An integral part of SNA is the scheme for controlling the communications functions within a network. This scheme is the Network Control Program that resides within a communications controller of the network. Discussed are the operations of the major components of the NCP and their relationships.

The role of the Network Control Program in Systems Network Architecture

by W.S. Hobgood

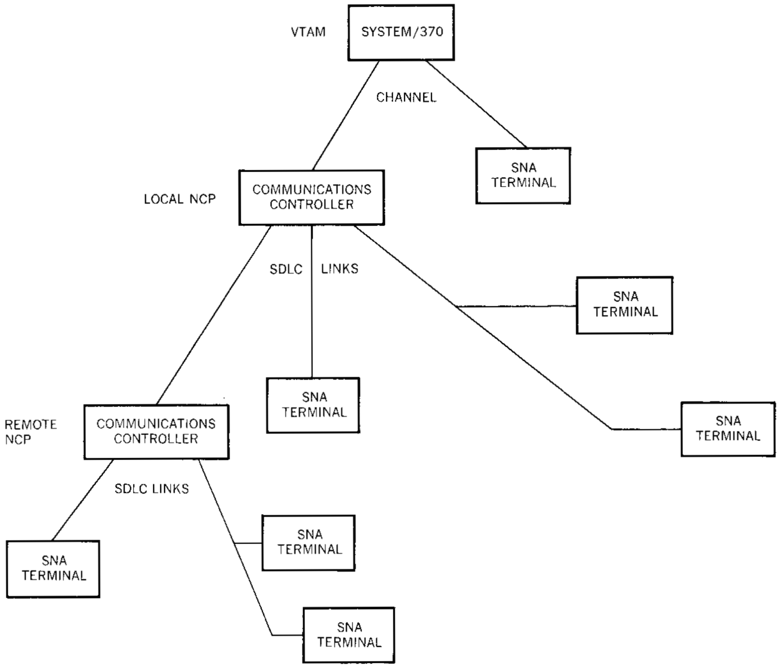
The Network Control Program/Virtual Storage (NCP/VS) is found at the center of the current implementation of the Systems Network Architecture (SNA) communications system. On one side, NCP deals through the Virtual Telecommunications Access Method (VTAM) with application programs in the host computer, and on the other side, NCP converses with a multiplicity of SNA components including other network control programs. In this paper, we will look at the communications network from the NCP vantage point; accordingly, the view is from the inside looking outward toward the end users of the system. The reader is presumed to understand basic SNA concepts and terminology.[1-3]

NCP/VS resides in the IBM 3704 or 3705 Communications Controller, a machine well-suited to the distributed function capability inherent in SNA. Even before SNA was announced, the NCP had begun to support removal of communications functions from the host. In this light, it would be fruitful to consider the development of the NCP and the evolution of its objectives prior to SNA being available.

Historical perspective

In response to the increasing complexity of teleprocessing networks in the early 1970s, IBM announced the 3705 programmable communications controller in March of 1972. This communications controller can be configured with from 16K to 240K bytes of memory and can have up to 352 communications lines attached.[4] The 3704 controller, a smaller version with up to 64K bytes of storage and 32 lines, was announced in February

Figure 1 Simplified SNA configuration



of 1973. Both machines have five levels of interruptions. The processors include specialized communications hardware to perform tasks associated with scanning lines, computing block checks, controlling and sensing modem operations, and dialing and disconnecting switched links.

