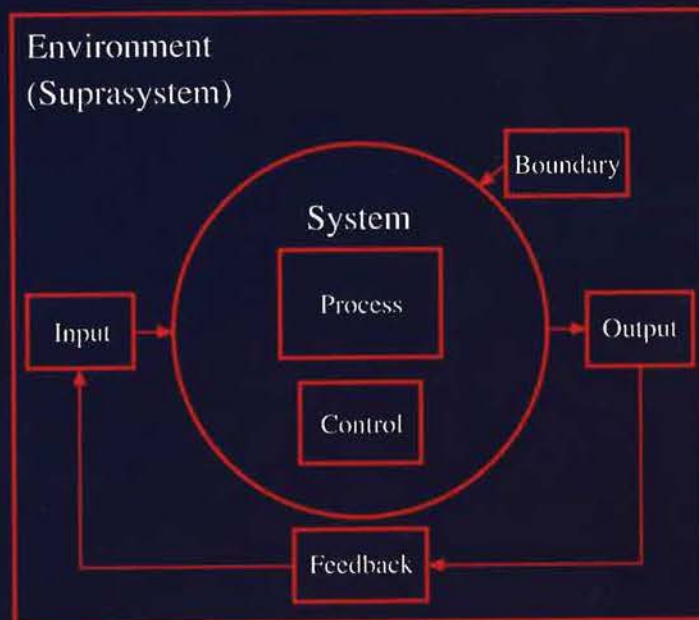


The Information System Consultant's Handbook

Systems Analysis and Design



William S. Davis and
David C. Yen

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and Design**

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chapter fifty-two

Network models

David C. Yen and William S. Davis

Contents

52.1	Purpose	415
52.2	Strengths, weaknesses, and limitations	416
52.3	Inputs and related ideas	416
52.4	Concepts	416
52.4.1	Star topology	416
52.4.2	Mesh topology	418
52.4.3	Bus topology	419
52.4.4	Tree topology	420
52.4.5	Ring topology	422
52.5	Key terms	423
52.6	Software	424
52.7	References	424

52.1 Purpose

Network models are used to determine the physical configuration of the computers and peripherals that form a network or distributed environment. This chapter describes several common network topologies.

Network design is a highly specialized discipline in its own right, and a detailed explanation of network analysis tools and techniques is beyond the

scope of this book. This chapter is written for systems analysts and information system consultants who must work with network specialists.

52.2 *Strengths, weaknesses, and limitations*

The strengths, weaknesses, and limitations of the various topologies will be discussed in context.

52.3 *Inputs and related ideas*

This chapter is concerned with the overall design of a network or a distributed system. The process of analyzing and design a given network is covered in Chapter 53. Chapter 54 discusses the process of routing messages among a network's nodes. Network design is related to hardware interface design (Chapter 42). The hardware interface is affected by the network topology, and each network node can be viewed as a hardware interface.

Readers who are not familiar with data communications theory and concepts should review the data communications chapter in an introductory management information systems or computer information systems textbook.

52.4 *Concepts*

Network models are used to determine the physical configuration of the computers and peripherals that form a network or distributed environment. This chapter describes several common network designs, or topologies. The terms *network design* and *topology design* are sometimes used to describe the process of designing a network topology.

A network consists of two or more computers linked by a communication line. The line might consist of coaxial cables, telephone wires, fiber optic cables, microwave signals, satellite signals, or some combination of media.

The computers that form a local area network are usually located in close geographic proximity (for example, within the same building, complex of buildings, or campus) and are generally linked by direct lines. The computers that form a wide area network are usually geographically disbursed and are often linked by common carriers. Each computer in a wide area network is called a host. Each connection point (computer, workstation, peripheral, concentrator, etc.) in the network is called a node.

52.4.1 *Star topology*

On a star network, all messages must pass through a central computer before they are passed to the destination computer. A simple star network (Figure 52.1) consists of several computers and/or peripherals each linked to a central host computer via a dedicated line. A variation of a simple star network

