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## Abstract

Scientific research vessels operating at sea collect a variety of oceanographic data such as bathymetric, magnetic, gravity, navigational, acoustic, meteorological and data related to the physical, chemical and biological properties of the oceans. The technology of shipboard data acquisition from various equipment on board scientific research vessels has been progressively improving with advances in microelectronics and computer technology.

This paper, first briefly describes the evolution of data acquisition techniques and different system implementations, on board research vessels. A data acquisition system being developed for a Coastal Research Vessel is then described which is based on IBM PC compatibles. The computers are located in different laboratories and are dedicated to data collection from one or more instruments. They are integrated by a local area network for real time sharing and integration of data. The special requirements of a local area network for ship board data collection are discussed in this application.

## Introduction

Early research vessels in India did not have contemporary facilities for automation in the area of data collection. As a result a lot of effort went into developing indigenous data loggers for specific applications such as meteorological [1], physical [2] and geological data [3]. A system for ship-to-shore data transmission via satellite was also developed [4].

The newer research vessels launched in the eighties had full-fledged facilities for acquisition and processing of data. Oceanographic research vessel (ORV) Sagar Kanya, launched in 1983, for instance contained three minicomputers (HP-1000) one for integrated navigation, another for weather radar processing and a third for post processing of data. There were also several desk-top computers (HP-9845) to collect a variety of data.

The experience gained with new ships and in-house development efforts, have led to the design of an Integrated Data Acquisition System (IDAS) that will be easy to maintain and expand depending on sophistication required or the complexity of data acquisition.

The IDAS will be implemented using personal computers in a network environment. Personal computers because of their low cost and universal availability are easy to maintain. The PCs in a network environment further facilitates concurrent data acquisition, processing and display. Moreover network systems can be easily expanded to accommodate computer nodes, when data acquisition and processing nodes demands it.

The advantages of using personal computers and their use in a distributed system, the special requirements of networks for shipboard use and network software standards that have formed the basis of the IDAS are discussed in this paper. The design aspects of the IDAS including interfaces, software and data integration are presented later.

## Personal Computers

The PDP series from Digital Equipment Corporation and minis and desk top computers from Hewlett Packard have been popular systems on board. Recently, however, the trend has been to use IBM PC compatibles. In spite of their inherent drawbacks for use in real time applications, PC's are preferred for the following reasons.

- \* Universally available hardware and spares at low cost facilitating easy maintenance.
- \* Users are not tied up to a single manufacturer for system upgrade, service or for application support.
- \* The large software base and a variety of add-on hardware modules ease the development of new applications.
- \* Well documented, well known and open architecture allows a system designer to build special interfaces with ease.

Performance of PC's in terms of speed, memory and storage have increased many fold and still continue to improve without effecting compatibility.

The major drawbacks of PC's, for real time applications, have been its I/O bus, inability to support multiprocessing and multitasking, limited interrupt inputs and inability to handle nested interrupts. These drawbacks are often overlooked when viewed against their real benefits.

## Distributed System

The distributed nature of equipments on board a research vessel naturally dictates a configuration of distributed processing centers servicing a group of one or more ship-borne equipment. However different equipment need to share data with other equipment such as positional information, speed and heading and bathymetry. The distributed processing centers need to be interconnected. A most simple (and widely used) method of interconnecting distributed computers is via a serial RS-232 link. The scope of RS-232 link is however limited by their maximum transmission speed of 9600 baud. Another technique is to use a high speed parallel bus. Such buses however cannot drive signals beyond a few feet, such as the IEEE-488 GPIB, and are not suited for interconnecting distributed systems.

With the advent of local area networks which emerged in recent years, transmission speeds in excess of 10 Mbit/sec are possible and they have become the ideal choice for interconnecting distributed systems. LAN based systems are easy to expand unlike systems connected point to point on RS-232 links. New systems can also be added to the network to share the data collected in real time. Another advantage is that data acquired at one node can be simultaneously monitored, analyzed and displayed by one or more nodes in a distributed system.

## Networks for Shipborne Applications

The use of personal computer networks have increased greatly and they have become standardized and reliable. The cost of a PC network controller has been decreasing and presently stands between 200\$ to 800\$. PC networks have become popular because of their use in office automation, however the aspects of networking protocols that need to be considered for their use on ships are discussed here. The media used in networking PCs and the topology of their interconnection is also discussed.

