

# **Integrated Data Acquisition System for Coastal Research Vessel**

**R.G. PRABHU DESAI AND E. DESA**

National Institute of Oceanography, Dona Paula, Goa-403 004, India.

## **ABSTRACT**

An integrated data acquisition system using personal computers interconnected by ARCNET local area network to log data from shipboard equipment and sensors is described. Each data acquisition node sends its data to a central computer which in turn broadcasts integrated information on the network; thereby network wide real time data can be monitored from any mode. Net- BIOS based peer-to-peer communication software supports real time transaction and guarantees hardware independence and software transportability. The data is logged on a central file server based on a Novell Netware operating system with fault tolerant features. Remote node communication allows easy access to data from shore-based LAN. The network supports microcontroller interface to log data, in addition to use of PCs. The system can be easily reconfigured for different requirements.

## **INTRODUCTION**

Scientific research vessels collect a variety of oceanographic data at sea, such as bathymetric, navigational, meteorological and data related to various physical, chemical and biological properties of the oceans. Early research vessels in India did not have contemporary facilities for automation and as a result indigenous data loggers were developed for specific needs [2,13,14]. New research vessels launched in the eighties had full-fledged capabilities for data acquisition and processing. The experience gained with these systems has led us to the indigenous development of Integrated Data Acquisition System (IDAS) for Coastal Research Vessel (CRV).

Shipboard equipment is usually distributed in different laboratories and this dictates a configuration of dedicated computers for acquisition of data from one or more equipment that form a natural cluster. The distributed computers need to be interconnected to share the data between different systems. Ship speed and heading data for instance is required by a meteorological system to correct wind

data. An integrated data acquisition system essentially consists of distributed computers interconnected to share the information.

Important considerations in the design of the IDAS include the following:

- i) selection of computer system
- ii) ability to share the data generated by different computers in real time
- iii) expandable and flexible architecture so as to meet different requirements of data acquisition.

Interfacing of equipment and computer is a straightforward task and is commonly achieved. Selection of a particular type of computer is generally based on factors such as price, availability of application specific hardware and software packages, etc. Personal computers turned out to be the obvious choice for us because of their low cost, user familiarity, universal availability of spares, hardware and software add-ons, etc., and wide range of options providing speed and memory without sacrificing compatibility.

Having selected computers for data acquisition, the next important issue is to link the distributed systems to share real time data generated from different equipment. In this paper, we have focused our attention mainly on this issue of interconnecting systems and equipment to share the data to form a truly integrated data acquisition environment.

The most common method of interconnecting computers is to use RS-232 asynchronous serial communication. The maximum data transfer rate of RS-232 link is limited to 9600 baud and in addition RS-232 serial link is not expandable. To overcome this problem of expandability (i.e., to be able to add one or more devices on the network), a Serial Ascii Instrumentation Loop (SAIL) was specifically developed for shipboard use [1,4]. SAIL networks are easily expandable, but they are limited to only 300 baud data rate and therefore have been confined to mainly equipment level interfacing.

The problem of computer interfacing, of being able to communicate at high speed on a simple two-wire link, was solved with the advent of Local Area Network (LAN) technology. LANs provide a high speed communication channel with typical transmission speed ranging from 1 to 100 Mbit/sec. The LAN-based system could be easily expanded in the sense that one or more computer systems can be easily added to the network to share the data. LAN-based systems are usually supported with operating system software to share the resources associated with other computers in the network, and with utilities to take care of protocol that handle multi-user file sharing. In shipboard environment, LANs have been used for off-line processing and data handling [7,8]. Newman [12] has reported the use of fibre optic LAN for data transmission from a subsurface vehicle to a shipboard system. In this paper, we report a novel technique of using LAN for real time shipboard data acquisition.

## SYSTEM DESCRIPTION

Figure 1 shows schematic configuration of IDAS. The PCs are dedicated for acquisition of data from different equipment and are named as NAV PC, MET PC, EDP PC, Wetlab PC, etc. The computers acquire data from the respective instruments and log the data on the central file server. The remote node PC allows communication with a shore-based LAN *via* VHF or satellite link. An active hub supports interconnection of 8 nodes. A passive hub is included to accommodate additional nodes.

Navigation computer NAV PC has been implemented as the heart of the centralized data acquisition system. Apart from the collecting ship's position, speed-log and gyro information, the NAV PC is assigned an additional task to collect the information broadcast on the network by different data acquisition nodes and to retransmit it back as a signal packet of integrated information. All the other computers are programmed to receive the broadcast datagram from NAV PC. The updated information is available at each computer. Typical update interval is programmable from 0.1 to 1 sec. The updated information is displayed in standard format selected using different function keys.

