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FAULT DIAGNOSIS AND AUTOMATIC RECONFIGURATION FOR A RING BUS SUBSYSTEM

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Fault Diagnosis and Automatic Reconfiguration for a Ring Bus Subsystem

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Abstract

A ring bus subsystem has been developed for a full scale high performance heterogeneous computer network. A system architecture for a highly reliable ring bus subsystem and reliability improvement techniques supported by the ring bus supervisor are presented. An algorithm for centralized system management, which automatically detects a malfunction and reconfigures the ring bus subsystem when a failure occurs, has been investigated and implemented to enhance system reliability.

Keywords : Ring bus subsystem, reliability improvement, operations and management, computer network, reliable operation.

1 Introduction

The Science Information Processing Center (SIPC) of the Univ. of Tsukuba has had several years of experience in the design and implementation of a full-scale computer network called the GAMMA-NET (General purpose And Multi-Media Annular NETwork) [1]-[3]. The system connects several heterogeneous computers by a dual 32 Mbps optical fiber Ring Bus Subsystem (RBS). The RBS plays a substantial role in quality control not only for normal operation, but also for malfunction-detection and reconfiguration in case of a failure. The more important a network system becomes in communication and computing power, the more critical become the reliability, availability and serviceability (RAS) of the ring bus subsystem. As far as the authors know, there are a limited number of reports on reliability improvement techniques for an actual ring bus system [4]-[11], though a number of papers on looped networks that have been published so far deal mainly with transmission efficiency [12]-[13]. Our primary motivations are to investigate an algorithm which improves the RAS of the ring bus subsystem, and to develop reliability improvement techniques for ring bus management.

Penny [14] has surveyed and shown that a looped network has the advantages of easier implementation and better cost-performance compared with mesh networks, star networks and hierarchical tree networks. Zafiropulo [15] concluded that a great reliability improvement is gained by a double looped network, while a simple, unidirectional loop network is concluded as being relatively vulnerable to a catastrophic failure.

Reflecting on these points, we have developed an RBS using double looped optic-lines under integrated control, a system architecture for a highly reliable RBS, and RAS improvement techniques supported by the Ring Bus SuperVisor (RBSV) in centralized control. Additionally, we have investigated the possibility of an automatic recovery system which will perform the self-reorganization and the recovery operation of the RBS without operator intervention.

The outline of general GAMMA-NET management and the RBSV is described in section two, the RAS operation of the RBS in section three, the control scheme of the RBS management system and an algorithm to detect a failed location in the RBS and to reorganize the system in section four, and some experimental results regarding the system implementation in section five.

2 System management of GAMMA-NET

2.1 Levels of system management

In general, the system was prepared with two levels of network service facilities; one is for network service to network users, and the other for monitoring and maintaining the system itself. The outline of system management is described briefly.

(1) System management by the Network Management Subsystem (NMS)

The NMS is the nucleus of the network operating system. The NMS periodically collects information from each host computer, as shown in Fig. 1, and uses this information to provide network information to users, to search automatically for files which are distributed within the network, and to balance the system load. The detailed operation of the NMS was discussed in our reports [2]-[3] [16] and will not be mentioned here.

(2) System management by the RBSV

The RBSV controls and maintains the RBS hardware resources or elements - an optical line, an optical REPeater (REP), a Ring Bus Processor (RBP) and a host computer - as shown in Fig. 2. The RBSV and the NMS are connected by a dedicated line and through mutual cooperation manage the GAMMA-NET system. This paper is mainly concerned with the RBS management system on and around the RBSV rather than with the NMS operation, and focuses on RAS improvement aspects.

2.2 RBSV

The RBSV performs the following functions to control the ring bus operations.

(1) Registration of RBS information

An Initial Configuration Table (ICT) and a Current Configuration Table (CCT) in the RBSV store RBS information related to the system connection topology. RBS information is explained in Table 1. Both tables are filled at the time of system initialization. RBS information in the CCT is updated dynamically by a console operator, or by the RBSV that checks the RBS health.

(2) Initiation and termination of RBS operation

The RBSV initiates the start-up health check of the RBS and starts the system operations. It also terminates the operations.

(3) Supervisory control and status display

The RBSV periodically supervises the RBS hardware conditions, displays the information on the console terminal if requested by an operator, and reports the information to the NMS.

(4) System degradation or reconfiguration

Whenever any part of the RBS fails, the defective part is cut off by bypassing it or by turning back the bus so that the rest of the system can continue operations. The RBSV not only monitors the health of the RBP's by checking the status of every RBP, but also orders an RBP to switch a line connection in the REP to reconfigure the system topology of the ring bus when it becomes necessary to do so.

(5) Detection of defective locations

The RBSV searches for the location of a defective part on the RBS when it finds that the frame is out of synchronization for a long period of time.

(6) Status logging

The periodic system operation status, the input history of operator commands and the status of malfunctions are recorded in the logging file for debugging or maintaining the RBS.

(7) Statistical data gathering

The Attached Service Processor (ASP) in an RBP collects statistical data - time stamps of events at every 60 micro seconds - by an order from the RBSV. Sampled data is transferred from each ASP to the RBSV. Thus, all of the samples are gathered together in the RBSV. This measured data is used for performance evaluation of the RBS.

(8) Man-machine communication

A system operator not only can examine the current system status and system configuration from the terminal attached to the RBSV, but also can manage and control the ring bus operation by entering operator commands.

(9) RBSV-NMS communication

The RBSV offers an accumulation of the sampled data or the system status to the NMS. The former is provided when required by occasional calls from an operator and the latter is reported every 30 seconds by the NMS.

3 RBS and its RAS issues

3.1 Basic structure of the RBS

The RBS consists of the following elements.

(1) Optical fiber bus

This bus consists of dual optical fiber lines which connect the adjacent REP's and a remote power supply line used to back up the local power supply.

(2) REP

Power is fed to an REP through two types of lines; one line comes from the local electric power source and the other from the power supplier of the neighbouring REP, as shown in Fig. 3. Dual optical Transmitters (T's) and Receivers (R's) are provided in the REP. Main REP functions are to convert electric signals to optical signals and vice versa, to receive or transmit electric signals, and when commanded to do so by the RBP, to switch the connections of the optical fiber lines in order to loop back or to bypass failed elements.

(3) RBSV

The RBSV consists of a Bus Service Processor (BSP) and dual Bus Control Units (BCU's) as shown in Fig. 4. The BCU synchronizes the frame transmission and supervises the ring bus operation with the help of the Supervisory Signal transmitter/receiver (SS), which transfers and receives control signals necessary for the RAS operation of the ring bus.

