Traffic Management by Using Admission Control Methods in Multiple Node IMS Network

Filip CHAMRAZ, Ivan BARONAK

Institute of Telecommunications, Faculty of Electrical Engineering and Information Technology, Slovak University of Technology, Ilkovicova 3, 812 19 Bratislava, Slovak republic

filip.chamraz@gmail.com, ivan.baronak@stuba.sk

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Abstract. *The paper deals with Admission Control methods (AC) as a possible solution for traffic management in IMS networks (IP Multimedia Subsystem) - from the point of view of an efficient redistribution of the available network resources and keeping the parameters of Quality of Service (QoS). The paper specifically aims at the selection of the most appropriate method for the specific type of traffic and traffic management concept using AC methods on multiple nodes. The potential benefit and disadvantage of the used solution is evaluated.*

Keywords

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

1. The Current Situation in Networks

Nowadays providers of telecommunication services are still migrating to IP networks. The previous generation of networks was based on circuit switching. The providers were using this technology for many years. But today when there are far more users and provided services, the capacity of networks is no more sufficient. One of the best solutions is to use the IP Multimedia Subsystem (IMS). IMS was created in 1999 as standard of 3GPP. It was the first success in the creation of the convergent network and at the same time creation of the single platform to provide multimedia services. IMS was based on IP technology and it was first used in UMTS networks to ensure IP connectivity. One of the biggest benefits of IMS is that it is able to guarantee Quality of Service (QoS) parameters. It brings potential benefits not only to service providers but to customers too. There are many services which must have guaranteed QoS. For example VoIP, IPTV, video communications, online gaming and others. Therefore the requirements for the network capacity (bit rate) were not the only reason to use IMS. But the guarantee of QoS is not the only benefit of IMS. It is able to cooperate with the previous generation of networks by built in gates and strong standardization. It is used for all types of services, radio, fixed and cable. IMS was created in 1999, the testing operation started in 2006 and 2007 in Japan, Korea and United States. Today it is possible to say that it is fully developed in far many countries. The situation in Slovakia is very good. The telecommunication providers as Slovak Telecom, Orange, O2 and Swan have already implemented the IMS technology [1].

2. QoS Guarantees

As it was already mentioned the IMS network is able to guarantee required QoS parameters for different services. But there are other solutions for improvinge this guarantee. For this we use Admission Control methods (AC). Admission control methods are used for creating a new connection to decide if a new connection will be accepted or rejected. AC methods are based on the probability theory and mathematical statistics and are designed to keep the balance between the use of network resources and previously agreed connection parameters. It is the first action 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. A new connection is allowed only if there is guaranteed QoS, otherwise the connection is rejected. QoS must also be observed for the existing connections in the network. If it is not met the new connection will not be allowed [2], [3], [4], [5], [6] and [7].

AC method solves the problem of 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 the given value ε. This probability can be expressed as:

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

AC methods should satisfy three main conditions:

- Effectively allocate bandwidth to maximally utilize the 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 occurs [2], [3], [4] and [5].

2.1. Known AC Methods

We know tens to hundreds of AC methods. They can be classified by several parameters. The first way to divide these methods is to divide them on the basis of traffic parameters, obtained from pre-defined 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 Packet Loss Ratio or an effective bandwidth and more. They are intended to be used in particular networks or in some nodes of Telecommunications networks. We have experienced many in our Institute of Telecommunications at The Faculty of Electrical Engineering and Information Technology of Slovak University of Technology in Bratislava. The use of the specific method always depends on the network parameters and the source of traffic. The best method to choose for VoIP traffic is usually different for simple traffic or mixed traffic data (VoIP + data + video). This was proved in [2], [3], [9], [10], [11] and [12].

