CONVERSION OF AUTOLAB TO A LOCAL AREA NETWORK

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Abstract

Twelve years have elapsed since the industrial implementation of AUTOLAB was initiated. Reliability, maintenance costs, and technical developments in the computer hardware and software fields have necessitated upgrading the systems. The selection and implementation of a local area network are described. Reasons for the selection of software, hardware and the network topology are given, along with the advantages of networks relative to multi-user mini-computer systems. Benefits gained from the conversion are detailed.

Introduction

The electronic capture and processing of data in the Cane Testing Service (CTS) laboratories, has continued since 1981. The implementation of AUTOLAB was described by King *et al.* (1979). An AUTOLAB Progress Report was also presented by King *et al*, (1981). The design and implementation of a mill laboratory system, an important addendum to AUTOLAB, was described by Taylor (1984).

Initial development of AUTOLAB was done on an IBM Series One mini-computer in 1978. Industrial implementation using Data General mini-computers commenced in 1981 and was phased in mill by mill over a period of five years. The initial installations centred around sixteen bit machines (S/140 & S/280 series) but towards the end of the implementation programme the later generation thirty-two bit machines (MV2000) were installed at the remaining mills. The original application software, written in PL/1 using the Data General INFOS database management system (DBMS), has been used since the inception of AUTOLAB.

In the course of time, it became evident that the following aspects posed a threat to the security of the system:

(a) The difficulty in recruiting and retaining suitable personnel with PL/1 and INFOS knowledge and experience for software maintenance.

(b) The uncertainty with regard to availability as well as cost of spares for the earlier generation mini-computers.

In early 1990 a plan was prepared to address these problems by replacing all old technology Data General computers with MV2000 systems and upgrading to UNIX-compatible fourth generation software. This plan was however re-examined in the light of rapid technological developments occurring in the computer industry. From this it was determined that the most cost effective solution would be personal computer (PC) based Local Area Networks (LAN).

To date, LANs have been installed at nine mills (including Union Co-Op) replacing all Data General S/140 and S/280 machines. The remaining seven mills all have Data General MV2000 systems in operation.

Multi-user mini computer vs local area network

The data capture task of AUTOLAB, with its associated inquiry and reporting systems, is ideally suited to a multi-user system, with many users accessing the same database. However, experience with a multi-user mini-computer has emphasised two main disadvantages, both basically cost driven:

(a) Using a mini-computer implies proprietary technology and therefore either very expensive maintenance contracts, or CTS technicians with specific training and an extensive range of spares. Maintenance costs are exacerbated by the geographical spread of the industry and the need for a 24 h per day operation.

(b) When expanding the system to incorporate more users there has been a constant need to update memory capacity and processing speed. The original installed capacity of 512 kilobytes (kb) RAM and 25 Megabytes (Mb) hard disk operating at 0,3 Mega Instructions per second (MIPS) has been increased over the years to 4 Mb RAM and 160 Mb hard disk operating at 0,9 MIPS.

A PC based LAN system on the other hand offers the following advantages:

(a) Cost effectiveness: A Data General mini-computer would cost approximately R150 000 to replace, excluding normal replacement costs of terminals and printers. The equivalent cost of installing a complete Network system is R80 000 to R100 000 including PC work stations and cabling. Hardware maintenance costs will be significantly reduced as off-the-shelf PC technology is used. Since the hardware components are readily available from multiple sources, the CTS is not locked into a single vendor with inflexible or expensive technology.

(b) Upgrades in technology are constantly occurring in both hardware and software fields. These improvements are easily incorporated into a PC network type system. Adding further users is simple and does not normally require an update of the file server or the network operating system.

(c) The use of intelligent work stations enables laboratory instruments to be connected directly without the use of multiplexers as previously required. With a hard disk installed, any work station has stand alone capabilities in the event of a network failure.

Network Selection

Novell or Banyan Vines?

Two network operating systems are currently widely used in the sugar industry, namely Novell Netware and Banyan Vines. The decision to opt for Novell was taken after extensive discussions within the industry and for the following major reasons:

(a) Novell has a world wide user base comprising some 75% of all network operating systems installed. In South Africa, the statistics are very similar with Novell having in excess of 76% of the LAN market share and Banyan having less than 20%. The balance is made up of several other suppliers. In the SA sugar industry, Novell had for some years been more widely used than Banyan Vines in the local area network environment and experience with a Novell network in the CTS head office

had been favourable. Novell is distributed by many vendors, and technical support is excellent.

