IMPACT OF NETWORK STATE INFORMATION ON QoS

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SUMMARY

Delay is one of the crucial factors which influence QoS. This factor depends not only on the network throughput. In case of single channel networks, delay depends on the access mechanism as well. This article reflects single channel network with random access and how the volume of network state information can influence the throughput. Markov model was used to describe and model this type of network. Simulations were done and results were compared with the analytical model. The first simulation results are presented in this paper.

Keywords: *single channel network, throughput, random access, simulation, Markov model, QoS*

1. INTRODUCTION

Intensive research on the decomposition of the term information and communication networks QoS is being conducted nowadays. The goal of this research is to find such QoS factors, which determine the service attributes on the one hand and which are general enough to apply for all the types of information and communication networks on the other hand. Considering crucial factors which influence QoS, we have to consider packet delay. On one hand, delay depends on the network throughput. On the other hand, when we focus on the single channel networks, delay depends also on the access mechanism used. We are investigating how the volume of network state information can influence the network throughput.

In single channel networks without packets buffering, only one packet can be successfully transmitted in the same time. When two or more users transmit packets in the same time, collisions arise and all the packets involved in the collision must be retransmitted. The higher network traffic, the more collisions arise, the more retransmissions, the higher probability of collision and the lower network throughput, ending with network congestion. Considering the situation of single channel network, the throughput can be influenced by the amount of information which the network provides about its state. When this amount of information is zero, we deal with random access network with no access control; otherwise we deal with controlling access network. It is evident, the more complete information the network provides about its state, the higher the network throughput. The question is, how to organize the random packets access into the network to guarantee a certain quality of service for customers and on the other hand to use network efficiently, i.e., not over-dimension the network resources.

We created Markov models of these types of networks to determine how utilizable the network capacity can be and we also simulated packet flows in the network to support the analytical model and to analyze dynamic network features in more details.

2. SINGLE CHANNEL NETWORK MODEL

Let us consider a single channel network with retransmissions, i.e., collisional and rejected packets are supposed to be retransmitted after random time interval. Let us consider a signalling information channel which signals the network state to all packets which ask for transmission through the network. Packet enters the network if this channel signals that the network state is "free" (state 0). In case that channel signals that the network state is "busy" (state 1), the packet has to wait until the network changes its state to "free", i.e., packet is retransmitted after random time interval. These considered assumptions are graphically interpreted by Fig. 1.

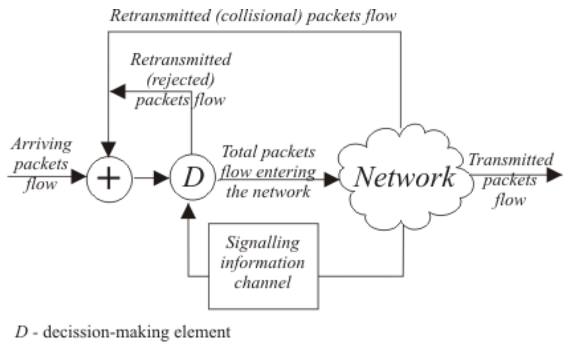

Fig. 1 Single channel network model

We can see a diagram of the signalling information channel on Fig. 2. Probabilities p, q, 1-p and 1-q express conditional probabilities P(x/y), i.e., probability of the event that signalling network state is "x" on the assumption that the real network state is "y".

In this article, we focus on the single channel network, which does not provide any information about its state, i.e., signalling information channel signals always the "free" network state (p = 1-q = 1, q = 1-p = 0 in Fig. 2). Shortly we say "a network without information". The Aloha satellite communication network is a typical example of this network type.

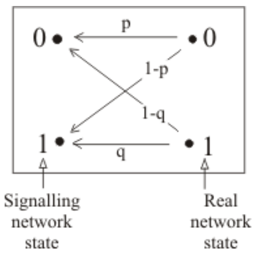

Fig. 2 Signalling information channel

2.1. Markov model

Let us consider Poisson process of packet arrivals with mean rate λ and exponentially distributed packet length with mean rate μ. Fig. 3 shows diagram of a single channel network without the network state information, where λ_{col} denotes the mean rate of collisional packets flow and λ' denotes the mean rate of the total packets flow, thus we can write:

$$\lambda' = \lambda + \lambda_{col} \tag{1}$$

We can also write:

$$\lambda_{col} = \lambda' p_{col}$$

where p_{col} denotes the probability of collision.

