Printing with ArcGIS® Desktop Software Hosted on Windows® Terminal Server/Citrix®

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J-9577

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Contents **Page**

J-9577

Contents **Page**

Appendixes

Printing with ArcGIS Desktop Software Hosted on Windows Terminal Server/Citrix

Introduction

Windows® Terminal Server (WTS)/Citrix® geographic information system (GIS) implementations are becoming more common as organizations consolidate application and database servers and other resources into central data centers. Moving the GIS infrastructure to a data center can offer a number of advantages including

- Reduced GIS software installation and maintenance costs
- Centralized management of data stores
- A more secure environment for data and applications
- Integration of GIS applications and data with other centrally hosted enterprise applications
- Reduced network bandwidth utilization between client software and file servers and geodatabases
- Support for remote users on low-bandwidth connections

While moving the applications and data to the data center provides many benefits, this configuration can present challenges to the task of printing or plotting large maps and other graphics-intensive documents common to GIS. The print data stream must make its way from the WTS server across the wide area network (WAN) to the user's printer or plotter. Since these data streams can be quite large (10–300 MB or more) and WAN bandwidths can be small (1.54 Mbps or less), users must carefully design a printing plan as part of their Citrix/WTS implementation. An accurate and realistic answer to this is critical to successfully implementing Citrix/WTS in GIS.

Printing is often the most difficult part of any Citrix implementation, but with the larger data streams and specialty plotters used in GIS, the level of complexity is even higher. Customer experience in printing with ArcGIS® hosted on Citrix over WANs has been mixed. The degree of success has been related to the expertise of staff with WTS, network administration and server administration, network bandwidth availability, and network stability. It is clearly more complex, for instance, to print over low-bandwidth connections, such as T-1 (1.54 Mbps) and below, or to manage printing with hundreds of printers in a terminal server environment. But organizations have been successful in utilizing strategies to overcome the challenges presented by this architecture. Often more than one technique is used to satisfy the variety of requirements that exist in organizations that are geographically dispersed and have different printing needs.

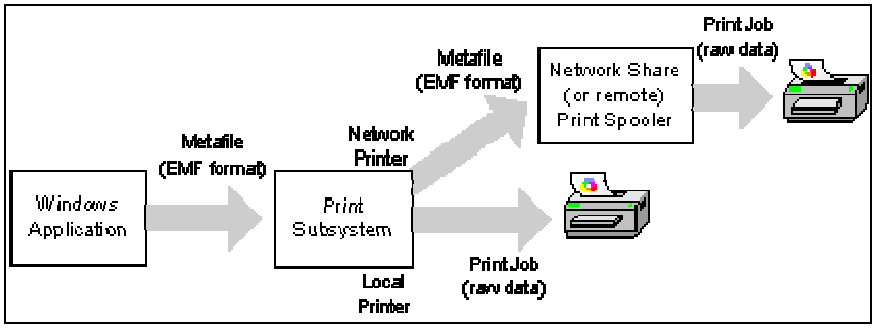
This document will first examine Windows and ArcGIS Desktop printing then WTS and Citrix printing in general, and finally, how ArcGIS Desktop printing works in a Citrix environment over WANs. Most of the diagrams and some general printing content included were taken from articles on WTS and Citrix on Brian Madden's Web site (www.brianmadden.com). (Brian is an expert on Windows Terminal Server and Citrix and has written several books and a number of articles on this subject.) Also incorporated are several real-life scenarios from users who have implemented Citrix/WTS-based ArcGIS printing.

Windows Printing

Windows printing occurs in several steps as shown in figure 1. These steps vary depending on whether printing is occurring on a locally connected printer (to the workstation or server) or sent to a network printer. Either way, the initial step is identical—the users' application interacts with a Windows component Graphic Device Interface (GDI) to produce a file in Enhanced Metafile (EMF) format. This file is not printer specific. The EMF file is then "rendered" by the Windows print subsystem, using the printer driver to produce a device-specific raw data file, which is then sent directly to the printer. The diagram below shows the basic steps for a local printer and a network printer using print subsystems.

There are three basic steps: producing the EMF file, rendering the raw data from the EMF file, and printing. For most applications, the EMF production process uses less processing power and memory on the workstation or server than the rendering process, and the EMF data stream is usually smaller than the raw data stream. For many GIS maps, however, producing the EMF may take more computer resources than the rendering process.

Figure 1
Windows Printing



Printing/Plotting from ArcGIS Desktop

ArcGIS Desktop software (ArcInfo®, ArcEditor™, and ArcView®) uses the Windows printing subsystem for printing and plotting of maps. There are several methods for printing or producing print files from this software.