(b) Banyan Vines is an excellent system for wide area networks but will only run on the UNIX operating system. In terms of costs, Banyan is more expensive to install than Novell.

Hardware Protocol: Ethernet and Arcnet

A decision was made to use thin Ethernet as this is supported by International standards and would suffice, in terms of distance, within the laboratory building. The problem of the greater distances to weighbridges and other remote points was originally to be solved by using a software package (PC Anywhere) on host PC's in the laboratory with remote work stations linked via the existing serial cables (complete with lightning protection, as used by the Data General systems). Unfortunately, PC Anywhere did not allow for the capture of data from weighbridge digitisers via a port on the remote work station. Rather than getting involved in extensive 'terminate and stay resident' software development to overcome this problem, a decision was made to install coaxial cables and to use Arcnet for these stations. The alternative of using fibre optic cables with Ethernet was investigated but rejected due to high initial cost and possible long delays (and cost) in repairing the cable if it were damaged.

The parameters that influenced the choice of an Arcnet network distribution system for use outside the laboratory building were:

(a) Reliability: It is required that the system functions continuously as the CTS operation runs 24 hours per day. A prolonged cable failure could have a detrimental effect on the mill operation.

(b) *Ease of maintenance*: In the event of physical damage to a cable, it is expected to have the minimum downtime that is possible. In such a case the damage to a coaxial cable could be repaired by the mill staff. With a fibre optic cable the installation contractor would have to be called. This could result in extended delays over weekends or holiday periods. Alternately, CTS staff could be trained to do the repairs, but the test equipment and special tools required are expensive.

(c) *Costs*: The installation of a fibre optic cable system at Noodsberg would have cost R30 000. The actual cost of a co-axial cable system was R3 975. A repair and test kit for a fibre optic cable system would cost approximately R12 000, whereas repairs to a coaxial cable system could be effected at minimal cost. In order to overcome a potential disadvantage of coaxial cable, i.e. its vulnerability to lightning strikes, the CTS has designed and developed its own improved protection devices for external network cables.

Selecting the Hardware

The selection of computer hardware was based on the following requirements:

(a) The availability of an industrially tested PC for use as a work station.

(b) Co-operation from the supplier regarding the supply of technical information, enabling the CTS to be self sufficient in repair and maintenance.

(c) A brand name file server certified by the software vendor (Novell) in case of networking software problems.

(d) The operator's PC to be configured to serve as a temporary file server, should the main file server fail.

(e) The use of 1,44 Mb stiffy drives as against Boot Roms so as to enable changes of network cards and/or PC's with minimal effort. The availability of stiffy disk drives on site allows for faster diagnosis of hardware problems.

A typical hardware configuration is shown in Figure 1.

File servers

Several high-quality PC's were evaluated for use as file servers. An important factor in their selection was the number of expansion slots as at least four are required; two for network cards, and two for disk controller cards. Originally AST 386SX machines were chosen. After several expensive failures with these machines just out of guarantee and generally poor vendor support, it was decided to change to Compaq 386SX PC's. The Compaq file servers have so far proved to be reliable. The current model has now been discontinued, however, and it is probable that a different make of machine will be used in the future. The system has two 340 Mb hard disks, each mounted in its own case with power supply. This means that a faulty disk may be exchanged very easily without disruption to the file server. The disks are duplexed to provide continuous operation in the event of a disk failure, i.e. data are copied to both disks simultaneously, using separate channels, controllers and cables.

Work stations

The PC work stations for the first five systems were EIGA 286 AT and EIGA 386SX machines. As the CTS had been classed as an Original Equipment Manufacturer, full circuit diagrams and technical information were supplied by the importing agent. Unfortunately, this agent went out of business and a change had to be made to a different supplier and brand of PC. For subsequent systems, ALLIED PC's have been purchased. With 286 AT PCs having become obsolete, all current PC work stations are 386SX models. Normally, a PC has two serial ports, one connected to a 9-pin and the other to a 25-pin male plug. All CTS PCs are modified so that both serial ports are 25-pin female plugs. This allows any weighbridge or laboratory instrument cable to be plugged into either port on any PC.