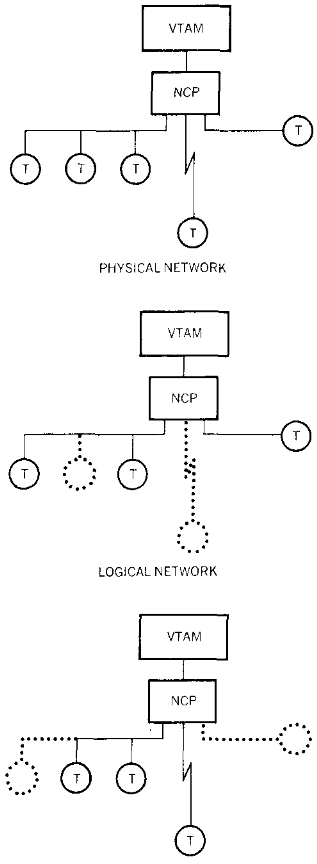
The initial programming for the communications controller was the emulator program, which provided a compatible replacement for the IBM 270X series of transmission control units. When the communications controller is used in emulator mode, each communication line requires a separate subchannel address, and many of the functions concerned with management of line protocol and error recovery remain embodied in the host access method or the application program. The emulator was designed as a migration path to the NCP, the primary programming for the communications controller. NCP helps to isolate teleprocessing considerations from the CPU, the operating system, and the access method. For example, the overhead associated with polling and addressing multipoint lines is handled in NCP. Messages from terminals are buffered in the communications controller, and the host is interrupted only at the completion of a successful data transfer rather than after each character received. Error recovery procedures are resident in the NCP and are available without interrupting the host computer or loading from a direct-access device. NCP uses only one subchannel address for all the components attached to the controller.

SNA objectives

The proliferation of binary synchronous and start-stop terminals, with subtle variations of link-level and higher-function protocols, resulted in numerous subsets of dependent programming in the NCP. A more cohesive approach to telecommunications architecture was required. SNA became the vehicle for a unified teleprocessing strategy by defining not only the link-level controls between adjacent nodes but a complete end-to-end protocol for network development. The rest of this paper discusses the relation of the NCP to an SNA teleprocessing system.

The layered structure of SNA provides for the distribution of teleprocessing functions so that network control activities can be performed in the communications controller as well as in the new terminal controllers that operate in the SNA environment. The SNA version of the NCP (NCP/VS) was structured to reflect the separation between data link control, path control, and the connection point management functions. These components are discussed in detail elsewhere.[5]

Figure 2 Logical and physical networks



NCP/VS in the SNA network environment

A local NCP/VS is attached to a System/370 Virtual Storage Operating System by a channel interface. SNA terminals are attached to NCP/VS by synchronous data link control (SDLC) communications links, as are other communications controllers containing remote NCPs. A simplified configuration is shown in Figure 1. In SNA terms, the local NCP/VS includes a boundary function to manage all the SNA resources that are directly attached to the local communications controller, and an intermediate function to route messages that are associated with components on other, remote NCPs. NCP/VS is highly modular in design so that the boundary function can be tailored to match the complexity of the SNA resources under its control. The boundary function may, in fact, be absent if the NCP has no SNA terminals under its direct control and functions only as part of an intermediate path to other network controllers.

For a given physical network, there may be multiple realizations of logical networks that are subsets of the physical one (see Figure 2). The organization owning the network defines its logical networks with NCP/VS system generation macroinstructions. The system generation procedure interprets the user's description of his logical networks, determines which NCP/VS subcomponents are required, selects the appropriate modules, and builds a control block structure that represents the characteristics of each SNA resource in the subnetwork controlled by the NCP being generated. The NCP/VS load modules are stored on a direct-access device in the host processor. Subsequently, under network operator control, a particular NCP/VS load module is transmitted to the communications controller as part of the network activation procedure.

After the NCP/VS load module has been sent to the communications controller and activated, it can be dynamically altered under VTAM control. A trace function can be invoked for any line in the system for diagnostic purposes. The description of terminals attached to switched links can be resolved at the time the connection is established, so that switched links are shareable among the entire family of SNA terminals. In short, the flexibility of NCP/VS permits its real-time adaptation to a multiplicity of complex communications environments.

