Proceedings of the 1992 Winter Simulation Conference
ed. J. J. Swain, D. Goldsman, R. C. Crain, and J. R. Wilson

THE TELECOM FRAMEWORK: A SIMULATION ENVIRONMENT FOR TELECOMMUNICATIONS MODELING

Greg Lomow
Jade Simulations

2010 Corporate Ridge, Suite 700
McLean, Virginia 22102

1422 Kensington Road NW, 3rd Floor
Calgary, Alberta, CANADA T2N 3P9

ABSTRACT

The telecommunications industry is changing rapidly. To help network planners meet this challenge, Jade has developed simulations tools for studying a wide variety of parameters important in the planning and operation of telecommunication networks.

These tools include:

1) high fidelity simulation model libraries of telecommunication networks;
2) an interactive environment, called the Telecom FrameWork[1], for defining, managing, and analyzing simulation experiments of telecommunication networks based on these model libraries;
3) a high performance simulation executive that makes the use of of high fidelity simulations practical.

The model libraries include a Trunk Network model, a Signaling System 7 model, and models of the control system for a packet-switched network. In the model libraries each call or message transmission is simulated individually - including all routing decisions (there are models for fixed, hierarchical, adaptive, and dynamic routing algorithms). The model libraries use object-oriented techniques and C++ thus allowing new or modified components to be easily added and allowing the model libraries to be used in conjunction with each other. For example, the Trunk Network model can be used to drive the SS7 model.

The models have been used for a side range of studies including:

1) comparing alternative routing algorithms in a network of central offices to validate the claims of a switch manufacturer;
2) studying the survivability of a trunk network under four different failure scenarios;
3) technology assessment involving evaluating alternative scenarios for transitioning a network from switches manufactured by one vendor to those provided by another vendor.

The Telecom FrameWork reduces costs by providing an integrated environment for using the network models and automating many common simulation activities. For example, the graphical interface of the Telecom FrameWork supports data input preparation, setting simulation parameters, executing experiments, and tools for analyzing the results of these experiments. Besides a core set of tools the open architecture of the Telecom FrameWork supports the inclusion of application-specific tools and tools from third-party vendors.

The major barrier to using high fidelity models to simulate large, complex telecommunication networks has been long execution times and large memory requirements. Jade's *Sim++* simulation library [Baezner, 90] [Baezner, 91] and TimeWarp [Jefferson, 85] [Fujimoto, 90] simulation executive eliminate this barrier by executing simulations in parallel using networks of Unix workstations. Equally important, the fact that the simulation is executing in parallel is completing hidden from the user.

1. INTRODUCTION

An important question for network managers, planners, and forecasters is, "What is the most cost effective way to expand existing networks and integrate new technologies?" Existing analytical techniques are best suited to modeling networks that are relatively homogeneous and static in nature. However, they can be difficult to apply to emerging networks that are larger, more heterogeneous, and more dynamic. The challenge is recognizing and responding to this changing environment.

Jade's response is based on high fidelity, call-by-call simulation. In call-by-call simulation, every telephone call and data transfer is modeled individually and every relevant piece of equipment is represented explicitly. Such high fidelity simulation is both accurate and flexible.

Call-by-call simulation is accurate. By modeling every call, data transfer, and piece of equipment individually, call-by-call simulation allows the network to be simulated at whatever level of detail is necessary. For example, each routing decision is simulated, each database access is simulated, each network management message is simulated, and each access control decision is simulated.

Call-by-call simulation is flexible. Since each piece of equipment, each database, and each algorithm is modeled explicitly, the user can add, modify, or replace any component in the simulation. This allows alternative network configurations to be easily studies and compared.

This flexibility also makes studying network reliability and failure scenarios possible. All of the following events can be simulated:

1) the failure of one or more switches;

[1] The terms Workbench and FrameWork are used interchangeably throughout this document.

2) the partial or complete failure of a trunk;
3) network partitioning;
4) buffer overflows;
5) corrupted messages.

2. TRUNK NETWORK MODEL LIBRARY

Jade's Trunk Network Model library (TNM) is used to simulate circuit-switched, voice traffic on inter-office trunk networks. The model library includes objects for simulating each office, each trunk group, and each network processor.