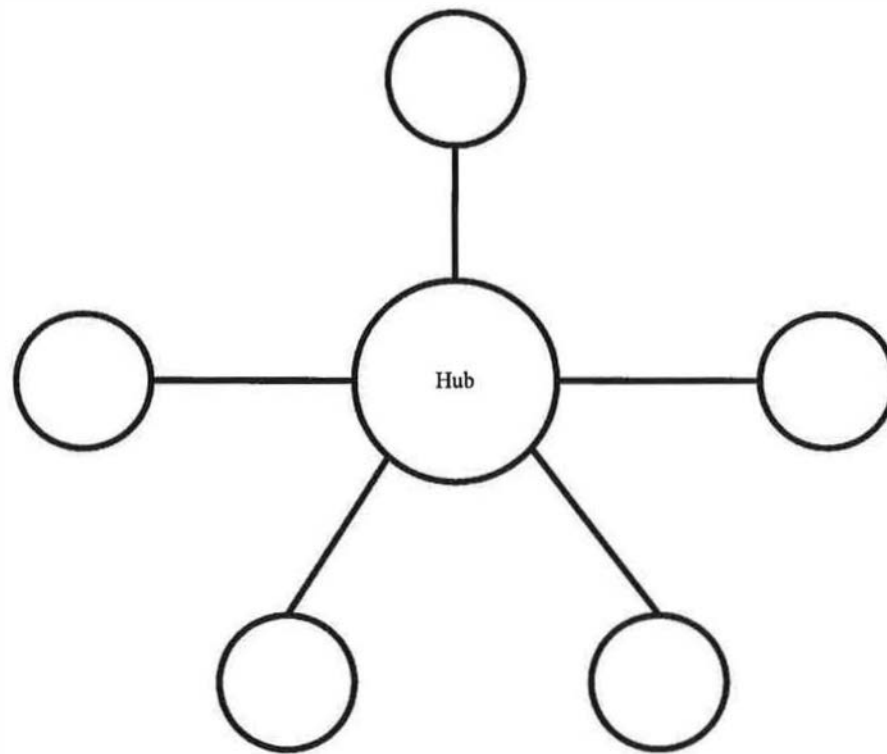


Figure 52.1 A simple star network.

features several computers, terminals, and/or peripherals connected to a cluster controller and sharing a communication link from the controller to the central computer.

Two or more simple star networks can be linked to form a complex star network as shown in Figure 52.2. Generally, one of the hub computers (usually, a powerful mainframe or minicomputer) serves as central boss and controls the network by scheduling, prioritizing, and holding incoming and outgoing messages. For example, in Figure 52.2, hub 2 and hub 3 must communicate with each other through hub 1, the central node or boss. If there is no single, clear, dominant, central node, several hub computers can work together as partners to relay messages.

Because dedicated lines are used to connect the remote nodes to the central node, star topology is the simplest but most expensive topology. The central node makes centralized supervisory and control functions relatively easy to perform. However, the entire network goes down if the central node goes out of service unless funds are spent to provide a reliable backup for both hardware and software. Many telephone company computer systems use star topology.

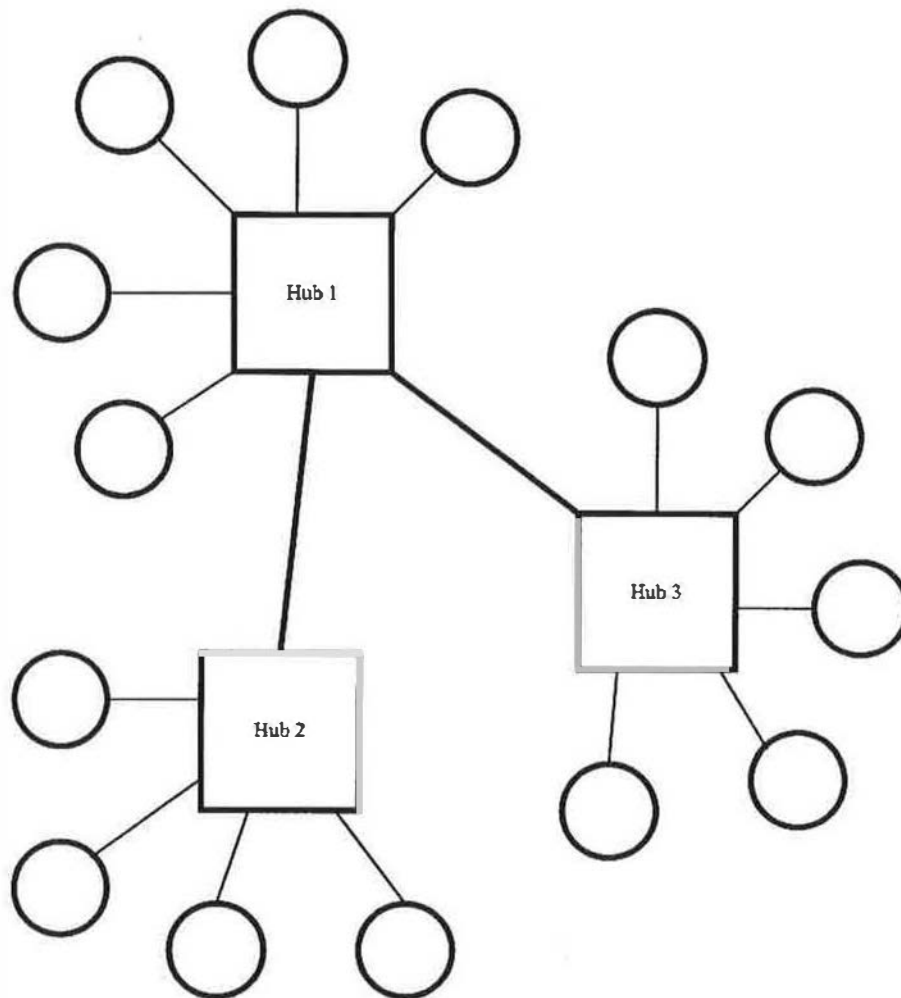


Figure 52.2 A complex star network.

52.4.2 Mesh topology

A mesh network allows any two remote computers to communicate directly, although there may be cases when a third computer relays a message from a source to a destination. In a fully connected mesh network every computer is directly connected to all the other computers in the network (Figure 52.3). In a partially connected mesh network, every computer is connected (either directly or via a relay computer) to at least two other computers in the network by more than one path (Figure 52.4).

