Introduction to Thin-Clients
The latest trend in computing is towards centralized management of applications and resources. It is like older huge mainframe based installation, running Unix like multi-user operating system. Mainframe systems had enough Memory, Storage space and processing power for many users. All the applications and data generated by users used to remain on the server. Users used to issue commands from the character-based terminals having lower processing power using slower communication media like telephone line on RS232C serial protocol.

In Thin-Clients based installation too, Applications and data are stored on the server rather than the individual machines. Thin-Clients use different chunks of memory and processing power of the server that they are connected to, while facilitating services to users. In contrast to older technology, it has colorful visual interface that can be operated through keyboard or mouse & Fast Ethernet protocol to access server over 100 Mbps network media. When a user logs on to the server from any of the Thin-Clients, server provides him with his/her desktop environment. We can restrict the accessibility of various applications. User sees only the applications he is authorized (by administrator) to use. Application’s accessibility and desktop-environment can be tightly monitored and configured by system administrator.

It seems the age-old adage, ‘history has a strange habit of repeating itself’, holds true even in computer technology though in a slightly different form even.

WHAT IS THIN-CLIENT?

For a novice a Thin-Client is nothing but a slashed PC devoid of CD-ROM player, floppy drive, add-on cards and hard disks. These devices can be managed centrally. Since all the applications are run on the central server and not on the Thin-Client they don’t require powerful resources on themselves. A Thin-Client is many folds cheaper than a PC.

Now, let us discuss why Thin-Clients are called “Thin-Clients”:

- The name seems to have been derived from the fact that the basic operating system/kernel of this device (to access all the I/O devices, memory management and handling all the processes) is embedded in a size of not more than 32 MB, which is real thin.

- Another reason may be - it is really sleek in look because almost all the electronics are on a single, small motherboard packed in a book-size plastic or metal case. If you compare it with PC that is also known as Fat-Clients it is comparatively small due to absence of many accessories.

- Another philosophy says that all the devices using less bandwidth over communication media (e.g. LAN, Wireless network etc) are known as Thin-Client. Because it takes less bandwidth to transfer the information.
Considering the physical shape & size, Thin-Clients are of mainly two types namely Desktop Thin-Clients and Tower Thin-Clients (Fig. 1.1).

However, we can plug in many types of peripherals into these Thin-Clients. At Air Port kiosks, people may plug in magnetic stripes readers, fingerprint readers, printers and so on. Building all such functionalities made the Thin-Clients into a relevant solution for such places.

In some technical literature we found that the term “Thin-Client” is also used as a synonym for both NetPC as well as the Network Computer (NC), which are somewhat different concepts.

Thin-Clients are generally based on Cyrix processors. The NetPC is based on Intel microprocessors and could be further classified into two groups. First one is WBT i.e. Windows
based Terminals which uses Windows CE kernel and software. The other one is LBT i.e. Linux base Terminal which uses embedded Linux as its kernel.

The network computer (NC) is a concept backed by Oracle and Sun Microsystems that may or may not use Intel microprocessors and uses a Java-based operating system.

**HOW DOES THIN-CLIENT WORK?**

Now, let's discuss the basic question as to how our Thin-Clients work as PCs when they don't even have enough memory or hard disk.

The answer lies with the standard feature present in the server based operating systems called Terminal Services. Using these services and standardized display protocols, the Thin-Clients are able to communicate with the Server and run desktop applications even without having much of hardware on themselves.

But before discussing the Terminal Services, let's look at the brief history of Terminal Services, which gave way to a low cost, secure and single-point administrative network.

**TERMINAL SERVICES**

It was Citrix Systems, which proposed the idea of multi-user version of Windows to Microsoft. As a result, Microsoft agreed to sell them the Windows NT 3.51 source code. Citrix then turned this into Citrix WinFrame:- a version of NT 3.51 that allowed multiple users to run on the same server. Later Microsoft incorporated this new technology into a special version. That is known as NT 4.0 TSE (Terminal Server Edition). Now they have incorporated Terminal Services in all versions of Windows Server Operating System.

The Terminal Server version allows the access of all ‘Windows’ software under Client-Server model. Users log onto the server using Thin-Clients and the server creates sessions in its memory dedicated to those users. The server (instead of the client) thus processes all the requests made by the user.

