Chapter 5
Resource Allocation in Store-and-Forward Networks with Point-to-Point Links

5.1. NETWORK ROUTING

There are two major classes of distributed routing algorithms, depending on where routing decisions for individual packets are made.

In the class of algorithms exemplified by the ARPANET algorithm, routing decisions are made by network switching nodes. Once packets are handed over to a network node, the source has no control over the routes to be selected for its packets. A description and an assessment of the original ARPANET algorithm was given by McQuillan et al. [MCQU 78b]. A description of the second-generation ARPANET algorithm appears in [MCQU 80, ROSE 80]. We reprint [MCQU 80] below. The design of this class of distributed routing algorithms that possess various correctness properties (e.g., loop-free, failsafe) has been addressed by Tajibnapis [TAJI 77], Merlin and Segall [MERL 79, SEGA 81], and Jaffe and Moss [JAFF 82], among others.

In the second major class of distributed routing algorithms, proposed by some IBM researchers and others, routing decisions for packets are made at the source nodes where the packets enter the network. Algorithms in this class are called *explicit path routing* or source routing. We reprint the article by Jueneman and Kerr [JUEN 76] below. A more detailed exposition of this approach can be found in the paper by Maruyama and Markowsky [MARU 80].

The problem of rerouting traffic flows to optimize network delay was addressed by Fratta, Gerla, and Kleinrock [FRAT 73] and Gallager [GALL 77]. They presented algorithms to reroute flows to achieve certain optimality conditions. See also [KLEI 76, GERL 77]. Various enhanced message-addressing modes in network routing (e.g., broadcast routing) were discussed by Dalal and Metcalfe [DALA 78] and McQuillan [MCQU 78a]. A good survey of routing algorithms as used in some existing networks can be found in [SCHW 80] which is reprinted below. Hierarchical routing was studied by Kamoun and Kleinrock [KAMO 79] and also by Chu and Shen [CHU 80].

5.2. FLOW AND CONGESTION CONTROLS

Early simulation work to study congestion problems and the performance of the isarithmic method for congestion control was described by Price [PRIC 77]. An analysis of the performance of a two-level isarithmic scheme was presented by Wong and Unsoy [WONG 77].

The buffer requirements of store-and-forward networks was studied by this author in [LAM 76]. An analysis of buffer-sharing schemes was given by Kamoun and Kleinrock [KAMO 80].

Extensive simulations were conducted by Giessler et al. to study the performance of flow controls, congestion controls, and deadlock-avoidance buffer management schemes [GIES 78]. Deadlock-avoidance schemes were proposed and studied by Gunther [GUNT 81], and independently by Merlin and Schweitzer [MERL 80].

The input buffer limit (IBL) scheme for congestion control was proposed and analyzed in [LAM 79]. Extensive simulations reported in [LAM 81a] showed that IBL schemes are very effective in controlling network congestions due to temporary network overloads. This article also provides a comprehensive treatment of network performance characteristics as functions of input buffer limits for congestion control, virtual channel window

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sizes, and nodal buffer capacities. It is reprinted below.

A description of routing and flow control in IBM's SNA networks can be found in [AHUJ 79].

An excellent tutorial on the topic of flow and congestion controls was given by Gerla and Kleinrock in [GERL 80], which is reprinted below.

5.3. MODELING AND ANALYSIS

Available analytic tools and methods for network design and analysis are mostly based on an open-chain queueing network model first formulated by Kleinrock in 1964 [KLEI 64, KLEI 76]. It has the advantage of having an explicit formula for the mean network delay in terms of the parameters of link (and processor) capacities and traffic flows, and is thus useful for optimal routing and channel capacity assignment studies [FRAT 73, GERL 77]. However this model is an abstraction of a network in which the mechanisms of flow and congestion controls are ignored. The conditions under which Kleinrock's model is accurate were investigated in [LAM 81b]. It was found that the interplay between routing and flow control has little effect on the accuracy of Kleinrock's model for networks that are lightly utilized. The accuracy of Kleinrock's model suffers significantly, however, when some of the links in the network are moderately or heavily utilized.

Queueing networks with closed chains and other population size constraints permit the modeling of a network's flow and congestion control constraints as well as its routing behavior [PENN 75, LAM 77, LAM 79, REIS 79, LAM 81b, LAM 82a, LAM 82b]. A serious drawback of closed-chain models is that they require algorithmic solutions for network performance measures (virtual channel throughputs and their mean delays). The computational time and space requirements of such algorithms grow exponentially with the number of closed chains (virtual channels). Existing algorithms have been designed primarily for models of multiprogramming systems and can only solve closed-chain models of networks with just a few virtual channels [SAUE 81]. To get around this difficulty, the tree convolution algorithm [LAM 83] was developed. It exploits the routing information of a given network which had not been utilized by previous algorithms. It provides an exact solution to networks with tens of closed chains having time and space requirements that are manageable on current computers.

The tutorials in [WONG 82, LAM 82b] on the modeling and analysis of packet-switching networks are reprinted below.

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