1. **ArcGIS Desktop can print directly to local (directly attached) printer or plotter or to a network-based printer or plotter.** Users select from a list of local or network printer/plotters that have been assigned to their workstation through standard Windows and vendor driver and utility installation processes. If a network-based printer is selected, the print data (EMF format) is spooled to a print server to which the printer is connected. The server or workstation that is directly connected to the printer performs the rendering of the EMF format data, producing the raw data that is sent to the printer. If the printer is attached to the user workstation or an application server, the workstation/application server renders the print data and sends it to the printer.

2. **ArcGIS Desktop can also produce a print file (in EMF format) that can be transferred (via e-mail, copying, FTP, etc.) to a workstation or print server where it can be printed.** The print file can be created in standard Windows print file format (.prn extension) or PostScript® (PS) format.

3. **ArcPress™, which is included with ArcGIS 9.1 Desktop and subsequent versions, can also output the print job in native raw data formats such as HP's RTL, replacing and, therefore, bypassing the Windows rendering process.** The ArcPress rendering process eliminates some of the server- and printer-side processing that must occur, resulting in faster printing.

4. **In addition to these methods, ArcGIS Desktop users can export printable files in encapsulated PostScript or PDF formats (among others), which can then be moved across the network to a server or workstation for rendering and printing.** Exporting to a PDF can produce significantly smaller files than EMF or raw data, which is advantageous in a WAN environment. The PDF print file creation mechanism separates vector and raster data and does not reduce the quality of the print image. (This is not true when rasterization takes place such as when a transparent layer is above a vector layer.) PDFs can be compressed utilizing WinZip® to further reduce the file size. Alternatively, the Compress Vector Graphics and Compression settings within the PDF exporter's options can be used. Adobe® Reader®, a popular, free download from Adobe, can be used to view and print these files. Utilizing PDF files can involve several manual steps to produce a print from ArcGIS. Automating this may require writing scripts to export and zip the file, move it to a server/workstation, unzip it, then print it.

   Technical note: The resolution of the exported PDF file inherits the resolution of the default printer assigned to the workstation or application server on which ArcGIS is running. To adjust this, the default printer setting must be changed and ArcGIS restarted. Also, when exporting large plot jobs, ArcGIS software can run out of system resources, causing the export process to fail.

With each of these methods, ArcGIS, working with the Windows GDI, generates the EMF file. With large-format maps and/or maps with raster data, this process can place significant processor and memory loads on the workstation or server on which it runs. The rendering and printing processes also place significant loads on the server/ workstation.

It should be noted that ArcMap™ stores the printer share name in the map document. This doesn't work for printing management systems in which dynamic printer names are used such as the session-based naming scheme with Citrix Presentation Server 4 (PS4).

ESRI is also developing an enterprise print-on-demand capability that uses ArcGIS Server to provide a Web interface for creating maps and print jobs, which are zipped and e-mailed or placed on FTP servers. This could be a good option for larger organizations with non-GIS users, for example, that need printed maps. Various third-party software packages (ZEH, among others) offer ArcIMS® software-based, high-resolution printing solutions for GIS as well. Although not WTS/Citrix based, these solutions provide a server-based printing capability with a Web user interface, which could be useful in some circumstances.

Print Data Stream Size

As mentioned in the introduction, GIS maps can generate large print files or data streams across the network. The size of the data stream is related to

- The target printer
- The printer driver that is being utilized
- The complexity of the map (i.e., raster map prints are much larger than vector maps)
- The page size of the print job (e.g., large-format plots will generate much larger print data streams than 8.5" x 11")
- The output format (RTL, PS, export PDF, etc.)

In brief testing to compare file sizes, various print formats were used to generate EMF and raster files. Printing a typical map with fairly complex raster and vector data to an HP® Designjet® 1050 plotter with a page size of 34" x 44" generated a 112 MB data stream. Printing the same map to the same printer with a page size of 8.5" x 11" generated a data stream of 41 MB. That same 8.5" x 11" print exported in PDF format generated an 8 MB file (with some loss of detail). Eliminating the raster data dropped the file size for the PDF format to 13 KB. The testing showed that the advantages of a PDF diminish significantly as the plot size increases. With small files, there is a 10 to 1 reduction in print file size, whereas with large files (200–400 MB), there is only a 2 to 1 reduction.

