Impact of Admission Control Methods to the Traffic Management

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Abstract. *The paper deals with Admission control methods (AC) in IMS networks (IP multimedia subsystem) as one of the elements that help ensure QoS (Quality of service). In the paper we are trying to choose the best AC method for selected IMS network node to allow access to the greatest number of users. Of the large number of methods that were tested and considered good we chose two. The paper compares Gaussian approximation method and one of the measurement based method, specifically „Measured Sum“. Both methods estimate effective bandwidth to allow access for the greatest number of users/devices and allow them access to prepaid services or multimedia content.*

Keywords

AC methods, IMS, IP, traffic control, QoS.

1. The Present Generation of Networks

IP multimedia subsystem (IMS) was created in 1999 as standard 3GPP. This standard was the first try of the creation of convergent network and creation of a single platform to provide multimedia services. It was originally designed to ensure IP connectivity in UMTS. It brought change from circuit-switched technology, which was used in older generations of the systems, to packet-switched technology. IMS guarantees QoS and brings a number of benefits, technical and economical, for the service provider and customer too. The biggest advantage is cooperation with a previous generation of networks by built-in gates and strong standardization. It is used for all types of services, radio, fixed and cable.

IMS testing operation started in 2006 in Japan and Korea and 2007 in the United States. Today IMS is already fully developed in Slovakia (for example telecommunications operators O2, Telekom, Orange). IMS is used to provide a wide range of services, for example. VoIP, IPTV, video communication, transfer of data services and others [1].

2. The Traffic Management

Admission control methods are used by creating a new connection to decide that a new connection will be accepted or rejected. AC methods are based on probability theory and mathematical statistics. Have the task keep the balance between the use of network resources and previously agreed on connection parameters. It is the first act to be carried out in the allocation of network resources for a particular connection. AC methods are the first protection against redundancy in the network. New connection is allowed only if there is guaranteed QoS, otherwise the connection is refused. QoS must also be observed for the existing connections in the network. If it is not met the new connection will be allowed [2], [3], [4], [5], [6], [7].

AC method solves the problem when the N connections in multiplex with a total capacity C, the probability that the sum of the immediate bit rate $r_i(t)$ of all connections in multiplex exceeds the total capacity C, is less than a given value ε. This probability can be expressed as

$$P\left[\sum_{i=1}^{n} r_i(t) \geq C\right] < \varepsilon. \tag{1}$$

AC methods should satisfy three main conditions:

- Effectively allocate bandwidth to utilize maximally of telecommunications network.

- Manage a telecommunications network to meet all requirements of QoS.
- Does not allocate the entire bandwidth so that no overload on the network node is [3].

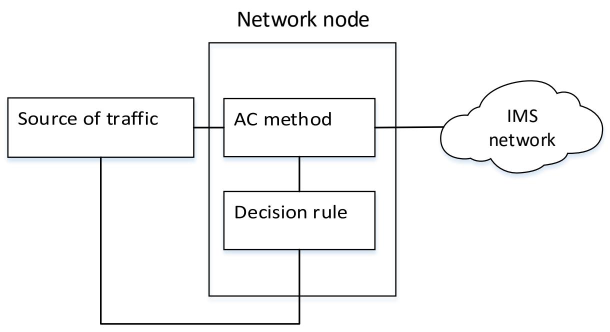

Fig. 1: AC methods.

2.1. Classification of Traffic Management Methods

AC methods can be classified of several parameters. It depends on the view, or parameters what they work with and under which requirements are evaluated. The first way to divide these methods is to divide them on the basis of traffic parameters, obtained from predefined values (Parameter Based Admission Control Methods - PBAC) or used online measurement of network (Measurement Based Admission Control Methods - MBAC). We can divide them through the use of a buffer or parameter PLR (Packet Loss Ratio) or effective bandwidth and more. We know several tens of AC methods that are intended to be used in particular networks or in some nodes of telecommunication networks. With many of them we worked well in our Institute of telecommunications FEI STU in Bratislava. The most frequently used methods are Gaussian approximation method, method of effective bandwidth, diffusion method, convolution method and others. This paper compares two methods, because it could not be possible to compare all known methods and even those most frequently implemented. For simulation the two methods were chosen, Gaussian approximation method and "Measured sum" algorithm. These methods were chosen because after trying many others, these came out better than the others. And of course these two methods are used in similar traffic models what is the reason why we were interesting about those methods right from very beginning [3], [4], [7].

