movement of the segment S_1, and their respective baseline. In these figures some graphs are shown, concerning the second week in November 2003, with the *baseline* in blue and the real movement that occurred on the day in green. We came to the following conclusions with the results shown in figures 4:

1. Clear peaks of traffic in the baseline everyday between 0:30 and 4:00 o'clock in the segment S_1 that are related to the backup performed in this period in the network server;
2. The profile of traffic for the workdays, figures 4 (a), generated by the ***bl-3*** model and 4 (c), (d), (e), (f) and (g), generated by the ***bl-7*** model, is quite similar with a strong time dependence along the day which, in this case,

Table 1: Variation of the baseline from January 2003 to January 2004, for segment S_1

	% of growth of the baseline/DSNS comparede with the previous month												
	Jan/03	Fev/03	Mar/03	Apr/03	May/03	Jun/03	Jul/03	Aug/03	Sep/03	Oct/03	Nov/03	Dec/03	Jan/04
IVBL	1,10%	1,51%	5,38%	0,07%	8,66%	2,94%	5,83%	6,38%	4,95%	4,12%	2,78%	2,89%	3,02%

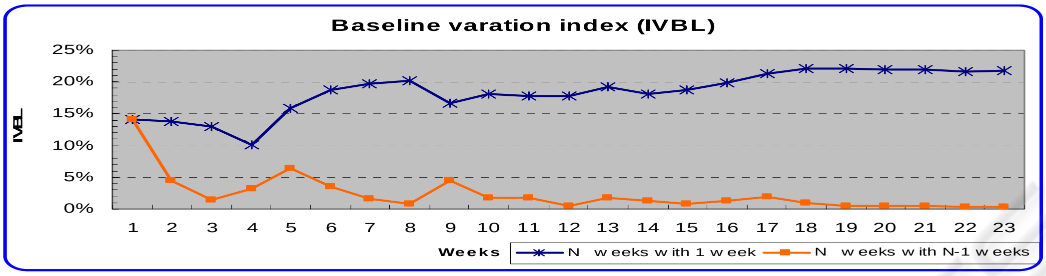

Figure 5: % of variation of the baseline of *n* weeks compared to the (n – 1) weeks and 1 week.

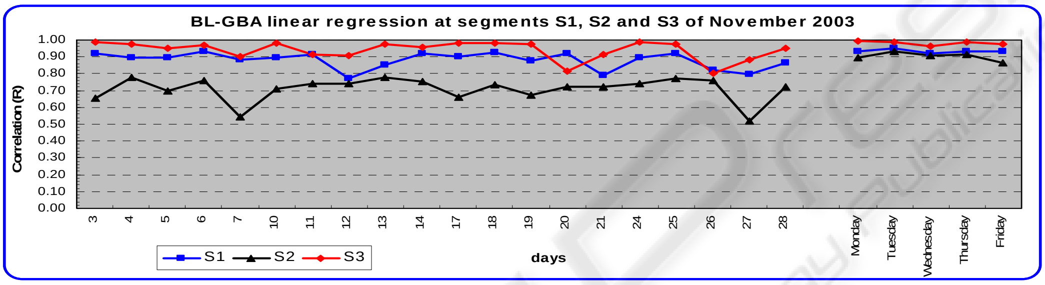

Figure 6: Analysis of the BLGBA by linear regression of November 2003.

is related to the working day hours of the university where the tests were performed. In the case of Saturdays and Sundays, the baseline generated for these days are exactly the same for ***bl-3*** and ***bl-7*** models, figures 4 (b), (h) shows this results;

3. Not only the baseline generated for the workdays ***bl-3*** but also the one generated for all the days of the week ***bl-7***, showed to be suitable for the characterization of the traffic. The ***bl-7*** is a model of baseline to be used in cases in which there is the need to respect individual particularities which occur in each day of the week, such as backup days, whereas the ***bl-3*** is the most suitable for the cases where this is not necessary, that is, all the workdays can be dealt with in a single baseline, leaving the decision on what model to be used to the network manager's;
4. Periods in which the traffic of the day becomes higher than the baseline. In this case, its color is changed from green to red, which means a peak of traffic above the baseline, and this could or could not be interpreted as an alarm;
5. The generated baselines fulfill their main objective which is the characterization of the traffic in the analyzed segments;
6. The baseline is influenced by time factors which, in this case, are related to the working day that starts at 8:00 a.m. and finishes at 10:00 p.m.
7. The baselines presented in figures 4 were generated by a 12 week sample collection of real data in segment S_1. Our studies have demonstrated that for segments with a lot of aggregate traffic as in S_1 and S_3, 12 weeks is necessary for a baseline formation.

Unfortunately, due to the limited quantity of information that is presented in this article, it is not possible to show other figures which corroborate what was presented in this work. Nevertheless, at the address http://gba.uel.br/blgba more information and results obtained through this work can be found.

