COMPUTER SELECTION

With the advent of the information age, the problem of computer selection touches every aspect of society, from private individuals to the largest governmental agencies and corporations. Computers have become integrated into every area of our lives and economy. It is no wonder that we aspire to obtain the best performance possible from our computing machines.

Given the plethora of upgrade options available to computer users, it can be a daunting task to consider the vast possibilities of both hardware and software that can improve the performance of our computing machines. Ideally, we would like to have some heuristic methodology for selecting the best combination of hardware and software that supports our computing goals.

In this article, we attempt to provide such a methodology and thereby facilitate a discussion of the various criteria involved in selecting hardware and software. Figure 1 shows a general overview of the process involved in selecting hardware and software to support computing applications. After briefly discussing and expanding somewhat on the steps in the selection process methodology shown in Fig. 1, we proceed to a discussion of some basic computer concepts needed to understand the steps in the selection process more fully. Following that discussion, we provide some additional detail that may be found in the steps of the methodology through the use of a case study involving a small business. Finally we offer a discussion of the status of the computer selection process established in the literature. When applicable, we demonstrate the robustness of the aforementioned methodology (selection process) through the use of illustrative examples.

How then does one go about the business of selecting hardware and software to support computing applications? The first step is to understand the reason for selecting the additional hardware and/or software. That is to say, we need to determine the objectives and intended uses for our computing environment. For example, a small business desires to upgrade its existing local area network (LAN) to support several new employees, or an individual user wants to purchase a new desktop system to increase computing skills and capabilities. As an integral part of answering this question, we also require that the individual or organization making the selection decision detail the characteristics that are desirable or necessary. For example, the US Department of Defense could require that the hardware it selects be fail-proof in case of emergencies, or an organization within a larger corporation could require that the computer upgrades stay within its budgeted allocations.

Having determined the objectives, characteristics, and intended uses of the equipment, we should always consider whether or not our existing hardware/software infrastructure supports our objectives. In Fig. 1, this step in the overall selection process is represented by the diamond-shaped symbol in the methodology diagram (flow chart). For example, if individual users can share an existing external modem to access the Internet between their desktop computer and laptop machines, it is unnecessary to purchase an additional modem for a second machine, assuming that only one machine is used at a given time and that the current modem supports the desired data transfer rate (a performance specification).

If the current hardware/software infrastructure generally supports the intended objectives, then it may become necessary to ask if the existing structure needs be modified to bet-