**THIN-CLIENT MIDDLEWARE**

Thin-Client middleware is a software layer that sits between the application running on the server and the screen on the client device. This middleware layer transforms the information on the server into a proprietary protocol. The information then passes through proprietary compression and encryption algorithms and is sent to the client device where it is decompressed, decrypted and displayed on the screen.

**THIN-CLIENT ARCHITECTURE**

Thin-Client implementation has a 3-tier architecture (Fig. 1.2) in which

- The Thin-Client hardware is at the 1st tier,
- The server at the 3rd tier and
- The terminal services at the 2nd tier acting as the binding layer.

Thin-Client implementation follows the Client/Server model.

- Thin-Clients may be physically connected to the server via UTP cable or a PSTN (through modem), but the logical connection between the Thin-Client and the server takes place via TCP/IP protocol. TCP/IP is a point-to-point protocol. Both Thin-Client and the server are assigned unique IP addresses and flow of data packets between the two takes place using these IP addresses in combination with the MAC Addresses.
Well, the MAC (Media Access Control) address is just a 16-bit Hexadecimal code engraved into the NIC (Network Interface Card) of the device.

**Fig. 1.2:** Thin-Client Topology.

- The communication between Thin-Client & the Server takes place using Terminal services running on the server with the help of communication protocols like RDP (Remote display protocol) or ICA (Independent Computing Architecture). The RDP and ICA are display protocols that run over TCP/IP protocols. They have a client as well as a server portion running over the Client and the server machines respectively. In case of ICA, the server portion is called CDS (Citrix device service). All the keyboard & mouse movement are captured by the client portion of these display protocols and transmitted to their counterparts running on the Server machine. The server portion of the display protocol interacts with the Terminal services for processing the inputs made by the client and the output of the processed request is sent back to the client portion of the display protocol running on the client machine.

- The terminal services responds to the connection initiated by server portion of the display protocol by opening an independent session. When the client inputs any keystroke or a mouse movement, the terminal services open a virtual channel through which the client communicates with the server. This channel runs by allocating memory space and CPU cycles for itself, which are independent and discreet of other virtual channels simultaneously running on the server. The allocation of resources depends on the kind of applications used by the clients as shown in Fig. 1.3. This sliced yet independent allocation of resource pool keeps the logged in user unaffected even if a process has crashed in some other virtual channel opened for some other user.
When the user logs on to the server, it checks for the user’s validity by checking its security database. In case of Windows 2000 server, if it’s in domain controller mode i.e. when using active directory, it checks for the file called “ntds.dit” for users’ authentication. And if it’s in a normal mode, the file named “sam” (security accounts manager) has the users’ authentication information.

Once the user has been authenticated, its profile and location of home directory is activated and the same is transmitted to the Terminal Services, which in turn sends them to the TC using display protocol. If a particular policy for user permissions/restrictions has been activated on the server it also gets enforced on that user. The server allocates as well as also helps user access other resources across network like printers, scanners etc.

**BENEFITS OF THIN-CLIENT IMPLEMENTATION**

Before we move on to technical discussion of the Thin-Clients, let’s see the main advantages of Thin-Client implementation. We will discuss this topic under following headings.

1. **Total Cost of Ownership (TCO)**

   The most convincing factor for Thin-Client adoption is Total Cost of Ownership (TCO). Senior management often gives preference to cost measures. Below is the comparison of TCO between a PC based installation & a Thin-Client based installation:

   - The initial hardware acquisition cost of a Desktop PC is at least thrice than the Thin-Client.
   - Administration, management, maintainability and helpdesk cost associated with installation using Thin-Clients is comparatively less than that of using PCs.
   - Compared to networked PCs, Thin-Clients offer simple installation & administration. It also eliminates upgrading the desktop hardware frequently.
   - Percentage of data loss at client end is nil.
   - Downtime (due to hardware failure) is very less compared to a Desktop PC.
   - Components which cause most of the problems in desktop PCs are HDD, CD-Drive, FDD, OS, virus infection, software updating. Such problems gets minimised in a Thin-Client based installation. It slashes running cost by large fraction.
INTRODUCTION TO THIN CLIENTS

- Fewer technicians with Administrators having sound knowledge are enough to maintain a set of Thin-Clients as compared to an equal number of PCs.
- TCO will go down by many factors if you use Thin-Clients in Unix environment. It’ll further go down if you use it with FreeBSD or Linux like ‘Open Source Operating System’ running GPL software e.g OpenOffice, GIMP, Postfix MTA, Apache etc.

