

# Effect of Buffer Size and Packet Delay on the Survivability of Packet Switched Networks

1<sup>st</sup> Vahid Mavaji

Department of Computer Engineering  
Sharif University of Technology  
Tehran, Iran  
mavaji@alum.sharif.edu

2<sup>nd</sup> Bahareh Abbasi

Department of Computer Engineering  
Sharif University of Technology  
Tehran, Iran  
b\_abbasi@alum.sharif.edu

**Abstract**—In this paper, the survivability of general-case packet-switched networks is studied. Most of network properties are considered as random variables and a queuing-theory based model is derived. In this model, the effect of buffer size and packets' delay on the survivability of the network is considered. Simulation results are used to validate the proposed model. The simulation results agree very well with the model.

**Index Terms**—Survivability, Packet Switched Networks, Buffer Size, Delay

## I. INTRODUCTION

The problem of designing networks able to survive an enemy attack or natural disaster is of paramount importance. Recent work has focused on the mathematical formulation of physically meaningful survivability criteria, the development of analysis methods to rank networks in terms of these criteria, and the generation of networks which are optimal with respect to these criteria. Numerous partial results for a variety of network models are available.

The study of network survivability has been divided into two nearly disjoint areas: deterministic survivability and probabilistic survivability. In the former, an adversary is usually assumed to have complete knowledge about the system to be attacked and also uses a deterministic attack strategy. In a probabilistic model, the adversary may have only partial information about the enemy's network or may employ a randomized attack strategy.

Because of the dichotomy of network and attack models, typical survivability criteria can also be classified as either deterministic or probabilistic. A network may be considered to “survive” an attack if 1) all points (nodes) can communicate with each other; 2) there are some flow paths between specified pairs of points; 3) the number of points in the largest connected section exceeds a specified threshold; or 4) the shortest surviving path between each pair of points is no longer than a specified length.

The object of a deterministic analysis might be to determine if these criteria are met subject to a known attack while a probabilistic analysis might seek to find the probabilities that these criteria will be satisfied. Corresponding design objectives could then be constructing networks subject to fixed resources which maximize the effort the adversary must make

to “destroy” the network, or the probability that the network will survive.

The purpose of this paper is to perform a probabilistic analysis of packet-switched network considering the packet loss and delay of packets as survivability measures. The effect of buffer size is also examined.

The rest of this paper is organized as follows: in Section II a literature survey is presented. In Section III the preliminaries and assumption of the problem are clarified. In Section IV a model for evaluating the survivability is derived. Section V presents the simulation results and Section VI concludes the paper.

## II. RELATED WORK

## III. PRELIMINARIES

## IV. EVALUATING THE SURVIVABILITY

With the above assumptions, we begin the modeling process.

**Step 1:** we calculate the packet loss of a typical path. The packet loss of a path,  $PL_{path}$ , is the sum of packet losses of all of its constituent nodes:

$$PL_{path} = \sum_{i=1}^n PL_i \quad (1)$$

$$E[PL_{path}] = E\left[\sum_{i=1}^n PL_i\right] = \sum_{i=1}^{E[n]} E[PL_i] \quad (2)$$

$$PL = P_{B+1} = \frac{\left(\frac{\lambda}{\mu}\right)^{B+1} \left(1 - \frac{\lambda}{\mu}\right)}{1 - \left(\frac{\lambda}{\mu}\right)^{B+2}} \quad (3)$$

$$\lambda_i = \lambda_{i-1} \times PL_{i-1} \quad (4)$$

$$\lambda_1 = \lambda \quad (5)$$

$$Delay_{path} = \sum_{i=1}^{E[n]} W_i + (N - 1) t_p \quad (6)$$

$$W = \sum_{n=0}^B \frac{(n+1) P_n}{\mu (1 - P_{B+1})} = \frac{L - (B+2) P_{B+1} + 1}{\mu (1 - P_{B+1})} \quad (7)$$

$$L = \frac{\lambda \left( 1 + (B+1) \left( \frac{\lambda}{\mu} \right)^{B+2} - (B+2) \left( \frac{\lambda}{\mu} \right)^{B+1} \right)}{(\mu - \lambda) \left( 1 - \left( \frac{\lambda}{\mu} \right)^{B+2} \right)} \quad (8)$$

$$\begin{aligned} E[Delay_{path}] &= \sum_{i=1}^n \left( \frac{L_i - (B+2) P_{i,B+1} + 1}{\mu (1 - P_{i,B+1})} \right) \\ &+ (E[N] - 1) E[t_p] \\ &= \sum_{i=1}^n \left( \frac{L_i - (B+2) P_{i,B+1} + 1}{\mu (1 - P_{i,B+1})} \right) \\ &+ \frac{E[Len_{link}]}{C} \end{aligned} \quad (9)$$

## V. SIMULATION RESULTS

### VI. CONCLUSION

We have presented in this paper a queuing-theory based model for general-case packet-switched network in which the nodes are  $m/m/1/k$  queues. Parameters such as buffer size and packets delay were considered important in determining the survivability of such network. Simulation results are in accordance with the model. It was shown that increasing the buffer size has a positive impact on the survivability. Increasing the number of nodes and the link failure probability both decrease the survivability.

The future work is to impose more realistic limitations on network properties such as dependence of node failures on each other, the impact of traffic resulted from path replacement on packet loss, the impact of link failure on packets' delay, assuming different structures for network nodes, dependence of link failures on each other, the possibility of repair and recovery in the network and so on.

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