(4) RBP

Fig. 5 shows the basic structure of an RBP. The RBP has dual Bus Interface Adapters (BIA's) and each BIA is connected to a T and an R. Both BIA's operate in parallel. A Transmission Control Unit (TCU) is connected to a channel of the host computer and can transfer data at the maximum speed of 2.7 Mbytes per second. An ASP not only watches the status of other elements within the RBP, such as the BIA's, the TCU and its REP, but also reports the status of each element to the RBSV via its Remote-Supervisory Signal transmmiter/receiver (R-SS) when requested by the RBSV. A Statistical Data Gatherer (SDG) measures the traffic that flows in and out of the ring bus and also reports the result to the RBSV when an operator enters a command to request this measurement result.

3.2 RAS facilities

RAS facilities related to RBSV operation are described here.

(1) Diagnostic test and RBS management at the RBSV

Every 250 milli-seconds the RBSV orders all of the ASP's of active RBP's to send back the diagnostic status of the RBP's and the host computers. When the RBSV finds a defective part indicated by this returned status report, it orders the related ASP to cut off the switches in the REP to bypass the bus. A power failure in an REP mechanically causes bypassing of that REP. Statistical data is also collected from an SDG and transmitted, via the associated ASP, to the RBSV. These data streams are shown in flow A of Fig. 6.

(2) Diagnostic test at local host level

A host computer can examine its operational status by turning test data back at its own RBP or at a remote RBP when it is connected to the bus. It can also examine its status by turning a path back physically to a remote REP as shown in flow B of Fig. 6.

(3) Diagnostic test between remote host computers

A specific test message is exchanged between host computers at 30 second intervals, to check the activity of logical link connections. Flow C of Fig. 6 shows a host level test in the case when host-A and B are communicating.

(4) RBS management

The NMS, which is connected with the RBSV by a dedicated line as shown in flow D of Fig. 6, requests the RBSV to provide information on the current status of the RBS configuration and on the activity status of the RBP's and the host computers, and displays the current operation status to network users.

(5) GAMMA-NET system management

The NMS is located within one of the host computers and examines the health of each native operating system every 60 seconds, as shown in flow E of Fig. 6.

The above RAS facilities are supported and executed by five kinds of diagnostic programs.

(P1) Ring bus management program in the RBSV,

(P2) ASP microprogram in the ASP,

(P3) TCU diagnostic program in the TCU,

(P4) Host level diagnostic program in the host computer,

(P5) RBSV diagnostic program in the NMS.

Fig. 6 illustrates the relationship between these programs and their information flows.

4 Control scheme of the RBS management system

4.1 Status transition of the RBS operation

Since the RBS is the essential link in our network, critical RBS elements such as the BIA's of an RBP, the transmitter and receiver of an REP, electric power supply lines and optical lines are duplicated; thus, the RBS can assume various system configurations. Normally the RBS operates in the Dual Transmission Systems (DTS) status; this means that both of the two optical lines are alive and operational. However, occasionally the RBS will be forced to operate in a Single Transmission System (STS) status or a Single Loop System (SLS) status due to an RBS failure. The STS status means that one of the transmission systems has failed and the other is in operation. The SLS status implies that the resulting status is a loop where the dual optical lines, at each REP on both sides of the failed REP, are connected to form a U-turn. Fig. 7 shows the status transition of RBS operations.

4.2 Loop back algorithm

We will explain the loop-back algorithm implemented on our system. Let us denote X(list) as the hardware elements X which are located at the nodes designated by the list in the parentheses. X is subscripted when it is necessary to show to which transmission system-A or B these elements are connected. The objects that are taken into account in the discussion of this section are limited to hardware elements such as BIA's and REP's. The node list is an array of node name where N_0 denotes the RBSV and N_1 a host computer which is located adjacent to the RBSV clockwise along the ring. Other host computers are numbered N_2, N_3, ... and N_n in that order. For example, the notation $X_A(N_0,N_i)$ denotes hardware elements X on transmission system-A and indicates the range between the RBSV and computer N_i within the parentheses. Further, let us denote L(range) as the optical transmission lines covered by the range in the parentheses. The range is designated by N_i-N_j to show the range between node N_i and node N_j, and only by N_i to show both sides of node N_i. Thus, the notation $L(N_1$-$N_i)$ represents optical transmission lines on two transmission systems between N_1 and N_i, and the notation $L(N_i)$ represents optical transmission lines on both sides of N_i.

It would be impractical and costly to detect defective elements through the use of hardware prompts in the environment of a full-scale network system, such as the GAMMA-NET. Consequently, the approach for checking defective elements within the system is to narrow down the defective element's location by sequential RBS status requests and checks. Executing the RBS status requests and checks sequentially clockwise and, then, counter-clockwise will allow the RBSV to detect the failed element.

A test procedure is prepared to check the RBS clockwise - a Clockwise Loop-back Check (CLC) and anti-clockwise - an Anti-clockwise Loop-back Check (ALC). In the CLC, the RBSV searches for a failed element clockwise along the ring, by using a BCU of the RBSV on transmission system-A (BCU_A) as shown in Fig. 8; in the ALC, counter-clockwise by using a BCU on transmission system-B (BCU_B).

In the following, we explain only the CLC algorithm in detail.

Clockwise loop-back check algorithm

(1) The RBSV builds a transmission path to make a single loop between N_0 and N_1 by turning back at $BCU_A(N_0)$ and at $BIA_B(N_1)$. Then, it transfers data to confirm the frame synchronization. When the frame synchronization is found to be sound, then the test advances to Step (2). If the frame synchronization is not maintained, the CLC terminates here.

(2) The RBSV builds the transmission path to make a new single loop between N_0 and N_2 by turning back at $BCU_A(N_0)$ and at $BIA_B(N_2)$, and bypassing both $REP_A(N_1)$ and $REP_B(N_1)$. Then, it transfers data to investigate whether the frame synchronization is maintained or not. If the synchronization is working, the test continues, otherwise it stops here.

(n) In the same manner as the above steps, the RBSV repeats them to construct a single loop up to N_n.

During the CLC test, if the RBSV finds a synchronization error at N_i, it recognizes that at least, the ring bus between N_0 and N_{i-1} is alive.

