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PERFORMANCE EVALUATION OF TYPICAL DATA NETWORKS: A PROPOSAL

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ABSTRACT

This paper presents a general framework for planning and dimensioning a multi-service Internet Protocol (IP) network supporting voice, video, and data. We describe a methodology for dimensioning link capacity and packet delay while meeting Quality of Service (QoS) requirements under general traffic distributions, using discrete event simulation. Additionally, the paper proposes a procedure to optimize transmission probabilities between nodes, aiming to increase throughput and reduce delay based on the offered network traffic. This procedure applies different transmission probabilities for each node type. Admission control is implicitly incorporated to regulate the number of active streams. A Jackson network is employed to validate the simulation model. Once validated, other probability distributions are explored to assess achievable delay and throughput, and the resulting suboptimal optimization outcomes are presented.

1 INTRODUCTION

Industry 4.0, Digital Twins, and modern telecommunications networks, including the new services, significantly increase the amount of data traveling through data networks. These networks may present bottlenecks that can compromise the sending of information, especially in critical cases, and, most importantly, delays that must be avoided. To illustrate the methodological proposal, a case study of a network with six nodes in which the data obtained by the application level must be sent to the end node, as in Leite (2019). Unlike Jackson's network with Markovian services, three non-Markovian services, one elastic, and two streams are placed in nodes 1, 3, and 5, respectively, and the remaining nodes are solely for traffic passage. Thus, the assessment of the traffic load offered to the network (in bps) is done at the application level, and traffic forwarding (in bps) is done at the physical/link level. Furthermore, this article also aims to evaluate different probability distributions corresponding to the specific types of services forwarded by the network, whether they have small variance or long tails. To perform the network optimization, the best routing probabilities between the nodes follow the topology presented in Figure 1, with the elastic (node 1) and stream services (nodes 3 and 5), as shown by Roberts et al. (1996), Ursini et al. (2015).

2 METHOD AND RESULTS

The next step is to exhaustively apply varying probabilities to each node that forwards traffic and evaluate the impact on throughput and delay when considering different types of service distribution (Constant, Exponential, and Lognormal). The simulation was performed by varying the values of the probabilities $[\frac{1}{6}, \frac{1}{5}, \frac{1}{4}, \frac{1}{3}, \frac{1}{2}]$ for each node and combining them all across all nodes, resulting in $5^3 = 125$ runs.

To evaluate the general network performance. First, with the assumption of Markovian services, the network can be calculated using the Jackson method. The network calculated in this manner serves as a reference for validating the simulation model. To calculate the effective transmission rate of each node (the sum of the generated rate and the data passing rate), to determine the appropriate service rate for statistical equilibrium of the system, the service rate must be greater than or equal to the arrival rate at each node. Due to the nonlinear characteristics of traffic, the reference assumption for network nodes is that they should have a utilization of 70% for the Markovian M/M/1 model utilization.

The results obtained with the initial switch relay probabilities for nodes 1, 2 and 5 were, $[\frac{1}{6}, \frac{1}{6}, \frac{1}{6}]$ respectively, showing that the average packet delay and network throughput vary depending on the service

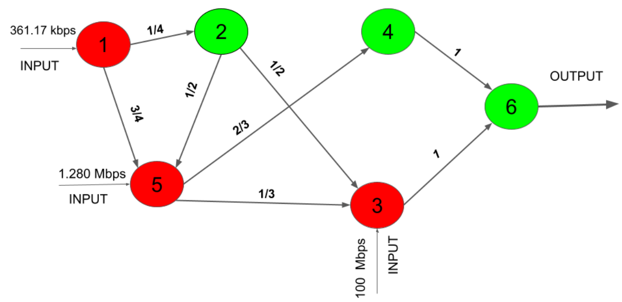

Figure 1: Simulation model with the respective routing probabilities.

time distribution. For the exponential distribution, the average delay is 0.0188 seconds, with a throughput of 101.6 Mbps. The constant distribution results in a lower average delay of 0.0069 seconds and a slightly higher throughput of 103.96 Mbps. For the log normal distribution, the delay is significantly higher at 0.0631 seconds, while the throughput is 101.78 Mbps. These results indicate that the choice of service time distribution has a noticeable impact on delay, while throughput remains relatively stable across distributions due to the fact that the value for node 3 has a higher data load comparing with the nodes 1 and 5.

3 CONCLUSIONS

To determine the performance of a communication network based on the Open Systems Interconnection (OSI) model, particularly at the application and physical-link layers, two essential factors must be considered: network delay and throughput. Server utilization (ρ) plays a crucial role in ensuring node stability, and should remain below 1. When delay is the critical factor, deterministic service provides the best performance; however, the optimal service distribution should ideally be derived from empirical measurements. For long-tailed distributions, it may be necessary to increase server capacity or service rates to meet performance requirements. In future work, additional tests will be conducted using more appropriate parameter values to better illustrate the methodology. Furthermore, assigning different probabilities to each service and analyzing their impact on delay and throughput constitutes an important avenue for further investigation.

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REFERENCES

LEITE, J. R. E. (2019). *Modeling and Simulation of IoT, AdHoc, and RFID Networks*. PhD diss., University of Campinas (UNICAMP), School of Technology.

ROBERTS, J., U. MOCCI, AND J. VIRTAMO (1996).*Broadband Network Teletraffic – Performance Evaluation and Design of Broadband Multiservice Networks (Final Report of Action 242)*, Lecture Notes in Computer Science 1155. Berlin: Springer-Verlag.

URSINI, E. L., P. L. MARTINS, V. S. TIMÓTEO, AND F. R. MASSARO JR. (2015) *Modeling and Simulation Applied to Link Dimensioning of Stream IP Traffic with Incremental Validation*. Winter Simulation Conference, WSC15.