2.2 Baseline Evaluation

We created an index with the purpose of evaluating the coefficient of variation of the baseline of one month in relation to the other. This index is called Index of Variation of the Baseline (IVBL). The IVBL is calculated based on the difference between one baseline and the other, as shown in equation (1). With the IVBL it was possible to conclude that there is usually a positive variation in the volume of traffic from one month to the other, showing that

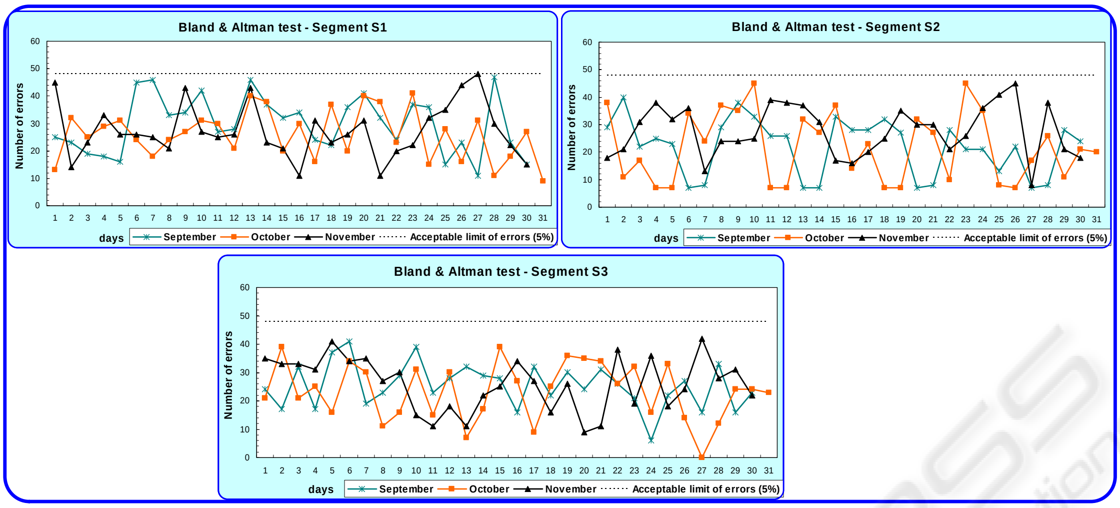

Figure 7: Bland & Altman test from September to November 2003 for segments S_1, S_2, and S_3.

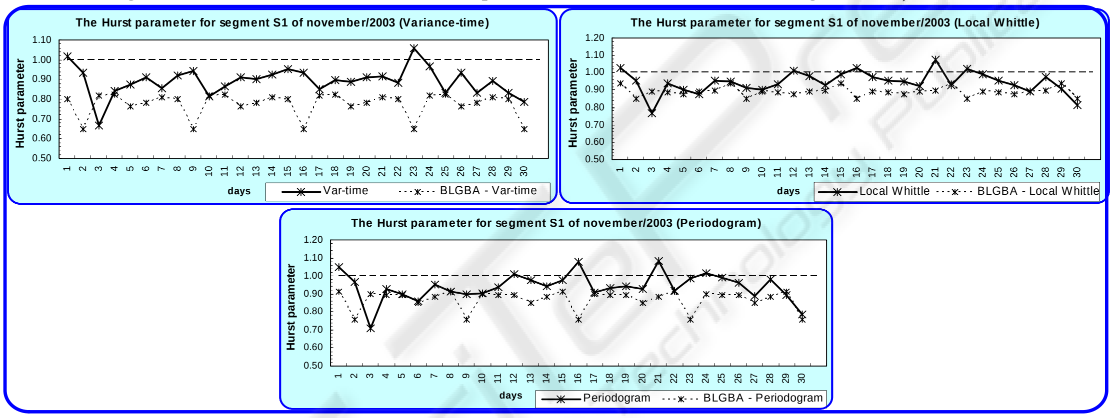

Figure 8: The Hurst Parameter for S_1 segment of November 2003.

despite being small, there is a tendency of growth in the volume of traffic in the analyzed segments. Table 1 shows the percentage of growth in the segment $\boldsymbol{S_1}$ from the network of UEL, from January 2003 to January 2004. In the other analyzed segments, a small percentage of growth was also observed.

$$IVBL = \left(\sum_{i=1}^{86400} BL'_i - BL''_i \right) \Big/ 86400 \quad (1)$$

Where *IVBL* = variation index of a *baseline* in relation to another

The IVBL was also used to calculate the variation of a baseline generated from $\boldsymbol{n}$ weeks and compared to a baseline of ($\boldsymbol{n}$ - *1)* weeks, and in the comparison between the baseline of 1 week with the baseline of $\boldsymbol{n}$ weeks. These calculations using weekly baselines were carried out with the purpose of evaluating and demonstrating the minimum quantity of samples necessary for the formation of the baseline. Initially it was concluded empirically that it would be necessary 4 to 12 weeks for the formation of the baseline. With the comparison of the baseline of $\boldsymbol{n}$ weeks with the one of ($\boldsymbol{n}$ – 1), during 24 weeks, it was observed that the percentage of variation tends to stabilize from the 12th week on, and not being significant for the formation of the baseline. And when a baseline of 1 week was established and a comparison was carried out for 24 weeks, it was also noticed that, from the 12 th week on, the percentage of variation tends to stabilize around 20%, showing no more significant variations that could be added to the baseline from this point on. The figure 5 shows the results of these comparisons.

