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Knowledge-based Simulation System for Reliability and Performance Analysis of Computer Networks

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Abstract

Modeling and analysis of performance of computer networks is essential for ensuring smooth operation of an organization's networks and preventing major failures. Mathematical analysis and simulation modeling are the common procedures for network system performance analysis. In this paper, a knowledge-based simulation system is developed that can be used for assessment and prediction of network performance and reliability.

Introduction

Traditionally, the measure for network reliability has been network connectivity. That is, the measure of reliability is based on the fact that whether all the operational nodes (stations) of the network are connected or if a fraction of all the operational nodes are connected. The analysis of connectivity problem has been discussed extensively in the literature [Bertsekas and Gallager 1992]. However, the problem being NP-hard, it is difficult to solve this problem within reasonable amount of time. Present day communication networks are generally built using very reliable components and improvements have also been made in the area of networking protocols [Kubat 1986]. Most of the networks have some form of redundancy built-in so that the messages can be re-routed in case of some component failure. Therefore, considering these facts it is important to not only consider the connectivity issue but also consider certain unacceptable delays in transmission as network failures. Transmission delays can happen due to several reasons like component failure (complete or partial), congestion, buffer overflow, etc.

Modeling and analysis of computer networks is important since it helps determine in advance how the network will perform. There are several ways in which network system performance analysis can be performed. Mathematical analysis and simulation modeling are the common procedures. Mathematical models are expected to provide exact solution, however, generally that is not the case and solution is approximate even if the analysis is exact [Kleinrock 1993]. In this paper, a knowledge-based simulation model is presented that can be used for assessing and predicting network performance and reliability.

Performance analysis of computer networks is no longer a consideration of network managers alone. The increasing use of client/server systems is dependent upon efficient and reliable computer networks. The end-user satisfaction of client/server systems depends heavily on the timeliness of information [Guimaraes and Igbaria 1997]. Therefore, database administrators and managers should be as concerned with this issue as network managers have been in the past. This paper provides an overview of knowledge based simulation, specifics of the method for performance evaluation of local area networks, which is followed by conclusions and recommendations.

Knowledge-based Simulation

Knowledge-based simulation models are essentially a hybrid of traditional numerical simulation and knowledge-based system. There are several different types of knowledge-based simulation models, mostly defined based on the way information is passed between numerical and knowledge-based components. According to Alfred Round [1989], there are four types of these models as follows: a) sequential integrated systems, where information flow is one way, b) parallel integrated systems, where information is transferred back and forth between the knowledge-based and numerical components, c) front-end, knowledge-base is used to define a numerical simulation model, and d) rule-driven simulation.

In this paper, the authors develop a parallel-integrated system for modeling local area networks. In this system, both the knowledge-based component and the simulation component function as independent entity. The two components pass data back and forth to each other as needed in order to assert facts or calculate numerical results. The overall design of this system is provided in Fig. 1. The local area network architecture used in this system is Ethernet or carrier-sense multiple access with collision detection (CSMA/CD). This is the most popular architecture for designing the local area networks in this country. For a comprehensive look at local area networks and their simulation, the reader is referred to Sadiku and Ilyas [1994].

The knowledge-base component of the system is the one that drives this simulation. At the start of the simulation, the knowledge base determines values for initialization of variables. The database within the knowledge base keeps information that is used to arrive at such values as the number of stations (users) in use during simulation (it may vary during the simulation), transmission rate, data packet length, number of packets to be transmitted during the simulation (which may also vary during the simulation), and maximum buffer (queue) size at a station, etc. As it is obvious from the above description of variables, it may be necessary to vary the values of simulation variables during the simulation process. This is not easily done in the traditional simulation models, therefore the use of a knowledge base is essential to model a more realistic situation.

In addition to initialization of variables, another task that is performed by the knowledge base is to continuously monitor such variables as average delay for a short time span (e.g., one minute or three minutes), number of collisions per short time span, number of retransmissions, number of packets in buffer (queue), and utilization rate of the transmission medium etc. This set of data is necessary to determine if a failure will occur or the delay in transmission will be greater than certain threshold value at certain time. These results, in turn, will determine if there is a failure in the network at that time.

Given below are some examples of rules in the knowledge base that monitor network performance periodically and determine if the network has failed or the risk of failure is high and keep record of these situations. Generally a reasonable value for maximum buffer size at a station is between 100 to 500. Assuming maximum buffer size used in a simulation is 400, if at a point the number of packets in buffer (queue) reaches very close to 400, it is a reason for concern since it may result in performance degradation. In the same manner, if the network utilization rate exceeds such number as eighty-five percent, it would result in network performance degradation. Examples:

IF the number of packets in more than 25% of stations during the last fifteen minutes is greater than 90% of the maximum buffer size THEN the risk of network failure during the period is high

IF the network utilization rate is greater than 90% during the time span THEN the network has failed

As mentioned earlier, in addition to monitoring the performance, the knowledge base also initializes or resets some of the simulation variables. For example, in a particular organization the network is up round the clock. However, the network activity may vary during different periods of the day. For simplicity, the 24-hour period can be divided into four, six, eight etc. periods. Suppose, considering the pace of network activity, the period in a particular organization can be divided into four six-hour periods as follows: 1) midnight to 6 am, 2) 6 am to noon, 3) noon to 6 pm, and 4) 6 pm to midnight. The number of such important variables as number of stations and maximum number of packets transmitted per hour would be different. Thus, the knowledge base would determine the values of these variables based on the time of the day during the simulation run.

