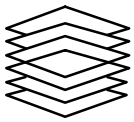

Positioning Thin Clients in the Enterprise

EXECUTIVE SUMMARY

Many users commonly perceive the future of the Network Computer (NC) as being closely related to the success of Java-based software. They assume that until Java-based applications become prevalent, the NC remains unlikely to be adopted in large numbers, except as a replacement for terminals. Indeed, the very specification of the NC condones this attitude through the insistence that all NCs come with a Java Virtual Machine (JVM) capable of running Java-based programs downloaded from the server. NCs also usually include character terminal (3270 and 5250) emulation and X Window client functions, further helping to support the myth.

Of course, the fact that Microsoft's enemies created the NC – many of whom see the NC as a way of breaking the Microsoft/Intel stranglehold on the desktop – does little to set the record straight.

To be sure, NCs are frequently deployed to replace low-function PCs based on Intel 80286 or 80386 processors which serve only as terminal emulators. However, the majority of NCs in use today do not act as "dumb", i.e. non-programmable terminals, nor as Java-based machines. In addition to handling e-mail and Internet access, many NCs serve as Windows terminals, offering the full range of Windows-based applications. This Windows terminal approach, based on WinFrame, Citrix Systems' multi-user version of NT, allows NCs to run Windows applications on the server, while minimizing the management issues by using a greatly-simplified client machine.

Indeed, this Windows terminal approach not only preserves the current investments in Windows applications, but can optimize them by creating a more stable environment for the end user, simultaneously enabling access to host-based legacy applications as well. Because all the user processing takes place on centrally-managed servers, and no state is kept on the user's NC, configuration issues can be dealt with by IT personnel instead of by users. Furthermore, NCs centralized approach enables groups of users to benefit from identical environments without the burden of separately configuring individual desktop PCs. This benefit extends to mobile users who can move from machine to machine without noticing environment discrepancies, because all of their configuration information can be retrieved from the server.

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Network Computer, NC, Thin Client, Windows Terminal, Network PC, Net PC, Sun, IBM, Oracle, Microsoft

Abstract: The majority of NCs in use today do not act as "dumb", i.e. non-programmable terminals, nor as Java-based machines, but as Windows terminals, offering the full range of Windows-based applications. This Windows terminal approach, based on WinFrame, Citrix Systems' multi-user version of NT, allows NCs to run Windows applications on the server, while minimizing the management issues by using a greatly-simplified client machine.

Microsoft itself recognizes the demand for a Windows terminal product, and plans to introduce multi-user functionality for NT in a future add-on product codenamed "Hydra." Hydra is based on the Citrix multi-user kernel extensions, but rather than using the Citrix ICA protocol to distribute functions, Hydra will use Microsoft's proprietary T.SHARE protocol. T.SHARE, however, will require a low-function version of the Windows operating system to reside on clients in order to manage user interaction remotely, thereby weakening the benefits derived from the pristine statelessness of ICA terminal devices.

While Windows terminal operation promises the best of the thin client and PC worlds – minimum of end user configuration responsibility with effective backwards-compatibility for existing Windows applications – some caveats remain. For example, although using NCs as Windows terminals provides users with an environment similar to PCs – complete with printer support – floppy disks receive poor to no support. More significantly, current Citrix-based solutions only offer a Windows NT 3.51 environment which does not have the Windows 95 look-and-feel. NC users will not gain Windows NT 4.0 support until Microsoft releases its Hydra extension.

THE PLAYERS

An examination of current offerings reveals that the NC vendors have had varying levels of success in offering the full benefit of NC-based thin client solutions. IBM currently offers the best overall ability to deliver a full-function NC solution. At the client, IBM's Network Station includes the ability to interoperate with all relevant server environments, building terminal functions into the base package, as well as supporting Windows terminal functions via the X Window System protocol and a Citrix-derived server back-end. The company's Network Station S/1000 also provides optimizations for running Java-based desktop applications such as Lotus e.Suite. While a number of other vendors offer similar client products, IBM complements its desktop offerings with the necessary server support, including hardware and software, to comprise a complete NC solution. For example, IBM provides Network Station Manager, a central management tool for MVS, OS/400, AIX, and NT, that can provide significant customization for individual users. In other words, different users can start their Network Stations and see very different screens and capabilities. The central administration can be performed via a Web Browser, allowing remote management if necessary.