J. Webster (ed.), *Wiley Encyclopedia of Electrical and Electronics Engineering*.

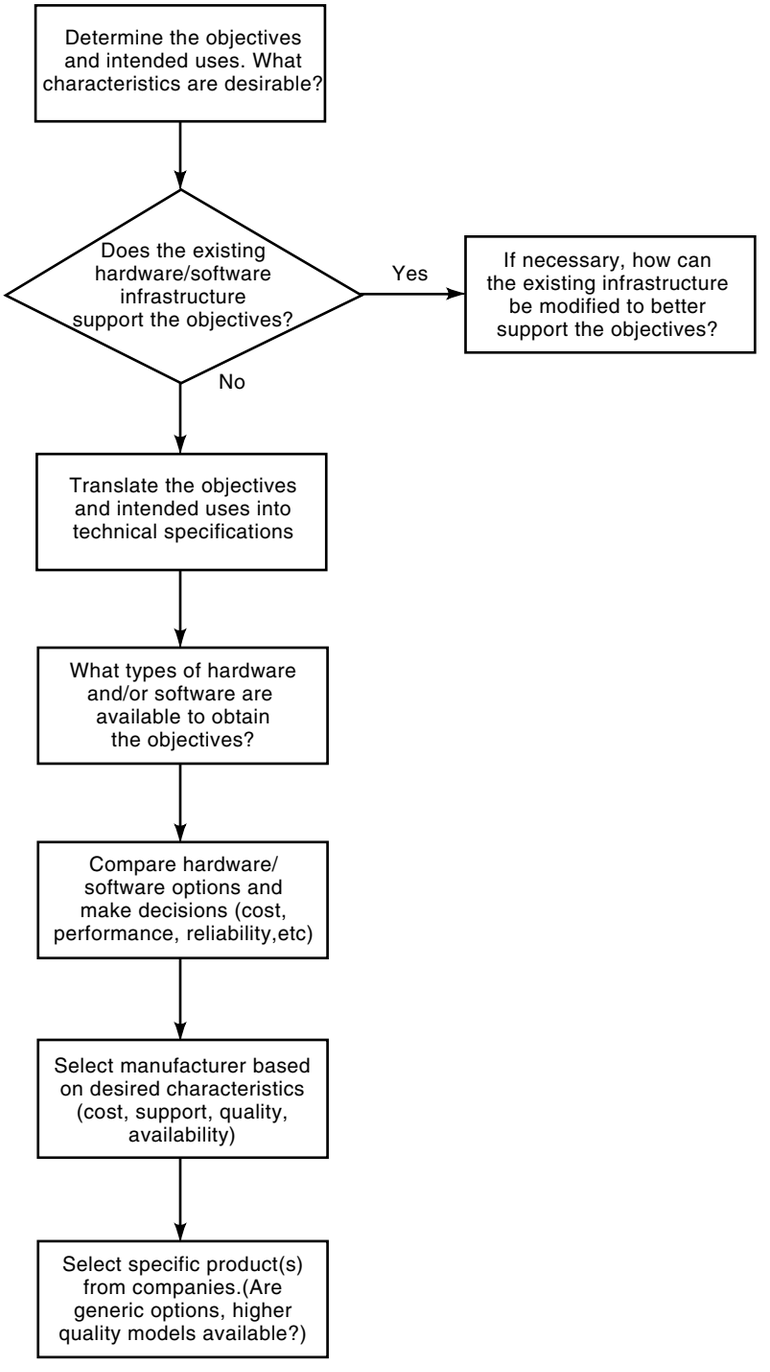

Figure 1. A procedure for computer users to follow when selecting computer hardware or software.

ter support the objectives (the flow emanating out of the Yes branch of the methodology diagram in Fig. 1). For example, a user who requires more space on a hard drive to store files but has a compression facility, could create an archive of files that remain compressed until needed rather than expanding the hard drive. While the cost of hard drives has decreased dramatically over the years, compression remains feasible since most users always seem to find ways to fill up available hard drive space. The user could also remove unnecessary or outdated software from the hard drive or employ a utility tool in the operating system to create more space on the hard drive.

If the current hardware/software infrastructure does not support the objectives and intended uses, then the objectives must be translated into technical specifications (the flow emanating out of the No branch of the methodology diagram in Fig. 1). The reason for this step in the methodology is that it is almost impossible to approach hardware and/or software suppliers (vendors) unless you have precise specifications that their products must meet. For example, suppose sales agents in a company want to view the drawing of a part on their computers as they are discussing a new or existing order for the part with a client. What is the amount of time the sales agents are willing to wait to have the desired drawing dis-

played on their computer screens? The difference between an answer of several seconds and an answer of subsecond response time critically effects the technical specifications for the hardware and/or software to meet this objective.

Once the technical specifications have been developed corresponding to the objectives, then it is time to examine the various types of hardware and/or software available to satisfy the objectives. Because new computing hardware and software products are continually becoming available, it is generally necessary to spend a considerable amount of time exploring existing and new ways to satisfy the technical specifications. For example, if individual users desire to improve their Internet access, a new Internet service provider could furnish access to additional lines and improved technical support, a higher speed modem could increase the transfer speed of data, and an increase in available random access memory (RAM) would circumvent the need for the user's computer to continually download the same information or to access its hard disk frequently.

After determining what types of hardware and/or software satisfy the technical specifications developed from the objectives, the next step is to compare the hardware and software options and make decisions based on the technical specifications and on any other constraints, for example, the total amount budgeted for acquisitions. The office manager of a small business, for example, may want to increase the performance of the office software. After completing the first four steps in the selection methodology shown in Fig. 1, it is determined that there are three potential options: all machines can be upgraded to the latest version of the software, new memory capability can be purchased for the most critical machines, or an entirely new set of machines can be purchased. All three options support the objective of increasing the performance of the office software. However, the company's key client already uses a new version of the software, and hence this may become the determining factor in the decision process. The new version provides increased options and performance within the company, and provides compatibility with the client's computer platform. Such situations can become critically important in the overall selection process.

Next, if there are several manufacturers of the desired product(s), the individual user or organization should select a manufacturer on the basis of its initial objectives and intended uses. A list of manufacturers for a particular product can be obtained by a variety of methods. A hardware/software consulting group can provide input about current manufacturers of available products, trade magazines and information systems publications may provide reviews of some of the products under consideration, and several Web sites and hyperlinks on the World Wide Web (WWW) may also provide a list of manufacturers for different types of computer-related products (1,2). Manufacturers can be selected on the basis of many factors, including product cost, quality, compatibility, availability, and customer support. For example, suppose a large organization determines that a new mainframe system will best support current and planned business needs. There are two manufacturers for the product desired. Assuming that cost is not the critical factor in the decision process, the manager in charge of the selection process notes that one of the manufacturers provides a staff of on-site consultants to ensure smooth implementation of the new system. Clearly, such support may become a deciding factor, given that the supplier (vendor) has satisfied all other specifications and constraints.

Finally, if the vendor selected has a variety of products available that satisfy the technical specifications, then it is necessary to select a specific product. For example, if a vendor can provide either a standard or professional edition of a particular software package, it must be determined which version of the software to purchase. In such a case, performance, product capabilities, and other considerations, such as cost, enter into the overall selection process.

SOME BASIC COMPUTER CONCEPTS

There are three basic steps involved in an information processing cycle, regardless of the type of computer used: input, processing, and output. Each of these basic steps may range from simple to complex, depending on the nature of the problem being solved. The input step may consist of utilizing a keyboard or mouse to enter information, using a scanner to read bar-coded labels, or using sensing devices at workstations throughout a business facility. The output step may consist of printing information, regulating energy settings, or applying brakes properly on an automobile under slippery road conditions. However, processing the information obtained from the input step to produce the information contained in the output step (the processing step) depends greatly on the type of computer (architecture) being used.