Mesh topology is the most reliable and most expensive network topology. Most mesh topology networks belong to the government, the military, or a big corporation that needs a secured path to transmit data.

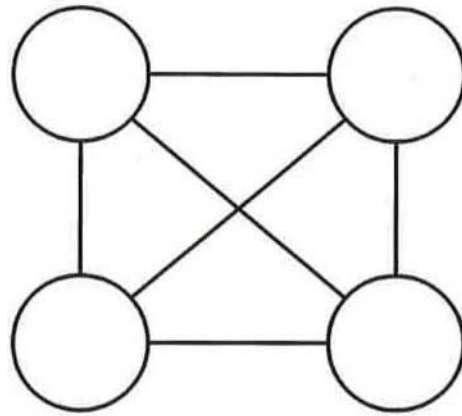


Figure 52.3 A fully connected mesh network.

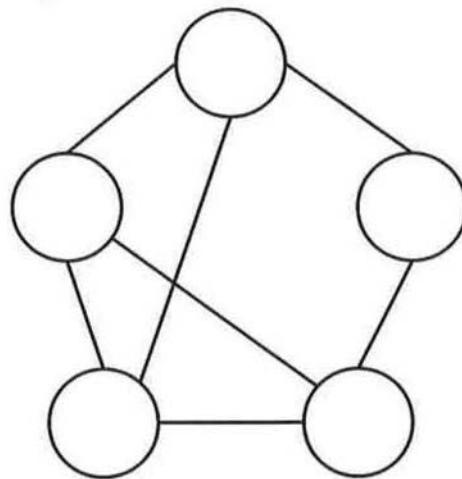


Figure 52.4 A partially connected mesh network.

52.4.3 Bus topology

On a bus network (Figure 52.5), the host computer is located at one end of a common communication line and all the other computers and peripherals in the network are attached to the same line.

A bus network is relatively inexpensive and easy to expand because all the nodes share a common communication path. However, traffic is heavy on the common line, and the network tends to degrade as the number of nodes increases. The location of the host node (relative to certain other nodes) can create an unbalanced network and negatively impact network performance. One host node may not be sufficient to handle all the traffic, and sophisticated equipment and software are needed to control the network.

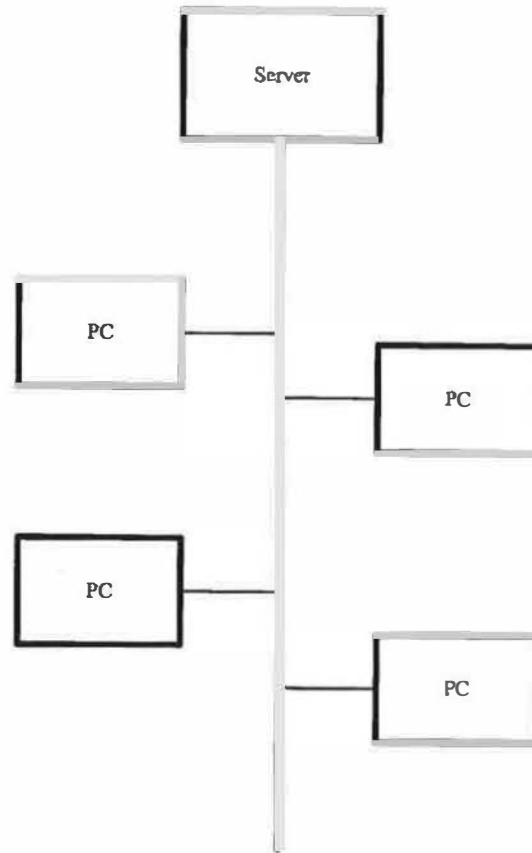


Figure 52.5 A bus network

52.4.4 Tree topology

Tree topology (or hierarchical topology) is a hybrid topology. Generally, two or more star or bus networks are connected to form a tree network. A rooted tree network (Figure 52.6) is a tree network with a clearly defined root node that serves as a base for the entire network. An unrooted tree network (Figure 52.7) has no clearly defined base root. Instead, there are several nodes that act as major hubs to relay messages or perform limited supervisory functions.

Tree topology is easy to implement using gateways, bridges, and/or routers. A major problem is that bottlenecks can develop in the equipment that connects the subnetworks.

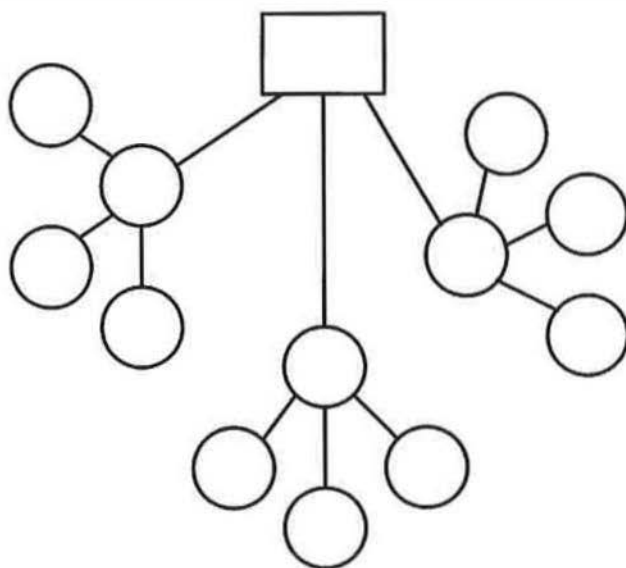


Figure 52.6 A rooted tree network.