TNM includes routing algorithms for fixed, hierarchical, adaptive, and dynamic routing. In the case of dynamic routing, the TNM also includes simulation models for the network processors that monitor network traffic load and dynamically calculate and update the routing tables in the offices.

Initially, TNM was developed to study the effects of dynamic routing on effective network capacity. In particular, that study addressed the specific problem of estimating the effects of dynamic routing on the exhaust point as forecasted traffic was increased over a four year period.

Subsequently, TNM has been used to study the effectiveness of dynamic routing with regard to network survivability in an NPA that included toll switches and several city networks.

3. SIGNALING SYSTEM 7

Common channel signaling is at the heart of the new consumer services offered by telephone companies, including voice mail, call forwarding, incoming caller identification, and call waiting. Common channel signaling will provide the technical basis for many enhancements to 800 services, calling card services, and virtual private network services. Signaling networks based on the Signaling System 7 (SS7) protocol are being deployed across North America and will be universal by the mid-1990s.

As with any new technology, SS7 requires further study and refinement before its full potential is realized. Recognizing this, Jade has developed a detailed SS7 network simulation. The model provides a testbed for investigating issues such as

1) performance;
2) network survivability;
3) congestion control;
4) screening policies at network interconnection points.

These factors can be studied under normal, stressed, and overloaded conditions. Stressed and overloaded conditions are particularly important to understand since failures usually occur in these situations. This has been demonstrated in a number of well publicized network outages.

The components of the SS7 network are modeled in sufficient detail to provide accurate simulation of network behavior under stress. These components include STPs, SPs, SCPs, and the signaling links. Figure 1 shows a simulation of an SS7 network.

The SS7 protocol layers are also represented in the model so that the specific processing of each significant traffic class is simulated, as well as the operation of the congestion control mechanisms.

Like the TNM library, the SS7 library uses call-by-call simulation. Thus, each message transfer in the SS7 network is simulated explicitly. This includes every database access and every network management message.

4. PACKET SWITCHED NETWORK

Jade's third model library is used for modeling the performance of packet-switched networks carrying control and monitoring messages for a network of intelligent T1 channel banks. These channel banks multiplex voice and data circuits from customer premises onto T1 lines. Voice and data traffic can be intermixed on a single T1 line, and bandwidth may be re-allocated dynamically from a network management workstation.