The future of AC methods is expected in the use of the methods that used the online measurement of network (MBAC), fuzzy logic and neural networks [10], [12].

3. Gaussian Approximation Method

In the terms of distribution it is PBAC method. The method for determining the required bandwidth, packet loss rate and memory overflow is based on the central limit theorem and Gaussian distribution. This algorithm approximates probability distribution of aggregated traffic provided that the number of connections is N, it is close to infinity and none of the connections is dominant. With an increasing of aggregated traffic converges to Gaussian model. Each of connections is determined by the mean bit rate λ_i and its standard deviation σ_i.

$$\lambda_i = SPR_i, \tag{2}$$

$$\sigma_i^2 = SPR_i(PPR_i - SPR_i). \tag{3}$$

The resulting mean value of bit rate is

$$\lambda = \sum_{i=1}^{N} \lambda_i. \tag{4}$$

And the resulting value of variance is

$$\sigma^2 = \sum_{i=1}^{N} \sigma_i. \tag{5}$$

If X is the aggregated bit rate of N connections we need to find capacity c_g for which it holds

$$P\{X > c_g\} \leq \varepsilon, \tag{6}$$

ε is a probability of packet loss

$$c_g \approx \lambda + \alpha'\sigma', \tag{7}$$

$$\alpha' = \sqrt{-2\ln(\varepsilon) - 2\ln(\pi)}. \tag{8}$$

The new connection is accepted only if $c_g < C$, otherwise is rejected. Estimation of the probability link overflow is

$$P_{overflow} = P\left[\left(\sum_{i=1}^{N} r_i(t) \geq C\right)\right] = \frac{1}{\sqrt{2\pi}} e^{-\frac{(\lambda - C)^2}{2\sigma^2}}. \tag{9}$$

The probability of packet loss is

$$P_{loss} = \frac{P\left[\left(\sum_{i=1}^{N} r_i(t) - C\right)\right]^+}{\lambda} = \frac{\sigma}{\lambda\sqrt{2\pi}} e^{-\frac{(\lambda - C)^2}{2\sigma^2}}. \tag{10}$$

$r_i(t)$ is a actual bit rate of connection i [bps]. The estimation of required bandwidth is calculated as

$$C_g = \sum_{i=1}^{N} \lambda_i + h \sum_{i=1}^{N} \sigma_i, \quad (11)$$

where

$$h = \sqrt{-2\ln(\varepsilon) - 2\ln(\pi)}, \quad (12)$$

then the resulting value of required bandwidth is

$$C_g = \sum_{i=1}^{N} \lambda_i + \left(\sqrt{-2\ln(\varepsilon) - 2\ln(\pi)}\right) \sum_{i=1}^{N} \sigma_i. \quad (13)$$

This approach has been already used in literature and the approximation gives very good results only for a large number of connections that have similar stationary distribution, long periods of burst and Gaussian character. For a small number of connections and short periods of burst it is not able to use those relationships. The resulting value of required bandwidth would be too conservative [7], [11], [15] and [16].

4. MBAC Methods

The methods are based on on-line measurements of traffic passing through the switch and the new connection requires only a minimum of information. But the additional information improves the efficiency of AC method. Initial estimate of bandwidth is made of the available parameters and further adjusted according to the measurement results. On-line measurement must be fast enough. It applies that the shorter measuring period then more connections can be served. AC method based on the measurement cannot be used directly by the current packet loss rates. Therefore use a simpler and more efficient way and measurement of bandwidth [8], [9], [13].

If N connections passing through the switch use the bandwidth C, we try to estimate the minimum bandwidth $C(N)$. $C(N)$ is bandwidth that these connections need to be able to guarantee predetermined parameters of packet loss rate.

4.1. Algorithm „Measured Sum“

It is one of MBAC methods and it is used the aforesaid principle. It is an improvement of „Simple sum“ algorithm which was published in [7], [10] and [13]. Algorithm allows connections until

$$C_r + r_{n+1} < \mu C, \quad (14)$$

where C - the maximum capacity of the line, C_r - is the sum of n bit rates and connection r_{n+1}, r_{n+1} - is the bit rate connection, requesting for permission and μ - is user-defined traffic usability (value is from zero to one).

Most often it is implemented in switches and routers where we donnot expect too much load.