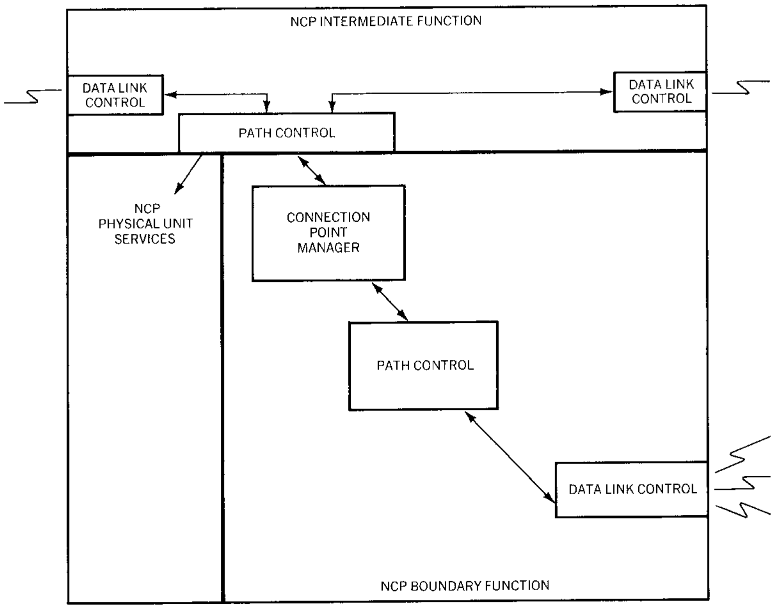
Overview of NCP/VS

From a high-level viewpoint, NCP/VS includes three major components: the intermediate function, the boundary function, and physical unit services. The intermediate function includes data link control and path control for other NCPS and for the host node, whereas the boundary function includes data link control, path control, and connection point manager facilities for the attached SNA. NCP physical unit services executes functions that alter the state of the NCP itself. The relationship among these components is as shown in Figure 3.

The intermediate function may be viewed as a first-in-first-out pipeline with a rudimentary routing function. The data link control element sits on both ends of the pipeline and performs the following functions:

1. Manages information transfer over the channel interface or the SDLC link as applicable.
2. Performs first-level error recovery procedures.
3. Adds and deletes link header information on transmission and receiving, respectively.
4. Participates with the hardware to generate and check the block check character.
5. Updates and verifies transmission counters.
6. Receives and routes link-level control information to physical unit services.

Figure 3 NCP overview



The intermediate path control element takes messages from the data link control layer and then performs the routing function as follows:

1. Verifies and interrogates the transmission header.
2. Consults internal tables to determine, based on address information in the transmission header, if the message should be handled internally or forwarded to a different NCP or host.

The boundary function is primarily concerned with managing the SNA terminals attached directly to the NCP; that is, those resources contained in the local address space. The data link control element governs the SDLC links to these resources and is comparable to the data link control element of the intermediate function.

The boundary path control element routes messages to and from the data link control element, performing the following services:

1. Converts the transmission header from the network form to a simplified local format and vice versa.
2. Determines to which SNA resource the traffic is to be sent, based on internal tables.
3. Splits the message into smaller elements for transmission to terminal controllers with buffering constraints.
4. Enqueues the traffic to a connection point manager for the associated resource.

The connection point manager oversees sessions and controls the flow of data to the local resource in the following manner:

1. Ensures that no information can flow to or from the resource unless the proper sessions have been established.
2. Confirms integrity of the physical and logical paths to each of the in-session resources.
3. Ensures a smooth flow of data while preventing overloads to the SNA resources.
4. Performs additional network functions for simpler terminals.

The NCP physical unit services oversees the operation of both intermediate and boundary functions, in conjunction with the system services control point in VTAM.[6] At this level, the functional support includes:

1. Activating and deactivating links.
2. Establishing contact and breaking contact with SNA stations.
3. Managing switched network operations.
4. Reporting maintenance statistics.
5. Loading and dumping attached communications controllers.
6. Overseeing testing services.

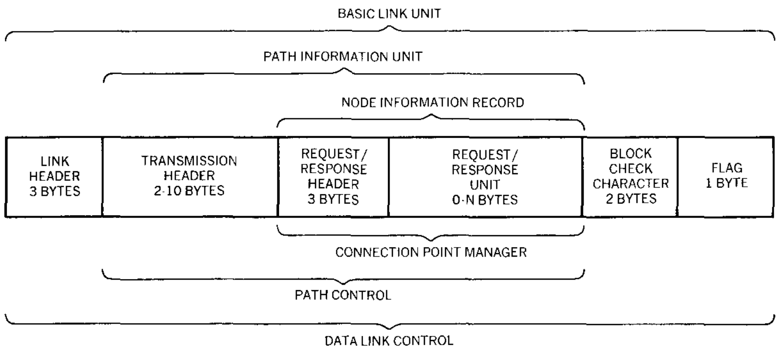
The three components, intermediate function, boundary function, and physical unit services, work together to manage the NCP's subnetwork. In the next section, we will take a closer look at the building blocks for these components: the NCP implementation of data link control, path control, and connection point management. Figure 4 shows the information unit for which each level is responsible.