All other factors being discussed below will further lower TCO in one-way or the other.

2. System Security

At places where the public can walk up to the device like airport kiosks, we wish to have security that protects the server from a hacker and lets the right people through. In such cases, Thin-Clients may provide great relief to the System Administrators. There are Thin-Clients available in the market with such strong security features like smart cards and biometric fingerprint readers, which operate as authentication tools. If all the above three features - username and password; smart cards; fingerprint readers are enabled, the Thin-Client setup would be almost foolproof.

As neither data nor application resides on user machine, there is no local security threat. Another aspect is that ICA and RDP protocols encrypt and compress the data being transferred. Due to which sniffing data out of the transport media can be overruled easily. In thin-Client based installations, Administrator configures the most restrictive permissions and profiles of a user. He gives rights as and when user’s requirement arises.

3. Centralized Administration

Resources like storage space, printers, scanners and the authorization to use applications can be administrated from a single location. It gives a lot of flexibility, saves time, aids faster implementation, increases productivity and gives user satisfaction. For example, if a user adds a Laser printer with his Thin-Client, administrator need not go to his/her workspace to load the required driver. Administrator can install the Laser Printer driver on the server from his seat. Later, the installed printer can be configured and appropriate permissions shall be granted to the user. Administrator can give or revoke permission for any user at any time without leaving his seat.

4. Software Upgradation

What’ll happen if we are using desktop PC in place of a Thin-Client in following cases?
- Deployment of new software
- Upgrading software to a newer version
- Applying service packs, patches & Hot Fixes
- Backup and restoration of user’s data and applications

If we have to do the above said jobs for 100 users, it will take quite a long time in implementation and out of which most of the time in traveling from one user to another. These jobs are such in nature that they should be finished at the earliest possible time. Suppose you are implementing or upgrading application software, all the users must access the same version of application simultaneously. Otherwise data may become inconsistent. This is true in case of service packs & hot fixes as well. Therefore, either upgrade all desktops at once or postpone for later suitable time. Similarly, if backup is not centralized it would require more time in taking backup of every individual PC.
In case of Thin-Client based installation all the above can be done at the server end itself. Looking at these cases, we can conclude following benefits

- Saving deployment time
- Saving Man-hours
- Increased overall system availability
- Increased user satisfaction level
- Increased productivity
- Efficient and maximum use of resources
- Ease of manageability
- High Data security
- Ease of deployment of new system policies

5. Remote Control of Users Desktop

One appreciable feature of terminal services is that you can remotely control the users’ desktop. This may be beneficial in the following ways-

- Helping users in resolving their application or OS related problems. Let us say a user is unable to find a particular address in the address book of his Mail Client. The administrator can take the remote control of user desktop and demonstrate the solution. This way, user is empowered to tackle similar problems in future.
- Spying the user activity. For example, proxy server report shows that a user is accessing an unsolicited site. He can be caught red-handed.

6. Data Security

One of the major concerns of any organisation is the security of critical data. This can be easily achieved by Thin-Client based implementation in which the data resides only on the central server and permissions can be granted as per the requirement. The data cannot be transported without the administrator’s permission, as Thin-Clients do not have Floppy drives attached to them. This also relieves the administrator and the whole network from Virus infection through users’ Floppies.

In case of Desktops, backing up critical data of the users, is also a major headache. A backup administrator have to backup each and every machine but in Thin-Client technology the whole data lie on the server and the administrator can backup the data of all the user at a single location. Consequently, we can restore them back in a jiffy.

Administrator may take daily backup on removable media (like 20/40 GB magnetic DAT media or non-magnetic virtual tape drive devices) or schedule automatic backup on on-line storage devices such as NAS or SAN. In view of the USA 9/11 attacks wherein there was huge loss of valuable data, we all understand the importance of data loss.

7. Maintainability

All the system resources, authorisation & accounting are centralised. Not only this, in most of Thin-Client we can upgrade firmware, change IP address, add or modify users, take profile backups, restore settings from server console. This slashes the maintainability of
hardware and Operating System by a large fraction. This can be done with the management software provided by Thin-Client manufacturer.