The computer architecture with which most people are familiar is called the von Neumann architecture. In its simplest form, this type of architecture consists of a single central processing unit (CPU) which processes all information (instructions, including input and output instructions, as well as data manipulation and processing). The CPU consists of three major components: memory (storage), an arithmetic logic unit (ALU), and a control unit. The main memory used by the CPU is memory that holds all instructions and data to be processed or which have just completed a processing step. Cache memory can also be installed in computer systems. Cache memory is generally faster than the main memory of the system. As the name suggests, the ALU handles all arithmetic operations (addition, subtraction, multiplication, division) and processes logical operators (AND, OR, and NOT). The control unit is responsible for timing, retrieving, and storing instructions and data in memory and decoding instructions to be performed. Thus, in a computer with only a single processor, that processor must handle any and all work (instructions) assigned to the computer. And, even if the processor is extremely fast, each CPU component can handle (execute) only one operation at a time. If the processor is extremely fast, it may appear that the computer is handling more than one instruction at a time, for example, performing an input operation while simultaneously handling computation (called multitasking). A very fast processor may appear to be performing a number of tasks simultaneously, but in fact it is not. Actually, it is the software controlling the computer (the operating system software) that is responsible for performing the multitasking, not the CPU. The operating system performs the multitasking by handing the CPU portions of all tasks to be accomplished, and the CPU alternately works on the various portions. All of this is accomplished so

quickly that it appears that the CPU is handling all tasks simultaneously.

In addition to the high-speed memory located within the CPU, most computer systems have additional memory devices for storing instructions and data. The most common ancillary storage devices are disk drives that are generally of two types: floppy and hard. Both types are normally installed in the same physical unit (box) that contains the CPU. However, floppy drives handle disks that may be inserted into or removed from the floppy drive by a user. Hard drives, on the other hand, are only directly accessible by the CPU. A user may have the CPU retrieve information from, or store information on, the disk in the hard drive, but a user generally does not come into direct contact with the disk inside the hard drive. Other major differences between a floppy drive and a hard drive are the rates of transfer of information to and from the CPU and storage capacities. The rate of transfer of information to and from a disk in the hard drive to a CPU is considerably higher than the comparable rate of transfer of information to and from a disk in the floppy drive to a CPU. The storage capacity of a hard-drive disk is normally many times that of a disk used in a floppy drive. Thus, in addition to concern about the capabilities (speed and amount) of CPU memory in a computer, a user must also be concerned about the capabilities of the memory of ancillary storage devices.

Another common storage device is a CD-ROM drive. This device is also generally contained within the same physical unit as the CPU, but unlike disk drives it holds a compact disk (CD) placed in it by a user rather than metallic-coated disks such as those used in hard drives and floppy drives. A CD in this sense is also a read-only memory (ROM) medium. This means that information can be transferred from a CD (one placed in the CD-ROM drive) to the CPU, but information cannot be transferred from the CPU to the CD contained in the CD-ROM drive, that is, the CD in the CD-ROM drive cannot be "written" on by the CPU. There are also write once, read many (WORM) drives that both write to and read from a CD. As the name WORM suggests, these devices can be used once to write information onto a CD (using a laser beam which burns the information into the surface of the disk) and to read from it as many times as a user pleases. There are also magnetooptical drives that use laser light and magnetic fields to read and write onto specialized compact disks. In this case, information contained on the disks can be written over (erased) by the CPU, unlike the information on a standard CD. In other words, disks used with magneto-optical drives that have both "read and write" capabilities. In addition to WORM and magneto-optical drives, Compact disk-recordable drives are also available. These drives model the characteristics of either the WORM, or magneto-optical, drive depending on the type of recording medium (disk) used with the drive.

Magnetic tape is another common type of medium for storing instructions and data. Unlike disk drives, tape drives are serial storage devices. This means that when a tape is placed in a tape drive and is either read from or written to, the data and instructions must be accessed sequentially. For example, if a tape is fully rewound and the desired data or instructions to be transferred to the CPU are located at the halfway point on the tape, all of the instructions and data located on the first half of the tape must pass through the read/write heads of the tape drive before the desired data and instructions can be located and subsequently transferred to the CPU. When using a disk drive, if the desired data or instructions are located in the middle of a disk, they can be located directly, that is, the read/write heads of the disk drive can be placed in the center of the disk without actually bothering with any of the data or instructions located elsewhere on the disk. For this reason, disks drives are commonly called random access storage devices. Notice that this type of random access storage is different from what is commonly referred to as random access memory (RAM). The term RAM describes a type of memory located in the CPU. That memory is accessible to the control unit even more directly and rapidly than the memory associated with a disk drive. The RAM in the CPU can be thought of as a bank of mailboxes located in most post offices. That is, a postal worker can place mail in (or remove mail from) a selected mailbox without considering the location or contents of any other mailbox (random access); only the address of the selected mailbox is important. However, there is really nothing random about accessing data and instructions in the CPU memory or on a disk. One of the major advantages of using tape as a storage medium is that one tape stores amounts of data and instructions that would require a number of disks. Because data and instructions on a disk can be accessed more quickly by the CPU than data and instructions located on a tape, disks are normally preferred as storage media when operating a computer system in a production-type environment, whereas tapes are an excellent medium for backing up and archiving data and instructions.