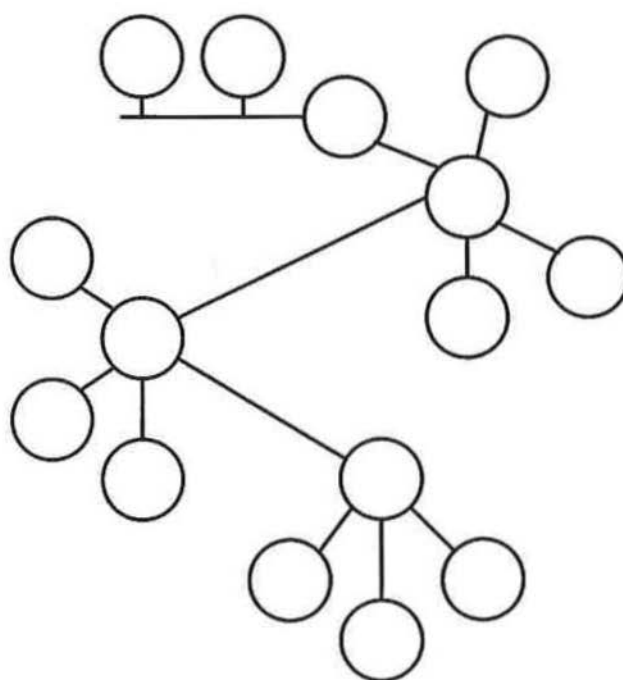


Figure 52.7 An unrooted tree network.

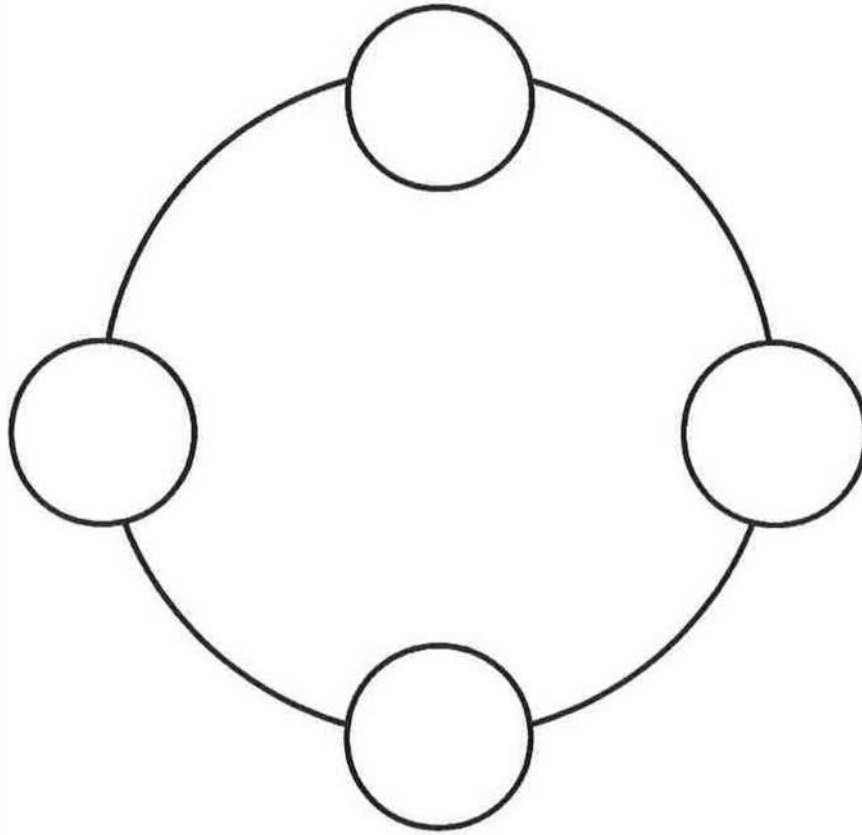


Figure 52.8 A ring network.

52.4.5 Ring topology

A ring network (Figure 52.8) consists of a series of nodes connected to form a ring. Each message is received, repeated, and retransmitted by each node as it works its way around the ring in a predetermined direction. A loop is a variation of a ring network with controlling nodes in the ring.

Because a ring or loop network transmits information in one direction only, transmission speed tends to be faster than with the other topologies. Ring networks are usually implemented using a token-passing protocol, which tends to limit network size, however. (For example, the nodes on a 500-node network can face lengthy delays waiting for the token.) The need for a special token symbol and procedures to enforce the direction of flow adds to the complexity of ring network design.

52.5 Key terms

Bus network — A network in which the host computer is located at one end of a common communication line and all the other computers and peripherals in the network are attached to the same line.

Complex star network — A network that consists of two or more linked simple star networks.

Data communication — The act of transmitting data from one component to another.

Fully connected mesh network — A mesh network in which every computer is directly connected to all the other computers in the network.

Host — A computer in a wide area network.

Local area network (LAN) — A network in which the nodes are located in close geographic proximity and are generally linked by direct lines (such as hard wires).