After finishing the CLC test, the RBSV in turn executes the ALC. It builds a single loop repeatedly, starting from N_n to N_1. The ALC follows the same steps as the CLC, except that subscripts A and B are interchanged in the explanation and the examining direction is counter-clockwise. Judging from the results of these two tests, the RBSV determines the range of defective parts or location of the failed element in the RBS, if a failure exists. The results to be detected are summarized in Table 2. For example, the third line (3) in Table 2 indicates that no error was detected in the CLC, but an error was detected at N_i by the ALC. From both results of the tests, the RBSV decides that there is something out of order with the BIA_A and the REP switchings of N_i.

Tests of the loop-back check are usually conducted before the system starts the initiation operation. They are also used for detection of failed parts when a frame error is detected by the RBSV.

4.3 Initiation of the RBS

In order to initiate the RBS operation, it is necessary to confirm that all the hardware elements specified in the ICT are operational. The initiation tests to certify sound system operation include the following.

(1) Health check of the RBSV

The BSP in the RBSV examines the active connection with its own BCU's, and verifies the soundness of the BCU's and thier REP.

(2) Examination for the initial RBS configuration

The RBSV checks the loop with the CLC and the ALC and decides whether the RBS can start operation that satisfies specifications of the ICT. If a failed element or an inactive one exists, the RBSV reorganizes the system, collecting the active status reports on an REP and an RBP(BIA's, a TCU and an ASP) and updating the associated contents of the CCT.

(3) Health check of every host computer

After the corroboration of (1) and (2), the RBSV makes requests to the ASP's of every RBP in order to determine if the computer is operational. The active computer will respond to the corresponding RBP that it is ready to offer service facilities as one of the host computers in the system. It also confirms the connectability between the NMS and itself. As a result, the RBSV knows how many computers are active.

Through Step (1), (2) and (3), the RBSV fills the CCT with the active configuration status. Finally, it starts the system operation.

4.4 RBS monitoring during the RBS operation

The RBSV monitors the RBS operation periodically by examining the current running status of the system. It takes the following checks into consideration for the RBS health check.

(1) Health check of the RBSV itself

The BSP of the RBSV supervises the BCU and REP conditions, if they are working normally. The BSP orders the SS to execute return-back tests in which the SS sends control signals to itself and receives them via the ring bus, and checks if the functions of the SS are working correctly.

(2) Health check of a host computer

The RBSV transfers a command, which requests a report on the status of the corresponding computer, to each ASP of the host computers. When the returned status is received the RBSV compares it with that of the the CCT to investigate whether abnormality or changes in operation have occurred or not. Patrolling of host computers occurs approximately every 30 seconds. Abnormality means that a host computer has suddenly gone down and cannot reply to the health check from the ASP. Another change that can be considered is that a new computer comes up and replies to the health check request. In this case, the RBSV promptly updates the status of the current configuration of the CCT and reports the event to the NMS. Then, it permits the computer to join the system.

(3) Quality check of transmission line

The RBSV always measures the bit error ratio of transmission lines and considers a transmission line to be faulty when an error rate becomes more than 10^{-4}. When the transmission line faults, the RBSV stops the ring bus operation to cut off the defective parts and tries to reconstruct the system.

(4) Health check of the NMS

A control message is exchanged between the RBSV and the NMS to check the activity of both machines. An NMS-down situation, however, does not induce the system operation to shut down; the result is only that network users cannot use NMS service facilities.

5 Discussion

Technical issues concerning the loop-back check algorithm, diagnostic overhead and some results obtained empirically are discussed, based on a couple years of system operation experience.

It would not be difficult to derive more sophisticaled loop-back algorithms in comparison to the algorithm now implemented on the GAMMA-NET system. For example, the current algorithm could be modified such that a new CLC test would search for a faulty element along a clockwise path using not only the $BCU_A(N_0)$ but also the $BCU_B(N_0)$. Likewise, the ALC test could also be modified in the same manner. However, the degree of sophistication required of a faulty element detection algorithm depends on the RBS reliability. The GAMMA-NET RBS has been shown to operate at a reliable level. Therefore, the previously presented algorithm is considered sufficiently accurate for fault-detection and is useful for application usage.

The mean rate of system-down, times at which the total network is inoperable, occurring was statistically calculated to occur once in every 1.2 month period. It should be noted, however, that in calculating the probability of system-down occurring, the result includes the debugging and testing period incurred during the installation and early stages of operation. From our calculations, the ratio representing the system operation period of the system while operating in the DTS, the STS, and the SLS status respectively is 60 : 3 : 1.

The overhead incurred due to the necessary diagnosis for the RAS operation was estimated to be the traffic ratio of the diagnostic messages to the total number of data messages which includes the former. Utilizing the statistical data gathering facilities of the RBSV, the traffic ratio of diagnostic messages to normal data messages was easily calculated. The result shows that 18.3 percent of the total traffic, measured in bytes, was occupied by various diagnostic messages. From this it was concluded that the diagnostic traffic does not overly interfere with the normal data transmission from the aspect of transmission efficiency.

From the experience of maintaining and operating the GAMMA-NET system, it has been found that network users will become impatient and give up on a job if they must wait for a system recovery which lasts longer than a few minutes. This fact suggests that the tolerable waiting time of users limits the fault-detection and reconfiguration of the system to within a few minutes. In the case of the GAMMA-NET system, it takes on an average about one minute to accomplish the fault-detection and system reconfiguration. As a result, it is considered that the recovery system is sufficient.

6 Conclusion

We can summarize loop reliability improvement techniques and the experimental results through the operation of the GAMMA-NET as follows:

(1) To improve the RAS of the RBS, we have established a practical algorithm to investigate malfunctions of the RBS and to reconfigure the system by bypass or loop-back techniques. The whole loop-back test requires about 1 minute for a system that has 6 RBP's in the RBS. The applied algorithm has been proved to be practical and useful.

(2) Centralization of monitoring the RBS operation on the RBSV enables an operator to control and manage the whole system by sitting at one display terminal. Centralized supervisory control reduces the labor of operating and maintaining the system. Without centralized control of the system management, an operator would need to search for a failed part of the RBS by walking along the ring bus and checking each element when the system-down occurred, and these may be distributed at great distances.

(3) Communication facilities for RAS have been installed in the RBSV and the RBP, and these are independent of facilities for high-speed data transmission in the RBS. This technique makes it possible to accomplish reliable supervision and recovery of the RBS without interruption of the normal operation of data transmission. Furthermore, this scheme is superior in expanding RAS functions to an architecture in which all of the sophisticated functions are combined into a single module.

(4) The automatic recovery system that functions without any help from the operators, using the loop-back algorithm mentioned in section 4.2, is now being improved for practical application. We have been temporarily using both the automatic recovery system and operator intervention to reconfigure the

system. The completely automatic recovery system will be installed in the RBSV after we have had more experience with it and can be sure that it is reliable.

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References

[1] Ikeda, K., Ebihara, Y. et al., Computer Network Coupled by 100 MBPS Optical Fiber Ring Bus - System Planning and Ring Bus Subsystem Description -, *COMPCON 80 Fall*, 159-165, 1980.

[2] Ebihara, Y., Ikeda, K. et al., Protocol Structure of GAMMA- NET, *Sym. of Distributed Processing, Information Processing Society in Japan* (in Japanese), 10-7, 41-48, 1981.

[3] Nakamura, T., Ikeda, K., Ebihara, Y. et al, Network Management Subsystem (NMS) of GAMMA-NET, *Sym. of Electronic Computer*, IECE (in Japanese), EC81-80, 41-49, 1982.

[4] Santos, P.J., Chalstrom, H.B., Architecture of A Network Monitoring, Control and Management System, *Proc. 5th Int. Conf. on Computer Communication*, 829-836, 1980.

[5] Fraser, A.G., Spider - a data communications experiment, *Computing Science Tech. Rep., Bell Lab.*, 23, 1974.

[6] Wilkes, M.V., Communication using a digital ring, *PACNET Conf.*, 47-55, 1975.

[7] Steward, E.H., A loop transmission sysytem, *Proc. 6th ICC*, 36/1-9, 1970.

[8] Kropfl, W.J., An experimental data switching system, *Bell Syst. Tech. J.*, 51, 1147-1165, 1972.

[9] Farmer, W.D., and Newhall, E.E., An experimental distributed switching system to handle bursty computer traffic, *Proc. Sym. on Problems in the Optimization of Data Communications*, 1-33, 1969.

[10] Farber, D.J., A ring network, *Datamation*, 21, 44-46, 1975.

[11] Wolf, J.J., Liu, B.W. and Tsay, D.P., Design of a Distributed Fault-Tolerant Loop Network, *Digest of 9th Annual Int. Sym. on Fault-Tolerant Comp.*, 17-24, 1979.

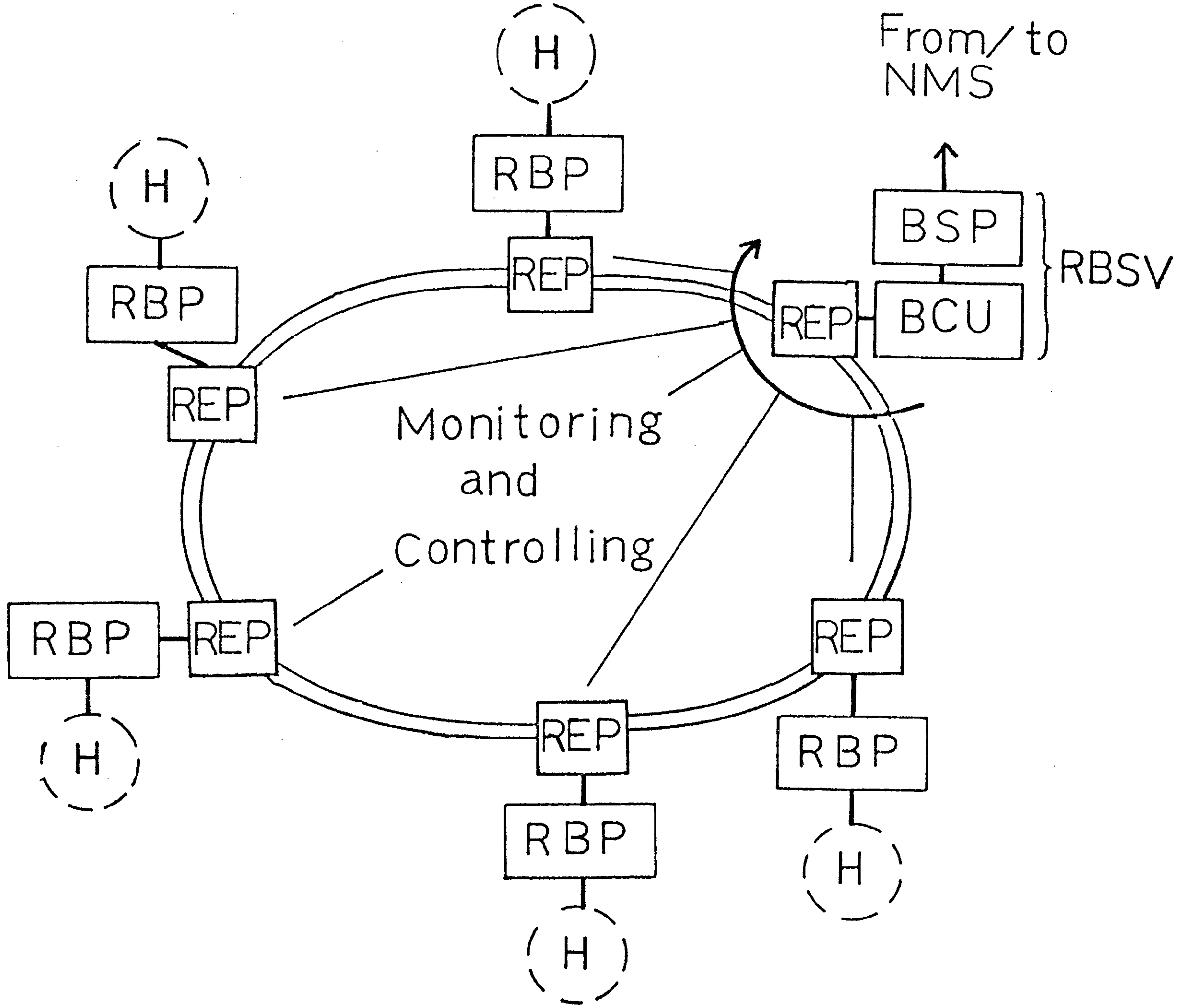
[12] Wong, J.W., Queing Network Modeling of Computer Communication Networks, *Computing surveys*, 10, 343-351, 1978.

[13] Kobayashi, H. and Konhein, A., Queing models for computer communication system, *IEEE Trans. on Comm.*, COM-25, 2-29, 1977.

[14] Penny, B.K. and Baghdadi, A.A., Surveys of computer communications loop networks: Part 1, *Computer Communications*, 2, 165-180, 1979.

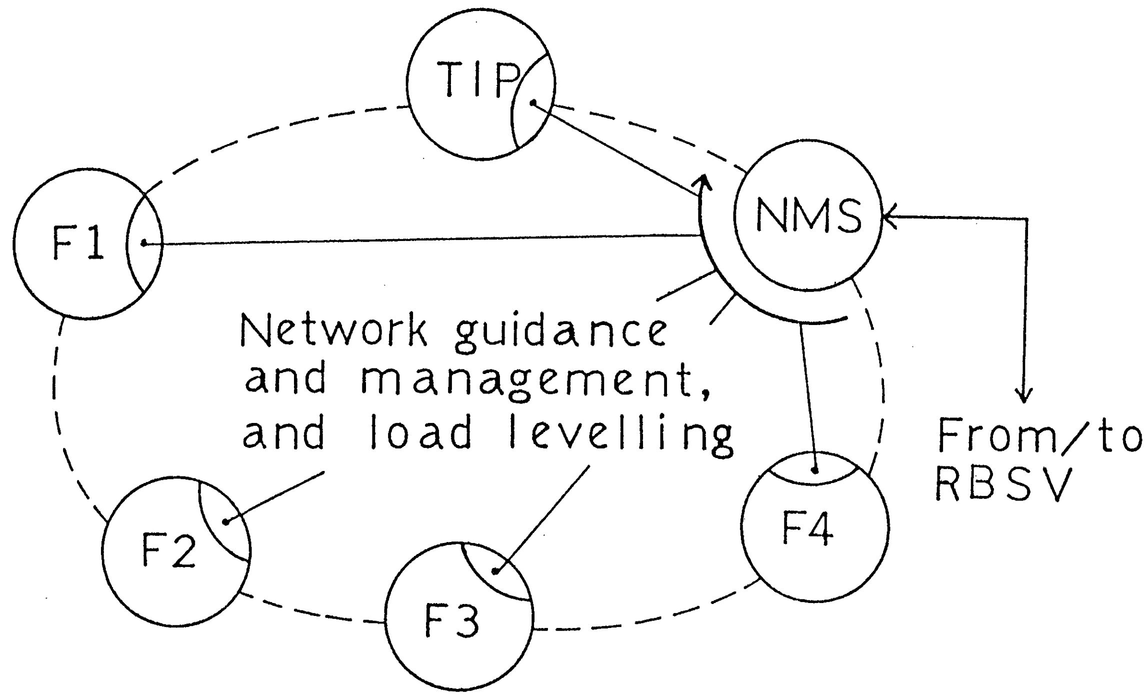
[15] Zafiropulo, P., Performance evaluation of reliability improvement techniques for single loop communications systems, *IEEE Trans. on Comm.*, COM-22, 742-751, 1974.

[16] Ebihara, Y., Ikeda, K. et al, GAMMA-NET: A Local Computer Network Coupled by High Speed Optical Fiber Ring Bus - System Concept and Structure -, *be submitted to Computer Networks*, 1983.



RBSV : Ring bus supervisor
BSP : Bus service processor
BCU : Bus control unit
RBP : Ring bus processor
REP : Repeater
H : Functional host computer

Fig. 1 Ring bus subsystem structure



TIP : Terminal interface processor
NMS : Network management subsystem
F1 : Batch processing computer
F2 : Administrative processing computer
F3 : Interactive processing computer
F4 : Educational processing computer

Fig. 2 Network operating system structure

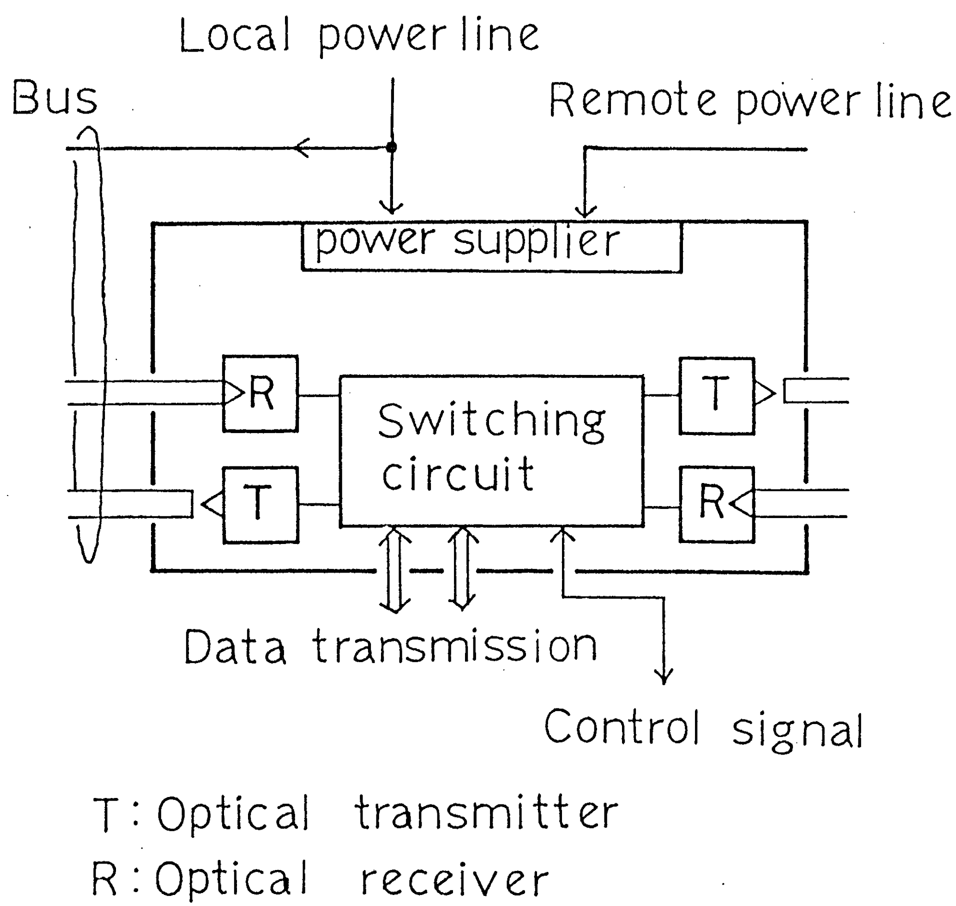


Fig. 3 Optical repeater

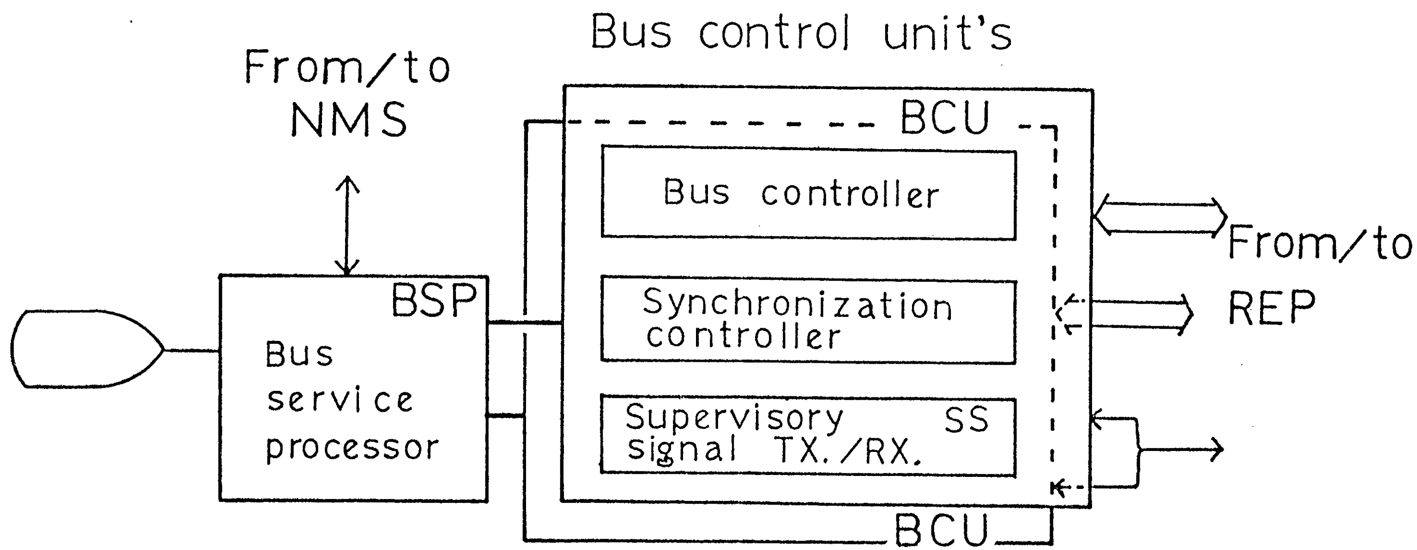


Fig. 4 Ring bus processor

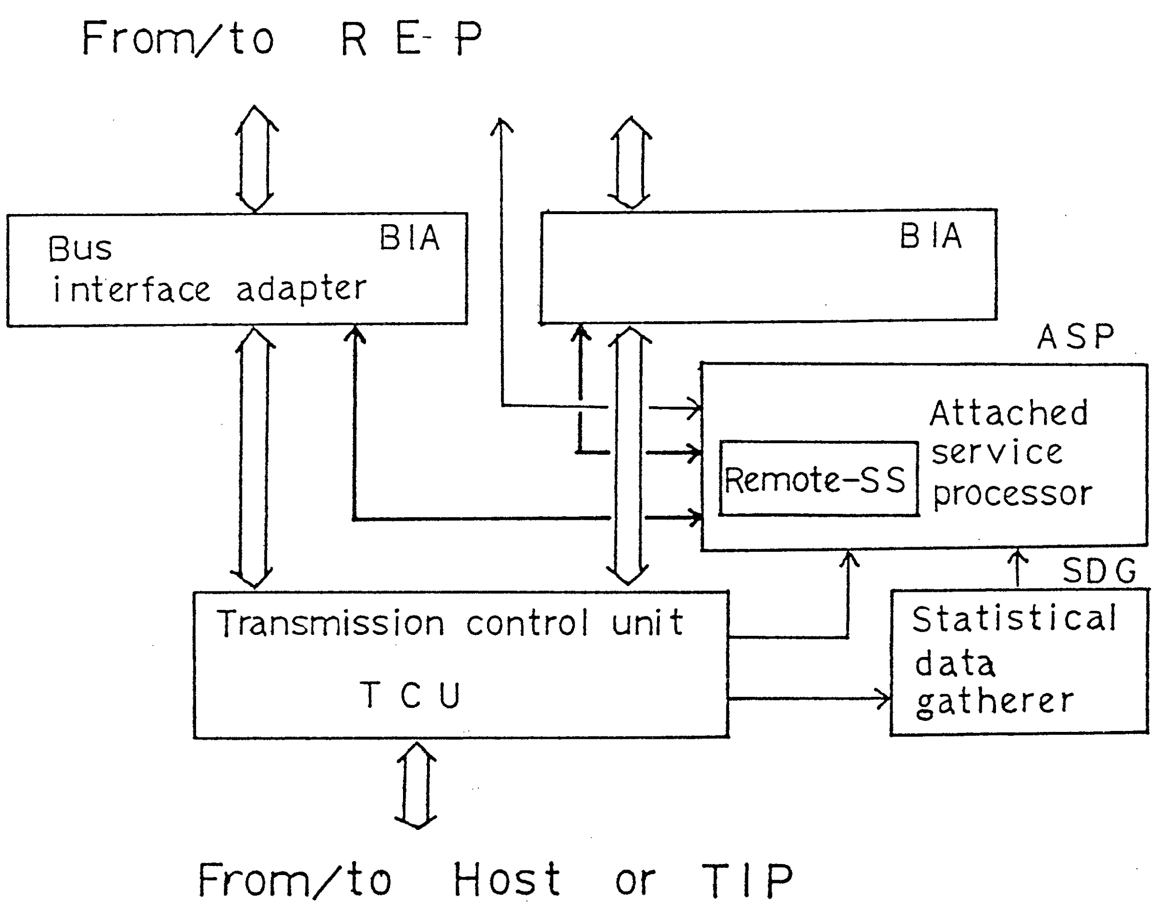
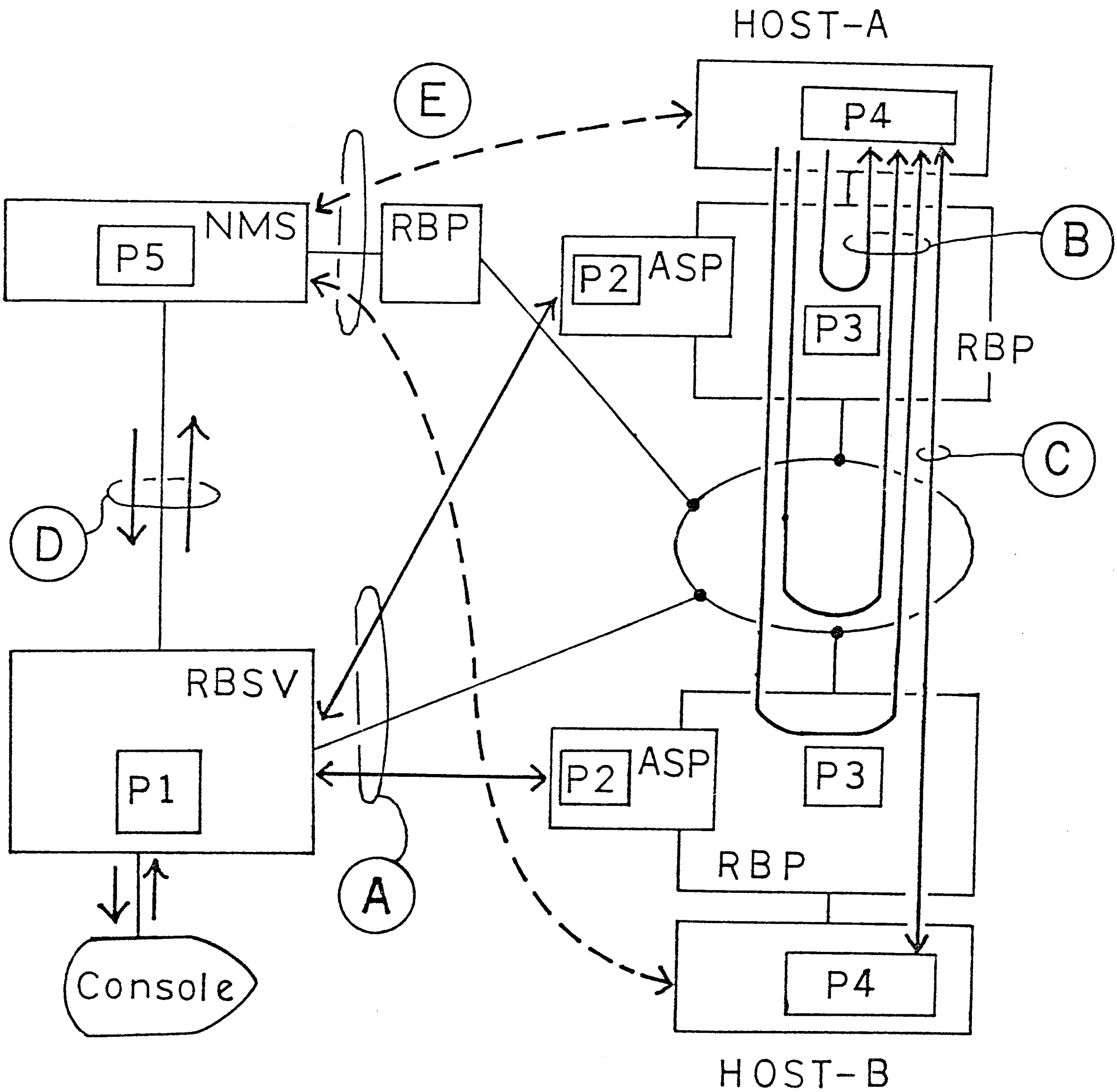


Fig. 5 Ring bus supervisor



P1: Ring bus management program
P2: ASP microprogram
P3: TCU diagnostic microprogram
P4: HOST level diagnostic program
P5: Ring bus subsystem diagnostic program

Fig. 6 Diagnosis flow and supporting programs

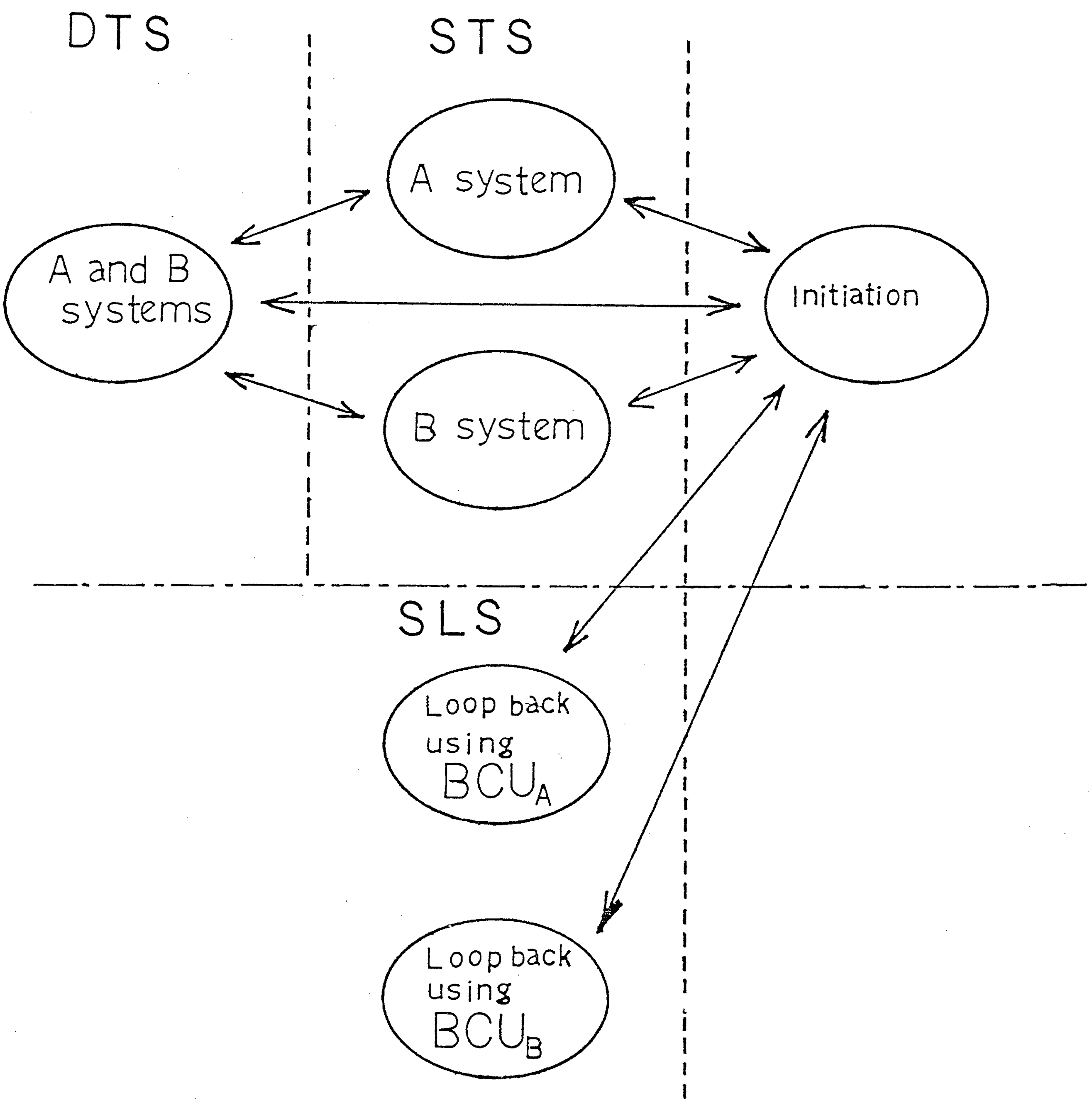


Fig. 7 Status transition of system operation

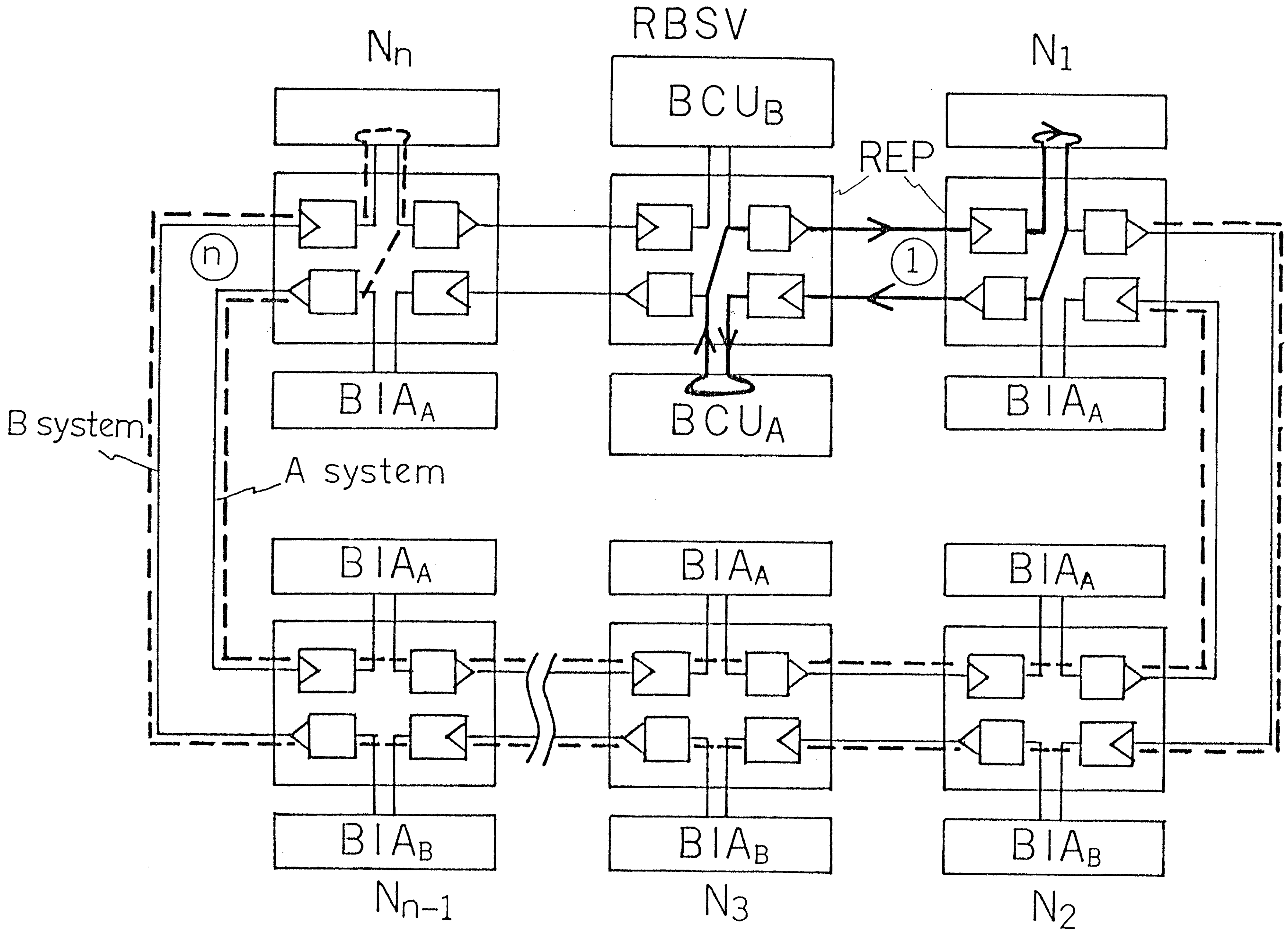


Fig. 8 Clockwise loop-back check algorithm

Table 1 Ring bus subsystem information

RBS Information

1 Identification and names of computers
2 Length of transmission path
3 Distance between adjacent computers
4 Physical RBP addresses
5 The number of active computers
6 The number of active REP's and RBP's
7 Status of RBP-computer connection
8 Transition status of RBS operations
9 Supplementary status related with RBS configuration

Table 2 Detected range of failures

	Loop back check		Range of failures
	CLC	ALC	
1	OK	OK	NO
2	OK	N_n	$BIA_A(N_n)$, $REP(N_0, N_n)$, $L(N_0 - N_n)$
3	OK	N_i	$BIA_A(N_i)$, $REP(N_i)$
4	N_1	OK	$BIA_B(N_1)$, $REP(N_0, N_1)$, $L(N_0 - N_1)$
5	N_j	OK	$BIA_B(N_j)$, $REP(N_j)$
6	N_j	N_i	
	$j = i$		$BIA_A(N_i)$, $BIA_B(N_i)$, $REP(N_i)$, $L(N_i)$
	$j > i$		$BIA_A(N_j)$, $BIA_B(N_i)$, $L(N_{i-1} - N_i)$, $L(N_j - N_{j+1})$
	$j < i$		$BIA_A(N_j)$, $BIA_B(N_i)$, $REP(N_j)$, $REP(N_i)$

CLC : Clockwise loop-back check

ALC : Anti-clockwise loop-back check

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Fault Diagnosis and Automatic Reconfiguration for a Ring Bus Subsystem

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ABSTRACT

A ring bus subsystem has been developed for a full scale high performance heterogeneous computer network. A system architecture for a highly reliable ring bus subsystem and reliability improvement techniques supported by the ring bus supervisor are presented. An algorithm for centralized system management, which automatically detects a malfunction and reconfigures the ring bus subsystem when a failure occurs, has been investigated and implemented to enhance system reliability.

SUPPLEMENTARY NOTES