NCP/VS data link control

channel data link control

Data link control for the channel manages traffic between a local communications controller and a System/370. Initial channel operations are managed by bootstrap microcode in the controller read-only storage, which allows an NCP/VS load module to be transmitted over the channel interface. Once the load sequence is completed, the channel is controlled on the NCP side by the channel adapter I/O supervisor. VTAM uses three basic channel commands—READ, WRITE, and WRITE BREAK—to communicate with NCP. These basic commands are supplemented by control commands that provide a simple method to recover from most channel interface errors. The control commands precede the channel program to define the pending data transfer as a retry of a previous block or a new block, using an alternating acknowledgment somewhat similar to ACK0 and ACK1 as used in binary synchronous communications.

Figure 4 Information units for each level

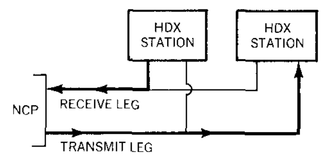


The host channel program can initiate a write operation at any time; however, it never initiates a read operation except in response to ATTENTION status presented by the NCP over the channel interface. Attention may be signaled whenever a message is ready for the host or after a specified delay. This feature, called channel attention delay, can be altered by the network operator as the network traffic varies through the day.

synchronous data link control

The communications links operate under the SDLC line discipline. NCP/VS supports SDLC stations in half-duplex (HDX) or full-duplex (FDX) mode. Additionally, HDX stations can be attached to FDX communications facilities so that the NCP can read from one terminal while writing to another terminal. This type of operation, known as multi-multipoint line control, is depicted in Figure 5. Data link control in NCP/VS involves adding the link header in front of the message, computing the block check character, and appending that character and frame characters to the end of the message. The details of SDLC concepts are discussed elsewhere.[7]

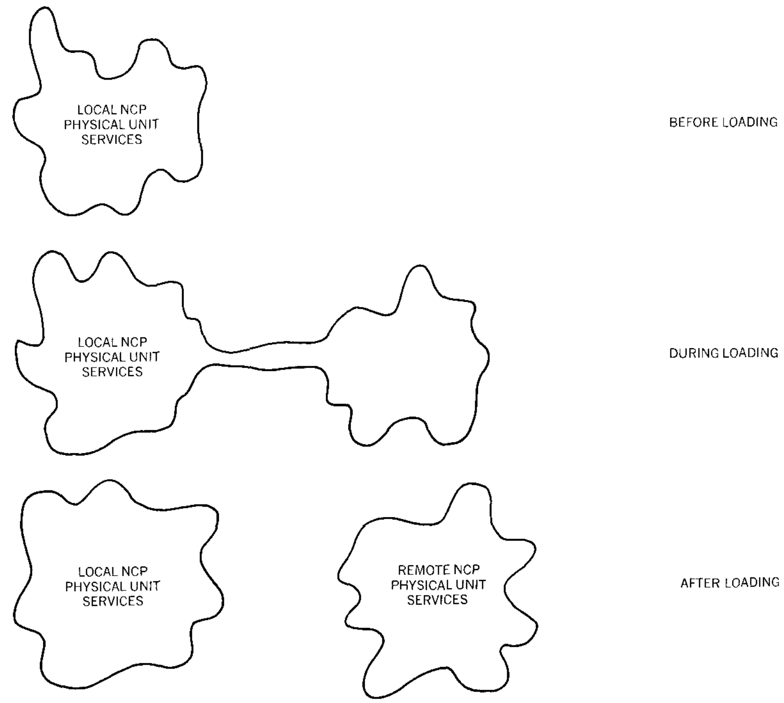
Figure 5 HDX stations on FDX links



HDX and FDX operations are scheduled differently, since in FDX it is desirable to maintain maximum traffiic over the receive leg and the transmit leg simultaneously. Once the link is initialized, the FDX scheduler attempts to poll stations whenever the receive leg is not actively receiving or does not have a pending response as a result of a previous polling operation. A service order table whose entries correspond to the attached stations is used for both FDX and HDX links to determine the order and frequency with which each station is to be polled. A station can appear in the service order table more than once to achieve priority scheduling on a station basis.

