COMPUTER INSTALLATION AND MAINTENANCE

Computer installation is the process by which a computer system is configured and made operational. Since the inception of computers, the entire installation and maintenance process and the problems associated with this process have required wide attention in the computer user community. Many forms of computers—mainframe, minicomputers, and supercomputers with high number-crunching ability—have emerged in a brief period of time. More recently, standalone and networked personal computers (PCs) with multimedia facilities have arrived on the market. PC users who demand Internet access have encouraged the convergence of personal communications and PC-based multimedia technology. Laptop computers are as small as one pound and they can connect to the internet or local networks using built-in wireless adapters as well as built-in or add-in cellular adapter cards. Handheld communications devices can now connect to both wireless networks and cellular networks around the world to permit browsing the internet, examination and modification of documents and complete e-mail handling tasks. PCs are evolving from portable to mobile form, so that mobile computing uses portable computers at multiple places. Intranet (the use of Internet technology for internal purposes), extranet (the use of Internet technology for both internal and external transactions) and client–server computing configurations (where one machine, called a server, is dedicated to network support and control, while others run applications) and three-tier distributed architectures (consisting of desktop PCs, application servers, and database servers with maintenance of application software done on application server) are capturing the heart of the corporate world. All these forms of computing, which use divergent products that give rise to interoperability concerns, have made the process of computer installation both challenging and difficult. In this article, we will deal with installation issues of PCs, servers, and large systems Many users have a laptop that they use in the office building at work each day connected to the network via hard wire cable or via wireless access ports. Those same users take their laptop computers home at night so that they can continue to work from the comfort of their living room connected to the internet via wireless access points securely connecting to the work network via a secure connection to the company virtual private network server. A complete installation requires installation of hardware, software (both system and application) typically followed by rigorous testing. At the present time, application software implementation has mostly become easy with the wizard-driven automatic or custom installation. This article, will, therefore, discuss the installation of system software such as the operating system which in most cases is non-trivial.

There are three main stages in the entire computer installation and maintenance process: planning and selection, implementation and testing, and maintenance and testing. Sometimes poor planning, poor implementation, or poor maintenance efforts require one to go back to earlier stages or repeat the steps.

INSTALLATION OF PC'S

The installation of the most easily available and common form of computers, the personal computer, is discussed first. The DELL PC (a) is selected as the example model of personal computers (1).

Hardware

Vendors usually provide detailed installation instructions such as a step-by-step set of pictorial instructions to walk the user through the unpacking and setup of their new computer system. They often include "read-me" texts supplied with the machine, user manuals, or instructions that can be downloaded from on-line sites or contained in a set of vendor-supplied CDs.. These directions contain a detailed step-by-step description of the installation procedure.

PCs are easy to set up; many systems come with a complete suite of installed software that automatically set up the beginning configuration by asking a series of questions at initial startup. Configuration of small office or home networks used to be a major task as the specific configuration dependent parameters were challenging to initialize, now the small office or home network is simplified using an automatic wizard that asks a series of questions and based on the answers it generates a configuration file that allows other computers in the network to be configured to the network automatically. Compared to the rapid pace of development of PC hardware products, PC operating systems evolve more slowly. Therefore each new release of a PC operating system has to keep up with the rapidly evolving processor, peripherals, and hard drive capacities. Many business firms, in order to keep pace, have to upgrade or buy new systems with add-on features every three to four years. Usually hardware comes in a box including a mother board, a hard drive, a floppy drive, a DVD and/or a CD-ROM drive, and a power supply. To install the hardware, the installer has to connect this with a power cord to grounded wall outlets, as well as with various input/output units like a keyboard, a monitor, a mouse, a printer, a speaker system, and so on. A vendor-supplied program such as "System Setup" can be run to configure the hardware and save the configuration in memory. The program sets the date and time, establishes a password, and alerts the settings for other features. The entire installation and test process may take from a half hour to forty-five minutes to complete.

Before installation of additional components such as an add-in board, the computer should be turned off, the power cord unplugged, and the peripheral devices disconnected. When the cover is lifted, jumpers or switches may need to be set on the add-in board. Next, an unused expansion slot needs to be selected. The bracket for the expansion slot has to be pulled out, and the board can then be inserted into the slot.

Software

Since software can be easily copied and illegal copies can create problems, it is desirable to negotiate with the vendor the number of copies and the nature of the licensing contract for a particular software installation (2). For personal or home use, the vendors offer a home version or

single pack, which include a DVD or a CD, or an online address used to download the software from the internet, or a package of diskettes, a license to run the software on one computer, and a manual. For academic institutions, various types of licenses are available. A lab pack is suitable for installing the software in a laboratory environment: it contains CDs, DVDs or diskettes, a license to run the software on a limited number of machines, manuals, and teaching materials associated with the software. A network version contains a set of media, a license to run the software on a file server from a network, a manual, and teaching materials. A site license allows unlimited single or cross-platform computer use.

The PC system software installation is more difficult. Before installation of software, the system requirements and compatibility must be determined. The computer system must have sufficient memory to run the system software. For example, the hard disk memory requirement for Windows 98' is 300 Mbytes (MB). Software written for an Apple Macintosh may not be compatible with an IBM PC system. The operating systems are usually downward compatible. Thus, application software that ran on an earlier version of the operating system (for example, Windows 98) may still run on the latest version of Windows (for example, Windows XP), but the converse may not be true.

Software is often delivered on DVD media that can hold as much as 9 GB of data. Currently hard disk capacity is between 60 – 600 GB and RAM memory capacities are over 1 GB in new machines, program files and data files are copied from the optical media (DVD or CD) to the hard drive to make access time as fast as possible.

Device drivers are distributed with the operating system for most devices that can be installed on the system. As the operating system age increases, new devices that do not have driver files included in the original distribution of the operating system have their driver files available at vendor websites as well as on the Microsoft Update website. The user can also download new or different device drivers from various network services such as Microsoft OnLine or Spectrum and use these to run new and/or different devices on the system.

Most home PC users want Internet connection. The PC user needs a connection to the Internet via dial up modem, DSL modem, cable modem or satellite modem. The dial up connection requires a telephone line (with call waiting disabled), a modem and an internet service provider (the cost of which at present is between $5.00 – 20.00 per month), this gives the user a connection speed of between 14000 bits per second through 54000 bits per second. A DSL connection also uses the telephone line but the signals are piggybacked on the copper connection using frequencies normally above the hearing spectrum. A typical DSL installation requires filters on each phone instrument to reduce the high frequency DSL signals and improve voice communications. A DSL modem connects directly to the unfiltered phone line and provides a high speed data signal directly to a USB serial port or an Ethernet network port. The speeds available from a DSL modem vary from 256000 bits per second through 6000000 bits per second. Typically the speed of the connection from the computer to the ISP is slower than that between the ISP and the computer. Cable modems connect directly to a TV Cable and provide a connection of between 1000000 bits per second to a high end of 100000000 bits per second depending on the contracted service and the provider. The PC user needs a modem and a telephone line for connection to an Internet service provider. The Internet service provider supplies a usercode/password on its host machine. Academic institutions (for students and staff), commercial firms (for office workers), and commercial information services such as AOL can provide such access directly. The access is provided with Internet communications software, supplied by the access provider. The software is self-reconfiguring: when it is installed, it checks the computer system for standard equipment, modem, and communication lines and selects the required software settings. Specialized software is also needed for accessing and viewing Internet information based on specially designed texts and graphics.

Security Aspects in Installation

Providing security is important in every type of installations. The first step in safe computing starts with a strong password. This is especially true for the administrator password for the computer. It is not best practice to use the computer on a regular basis with an account set up with administrator privileges. The user needs to log out of the administrator account and log into the system using an account with user or power user access. The passwords for the user's accounts should be different and strong. Strong passwords use at least 8 characters; both upper and lower case letters, and numbers and special characters.

Software is not perfect. New exploits are found every day. Continual monitoring of update status is required to ensure patches are applied as soon as possible minimizing the time the implemented system is vulnerable to attack using newly identified attack strategies. Microsoft has now expanded their update monitoring system to include more than just operating system vulnerabilities. The new Microsoft update system [http://update.microsoft.com/microsoftupdate] as opposed to the older Windows Update system [http://windowsupdate.microsoft.com] provides automated updates to the entire suite of Microsoft office suite and development tools in addition to the Windows operating system. Other important update systems to use include the update system built into antivirus and anti spyware software packages, and update utilities built into other software packages running on your computer system.

We next discuss a few types of general security protection schemes as follows.

Antivirus

Antivirus software is critical for operating a computer connected to the Internet or any network. The viruses currently moving around networks and the Internet do not require active acceptance to gain access and control of a computer. In the past it was necessary to open an e-mail, program or file before the virus could infect a computer. In recent history, viruses have been constructed that do not have to be invited into the installed computer. They can

gain access to the computer even if it is just connected to the network and idling. Not only is it important to always be running an antivirus program in the background, it is critical to ensure the virus signature files are updated on a regular basis. This requires the user to have a current subscription to the antivirus update service. The cost of such a subscription is very small when compared with the cost one must pay to recover from a successful virus attack.

Antispyware

Antispyware is another tool that is virtually required for safe computing. Many software publishers and others selling goods and services on the Internet include snippets of code that tie into the installed system and keep track of critical information about the use of the computer. This information is then available to others when one browses to one of their websites or the snippet may even send the information to the outside user periodically without the users' knowledge. Spyware often clogs the user's computer to the extent that only a small percent of the available system resources are available to the user.

Spam prevention

Spam is unwanted mass mailing e-mails. It is an annoyance and a waste of computer resources. Avoiding it is becoming somewhat easier. The e-mail address of the installed system should not be published on the web. Getting an expendable e-mail address such as from mail.yahoo.com that one can discard and not worry about when the spam level gets too high on that account can be considered. On line form fill-up should be avoided to prevent lots of undesired e-mail. If the user receives an e-mail from an unknown source that has a provision to reply or go to a specific website to remove one's e-mail address from the mailing list – as a rule – one should not do that – it just notifies the sender that there is an actual person attached to that e-mail address that does not want additional e-mail. The fact that the user did respond and request to be removed from that list may happen but it is likely that one's e-mail address will be added to one or more even more persistent e-mail address lists.

House Cleaning is a standard form of maintenance in a PC environment. Periodic house cleaning will help the user's system continue to work for her at full efficiency. About every two weeks (or when the user notices a significant slow down of responsiveness) the user needs to delete the files in the system temporary directory. The temporary internet files and cookies need to be cleaned out periodically also. The exact instructions to do these in Windows-based environment can be found in http://www.personal-computer-tutor.com/deletingtempfiles.htm.

PC Installations—Windows and non-Windows

Various versions of Windows systems exist today. We only focus on two latest versions–Windows XP and Windows Vista in the present article.

PC Windows XP Pro Edition Installation

The same guidelines should be used when upgrading from an earlier version of windows to Windows XP Pro edition. The pro edition has much stronger security built in than the home edition. The encryption software is also much stronger in this edition. So Windows XP Pro edition can be strongly recommended over all of the previous Windows 9x editions as well as the previous Windows NT versions. Security of Windows XP Pro can be greatly improved by following the recommendations and recipes listed at the following URL: http://www.windowsecurity.com/articles/Windows_XP_Your_Definitive_Lockdown_Guide.html.

PC Windows Vista Installation

Windows Vista will be a much more complicated task to first decide on the particular edition of the software to purchase, the various versions have different hardware requirements and different capabilities. For example, Windows Vista Professional Edition includes extensive networking features not found on the home editions including a new PC fax and scanning utility.

Windows Vista hardware requirements for a system to run a reasonable set of applications simultaneously:

- A computer with 1.6 GHz or higher Pentium/Celeron or AMD K6 Athelon/Duron processor
- 1 GB of ram or higher (2 GB is recommended)
- 15 GB available hard disk space
- A video card with the ability of supporting Aero display and the WDDM with a DirectX 9 class Graphics Processor Unit with 128 MB video RAM (256 MB recommended)

NOTE: Windows Vista will run on slower, less capable systems but with degradation of display and responsiveness.

It is recommended that if one of the business editions of Vista is to be installed that prior to installation, a partition on the hard disk of 1.5 GB be established immediately following the primary partition where Vista is to be installed. This will ensure that the Bit Locker encryption system can be installed easily. When the Bit Locker encryption system is installed, be sure to save SEVERAL copies of the security key in both a machine readable file as well as a human readable file.

To transfer the files and settings from an XP or 2000 machine, use the file transfer program that is on the Windows Vista DVD. Do not attempt to use the File and Settings Transfer program that came on the windows XP or windows 2000 CD's to do the transfer to a Vista system. Both the old system and the new system need to run the same file and settings transfer program.

There are several other versions of Vista such as Windows Vista Enterprise for enterprise computers, Windows Vista Home Premium and Windows Vista Home Basic for home use. The installations of these may require different hardware configurations.[19]

Configuring the system to work with software the user has purchased and installed on another system that the user is replacing is not a trivial task and is a problem faced by many users. Users usually ask the question, "How do I move a software package that I spend a great deal of money on but I can't find the original disks?" There are utility programs such as Laplink's PC Mover software that will copy the files and if desired settings and software to the new machine. There is no real guarantee that the software will work on the new machine but the probability is high that it will work.

A non-Windows Installation: Linux

Setting up a non-Microsoft operating system such as Linux is not also a trivial task. Using installation program, Linux can be installed as usual, from a CD-ROM /DVD. Other alternative to such installation is a thin client installation where the operating system is loaded and run over a network connection. Linux has many distributions and Debian, Red Hat, SUSE, Mandriva are several common distribution systems of Linux, covering from desktop PCs, servers to supercomputers. Not all distributions are compatible; however, programs such as Alien are available for such compatibility. Linux is considered more secure and its open source and support of an active developer community makes Linux cheaper and easier to install.

For further details, refer to http://www.linux.org/docs/beginner/install.html or Linux Wikipedia versions presently existing on the Web.

Network Installation

A Home PC LAN Installation

Setting up a home PC network is relatively easy and many web sites exist that discuss this issue. See, for example, the following article: (http://www.linksys.com/servlet/Satellite?c=L_Content_C1&childpagename=US%2FLayout&cid=1114037291160&pagename=Linksys%2FCommon%2FVisitorWrapper).

Setting up a wireless network in a home/small office environment mainly consists of setting up the wireless router. Wireless routers have become very inexpensive permitting the establishment of a wireless access point at home allowing the user to use her laptop or other wireless accessories within home without having to be tethered to a network cable. It is critical that the user takes common sense precautions before she sets up her wireless network at home. If the user does not follow these simple precautions, she may be inviting others to join her network and possibly to gain access to her entire home network. First, it is important to change the administrator password on the router to some other password. Default setting is not desirable. Next, the SSID needs to be changed to a name that user selects – default setting is not desirable. Next, the transmission of the SSID needs to be disabled so that the new name is not periodically transmitted to all systems that may desire access. This will limit the access to those systems that know the SSID before they attempt to access the network. Next MAC address filtering has to be installed that tells the network's access point to allow only the devices with the specific MAC addresses specified to access the network. Finally a strong an encryption scheme is needed to be set up to support all of the devices. This is not failsafe or impossible to break into but it is much more difficult to access than the totally unsecured network that is probably next door. For more details, refer to (6).

INDUSTRIAL SYSTEM INSTALLATION

Installation of industrial computer systems requires more careful planning and thinking. As the computing needs of firms vary, many types of installations are possible.

Steps in Industrial Installation

The main steps in any industrial installation process are as follows (3):

1. Getting started
2. Organizational information distribution
3. Kickoff
4. Post implementation details

Getting Started: Pre- and Post-selection Phases. One expert has aptly remarked, "Careful planning is the key to a successful implementation" (4). This is the first step of the entire installation and maintenance process. It starts with the questions: what kind of computing need exists in the firm, and how best to satisfy that need within the allotted budget. A few other interesting questions that need to be resolved at this stage are "Should the installation be incremental or all-at-once?" "How should the installation and maintenance support be provided (in-house or out-of-house)?" As an example, careful planning ensured a smooth and steady implementation of a hospital computer system at Norwalk hospital in New York (5). The management went through two years of working and planning to define the scope of the system, hired a consulting firm to do an eight-month study, which resulted in a 700-page report on how to install the system successfully. The hospital then went for a careful step-by-step incremental installation. As another example of importance of planning, the Triangle Lawn and Garden case of computer installation can be cited (5). The computer system for the small firm was selected after a careful study that included considerations for benefits resulting from instant on-line information, cost–benefit considerations, and future potentials. Similar installed systems were analyzed and two systems were tested for final selection. The hardware, as well as the total accounting software, was selected from a turn-key system designer and installed. The installation ran into delays and problems as the support of the vendor/supplier was not calculated properly and the firm did not have enough in-house expertise to proceed on its own. Provisions for future expansion and exigencies also should be made at this stage and may include provisions of disaster recovery and redundancy. This is illustrated in the Mazda Motor case. The Japanese car automaker lost one of its two U.S. data centers in a natural disaster but quickly recovered due to the firm's policy of maintaining both on- and off-site

