NETWORKING AND SHIP-TO-SHORE SHIP-TO-SHIP COMMUNICATION

Ronald L. Moe

Shipboard Computer Group, A-023
Scripps Institution of Oceanography
La Jolla, California 92093

ABSTRACT

This paper discusses shipboard communication as it applies to computer networking between ships and the shore facilities at the Scripps Institution of Oceanography. Different communication links are discussed including satellites and VHF (high frequency radio). Further detail is given relating to the networking options aboard ships and at SIO while pointing out some of the advantages, disadvantages, and limitations of the different systems.

INTRODUCTION

Communication between the shore facilities at the Scripps Institution of Oceanography (SIO) and the ships in our fleet has always been a necessity. The need to communicate may be for ship's personnel to have contact with the Marine Facilities or for scientists to be able to pass messages to SIO or to their own institutions if they are not affiliated with SIO. Members of the scientific party are usually made up from many diversified groups, such as scientists and technicians from SIO or other institutions both in the U. S. and abroad, as well as observers from foreign countries if survey work is done in their territorial waters. The larger of the ships can be anywhere in the world with the associated problems of long distance communication. To meet the communication needs, SIO has always operated and maintained its own licensed radio station, call letters WWD.

In 1966, it was decided to install permanent computer centers on our larger ships. The computers were to be used for real-time data acquisition and control. The post-processing of data and general purpose computing were also to be supported. The Shipboard Computer Group was created and charged with the responsibility for this task. Along with the shipboard installations, an identical facility was established on shore to support the ships and to provide general computing services at SIO. Soon it was recognized that there was a real need for computer to computer communication. Initially what was envisioned was the ability to transfer messages between individuals, small programs or documentation, and maybe even small amounts of data.

Ship to shore communication has evolved from CW, Morse code sent with a telegraph key keying a transmitter, to currently using satellites that provide near telephone quality service. We will briefly discuss how some of the communication facilities function between the ships in the SIO fleet and the shore based station; and how we have attempted to utilize them in networking schemes.

SHIP-TO-SHORE

Since the early days, the primary means of ship-to-shore communication has been radio-teletype (RTTY) or high frequency voice (VHF). Radio-teletype is sometimes the only communication path available because of distance, atmospheric conditions, etc. Since it is slower and less flexible than voice communication, voice is the preferred method to communicate.

Approximately ten years ago, satellite communication became available to the oceanographic community. NASA had two transponder relay satellites that were originally VHF communication experiments. NASA wanted to determine the reliability of VHF communication with the satellites. The results from the experiment showed that VHF communication was not very reliable. The satellites had served their intended purpose and were no longer being used. Access to the satellites by the oceanographic community was allowed by NASA for communication purposes. The satellites are referred to as ATS-I and ATS-III. Both satellites are in geosynchronous orbits and appear to remain stationary in the sky if the observer remains stationary on the ground. As a ship station moves on the surface of the earth, the apparent position of the satellite in the sky will change. This change is very slow and changes in the ship's heading will cause tracking problems.

The satellites were to be maintained stationary over a specific longitude by NASA ground control. ATS-I was maintained over 149 degrees west while ATS-III was maintained over 105 degrees west. The satellites oscillated about the equator and ATS-I would move about 11 degrees above and below the equator. ATS-III would move about 9 degrees above and below the equator. The period of the oscillation is twice per day. One problem that has developed is that the fuel for the satellites positioning motors has been used up so no control can be exerted over them. ATS-III is parked in a gravity anomaly and should remain there forever. ATS-I has drifted into and back out of ATS-III's territory and both have a wobble in their orbits. These satellites have long outlived their projected lives but are still in useful condition.

The ATS satellites are translating devices rather that repeaters. They re-transmit exactly what they receive and the amount of power that they provide during transmission

Table 1 ATS Channel Definitions

Channel	Principal Usage
SDR (Ship Data Receive)	This is the "low data channel" and the ship stations receive data on this channel. The land stations transmit data on this channel.
CH2 (Channel Two)	ATS-III voice channel.
CH3 (Channel Three)	This is the "center channel" and is reserved for ATS-I operation only.
CH4 (Channel Four)	ATS-III voice operations.
SDX (Ship Data Transmit)	This is the "high data channel" and the ship stations transmit data on this channel. The shore stations receive data on this channel.

Note that SDR and SDX combined give full duplex operation. These five channels are defined for the convenience of the satellite's users. At the satellite, they appear as a single wide channel.

is dependent on the amount of power received from the earth station. The stronger the received signal, the stronger will be the re-transmitted signal. ATS-I is a very basic translator and can support only a single user at any given time. This means that voice must be operated simplex and there are no data channels on this satellite. It is quite easy to transmit data on ATS-I but the data must be transmitted one way at a time. ATS-III is a more advanced translator and can support several users simultaneously. There are five defined channels for the ATS satellite communication system (Table 1) and ATS-III can support all of them. The only real limitation on multiple user operations on ATS-III is the total power available from the satellite.