Oracle's subsidiary, NCI, produces a reference design and software for NCs that it licenses to third parties. While some of the products deriving from NCI's specifications include Windows terminal support, most target the consumer and educational space. Furthermore, few of NCI's partners have the ability to provide a full NC solution, lacking the necessary server hardware offerings.

Sun, like IBM, has the ability to deliver a complete NC solution including server hardware and software. However, of all the NC vendors, Sun's product not surprisingly has the most dogmatic dependence on Java-basedsoftware. Sun's JavaStation supports Windows terminal functions only weakly – the necessary Citrix client is in beta at present – and suffers from limited performance due to interpretation overhead. Further, Sun's server offerings only run UNIX today, and therefore do not support a Citrix back-end. Windows terminal functions, therefore, require third-party involvement.

In advance of promised support for Hydra Windows terminals, Microsoft and Intel have made efforts to introduce incremental measures simplifying desktop management. Specifically, two new initiatives have been launched:

- Network PC (Net PC), a “managed” PC reference design that includes features designed to reduce configuration requirements.
- The Zero-Administration Kit (ZAK), a collection of software-only modifications for traditional desktop PCs that provide the ability to “lock down” user desktops, preventing unproductive modifications.

FUTURE: HYDRA

Meanwhile, Microsoft positioned the Net PC as a desktop system, optimized for corporate environments, building in centralized management features, without trading off the benefits of traditional PCs. Microsoft also left the Net PC's specification open enough to enable broad classes of usage. Net PCs can even be configured to serve as Windows terminals to Citrix servers.

The largest single distinction among Net PCs and NCs, though, remains the fact that a Net PC must be configured with full local copies of the Windows operating system, and usually with the application software as well. Even when large numbers of users require the exact same environment, each individual client must potentially maintain hundreds of megabytes of information just to support basic functions, thereby introducing significant potential for error. Further, like all PCs, Net PCs must be configured explicitly with the tools to interoperate with server environments such as mainframes or UNIX servers running the X Window System, introducing yet more complexity. Finally, the ability to achieve location transparency, akin to that offered by NCs or dedicated Windows terminals, requires painstaking, and poorly supported, configuration of servers.

CONTENTS

I. THIN CLIENT ARCHITECTURES

Thin clients offer an effective way to simplify the management of large numbers of full-function desktop systems. In general, all thin clients optimize by minimizing *state* – i.e. configuration requirements that are unique and specific to a particular desktop device. By contrast, fat clients usually maintain a significant amount of state on the client itself. For example, workstation and PC hardware firmware must keep track of all the peripherals and storage, and communicate this information to the operating system. Further, the operating system maintains extensive configuration information relating to installed software, user preferences and so on. Thin clients, however, store most of the configuration information on the server, not the client.

Fully-loaded PCs – heavily configured with peripherals and storage – running a complex operating system such as NT, or an engineer's workstation running UNIX, represent one end of the spectrum as the archetypal "heavy" clients. At the other end of the spectrum, the ultimate thin client is represented by a "dumb", i.e. non-programmable, terminal.

Three approaches have emerged in the middle of the spectrum that reducethe desktop management burden by off-loading various degrees of state from the client to the server: Network Computers, Windows Terminals, and Network PCs.

NETWORK COMPUTERS

The Network Computer (NC) is a desktop computer optimized for connectivity to a network, particularly intranets and the Internet. Unlike PCs – which run a full-function operating system that manages local copies of applications – NCs are designed to download all applications from a server and to store the user's data back on the server. Similar to diskless workstations, NCs do not need floppy or hard disk storage, although in practice some NCs may leverage local storage transparently to the user for caching purposes. Typically, NCs run a compact operating system that can be booted from the network, including a Web browser and Java Virtual Machine (JVM) for running Java-basedapplications. NCs may also include slots for smart cards, used by applications such as user login verification.