Further we denote by ρ the load triggered by packets arrivals:

$$\rho = \frac{\lambda}{\mu} \tag{2}$$

and we denote by ρ' the load triggered by total packets flow and ρ_{re} the load triggered by retransmitted packets flow, then we can write:

$$\rho' = \rho + \rho_{re} \tag{3}$$

and we can also write:

$$\rho = p_{\overline{col}} \rho' \tag{4}$$

where $p_{\overline{col}}$ is the probability of successful packet transmission.

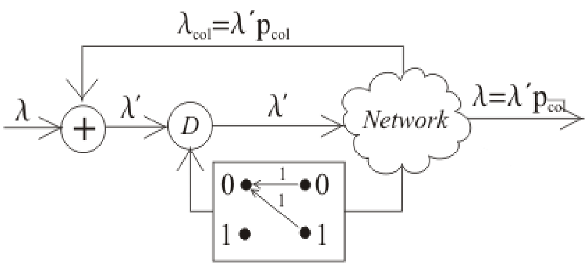

Fig. 3 Single channel network without information

If we focus on this type of network from Queuing theory point of view, we see the system M/M/∞, where the state of the system stands for number of packets which are simultaneously present in a single channel network.

2.2. Probability of successful packet transmission

We identified two potential collision types in the network. For successful packet transmission, we have to ensure that no type of collision occurs. We derive probability of successful packet transmission to determine the network throughput.

Fig. 4 shows collision of the packet A. This observed random length packet (τ denotes the length) collides with another packet (packet B on Fig. 4 with length τ') if their transmissions overlap in time.

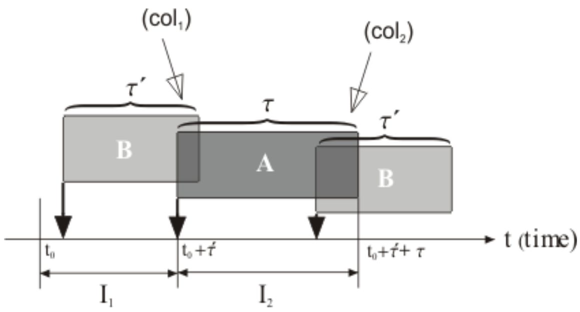

Fig. 4 Packets collision, critical intervals I_1, I_2, type 1 collision (col_1), type 2 collision (col_2)

We find 2 critical intervals (where collision is possible) by moving packet B on the time axis:

1. *Interval I_1:*
   If packet B arrives into the network during time interval I_1, arrival of the observed packet A causes collision. Packet A arrives into busy network. We denote this collision as type 1, p_{col_1} as probability of type 1 collision, $p_{\overline{col_1}}$ as probability of no-collision of type 1 (situation when collision of type 1 does not occur).

2. *Interval I_2:*
   If the packet B arrives into the network during interval I_2, it causes a collision. Another packet arrives into the network during packet A transmission. We denote this collision as type two, analogously we denote p_{col_2} and $p_{\overline{col_2}}$.

For successful packet transmission, none of these two types of collisions is allowed to occur. Let us denote by col event that neither type 1 collision nor type 2 collision occurs ($\overline{col} = \overline{col_1} \cap \overline{col_2}$). We can write $p_{\overline{col}} = p_{\overline{col_1} \cap \overline{col_2}}$ and since we assume Poisson packets arrivals, $\overline{col_1}$ and $\overline{col_2}$ are independent events, thus we can write: $p_{\overline{col}} = p_{\overline{col_1}} p_{\overline{col_2}}$.

Further we can write that $p_{\overline{col_1}}$ is probability that stable system M/M/∞ is empty:

$$p_{\overline{col_1}} = \pi_0 = e^{-\rho'}, \quad \rho' = \frac{\lambda'}{\mu} \tag{5}$$

where $\frac{1}{\mu}$ is mean packet length, λ' is mean rate of total packets flow $(\lambda + \lambda_{col})$.