2.2. MBAC Methods

In this article we focused on MBAC methods because these methods are able to meet the required parameters better in comparison with PBAC methods. MBAC methods are able to work better with the available bandwidth. They allocate and redistribute the available bandwidth more efficiently to more users/requirements. This benefit arises from the fact that MBAC are based on on-line measurements of traffic passing through the switch and the new connection requires only minimum of information. The additional information improves the efficiency of the AC method. It means the MBAC method works/calculates with specific real parameters instead of constant defined pre-defined parameters as PBAC methods. The initial estimation of bandwidth is performed available parameters and is furtherly adjusted according to the measurement results. The on-line measurement must be fast enough. It means that the shorter measuring period, the more connections can be served. The AC method based on the measurement cannot be used directly by the current packet loss rates. Therefore, we use a simpler and more efficient way of bandwidth measurement.

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

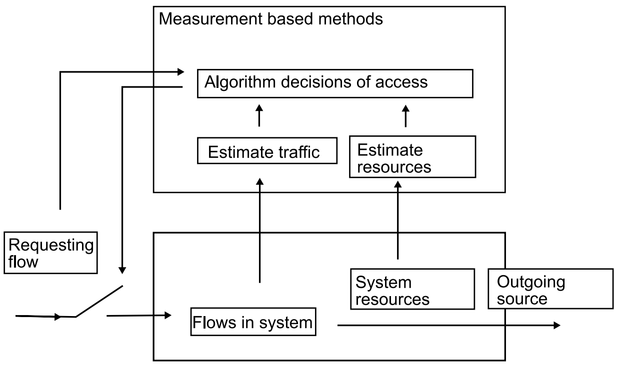

Fig. 1: Measurement based AC methods.

2.3. Reviewed AC Methods

As mentioned previously the main purpose of AC methods is to allow the maximum number of connections with the guaranteed QoS parameters. As it was mentioned before, the choice of the specific method depends on network parameters and the traffic source. Therefore we chose some of the best methods to use for specific parameters and traffic that are described in the Subsection 3.1.

1) Algorithm "Measured Sum"

It is one of MBAC methods and it is used with the abovementioned principle. It is an improvement of the "Simple sum" algorithm which was published in [2] and [5]. Algorithm allows connections until:

$$C_r + r_{n+1} < \mu C, \quad (2)$$

where C is 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 a permission and μ is user-defined traffic usability (value between zero and one).

It is mostly implemented in switches and routers where we do not expect high load [9], [10] and [12].

2) Hoeffding Bound

This method uses Hoeffding bound for the estimation of link traffic. Hoeffding bound sets the higher bound of traffic for connections in networks according to the equation:

$$\hat{C_H}\left(\hat{\nu}, \{R_i\}_{1\leq i\leq n}, \varepsilon\right) = \hat{\nu} + \sqrt{\frac{\ln\left(\frac{1}{\varepsilon}\right)\sum_{i=1}^{n}(R_i)^2}{2}}, \quad (3)$$

where $\widehat{\nu}$ is the total traffic of all connections (bps), R_i is the peak rate of i-th connection (bps) and ε is the prediction that traffic will exceed link capacity.

Hoeffding bound algorithm makes decision based on the equation:

$$\hat{C_H} + R_{n+1} \leq C. \quad (4)$$

If the sum of Hoeffding bound of all existing connections and peak rate of a new connection is lower than the available link capacity the admission control accepts the new connection into the network. On the contrary, if this sum is higher than the available link capacity, the connection will be rejected. Compared to the "Measured sum" algorithm, the Hoeffding bound algorithm will not reserve higher bandwidthfor a short-term raised traffic, because Hoeffding bound is adapted for this case. The mechanism of measurement used in this algorithm uses exponential averaging. Firstly, the average rate is measured, then the exponential average is calculated and finally Hoeffding bound C_H is estimated.

3) Tangent at Peak

This method is based on the Chernof bound and Hoeffding approximation. The new connection is allowed if:

$$np\cdot\left(1 - e^{-sp}\right) + e^{-sp}\cdot\nu \leq C, \quad (5)$$

where n is the number of accepted flows, p is the peak transfer rate (bps), s space parameter of acceptance region (value is from zero to one), ν is the bandwidth of current traffic load (bps) and C is the link bandwidth.