Besides the visual evaluation of the results, other analytical tests have been carried out aiming to evaluate the reliability of the baseline generated by the BLGBA in relation to the real movement. The tests were carried out from January to November of 2003, below is presented a synthesis of the results:

I. Linear Regression (Bussab, 2003) (Papoulis, 2002): Figure 6 presents the results of the linear regression for the segments $\boldsymbol{S_1}$, $\boldsymbol{S_2}$, and $\boldsymbol{S_3}$

for all workdays of November of 2003. The results demonstrate a high correlation and adjustment between the movement that occurred those days in relation to their baseline;

II. Test purposed by Bland & Altman (Bland, 1986): Refer to the deviations analysis that occur between the baseline and the real movement. 95 % of the deviations/errors observed during all days from September to November 2003, in segments S_1, S_2, and S_3, are between the required limits of $\overline{d} \pm 2 * s$, where $\overline{d}$ is the mean and s is the standard deviation of the differences between the baseline and the real movement, as shown in figure 7. In the other months of the year the results had also confirm the reliability of the model, keeping 95 % of the cases inside the limits established of $\overline{d} \pm 2 * s$;

III. Hurst parameter (H): Tests carried out with the real movement and the baseline generated by the BLGBA, using the statistical methods Variance-time, Local Whittle and Periodogram (Leland, 1994) generate the hurst parameter *H*. The analysis confirms that the traffic is self-similar and the baseline is also self-similar, however presenting a lower hurst parameter. Figure 8 illustrates an example of these calculations for S_1 segment during November 2003. In most of the cases, these tests also allow us to notice that in segments with lower number of computers like S_2, the hurst parameter presents a lower rate between 0.6 and 0.7, in segments with great aggregated traffic like the S_1, and S_3 it presents a rate between 0.8 and 1.0. The Hurst parameter evaluation was made using the samples collected second by second with the GBA tool. Calculations were made for each day between 8:00 and 18:00 hours, the period when the traffic is more similar to a stationary stochastic process. Its utilization makes possible the evaluation of the baseline quality in segments of different burstiness. Indicating that the greater the burstiness of the segment, the bigger the Hurst parameter and the better the characterization showed by the baseline. And the lower the burstiness of the segment, the smaller the Hurst parameter and worse the results shown by the baseline. These results are corroborated by the other tests utilized to validate the baseline that also indicate an increase of the baseline quality in segments with a higher burstiness.

3 CONCLUSION

This work presented a contribution related to the automatic generation of baseline for network segments, which constitutes itself into an important mechanism for the characterization of the traffic of the analyzed segment, through thresholds that reflect the real expectation of the volume of traffic respecting the time characteristics along the day and the week. This enables the network manager to identify the limitations and the crucial points in the network, control the use of the network resources, establish the real use of the resources, besides contributing to the planning of the needs and demands along the backbone.

The use of an alarms system integrated to the baseline as well as with the monitoring performed real time by the GBA, figure 1 (b) and (c), can make possible for the network manager to be informed through messages, at the exact moment a difference related to the expected traffic and the baseline, was found out. This possibility is fundamental for the segments or crucial points of the networks that demand perfect control and pro-active management in order to avoid the unavailability of the services rendered.

The use of graphs such as the ones shown in figures 4 with information about the baseline and about the daily movement, makes a better control over the segments possible.

It could be noticed that the behavior of the traffic of the Ethernet networks is random, self-similar and extremely influenced by the quantity of bursts, which intensify as the number of hosts connected to the segment increase, as shown in (Leland, 1994). It also showed that the model chosen for the characterization of the baseline, presented in this work, is viable for the characterization of the traffic in backbone segments that concentrate the traffic of a great number of hosts, as shown in the examples of section 2.

Tests were also realized with baselines from other MIB objects, like ipInReceives, icmpInMsgs, udpInDatagrams. The results have been satisfactory and demonstrated that the BLGBA model can be used for other MIB objects.

Besides the tests performed at the networks of UEL and be initiate in the Communications Department of the Electric Engineering Faculty of UNICAMP, which results validating the model presented in this work, tests with different types of networks, such as factories, large providers and industries shall be performed, aiming to evaluate and perfect the model proposed for generation of baseline.

Another future work being developed refers to the creation of a multiparametric model for alarms generation aiming to aid the security, performance and fault management, using a set of some monitored objects baseline, such as IP, TCP, UDP and ICMP packet traffic, traffic volume in bytes and number of errors. The model consists in the utilization of a baseline set, information about possible network anomalies and rules for alarm generation based on thresholds in differentiated levels, which would indicate specific conditions to customizable problems to the network. A creation of an efficient mechanism of anomaly detection and alarm generation is expected.

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