Let us express $p_{\overline{col_2}}$ probability of an event that no other packets enter the network during the interval τ (exponentially distributed packet length with mean rate μ):

$$p_{\overline{col_2}} = \int_0^\infty \frac{(\lambda'\tau)^0}{0!} e^{-\lambda'\tau} \mu e^{-\mu\tau} d\tau = \mu \int_0^\infty e^{-(\lambda'+\mu)\tau} d\tau =$$
$$= \mu \left[\frac{e^{-(\lambda'+\mu)\tau}}{-(\lambda'+\mu)} \right]_0^\infty = \mu \left[0 + \frac{1}{\mu+\lambda'} \right] = \frac{\mu}{\mu+\lambda'} =$$
$$= \frac{1}{1+\rho'} \tag{6}$$

Finally the probability of successful packet transmission is as follows:

$$p_{\overline{col}} = p_{\overline{col_1}} p_{\overline{col_2}} = \frac{e^{-\rho'}}{1+\rho'} \tag{7}$$

2.3. Maximum network throughput

Substituting (7) in (4) we have:

$$\rho = \frac{\rho'}{1+\rho'} e^{-\rho'} \tag{8}$$

Graphical interpretation of this function for different values μ (mean rate of packet length) is depicted in Fig. 5.

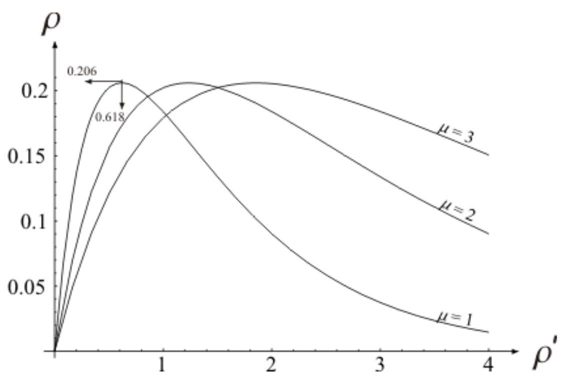

Fig. 5 Throughput of the introduced Markov model of the network for different mean packet length $\frac{1}{\mu}$

We determine the maximum network throughput by finding the maximum of the function expressed in (8). The maximum value of the function is $\rho \approx 0.206$ for the value $\rho' \approx 0.618$.

We have a conclusion from analytical model that maximum throughput of the network is 20%. When we consider transmission capacity of the single channel network without information, then the total load which we can transmit through the network is 60%. In this case, when total network load is 0.618, we can transmit maximum packets load 0.206. For packets arrivals mean rate $\lambda > 0.206\,\mu$ network starts to be unstable.

3. SIMULATION

3.1. Simulation model of a single channel network without information

In this section we introduce the comparison of results from analytical Markov model of the network with results obtained from simulation. Simulator was developed using Delphi programming language in order to monitor, observe and estimate the performance of the single channel network without information. Let us consider three important values which are used in the simulator:

- λ packets arrivals mean rate
- $\frac{1}{\mu}$ mean packet length
- $\frac{1}{\mu_{re}}$ mean length of an interval after which a collisional packet is retransmitted

Results obtained from simulation confirm results from analytical model. We depicted the values ρ' for different values ρ obtained from simulations and the curve obtained from analytical model for comparison in Fig. 6.

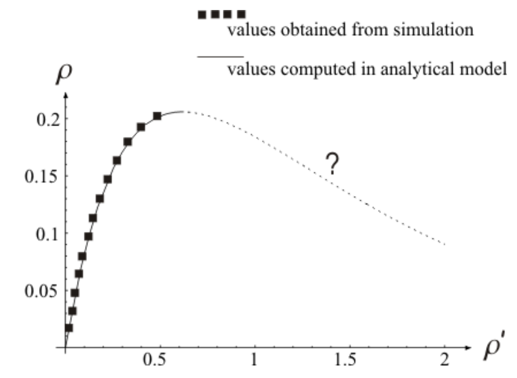

Fig. 6 Throughput values obtained from simulation

3.2. Network congestion

In Fig. 6 we can see that there exist two different values for every ρ. Since this situation is not trivial, we decided to analyze it through simulation. It is assumed that we can get second value ρ' first by achieving the unstable network state, then by decreasing the packets arrivals mean rate to the given value ρ . Unfortunately, our simulation doesn't confirm this assumption. On the contrary it shows that this second value is practically unreachable. The only way we are able to stabilize the network (which was in an unstable state) is to stop packet arrivals $(\lambda = 0)$. On that account we hope that we will be able to understand this behavior when we do more simulation experiments under different methods approaching the unstable state and various methods of decrease in packets arrivals mean rate.