The current schedule calls for three one hour windows for oceanographic use for voice traffic. The times are 1400Z to 1500Z, 1800Z to 1900Z, and 2300Z to 0000Z. The data channels on ATS-III can be used at any time although by only one user at a time. The data channels are operated on simulated low power. The simulation of low power results from the location of the data channels on the satellite's base band. The data channels are near the edge of the satellites response so it takes a lot of power to operate over them and they normally provide relatively weak signals. This allows the ship systems to use maximum available power and still avoid interference with voice channels. While the ship use of the data channels must never interfere with a voice channel, it is often the case that a voice channel will interfere with the use of a data channel. This is one of the limitations on the use of the data channels.

One of the more recent communication systems installed on SIO ships is the Inmarsat, International Maritime Satellite Organization, satellite link. It uses the Marisat satellite system as a marine communication system that provides Telex, telephone, and data services on a worldwide basis. Data transmission rates of up to 2400 baud are provided. More recently however, AT&T International using Inmarsat facitilies has made available a data communication service with simplex data transmission rates of 56 Kbytes per second. Inmarsat's three Marisat geostationary satellites were launched in 1976 and are positioned to cover the Atlantic, Pacific, and Indian Ocean regions. The complete Inmarsat space segment is made up of eight satellites which provides near global coverage with the exception of the polar regions and a band in the middle of North America. Four new dedicated satellites are currently under construction and will be launched beginning in 1989.

Besides voice and data communication over the satellite systems, it is possible to send graphics data. The ATS does this throught Qwip which we have used to send bathymetry maps, administrative forms, and program listings. The Inmarsat has FAX capability. Besides being monochrome, our shipboard FAX machines have gray scale processing and have been used to send high resolution pictures to shore facilities.

EARLY COMPUTERIZED ATTEMPTS

In the early 1970's, our first attempts at computer to computer message passing used a computer to send or receive 16 bits of binary data to a black box built in-house. The box provided two frequencies that represented 0's and 1's. These were then sent to key the appropriate equipment which were then transmitted over the RTTY. This attempt did work, but because it involved three people on shore in three different locations and two people aboard ship to set up the communication and make it work, and because of the lack of constantly reliable transmissions, this project was never used.

A later attempt was made utilizing the ATS data channels to provide a path for the computers aboard two ships. This demonstrated to us that it was indeed feasible to communicate this way, although with varying degrees of bit error rates. Operating from two different moving platforms trying to keep their antennas tuned to the satellite does not always produce the best of conditions. Today almost all computer traffic is from ships to our shore facility and vice-versa and ship-to-ship communication via computer is rarely done.

CURRENT IMPLEMENTATION

The Shipboard Computer Group of the SIO uses a DEC VAX-11/750 in its shore facility and two 11/730's aboard the R/V *Melville* and *Thomas Washington*. The computers run under the Berkeley UNIX* 4.3 operating system. The computers aboard ship are networked together via Ethernet with provisions to connect other computers brought on board if they have the appropriate connecting hardware. The computers on shore are networked via Ethernet to the University of California at San Diego's campus wide Ethernet network and also to UCSD's local area network (LAN). In addition, smaller computer systems around SIO are linked to these facilities by our computer.

In early 1985, it was decided at SIO to "computerize" the radio station, and to a lesser extent, the larger of the ships equipped with computers operated by the Shipboard Computer Group. The goals for the radio station were to be able to send and receive electronic mail (e-mail), between the radio station and the people using its services. The messages transmitted between the ships and the shore radio installation were then to be sent under computer control to the various facilities. The communication facilities of interest were the ATS, RTTY, Telex, and two message repeaters ashore where all messages are printed, one in the administration offices and one in the marine operations offices.

To implement e-mail for the radio station was an easy task. It was only necessary to run the appropriate hardwire lines between the station and our facility, and to furnish them with a terminal and an account on the computer.

The ATS was the next easiest implementation. Because data channels in the radio station were already connected to a hardcopy terminal via RS-232 lines, it was only necessary to install a switch to select the current terminal or a computer connection, and to string more hardwire lines from the switch box to the computer. In this case, the lines were connected directly to one of the computer's RS-232 ports. Data had been routinely transmitted in ASCII code so no data conversion was necessary.