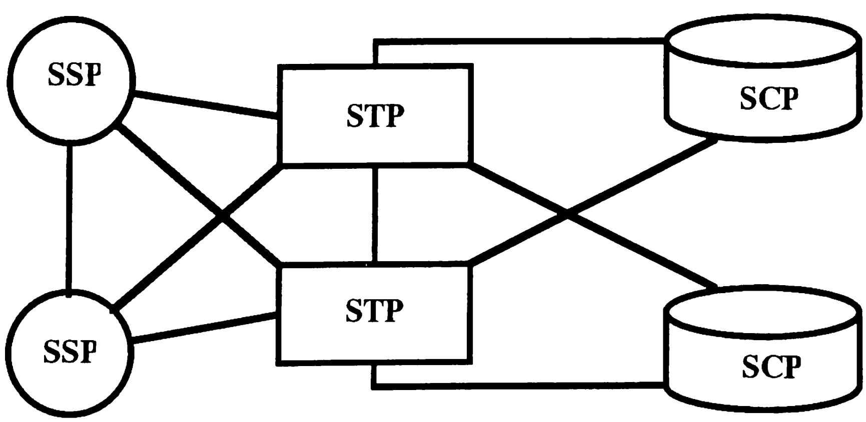

Figure 1. SS7 Network Simulation

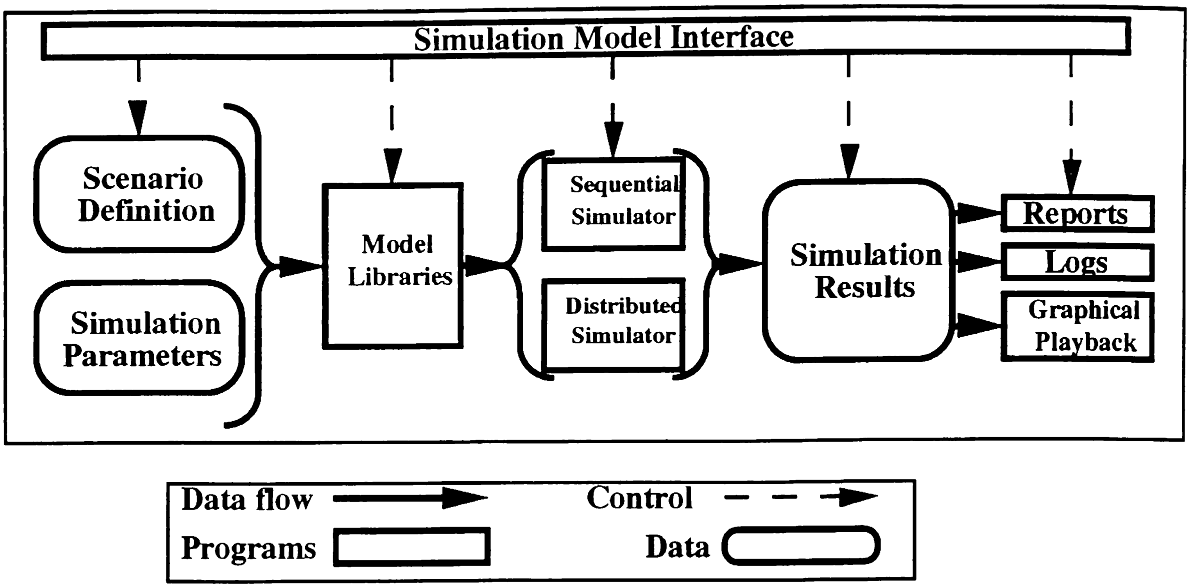

Figure 2. Simulation Framework

The re-configuration of T1 links and monitoring of line states is mediated by network management messages carried by the control system. The control system connects the intelligent multiplexers to each other and to the network management workstation. The control network consists of several inter-connected sub-networks, including Ethernet LANs and point-to-point sub-networks made up of T1 channels.

The models for simulating the packet-switched control system includes the following features:

1) The mode of operation of both Ethernet and point-to-point networks is simulated in detail;
2) Every network transaction and message is simulated as a separate event;
3) The simulation model is data-driven; the network topology, Ethernet and client/server configurations, and the control traffic loads are all defined in input data files.

5. SIMULATION FRAMEWORK

Jade's Simulation Framework is an application-independent collection of general tools and interfaces that automate most common simulation activities. These activities include specifying simulation scenarios, specifying experimental parameters, automatically running multiple replications of simulations, and collecting and archiving simulation results.

As shown in Figure 2, the Simulation Framework 1) combines input data (scenario definitions and simulation parameters) with a set of models from the model library, 2) runs the simulations using either the sequential or distributed simulator, 3) stores the results in a database, and 4) allows the results to be analyzed using the results analysis tools. All of these functions are controlled through the graphical user interface labeled the Simulation Model Interface.

The Simulation Framework is not intended to be used directly. Rather, Jade tailors it to specific applications by "populating" it with application-specific model libraries, additional results analysis tools, and additional graphical user interfaces.

6. TELECOM WORKBENCH

Jade's Telecom Workbench is an instance of the Simulation Framework that is tailored to supporting the simulation and analysis of telecommunication systems. The Workbench differs from the Framework in the following ways.

1) The scenario definition module for the Telecom Workbench is specialized to allow users to specify network definitions, workloads, and events appropriate for telecommunication systems.
2) The model library module for the Telecom Workbench includes the Trunk Network Models, SS7 Models, and Packet-Switched Models which replace the generic simulation libraries shown for the Simulation Framework.
3) The Telecom Workbench includes data preparation and data translation utilities for converting actual network data from an operational, online database into a form that can be used by the simulation models.
4) The Telecom Workbench includes additional, application-specific animation and results analysis tools.