4. DISCUSSION AND FUTURE RESEARCH

In this article we have been mainly focused on a single channel network without information. On the other hand it is evident, the more complete information the network provides about its state, the higher the network throughput. Analytical non-Markov models of single channel networks which provide non-zero information about its state are analyzed for instance in [1], [2]. Since we deal with Markov models of single channel networks, our future goal is to create Markov models of single channel networks which provide non-zero information about its state.

With respect to general diagram of a single channel network model (Fig. 1 and 2), we can see that for single channel network which provides partial information about its state, conditional probabilities are as follows: $(p\neq0 \wedge p\neq1) \vee (q\neq0 \wedge q\neq1)$. Fig. 7 illustrates a single channel network with partial information. The Ethernet network with CSMA/CD access method is typical example of this network type.

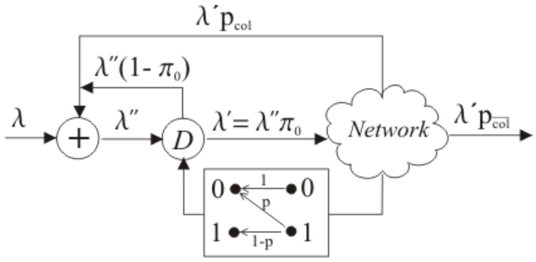

Fig. 7 Single channel network model with partial information

Analogously we depicted single channel network model with complete information on Fig. 8.

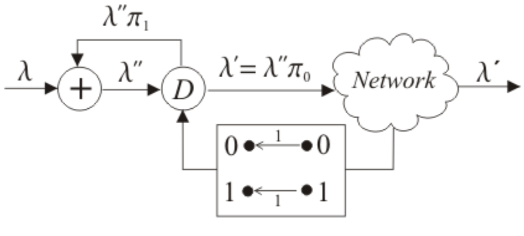

Fig. 8 Single channel network model with complete information

On the one hand we can say that network state information influences the throughput of a single channel network. On the other hand to be more specific we need to determine a single channel network capacity dependence on signalling information channel capacity. This specific determination requires creating network models based on theory of information using knowledge of authors published in [3], [4].

5. CONCLUSION

Network state information directly influences the throughput of a single channel network. We created Markov model of a single channel network which does not provide any information about its state and we computed that maximum network throughput is 20%. Results from simulation confirm this analytical approach. If we know, that the network will not be used more than 20%, a single channel network without information is very simple and it is working method how to organize the access to the network. Packets arrivals load higher than 20% causes network congestion. Simulation results concerning the network congestion does not confirm the results from analytical model until now. The unstable state will be investigating through simulation in the future research.

REFERENCES

[1] Bertsekas, D., Gallager, R.: Data Networks, Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

[2] Schwartz, M.: Telecommunication Networks: Protocols, Modeling and Analysis, Addison-Wesley Publishing Company.

[3] Reza, M.: Introduction to Information Theory, Addison-Wesley Publishing Company, 1994, ISBN 0-486-68210-2.

[4] Klimo, M.: Teória informácie a prenos dát, Skriptum, Alfa, 1990, ISBN 80-05-00418-4.

BIOGRAPHY

Jana Uramová was born in Zvolen, Slovakia, in 1980. She graduated at Grammar School of Ľ. Štúra in Zvolen and she studied at the University of P. J. Šafárik in Košice. She defended dissertation thesis in 2005 and she has been continuing her PhD study and research of Information models of network throughput. She has been acting as a lecturer at the Department of information networks at University of Žilina from 2003. She is an instructor of Regional Cisco Network Academy in Žilina and she is lecturing the subjects exercises Communication Networks, Theory of Information, Introduction into Engineering and Computer Networks.