Vendors such as IBM, Oracle, and Sun have attempted to position the NC as an alternative to traditional Microsoft Windows-based PCs. Together, these companies created the Network Computer Reference Profile, a formal standard that defines the minimum set of capabilities that an NC should contain. The Network Computer Reference Profile has since been renamed the Network Computer Profile, and is expected to become part of The Open Group's Network Computer Program. Vendors that license the specification and build their machines in compliance can brand them with the NC logo. Although IBM, Oracle, and Sun have all driven the NC concept with similar levels of passion, in practice they are promoting divergent visions for the role of NCs.

Sun views the NC as a desktop device optimized to run Java-based software. As the only NC product to be based on Java-based software from the ground up, Sun's JavaStation serves as just one component in Sun's larger strategy to promote Java-oriented computing across many environments. Since Sun offers no PC hardware, JavaStations also represent the company's best opportunity to gain some volume desktop leverage independently of Intel or Microsoft. In practice, though, JavaStation's fundamental dependence on Java-based software hampers its momentum in the market, constraining its usage to the limited selection of production-quality Java-based software available today. Sun estimates that the early adopter phase for JavaStations will not begin until 1998, with volume opportunities materializing only in 1999.

IBM views the NC as desktop device optimized for communicating with a broad array of back-end servers and hosts, including AS/400s, mainframes, RS/6000 UNIX servers, and PC Servers, as well as the Internet. IBM's role as a leading PC supplier means that it has a vested interest in offering traditional fat clients when appropriate. Indeed, IBM views the initial NC market primarily as a richer-function replacement for 3270 terminals. Although IBM does not limit the role of NCs to terminal functions, it continues to position PC products for other desktop uses.

Oracle sees the NC as a "universal digital appliance," suitable for consumers as well as professionals, that will cost about $400. However, as a software vendor, Oracle does not directly sell NCs: Rather, an Oracle subsidiary, Network Computer, Inc. (NCI), develops software for low-cost Internet appliances for the corporate market, which it then licenses to third-party NC manufacturers. NCI also manages the NC Reference Profile to which products must conform in order to classify as NCs. In addition, the company manages maintains a hardware reference design which manufacturers can use to supply NC products. Thus, Oracle's involvement with NCs remains somewhat indirect. Focused on driving its back-end database software systems, Oracle mainly seeks to promote the NC vision and supply the tools for fulfilling it, rather than getting involved in actual unit shipment. Underscoring Oracle's focus on consumer NC applications, NCI recently merged with Navio, a developer of software for set-top boxes and TV Web navigational software.

Table 1: Comparison of NC Solutions

Function	IBM	Oracle (NCI)	Sun
Terminal Replacement	Provides native-code terminal emulators	Terminal emulator support varies by OEM	All terminal emulators written in the Java language, incurs performance drag
Windows Applications Access	Run remotely via X Window System protocol to Citrix WinFrame server (Citrix ICA protocol in future)	Run remotely via X Window System protocol to Citrix WinFrame server	Run remotely via Citrix ICA protocol to Citrix WinFrame server, but front-end in Beta only and written in the Java programming language, which incurs performance drag
Internet/Web Browsing	Includes Spyglass, NCI's Navio Web Browser, and Sun's HotJava Browser	Includes NCI's Navio Web Browser	Includes Sun's HotJava Web Browser
Java-based Applications	Includes JVM and Lotus e.Suite	Includes JVM	Includes JVM

WINDOWS TERMINALS

Administrators value the ability to centralize as many operations as possible, but remain justifiably concerned with protecting their ability to support the huge installed base of desktop Windows applications. Recognizing the need to balance these requirements, Citrix Systems established an unusual relationship with Microsoft in which it adapts and resells the Windows NT operating system for distributed multi-user operation.

The Citrix solution, called WinFrame, consists of the following components:

- The Windows NT Server base operating system, for which Citrix has licensed the source code from Microsoft. Microsoft licenses NT source code to many third parties, including universities for purposes of teaching students about operating systems and very large organizations who have made a heavy commitment to NT and need source code access for purposes of support. However, Citrix represents the only entity outside of Microsoft that may modify *and* sell NT.
- Kernel extensions to NT's memory manager and scheduler, which provide NT with true multi-user capabilities. Unmodified, NT can manage multiple user profiles, allowing multiple users to log onto an NT system *sequentially*. However, the NT kernel can not manage the activities of multiple users *simultaneously*, in the manner of traditional time-sharing systems such as UNIX, AS/400's and mainframes, for example. The Citrix extensions allow NT to coordinate the activities of many users at once, each with their own runtime environment and security profile. Indeed, Microsoft has re-licensed the Citrix kernel extensions for inclusion in its own multi-user version of NT, code-named Hydra, which is planned for shipment in 1H98.