Mesh network — A network that allows any two remote computers to communicate directly.

Network — Two or more computers linked by a communication line.

Node — A connection point (computer, workstation, peripheral, concentrator, etc.) in a network.

Partially connected mesh network — A mesh network in which every computer is connected (either directly or via a relay computer) to at least two other computers in the network by more than one path.

Ring network — A network that consists of a series of nodes connected to form a ring.

Rooted tree network — A tree network with a clearly defined root node that serves as a base for the entire network.

Simple star network — A network that consists of several computers and/or peripherals, each linked to a central host computer via a dedicated line.

Star network — A network on which all messages must go through a central computer before they are passed to the destination computer.

Token passing — A network management technique in which an electronic token is passed continuously from node to node around the network and a given node can transmit a message only when it holds the token.

Topology — A map of a network; a physical arrangement of the nodes and connections in a network.

Tree topology (hierarchical topology) — A hybrid topology that usually consists of two or more linked star or bus networks.

Unrooted tree network — A tree network with no clearly defined base root; instead, there are several nodes that act as major hubs to relay messages or perform limited supervisory functions.

Wide area network (WAN) — A network in which the nodes are (usually) geographically disbursed and linked by common carriers.

52.6 Software

Not applicable.

52.7 References

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chapter fifty-three

Network analysis

David C. Yen and William S. Davis

Contents

53.1 Purpose 425

53.2 Strengths, weaknesses, and limitations 425

53.3 Inputs and related ideas 426

53.4 Concepts 426

 53.4.1 Requirements identification 426

 53.4.2 Network design 427

 53.4.3 Cost estimating 427

 53.4.4 Documentation 427

53.5 Key terms 428

53.6 Software 430

53.7 References 430

53.1 Purpose

The purpose of this chapter is to overview the key activities in the network analysis and design process. Network analysis is a highly specialized discipline in its own right, and a detailed explanation of network analysis tools and techniques is beyond the scope of this book. This chapter is written for systems analysts and information system consultants who must work with network specialists.

53.2 Strengths, weaknesses, and limitations

Not applicable.

53.3 *Inputs and related ideas*

Network topologies are discussed in Chapter 52. Location connectivity analysis is covered in Chapter 54. Simulation (Chapter 19) and queuing theory (Chapter 79) are two mathematical tools that are often used to support network analysis. The cost estimating process might include a cost/benefit analysis (Chapter 38). Network consultants often develop detailed cost estimates in response to a competitive procurement opportunity (Chapter 41). The need for a network is established during the analysis (Part IV) and high-level design (Part V) stages of the system development life cycle. Key network design parameters are documented in the requirements specifications (Chapter 35).

53.4 *Concepts*

The purpose of this chapter is to overview the key activities in the network analysis and design process. A detailed explanation of network analysis tools and techniques is beyond the scope of this book.

53.4.1 *Requirements identification*

The purpose of requirements identification is to ensure that the network designers have clear definitions and a detailed understanding of the essential network requirements and related network design attributes.

Geographical requirements analysis begins with a careful study of the system's geographical locations (i.e., buildings and areas) and focuses on such issues as topology (Chapter 52) and transmission media (dedicated cable, microwave, satellite, common carrier). Traffic flow pattern analysis is also used to help define the network's topology (Chapter 52) and connections (Chapter 54) as well as message volumes associated with the various data flows.

Traffic load analysis includes such elements as peak load analysis, message duration analysis, and busy hour analysis. Together, they are used to determine the required number of communication lines, the maximum required capacity for each line, the time slots during which the communication lines are likely to be busy, and several related network performance parameters. The purpose of availability requirements analysis is to determine and document the effect of time differences (time zone shifts) between the different geographical areas covered by the network.

As the name implies, response time analysis is concerned with determining the system's response time requirements (e.g., interactive, store and forward, real-time, etc.). Reliability requirements analysis provides information that helps the designer develop a back-up plan or create necessary redundancies.

Hardware analysis is used to define the requirements for the personal computers, workstations, terminals, peripherals, communication interfaces,

modems, and other hardware that will be attached to the network. Additionally, such software as the operating system and communication protocols must be specified. Future projection analysis focuses on parameters that affect capacity planning, storage requirements, transmission speed, connections with the Internet, and the highway (or Turnpike) effect.

53.4.2 Network design

Based on the network requirements identified in the previous stage, the network is physically designed.

Topology determination focuses on physically laying out the network using such tools as location connectivity diagrams (Chapter 54). The required line speeds are defined based on such criteria as transmitted characters per day, computer time (input, output, and processing) per message, and the required response time. Concentration point determination is concerned with the system's concentration points (or hubs). Such factors as the number of hubs, the capacities and related requirements for the lines that link the hubs, and the number of clients per server (or per hub) must be weighed against network efficiency.

Bottlenecks (or choke points) are places in the network where message flow exceeds capacity, resulting in delays and even lost messages. Bottleneck analysis (an application of queuing theory, Chapter 79) is a useful, mathematical tool for identifying choke points and for evaluating how various line capacities, transmission speeds, and hardware options (processing speed, storage capacity) affect performance. Queuing theory can also be used to gauge the sensitivity of a network design to such variables (or assumptions) as average message length, message duration, and busy hours. Simulation (Chapter 19) is another useful mathematical tool that can help identify and solve many network design problems. The advantages of using mathematical tools such as queuing theory and simulation include quick feedback, the flexibility to consider numerous variables or assumptions, and low cost.