back-up copies of all its key files (5). In many firms, for example, hardware resource sharing (printers, modems, fax, CDROMS, hard drive space), multiuser programs, and data sharing, as well as email facilities, are considered essential. For these firms, a local area network (LAN) could be the best computing solution. If a firm has multiple branches spread over the nation, a wide area network (WAN) needs to be implemented. Firms with mobile employees working from remote sites may need additional infrastructure for mobile communications. Due to corporate downsizing, LAN systems (PC-, workstation-based) are proving to be the computing choice of corporate America. LAN environments are selected here as illustrations for industrial implementations. For a discussion of components of a mobile wireless network and its installation, refer to Ref. 6.

Before installing a LAN, the interconnection scheme, configuration type, cable type, etc., first need to be decided on. In a client–server mode, the server is a dedicated computer responsible for network support and control. In contrast, in a peer-to-peer system, all computers can run all programs; however, one computer still has to run the control of the network. The client–server solution is comparatively costly, but superior in performance and reliability and so more extensively implemented. The configuration is also important. A daisy-chain configuration is simple and low-cost, but fails all other machines in the chain when one computer in the chain is down. In a star configuration, individual computers are connected to the host, making the interconnection more costly, but the network less failure-prone. The selection of the configuration determines the type of cabling. Star networks usually use twisted pairs whereas a daisy chain may use thin or thick coaxial cable. Firms that use large-bandwidth information exchange may opt for fiber-optic cable. For interconnectivity purposes, most installers may prefer Ethernet. TCP/IP is the preferred choice of protocols at the network layer level. Another important pre-implementation selection item is the network operating system (NOS). Criteria and goals for selecting a NOS can differ widely for different firms. In a school, for example, the priority could be for a NOS that supports a wide range of changing users, provides easy use and easy administration of the system, and provides error-free functionality. Commercial systems such as the Windows 2003 server, or Linux can all deliver the service, but differ in price, performance, extendibility, and support functions. A library LAN may need to have multiple and simultaneous access to on-line information. CD-ROM support is essential in this case. A commercial firm may need to have a LAN that can provide access to the central database, both from outside and inside the firm, as well as to MS Office-like products by all employees. Remote facilities and sharing of MS Office software products may be essential in this case. The security issue is important to many firms. The NOS, for example, provides security with password verification, exception notification, and recording of detailed user log-in and activities.

Additional safeguards—an uninterruptible power supply (UPS) for the server, a backup system for automatically backing up all files on the network, and provision for having at least one computer to act in a standalone fashion—can be adopted to keep the network trouble-free.

Who is responsible for an installation? Usually, a steering committee is formed to provide the overall direction. Next comes the project team, which consists of people who will operate and control the system (operator/controller) and the end users. Focused user teams that are responsible for specific units of the firm and who have very specific information about the requirements of the units they represent are also formed and consulted. The implementation leader is typically the data-processing manager, who has in-depth knowledge about the technology and the firm. Additionally, one or more outside consultants are often hired to smooth out the technical problems. Vendors frequently provide installation and maintenance services for a fee. Additionally small firms that help in installation and/or maintenance have emerged. These firms have mobile vans that provide on-site service.

At this stage, after meetings of the various people associated with the implementation, an overall plan of implementation is drawn up.

Organizational Information Distribution. The entire organization needs to be periodically informed about the implementation. The workers have to be informed about the new environment, what it does for them, and how to use the system. New-user procedures have to be developed. Education and training programs have to be introduced.

Kickoff. A plan and a schedule of implementation have to be drawn up and maintained as far as possible. A time schedule is very important, as normal work may be disrupted and any delay in implementation may result in additional implementation cost. Documentation of the existing system has to be done at this stage, for two reasons. First, the implementation team should familiarize itself with the existing computing environment in order to provide to the user the continuing benefits of the existing system. Second, details on the numbers and types of disk drives, amount of memory, and workstation features help in making an easier transition to a new LAN system.