Certain commands used for station initiation and termination are scheduled on a slow poll scheme so as to minimize interference with on-going data transfer. The slow polling operation is per-

Figure 6 Loading a remote NCP



formed when the entire service order table is exhausted during a regular poll pass without a response from any station, or after a specific number of passes through the table.

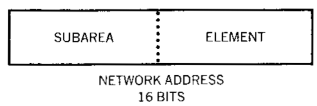
Data link control is responsible for maintaining the send and receive sequence counts for each station in the system. If a mismatch occurs, the frames in error are retransmitted at the next cycle through the service order table, unless the user has specified an immediate retry option. In any case, the frames that have been transmitted but not yet acknowledged are retained by the NCP on a link outstanding queue in case such an error occurs. The number of times a retransmission should be attempted, as well as the length of pause between retransmissions, are specified during the system generation procedure for each station in the system. Thus, the error recovery procedures can be highly sensitive to the physical characteristics of the communications network elements.

The remote communications controller is attached to the system by means of an SDLC link. The scheduling mechanism used is the same as that for the other SNA components, with a slight modification for the load or dump operations. The NCP in a remote communications controller cannot operate until it has been loaded and activated. Similarly, when the NCP terminates abnormally, it cannot dump itself to the host. A remote loader program stored on a diskette is used to manage the secondary side of the link during loading or dumping. Technically, the remote loader program is a specialized extension of the local NCP physical unit services, which coincidentally executes in a different communications controller (see Figure 6). The station is in a noncontacted state, and the load or dump records are transferred conceptually within local NCP physical unit services. After the NCP is loaded, a contact operation takes place, and the fresh NCP in the remote communications controller responds. Thereafter, the primary side of the link comes under control of the normal scheduling procedure in the local NCP, and the remote end of the link is managed by the remote NCP's secondary SDLC programs.

Data link control's responsibility is limited to link-level operations. After a message has been received successfully over the link, data link control strips away the link header and the block check character and passes the remaining part (the path information unit) to path control for further processing. The reverse procedure occurs when traffic is to be sent out to an SNA component. Next we will consider the steps path control takes to prepare a message for transmission by data link control.

NCP/VS path control

Figure 7 Network address

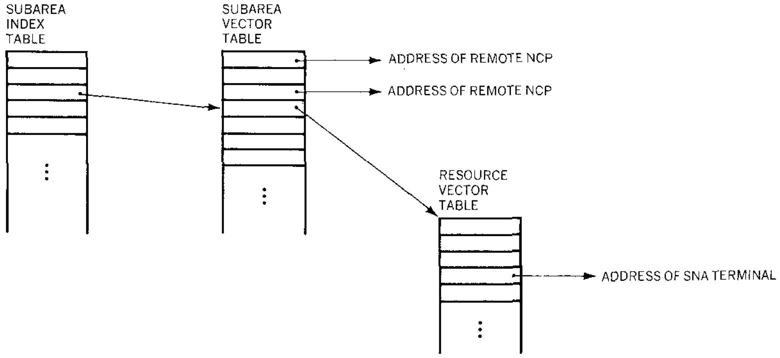


Intermediate path control is primarily concerned with interpreting the network address portion of the transmission header and performing routing services. The network address is divided into two parts, a subarea and an element, as shown in Figure 7. The boundary between the subarea and element can be specified by the user but is fixed for a given network.

The routing function for outbound traffic is based on NCP tables shown in Figure 8. Path control uses the subarea part of the network address to find an entry in its subarea index table (SIT). Each entry in the table references a subarea vector table (SVT) entry, which is the address of a control block for a remote NCP if the subarea refers to a resource that is not attached to this NCP. If the subarea corresponds to this NCP, the SVT entry points to a resource vector table (RVT). The element part of the network address references a particular RVT entry that points to the control block associated with the appropriate local resource. Intermediate path control then enqueues the message to the control block, and the connection point manager function takes over from there.

Boundary path control takes a message from the connection point manager and directs it to a particular link. In addition to routing, boundary path control changes the transmission header

Figure 8 Outbound path control routing tables



from a network form to a simpler local form that is recognizable by the SNA terminal. This transformation follows one of two algorithms depending upon the type of physical unit implemented in the SNA terminal.