  A display protocol, Intelligent Console Architecture (ICA), which transmits Windows GUI events across a network to remote devices. ICA allows Windows applications to run on a server, but sends all graphical output to remote software or hardware for display. Working in the opposite direction, ICA carries remote keystrokes and mouse events back to the application. The X Window System has long offered similar capabilities for UNIX GUIs. However, unlike the X Window System protocol, ICA is designed for all types of bandwidth requirements and runs efficiently over dialup connections, for example. The X Window System, by contrast, performs less efficiently over low-speed connections, and also consumes more client-side resources than ICA.
- Lightweight client software, which communicates with servers via ICA. Citrix supplies clients for DOS, Windows 3.1, Windows 95, Windows NT, Active X, and Netscape Plug-ins. OEMs have developed clients for Macintosh and UNIX. Each of these clients provides a virtual Windows desktop, appearing to users as a full-functional Windows machine, when in fact the entire environment, including all applications, runs off a remote server. Because the server itself runs Windows NT, emulation does not result in a performance penalty.
- Miscellaneous server-side components for managing applications and user environments, including load-balancing facilities for distributing client sessions across multiple back-end servers.

The Citrix solution satisfies a key criteria for thin client requirements: the server maintains all state and code. Thus, the actual client hardware on which the user works becomes irrelevant, allowing hardware to be replaced arbitrarily, without affecting the user's environment. More importantly, users continue to run familiar Windows applications. Of course, the Citrix solution introduces new management responsibilities. Virtually every user action results in a distinct, albeit modest, burst of network traffic. Load capacity on the server must be planned as well, since the server must literally run all applications used by all users at any given

time. However, because at no point are applications or entire data sets downloaded to the client as in NCs, “boot-storms” at the beginning of the business day do not represent as much of a problem.

Some desktop hardware vendors are capitalizing on Citrix' capability to deliver “Windows terminals” – devices optimized specifically to communicate with Citrix servers. For example, vendors such as Wyse, Boundless Technologies, and Neoware Systems (formerly HDS), include support for the ICA protocol in hardware. Others, including Insignia, Tektronix, and Network Computing Devices (NCD), have licensed and modified WinFrame to use the X Window System protocol rather than ICA for transmitting GUI events. This allows Tektronix and NCD, which have long sold X Window System terminals, to also position their products as Windows terminals. Insignia licenses its implementation to other X Terminal vendors, including Hewlett-Packard.

Some of these systems are “dumb” Windows terminals in the truest sense, and have no function other than to interact with WinFrame. Others include enough intelligence to support the functions required for NC certification, including a light-weight operating system and a JVM.

Microsoft also recognizes the need for Windows terminal functions, and plans to introduce multi-user NT functionality in a future add-on product codenamed “Hydra.” Hydra is based on the Citrix multi-user kernel extensions, but rather than using the Citrix ICA protocol to distribute functions, Hydra will use Microsoft’s proprietary T.SHARE protocol. T.SHARE, however, will require a cut-down version of the Windows operating system on the client in order to remotely manage user interaction, weakening the benefits derived from the pristine statelessness of ICA terminal devices.

NETWORK PCS

When Sun introduced the JavaStation NC in the Fall of 1996, the company drew attention to the potentially high cost of ownership related to Windows-based PCs. In particular, Sun highlighted the potential for PC users to waste significant amounts of time reconfiguring their systems, both in terms of hardware and software. By contrast, NCs promised to limit configuration requirements by controlling all software – including operating system and applications – from the server.