There are a number of other ancillary storage devices used with computer systems for information processing and storage, but the ancillary storage devices (tapes, disks, and CDs) previously described are the most common. Data cells (arrays of cylindrical tubes) and magnetic drums (magnetically coated and barrel-shaped) are two such devices commonly used with large-scale computers. Each ancillary storage device has advantages and disadvantages, and the use of any ancillary storage device depends on satisfying an objective or intended use requirement.

In terms of information storage, one other distinction needs to be made relative to the type of memory normally used in the CPU and the ancillary types of memory associated with storage media such as disks and tapes. When power is shut off to a computer system, any information stored in the memory of the CPU is generally lost because it is not stored on a magnetic surface. This is called volatile memory, in contrast to disks and tapes, which are called nonvolatile memory (read-only memory or ROM); that is, when power to a computer system is lost, any information already written on a disk or a tape is not lost. However, there are times when nonvolatile memory is required for a CPU. For example, applications in space exploration generally require nonvolatile memory for a CPU. When the lives of people or national security issues are involved, one can quickly understand why nonvolatile memory in a CPU is required. Again, it goes back to satisfying the objectives and intended uses developed in the first step of the methodology shown in Fig. 1 for selecting the best combination of hardware and software.

When a user intends to send information to a monitor for output, a distinction needs to be made among the various types of monitors available for displaying output. Again, during step 1 of the methodology shown in Fig. 1, objectives must

be established for the types and quality of output that are to be shown on a monitor. Eventually, during step 3 shown in Fig. 1, the objectives for the monitor need to be translated into technical specifications. Then, if a new monitor must be selected and purchased, the technical specifications establish which monitors are candidates for selection. If the output of the monitor is to be printed, technical specifications also need to be established for the printer(s) so that the level of detail transferred from the monitor to the printer is properly captured.

Two other hardware devices need to be considered when selecting computer hardware and software. They are devices used for user input: a mouse and a keyboard. Unlike operating systems software, application software (for example, word processing software) is the software developed by vendors that provides a direct interface with most users. Because most application software today is developed using graphical user interface software development tools, the mouse is used to locate icons and data-entry boxes on the monitor, and the keyboard is frequently used to enter data so that the application software performs properly. Thus, during step 1 in the methodology described by Fig. 1, establishing objectives and intended uses for these two hardware devices are necessary so that proper decisions are made regarding them later in the methodology for selecting the best combination of hardware and software.

SOME CASE STUDY DETAIL

A small business has an antiquated computer system (well over 10 years old) that has created a lot of extra work for some of the staff. It does not allow the staff to utilize it fully in the performance of their day-to-day business activities. The business owner decides to explore the possibility of replacing the current computer system. The decision to consider replacing your current computer system is based on a number of factors. Those factors include the fact that the company's application software vendor has customized its application software over the years to accommodate the particular needs of the business (with little or no documentation of those changes). Therefore, new releases of the operating systems software used by the computer system cannot be installed. As a result of the situation with the operating systems and application software, the application software cannot now perform tasks associated with handling dates beyond the year 1999 (called the Year 2000 problem) (3). However, costs are a real concern, both in terms of overall costs, and with respect to the current cash flow of the business.

The business owner personally has considerable computer knowledge, conceptually understands the methodology shown in Fig. 1, and is willing to take the time to assume the responsibility for managing the overall hardware/software selection process. The company decides to use the methodology displayed in Fig. 1 by establishing the following scenario:

1. Determine the objectives and intended uses by interviewing each member of the staff responsible for a functional operating area (department) within the business. As a result of the interviews, the company develops a request for proposal (RFP) that it sends to a set of potential vendors so that they can prepare proposals to submit. It is worthwhile to note that the business owner is assuming the responsibility for developing a set of potential vendors.
2. Regarding step 2, the company has a number of terminals that display text-only output and a number of workstations (for example, some used for marketing and others used for part design). Some of the staff members also have application software packages that they prefer to use on their workstations in performing their assigned duties. Although these issues can be considered a portion of the Yes branch in step 2 of Fig. 1, essentially the company is following the flow associated with the No branch in Fig. 1.
3. The company owner translates the objectives and intended uses established in step 1 (as a result of interviews with the members of the staff) into technical specifications which are then incorporated into the RFP.
4. The choices of hardware and/or software available to realize the objectives are largely driven by the proposals received from the set of potential vendors. However, it is the tacitly assumed that the potential vendors can be persuaded through negotiations to incorporate the existing terminals and workstations into their proposed solutions whenever and wherever possible. In general, potential vendors are willing to negotiate (and make considerable concessions) when they are attempting to secure business.
5. The company compares its hardware/software options after all potential vendors have made presentations regarding their products. Their presentations and pricing help to form the basis for the final decisions and will be used by the company to narrow the set of potential vendors that really have solutions that satisfy its objectives and intended uses. The evaluation system that the company is considering using is one that awards each potential vendor two ratings. One rating is based on responsiveness to the RFP (did they read and understand it), and the other rating is based on how the owner and each staff member believes the proposed solution satisfies the objectives and intended uses in each respective area (as translated to technical specifications in the RFP).
6. A vendor is ultimately selected on the basis of the presentation(s) and perhaps also on reference calls that the owner and staff members make to some of the vendor's current clients. Of course, pricing and any trade-offs made during negotiations (contingent upon satisfying the overall cost objective and cash flow considerations) definitely affect the final vendor selection.
7. Many vendors base their prices on the specific set of products that needed for the business. For example, there is a price for the accounting software packages (either priced separately, or as a group) and, generally, separate prices for the manufacturing, sales, and marketing software packages (these are all application software packages). If the purchase of an operating system is involved, then the operating systems software is probably priced separately. There is yet another set of