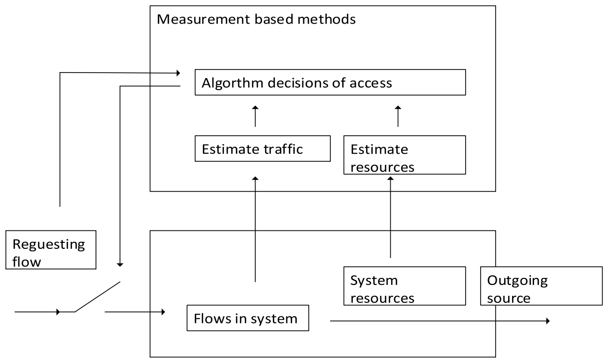

Fig. 2: Measurement based AC methods.

5. Simulation

Simulations and all the necessary calculations for the individual compared of all methods were developed in Matlab (R2010). All results of the individual simulations are shown through specific graphs for their better readability and follow much easier interpretation. Because of all the necessary calculations and their results should clearly not choose a more appropriate method and the results should lose its importance.

5.1. Traffic Model and Parameters 1

For the simulation (and all the necessary calculations had to be performed at each of the compared methods) were defined traffic parameters. It was necessary calculate with these parameters. And in evaluating the results, taking to consider some limits, so that we can clearly determine the appropriateness of the method [8], where we define: C - maximum capacity of the line, $P_{overflow}$ - maximum value for probability of line overflow, P_{loss} - maximum value for probability of packet loss.

Parameters were defined as follows: $C = 10$ Mbps, $P_{overflow}$ is from 10^{-7} to 10^{-5}, P_{loss} is from 10^{-6} to 10^{-5}.

In Fig. 3 you can see simulated node of IMS network. As a source of traffic was used randomly generated traffic matrix on the size of $n \times T$, were $n = 3000$ represented the number of used resources and $T = 3000$ represented the number of time cycles, when the traffic was simulated. Traffic matrix represented requirements of network (or users) for connection (user's access to

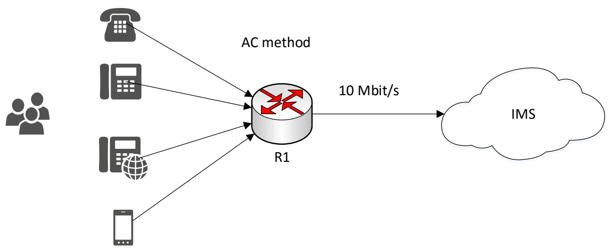

Fig. 3: Model of traffic for simulations.

his subscription services). Individual network requirements represented specific multimedia devices (smartphone, telephone, telephone - VoIP). VoIP telephones represent users who use codecs G.711 and G.729E for making a voice call (VoIP). It means that the requirements for bandwidth ranged from 12 kbps for codec G.729E to 64 kbps for codec G.711. In Fig. 4 you can see incoming requirements to the node R1.

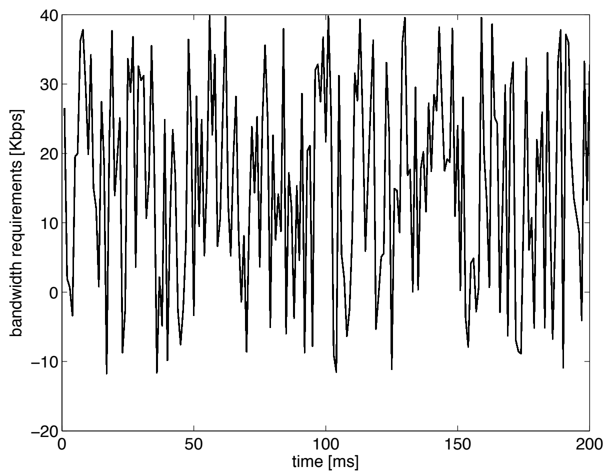

Fig. 4: Incoming requirements for bandwidth for traffic model 1.

5.2. The Simulation Results for Gaussian Approximation Method Traffic Model 1

The first selected and simulated was Gaussian approximation method. In Fig. 5 you can see a graphical simulation result for the resultant required bandwidth C_g. For access ask 9000 requirements. As you can see, access is granted to 8031 users/acceding devices. It means that 89.23 % of all incoming requirements are enabled. Other attempts to create a new connection by any other device would already cross maximum capacity of line $C = 10$ Mbps. So another user will already have access denied because there is no available bandwidth.