For a Type 1 physical unit with limited SNA function, such as the IBM 3767 communications terminal, the network transmission header is transformed to an abbreviated form that does not include sequence numbers or a full addressing capability. Since this information is absent from the local header, the functions of sequence number management and some address interpretation are performed in the boundary function. For a Type 2 physical unit, such as the IBM 3770 data communications system, the local transmission header includes the abbreviated addresses of the origin and destination as well as sequence numbers. As more information is included in the local header, more network function can be distributed to the SNA terminal controller.

Boundary path control also is aware of buffer size constraints in the terminal. If a path information unit is too large for the buffer, the unit is split into several segments, each of which fits in the terminal's buffer. Data link control (unaware of segmenting) sends each segment out as a separate basic link unit.

NCP/VS connection point manager

A logical connection point manager facility in the boundary function is associated with each session that flows through the NCP. The functions performed include session control and integrity checking, configuration integrity, and control of the flow of data to the attached logical and physical units.

When a session activation or deactivation command flows through the NCP, the connection point manager facility for the associated resource ensures that the request is valid and remembers the change in session status. The traffic flow to the resource is monitored so that no messages are transmitted to resources that are not in session. The connection point manager also checks the origin address of each request to ensure that the request was initiated by the primary logical unit that began the session.

The configuration integrity is also checked by the connection point manager, and no requests are allowed to flow unless the NCP itself, the communications controller port, the link, and the station on the network are all operative.

A final connection point manager function governs the rate of message flow through pacing. A user specifies at system generation time certain parameters whereby the SNA resource can signal the NCP when it is able to accept more messages. This signal can be carried on a response to a previous message or carried as an isolated pacing response. The NCP will not schedule traffic for the secondary logical unit if that logical unit's buffers are tied up or if its control unit is busy processing previous requests.

Additional functions are performed in connection point management on behalf of the Type 1 physical unit. For example, the boundary function generates and checks sequence number fields and handles the error recovery associated with sequencing errors, since the local transmission header does not contain a sequence number.

Physical unit services are performed entirely within the boundary connection point manager for the Type 1 physical unit. Thus activation and deactivation requests are turned around in the NCP, and the session between the host and the physical unit is short-circuited. Information flow is blocked in the NCP unless a session has been established. By removing physical unit services to the boundary function, certain SNA terminals can be built less expensively. However, since the surrogate physical services in NCP is unaware of the precise state of the hardware, certain advanced functions such as switched network backup or physical unit testing services cannot be implemented for the simple SNA terminals that are built as Type 1 physical units.

NCP/VS physical unit services

The physical unit services component is the NCP's director of system services control, concerned with the resources associated with or attached physically to the communications controller. The functions performed include bringing links up and down, managing the establishment of contact and the breaking of contact with attached physical units, setting up routing tables, allocating and deallocating NCP control blocks for switched network resources, reporting maintenance statistics to the system services control point, loading and dumping attached boxes, and overseeing testing services.

The system services control point initiates link activity by issuing an ACTIVATE LINK request to the NCP physical unit services. If the link is nonswitched, the NCP enables the link by setting certain hardware latches. If the link is switched, the ACTIVATE LINK command results in a logical NCP operation that simply marks the link active.

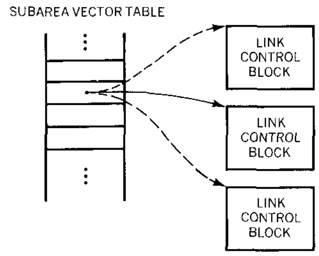
Additional commands flow between the system services control point and NCP for switched links. The control point may instruct the NCP to enable a switched port for subsequent dial-in operations. It may direct the NCP to dial the station, in which case NCP physical unit services oversees a dialing operation that can be done manually by a network operator or automatically using some type of auto-call equipment. In either case, the NCP notifies the system services control point when the connection is established and includes identification information supplied by the terminal in an initial handshaking operation.

Because the type and configuration of a switched SNA station is unknown until the physical connection exists, the control block structure must be built under program control. After the system services control point interprets the terminal identifier, it sends a series of commands to the NCP to build skeleton control blocks and establish pointers appropriately. Subsequent commands are sent with parameters which the NCP uses to set control information unique to the particular SNA controller, such as addressing characters, error retry counts, pacing parameters, and local addresses. Once the control block parameters are filled in, the NCP is configured just as if the terminal had been generated on that line, and the system services control point can proceed to contact the physical unit and establish a session with its physical unit services.