The RTTY connection was more difficult to implement. The output from the transmitter was usually connected to a teletype. This meant current loop connections and BAUDOT code. A Black Box system was purchased to convert the current loop to RS-232 signals and back; and another box was purchased to convert the BAUDOT code to ASCII code or vice-versa in real time. The data conversion could have been done easily by the computer but since an inexpensive box could be purchased to do the code conversion and to manage the RS-232 I/O requirements, it was decided to do it in hardware. Once again four more wires would need to be strung to connect the transmitter to a computer port and the hardwire requirements would be satisfied.

* Trademark of AT&T

To implement the Telex connection required still another set of rules. Access to Telex was made over telephone lines, and SIO subscribed to several companies to provide Telex services. Communication protocols for the different services were never quite the same. In order to connect to a phone line, we purchased a NU-DATA Series 106 controller which contains an originate/answer modem and an auto-dialer. This box took care of the basic protocol requirements to communicate over Telex. Output from the box was RS-232. The Telex services we subscribe to also use ASCII data code so no data conversion was necessary. Four more lines to the computer and the Telex hardware requirements were met.

The radio station required that all traffic transmitted, or received, be logged on hard copy. Therefore, all equipment also had a printer in parallel. For equipment operating in particularly noisy environments, like the ATS, a device built in-house was also provided to filter out non-ASCII characters to the printers. This prevents the printers from taking unexpected form feeds, going into strange modes, etc. One other requirement by the radio station was to cover times when the computer was not available due to hardware problems, preventive maintenance, or some other reason. For this, all equipment also have a terminal that can be switched in place of the computer. Data can be sent directly as it is being typed in by the operator or up to four screens of data, 24 lines by 80 or 132 columns per screen, can be saved in the terminal's memory and transferred after being entered.

Up to eight RS-232 lines were needed to support the radio stations requirements. However, after following the various tunnels, conduits, etc., the length of the wires far exceeded the RS-232 standard. Therefore it was decided to string only two twisted pair lines, four wires, and have a multiplexor on each end that would provide the eight lines needed. Traffic through the multiplexor was not expected to be very heavy and well within its limits. Only the terminal ports runs at 9600 baud. The ATS port is set at 300 baud and the other ports at 110 baud.

The original implementation of the repeater loops for messages to the administration and Marine Facilities was one loop on a dedicated teletype line. The hardware required was identical to the RTTY. Recently the teletype line has been removed and the two printing functions separated. The administration's printer is located close enough to the computer that wires were strung directly to the printer from the computer and a print spooler implemented to output all messages. The link to the Marine Facilities spanned approximately 15 miles and was more involved as it was necessary to go over telephone lines. In this case the computer port was connected to a modem with autodial capabilities and the printer was connected to a dedicated phone line with another modem. A print spooler was implemented to deal with potential printer error conditions (e.g. off line, out of paper, paper jammed, and phone line noise).

The above descriptions cover most of the hardware requirements needed to route traffic at the radio station by the computer. Aboard the ships, only a subset of the hardware described above was needed, and it was identical to that used in the shore installation.

In order to make all of this hardware work, a certain amount of software was required. UNIX provides most of the utilities needed although in some cases maybe not quite as well as the user might like. The main problem encountered in the automating of the radio station has been acceptance by the radio operators. Most of them had no computer backgrounds and were reluctant to learn the necessary computer operations. Fortunately, UNIX provides a facility for writing scripts containing lines of commands that are executed by the operating system. To make it easier for the operators to use the computer system, this facility was used to construct a menu to walk an operator through whatever function he wanted to perform. Functions were included to read or compose e-mail, start and stop receiving traffic from any of their communication facilities, starting editors to compose messages, list contents of directories, remove files, or any other function that they would need. The disadvantage to this way of operating is that scripts are slow since they are interpretive and are submitting commands to the operating systems. Also there is the necessity of doing extensive error checking on operator input. The system does work well and has achieved the desired objective with half the number of operators required at the station.

THE NEXT STEP

Our usual way to establish a connection between computers is to listen or send on a port with no interaction between computers. However, once the various transmitters have been connected to the computer, the link for computer to computer hookup has been established. The radio link is really nothing more than a copper wire link with probably a somewhat higher bit error rate. To go a step further is to use one computer to connect to the other computer. The only change for the computer is that on one end, the port corresponding to the communication device must be configured so that the computer can be "logged into". Connecting computers together can be done through RTTY or voice channels but with the current hardware we only do it through the ATS. Hardware does exist for the RTTY and voice channels that provides more reliable communication and in a full duplex environment but so far there has been no interest in purchasing it.