There are three different types of networks viz. ethernet, token bus and token ring. Ethernet networks are the oldest and use a carrier sense multiple access/collision detect (CSMA/CD) technique for network transmission. Ethernet networks use statistical avoidance methods for transmission, as a result of which increasing number of nodes decrease the throughput due to increased collisions. A worst case access time per node is not guaranteed in a standard ethernet network making this type of network unsuitable for real time applications. Presently however, network controllers with deterministic contention resolution capabilities such as Intel's 82590 seem to offer guaranteed access features, which may, make ethernet

a suitable network type in real time applications.

Token bus and token ring networks on the other hand use controlled access protocols and have deterministic worst case access time per node. Token networks automatically reconfigure themselves when a node is switched ON or OFF or if a token is lost under any circumstances.

An example of a token bus protocol is ARCNET a network manufactured by Standard Microsystems. ARCNET supports 2.5Mbit/sec. transmission rate and a maximum of 255 nodes. Typical lost token recovery for an ARCNET network varies from 20 to 60 msec [5], which are tolerable for ship board networking. ARCNET products are well established since their introduction in 1977 and now support fiber optics media as well as new software standards. The use of an ARCNET network for shipboard applications has been addressed by Swift S.G. in 1983 [6]

Token ring technology is relatively new and has gathered momentum since 1985. Token ring networks are more suitable when compared to a token bus for real time applications and shipboard use since they support nodal priorities in addition to being deterministic and fault tolerant [7]. The technology for 16 Mbit/sec twisted pair and 125 Mbit/sec fiber distributed data interface (FDDI) are gradually becoming available, and standards governing them are being evolved simultaneously.

In addition to network protocols other aspects such as network media and topology require special attention for shipboard use. Ship board environment produces electrical noise associated with generators, motors, arc welding machines and other heavy machinery operating in the vicinity of laboratories. The choice of a suitable network interconnection media therefore becomes important. Fiber optic cable seems a good choice for the following reasons.

- \* has immunity against electromagnetic and radio frequency interferences and high voltage transients.
- \* avoids potential problems arising in a hazardous environment due to grounding and shorting.
- \* is easy to bend and route being light and thin.
- \* is unaffected by the corrosive effects of the marine environment.

Having discussed the advantages of fiber optics network media, we now mention the physical topology of interconnecting PCs. The two main network interconnection

methods are bus and star topology. The star topology with centralized hub is preferred to a bus topology as it allows network expansion and isolation of faulty cables. Moreover routing of cables from a centralized hub is easy for a star topology network. These characteristics make a star topology a good choice for use in a shipborne environment.

#### Software standards

International Standards Organization's, seven layered, Open System Interconnect model has been the basic frame work for LAN design. IEEE 802 committee defined standards 802.3, 802.4, 802.5 for ethernet, tokenbus and token ring protocols. These IEEE standards have covered the hardware aspects viz. network protocol, transmission bandwidth, topology and media defined at Layer1 and Layer2 of the OSI model.

The higher level layers of the OSI model define software protocols for application to network interfaces. Until 1985 standardization did not exist on software protocols. IBM's NetBIOS program released in 1985, has now become an industry standard for program to program communication. NetBIOS is hardware independent and NetBIOS based programs can be transported between networks from different vendors using different protocols. A ship board data acquisition software, for instance, written for an ARCNET network will be portable to future systems using a 16Mhz token ring or FDDI networks.

Before the emergence of software standards, particularly NetBIOS, use of PC LAN's for shipboard or control applications had been difficult from an user's point of view. The application packages for PC Networks supported the office and business environment that used a disk or file server for communication. NetBIOS has not only facilitated program to program communication but has also assured the portability of software between different networking products.

NetBIOS supports four categories of services viz. name, datagram, session and general services. Name services are responsible for identification or addressing of nodes. The datagram and session services are transport services for communication between user processes. The datagram service uses a connectionless transport mechanism and does not guarantee delivery of data whereas the session service establishes a connection between user process and guarantees the delivery of data.

In addition to transportability of NetBIOS to different networks, the industry standard TCP/IP compatible NetBIOS implementations have been demonstrated recently that support internet routing. Internetwork routing capabilities will allow the ex-

change of data between different networks on ships and shore.

#### Integrated Data Acquisition System

The concepts discussed so far of personal computer and networking have been the basis of an Integrated Data Acquisition System being developed at National Institute of Oceanography for a Coastal Research Vessel (CRV) that is shortly to be acquired. CRV will be a small vessel of 45 meters length and 10 meters breadth. CRV will have two standard laboratories viz, a 'WET lab' and a 'DRY lab' to collect basic oceanographic data. Provision has also been made for two mobile container laboratories for the specific disciplines of the cruise. Figure 1 shows the schematic diagram of the system consisting of dedicated PCs interconnected using an ARCNET network. The configuration of the IDAS is restricted to a small network due to the small size of the vessel. Table 1 shows a list of personal computer stations and associated group of equipments that fall into natural clusters around each station. These clusters are listed below.