8. Scalability

Scalability is excellent, provided we have taken care of it at the time of deployment. If we have sufficient server resources and extend the existing network for more hosts, adding additional Thin-Client is a cinch. Plug the Thin-Client on to the network, assign IP address, and configure ICA or RDP to finish the Thin-Client side configuration. On server you have to create new user and register additional licenses, if required. Neither user nor administrator has to think about OS and Application software to be loaded on hosts as in case of PCs.

9. Availability

Thin-Client based setup availability is very high in comparison to server-client based installation or peer-to-peer installation due to following reasons:

- Thin-Clients don’t have components like Operating System, Hard Disk, Floppy Disk, CD-ROM etc, which cause most of the problems. So failures in Thin-Clients are much lesser than that of PCs.
- In case of replacing Thin-Clients, we don’t have to load any additional software on host end.
- Comparatively very few shutdowns are required in Upgradation & patching.
- Downtime due to data loss can be minimized to zero.
- Almost all problems related to software configuration can be sorted out thru remote administration.

10. Virus Protection

You neither have to load virus scanner software (on each user workstation) nor have to update virus definitions time to time. Just updating the central server will solve the purpose in case of thin-Client based installation. It will save money as well as time & reduce the virus infection risk also.

11. Training

User definitely need not know about application loading and configuration. There is no client part, as such. Training requirement is also not much because Thin-Client setup is simpler than desktop. Leave the user to work on applications and provide assistance remotely as and when required. The low cost and ease of installation gives us the flexibility to replace the failed device quickly with ease. No data is lost even when Thin-Client crashes, as all data resides on the central server.

SCHEMA OF A SAMPLE NETWORK

Before further discussion, we introduce you to a sample implementation of Thin-Client based network (Fig. 1.4). It has all the basic components like Thin-Clients, printers, Windows Server, Linux Server, License Server, Gateway, Print Server, Network Attached Storage and a Fax server.
In the above diagram, the Thin-Clients are networked via ‘Terminal Services’ (TS) on Windows and Linux server. The License Server of the TS enabled Windows server is a different machine in this diagram. Both can be combined on a single machine, too. These servers in turn are connected to Internet via Gateway. Several other resources like Print Server, Fax Server and Network Attached Storage also connected to the network. We have introduced this network at this stage of the book to familiarize you with it coz the same would be referred very frequently in later stages of our discussion.
BASIC REQUIREMENTS OF THIN-CLIENT IMPLEMENTATION

The basic requirements of Thin-Clients may be categorised as:

1. Server

The first & foremost requirement for Thin-Client implementation is a machine that will work as ‘Server’. It would facilitate the Thin-Clients to behave as PC so that the user won’t know whether he is working on a PC or a Thin-Client. The Server hosts Thin-Client sessions connected to it. Because of the tremendous technology advances in the last few years in entry-level machines, many installations will not even require a true server class computer. The computing requirements for ‘lighter’ applications (Excel, VB Applications, etc.) are even lower. The main requirement is that the servers must have enough memory to handle the sessions.

However, to find the exact requirements of the server, we must first analyze the types of users and the kind of applications they would be accessing thru Thin-Client.

There are mainly three types of users:

- **LIGHT USERS**: These users usually run 2-3 applications like word, excel, power point and at most some mail access client.

- **MEDIUM USER**: These users are more enthusiastic users who like to work on 3-6 applications simultaneously.

- **HEAVY USERS**: This class of users is most demanding that they want to work on more than 6 applications involving graphics & multimedia applications and which require a lot of processor time.

(i) **RAM.** The server requires a minimum of 150 MB of RAM to run the operating system if it is Windows 2000 server. The minimum RAM requirement to run users’ processes is approximately 15 MB per user. This also includes RAM requirement for running the Server Portion of Display protocol.

(ii) **APPLICATION REQUIREMENTS.** The 32 bit applications like MS-word, PowerPoint requires 2-4 MB of server RAM per application.

The 16 bit applications run on Windows server by opening up a WOW (Windows on windows) as the OS is a 32 bit. In other words WOW is a kind of emulation platform for running 16-bit application. These applications require a minimum of 4 MB for WOW and another 2 MB for itself.