prices for various hardware components. Some of the application software may be priced by the number of people who will use the software simultaneously (called purchasing tokens, the number of tokens can be set and adjusted by the vendor at any time). In any case, separate pricing can be very helpful in negotiating and managing total costs.

To divide the company into functional operating areas, the owner has decided on the following classifications: accounting, computer system administration, marketing, inventory, purchasing, production control, production, sales, personnel, quality control administration, research and development, and general issues. Let us look at how this information would be gathered in several of these functional operating areas, and how the write-ups might appear in the RFP.

Marketing

The ultimate goal of the marketing department is to conduct marketing studies and research that contribute to the overall company goal of increased sales and growth. One method of accomplishing this goal is through the development of a marketing information system built on information contained within the company's central database (this assumes that the new computer system will contain a central database of company information from which all functional operating areas will draw, ideally, based on standard, relational database software). Relational databases differ from hierarchical databases both by design and operation when users are seeking information. More specifically, the marketing department needs to interrogate the overall database to produce reports and also to download information from that database in a format acceptable to a microcomputer software package of choice for further manipulation. What follows is a description of the fields (smallest, indivisible piece of information in a database, such as city, state, and zip code):

1. General customer information: account number, set-up date (when the customer entered the database), end user/original equipment manufacturer (OEM) or distributor, drop ship (yes or no), last-sold date, company name, address (two address fields), city, state, zip code, fax number, telephone number, WWW address (URL), e-mail address, territory/region (as defined by the company), branch location, source of account, description (a large text field), and 15 fields for contact names with 15 corresponding fields for titles.
2. Sales data: total company and individual branch sales per month, total company and individual branch sales for the current year, total company and individual branch sales for the past four years, total company and individual branch sales per product category (as defined by the company—at least 100 such categories currently exist) during the current year, total company and branch sales per product category for the past four years, and total sales by state or territory/region.
3. Marketing budget fields: advertisement cost, description, trade show expense, 800-telephone expense, printing costs, direct-mail postage costs, financial screening costs, costs for promotional items, and miscellaneous.

Production Control

The production control department needs the current size for a part number field to be greatly increased. A standard question for anyone submitting a proposal to the company is, "What is the maximum length (field width) in the system for a part number?" Currently, the limit on the number of characters in a part number is eight, and because of the large number of part numbers associated with the company's product lines, the company is running out of space for logical combinations which have been set up to accommodate part number coding. The production control department must be able to edit or create part numbers, set up bin locations, have on-line review for all items relative to on-hand quantities, and be able to review item pricing. The production control department must also be able to relieve individual items from inventory (through invoicing) when a loaded product ships out the door. In addition, the department must be able to edit, create, delete, or change part numbers with associated bills of materials and review bills of materials to check items in stock.

Sales

The sales department needs to have a user friendly sales/quote system that allows the department to access data to support daily activities and decision making. To those ends, the sales department requires a quote system to be shared among sales department staff members so that quotes can be rapidly prepared. A follow-up system for quotations is also needed as well as the ability to "tag" a print for on-line faxing of a follow-up to a quote. Thus, the ability to access part prints on-line is also necessary for the sales department. For the quote system, the sales department also needs to be able to add data/information to quotes and have that information remain on the order through invoicing. The sales department also needs to be able to track the number of quotes and the number of orders. E-mail and access to the Internet/WWW are also requirements at each station in the sales department. The sales department must have the ability to convert a quote into an order. Having the last price paid for an item by a customer instead of standard pricing is also necessary for the sales department in developing quotes. A flagging system for accounts that are slow paying is also desirable.

Access to marketing information along with customer profile information would be most helpful to the sales department staff.

The sales department must be able to review an order once it has been invoiced, and it must be able to review inventory levels. The sales department staff members should also be able to perform direct order entry and have access to the order entry system so that the sales staff can supply customers with order status information. Order tracking/status must be performed by customer and other field keys, such as date. The sales department would like to be able to maintain a three-year history of sales/orders on the computer system. One feature of a system that would greatly aid the sales department staff is the ability to electronically handle (create and fax on-line) return materials authorizations (RMAs).

The sales department is another area that requires many of the same computer-related capabilities as the personnel de-

partment. The sales department wants to have digital phones integrated into its computer operations along with remote capabilities for most, if not all, of their features. The possibility of utilizing videophones is also a real prospect for the sales department. One necessary feature is for the sales department to be able to refer potential customers instantaneously to distributors—for example, to fax the information to the customer and related distributor.