#### Wet and Dry Labs

The "NAV PC" is a personal computer that will collect navigation data from a satellite navigator, depth data from two echosounders, ship speed and heading data from a speed log and a gyro compass. This data will be logged every 10 seconds and broadcast to all other PCs on the network.

"NET PC" will collect data from a suite of meteorological sensors viz. wind speed, wind direction, solar radiation, barometric pressure and temperature. Corrections will be applied to wind data using the "NAV PC" output.

"WET LAB PC" will be dedicated to equipment such as the conductivity - temperature - depth (CTD) profiler, shipborne wave recorder, salinometer, turbidity meter and an autoanalyzer.

Other computers on the network will include a "File Server PC", an "EDP PC" and a "BRIDGE PC". The data collected at each node will be stored on a local hard disk as well as on the server whilst data is being acquired. The choice of an "EDP PC" is meant to facilitate data processing and plotting as well as monitoring of data acquisition occurring at any other node. The "BRIDGE PC" could be configured for graphic navigation display or for remote node communication between ship and shore via a satellite link.

#### Container Labs

Modular laboratory computers will receive data from equipments such as magnetometer,

current meter, bathythermograph and a buoy receiver etc.

### Interfaces

The type of interface required for connecting each equipment is shown in Table 1. COM1 and COM2 ports of each PC provides serial interface connections. Parallel interfaces have been designed for BCD inputs. Analog signals are converted into digital form by a Kiethley Instruments DAS-570 analog-to-digital conversion subsystem.

### Software and Data Integration

Software is being developed in 'C'. The availability of graphics support and the large library of function calls have eased the programming task.

The transmission and reception of commonly required data such as position, time, and ship's speed and heading is planned through NetBIOS calls without involving the file server.

The data acquisition program will be interrupt driven so that data is not lost whilst updating the discs or whilst waiting for network communications. The data acquired at each node will be stored on local hard discs as well as on a server. The NAV PC has been assigned the task of keeping a backup of data logged on the server. The dual storage ensures safety against disk failures. The maximum data collected by all equipment on the CRV will not exceed 1 Mbyte/day and the 40 MB disc on the server will easily store the data generated by a full length cruise of 30 days.

### Conclusions

We have demonstrated that personal computers have become an appropriate choice for data acquisition systems because of their easy availability, low cost hardware and add-on modules, a large software base, well documented open architecture and a continued increase in performance without sacrificing on compatibility.

Furthermore it has been shown that distributed PCs connected in local area networks allow concurrent data acquisition, processing and display. LAN based configurations can be enhanced depending on the size and complexity of the application. The emergence of networking software standards for PCs has allowed process-to-process communication between different nodes without involving the file server or disc, thus reducing time overheads associated with disc access.

An Integrated Data Acquisition System has been described for a small research vessel. It can be easily expanded for addi-

tional acquisition, processing, display and storage nodes depending on the required sophistication and to tackle complex situations. The availability of software standards assures that the system can be enhanced with new networking products that are expected to be available in future such as the 16 Mbit token ring and FDDI. Internetworking protocol standards will also facilitate data exchange between different networks on ships and shore. The distributed system may be built with heterogeneous systems using different operating systems such as DOS, Unix, and real time operating systems, individually suited for different applications.

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TABLE 1:

Sr. No.	Computer name/Type	Equipments	Interfaces /Signals	Sr. No.	Computer Name/Type	Equipments	Interfaces /Signals
1.	EDP PC AT/386	Plotters Printers Tape backup		4.	WET PC PC/XT	CTD system Salinometer Turbidity SST Auto analyzer Wave recorder	16 bit I/O RS-232 -do- -do- -do- Analog 1V
2.	File-Server AT/386	Printer Tape backup		5.	MOD PC1 PC/XT	Magnetometer EBT	BCD RS-232
3.	MET PC PC/XT	NIO AWS Lambrech AWS  Wind speed Wind direction Air Temp. Surface Temp. Water Temp. Barometric pressure Wet bulb Pyranometer	RS-232 Analog (0-5 Volts) -do- -do- -do- -do- -do- -do- -do-	6.	MOD PC2 PC/XT	Current meter Buoy receiver	RS-232 -do-
				7.	BRIDGE PC	SATCOM	Modem
				8.	NAV PC AT/386	Satellite Echo sounder Speed log Gyro Master clock	RS-232 RS-232/BCD Pulses 3φ synchro BCD

FIGURE 1:

