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Telecommunication network analysis with COMNET II.5

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ABSTRACT

COMNET II.5 is a general SIMSCRIPT II.5-based model for the performance analysis of circuit-switched, message-switched, or packet-switched networks. A variety of alternate-routing and adaptive shortest-path routing algorithms are built-in. After creating a network description with a convenient menu-driven editor, simulation follows immediately. There are no programming delays. Network operation is animated during the simulation. Reports show blocking probabilities, call queueing and packet delays, network throughput, link group utilization, and link group queue statistics. This paper highlights some of COMNET II.5's latest features, which include capabilities for modeling call preemption, call retries, dynamic bandwidth allocation, link failures, and source-node routing.

INTRODUCTION

COMNET II.5 is a performance analysis tool for telecommunication networks. Based on a description of a network and its routing algorithms, COMNET II.5 simulates the operation of the network and provides measures of network performance. No programming is required to use COMNET II.5. Network descriptions are created with a convenient menu-driven screen editor that is extremely easy to learn to use.

By using discrete event simulation methodology, COMNET II.5 provides realistic results. The drastic simplifying assumptions required when using analytical methods to analyze complex telecommunication networks are eliminated.

The network modeling approach used in COMNET II.5 is designed to accommodate a wide variety of network architectures and routing algorithms.

The COMNET II.5 package consists of two parts: COMNETIN and COMNET. COMNETIN is the menu-driven, screen editor that is used to create and modify a network description. COMNET is the telecommunication network simulation program. The primary input to COMNET is the network description created by COMNETIN.

COMNET can be used to simulate any wide-area network which uses circuit switching, message switching, or packet switching. Packet-switched networks with virtual circuit or datagram operation can be modeled. Alternate-routing and adaptive shortest-path routing algorithms are built-in.

COMNET prompts you for the name of the file created by COMNETIN and several simulation control parameters, such as the length of the simulation. After reading the network description file, the simulation begins. If you request animation of the simulation, you see a picture of the network in operation. Routing choices and changing levels of circuit group utilization are apparent.

COMNET II.5 is analogous in many ways to NETWORK II.5, which is another CACI product that is used for simulating the performance of computer systems and local area networks. NETWORK II.5 models processing, storage, and communication resources, while COMNET II.5 focuses primarily on communication resources. NETWORK II.5 facilitates modeling of general hardware-software interactions; COMNET II.5 facilitates modeling of circuit and packet-switching operation.

COMNET II.5 and NETWORK II.5 use different models for data transport that make COMNET II.5 better suited for modeling wide area networks and NETWORK II.5 better suited for modeling local area networks. COMNET II.5 uses a network level model of data transport, where the focus is on end-to-end and link group performance measures, as well as on routing issues. NETWORK II.5 uses a link-level model of data transport, where the focus is on individual link performance measures, as well as on link access protocols that are so critical to local area network performance.

CREATING A NETWORK DESCRIPTION

A network description created by COMNETIN consists of three major categories of data: network topology, network traffic, and network operation.

Network Topology

The network topology is defined by the nodes of the network and the link groups connecting the nodes. Nodes represent sources and destinations for network traffic. In addition, nodes may perform circuit switching, packet switching, or both. A link (or circuit) group is a collection of identical, point-to-point transmission channels connecting exactly two nodes. Voice, data, and other types of traffic can be routed over the same link group. Multiple link groups can connect the same pair of nodes. Any network topology in which a link group connects exactly two nodes can be represented.

Node attributes include parameters such as the circuit-switched call setup time, the number of packet-switching processors per node, the packet-switching time per processor, and the total packet buffer space at the node.

Link group attributes include parameters such as the nodes at each endpoint, the number of links, the call priority required to access the group, an indicator if the group can carry tandem calls, an indicator if the group supports call queuing, the effective speed (bit rate) of each link, an indicator of half duplex or full duplex operation, and the propagation delay. The capacity of a link group can be defined in terms of the number of links (i.e., transmission channels) or the total bandwidth available. Link group availability is specified by the mean time to failure and the mean time to repair. Link group failures can occur at fixed intervals or at random; the repair time can also be constant or random.

Network Traffic

There are three kinds of traffic that can be defined: circuit-switched calls, data messages (which can be circuit-switched or packet-switched), and virtual-circuit calls. For a typical network, there are many categories of calls or messages. Each category is defined by an origin node, a destination node, and a class of service.

The class of service can be used to define several categories of calls and/or messages with the same origin and destination, but with other characteristics (e.g., message size distribution or call holding time distribution) that vary. For circuit-switched calls, each class of service has a priority level and may have a bandwidth requirement and a call retry interval. The priority level determines which link groups a call is allowed to access and, for networks with preemption, which classes of calls can be preempted. The bandwidth requirement is used during routing to determine if a link group has enough unused bandwidth to handle a call. Blocked calls belonging to a class of service with a retry interval are reattempted after a fixed or random retry interval. Class of service is also used by some of COMNET II.5's algorithms for routing messages and the packets formed from messages.

In addition to the origin, destination, and class of service, other attributes for a circuit-switched call category include the call interarrival time distribution, the call holding time distribution, and an indicator if calls in the category can queue.

For each data message category, an important attribute is the message size distribution. Depending on the message size distribution, data messages can represent batches of data ranging in size from short inquiries or requests up to large files. If a data message is circuit-switched, the holding time for the message is determined by the message size and the speed of the circuit-switched connection. If a data message is packet-switched, the data message is broken into packets and the packets are transported through the network using datagram operation.

Virtual-circuit call traffic is used for the traffic load in packet-switched networks which transport packets using virtual-circuit operation. Additional attributes for each virtual-circuit call category include the call interarrival time distribution, the messages-per-call distribution, the message interarrival time distribution, the message size distribution, the probability of a response message, the response message size, and the delay before transmission of a response message.