Installation. Once the hardware and software selection is made, implementation becomes less complex. The software implementation (operating system generation and loading) has in recent times become automated and easier. The hardware part of physical routing of wire, making the cable connections and inserting the network interface cards has to be done first. The hardware components must be of high quality for prolonged usage. The following components are ideally needed for wired LAN: network interface card (NIC), cable, NOS, server and workstation, power supply, tape backup system, and printers.

The server of a LAN is crucial for its performance. For details on Netware LAN servers refer to Ref. 8. For details on installation of another popular server, Windows 2003, refer to Ref. 9. For details on installations of a UNIX Workstation LAN server and Linux servers, refer to Ref. 10 and Ref. 11, respectively.

Large-Scale Computer/Software Installation. The installation of supercomputers and main-frame systems is more complicated and the process, from site-preparation (including air-conditioning or liquid cooling provisions, electrical arrangements) to testing, may take days or weeks (not hours). Similarly, large-scale software installation is

inherently complex in nature and depends on proper selection and design decisions. Take the example of a large software installation. Proper selection of tools and design techniques must be made, and testing of the modules both at unit, component, and integration levels should be conducted at an early stage. It is difficult to coordinate the activities of many developers without a careful plan and proper project management. CONFIRM was an application system project designed to integrate hotel, rental car, and airline reservation systems, and was jointly undertaken by Hilton Hotels, the Marriot Corporation, and Budget Rent-A-Car in 1988 (12). Five hundred technical specialists worked for more than three years at a total project cost of more than $125 million. The system was designed to run on two IBM 3090 mainframes. One of these hosted the central reservation system, the other ran a DB2 relational database on an MVS operating system for decision-support information. The two systems needed to coordinate closely. A Computer-Aided Software Engineering (CASE) tool called IEF was used to generate codes that ran on the MVS system. The other system used C language to develop the code. During installation, testing revealed that the two systems could not communicate well. The problems were estimated to require another two years to fix and the project had to be abandoned. Poor selection of development tools and methodologies was cited as one major reason for the failure. As another example of a large-scale computer application implementation, California's DMV project can be cited (12). In 1987, DMV initiated an SQL-based implementation running on 24 Tandem Cyclone computers. Applications were developed in COBOL and other fourth-generation languages. After seven years of work and at a cost of $44 million, the project was abandoned because the system could not be installed properly. Untested relational database technology, incompatible computer systems, and a lack of standards were cited as reasons for the project's failure. As many as 75% of all large systems are considered by many experts as operating failures. Poor design, inaccurate coding, inaccurate or incomplete data, and inadequate testing are some of the technical reasons for such improper installations. Various organizational, non technical factors also play a role in the success or failure of a large-scale computer project installation (12).

Implementations of recent complex software such as enterprise resource planning (ERP) and customer relationship management (CRM) are complex in nature and not always successful. A successful implementation of ERP systems, for example, poses many obstacles. Organizations can get restructured and initial productivity can drop. Involving every user of the system and developing a team attitude are essential components of success.(20) Project management issues, poor contingency planning and cultural and people issues may lead to an implementation and use failure, even if the software could be good (23). Large software projects are typically prone to failure or implemented with delays, less features and more expenses—and this rate could be as high as 80% (21). These take years to implement and may run into huge overhead costs, if not properly managed (Space database case). Several other reasons have been cited for such complex software design: unclear business objectives, project management problems (poor or lack of methodology, inexperienced project team), change management problems to name a few. Some recommend breaking up of a complex software project into smaller implement able parts. (22)

Nike, a leading footwear and apparel firm, for example, experienced a failure in supply chain software installation in 2001, which was a part of ERP system implementation (24). Lapses in project management, too much customization etc, were blamed for the failure. In 2004, the company was able to successfully implement its supply chain project. Many examples of such initial ERP implementation failures exist (22, 23). California State University (CSU) system failed to implement a PeopleSoft-based solution, Coca-Cola, after investing $10 million, failed to implement a SAP-based implementation, Cleveland State University system failed to implement a PeopleSoft-based solution, exceeding more than $10 million over the expected budget, Ohio State University system exceeded its budget for its PeopleSoft's implementation by more than $30 million and University of Minnesota exceeded its budget for its ERP implementation by more than $22 million.