Three configurations of PC work station are used:

(a) *Standard work station*: This PC has 1 Mb RAM memory, monochrome monitor, an internally mounted 1,44 mb stiffy drive and a network card. As floppy disks are the primary source of virus infections, the mounting of the drives internally reduces accessibility thus minimising the possibility of these infections.

(b) *Weighbridge work station*: These PCs have 42 Mb hard drives, and 1,44 Mb stiffy drives with normal access. The stiffy drives are fitted with dust-covers to prevent failure due to dirt build-up. In the event of network failure, the work station is changed over to standby mode and all data are captured on the local hard disk. Once the network is restored, the data are down loaded to the file server. Should the breakdown be extensive (such as a cable break), data may be sent to the laboratory on stiffy disk to allow the laboratory operations to continue uninterrupted.

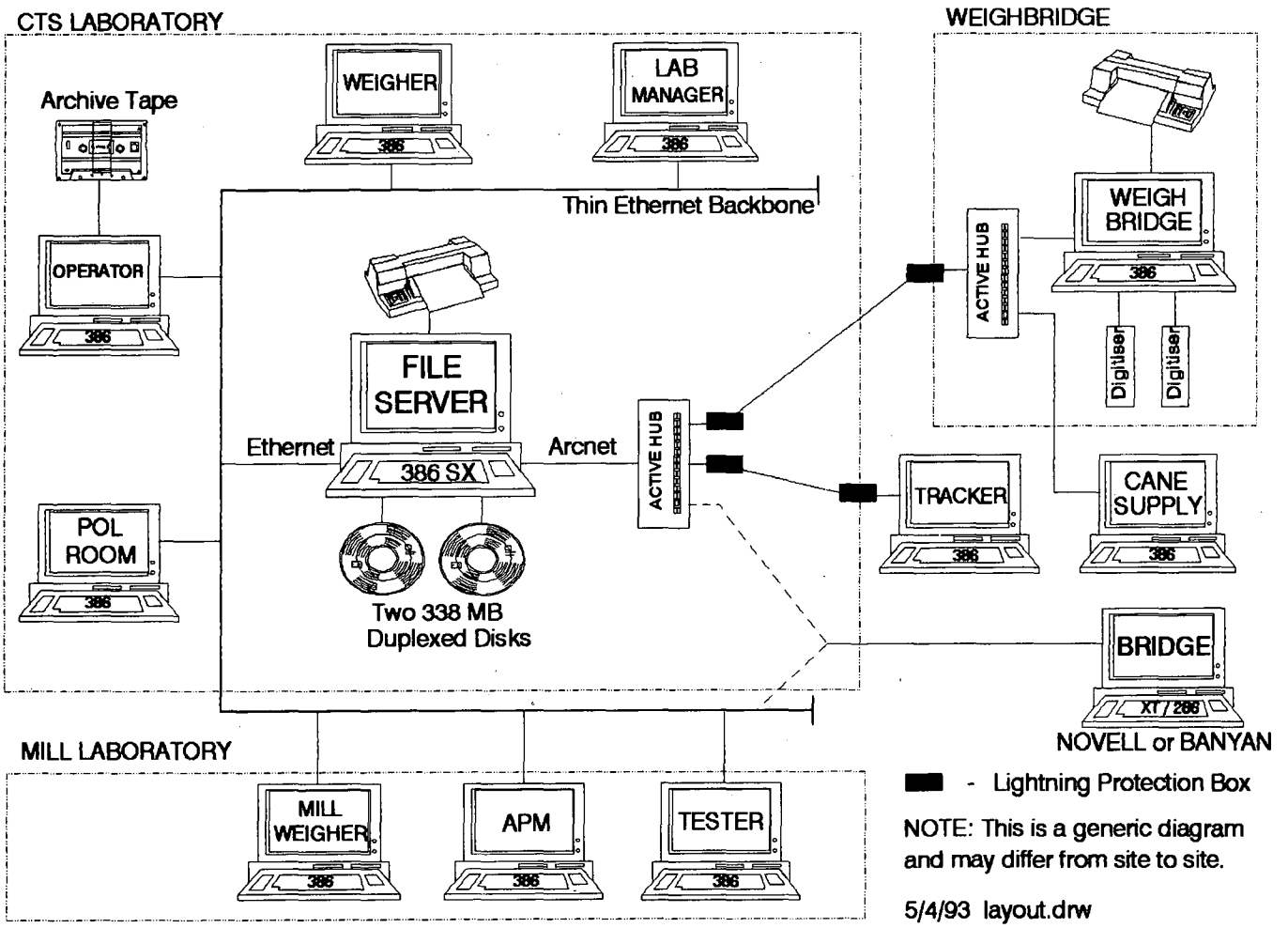

FIGURE 1 Autolab lan configuration

(c) *Operator's work station*: The operator's PC work station is fitted with 4 Mb RAM to provide adequate memory for the processing of batch jobs. This PC also has the archive tape streamer fitted to it. Should the file server become faulty, the tape drive may be removed, and one of the hard disks from the file server may be connected in its place. This PC may then be booted up as a standby file server.

Power supply

The existing un-interruptible power supplies (UPS) installed for the mini-computers continue to be used within the laboratory. Having intelligent work stations as opposed to dumb terminals requires a secure power supply to ensure data integrity. Additional small UPSs have therefore been installed to support work stations in remote sites (e.g. weighbridges).

Software Selection

It was recognised some years ago that it was desirable to move away from the software then in use as the complexities and inflexibility of the Data General INFOS DBMS was a major headache for software personnel. Originally, the line of progression was to be via MV2000 computers, using a UNIX operating system with a fourth generation language. The subsequent move to PC LAN systems required that new application development software be chosen for a complete rewrite of the AUTOLAB system.

Data base management software

In order to have data available to all users within the industry, it was agreed to use a *de facto* industry standard for data base management. To this end the 'XBase' format was chosen. A variety of software tools are available for this standard, and data can be exported to, or imported from, a range of other software systems without problems.

Application software

The application software common to all sites was developed in Clipper. Although several fourth generation packages were available, all of which would have provided fast development time, Clipper was chosen, very largely due to its low cost and ease of implementation. Several commercially available Clipper libraries have been acquired to give greater functionality to the application programmes.