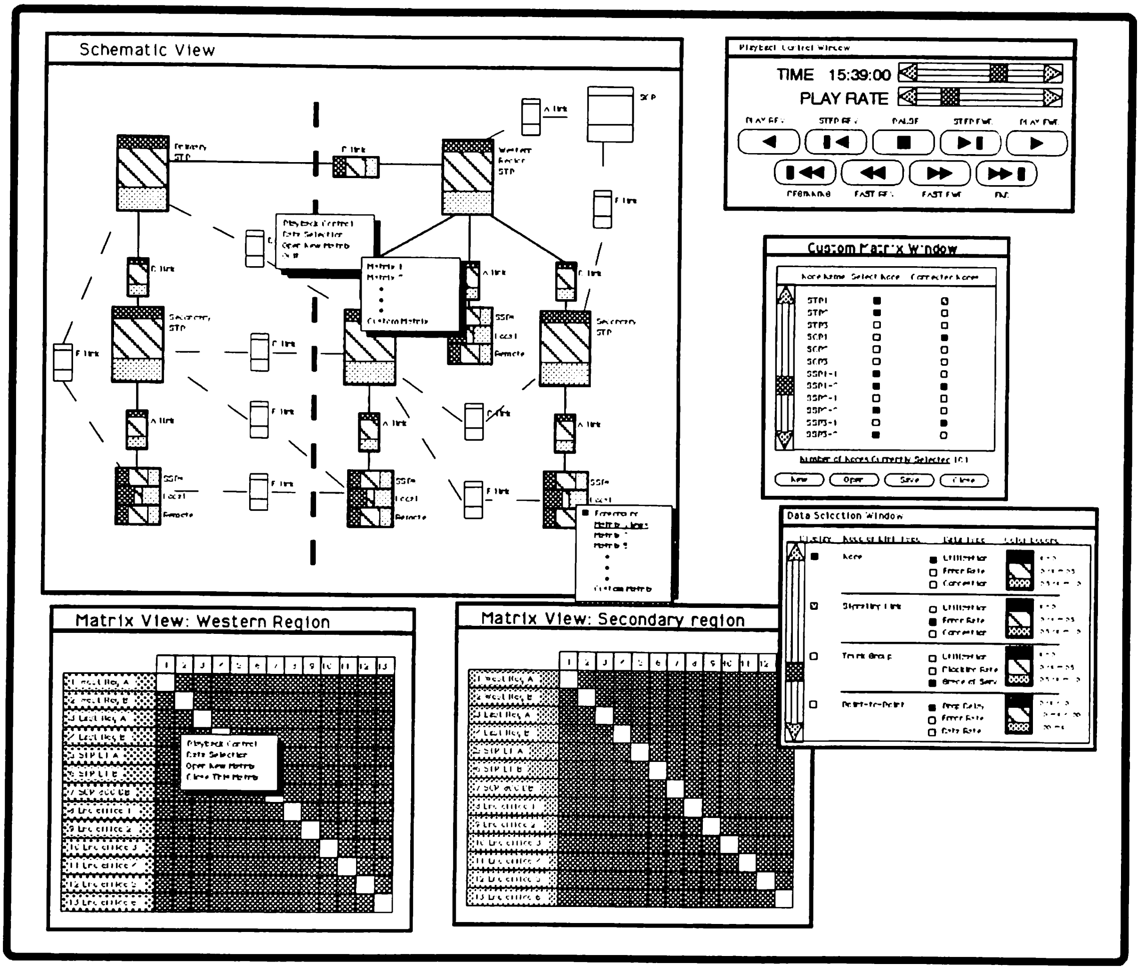

Figure 3. SS7 Graphical Analysis Tool

Figure 3 shows a screen dump from a session using the SS7 Graphical Analysis Tool. It is one of the results analysis tools available through the Telecom Workbench. The SS7 Graphical Analysis Tool is a graphical data analysis tool for visualizing and analyzing the results produced by the SS7 Simulation Model. It includes the following displays:

1) **Schematic View** - Allows the user to see the logical connectivity of the nodes and links which comprise the network.
2) **Matrix View** - Allows the user to see every node and connecting link between every pair of nodes in either the full network or a subset of the network. Each square in the matrix view shows the status of a link.
3) **Custom Matrix View** - Allows the user to filter the data collected by the simulation and customize the presentation of that data.

7. *SIM*++ AND TIMEWARP

Jade's *Sim++* is an object-oriented, discrete-event simulation library written in C++. *Sim++* is a general-purpose package suitable for any form of discrete-event simulation including telecommunications simulation [Corson,92], transportation system simulation, military simulation [Baezner,92], and manufacturing simulation.