3. Traffic Management in Multiple Node Network

As was proved in [3], it is possible to use AC methods as a solution for traffic management in a single node network. If we use this concept and apply it to the multiple network it will work.

Simulations and all the necessary calculations for the individual comparison of all methods were developed in Matlab (R2014b). All results of the individual simulations are shown inspecific graphs for their better readability and follow much easier interpretation.

3.1. Traffic Model

For the simulation and all the necessary calculations had to be performed with each of the compared methods, were defined traffic parameters. IT was necessary to calculate with these parameters. Inthe evaluation of the results, take into consideration some limits, so that we can clearly determine the appropriateness of the method, where we define: C is the maximum capacity of the line, $P_{overflow}$ is the maximum value for probability of line overflow P_{loss} is the maximum value for probability of packet loss. The parameters were defined in Tab. 1.

Tab. 1: Available network parameters.

C	1 Mbit·s^{-1}
$P_{overflow}$	10^{-7} to 10^{-5}
P_{loss}	10^{-7} to 10^{-5}

In Fig. 2 you can see simulated nodes of IMS network. As a source of traffic, randomly generated traffic matrix on the size of nxT was used. For the simulation of traffic, $n = 100$ represented the number of used resources and $T = 1000$ represented the number of time cycles. The traffic matrix represented re-

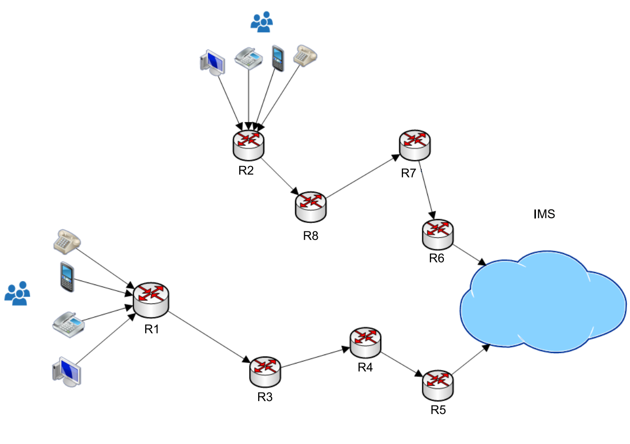

Fig. 2: Traffic model of multiple nodes for simulations.

quirements of the network (or users) for the connection (user's access to his subscription services). Individual network requirements represent 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. 3 you can see incoming requirements to the node R1. Requirements of the other nodes are similar.

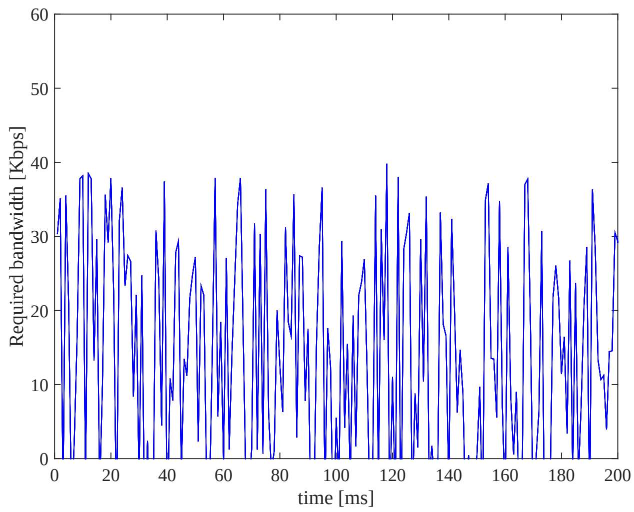

Fig. 3: Incoming requirements for bandwidth for multiple node traffic model.

In Tab. 2, you can see the minimum, peak and average values of the incoming requirements which you can see in Fig. 3. The values are in kbps.

Tab. 2: Values of the incoming requirements.

Required Bandwidth (kbps)	minimum	peak	average
	12	40	14

In Fig. 4 you can see the comparison of selected methods, algorithm "Measured sum" (blue line), Hoeffding Bound (green line) and Tangent at peak (magenta line).

From the direct comparison of those three methods it is obvious that the method Tangent at peak allows the access to the highest number of users. Tangent at peak is able to allow access to 65 users, algorithm "Measured sum" to 62 users and Hoeffding Bound to 52 users. The difference between methods Tangent at peak and "Measured sum" is represented only by three users. That is 95.3 % of the value of method Tangent at peak. The difference between methods Tangent at peak and Hoeffding Bound is represented by 13 users. Itis only 80 % of value of method Tangent at peak. But the decision rule is to allow access to the highest number of users. So the choice is obvious.

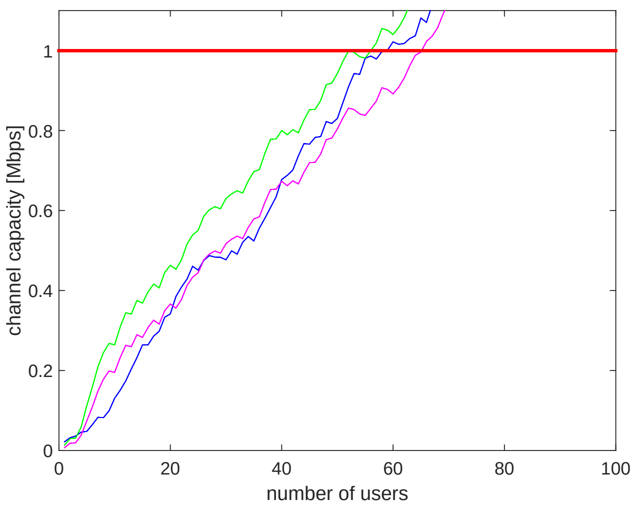

Fig. 4: Comparison of simulated methods for multiple traffic model.

In Fig. 5 you can see utilization of line in time from 0 to 200 ms where selected simulated methods are represented by the same colors as it is in the previous graph (algorithm "Measured sum" (blue line), Hoeffding Bound (green line) and Tangent at peak (magenta line)).

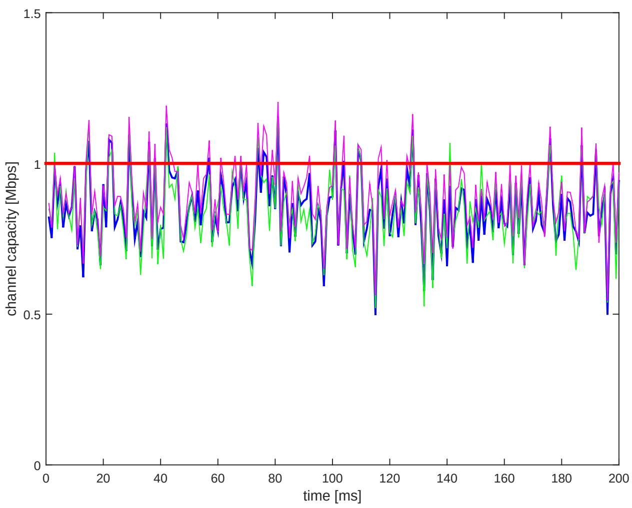

Fig. 5: Comparison for utilization of line of all simulated methods.

You can see that the method Tangent at peak represented by magenta color is able to get the best utilization of line. For better proof there is the detail of Fig. 5 in Fig. 6 and Fig. 7. In Fig. 7 you can see the detail in time from 100 to 140 ms.

You can see that for all the three simulated methods there are values that are higher than the maximum available bandwidth. Even the method Tangent at peak gets the most overrun, at the same time it is the best choice how to reach maximum utilization of the available link capacity.