In Fig. 6 you can see how changes the probability of line overflow. For 8031 users, reaching the max. capacity of the line is the probability of line overflow $9.473 \cdot 10^{-7}$, which does not exceed the maximum allowed probability of line overflow $P_{overflow}$ (allowed from 10^{-7} to 10^{-5}).

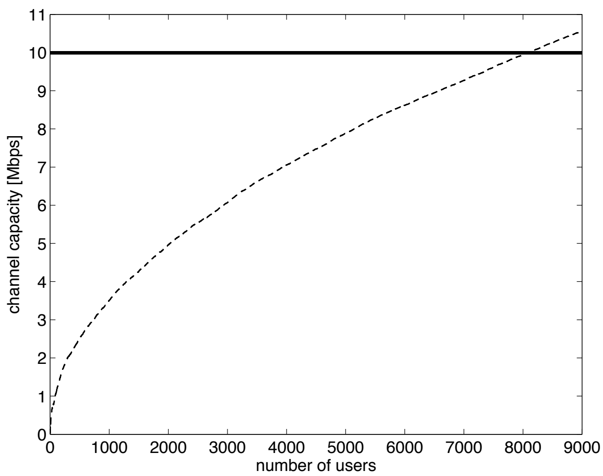

Fig. 5: Resultant required bandwidth C_g.

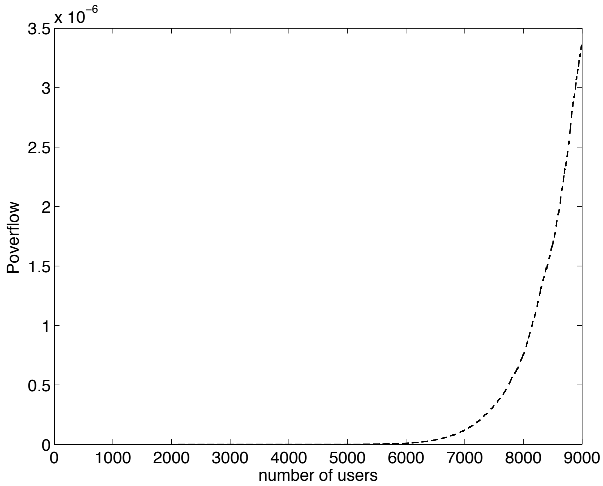

Fig. 6: Probability of line overflow $P_{overflow}$.

It is obvious that if there are more than 8031 users in network this probability still does not exceed the maximum allowed value. Problem is there is no available bandwidth to satisfy those users.

In Fig. 7 you can see how changes the probability of packet loss. For 8031 users, reaching the maximum capacity of the line is the value of probability of packet loss much greater, than selected maximum value. But for 6355 incoming requirements probability of packet loss is $4.6 \cdot 10^{-6}$ what does not exceed the maximum allowed value. It means we are not able to enable access to 8031 users which exceed maximum capacity of the line.Access is enable only to 6355 incoming requirements. It represents that 70.61 % of all incoming requirements are enabled. For 6355 requirements the uti-

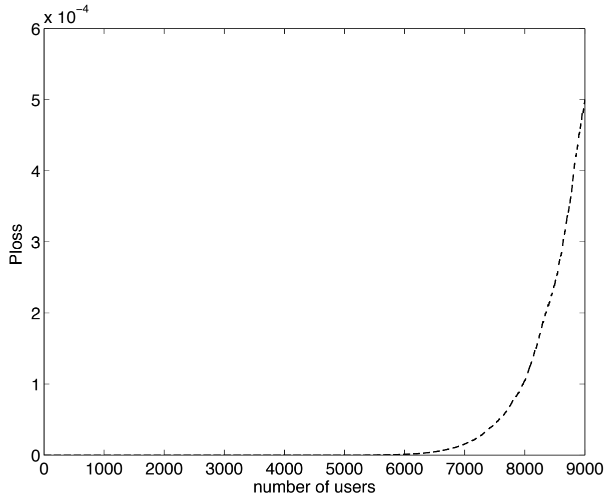

Fig. 7: Probability of packet loss P_{loss}.

lization of bandwidth (line) is 8.943 Mbps. You can see the utilization of line in Fig. 8. So we are not able to use whole bandwidth.