Sim++ is unique because it is designed for writing simulations that can either run sequentially on a single workstation using a traditional event list or run in parallel on multiple workstations using a special synchronization executive called TimeWarp

Jade's TimeWarp is a synchronization executive that coordinates a *Sim++* simulation running on multiple processors. TimeWarp is responsible for delivering events to entities in timestamped order and regulating the execution of the entities running on different processors so that their execution is consistent with an equivalent sequential simulation. At the same time, TimeWarp executes entities running on different processors in parallel when their actions do not affect each other.

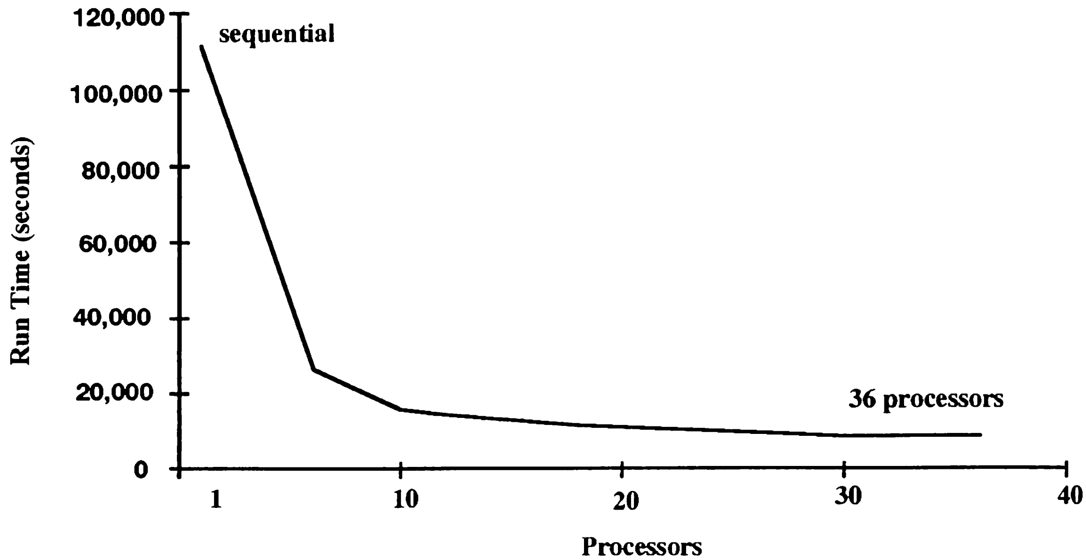

Figure 4. Speedup Graph for Trunk Network Simulation

The advantages of parallel execution on multiple processors using TimeWarp include:

1) running simulations faster;
2) running larger simulations that have more objects;
3) running higher fidelity simulations with more detail.

Figure 4 shows a speedup curve for a simulation written in *Sim++* and executed using TimeWarp. The simulation is modeling a network of 40 central offices in a circuit-switched voice network. It is simulating the busiest hour of the busiest day and processes over 2 million phone calls. The graph shows that the execution time is reduced from almost 3 hours when the simulation is run sequentially to about 14 minutes when running on 36 processors. This is a 13.8 times speedup.

Sim++ and TimeWarp run on Sun Sparc workstations, IBM RS/6000 workstations, and HP Series 700 workstations.

8. CONCLUSIONS

High fidelity, call-by-call simulation is needed for analyzing complex, diverse, and heterogeneous telecommunication networks.

The Telecom Workbench provides an integrated framework for defining, managing, and experimenting with models of the telecommunication network and for analyzing the results of those experiments.

Object-oriented simulation using *Sim++* provides the foundation for building and linking models of the separate subsystems that comprise telecommunication networks.

Distributed and parallel simulation using *Sim++* and TimeWarp makes high fidelity, call-by-call simulation practical by providing the needed computational power.

ACKNOWLEDGEMENTS

Thank you to everyone at Jade who prepared material that was used in this paper. Also, thank you to everyone who is participating in or has participated in building our set of simulation tools and using them on projects for our clients.

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AUTHOR'S BIOGRAPHY

DR. GREG LOMOW is Director of US Operations for Jade Simulations. He has worked for over 10 years in simulation, modeling, and advanced software development. He obtained his PhD in Computer Science from the University of Calgary in 1988. Dr. Lomow can be contacted at 703-749-1467 or lomow@jade.ab.ca.