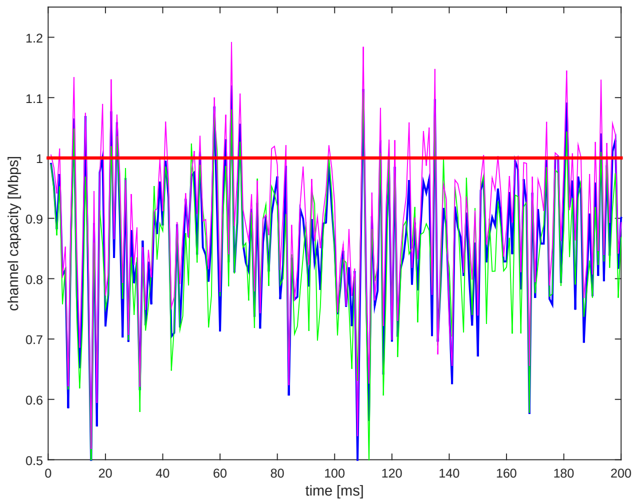

Fig. 6: Comparison of utilization of line for all simulated methods-detail.

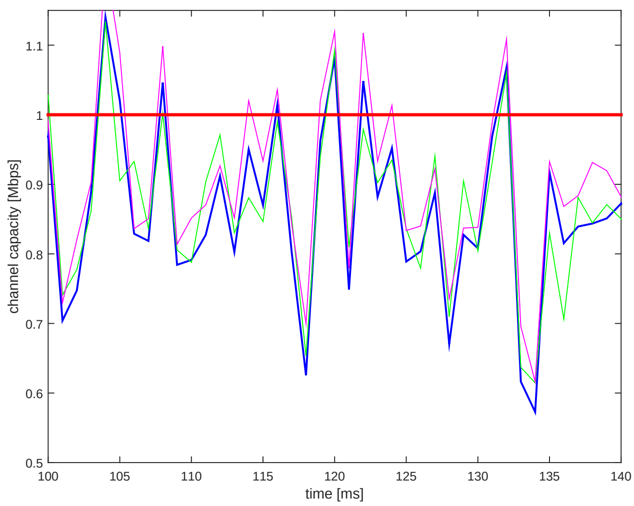

Fig. 7: Comparison of utilization of line for all simulated methods-detail.

In Fig. 8 you can see how the probability of packet loss P_{loss} changes. As mentioned earlier the access was allowed to 52, 62 and 65 users for each simulated method. P_{loss} moves from $3.149 \cdot 10^{-7}$ for 52 users (Hoeffding Bound) to $8.322 \cdot 10^{-7}$ for 65 users (method Tangent at peak). It does not exceed the maximum allowed P_{loss} (allowed from 10^{-7} to 10^{-5}). In Fig. 9 you can see the detail of P_{loss} from 50 to 70 users (It is not able to allow access to 70 users with no selected methods, but the value of P_{loss} would still not exceed the maximum allowed value).

In Fig. 10, you can see how the probability of the line overflow $P_{overflow}$ moves from $2.238 \cdot 10^{-8}$ for 52 users (Hoeffding Bound) to $3.491 \cdot 10^{-8}$ for 65 users (method Tangent at peak). It does not exceed the maximum allowed P_{loss} (allowed from 10^{-7} to 10^{-5}). In Fig. 11 you can see detail of P_{loss} from 50 to 70 users. It is not able to allow access to 70 users with none of the