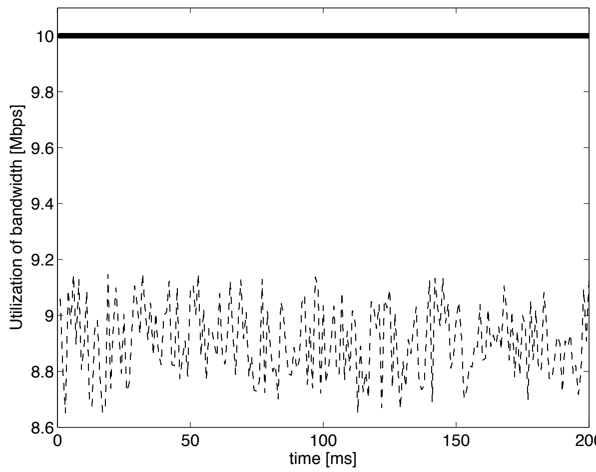

Fig. 8: Utilization of line.

5.3. The Simulation Results for „Measured“ Algorithm Traffic Model 1

In Fig. 9 you can see the simulation result for algorithm „Measured sum“, which is measurement based AC method. You can see that access is granted to 751 incoming requirements. Once there are 751 users/acceding devices in network there is no available bandwidth for any other users. This small number of users that access is granted may be caused by the simplicity of the algorithm that uses this method. Algorithm assumed traffic usability $\mu = 0.7$, which means 70 % utilization. Therefore the effect of the advantages of online measurements with this method not show fully.

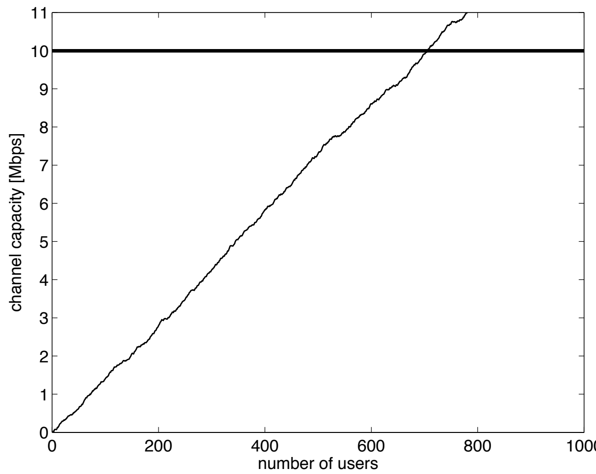

Fig. 9: The simulation results for „Measured sum“ algorithm.

5.4. Traffic Model and Parameters 2

In the traffic model 2 there are the same parameters of network node as in model 1 that you can see in Fig. 3. There are same values of C, $P_{overflow}$ and P_{loss}. The difference between model 1 and 2 is in the source of traffic. As a source of traffic was used randomly generated traffic matrix on the size of $n \times T$, were $n = 3000$ represented the number of used resources and $T = 3000$ represented the number of time cycles, when the traffic was simulated. Traffic matrix represented requirements of network (or users) for connection (user's access to his subscription services). Individual network requirements represented specific multimedia devices (smartphone, telephone, telephone - VoIP). VoIP telephones represent users who use codecs G.711 and G.729E for making voice call (VoIP). It means that the requirements for bandwidth ranged from 12 kbps for codec G.729E to 64 kbps for codec G.711. Smartphones represents users who use data downloads. Maximum bandwidth for smartphones is 512 kbps. In Fig. 10 you can see incoming requirements to the node R1 for traffic model 2.

5.5. The Simulation Results for Gaussian Approximation Method Traffic Model 2

In Fig. 11 you can see a graphical simulation result for the resultant required bandwidth C_g for Gaussian approximation method. For access ask 100 requirements. As you can see, access is granted to 88 users/acceding devices. It means that 88 % of all incoming requirements is enabled. Other attempts to create a new

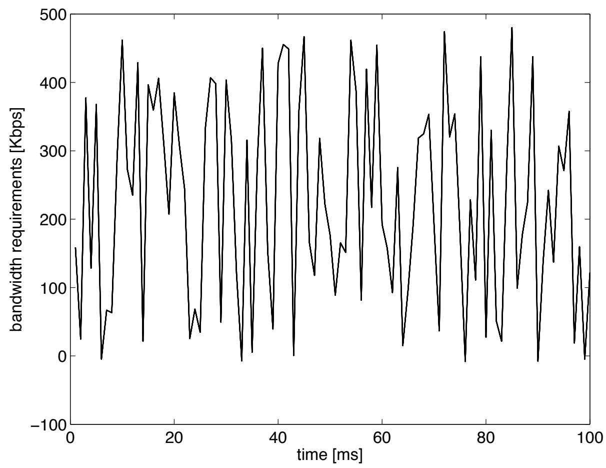

Fig. 10: Incoming requirements for bandwidth for traffic model 2.