As far as product information is concerned, the sales department probably needs more access to a variety of product information than any other department within the company. Access to information such as inventory levels, order status, product description, part prints, pricing (accuracy is very important here), cost, sales history, margin, vendor, availability, and last price paid by customer is extremely important and valuable to the sales staff. Sales history needs to be maintained on-line for a period of three to four years. The company has approximately 7,000 sales orders per year.

The sales department, in particular, desires access to electronic data interchange (EDI) capability. EDI software allows businesses to send and receive information such as invoices and purchase orders with other business establishments.

General Issues

Once the interviews are complete and the departmental objectives and intended uses of all functional operating areas have been translated into technical specifications, the company needs to specify some general concerns related to all functional operating areas, the computer system itself, or to its best interests. What follows is a partial set of such issues:

- Because the company is considered a "small business," the business owner has decided that most proposals call for installation of a local area network (LAN) as a solution to its computer system problems. There are three common types of LANs that the company has decided to consider. The architectures of these common types of LANs are shown in Fig. 2. Individual machines in a bus architecture are hooked together by a contiguous cable. However, if the cable breaks, then all machines are down. In a ring architecture, individual machines are again hooked together by a contiguous cable, but if there is a single break in the cable, the network will continue to operate (essentially it becomes a bus architecture). In a star architecture, machines are connected individually to a hub, and if a cable breaks, only one machine goes down. The company prefers the "star or hub or spoke" LAN architecture as opposed to the "ring" or "bus" LAN architectures depicted in Fig. 2. Thus, the maximal length of a cable run from any of the hubs to any individual workstation and the maximal length of a run from any hub to the server (central computer) are of concern. The company also shown in Fig. 2 that it desires to have a "firewall" between the server that contains business information and the server that is going to handle its external communications, for example, its connection to the Internet. The firewall can be implemented in a number of ways, that is, using either hardware and/or software. The company has noted that servers and associated firewalls can also be incorporated into the other two LAN architectures (ring and bus) shown in Fig. 2.
- The company has some computer workstations, and would like to continue to use them in conjunction with other new equipment it may have to install.
- The company currently has computer equipment that it purchased from one company, and it purchased its current software from another company. This has caused headaches on numerous occasions when something has gone wrong with the computer system. The hardware company blames the problem on the software company, and vice versa. The business owner has decided that you want a single-vendor solution (in terms of both hardware and software).
- A key issue for everyone in the company is the maximal response time to any inquiry directed to the central computer system. Almost everyone has agreed that two to three seconds is the maximal length of response time by the central computer to any inquiry. However, the sales department has requested subsecond response time for reviewing current past prints on-line.
- Although vendors (their sales agents) are extremely gifted at talking about new releases of operating systems and application software, what really matters is the normal length of time from the announced release date (by the vendor) until the actual new release is installed on the clients' computer systems. Each proposal must address this issue, and the company plans to verify a vendor's claim with one, or more, of its current clients.
- A major concern to everyone who works for the company is the migration of data from the current system to the new system. How will a potential vendor handle this issue, how long will it take, how much data is to be maintained on-line (this affects ancillary as well as CPU memory requirements), how will data be archived, how much data is to be archived, and how will archived data be restored to the system? There are companies that offer archiving services (including off-site storage of archived data), and the company plans to investigate these as it follows through with its overall computer purchasing methodology. In some applications it may have to consider an "expert" to aid the organization in its data migration efforts. Although some of the staff can be of help with data migration, the business owner does not want to tie them up with a task that can potentially be handled much more efficiently by using an "expert." The owner also wants to know about recommendations from vendors concerning regular back-up routines (daily, weekly, monthly, complete system or partial).
- What type of ongoing support is available from vendors? Vendors will be asked to describe their support mechanisms (training, phone support, consultation) and associated pricing. Although initial pricing is of great concern, these are longer-term costs that must be considered.
- The company has a remote manufacturing facility in another state. It wants to be able to communicate with them (send them orders and part prints). The server have provided with the LAN for external communications will be the linking mechanism to its remote manu-