53.4.3 Cost estimating

Networks are expensive to develop and to operate. Clear, accurate development, and operating cost estimates are essential before the final decision to implement a network is made. The cost estimating process might include a cost/benefit analysis (Chapter 38). Network consultants often develop detailed cost estimates in response to a competitive procurement opportunity (Chapter 41).

53.4.4 Documentation

Once the network analysis is completed, the various design decisions must be carefully documented. Connection diagrams define the topology, connection points, and traffic flows. Key supporting details include the

types of transmission media, the desired technology (e.g., T1, ISDN, fiber optics, satellite, microwave), the capacities, speeds, and costs of those media, and a back-up plan. The act of preparing the connection diagrams and supporting documentation is sometimes called logical documentation and preparation.

During the physical documentation and preparation phase, a complete component list is prepared for each node in the network. Key parameters include the brand name, model, speed, and other relevant specifications for such hardware components as the computers, the modems, and related peripherals (printers, scanners, etc.), and the nature and description of all cables and connectors. Sometimes, hierarchy charts (Chapters 48 and 62) are prepared to help document the components that form a subnetwork controlled by a hub.

The network specifications incorporate all the information related to the network. In addition to the documentation described above, routers, bridges, and other message switching equipment or devices must be documented in detail. Finally, such details as floor plans, rising cables, distributing cables, central switch boxes, server locations, telephone jack locations, and power outlets must be documented in a wiring diagram.

53.5 Key terms

Availability requirements analysis — A network analysis process that helps to determine and document the effect of time differences (time zone shifts) between the different geographical areas covered by the network.

Bottleneck (choke point) — A place in the network where message flow exceeds capacity, resulting in delays and even lost messages.

Bridge — A computer that links two networks with similar protocols.

Client — A computer (more generally, a node) that requests a service from a server.

Client/server — A network in which client computers request services from a central server computer.

Concentration point determination — A network analysis process that is concerned with the system's concentration points (or hubs).

Connection diagram — A diagram that shows the topology, connection points, traffic flows, and patterns of a network.

Data communication — The act of transmitting data from one component to another.

Distributing cable — Generally, a cable that links the computers or nodes on a single floor.

Future projection analysis — A network analysis process that focuses on parameters that affect capacity planning, storage requirements, transmission speed, connections with the Internet, and so on.

Gateway — A computer that links two or more networks with different protocols.

Geographical requirements analysis — A preliminary network analysis process that begins with a careful study of the system's geographical locations and focuses on such issues as topology and transmission media.

Hardware analysis — A network analysis process that helps to define the requirements for the personal computers, workstations, terminals, peripherals, communication interfaces, modems, and other hardware that will be attached to the network, and such software as the operating system and communication protocols.

Highway effect (turnpike effect) — The tendency of users to quickly adopt new technology as soon as it proves its usefulness; because of the highway effect, the demands placed on a system often exceed projections. This term was initially coined in the 1950s when the traffic load on the Pennsylvania Turnpike exceeded the designers' long-term, worst-case projections soon after the road opened.

Host — A computer in a wide area network.

Hub — A central controlling device, point, or node in a network.

Local area network (LAN) — A network in which the nodes are located in close geographic proximity and are generally linked by direct lines.

Message switching — The process of routing a message from its source to its destination; note that sometimes messages are decomposed into packets that reach their destination via different transmission paths.

Network — Two or more computers linked by a communication line.

Network topology — A map of a network; a physical arrangement of the nodes and connections in a network.

Node — A connection point (computer, workstation, peripheral, concentrator, etc.) in a network.

Protocol — A set of rules that governs data communication.

Reliability requirements analysis — A network analysis process that helps the designer develop a back-up plan or create necessary redundancies.

Response time analysis — A network analysis process that helps to determine the system's response time requirements (e.g., interactive, store and forward, real-time, etc.).

Rising cable — Generally, a cable that runs between two floors in a building.

Router — An intelligent device that provides network connections and performs such services as protocol conversion and message routing.

Server — A computer that holds centralized resources and provides them to clients on request.

Token passing — A network management technique in which an electronic token is passed continuously from node to node around the

network and a given node can transmit a message only when it holds the token.

Topology — A map of a network; a physical arrangement of the nodes and connections in a network.

Topology determination — A network analysis process that focuses on physically laying out the network using such tools as location connectivity diagrams.

Traffic flow pattern analysis — A network analysis process that helps to define the network's topology and connections as well as the message volumes associated with the various data flows.

Traffic load analysis — A network analysis process that helps to determine the required number of communication lines, the maximum required capacity for each line, the time slots during which the communication lines are likely to be busy, and several related network performance parameters.

Wide area network (WAN) — A network in which the nodes are (usually) geographically disbursed and linked by common carriers.

53.6 Software

Not applicable.