Sun’s hyper-marketing fell short of proving that NCs would solve the long-standing desktop management problem. However, resonating a genuine concern among system managers, Sun’s claims did succeed in drawing enough attention from Microsoft and Intel users to elicit the vendors’ commitment to address the issue. Microsoft responded with two initiatives: a “managed” PC reference design called Network PC (Net PC) that includes features designed to reduce configuration requirements; and software-only modifications for traditional desktop PCs called “Zero-administration Windows” (see below).

Microsoft positioned the Net PC as a desktop system, optimized for corporate environments, building in centralized management features without sacrificing the benefits of traditional PCs. Microsoft has made the Net PC's specification vague enough to enable broad classes of usage. The fact that that a Net PC must be running a full local copy of the Windows operating system represents the largest single difference among Net PCs, NCs and Windows Terminals, it is.

The Net PC specification includes the following requirements:

- Minimum 133 MHz Pentium equivalent, comparable or better. Level 2 cache must be at minimum 256 KB.
- 16 MB RAM (32 MB recommended)

- An internal hard drive.
- All hardware fully detectable and configurable via software. The specification requires that the Net PC system board supports Microsoft's Advanced Configuration and Power Interface (ACPI). ACPI enhances power management in Net PCs to provide a low-power sleep state that can be used instead of turning the Net PC off. The specification also enables Net PCs to turn on and off peripherals such as CD-ROMs, network cards, hard disk drives and printers.
- Lockable case. Although hardware devices must be recognizable and managed automatically by software, hardware upgrades should be administrator-only tasks. For example, the Net PC specification insists that if the capability to upgrade memory and CPU is provided, this capability must not be end-user accessible.
- Universal Serial Bus (USB) with one USB port at minimum. USB is a new PC computer bus, endorsed by Intel and others, that has a total bandwidth of 1.5 MB/s and can daisy-chain up to 128 peripheral devices. USB proponents hope that the new bus will replace the PC cable clutter. Designed to handle a broad range of devices – including telephones (analog, digital and proprietary), modems, printers, mice, joysticks, scanners, keyboards and tablets – USB is designed to be completely "plug and play," meaning that devices will be correctly detected and configured automatically as soon they are attached. USB also supports hot attach and detach, which allows devices to be added or removed at any time, without powering down or rebooting the computer.
- Support for OnNow, a specification to ensure that the operating system and device drivers control the state of individual devices and the system board.
- Support for Wake-up on LAN. Beginning in 1998, Net PCs must support wake-up capabilities from a LAN, based on matching patterns specified by networking software. Pattern matching-based wake-up enables remote applications to "wake up" machines from lower power (sleep) states.
- Provide platform information used by management applications. Net PCs must supply instrumentation data used by a broad array of management frameworks, including Web-Based Enterprise Management (WBEM), Desktop Management Interface (DMI), CIM Object Manager (CIMOM), and Simple Network Management Protocol (SNMP).

Although the Net PC specification promises to simplify the management of PC hardware, much of the functionality required is new and has not yet been fully proven in the market. For example, USB support only recently began to ship in products and, in the near future, will have to be positioned relative to other emerging peripheral connect technologies such as FireWire, the IEEE 1394 serial bus standard which may overlap with some USB functionality.

After being pushed by the potential impact of NCs, Microsoft positioned the Net PC as a "catalyst" for the industry to create more cost-effective, manageable PCs, and claims that the intention of the Net PC initiative is to "push the hardware technologies that help reduce corporate TCO throughout the enterprise." Microsoft openly acknowledges that Net PC functions will all appear on conventional PCs as well.

Some vendors shipping Net PC-compliant products add value to the standard specification, thereby significantly enhancing management features. Compaq, for example, ships the Desktop 4000N, a Net PC-compliant unit with additional functions that simplify remote management, through features for managing configuration, assets, security, faults, and integration. However, most of Compaq's extensions are proprietary and are effective only if deployed with other Compaq workstations and servers.

ZAK-EQUIPPED PCS

Microsoft also offers the Zero Administration Kit (ZAK), software extensions to simplify the management of Windows-based PCs (Windows 95 and NT). The ZAK includes tools, methodologies, and guidelines designed to allow managers to implement secure, policy-based management for Windows PCs. ZAK provides a pre-configured set of system policies for NT Workstation 4.0 and Windows 95 that provides three functions:

- Centralized desktop configuration, allowing administrators to specify remotely which applications a user can run, the look of the desktop, and where user data resides.
- Restricted local desktop access, prohibiting users from installing applications on their desktop or making any configuration changes.
- Centralized application and data storage, pre-configuring desktops to load applications from servers, using the local hard drive as a cache.

