Contribution to the Management of Traffic in Networks

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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 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 diffusion method and one of the measurement based method, specifically „Simple 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.

1. IMS

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. 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].

2. AC Methods

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 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.

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 [3], [4]:

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

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].

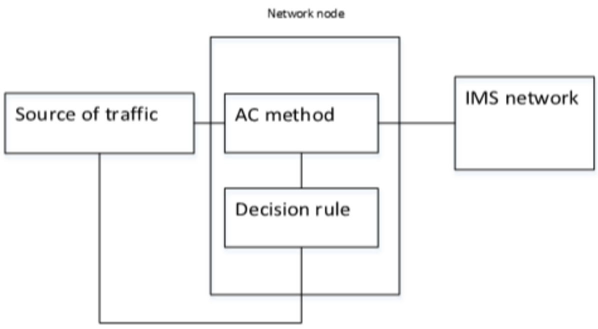

Fig. 1: AC methods.

2.1. Distribution of AC Methods

AC methods can be classified of several parameters. It depends on the view, or parameters which they work 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 pre-defined values in the descriptor service or used online measurement of network. We can divide them through the use of 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 Faculty of Electrical Engineering and Information Technology at Slovak University of Technology 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, diffusion and Simple 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.

The future of AC methods is expected in the use of the methods that used online measurement of network, fuzzy logic and neural networks [3], [4], [6], [7].

3. Diffusion Method

In terms of distribution diffusion method uses data from the traffic descriptor. Diffusion processes in this case are more precise approximation of continuous systems with discrete line slot. Method assumes total capacity of the output link C and buffer size B. The process is determined by the maximum speed of the source R, average speed of the source r and the average cluster size b. We will use diffusion method based on two relations that describe the required bandwidth for the models with finite (FB – finite buffer) and infinite (IB – infinite buffer) capacity of line slot [3].

Packet loss probability of a final buffer size can be defined as:

$$P_{FB} = \frac{1}{\sqrt{2\pi}} e^{\frac{2B}{\alpha}(\lambda - C) - \frac{(\lambda - C)^2}{2\sigma^2}}, \tag{2}$$

and the probability of packet loss with infinite buffer size as:

$$P_{IB} = \frac{\sigma}{\lambda\sqrt{2\pi}} e^{\frac{2B}{\alpha}(\lambda - C) - \frac{(\lambda - C)^2}{2\sigma^2}}, \tag{3}$$

aggregated mean value of the bit rate:

$$\lambda = \sum_{i=1}^{N} r_i, \tag{4}$$

σ^2 the aggregate variance bit rate:

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

$$\sigma_i^2 = r_i(r_i - R_i). \tag{6}$$

Immediate variance of arrival packet α calculated as:

$$\alpha = \sum_{i=1}^{N} r_i CV_i^2, \tag{7}$$

where

$$CV_i^2 = \frac{1 - (1 - \beta_i T_i)^2}{(\beta_i T_i + \gamma_i T_i)}, \tag{8}$$

$$T_i = \frac{1}{R_i}, \tag{9}$$

$b_i = \frac{1}{\beta_i}$ is the mean value of the active period of the source, $\frac{1}{\gamma_i}$ is the mean value of the inactive period.

Relations for calculating statistical bandwidth for FB and IB model, where the packet loss rates is less than ε, can be expressed as:

$$C_{FB} = \lambda - \delta + \sqrt{\delta^2 - 2\sigma^2\omega_1}, \tag{10}$$

$$C_{IB} = \lambda - \delta + \sqrt{\delta^2 - 2\sigma^2\omega_2}, \tag{11}$$

$$\omega_1 = \ln(\varepsilon\sqrt{2\pi}), \tag{12}$$

$$\omega_2 = \ln(\varepsilon\lambda\sqrt{2\pi}) - \ln(\varepsilon), \tag{13}$$

$$\delta = \frac{2B}{\alpha}\sigma^2. \tag{14}$$

The resulting statistical effective bandwidth is then determined as:

$$C_{df} = \max\{C_{FB}, C_{IB}\}. \tag{15}$$

Decision algorithm for accepting or rejecting new connection can then be summarized as follows:

- At each point of time are monitored parameters λ, σ^2, α.
- After the arrival of a new connection values of parameters λ, σ^2, α are recalculated, so as to include a new connection.
- Calculate the value C_{df}.
- If $C_{df} \leq C$ new connection is accepted.
- Else, a new connection is rejected and the previous values of the parameters λ, σ^2, α are restored.