(iii) **PROCESSOR.** The average number of users supported by a single P-III, 500MHz processor is approximately:

- Light users : 60
- Medium users : 40
- Heavy users : 23

(iv) **HARD DISK.** As the cost of storage byte is reducing day by day, one could plan in advance whether they need RAID-5 or RAID-1 for redundancy. It is recommended that the OS be allotted a minimum of 8 GB space. And depending upon the data generated by the users, the storage capacity may be scaled.

**Example:**

Considering there are 100 users out of which there are 30 light users, 50 medium users and 20 heavy users who are to be connected to the Server running Windows server using Thin-Clients. We further assume that the users are running three 32-bit applications and one 16-bit
application, whereas the medium users are using six 32-bit applications and two 16-bit applications. The heavy users are running eight 32-bit applications and four 16-bit applications.

**Note:** We have increased the number of applications for medium & heavy users in comparison to the light users considering the analytical calculations involved & the processor requirement by the applications used by such users.

Now we can calculate the RAM requirement for the server as below:

(a) For OS : 150 MB
(b) For light users : $30 \times 15 + 30 \times 3 \times 2 + 30 \times 1 \times 4 = 750$
(c) For medium users : $50 \times 15 + 50 \times 6 \times 2 + 50 \times 2 \times 4 = 1750$
(d) For heavy users : $20 \times 15 + 20 \times 8 \times 2 + 20 \times 4 \times 4 = 940$

The total RAM requirement for the server is $= (a) + (b) + (c) + (d) = 4$ GB (approx.)

(v) CPU. Let’s consider that all the users are medium users. If we refer to the Processor requirement given above, we can conclude that:

One P-III, 500MHz processor can support = 40 medium users
So, 100 medium users can be supported by $= (\text{Total 100 users})/(40 \text{ users per processor})$

$= 2$ processors

Then, to implement Thin-Clients for 30 light, 50 medium and 20 heavy users, the server we require a minimum of two processors (P-III, 500 MHz) and 4.0 GB RAM.

### 2. Operating System

For the implementation of Thin-Clients, the Operating System running on the server machine should support Terminal Services. This could be a LINUX, Windows NT 4.0 terminal server edition, Windows 2000 Server or Windows 2003 Server. Terminal Services enable the users to avail the multi-user feature of Windows Operating System in true sense.

### 3. Licenses

The most important part of this discussion is licensing. If you are going for the Linux based solution then licensing is not a big issue as it’s an open source product. But for windows based implementation licensing is a real big concern as MICROSOFT is very stringent about its licenses. For windows based solution, we require two kinds of Licenses for every Thin-Client.

1. CAL (Client Access License)
2. TSCAL (Terminal server client access license)

The TSCAL licenses must be registered on the Microsoft site before integrating Thin-Clients.

### 4. Thin-Client

The final component is the Thin-Client itself, and this is where decisions must be made. We can use even the old PCs (having processor as old as 486), with 4 MB RAM, hard disk just capable of loading the Win 3.1x, NIC card and a monitor for our use. Alternatively, we could go for the commercially available Thin-Clients, which come at a price as low as 12000 INR. Few of Thin-Client brands are Itona series of VXL, Evo series of HP and Winbee series of HCL.

### 5. Communication Protocol

For Thin-Clients to talk to the server, the communication protocols must be supported on the Thin-Client as well as the Server machine. The popular firms providing such protocols
are Microsoft and Citrix. Microsoft provides RDP (Remote Desktop Protocol) for client / server communication and Citrix provides ICA (Independent Computing Architecture) protocol to use Terminal Services. These are well supported on Windows platform. There are few other less popular third party protocols too. We may prefer to use RDP because it is from the same company that develops Windows Operating System. Not only this, you don't need to install server portion on your Server separately, to support the protocol. For example to support ICA protocol, you have to install Citrix Device Services (CDS) package (discussed in later chapters) on Windows 2000 Server for basic facility. For advanced features you must go for Metaframe series of product on Windows 2000 & Windows 2003 Operating System. CDS must also be registered at Citrix site before use.

To access Linux Server, Thin-Clients must support X-protocol, XDMCP (X Display Manager Control Protocol) or VNC (Virtual Networks Computing) clients.

To access Windows server's desktop from a PC, we have to install appropriate client portion for the protocol on your PC. Microsoft has a software client available for free on their website called TSAC (Terminal Server Advanced Client). It is simply an Active-X plug in (COM object) that allows us to run Terminal Services sessions within Microsoft Internet Explorer Web Browser. Alternatively we can create the client program (from Windows Server Operating System) using Terminal Services Client Creator.