Every mill has specific needs in terms of reports on cane deliveries, etc. These are produced using R&R, a fourth generation reporting package that is used in conjunction with Clipper.

The routines which interface the Clipper programmes to devices such as weighbridges and laboratory instruments have been developed using Microsoft C.

The software interface between users and computers

The complete software system has been developed so that semi-skilled staff may operate the system easily and effi-

ciently with the minimum of training. The application software is entirely menu driven, and all menus and programmes have a uniform structure to provide a logical and secure user interface. To this end, a locally developed menu system, TX-Menu, has been purchased. Where required, security is applied on several levels by the use of passwords. At system level the Novell password, user rights and directory rights structure provide security. In individual programmes, up to three types of password can be implemented at operator, manager and system supervisor levels. Any non-routine, sensitive operations are logged, to allow monitoring by the CTS Laboratory Manager or Mill Assistant Process Manager. The overall result is a more secure system than was possible with the Data General mini-computers.

Problems Encountered

Apart from some software bugs which, generally, have been easily sorted out, most of the problems have been hardware related. In 1992, of the five initial LAN installations, only one produced fairly serious and ongoing problems. These were found, over a period of time, to be due to poor quality cable connectors, mains power supply problems and faulty network cards. These problems have all been dealt with successfully. A positive outcome of these problems has been the development of specialised diagnostic and recovery software to minimise the corruption of data. The benefits of duplexed disks has been well proven. Despite one disk failing and numerous file server crashes due to power problems, it has never been necessary to restore data from a backup tape.

Benefits attained from LANs

Hardware

In selecting a PC based system, it has been possible to rationalise the amount of electronic hardware spares in stock. As all PCs are made up of standard components such as power supply, mother board, disk drives and controllers etc., as compared to the monolithic structure of Data General terminals, it is possible to repair PCs quickly and cost effectively.

The replacement of the multi-core cable system by a single co-axial cable should drastically reduce down time in the event of physical cable damage.

Software

As the complete operational data base and file management systems had to be re-written, the opportunity was taken to make some improvements and to provide the necessary structures to add further enhancements when time permits (see Appendix A). For example, the mill laboratory system now includes a means of capturing user defined mass/volume and/or analytical results not catered for on the Data General system. The reporting facility can now include up to 3000 user defined report items with improved calculations. Separate mass balances over the raw house and refinery are now possible, as well as the overall factory balance.