To activate an SNA station attached to the NCP, the system services control point sends a CONTACT request to NCP physical unit services. NCP data link control then begins a slow poll sequence. When the station's data link control responds, NCP physical unit services originates a CONTACTED request for the control point, and the sessions can then be established with the physical unit and logical unit(s) in the SNA controller.

The reverse procedure takes place after all the resource's sessions have been disestablished. The system services control point sends a DISCONTACT (break contact) request and the NCP physical unit services directs data link control to break contact with the station using slow poll scheduling. When the station responds, NCP sends a DISCONTACTED request to the control point.

Figure 9 Association of a particular link with a remote subarea



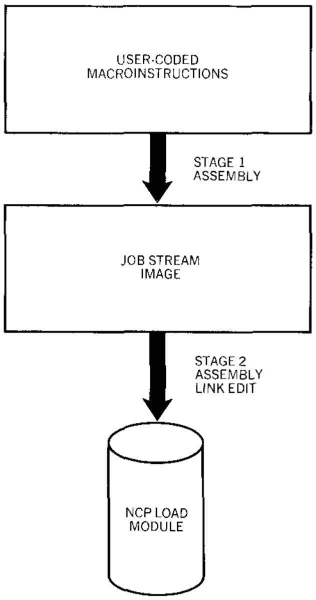
Physical unit services in the local NCP has some additional responsibilities if the SNA resource is another NCP in a remote communications controller. Before the remote controller can be loaded, a relationship must be established between the subarea that corresponds to the attached components of the remote NCP and the control block structure in the local NCP that represents the station and the link. The system services control point sends a SET CONTROL VECTOR request to NCP physical unit services, which identifies the link that is to be associated with the subarea corresponding to a remote NCP. Physical unit services then establishes a pointer from the subarea vector table to the required link control blocks as shown in Figure 9. Thus, under program control, a given remote communications controller may be attached over one of several different links, increasing network availability.

Another function of physical unit services is recording and reporting statistics. Information on network usage is recorded in counters that are internal to the NCP, maintained separately for links and stations. These counters are reported back to the system services control point by means of a RECORD MAINTENANCE STATISTICS request. The request is sent whenever an unrecoverable error occurs for the applicable resource, whenever the counters overflow, or whenever the control point deactivates the NCP physical unit services component. The contents of the statistics request include a transmission counter, a count of the temporary errors, the current input/output command and modifiers, the send and receive SDLC counts, the state of the link scheduling flags, and other similar data.

Testing services are also managed by NCP physical unit services as directed by the system services control point in an EXECUTE TEST request. This request contains one or more interpretive commands by which the testing programs in the host can direct the NCP to perform operations on the link or attached terminals.

The types of testing operations that can be performed for SDLC links include branching, counting, setting time delays, and modifying certain hardware registers and latches. SDLC operations provide for transmitting or receiving with or without count control, turning the line around, and dialing over autocall units. The interpretive commands can be executed in any of three interruption levels under control of the interpretive command stream.

Figure 10 NCP system generation



System generation

The NCP system generation is a two-stage process as diagrammed in Figure 10. The user specifies his network with macroinstructions defining characteristics of the communications controller, and the attached links, physical units, and logical units. These macroinstructions are processed by the NCP Stage 1 system generation program that prepares a card deck of internal macroinstructions, tables, and linkage editor instructions. This Stage 2 deck is then executed, and the output is a complete NCP load module that is stored on disk at the host.

The source statements that the user specifies in Stage 1 are the same input used to generate VTAM. The system generation procedure is thereby simplified, and the user has compatible subsystems.

Summary

The role of NCP/VS in an SNA environment has been examined from a vantage point within the network looking outward toward the host application programs and the terminal facilities. Data link control, path control, and connection point management work together to oversee the network traffic while maintaining separation of the SNA functional layers. The NCP physical unit services component cooperates with the system services control point in the host to govern operation of the physical resources associated with the NCP, as well as to oversee sophisticated testing and statistics recording. Thus, network functions are distributed amongst the host computer and the communications controllers throughout the network.

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