Conclusions and Recommendations

This paper presents a knowledge based simulation approach that can be used for performance analysis and for determining reliability of computer networks, especially local area networks. The advantages of this approach are that it allows consideration of organization specific data and the knowledge gained in the past about specific network parameters, it allows for learning (the database/knowledge base can be easily updated) from past information, and it is relatively simple to implement. This paper considered only Ethernet type of local area network, however the methodology outlined here can be easily applied to other types of local area networks and to wide area/metropolitan area or backbone networks.

References

Bertsekas, D. and Gallager, R. [1992] “Data Networks, Second Edition,” Prentice-Hall.

Guimaraes, T. and Igbaria, M. [1997] “Client/Server System Success: Exploring the Human Side,” Decision Sciences, 28(4), 851-876.

Kleinrock, L. [1993] “On the Modeling and Analysis of Computer Networks,” Proceedings of the IEEE, 81(8), 1179-1190.

Kubat, P. [1989] “Estimation of Reliability for Communication / Computer Networks – Simulation/Analytic Approach,” IEEE Transactions on Communications, 37(9), 927-933.

Round, A. [1989] “Knowledge-based Simulation,” in “The Handbook of Artificial Intelligence, Volume IV,” Barr et al., eds., Addison-Wesley.

Sadiku, M.N.O. and Ilyas, M. [1994] “Simulation of Local Area Networks,” CRC Press.

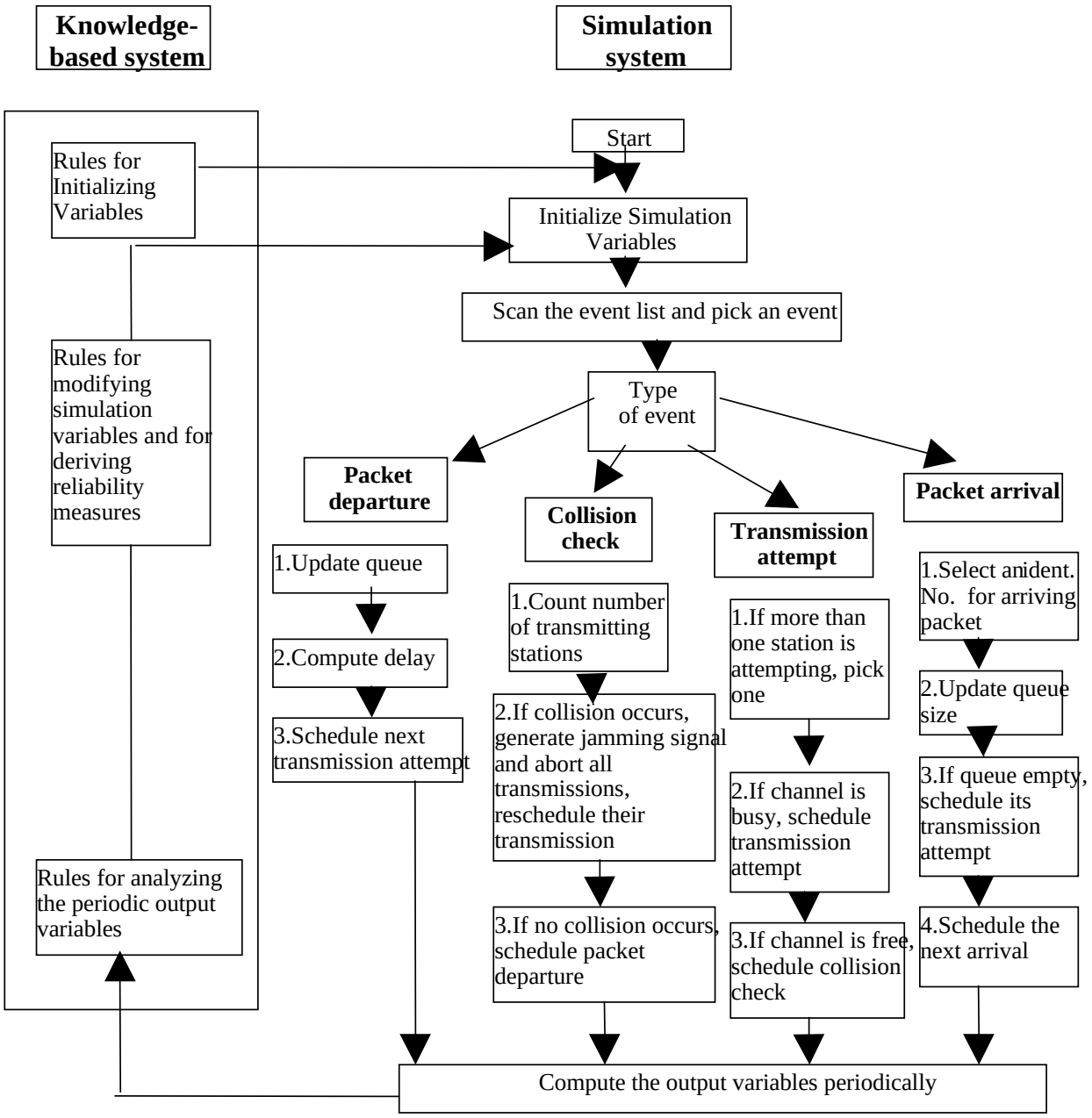

Figure 1. Knowledge-based Simluation System