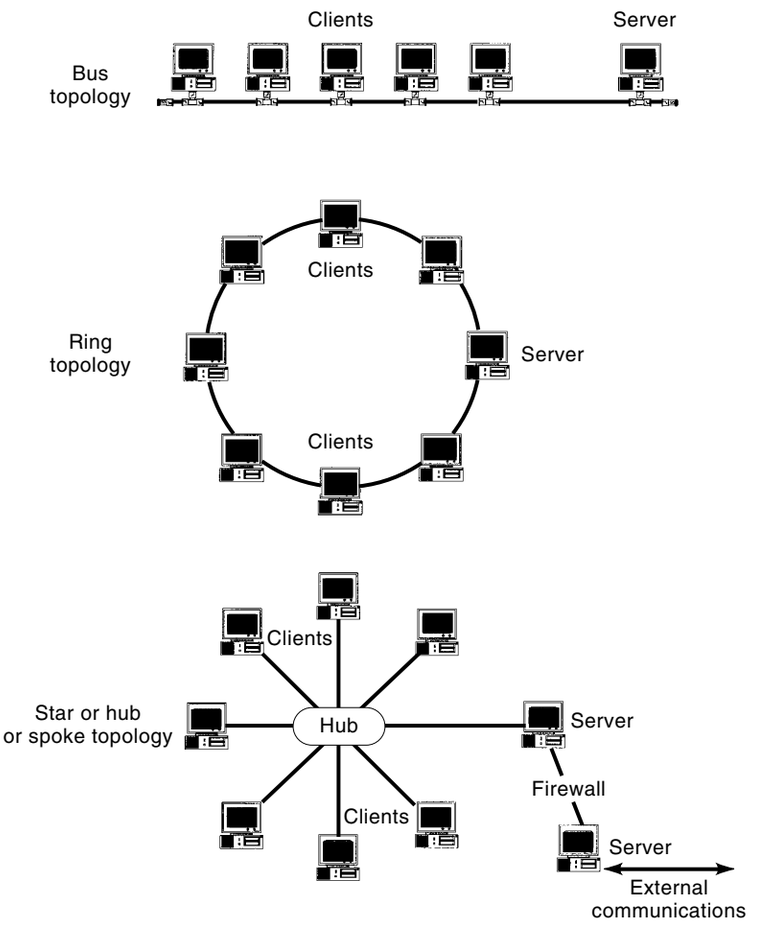

Figure 2. Three common types of local area network (LAN) configurations.

facturing facility. However, the company will have to consider appropriate hardware and software so that the remote manufacturing facility can handle communications with your central manufacturing location. This external communications server on your LAN will also handle email for your organization (whether actually on your external communications server or at a commercial server service).

- The company plans to allow itself approximately three months to develop the RFP. It is estimated that it will take another three months to get the RFP into the hands of the potential vendors, have them develop proposals, deliver them, and have them deliver their first set of onsite presentations to the staff. Thus, the company plans to make its vendor selection in approximately six months. It will announce its timing plans to the set of potential vendors in the RFP. This will eliminate dealing with many phone calls and/or e-mail messages from the set of vendors (after they have made their initial presentations) wanting to know when the company will make its final decision.
- The business owner and staff are very concerned about security and privacy issues. They want the vendors to describe the various security levels that their hardware and software provide and who in the organization will have access to various types of information maintained by individual staff members on their workstations. Not only are security levels and "access permissions" for individual users (perhaps at selected workstations on your LAN), wanted security for certain files and workstations is also needed.
- Once the new computer system is installed, the company does not want power problems and failures to cause trouble with the system or to shut the system down (so that information does not get totally fouled up). Thus, it wants the vendors to consider presenting plans which incorporate an uninterrupted power supply (UPS).
- Since the business owner plans to have e-mail and Internet services for the staff, there is concern about computer viruses infesting the new computer system. Thus, the company wants the potential vendors to recommend (and possibly install and maintain) the best antiviral software available as part of their overall proposals.
- Currently, the company has an employee who administers its computer system. Plans call for the person to continue as the computer system administrator. The administrator will need to hear from each potential vendor with respect to how administrative issues, for example, granting permission to users and recovery from computer system problems and disasters and crashes are handled by the proposed system.
- There is a very real concern about a vendor who may eventually go out of business. The reason for the concern

is that the business owner has read about the problems others have had when this occurs, and they are left with no source code (original programming code that contains the instructions for processing data with their systems) for the software that they are using. Although the company hopes to select a vendor who is financially stable, it wants to guard against the possibility of being stranded with no source code. Thus, it will want each potential vendor to have the most recent version of its source code held in escrow, where the company has access to it if the vendor ceases doing business for any reason (to be written into the final agreement documents, which the business owner plans to have double-checked with the attorney who handles such matters.

- As previously mentioned (several times), overall costs and cash flow are real concerns to the business owner. The company will have all vendors present their final quotations in two ways: cash price and lease price. In addition, the company plans to investigate its own leasing plan using the financial institutions with which the company currently does business.

STATUS OF THE COMPUTER SELECTION PROCESS

Although this case study may give the reader some insight into a portion of the work which typically goes into selecting a computer system for a small business, other factors enter into the methodology if the computer system is being selected for an individual user or for a large company. For example, when a large computer system is being selected, evaluating various operating systems becomes a very important issue. To evaluate operating systems for large-scale computer systems, one frequently used technique is "benchmarking." Benchmarking operating systems consists of putting together typical sets of user "jobs" (data) that are processed on the user's current computer system and then running them on potential vendors' computer systems. Time comparisons of operating systems software can be made using benchmarking, and also such things as report formatting, handling of input and output (sometimes handled on separate processors rather than on the one that handles the actual processing of information), and any difficulties with using a large-scale computer's job control language (JCL), that is, operating system programming steps (code) for having the computer system process a set of jobs, can also be evaluated. Another factor that requires consideration when purchasing a large-scale computer is the type of architecture required. Although a standard von Neumann architecture is the most common, there are alternative architectures available for use in solving more complex problems (in terms of time requirements and the amount of computation required) than those that can generally be solved using standard von Neumann architectures. Parallel computers (typically using arrays of von Neumann processors to attack parts of a problem simultaneously) are generally alternatives for these types of requirements. If the organization selecting the computer is required to process a large number of transactions (such as the New York Stock Exchange or banks using ATM machines and processing checks every day), then there are computers specially designed to handle just these types of tasks (labeled transaction processing computers). Notice that we have been considering global objectives and intended uses (the first step in Fig. 1). Once the global objectives and intended uses have been refined, the remaining steps in the methodology shown in Fig. 1 will guide the way for anyone interested in selecting the best combination of hardware and software to satisfy computing requirements.