Related technical notes: When printing or exporting maps that use transparent symbology (picture marker symbols, etc.), ArcMap will rasterize these, which will create huge print data streams or exports (1 GB). See the ESRI Support Knowledge Base document at http://support.esri.com/index.cfm?fa=knowledgebase.techArticles.articleShow&d=17332.

Transparent symbology should be turned off prior to printing or exporting to avoid this.

Also, if ArcGIS maps fail to print or if print files or data streams are too large, various workarounds can be used. See the ESRI Support Knowledge Base document at http://support.esri.com/index.cfm?fa=knowledgebase.techArticles.articleShow&d=17271.

Print format selection is an important consideration with GIS map plotting and may need adjusting during a data center consolidation implementing Citrix/WTS.

As described earlier, Windows print data streams are of two types: EMF and raw. The EMF data streams are generated by the application programs and are device independent. These data streams are then converted by the Windows printing process (or other processes) to the raw format, which is consumed by the printer. Usually the raw data streams (print jobs) are significantly larger than EMF; however, in a raster environment, this difference may not be as great (or in some cases, could actually be *reversed*) as with text or low-graphics print jobs. In a workstation environment where the printer is attached directly to the workstation, the workstation generates both data streams; however, the data stream never traverses a network. In a network environment where print servers are used, the workstation generates the EMF file, which is sent to the print server over the network. The print server then generates the raw format to the printer, which is directly connected to the print server.

J-9577

ArcGIS Printing from Windows Terminal Server/Citrix

As mentioned earlier, consolidating application software on centrally hosted servers has many advantages for managing software and conserving network resources. In some cases, however, it separates the users' printers and plotters from the server that is creating the print job (Citrix/WTS). This may introduce performance issues since some printers may be connected to the device producing print output with low-bandwidth connections. Hosting applications on WTS/Citrix also introduces another layer of complexity and administration to printing.

In addition to introducing potential printing performance and administration issues when using WTS, overall terminal server performance and reliability can be affected by printing processes. Using an incompatible driver, for instance, can cause the entire application server to freeze or hang, affecting all GIS users on that server. Generating huge plots can consume a great deal of CPU and memory on a terminal server. It is important, therefore, to implement WTS printing solutions that minimize these risks.

There are basically two types of printing from WTS:

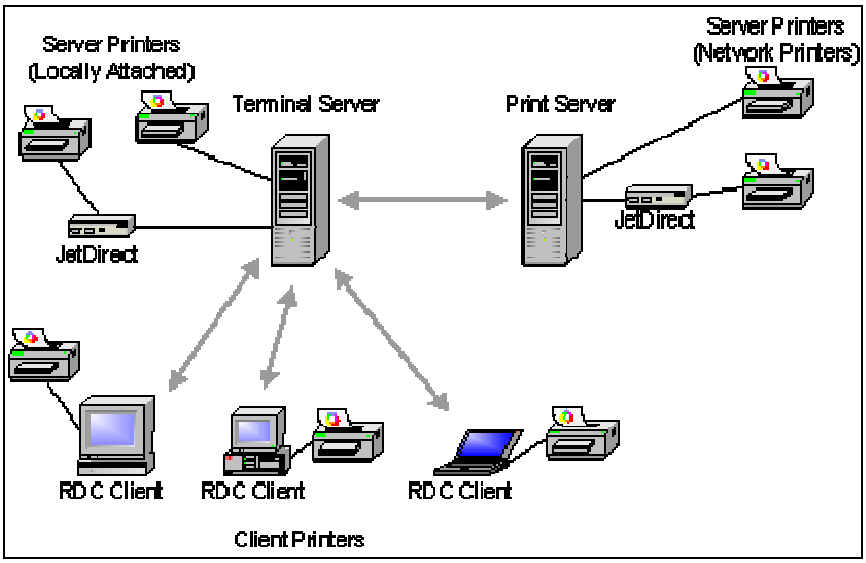
Server Printers—Printers in which WTS has direct access to the print queue. This could include network printers accessible via a network share or printers that are connected directly to a WTS server. These printers are installed on the WTS server with the drivers and utilities required. The EMF file is created on the application server and sent to the print server where the raw data stream is generated and sent to the printer.

Client Printers—Printers that are directly attached to the client workstation (installed) or mapped over the network from the client. In either case, for WTS to print to the client printer, the driver must be installed on the application server. All printing processes (EMF and raw data) occur on the application server, which may not be desirable. The compressed raw data stream is sent over the Remote Data Protocol (RDP)/Independent Computing Architecture (ICA) virtual channel to the client for printing. This method may not work well for GIS users in low-bandwidth situations.