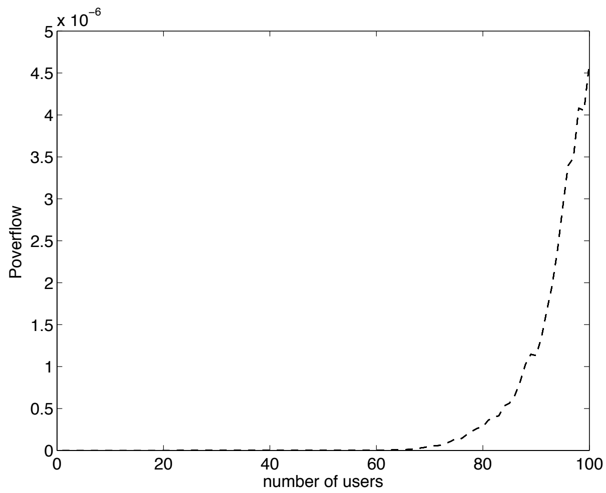

Fig. 12: Probability of line overflow $P_{overflow}$.

connection by any other device would already cross maximum capacity of line $C = 10$ Mbps. So another user will already have access denied because there is no available bandwidth to satisfy his requirements.

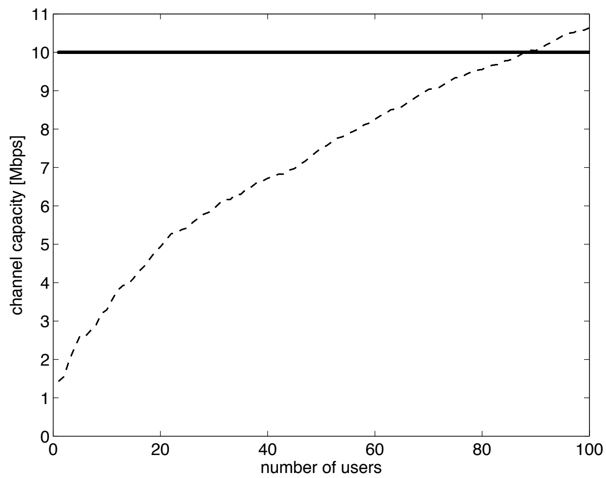

Fig. 11: Resultant required bandwidth C_g.

In Fig. 12 you can see how changes the probability of line overflow. For 88 users, reaching the maximum capacity of the line is the probability of line overflow $1.031 \cdot 10^{-6}$. This does not exceed the maximum allowed probability of line overflow Poverflow (allowed from 10^{-7} to 10^{-5}) and do not come close to these values. It is obvious (in this model too) that if there are more than 88 users in network this probability still does not exceed the maximum allowed value. Problem is there is no available bandwidth to satisfy those users.

In Fig. 13 you can see how changes the probability of packet loss. For 88 users, reaching the maximum capacity of the line is the value of probability of packet loss $9.848 \cdot 10^{-6}$ which does not exceed the maximum allowed probability of packet loss P_{loss} (from 10^{-6} to 10^{-5}) and do not come close to these values. So in this model we are able to granted access to all 88 users because the maximum allowed value is not exceeded.

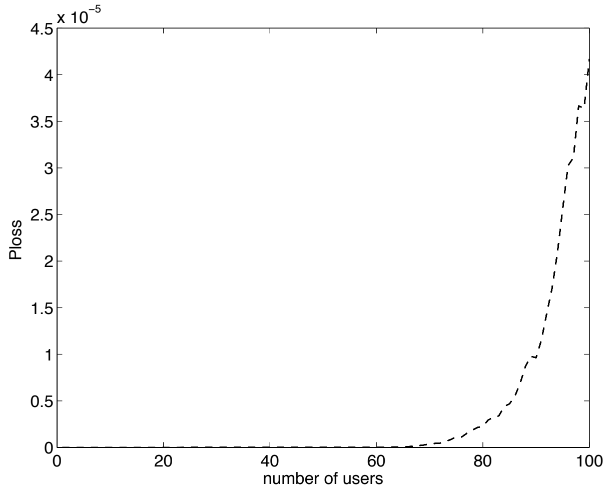

Fig. 13: Probability of packet loss P_{loss}.

In the comparison with results for traffic model 1 you can see that we are using whole available bandwidth and there is no bandwidth for another type of services.

5.6. The Simulation Results for „Measured“ Algorithm Traffic Model 2

In Fig. 14 you can see the simulation result for algorithm „Measured sum“. You can see that the maximum line capacity is exceeded for 43 acceding users. This small number of users that access is granted may be caused by the simplicity of the algorithm that uses this method. Algorithm assumed traffic usability $\mu = 0.7$, which means 70 % utilization. Therefore the effect of the advantages of online measurements with this method not show fully.

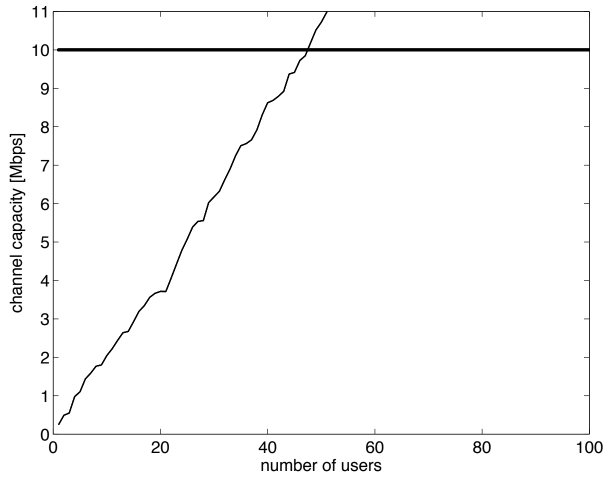

Fig. 14: The simulation results for „Measured sum" algorithm.

6. Comparison of Gaussian Approximation Method and „Measured Sum" Algorithm

6.1. Comparison for Traffic Model 1

In Fig. 15 you can see simulation results for traffic model 1 for „Measured sum" algorithm and Gaussian approximation method and Diffusion method published in [13] and [14]. From this direct comparison of Gaussian approximation method and „Measured sum" algorithm it is obvious that Gaussian approximation method is much better for the our traffic node R1. As was mentioned „Measured sum" algorithm (yellow line) allows access to 751 users, Gaussian approximation method (green line) allows access to 6355 users and diffusion method (blue line) to 2360 users.

From simulation results and the graphs presented for traffic model 1 it is obvious that the preferable AC method in our traffic node is Gaussian approximation method.

Of course „Measured sum" algorithm is easier to implement in the node because there are less computing requirements, costs (it is easier to implement = economical). „Measured sum" algorithm is capable to do great work in the nodes where we do not expect too much load. In our node we assumed 70 % utilization.

Gaussian approximation method works great only if there is high value of requirements in the node. In our case where there are 9000 requirements it works great. We were able to enable access to 8031 users.

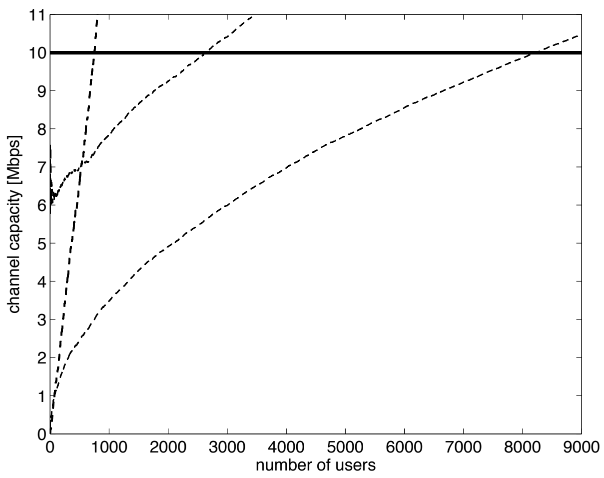

Fig. 15: Comparison of simulated methods for traffic model 1.

But we must be very careful and watch the probability of packet loss. Because by 8031 enabled accesses there is too high value of probability of packet loss. Acceptable value of probability of packet loss is $4.6 \cdot 10^{-6}$ and it means "only" 6355 enabled accesses. This number represents 70.61 % of all incoming requirements. It also represents 89.43 % utilization of line (use of bandwidth). The rest of bandwidth is free to use for another type of service. There is 1.057 Mbps available bandwidth.

When we compare the results of simulation Gaussian approximation method allows access to 8.46 times more users that „Measured sum" algorithm.

6.2. Comparison for Traffic Model 2

In Fig. 15 we can see simulation results for traffic model 2 for „Measured sum" algorithm and Gaussian approximation method From this direct comparison of Gaussian approximation method and „Measured sum" algorithm for traffic model 2 it is obvious that Gaussian approximation method is still much better for our traffic node R1. As was mentioned „Measured sum" algorithm (blue line) allows access to 43 users, Gaussian approximation method (green line) allows access to 88 users. From simulation results and the graphs presented for traffic model 2 it is obvious that the preferable AC method in our traffic node is still Gaussian approximation method.

Of course „Measured sum" algorithm is easier to implement in the node because there are less computing requirements, costs (it is easier to implement = economical). „Measured sum" algorithm is capable to do great work in nodes where we do not expect too much load. In our node we assumed 70 % utilization.

Gaussian approximation method works great only if there is high value of requirements in node. In our case

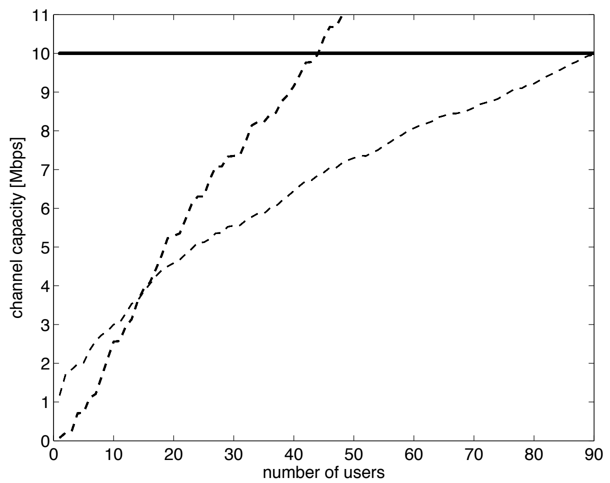

Fig. 16: Comparison of simulated methods for traffic model 2.

when there are 100 requirements it still works great. We were able to enable access to 88 users. In comparison with results for traffic model 1 you can see that the values of probability of packet loss are in pre-defined range. So we are able to enable 88 % of all incoming requirements. In this case there is no more available bandwidth for other type of services. When we compare the results of simulation for traffic model 2 Gaussian approximation method allows access to 2.05 times more users that „Measured sum“ algorithm.

7. Conclusion

In the simulated node we use the advantage of Gaussian approximation method that it has good results only for a high number of users. The disadvantage of this method may be economical. In comparison with „Measured sum“ algorithm is more expensive. Another disadvantage is that there are more computing requirements. To the decision that the connection is enabled or rejected there must be calculated three values. Resultant required bandwidth Cg, the probability of packet loss P_{loss} and the probability of line overflow $P_{overflow}$. „Measured sum“ algorithm needs to calculated only one.

For all our simulations and calculations it is obvious that the number of allowed requirements depends on the traffic source. When we use as a source of requirements only VoIP calls as it is in traffic model 1 there are very good results with Gaussian approximation method. In the case for traffic model 2 when we use as a source of requirements VoIP calls and data download there are still good results for Gaussian approximation method. In both cases Gaussian approximation method is better than „Measured sum“ algorithm. But for the traffic model 2 we can expect that there are AC methods which are able to allow access to more connections than Gaussian approximation method. For example it could be diffusion method.

Small and cheap solution to improve the method or system may implement certain warnings or queues. From the view of the setting of the user's device and the settings of the network itself in reaching maximum capacity, the device may be reminded to wait until the available capacity. Capacity may be after released allocated and device may be notified about availability or same as it is now device can be rejected. In the last case, the device will have to try the new connection. The first cases should preferably wait in the queue and would rather be serviced. This would of course lead to greater user satisfaction but mainly to more efficient distributing of the source.

Our simulations prove that choose of AC method has high impact to traffic management. But we must be very careful by choosing of AC method because it always depends on traffic source. There are other conditions for only VoIP traffic and for VoIP+ data traffic.

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