If a computer is being selected for an individual, then the number of factors that must be considered remains considerable: monitor, CPU (including the desired chip manufacturer), cache memory, coprocessor(s), disk drives (style and capacities, external or internal), modem (speed, external or internal), external speakers (if the system is to be high-quality multimedia), printer(s), mouse, keyboard, CD-ROM drive(s), operating system software, application software, antiviral software (and a way to keep it current), utility software (to help manage files and recover "lost" data), e-mail service provider, backup procedures, browser software (for use with the WWW over the Internet), scanner (for importing documents and photographic materials to the computer), video cam (for visual contact during phone or videoconferencing), and adequate power supply (particularly if external devices need to draw power from the power supply located in the central computer). Other items which a buyer should consider purchasing are power strips (particularly if two or more external devices will require power) and a surge protector (for power problems, such as spikes, which can occur in some homes and in various regions of different countries). When purchasing a computer, an individual buyer must always remember to purchase the necessary cables to connect external devices to the central unit and to obtain the documentation for all of the products (some of the documentation now comes with the software that accompanies the related hardware or software component). Other concerns that an individual buyer must keep in mind are the expansion capabilities of the computer being purchased (amount of RAM and ports for connecting external devices to the central computer unit), and the practical limit on how far the computer can be upgraded as technology advances (using the Yes branch from the decision block shown in). However, it really does not matter who is selecting the computer system or what are its ultimate end use(s) because the methodology shown in Fig. 1 is always robust enough for selecting the best combination of hardware and software.

When personal computers became available in the early to mid 1980s, a number of books were offered to assist people and small businesses in selecting computers and associated components (4–8). However, since the late 1970s through the mid-1980s, few books have appeared to aid people in selecting computers and associated components (9,10). This may be because after the mid-1980s either people were educated enough to select a computer intelligently or almost everyone knew someone who was a "computer expert," and relied on that individual to guide them through the computer selection maze. Of course, a lot of mistakes were made by individuals and owners of small businesses, but the problems we usually resolved eventually. Large companies, large educational institutions, and governmental agencies had a better time of it because they had the luxury of groups working on computer selection problems. Members of these groups had a variety of backgrounds and experience from which to draw, and therefore better computer selection could be made for large

companies, large educational institutions, and governmental agencies.

Today, there are a variety of sources to which an individual or small business can turn when trying to select, upgrade, or repair a computer. Some of these sources are books (see, for example, Refs. 11–18). However, such books generally do not give the reader any information about a methodology to follow in making decisions, although some devote a few paragraphs to the process to be followed in making decisions. The books generally tend to detail various aspects of hardware and/or software products to be used with a computer system. There are also a number of magazines and professional publications that devote considerable space to advertising, promoting, and reviewing various products being offered by hardware and software manufacturers (19–25). Other sources that can be consulted include current issues of magazines that attract general readers as well as those geared toward readers in particular fields (26–28). Small business owners who decide they need a consulting service can search locally if they are in a major metropolitan area (in the Yellow Pages, for example), or they can search the WWW if they are located some distance from a major metropolitan area (29). An individual or small business user may be tempted to visit a store which specializes in computers to seek help in selecting a computer. This is analogous to visiting a car dealer to get help in buying a car. Such urges should probably be restrained until the involved users have done their homework.

There are two professional organizations that serve the computing community-at-large: the Computer Society of the Institute of Electrical and Electronics Engineers (IEEE Computer Society) and the Association for Computing Machinery (ACM) (30,31). Both of these organizations try very hard to include both academicians and practitioners from industry, education, and government. Their publications feature practical and theoretical information. For example, the ACM has 36 special interest groups (SIGs). These SIGs cover nearly every area that may be considered computer-related, including the Special Interest Group on Algorithms and Computational Theory (SIGACT), to the Special Interest Group on Computers and Society (SIGCAS), and to the Special Interest Group for Computing at Community Colleges (SIG3C). The interested reader is encouraged to consult a variety of the publications produced by these globally oriented organizations.

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COMPUTERS, ELECTRONIC ANALOG. See ANALOG COMPUTER CIRCUITS.

COMPUTER SIMULATIONS. See PHYSICS COMPUTING.

COMPUTERS IN MEDICINE. See MEDICAL COMPUTING.

COMPUTER SOFTWARE. See SPREADSHEET PROGRAMS.

COMPUTER SPEECH. See SPEECH SYNTHESIS.

COMPUTER-SUPPORTED COOPERATIVE WORK. See GROUPWARE.

COMPUTERS, VON NEUMANN. See VON NEUMANN COMPUTERS.

COMPUTER SYSTEM MONITORING. See SYSTEM MONITORING.

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COMPUTER SYSTEMS, FIFTH GENERATION. See FIFTH GENERATION SYSTEMS.