Data acquisition and its circulation in the network is implemented as background interrupt driven tasks, whereas foreground processes take care of display,

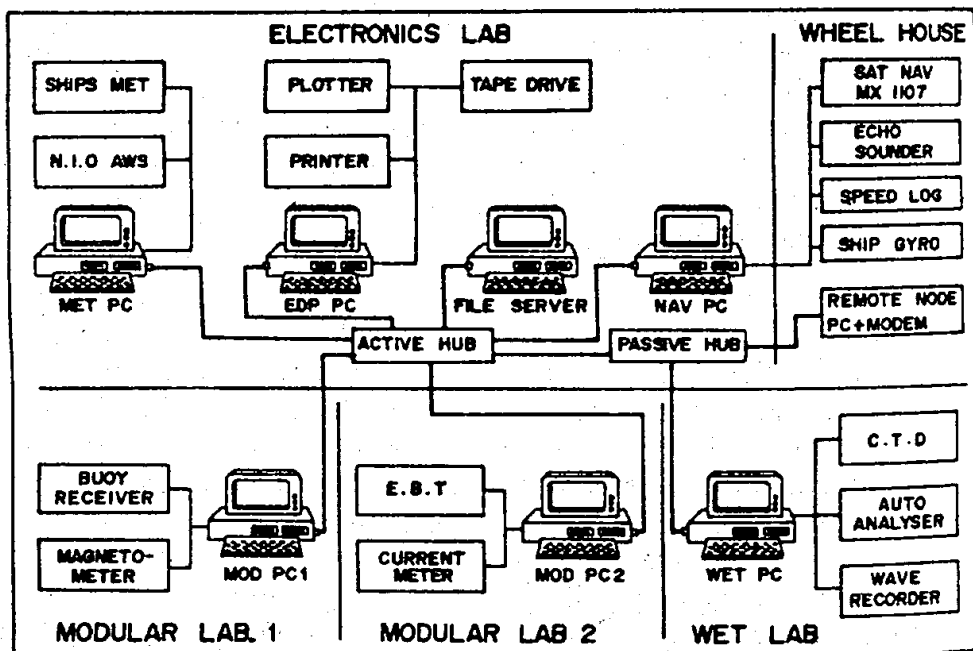


Fig.1 — A schematic diagram of Integrated Data Acquisition System for coastal research vessel

print, keyboard entry and data storage. The ability to view the data acquired at other nodes irrespective of which background process is running at the computer provides an integrated environment to the end user. The data is stored on a central file server and display node can access the server information even while data is being logged. The display programs can monitor for instance a CTD cast data from any node in the network.

## NETWORKING

Different types of local area networks were evaluated for shipboard use. LANs have well established hardware specification and software protocols governed by IEEE 802.3, 802.4 and 802.5 standards respectively for ethernet, token passing and token ring networks [5,6]. Ethernet network was dropped because of its non-deterministic access time, which would not support real time communication. Token type network provides deterministic access. IEEE 802.4 protocol supports a different class of services for messages, whereas IEEE 802.5 provides priority for messages and fail-safe and graceful degradation features [9,18]. A Pronet-10 token ring implementation supports fibre optic link and such a network is highly desirable for shipboard use [12]. However, at the time of selection of network for IDAS, the token ring technology was relatively new and sufficient literature on its performance, software support and source code, etc. was not available.

An ARCNET network pioneered by Standard Microsystems was selected as it was well established and provided our basic requirement of speed and deterministic access time.

### ARCNET for data acquisition

ARCNET (attached resource computer network) was originally designed by Datapoint Corp. The possibility of using ARCNET network for shipboard use was addressed by Swift [17] in 1983. ARCNET supports bus, star or tree topology using either twisted pair, coaxial or even fibre optic cable. ARCNET maintains a raw data transmission speed of 2.5 Mbit/sec and distances up to 4 miles and supports a maximum of 255 nodes.

Each node in the ARCNET network has a unique identification number ID and communication between different nodes is governed by a labelled control packet called token. A node that has no data to transmit or if it has finished transmitting its data, transfers the token to the next logical node. Regardless of network topology, ARCNET is a logical ring. A simple token pass in the network takes about 28 micro seconds. Therefore, the best possible access time  $t_b$ , for a round trip pass is  $28*N$  micro seconds where N is the number of nodes. When a node has data to send, a LAN controller adds a fixed delay of 113 micro seconds and takes about 4.4 micro seconds for each 1kbyte in the message. The worst case access time  $t_w$  therefore will be

$$tw = tb + (113 + 4.4 * B) * N$$

where B is the average number of bytes and N is the number of active nodes transmitting data [11].

For a small configuration of 8 nodes, as in our IDAS, the worst case wait times for average message size of 100 bytes turns out to be approximately 5 microsec. That is each node can send as many as 200 messages/sec, whereas we need to access the network once every 100 msec from any node. However, if any node in the network fails or if a node is powered off, then the network needs reconfiguration, since each node must know its logical neighbour to pass on the token. This reconfiguration time varies from 21 to 60 msec. IDAS can function properly even in such cases, since the network is reconfigured without adding excessive wait times.

Each PC in the IDAS network is installed with a standard commercially available ARCNET adapter and the nodes are linked through an active hub using coaxial cable. Active hub provides large cable drive capability and star topology for interconnection that facilitates identification of cable faults. Individual cable segments between a node and active khub could be checked separately.

### **Network communication**

In an effort to bring standardization in local area network, International Standard Organization (ISO) has come out with a seven layer open system interconnect (OSI) model (Fig.2). Each layer of the seven layer model has unique and well-defined functions. The highest layer in the OSI model, the application layer, handles user applications and generally deals with directory, file and database type of services. The next presentation layer is responsible for security and privacy of data. The session layer takes care of logical connection between various network entities and mapping of logical names to physical addresses. The transport layer services take care of peer-to-peer communication employing either datagram or session protocols. The next layers define inter-networking procedures, channel access, modulation, detection of signals, etc.

Most commercially available software has supported this seven layer model. In the IDAS, high end services requiring file and database services are handled using Novell Netware Software, whereas peer-to-peer communication between nodes is implemented using IBM NetBIOS software that provides services of session and transport layer defined OSI model.

### **NetBIOS**

NetBIOS has been extensively used and has in fact provided great ease in network communication. An industry standard version of NetBIOS with TCP/IP was released by IBM in 1987 [3,15]. NetBIOS supports four categories of services, viz. Name, Datagram, Session and General support commands. Name utility allows different computers in the network to be distinguished by names.

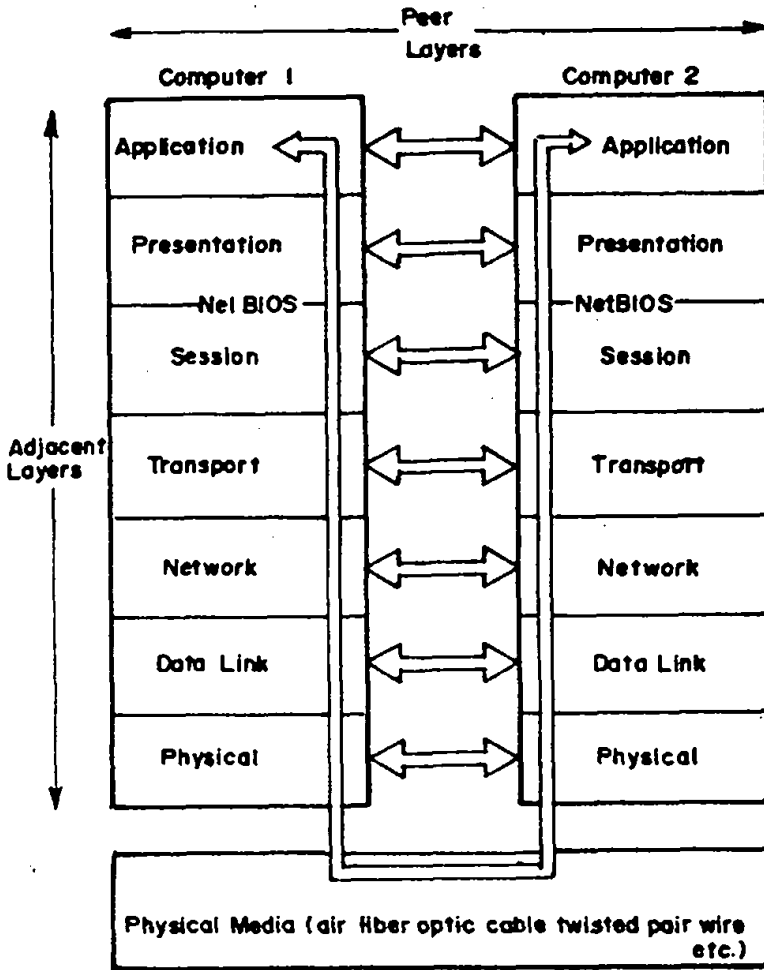


Fig.2 — Seven layer ISO/OSI network model

Datagram and session utilities allow transmission of messages. In datagram, message delivery is not acknowledged back from the receiving end, whereas in the session the message delivery is acknowledged back. The general commands include utilities to reset and initialize adapter and to monitor adapter status and to cancel pending commands which are not completed.

A NetBIOS command is executed by properly initializing a network control block (NCB). Typical parameters of NCB involve command code, local adapter name, remote system name, address of the message, time out values for a command and post-routine address, if an immediate action is required at the completion of a NetBIOS command. After initializing NCB, PC-DOS interrupt vector 5c is invoked to execute NetBIOS command.

To evaluate the performance of the network, a simple routine was written to continuously transmit a dummy message on the network. Message size was 100

Table 1 — NetBIOS Performance Evaluation Test Results

No. of nodes	Average number of datagrams/sec						Total
	386/AT 25MHz	386/AT 16MHz	386/AT 16 MHz	286/AT 10 MHz	XT 4.7 MHz	XT 4.7 MHz	
1	779						779
2	529	510					1035
3	383	346	354				1083
4	380	340	340	231			1291
5	379	340	339	230	97		1385
6	377	340	339	229	97	97	1479

bytes long and the computer kept the record of mean number of messages or broadcast datagrams transmitted per second. The loading of the network as the number of active transmitting nodes is increased is shown in Table 1. It is seen that network speed is higher than the rate at which a single PC could send the data to the network. The test routine was written in C and obviously took longer time to execute, as compared to network speed. A faster PC could, therefore, send more data than the slower one. With all six nodes, a total of 1479 messages could be transmitted, which corresponds to a throughput of 1.3 Mbit/sec. Similar tests have been reported on the NetBIOS performance by Lide *et al.* [10].

### Novell Netware

We have discussed the peer-to-peer communication using NetBIOS and its use for real time flow of integrated information. Apart from this, we also need to log the data on a central storage or file server. Although network servers does no application processing, their workload can be high. File servers must service several simultaneous requests for disc access. We have selected Netware operating system that is based on high speed multitasking kernel specifically designed to handle multi-user file access and to minimize IO processing. The standard features include directory hashing, directory caching, elevator seeking, turbo file allocation table, UPS monitoring, etc. A fault tolerant version of Netware is installed, which supports disc mirroring in which the entire physical volume is duplicated on the separate hard disc as a precaution against disc failure. Netware also provides security by offering password against unauthorized access and can limit user access for certain resources and for duration of time. Netware also supports remdote PC communication which lets a remote user access the network through modem and phone line.

The file server is based on a 25 MHz 386/AT type PC with 100 MB disc space. An average rate of data to be logged on the server from all the equipment was less than 20 bytes/sec, since most of the parameters did not vary fast. A 60 Mb space

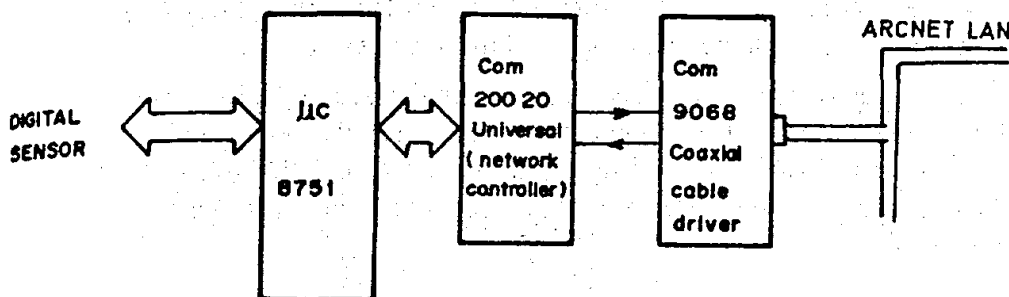


Fig.3 — A schematic diagram of microcontroller interface to ARCNET network

was found to be sufficient for the entire cruise data. A tape backup facility has been provided with EDP PC for regular backup.