Network Operation

Network operation parameters include a description of the network's routing algorithm. The routing algorithm determines how the network traffic moves through the network topology from origin to destination. COMNET II.5 includes both static and adaptive routing strategies.

With static routing, routing tables are predetermined. Node-by-node routing tables contain lists of link groups. The correct list is selected based on the kind of traffic, the node at which a routing decision is being made, and the destination node. A link group is selected from the list according to the type of traffic and a user-specified selection criterion. A special type of static, node-by-node routing is flood routing, where a packet is routed over all outgoing link groups. Source-node routing tables contain lists of end-to-end paths. Each path is a sequence of link groups from source node to destination node. There is a separate table for each category of traffic.

With adaptive routing, the routing tables are updated dynamically during the simulation so that traffic is routed along the shortest path to the destination node. The shortest path depends on the distance metric used for the link groups in the network. One example of a distance metric is the average link delay during some measurement interval. In this case, the shortest path through the network corresponds to the path with the shortest expected delay. Another type of distance metric allows the user to assign a set of weights or penalties to a link group. As traffic on the group increases, the length of the link group increases to the next penalty level.

Examples of additional network operation parameters include packet sizes, retransmission intervals for blocked packets, the measurement interval for updating the shortest path calculations, and end-to-end flow control methods for virtual calls.

THE COMNET SIMULATION MODEL

Each circuit-switched call that is generated during the simulation proceeds through a connection setup process. (A process is a sequence of events separated in time.) Since there are typically signaling and sometimes queueing delays during connection setup, there are generally multiple connection setup processes active at the same time. The connection setup process creates a record for the call and uses the routing tables to trace a path from origin to destination. The call record includes the end-to-end connection path chosen for the call. A circuit is made busy for each circuit group on the connection path as connection setup proceeds. If all circuits are busy on all accessible alternate routes and queueing is not allowed, the blocked call counters are incremented and a connection termination event is scheduled to occur immediately. Otherwise, a connection termination event for the connected call is scheduled to occur after the call holding time. The call holding time is drawn from the appropriate probability distribution. Once the connection termination event is scheduled, the call setup process terminates.

Upon execution of the connection termination event, a circuit is made idle for each circuit group in the call's connection path. In addition, COMNET's circuit group contention manager is executed in case any other traffic is waiting to use the circuit that just became idle. Circuit-switched messages are modeled in the same way, except that the connection termination event is scheduled after the message transport time, which is a function of the message size and the speed of the connection.

Rather than modeling, as a process, the event sequence followed by a packet from origin to destination, COMNET defines a packet switching process that models the operation of a generic packet switch. A separate packet switching process is activated for each node in the network and exists during the entire simulation. If the input queue to a packet switching process is empty, the process suspends itself. Otherwise the first packet is removed from the input queue. After a packet switching delay that depends on the type of packet and the packet switching speed, the process selects an outgoing link group for the packet (unless the packet has already reached its destination). The route selection logic depends on the type of packet. For example, a datagram packet is routed independently, whereas a virtual-call information packet must follow the virtual-circuit connection path already established by a virtual-call setup packet. If the outgoing route has an idle link, the link is made busy and a transit-packet arrival is scheduled at the next node after the transport delay for the packet. Otherwise, the packet is added to the queue for the outgoing link group. The packet switching process then iterates to remove the next packet from its input queue.

Upon execution of a transit-packet arrival event, the incoming circuit is idled, the arriving packet is added to the queue for the packet switch at the receiving node, the packet switching process at the receiving node is activated (if necessary), and COMNET's circuit group contention manager is executed in case any other traffic is waiting to use the link group. The circuit group contention manager gives highest priority to circuit-switched calls; otherwise, as a general rule, traffic is handled on a first-come, first-served basis.

Whenever a link group failure event occurs during the simulation, routing tables are updated to reflect the failure. All calls using the failed link group are disconnected and all virtual calls are rerouted. A link group restoration event is then scheduled. When the restoration event occurs, the routing tables are again updated and the next failure event is scheduled for the link group.

NETWORK PERFORMANCE MEASURES

COMNET produces several reports summarizing network utilization and network service. The Circuit Group Report for Circuit-Switched Traffic shows circuit group utilization and call and message statistics by circuit group. The statistics include blocking probabilities and queueing delays. The Circuit Group Report for Packet-Switched Traffic shows circuit group utilization, buffer use, and packet statistics by circuit group. The Packet Switch Report shows buffer utilization, packet switching delays, and packet throughput statistics. The Voice Call and Virtual Call Reports show the network service received by each category of call. An example of a measure of network service for a voice call is the end-to-end blocking probability. The Message Report shows the network service received by each category of message. Examples of measures of network service for a message category are the average, standard deviation, and maximum response time. The Disconnected and Preempted Calls Report gives, for each call category, a count of the number of calls disconnected due to link failures and the number of calls preempted by higher priority calls. The Call Routing Report gives, for each call category, the number of calls routed over each possible end-to-end path defined in the source-node routing tables.

AUTHOR'S BIOGRAPHY

ROBB MILLS is the COMNET II.5 Product Engineering and Development Manager at the CACI Products Company. In addition to directing the development of COMNET II.5, he teaches regularly scheduled classes on network performance analysis using COMNET II.5 and consults with CACI clients on modeling and simulation projects. Prior to joining CACI in 1986, he was with AT&T Bell Laboratories for 12 years, where he completed various systems engineering and operations research assignments for telecommunication systems and networks.

He has bachelor's and master's degrees from Cornell University in industrial engineering and operations research and a doctorate from Columbia University in operations research.

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