53.7 References

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chapter fifty-four

Network routing tools and techniques

David C. Yen and William S. Davis

Contents

54.1	Purpose	431
54.2	Strengths, weaknesses, and limitations	432
54.3	Inputs and related ideas	432
54.4	Concepts	432
54.4.1	Centralized routing	432
54.4.2	Distributed routing	433
54.4.2.1	Static routing	433
54.4.2.2	Adaptive routing	433
54.4.2.3	Broadcast routing	434
54.5	Key terms	435
54.6	Software	436
54.7	References	436

54.1 Purpose

This chapter focuses on several common network routing techniques (generally, location connectivity analysis). The major objectives of these routing techniques include controlling network data flow, determining the status of the sending and the receiving nodes, identifying the best (sometimes optimal) route to transmit data, reducing transmission delays and related errors, and preventing the overuse of a particular route or node.

Network design is a highly specialized discipline, and a detailed explanation of location connectivity analysis tools and techniques is beyond the scope of this book. This chapter is written for systems analysts and information system consultants who must work with network specialists.

54.2 *Strengths, weaknesses, and limitations*

The techniques described in this chapter are used to estimate and/or predict data flows and minimize data congestion in a distributed information system. Using these techniques can help reduce transmission problems owing to the speed and capacity constraints imposed by the transmission media.

It is difficult to measure the highway effect or to match users needs with emerging computing technology using these techniques. Also, the techniques described in this chapter do not always yield the best route for data transmission.

54.3 *Inputs and related ideas*

Network topologies are discussed in Chapter 52. Network analysis is covered in Chapter 53. The need for a network is established during the analysis (Part IV) and high-level design (Part V) stages of the system development life cycle. Key network design parameters are documented in the requirements specifications (Chapter 35).

54.4 *Concepts*

A network consists of a set of nodes (computers, routers, etc.) linked by communication lines. When a source node transmits a message, there are typically several possible paths the message can take from node to node through the network to reach its destination. The specific path selected for a given message is called a route. Location connectivity analysis is used to control network data flow, determine the status of the sending and receiving nodes, identify the best (or optimal) route, reduce transmission delays and related errors, and prevent the overuse of a particular route or node. This chapter focuses on several common routing techniques.

54.4.1 *Centralized routing*

Centralized routing is used when the distributed network is centrally controlled. The basic idea is to provide the central node with super-authority over all the other nodes. The network routing software installed on the central node can be used to overview the operation of the entire network, locate bottlenecks and underutilized nodes, calculate and recompute the optimal path between a sending node and a receiving node, and adjust the routing path by constructing a new routing table.

Centralized routing provides centralized control, integrated supervision of the network, very good security, and excellent back-up control. The central node is relatively expensive to operate and maintain, however, and the entire network goes down if the central node fails. Some operating inefficiency is possible because the central node must perform all routing calculations. Also, the calculated optimal paths may not reflect the current status of the network if they are based on (even seconds old) historical network information.

54.4.2 Distributed routing

Distributed routing relies on each node to compute its own routing table and build the required connections with its neighbors. Ideally, the network operation, status, and architecture of each node is transparent. Distributed routing is more flexible than centralized routing because each node handles its own routing. The result is often improved system performance.

54.4.2.1 Static routing

Static routing establishes routine paths between sending and receiving nodes based on a data flow analysis of historical data. With static routing, the path is selected from a predefined table, so there is no need to readjust paths or compute the next node. However, if the established link between any pair of nodes fails, static routing cannot adjust. Also, as transmission patterns change, static routing patterns can quickly become inefficient.

Fixed routing always utilizes a predetermined fixed route when transmitting between a specific pair of nodes. Fixed routing is widely used in mesh topology networks, particularly when reliability and security are primary objectives.

With weighted routing, different routing paths are selected for each message based on a predetermined desirable utilization rate. For example, imagine that there are three paths (via node A, B, or C) between the source node and the destination node (Figure 54.1). The objective is to transmit 50 percent of all messages via node A, 30 percent via node B, and the remaining 20 percent via node C. The source node uses a random number generator to select the route based on the predetermined probabilities.

54.4.2.2 Adaptive routing

Adaptive routing, also called dynamic routing, selects the best route based on such criteria as the speed, capacity, or cost of the link, the utilization rate of a particular node, the failure rate of a particular path, the type of data to be transmitted, response time, throughput, and so on. Often, a prioritized list of decision criteria (called a portfolio) is used.

The objective of the quickest route algorithm is to send the message to the next available neighboring node (other than the sending node) as quickly as possible. The advantage is fast transmission, but there is no

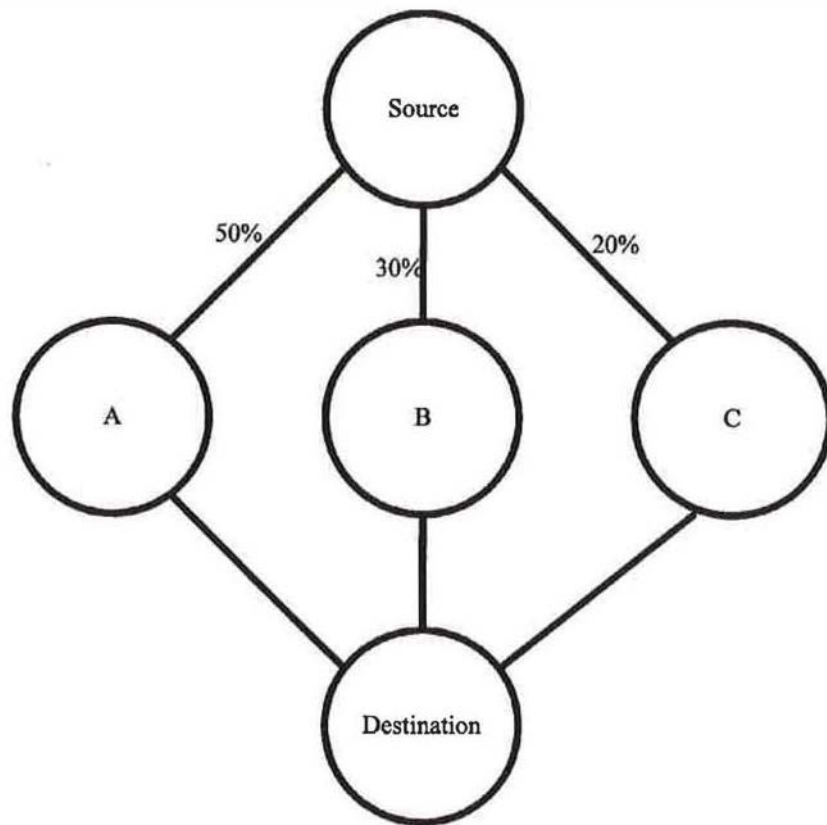


Figure 54.1 Weighted routing.

guarantee that the node selected will be closer to the destination. In some cases, the quickest route algorithm can increase the time required to deliver a message.

The best route algorithm uses such parameters as the type of message, the rate of under-utilization or over-utilization of a particular node, and the number of intermediate nodes between the source and the destination. Such tools as linear programming, goal programming, and similar management science techniques can be used to select and rank the different routing alternatives based on the established criteria.

54.4.2.3 Broadcast routing

With broadcast routing, a header containing the address of the receiving node is added to the message. The message is then transmitted to all the nodes in the network, and the node whose address matches the header reacts to the message. Note that each node must have a list of addresses of all the nodes in the network. Security is a major concern because every node receives a copy of the message. Broadcast routing is popular in collision detection networks.

54.5 Key terms

Adaptive routing — A distributed routing technique that selects the best route based on such criteria as the speed, capacity, or cost of the link, the utilization rate of a particular node, the failure rate of a particular path, the type of data transmitted, response time, throughput, and so on; also known as dynamic routing.

Best route algorithm — An adaptive routing technique that uses such parameters as the type of message, the rate of under-utilization or over-utilization of a particular node, and the number of intermediate nodes between the source and the destination.

Bottleneck (choke point) — A place (usually, a node or a path) in the network where message flow exceeds capacity, resulting in delays, and even lost messages.

Broadcast routing — A routing technique in which a header containing the address of the receiving node is added to the message; the message is then transmitted to all the nodes in the network, and the node whose address matches the header reacts to the message.

Centralized routing — A routing technique in which the central node has super-authority over all the other nodes.

Collision detection — A network management technique in which the nodes are allowed to transmit at any time; if two messages collide, the collision is sensed and the messages are retransmitted.

Distributed database — A database with different subsets of data distributed among several sites that are connected by a network.

Distributed routing — A routing technique that relies on each node to compute its own routing table and build the required connections with its neighbors.

Fixed routing — A static routing technique that always utilizes a predetermined fixed route when transmitting between a specific pair of nodes.

Highway effect (turnpike effect) — The tendency of users to quickly adopt new technology as soon as it proves its usefulness; because of the highway effect, the demands placed on a system often exceed projections. This term was initially coined in the 1950s when the traffic load on the Pennsylvania Turnpike exceeded the designers' long-term, worst-case projections soon after the road opened.

Location connectivity analysis — A network and distributed database design technique used to help control network data flow, determine the status of the sending and receiving nodes, identify the best route to transmit data, reduce transmission delays and related errors, and prevent the overuse of a particular route or node; also known as connectivity analysis or routing analysis.

Network — Two or more computers linked by a communication line.

Node — A connection point (computer, workstation, peripheral, concentrator, etc.) in a network.

- Path** — A group of connected links that allow the transmission of information from a source to destination(s).
- Portfolio** — A prioritized list of routing decision criteria.
- Protocol** — A set of rules that governs data communication.
- Quickest route algorithm** — An adaptive routing technique that sends the message to the next available neighboring node (other than the sending node) as quickly as possible.
- Route** — The path(s) or subset used to actually transmit information from a source to a destination(s).
- Router** — An intelligent device that provides network connections and performs such services as protocol conversion and message routing.
- Routing** — The process of determining the best available path (or path segment) to transmit a message.
- Static routing** — A distributed routing technique that establishes routine paths between sending and receiving nodes based on a data flow analysis of historical data.
- Token passing** — A network management technique in which an electronic token is passed continuously from node to node (following the direction of flow) around the network and a given node can transmit a message only when it holds the token.
- Topology** — A physical arrangement of the nodes and connections in a network.
- Weighted routing** — A static routing technique in which different routing paths are selected for each message based on a predetermined desirable utilization rate.

54.6 Software

Not applicable.

54.7 References

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