Once the computers are talking to one another, it is possible to do remote computing or other computer functions. It is possible to make data transfers under computer control making the transfers much more reliable. One often used file transfer facility is Kermit. It does not have error correction abilities like cyclic redundancy check (CRC), checking to enable data stream correction as the bits go by. It works by using checksums to determine if a packet has been sent error free. If the checksums do not match, the receiving computer requests the sending computer to retransmit the packet again. We have used Kermit to transfer files between computers with 100% reliability. Because Kermit has been ported to so many computers including personal computers such as IBM PCs and Apples, this capability allows for a convenient and reliable means of transferring files.

Another UNIX utility that could be used, although we have not, is the UNIX to UNIX COPY, (UUCP), program. It could be used to advantage for sending electronic mail between ship and shore. The electronic mail utility in UNIX uses UUCP and Ethernet to transfer messages. The UUCP program, like Kermit, will keep retransmitting packets until a successful transfer takes place. With UUCP, mail is held until a connection is established. Once the connection is established and verified, all the mail that is being held by both computers is sent without operator intervention.

Aboard ship or on shore, people can connect their computers to our VAX systems via RS-232 lines or the Ethernet links. These computers can then go further. Once they have logged into the remote host computer aboard ship or ashore, they can log into any desired computer that has been connected to the remote Ethernet network. Ashore, since UCSD has access to most of the major nets, a user aboard ship can transmit mail or attach themselves to virtually any net or computer anywhere via the UCSD networking facilities.

As already stated, our system is used on a daily basis in the more passive mode, with the computer listening at the port or sending data out the port to the transmitter. This mode requires very little operator interaction. The operator need only turn it on or off by software. To perform real computer communication requires the radio operators at both ends to establish the communication path. On shore, because the radio facilities and the computer facilities are a distance apart, the radio operator must then call the computer user over the telephone to notify him that communication has been established. The user can then proceed with his computer link. After he is through, he must then call the radio operator back so he can break the radio connection. Setting up the "normal" computer mode must then be done. Radio operators would prefer not to go through this routine, so it is only done in cases where large file transfers need to be completed in an error-free environment. To alleviate this problem, the necessary ATS equipment should be purchased to allow the Shipboard Computer Group to perform all the necessary functions required to set up the ship-to-shore link themselves. This would expedite matters tremendously but funds have not been available to do this.

One other means of connecting computers has been achieved by way of Inmarsat. Using a triple speed modem (300, 1200, and 2400 baud) with error correction capabilities, a user aboard ship can use a voice channel to call any compatible modem. Our experience has been that using voice channels can result in a noisy environment. The error correction option within the modems has never been tried. Our use of this system has been restricted by the cost of Inmarsat voice channel communication. The current cost is $30 for the first three minutes and $1 for every following tenth of a minute. In most of the cases where the data collected aboard ships would be usefully sent to shore for analysis, the quantity of data is too large to be cost effective. Some of the typical large data streams collected at sea include seismics profiles and Sea Beam bathymetry, both of which accumulate many millions of bytes of data on a daily basis.

Some experimentation has been done with intelligent controllers sending out packets with error correction and/or packet retransmission over the different transmitters. This makes connecting computers together by RTTY or VHF more practical. These controllers have internal microprocessors to take care of all decoding, signal processing, and protocol requirements, and their output can be made compatible with VHF, RTTY, and RS-232 requirements. The internal modems can transmit packets at rates up to 1200 baud with the option of using an external modem for higher baud rates. One controller tested also supported many parallel, dot matrix graphic printers with a direct connection to print HF monitored FAX signals.

Another concern to consider is that the captain and the radio officer are responsible for all communication to and from the ship. The ATS in particular is technically a telephone and not under FCC regulation. It therefore does not need a licensed radio operator. Also, on SIO ships it is considered as a piece of scientific equipment and depending on the ship, different people may operate the ATS. On the smaller SIO ships that do not have radio operators, the captain or a member of the scientific party may operate it. On the larger ships, it may be the radio operator exclusively or a member of the scientific party. There still is apprehension by captains and radio operators for anyone using the ATS or any other radio without their direct control. In a computer-to-computer hook-up, this control is obviously lost.

CONCLUSIONS

For us, ship-to-shore computer-to-computer data communication, even under the best of circumstances, has the problem of various degrees of bit error rates. Satellites provide the best and easiest transmission mediums. The limitations on ATS are its slow transmission rates, limited availability, manual antenna tracking, and lack of global coverage. Its main advantage over Inmarsat is that after its initial cost, its use is free except for maintenance on the equipment. The limitation on Inmarsat is its expense, $30 for the first three minutes and $1 for each additional tenth of a minute to North America. Its advantages are transmission speeds up to 2400 baud over voice channels or 56 Kbytes over data channels, it is always available and with near global coverage.