### Microcontroller-based LAN interface

The concept of IDAS presented so far is based on the dedicated PCs for data acquisition and networking PCs to share the data. If a new equipment is to be added into such a system, one will have to dedicate another PC for equipment interfacing and connect that PC to the network or reallocate functions of existing PCs to accommodate a new equipment. Under certain situations, both alternatives may not be attractive when space and cost would be a concern. A cost effective and compact microprocessor-based design solution is presented for such applications. The solution is based on the new device released by Standard Microsystems for embedded control called COM20020, a universal LAN controller [16]. The device is processor compatible and incorporates a complete token passing ARCNET protocol with internal  $2\text{ k} \times 8$  dual port RAM memory. A schematic diagram of 8751 microcontroller-based network interface for digital sensor is shown in Fig.3.

## RESULTS AND DISCUSSION

In our indigenous design of IDAS for CRV, we have deviated from the previous approaches to similar problems. The use of personal computers for IDAS is well justified. Instead of conventional RS232 interconnection, the use of LAN has given a flexible approach to the system, since it could be easily modified or upgraded to meet different requirements of data acquisition. NetBIOS-based communication has allowed access to network-wide data in real time. A truly integrated environment is established by way of ability to monitor data collected at any node from any other node in the network. The data on the file server could also be monitored from any PC in the network even while being updated.



The worst case access time and network re-configuration delays were tolerable, since the system did not require network access faster than every 100 msec. The actual throughput and network loading have been tested.

IDAS was originally designed for a coastal research vessel proposed by the Department of Ocean Development. As this vessel was not available for installation, we have installed a reconfigured version of the IDAS on other research vessel, *R. V. Gaveshani*. The system is operational and in use since its installation in August 1991.

### ACKNOWLEDGEMENT

Authors wish to thank the Director for extending facilities to carry out the work and Prof. Srinivasan for encouragement and valuable suggestions. The project received funding from Department of Ocean Development.

### REFERENCES

1. **Bradly, A.M. and W.E. Terry, Jr.** 1983. A Coherent Approach to Instrument Interconnection & Testing Using SAIL. IEEE Proceedings of the third working symposium on Oceanographic Data Systems: 51- 54.
2. **Desa E.S., E.J. Desa and R.G. Prabhu Desai.** 1986. A low cost data logging system with satellite transmission capabilities. Proceedings, Marine Data Symposium. USA.
3. **IBM Manual:** NetBIOS Application Development Guide.
4. **IEEE Standard.** 1985. Serial Ascii Instrumentation Loop (SAIL) for Ship Board Data Communications. ANSI/IEEE std 997-1985.
5. **IEEE Standard.** 1985. 802.4 Token Passing Bus.
6. **IEEE Standard.** 1989. 802.5 Token Ring Access Methods.
7. **Knudsen H.P.** 1990. The Bergen Echo Integrator. *J. Cons. Int. Explor. Mer.* 47: 167-174.
8. **Knudsen H.P.** 1989. Computer network for fishery research vessel. *Proc. Inst. Acoustics.* 11(Pt 3): 115-122.
9. **Kummerle K., J.O. Limb and F.A. Tobagi.** 1987. Frontiers in Communications: Advances in Local Area Network. IEEE Press, New York.
10. **Lide D.A. and D.H. Walters.** 1988. A Functional and performance comparison of NetBIOS and APCC/PC, *IEEE Proc. Computer Networking Symposium.* 235-244.
11. **Mort H.** 1983. LAN controller regulates token passing traffic. *Electron Des.* Dec.22: 139-144.
12. **Newman J.B.** 1990. Fiber Optic Data Network for the ARGO/JASON vehicle system. *IEEE J. Oceanic Eng.* 15(2): 66- 71.
13. **Prabhu Desai R.G. and B.A.E. Desa.** 1986. A Ship-borne Meteorological Station for Ground Truth Measurements. Proceedings. Marine Data International Symposium. USA.
14. **Prabhu Desai R.G., E.J. Desa, E.S. Desa and S. Afzalpurkar.** 1986. A Geological Data Logger. *IEEE J. Oceanic Eng.* 11(3): 428-437.
15. **Schwaderer D.W.** 1988. C Programmer's Guide to NetBIOS.
16. **SMC Manual.** COM20020 Design Guidelines.
17. **Swift S.G.** 1983. Using Distributed Microprocessors in Marine Applications. Proceedings Ocean's: 150-154.
18. **Werner B.** 1989. Token ring local area network and their performance. *Proc. IEEE.* 77(2): 238-256.