Applied Math 254: Computer Networks - Course Outline

Dr. John M. McQuillan, Mr. David C. Walden
(Bolt Beranek and Newman Inc.)

Discusses the historical growth and technical development of computer networks. The ARPA Network is used as a major example throughout the course; other network projects are also studied as appropriate. Reviews the evolution of the concept of networking, basic parameters of network design, and criteria of network performance. Examines algorithms for node-to-node transmission and source-to-destination transmission, and for routing. Considers the design of the network topology and of the communications processor. Describes network applications, Host protocols, political, social, and economic issues, interconnection of networks, and other new directions of development.

The course will be in seminar form; students will choose topics in the areas cited above for further individual study.

Lecture Outline (each lecture 3 hours)

1. Introduction to Computer Networks

Explains the rationale for packet-switching networks, outlines their historical growth and identifies various possible configurations. Gives a brief discussion of many actual and proposed computer networks, together with the present and planned uses of these networks. Provides an overview for the rest of the course.

Reading: Roberts on the ARPA Network, Farber survey article, Roberts historical analysis paper, notes on several networks

2. The ARPA Network

Describes the process of designing the ARPA Network from a historical viewpoint, showing the influences on the designers and noting the technical constraints at the time. Outlines the groups who worked out the initial design, and points out their fundamental strategies and basic principles. Presents a demonstration of the use of the ARPA Network.

Reading: SJCC 1970 session on ARPA Network (4 papers), Crocker SJCC 1972

3. Network Performance

Identifies the components of a network, in a hierarchical structure: applications programs, Host systems, subnetwork systems, subnetwork topology. Explains the four basic network performance criteria: delay, throughput, cost, and reliability, in relation to each network component. Discusses measurement and monitoring techniques in a network environment.

Reading: Frank, Kahn, Kleinrock paper, excerpts from McQuillan thesis, McKenzie NCC paper, BBN Rept 1822, Metcalfe thesis, and Cole thesis

4. Network Topology

Describes the network layout problem and the tradeoffs between delay, throughput, cost, and reliability. Discusses various techniques for modeling, measuring, or analyzing these variables in the context of topological design. Explains some methods for network synthesis: generating starting networks, improving them, and the specialized techniques employed. Considers the effect of the approximations made in laying out a network topology as related to the realties of network use.

Reading: excerpts from Gerla thesis and NAC semiannual reports

5. Subnetwork Design - Node-to-Node Transmission Algorithms

Describes the ARPA Network implementation of transmission and flow control procedures between adjacent IMPs. Points out some of the issues in program and data reliability in a network environment, especially as related to ARPA Network experience. Contrasts this with approach taken in Cyclades, and extends it to the procedures followed between Satellite IMPs, including random and slotted ALOHA techniques, and TDMA and reservation systems.

Reading: McQuillan FJCC 1972, Pouzin ACM 1973, Crowther ACM 1973, SIMP paper

6. Subnetwork Design - Source-to-Destination Transmission Algorithms and Routing Algorithms

Develops the ARPA Network implementation and some other suggestions in a parallel with the previous lecture. Addresses the question of division of responsibility between network and Host, with specific reference to such message processing functions and algorithms as sequencing, buffering, flow control, storage allocation, etc. Relates these issues to network delay, throughput, cost, reliability, growth, flexibility, maintainability, fairness, and accountability. Considers the basic design questions for specifying a routing algorithm, and describes the original ARPA Network algorithm.

Reading: McQuillan Infotech 1974, excerpts from papers by Pouzin, Cerf, and Kleinrock, and from McQuillan thesis

7. Subnetwork Design - Routing Algorithms

Presents a classification and analysis scheme for routing proposals, and evaluates various structures: fixed, isolated, centralized, and distributed. Develops several improved techniques for distributed routing computations, and outlines some of the open problems. Discusses a unified theory of the node algorithms for transmission and routing, and considers the interactions between the different procedures.

Reading: excerpts from McQuillan thesis, Gerla thesis, and Fultz thesis

8. Subnetwork Design - The Communications Processor

Identifies the critical components and performance criteria for the hardware structure of the processor,memory, and I/O system, using the IMP and TIP as examples. Follows a parallel investigation of the critical components of the software, in program control and data flow. Performs a similar analysis for the multiprocessor High Speed Modular IMP.

Reading: excerpts from Davies and Barber book, Heart SJCC 1970, Ornstein SJCC 1972, 2 HSMIMP papers, Pouzin ACM 1973

9. Network Applications and Basic Protocol Issues

Mentions some of the design considerations for user and server Hosts in a network environment, and describes typical uses of a network in detail, including man-to-man, man-to-computer, computer-to-computer, and distributed uses with more than 2 users. Explains the basic issues in Host protocol design, including addressing, ordering, buffering, accounting, flow control, etc. Compares connection-based protocols with message-based protocols, Walden's MSP, the protocols developed for Cyclades, and for internetworking experiments.

Reading: Postel NCP survey report, McKenzie paper on interworking, Metcalfe thesis, Retz NCC+E 1975 paper, Walden Infotech 1974, Walden ACM paper, Pouzin protocol paper, Cerf/Kahn paper

10. Host Protocols

Describes the layered approach taken in the ARPA Network, including the IMP/Host and Host/Host protocols, and contrasts this with non-layered alternatives. Explains the goals and techniques of several specialized protocols for the ARPA Network, including Initial Connection Protocol, TELNET, File Transfer, Data Transfer, Remote Job Entry, etc. Describes the issues in designing distributed protocols.

Reading: BBN official IMP/Host and Host/Host protocol specifications, ARPA Network official specification for each protocol, Postel thesis, Thomas on RSEXEC

11. Political, Economic, and Social Issues

Discusses the issues of bilateral vs. multilateral agreements, standards for networking, security, privacy, accounting, tariffs, regulation of networks. Considers the options faced by an organization or individual contemplating network service: to buy, lease, build, or join network facilities; to choose a centralized or decentralized network; to use standard protocols or design specialized ones, etc.

Reading: Kuo papers, Massy Science article, Roberts papers

12. Internetworking and New Technologies

Discusses the technical problems of internetworking: design choices such as fragmentation/reassembly, the structure of internetwork addressing and routing, the functions of the gateway, the functions of the internetwork protocol. Also examines the performance of such systems: throughput or delay penalties for internetworking, reliability problems, etc. Considers the effect of new technology on computer networks: multiprocessor node computers, satellite links, radio links, connection between networks, very high bandwidth circuits, etc. Develops the theme of hierarchical design as a method to deal with large problems: architecture for node processors, structure for the routing algorithm, structure for the network topology. Evaluates the influence of the ARPA Network on new networks.

Reading: Cerf/Kahn paper, McKenzie paper on interworking, Pouzin papers, excerpts from McQuillan thesis

13. and 14. Open

Depending on student interest, the last lectures can take the form of further lectures on the topics considered earlier, or on new topics suggested during the term, or they may be reports by students in areas of their own choosing.