Diffusion method is conservative with respect to packet loss, but more economic in bandwidth allocation. At the same time provides greater opportunities for homogeneous and heterogeneous telecommunication traffic. This method is easy to implement, technically and economically too.

4. Measurement Based AC 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 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 can't be used directly by the current packet loss rates. Therefore use a simpler and more efficient way and measurement of bandwidth.

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 [3], [5].

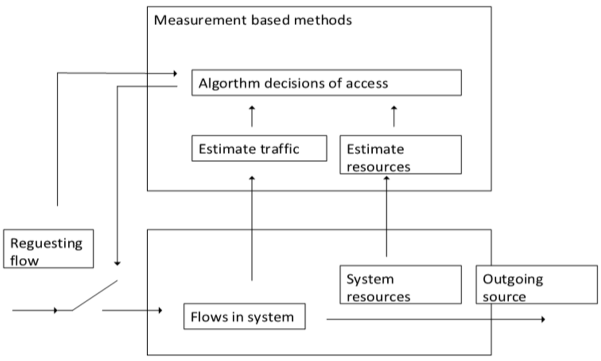

Fig. 2: Measurement based AC methods.

4.1. Algorithm „Simple sum“

It is one of measurement based AC algorithm and it is used the aforesaid principle.

$$C_r + r_{n+1} < C, \tag{16}$$

C the 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.

Most often it is implemented in switches and routers where we don't expect too much load [6].

5. Simulation

Simulations and all the necessary calculations for the individual compared for all methods were developed in Matlab (R210). 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

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.

Defined was:
C capacity of the line,
B buffer size,
ε maximum value of a loss of packets.

Parameters were defined as follows:
$C = 100$ Mbit·s^{-1},
$B = 45$ packets,
ε from 10^{-6} to 10^{-5} packets·s^{-1}.

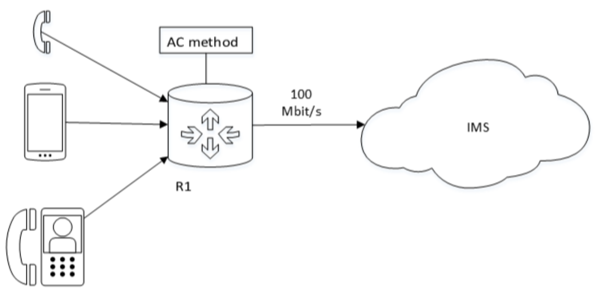

Fig. 3: Model of traffic for simulations.

As a source of traffic was used randomly generated traffic matrix on the size of $n \times T$, were $n = 300$ represented the number of used resources and $T = 300$ 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 ranged from 1 Mbit·s^{-1} to 6 Mbit·s^{-1} represented specific multimedia devices (smartphone, tablet, telephone - VoIP), which requested access, to download data (whether from different cloud or web sites), watching video (Youtube) and VoIP communication.

5.2. The Simulation Results for Diffusion Method

The first selected and simulated was diffusion method. In Fig. 4 we can see a graphical simulation result of simulation for the resultant statistical effective bandwidth C_{df}. For access asks 200 users. As we can see, access is granted "only" to 170 users/acceding devices. On further attempts to create a new connection by any other device would already crossed maximum capacity of line $C = 100$ Mbit·s^{-1}. And another user will already have access denied.