A major improvement in the CTS system has been the provision of weighbridge standby facilities which allows continued operation on a stand alone basis if a fault occurs on the network. The data collected during standby are automatically updated to the file server when the fault has been corrected. This type of facility may be extended to the other users when opportunity permits. System Maintenance has been enhanced by a wide range of commercially available software tools and utilities.

Data accessibility

Emphasis is placed on making data readily available through the linking of networks to a variety of users within the industry, e.g. both Tongaat-Hulett and CG Smith head offices in Durban are logging onto CTS networks at mills and extracting data.

Cost benefits

Installation costs of a LAN are significantly lower than the replacement cost of a mini-computer system and the ongoing maintenance costs will be reduced due to the use of readily available components and sub-systems. The dependence on in-house manufactured interfaces for instruments required by the existing mini-computers will fall away, with further savings in maintenance costs.

Conclusions

To date the conversion from mini-computers to LANs has proceeded smoothly, except at one mill where a number of teething problems were experienced. These were overcome and the experience gained has proved beneficial in that a great deal more was learnt about networks than might otherwise have been the case.

The ease with which changes/improvements to the application programmes have been dealt with has been very encouraging. The use of Clipper has been well justified in this respect.

Staff at the mills have had no problems in changing to LANs and the improvements such as the weighbridge standby system have been widely welcomed. As the MV2000 mini-computers become due for replacement, further LANs will be installed.

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APPENDIX A

Summary of main improvements to AUTOLAB

1. **Cane testing system**

1.1 The structure of the grower code is now user definable up to 10 characters (previously fixed 10 character structure).

1.2 The structure of the field numbers is now user definable up to 6 characters (previously fixed 4 character structure).

1.3 The PC work station in the weighbridge now provides for a standby system which is identical to the main programme from the operator's point of view. Data captured during standby operation is automatically updated to the file server. Using a PC work station also renders the CTS weighbridge controllers unnecessary.

1.4 Weighbridge digitisers with RS232 serial output can be connected directly to the PC work station, allowing CTS assize controllers to be phased out as old digitisers are replaced.

1.5 Saccharimeters and refractometers with RS232 serial output can be connected directly to the pol room PC work station, allowing CTS instrument controllers to be phased out.

1.6 Provision is made for user created reports of delivery, crush or siding data.

1.7 A combined programme provides for the simultaneous amendment of delivery, crush and siding records.

1.8 Provision is made for the inclusion of grower addresses for printing on daily advices.

1.9 Provision is made for allocating a bundle number to a vehicle of loose cane (applicable to one mill in particular, allowing correct capture of FRS data).

1.10 The reduced frequency system has been made optional (not applicable to South African mills).

2. **Factory laboratory system**

2.1 Mass/volume data capture has been split into two separate functions, viz.:

2.1.1 Mass data used to calculate the mass of pol, brix, etc. in a product may now be captured in either of two ways:

(i) capture weight in kg directly (e.g. as from a scale reading)

(ii) capture mass via a standard stock calculation (e.g. by capturing cm out)

2.1.2 Other mass/volume data for reporting purposes are separately defined, with user defined name and number of decimal places.

2.2 Dilution definitions now allow for the double dilution required for Preparation Index analysis.

2.3 Starch analysis now allows for the automatic weighing of samples.

2.4 Conductivity ash (CA) analysis now allows for the automatic weighing of samples, if CA/Bx is required (refinery products) using the actual brix to determine the mass of sample to be weighed.

2.5 Colour/turbidity analysis now allows for the automatic weighing of samples. In the case of juice and syrup, the actual brix is used to determine the mass of sample to be weighed.

2.6 Up to five user defined functions may be used to capture either mass/volume type data or analytical results not otherwise defined. Each one allows for user defined names and number of decimal places.

2.7 The weighers work station may now have up to three balances linked directly, allowing one station to do all weighing functions.

2.8 All instruments with RS232 serial output may be linked directly to the relevant work station, doing away with the need for CTS multiplexers.

2.9 The reporting facilities now allow for 3000 user defined records, each record containing day, week, month and to date items. These items may be the result of analyses or calculations not catered for in the standard report file.

2.10 Provision is made for raw house, refinery and overall factory recoveries to be calculated (previously only overall recoveries were calculated).

2.11 Provision has been made (although not implemented at the time of writing) for the inclusion of other products over the weighbridge (sugar, filter cake etc.) into the factory laboratory system.