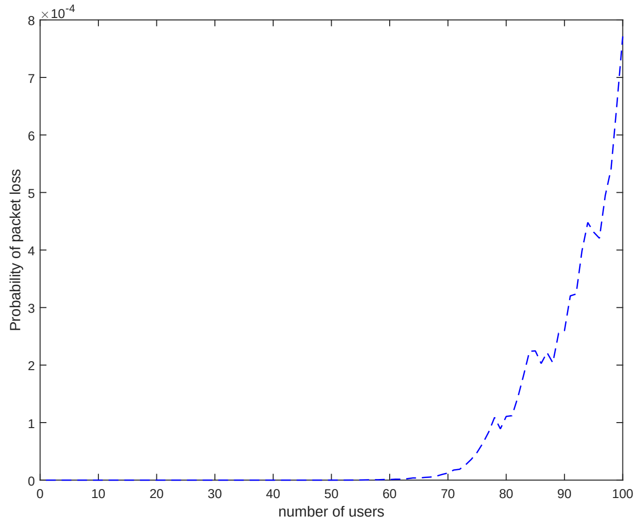

Fig. 8: Probability of packet loss.

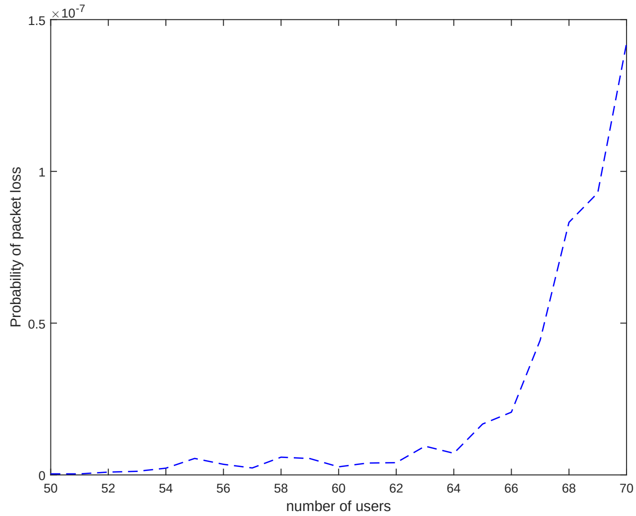

Fig. 9: Probability of packet loss – detail.

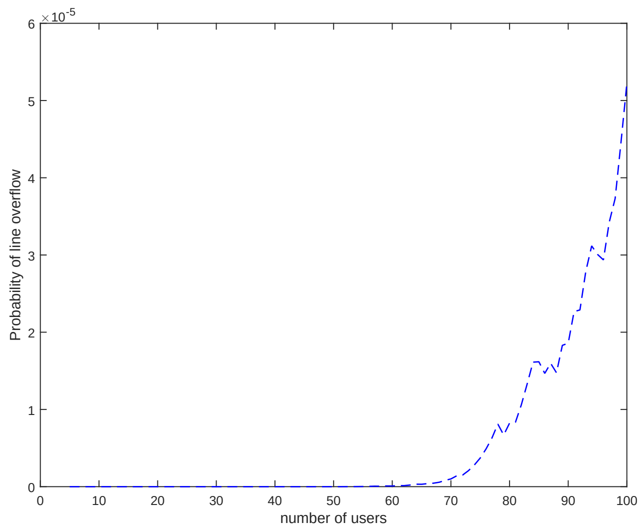

Fig. 10: Probability of line overflow.

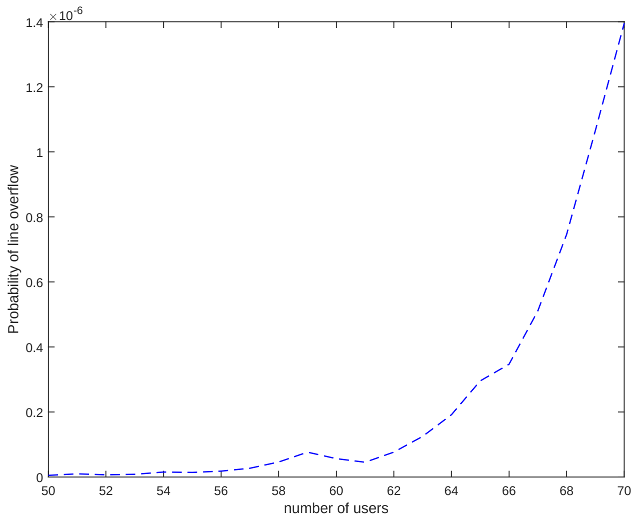

Fig. 11: Probability of line overflow – detail.

selected methods, but the value of P_{loss} would still not exceed the maximum allowed value.

4. Benefits and Disadvantages of Used Concept of Using AC Methods as Traffic Control Method

It was proved that it is possible to use AC methods as the traffic control method in the single node and in the multiple node network too. There are some benefits and disadvantages of using them and therefore must be precisely considered before using the solution.

4.1. Benefits

AC methods are designed to allow access to a maximum number of users. But at the same time they are able to guarantee QoS parameters. In our case when we use AC methods to traffic control on multiple nodes in network QoS is increasing. By using the same AC method on all nodes, it takes less time to make a decision of which method to use in case when every single node makes this decision separately. Therefore the time for the decision is shorter, packets move through the network faster. It means that the delay and jitter can decrease by mili (ms) or micro (µs) seconds. It maximizes the effectiveness of use of the available network resources (bandwidth).

4.2. Disadvantages

The disadvantages are caused by the main concept of AC methods. They are designed as an universal solution to allow access to the maximum number of users and ensure required QoS parameters for all types of services. The use of only one method (even the best) on all nodes in the network denies the main concept of them. If we want to use this solution, there is an accurate requirement for the node parameters and capacity of the line (bandwidth) between nodes. If there is one different node in the network which has smaller throughput, other nodes must adapt to it. To get the same or similar parameters on nodes can be a problem in older networks. The solution is better for new or private networks as an improvement or optimization. Another problem can be if the service is getting from private network to public. Then we are not able to ensure parameters for traffic nodes or throughput between them. The problem can be with the computing power of nodes, too. It is because some methods need more computing power than others to make a decision or to choose the best method. The decision policy in a private network is almost always different from a public network. If we think specifically about VoIP service, the used codec is different. In the private network we can use codec G.711 because we have sufficient bandwidth. But in the public network codec G.729E can be used because there are more users and we want to maximize the use of available bandwidth. Consequently, we use a codec with fewer requirements for bandwidth. As a result, the required computing power is different for different codecs (compression algorithm. . .). All of these factors can decrease QoS parameters of the service.

5. Conclusion

It was proved that it is possible to use AC methods as a traffic control solution for a multi-node network. It is based on the same concept as traffic control in a single node network. But if we are able to use this solution, there are some benefits and disadvantages that must be considered by network operators. From all the mentioned disadvantages, there are the two major ones. It denies the main design of AC methods, it is good to be used only in private networks with specific parameters. Network operators must consider the use of this solution, and focus if the benefits are worth it. There is no technological obstacle for the described solution. The main benefit of the solution is the increasing QoS and shorter delay in network.

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About Authors

Filip CHAMRAZ was born in Malacky, Slovakia, on March 1992. Nowadays he is a student at the Institute of Telecommunications, Faculty of Electrical

Engineering and Information Technology, Slovak University of Technology in Bratislava. He graduated in 2016. He focuses on problems of traffic management, IMS and admission control methods.

Ivan BARONAK was born in Zilina, Slovakia, on July 1955. He received Master of Science degree (electrical engineering) from Slovak Technical University Bratislava in 1980. Since 1981 he has been a lecturer at Department of Telecommunications. Nowadays he works as a professor at Institute of Telecommunications of Faculty of Electrical Engineering and Information Technology, Slovak University of Technology, Bratislava. Scientifically, professionally and pedagogically he focuses on problems of digital switching systems, Telecommunication Networks, Telecommunication management (TMN), IMS, VoIP, QoS, problem of optimal modeling of private telecommunication networks and services.