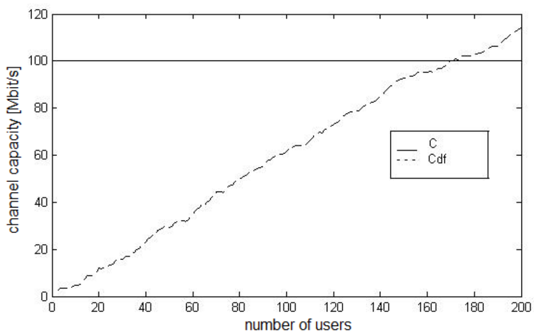

Fig. 4: The resultant statistical effective bandwidth C_{df}.

For a comparison of the resulting statistical effective bandwidth in Fig. 5 we can see waveforms for statistical bandwidth with finite C_{FB} and infinite C_{IB} buffer size that were simulated (calculated) according to given relations for diffusion method. It was necessary to calculate them, because the resulting statistical effective bandwidth C_{df} is calculated using these relations. Directly as the maximum of the values C_{IB} and C_{FB}, as was mentioned in the description of the method above. We can see, that C_{FB} obtained with the given parameters the maximum capacity of the line rather than C_{IB}. C_{IB} maximum capacity of the line in case of 200 users doesn't reached. It would reach in the case of 255 users. There would also exceed the parameter of loss of packets ε (would be lost to too many packets, about 10^{-3} [packets·s^{-1}]). This is why we take the resulting statistical effective bandwidth C_{FB}, the maximum value of this two, because it keeps all the parameters within the given prescribed values for by us simulated network

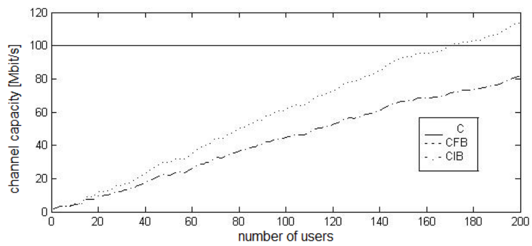

Fig. 5: Statical bandwidth with finite C_{FB} and infinite C_{IB} buffer size.

In Fig. 6 we can see how changes the probability of packet loss with a finite buffer size P_{FB}. Up to 144 incoming connections from users is probability of the loss of packets about 10^{-11} [packets·s^{-1}]. For 170 users, reaching the maximum capacity of the line is the probability of loss of packets about 10^{-9} [packets·s^{-1}], which does not exceed the maximum permissible loss of packets ε (from 10^{-6} to 10^{-5} [packets·s^{-1}]) and do not come close to these values. Even when exceeding the maximum line capacity $C = 100$ Mbit·s^{-1} do not comes to exceeding the maximum acceptable value of loss of packets ε, it is about 10^{-8} [packets·s^{-1}].

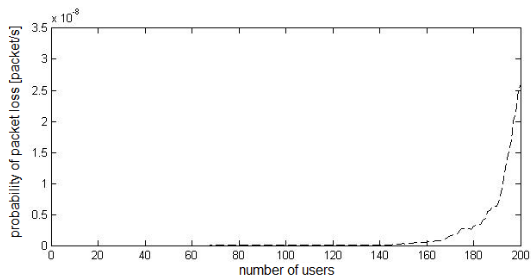

Fig. 6: P_{FB} - The probability of packet loss with a finite buffer size.

In Fig. 7 we can see how changes the probability of packet loss with infinite buffer size P_{IB}. Up to 140 incoming connections from users is probability of the loss of packets about 10^{-8} [packets$\cdot$s^{-1}]. For 170 users, reaching the maximum capacity of the line is the probability of loss of packets about 10^{-6} [packets$\cdot$s^{-1}], which does not exceed the maximum permissible loss of packets ε (from 10^{-6} to 10^{5} [packets$\cdot$s^{-1}]). Even when exceeding the maximum line capacity $C = 100$ Mbit$\cdot$s^{-1} do not comes to exceeding the maximum acceptable value of loss of packets ε, it is about 10^{-5} [packets$\cdot$s^{-1}]. It's been a while for the imaginary border of loss, but still within the range of the parameter.