The ZAK comes with two predefined user modes, classified by user activity and appropriate restrictions:

- *TaskStation Mode*: intended for single task-oriented workers such as clerks or bank tellers who require access only to a single line-of-business application. TaskStation boots directly into a single application and completely locks down the desktop, preventing the user from starting any other activity or accessing any other data.
- AppStation Mode: a more relaxed environment intended for "knowledge" workers who require access to multiple business applications. AppStation mode prevents system reconfiguration or direct access to data by end-users, and limits application access to a predefined set. All applications and data are accessed from the server.

ZAK provides an evolutionary method of curbing some of the factors eroding productivity for certain classes of PC users. However, ZAK itself remains a complex application and effective implementation may prove to be a challenge. Although ZAK is free, it must be downloaded from Microsoft's Web site and installed by administrators themselves. ZAK will evolve as Microsoft continues to focus on cost-of-ownership problems, with significant changes likely in the future. For example, ZAK still has to be reconciled with system management frameworks from Microsoft and third parties.

Like the Net PC, ZAK represents a symbol of Microsoft's commitment to address desktop complexity issues, and provides moderately credible evidence that PCs can indeed be reigned in when necessary.

VENDOR OVERVIEW

Virtually all vendors targeting the desktop agree that thin clients are appropriate for at least some classes of users. However, the actual approaches taken by the vendors to reduce complexity on the desktop vary widely (see Table 2).

Table 2: Vendor Positioning of Thin Clients

Vendor	NC	Net PC
Compaq	-	Deskpro 4000N
Dell	-	OptiPlex Net PC
Digital	-	Future
Hewlett-Packard	ENTRIA/ENVIZEX (limited support for running Java-based software)	Net Vectra
IBM	Network Station 100/300/1000	-
NCD	Explora	-
Sun	JavaStation	-

Most of the PC companies share Microsoft's dogmatic dependence on running a full-function operating system at the desktop. Thus, for the most part, the PC vendors thin client approach involves offering Net PC products. Compaq and Dell have both announced Net PCs, the Deskpro 4000N and OptiPlex Net PC, respectively.

Digital demonstrated NC products – based on the Oracle/NCI hardware reference design, which specifies Digital's low-end ARM processor – but has not yet shipped a product. Digital's PC business unit has promised a Net PC offering in the future.

Hewlett Packard established an X Window System terminal business which the company currently extends into the thin client space. HP's ENTRIA and ENVIZEX thin clients allow users to run Windows applications remotely from a server configured with Insignia's NTRIGUE. Although HP's thin clients contain a Java Virtual Machine, they do not meet the entire NC Reference Specification, and thus cannot be called NCs. HP's PC business unit has introduced the Net Vectra Net PC.

IBM embraced NCs as a convenient method of accessing diverse types of servers and hosts from a single desktop. IBM's current generation of NC product is the Network Station 100/300/1000. The Network Station includes a JVM, and meets NC specifications. Separately, IBM's PC division decided to pursue configuring traditional PCs with Net PC features and ZAK software, rather than introducing actual Net PC models.

Consistent with its strong position driving Java-based software, IBM's Network Computer Division recently delivered a new model, the Network Station 1000, which is optimized for running Java-based applications.

Like HP and other vendors, NCD is extending its X Window System terminal business into the thin client space. By remapping Windows GUI events into X Window system primitives, users can run Windows applications from NCD's terminals remotely on a server. Later this year, NCD will add support for the Citrix ICA protocol natively, passing on ICA's advantages over low-speed lines and eliminating the requirement to rely on the X Window System protocol.