Run and Test. Once the system is installed, it needs to be run and tested. Typically, one week may be needed for testing, trouble shooting, and reconfiguration of a medium-sized LAN. Twelve types of tests, like unit (checking every line of software program), component (testing functions developed by multiple developers), integration (testing to see whether multiple units/functions work together), system (testing to verify that the system will work), acceptance (testing for final certification), and so on, exist and some of these tests need to be conducted in the case of a LAN (12). A number of problems can be exposed by these tests. Successful implementation must take care of these problems.

In a LAN environment, for example, initial users may face problems with log-on; lack of compatibility of various LAN components obtained from different vendors may pose a problem; software errors may disrupt the system. Only careful and detailed testing can discover and eliminate these problems. Sometimes, computer network service providers can be contracted to start maintenance right after installation, especially if the firm lacks a skilled maintenance staff.

The use of add-on software for configuring a desired system is frequently required in computer system installations such as LANs.

End-User Training. Users need to be trained on network operations. The training sessions may last from a half hour to two hours.

Postimplementation Details. The post implementation part is concerned with the evaluation of goals set in the beginning and the extent to which these goals were met. Auditing is also done at this stage.

MAINTENANCE

The discipline that is concerned with the changes and upkeep of the computer system after implementation is known as computer maintenance (14, 15). The management and control of the installed computer system can be challenging in terms of both time and effort. Typically,

hardware maintenance consists of PC and network repairs (routers to user's systems), PC and network add-on component installation, and processor upgrade. Remote access (which allows someone to gain access to your computer from some other location) can be very useful in the maintenance of computers within a large organization. PC Repair technicians can sit in their workshop and log into computers connected to the network and effect repairs or examinations of systems anywhere else on the network.

Studies show that software maintenance is a very important part of the system life cycle in terms of cost and can account for 40% to 70% of the entire software life cycle. Software maintenance may consist of after-delivery modification of the software, correction of faults, improved performance and other attributes, or adaptation of the product to a modified environment. The term software in this context may mean not only computer programs, but also documentation (analysis/specification, design, implementation, testing) and operating procedures (instruction on setup, reaction to failures) associated with the program.

The *reliability* of a computer system is usually defined as the probability that the system performs successfully for a given time period. Limited reliability of the majority of general-purpose computer systems causes periods of downtime when systems are not available. The *availability* is defined as the probability that the system performs successfully at a given point in time. This probability can be estimated as the percentage of uptime over long observation periods. To achieve a specific level of availability for any application area it is necessary to provide maintenance of both hardware and software.

The concepts of reliability and availability are defined in the same way for hardware and software. However, maintenance of hardware and software differs in several ways. Hardware errors are caused by poor-quality fabrication or by wear out, while software errors are primarily design errors. If a hardware component does not perform correctly, it can be replaced with a new component. If a software component (e.g., a procedure or a function) does not work correctly, it usually cannot be replaced; it must be redesigned. The maintenance (repair) of software is frequently accomplished by its designer. By contrast, maintenance of hardware is normally not done by individuals who designed the hardware, but by service organizations. In maintenance contracts it is possible to guarantee a maximum time for hardware repair. In software maintenance contracts this kind of guarantee is usually not available. For example, no manufacturer of an operating system would give a guarantee that the product will be error-free, or that detected errors will be eliminated within a predefined time period.

Maintenance of computer hardware can be done by the computer manufacturer, by independent service organizations, or by the owner/user of the computer system. Local maintenance of computer systems by on-site maintenance personnel is used for large and sensitive computer installations, such as computer systems in military and governmental organizations, financial institutions, and online service organizations. In addition to trained personnel, such maintenance requires local storage of spare parts, and it is regularly quite expensive. Local maintenance can sometimes be reduced to routine preventive maintenance, and to substitution of parts that need periodical replacement. The availability of hardware can be improved by using redundant (parallel and distributed) components. Such systems are designed to remain operational when some components are down, yielding graceful degradation of performance level. Examples of such design concepts include networked systems supporting distributed applications, redundant arrays of inexpensive disks (RAID), and systems that apply mirroring/shadowing techniques. For such systems the maintenance of hardware is less critical and consists in replacing units that are not operational. In special cases where it is necessary to achieve extremely high reliability, it is possible to implement specially designed fault-tolerant systems.

Old and new machines may provide the same functionality but different maintenance prices. Old machines are usually more costly to maintain.