WHO NEEDS THIN-CLIENTS?
Thin-Clients provide lower ownership costs and offer improved manageability, stability for the enterprise. Thin-Clients are ideal for companies that seek to improve application deployment, decrease hardware maintenance, simplify their architecture and reduce the strains on their IT staff.

Thin-Clients are for

- Firms that require a highly reliable network of computers connected to a centralised server running mission critical applications. Education Institutes, Publishing industries, Hospitals, insurance agencies, airline reservation centers, hotels etc. are typical businesses that fall into this category.

- Information accessing and data acquisition thru a web-based interface (with bare minimum facility) is an emerging scenario. In this case we need not configure any protocol to access an Operating System Desktop. Now a days all the Thin-Clients based on Linux or other open source kernel come bundled with browsers like Mozilla / Netscape / FireFox. Those based on Microsoft Kernel come bundled with browser Internet Explorer. Travel agencies, supermarket, medicine counter, fast food restaurant etc are few areas where this type of requirement may arise. But you need to assure two things before going ahead:
  - The web browser of Thin-Clients has plug-ins to access your web server, e.g macromedia flash plug-in to show pages having flash pictures; Java related plugins to access JSP pages. It is strongly advisable to check the Thin-Client product for such features before buying. Browser capability varies vendor to vendor & product to product.
  - Printing may be a big headache if you are accessing your web page thru Thin-Client browser. Chances are that only ASCII documents would be printed on your generic printer.
• Firms that utilize highly standardized computing tasks, like call centers, data entry jobs or technical support desks can realize substantial cost savings from Thin-Clients. The computing power and flexibility of a PC is often unnecessary and potentially undesirable as end-users can reconfigure, load applications or otherwise tamper with the computer's settings.

• Educational institutions are examples of typical concern that require more computing resources and at ever-shrinking budget. Universities and schools with under-resourced IT infrastructure can keep hundreds or thousands of Thin-Client devices up and running with latest softwares.

• Call centers, transportation, retail, hospitality, health care, government, broadcasting, content creation, chemical manufacturing, drug companies are quite a broad spectrum of Thin-Client use.

• Fortune 1000 firms with aggressive cost cutting agendas can help reach their goal with Thin-Clients. IT managers are challenged daily to do more with less budget. Most firms can realize tremendous cost savings by reducing the amount of support staff from 5:1 if they use Thin-Client in place of PC. Thin-Clients enable network administrators deploy new systems in rapid fashion because a Thin-Client can be set up and made functional within 15 minutes. Firms that are used to old-style character-based “dumb” terminals would like to upgrade to a more robust, colorful GUI platform available with Thin-Clients. It can handle email access programs (Outlook Express, ThunderBird) and common business applications (OpenOffice, MS office) while retaining access to legacy application (by using some terminal emulation program).

Thin-Clients are not for
The same aerodrome can’t be used for Fighter Planes, Passenger Planes and helicopters. It is also true in technologies too. There are situations in which using Thin-Client based setup is not advisable, at least practically. These may be categorized as -

• If intended users fall in power user categories then better to provide them desktop PCs, workstation and Laptops instead of Thin-Client. Design engineers, scientists, graphic artists, multi-media developer, Animation industry professional, web designers, marketing and sales professionals etc have requirements for powerful local processing, local storage, special multimedia hardware, the ability to read/write from CD-ROMs, Scan and print document. Since they use a lot of server resources and network power, Thin-Clients would cause an unnecessary headache for administrators.

• If you own low bandwidth network like Thick Ethernet and co-axial or number of hubs on your network, avoid adopting this technology. You have to wait till your network administrator upgrades it to Fast Ethernet. You might be clear that as everything is being processed at server output of the programs will travel on network to be displayed on user monitor. So, if a power user application is being accessed thru Thin-Clients it will consume enough network bandwidth. Second point you have to consider here is - there should not be a single point of failure if your installation is going to span in many building or cities in rather large geographical area.

So far, we have discussed about the Thin-Client technology, requirement to be considered before planning. We have also discussed, when and where this technology can be of use. In coming chapters we will explain the way of quick implementation & getting maximum out of less investment. Further we will discuss the issues one can face during implementation and how to troubleshoot, isolate & tackle the problem and find the solution.