Sun currently offers the only NC built around Java-based software from the ground up. The JavaStation provides an optimal environment for running Java-based software, and ISVs are developing Java-based software alternatives to mainstream Windows desktop software. However, many sites need to continue supporting the huge installed base of desktop Windows applications. Citrix will soon offer a Java-based Winframe client (currently in beta) that allows

JavaStations to act as Windows terminals. JavaStations, however, still lack a Just-in-Time (JIT) compiler to increase the performance of Java-based applications. Without the JIT compiler, JavaStations fall short of matching the response of native Windows environments. Sun does not currently sell PCs, and thus does not have any involvement with Net PCs.

Another established terminal vendor, Wyse, embraced the Citrix solution early on and established significant momentum in the Windows terminal market with its Winterm products. Winterm products support the ICA protocol in hardware, and are, therefore, optimized to communicate with Citrix servers. However, Winterms lack a JVM and are not certified as NCs.

II. THIN CLIENT OPERATION

RELATIVE INSTALLATION BURDEN

NC	Net PC
Server requires configuration to supply applications and maintain data	Server configuration varies from none to setting up remote management facilities
To run Windows applications, server requires configuration with Citrix or equivalent	Administrator must initialize client, either locally or remotely
Client installation minimal, plug in and enter minimal user information	Requires installation of full-blown operating system and applications on desktop

The relative installation burden of thin clients varies according to the approach. All of the variations seek to minimize the installation burden on the client, shifting as much of the process as possible to the server. Consequently, server installation may become significantly more complex.

Because NCs are designed to download all of their software – including operating system and applications – from the server on demand, clients require minimal installation. Typically, the NC simply attaches to the network and gets assigned an IP address by an administrator, with all further installation occurring automatically.

Since Net PCs run a local copy of the Windows operating system, they must at some point be configured by an administrator working either locally or, to the extent possible, remotely.

SOFTWARE DISTRIBUTION PROCEDURES

NC	Net PC
Downloads operating system and all applications from server, client may cache on local hard drive	Operating system stored and run locally, can be configured to download applications from server

NCs run applications locally, so administrators must configure servers to respond to client requests for software. If the NC client caches applications, version control must be implemented as well. By contrast, Windows Terminals run all applications on the server, so applications typically only need to be maintained in one place. Net PCs can be configured to store applications either locally or remotely, so the software distribution process will vary. However, operating system software must at some point be installed explicitly on a Net PC.

NETWORK/SERVER LOAD CHARACTERISTICS

NC	Net PC
Remote Windows applications network traffic minimized by ICA efficiency, servers may need to be load-balanced Java-based application downloads load network on demand, risk "boot storms" at critical times	Varies from none, if software is stored locally, to boot-storm conditions, if key applications are all loaded at the same time from server

When used as a Windows terminal, NCs generate network traffic for literally every user action, including keystrokes and mouse clicks. The ICA protocol has therefore been optimized for efficiency, with the ability to work well over low-speed communication lines. Still, because all applications run on the server, administrators need to manage back-end capacity to insure satisfactory responsiveness and reliability. For this purpose, Citrix supplies load-balancing facilities.

Since NCs download all Java-based applications from the network, they incur more network load than traditional PCs. During critical times such as the beginning of the business day, NCs may cause "boot-storms" when the network slows down from heavy usage of Java-based applications, as all users attempt to load their environments at once. Caching software on the local hard drive may alleviate network load, but requires implementation of version control. Future "flash boot" techniques, in which the operating system is stored in local flash memory, will help alleviate the problem as well.

Net PCs can be configured in many ways, including in a mode where applications are downloaded from the server. Microsoft's ZAK provides the necessary software support for centralized application distribution.

INTEROPERABILITY/INTERCHANGEABILITY

NC	Net PC
For remote Windows applications, any ICA or X Window System client can act as a Windows Terminal Interchangeability limited by product and vision divergence	Set by Microsoft standard

Although NCs conform to a open standard architecture, enough options exist to introduce some interchangeability and interoperability issues. In particular, the NC standard does not fully determine the back-end requirements for servers that support NC clients. Thus, NCs today must typically be installed as part of a solution, including a server from a specific vendor. Some NCs support emulators and terminals for communicating with particular host environments. At the application level, NC interoperability is being driven largely by the capabilities of the Java-based software.

To run remote Windows applications, clients need only support the ICA or X Window System protocol to access an application server. Since the back-end runs native Windows applications, users benefit from the same interoperability that is available to the Windows base at large.