There are several quantitative parameters that can be used to describe the maintenance of computer hardware and software. The operation of each system can be considered as a sequence of uptime–downtime cycles. We assume that records of successive uptimes and downtimes are available, let Tu denote the sum of all uptimes, and define the mean time to failure (MTTF) as the average uptime. Similarly, Td denotes the sum of all downtimes, and the mean time to repair (MTTR) is the average downtime. The average length of an uptime–downtime cycle is the mean time between failures (MTBF). Hence, MTBF = MTTF + MTTR. The MTTR can be further decomposed as the sum of the mean wait time and the mean repair time of the maintenance service. The mean wait time is defined as the time from the moment a fault is reported to the service organization to the moment when the service person arrives and starts repairing the system. This parameter is usually specified in maintenance contracts. The steady-state availability can be defined as $A = Tu/(Tu + Td) = \text{MTTF}/\text{MTBF}$.

A standard way to reduce maintenance costs is to share the maintenance service among multiple computer users. In such cases it is necessary to precisely define the required quality of service, and to provide legal protection through an appropriate maintenance contract. The first step is the evaluation of the expected quality of maintenance service, based on a variety of parameters. These include statistical parameters of the uptime achieved by the maintenance service for a similar type of user.

If the maintenance is provided by the local branch office of a hardware manufacturer, then the relevant components for evaluation include the maximum wait time (e.g., a few hours, or the next working day), the possibility of maintenance after normal working hours (night, weekends, holidays), the number of trained service personnel per installed system, the location of the spare part storage and the spare part access time, the availability of external help when the problem cannot be solved by the local office, and some legal and financial warranties (e.g., the warranty of the availability of maintenance over a given time period, the responsibility for accidents and insurance against losses caused by maintenance problems, and the warranty of limited increase of maintenance costs for a given time period). The

maintenance service can sometimes be supplemented by the availability of backup systems.

In the case of software (both system software and application software) the repair of software can be defined as adjusting it to meet specifications and correct design errors, improving it to satisfy performance requirements, debugging and error correction of the code, or just reinitialization (to clear an error caused by a particular input and/or system state). Software errors are defined as system failures that are traceable to underlying software faults. Some special software systems are considered unrepairable because (as in the case of air traffic control systems) downtime for repair is not available. In the case of repairable systems the software repair is defined as restoring the system to operation. This process includes the recognition of the problem, identification of the error, correction of the error, testing of the correction, and reinitialization of the system. Software maintenance service is supposed to remove software faults. The available maintenance levels of service can be expressed through the period of time the software manufacturer guarantees to remove a detected fault. Usually this can be a fixed time period (backed up by penalty payments), or a warranty of immediate consideration but without time commitments and penalty payments.

The yearly maintenance revenue generated by US firms is impressive: According to one estimate, it reached US $23 billion in 1993 (16). Five major players in this maintenance business are IBM, HP, Unisys, DEC, and AT&T, which shared most revenue earned in the US in this business.

Maintenance Contract

Maintenance contracts should be carefully designed to achieve the necessary quality of service and control the maintenance cost. It is reasonable to request that the maintenance contracts relate the cost of maintenance to the measured availability of computer hardware and/or software. In such cases the nominal maintenance cost Co should correspond to the nominal availability A_0. If the maintenance service achieves availability above the nominal value, it is rewarded with extra payment according to a cost formula. If the achieved availability is below the nominal level, then the maintenance payment is reduced. An example of a linear cost formula is $C = Co[1 + R[A - A_0]]$, where R denotes the reward-penalty factor. If $A_0 = 0.9$ and $R = 2$, then a maintenance service that achieves $A = 0.96$ will get $C = 1.12C_0$ (a 12% reward). Similarly, if the achieved availability is only $A = 0.8$, then $C = 0.8C_0$ (a penalty of 20%). The parameters Ao, Co, and R are specified during contract negotiations. The maintenance contract can contain additional conditions (e.g., the maximum penalty can be limited), other (possibly nonlinear) cost formulas, or other parameters (e.g., a reward based on the mean uptime and penalty based on the maximum downtime).

We have touched upon the complex issue of computer maintenance from a technical point of view. For a detailed study involving organizational issues that affect maintenance, like policies and strategies of the host organization, best maintenance management techniques, staff selection, and development, etc., refer to Ref. 18.

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