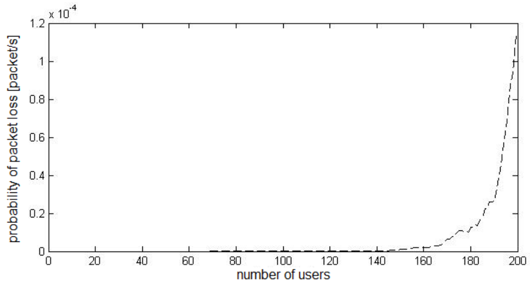

Fig. 7: P_{IB} - The probability of packet loss with an infinite buffer size.

5.3. The Simulation Results for „Simple sum“ Algorithm

In Fig. 8 we can see the simulation result for algorithm „Simple sum“, which is measurement based. We can see that the maximum line capacity is exceeded for 49 acceding users. This small number of users that access is granted may be caused by the simplicity of the algorithm that uses this method. Therefore the effect of the advantages of online measurements with this method not show fully.

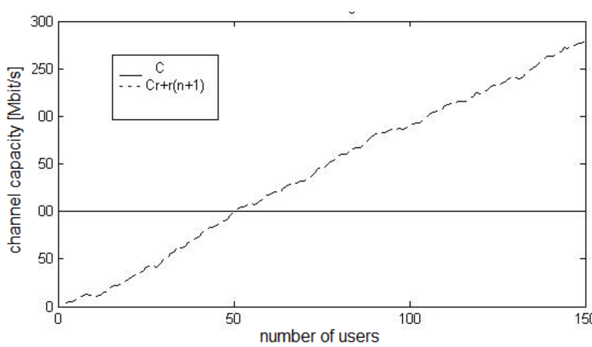

Fig. 8: The simulation results for „Simple sum“ algorithm.

5.4. Comparison of Diffusion Method and „Simple sum“ Algorithm

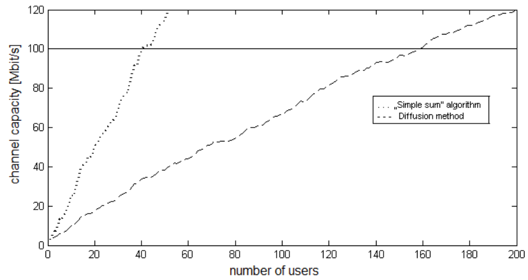

Fig. 9: The simulation results for „Simple sum“ algorithm and diffusion method.

In Fig. 9 we can see simulation results for „Simple sum“ algorithm and diffusion method. From this direct comparison of diffusion method and „Simple sum“ algorithm it is clearly that diffusion method is much better for our traffic model. As was mentioned „Simple sum“ algorithm allows access to 49 users, but diffusion method allows access to 170 users.

6. Conclusion

From the simulation results and from the graphs presented it is clear to see that it is preferable in our network node use diffusion method and not the algorithm „Simple sum“.

Algorithm „Simple sum“ is easier to implement from the economic point cheaper and requires less computing capacity of the system but it is simplicity is in this case more loss. Therefore as was already mentioned is mainly used for switches and routers where we don't expect too much load. In contrast diffusion AC method is more difficult by computing capacity, handling all of the necessary calculations to the decision to allow a new connection takes time computing resources (about μs or ns). Diffusion method is more difficult even from the economic point but still a reasonable and profitable as possible. Comparing the financial resources that we use to implement this method in our network and benefit from a number of service users/customers in a very short time we will return our investments. In the very core of the algorithm is indeed more complex but allow network access to multiple users while respecting maximum packet loss rates ε. Diffusion method allows access 3 - times more users than „Simple sum“ algorithm.

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 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 notified equipment about availability of or as it is now device can be rejected. In the last case, the device will have to try to new connection. The first cases should preferably wait and order 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.

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