Net PCs must conform to the Microsoft standard, so they are interchangeable at the levels set by the specification. Since Net PCs run copies of the Windows

operating system, users have the same interoperability benefits as any other Windows user.

III. APPLICATION AVAILABILITY

DESKTOP PRODUCTIVITY APPLICATIONS

NC	Net PC
Via Windows terminal function, provides access to Windows applications Java-based productivity applications such as Lotus e.Suite are just emerging. Ability to access Windows apps via Citrix varies by product	Provides access to all Windows applications, Java-based applications via Web browser

Most NCs allow users to run Windows applications remotely through Citrix server functions. Current Citrix-based solutions provide only a Windows NT 3.51 environment, which does not have the Windows 95 look-and-feel. NC users will not gain Windows NT 4.0 support until Microsoft releases its Hydra extension. Although some ISVs have initiated high-profile efforts to match the capabilities of leading Windows-based productivity packages with Java-based applications, the immaturity of the Java-based software environment has delayed the introduction of production versions.

Net PCs provide users with a true native Windows environments, capable of running the existing base of Windows software.

JAVA-BASED APPLICATIONS

NC	Net PC
Strong support for Java-based software, mixed performance enhancements	Requires support for Java-based software to be configured on client

The NC specification mandates the inclusion of a Java Virtual Machine, so NCs, by default, can run Java-based applications locally. However, since Java-based software is usually interpreted, running performance-sensitive Java-based applications sometimes requires the presence of a Just-in-Time compiler to translate code on the fly into native instructions. However, evidence suggests that JITs may not be required for productivity applications, where adequate responsiveness can be yielded even under interpreted conditions with a fast enough processor. Currently, NCs vary widely in terms of their support for native JITs.

Net PC users need to have access to JVMs within their Windows environment in order to run Java-based applications. Microsoft currently bundles a JVM with the latest version of its Internet Explorer Web browser, but this serves mainly to run Java-based *applets*, i.e. small interactive tools. Additional configuration may be needed to support Java-based software more comprehensively, including the ability to run whole Java-based *applications*.

WEB BROWSERS

NC	Net PC
Varies by product, Java language browsers still immature Via Windows terminal functions, can	Can access both IE and Netscape

access both IE and Netscape remotely	

The NC specification requires that the NC includes a Web browser. Current NC products ship different browsers: For example, Sun's JavaStation includes Sun's own HotJava browser, while others include the Navigator browser developed by Navio, now part of Oracle's NCI subsidiary. In addition, NCs can access Windows-based browsers remotely via Windows terminal functions.

Net PCs provide access to the same browsers available to other Windows users, including native Windows versions of Microsoft's Internet Explorer, and Netscape's Navigator.

GUI TRANSACTIONS

NC	Net PC
For remote Windows transactions, ICA protocol optimized for carrying GUI transactions Java-based functions require implementation of Java-based GUI	Standard Windows support

Single-task users typically spend most of their on-line time generating transactions to databases using GUI-based query screens. Thin clients need to provide the ability to support such operations efficiently. For example, IBM has developed specific 3270 and 5250 emulators for its Network Stations.

When using NCs as Windows terminals, users can engage in the same transactions available to native Windows users. The ICA protocol used by Citrix has been optimized to maximize the response of transactions over both traditional networks and low-speed communications lines.

Because Windows applications have long been used for just such operations, Net PCs generally support GUI transactions well. Citrix claims to have optimized ICA for delivering GUI entries with a minimum of network traffic.

TERMINAL EMULATION

NC	Net PC
Varies by product	Standard Windows support

NCs typically include some terminal support, but vary in the breadth of remote environments supported. Because Sun's JavaStation runs only Java-basedsoftware, all terminal front-ends must be implemented in Java-basedsoftware and remain subject to the performance limitations of that environment. Other NCs, such as IBM's Network Station and HP's terminals, include terminal applications written in the native code of their processors and are capable of communicating with a variety of host environments.

Net PCs run the standard terminal offerings available in Windows by default. For full interoperability with a variety of server environments, administrators must typically install add-ons from third parties.