Figure 2 shows the various printing configurations Citrix/WTS supports including printers attached to Citrix servers, printers attached to user workstations, and local and remote print servers.

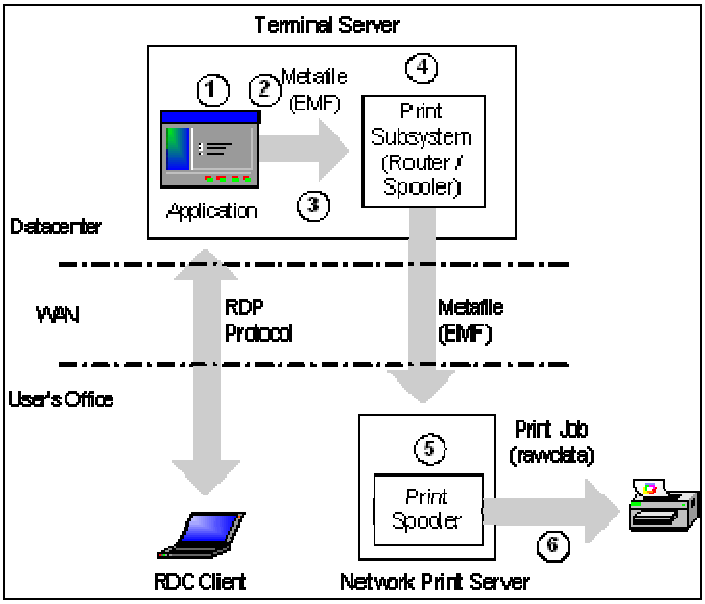
J-9577

Figure 2
Citrix Printing Options



In a WAN environment where remote users have printers and plotters, figure 3 shows a typical server-based printing process. Note that the EMF file must move across the WAN between the data center and the network print server. There is no compression of this file as the data does not move through the WTS virtual channel with RDP or ICA protocols.

Figure 3
Citrix Printing across a WAN



J-9577

Defining and Administering Printers

Before a printer can be used by a WTS user, the WTS server must have access to the print driver and the user must be able to access the printer. Defining the printer can occur in several different ways. Print drivers can be loaded onto WTS/Citrix servers and defined via Citrix policies. Or Citrix can be configured to automatically upload the defined print drivers to the user's workstation. In either case, when a user requests a print job, Citrix negotiates with the print driver to "map" the print driver to the Citrix server.

In large environments with dozens or hundreds of printers, printer administration on application servers can add a significant level of work and complexity to system administrators' jobs. In these environments with load balancing across servers, each application server must have all printers defined to it. To get around this, some third-party print products allow off-loading of the rendering process so that no drivers are required on the application server. Instead, the rendering process (which requires the native drivers) occurs on the client workstation or print server.

Once printers are defined, users must have a way to access them, and there are several methods that can be used:

- Map printers in users' logon scripts (this may be the best option).
- Map printers as part of a user's profile and policy settings.
- Install the printer locally on the server and configure its permissions (not a best practice, especially in large environments).

Some Citrix administrators have found that it is very important to have all user printers mapped to the terminal server before the user starts ArcMap. If this does not occur, users may not see all the printers that are assigned to them. Administrators can use logon scripts to do this mapping.

Large organizations with hundreds of printers can face a burdensome printing administration task in a Citrix/WTS environment. Given the complexities of printer and print driver management, assigning a single person or a team of people to handle this task can be an effective method for minimizing problems in the Citrix environment. Off-loading the rendering process from the application servers so that native drivers are not required can also dramatically reduce the administrative burden.

For additional information on these methods, check the Citrix or WTS administration guides. For discussion of these options, read Brian Madden's paper on WTS printing, which is available on his Web site (http://www.brianmadden.com/content/content.asp?ID=62).

Print Driver Compatibility

Not all printers and plotters are functional with Citrix/WTS. Citrix and HP have published a list of compatible devices and drivers; however, this does not guarantee that those printers will work in every environment. Even if a printer is supported, finding compatible drivers is important. When drivers are installed on application servers, there can also be compatibility issues between printer servers and application servers. For instance, if a 64-bit application server OS is being used with a 32-bit print server OS, there may be no drivers available to support the two environments. Using the wrong drivers can cause severe functional and performance problems, so testing each printer/driver combination is required. These problems can affect not only the printing process but also the overall performance of the Citrix application servers. The most current drivers for a printer may not be the best choice in some cases as well. Sometimes older drivers are more compatible with the WTS printing subsystem.

One symptom of incompatible drivers is long printer mapping time (negotiating between Citrix and printer drivers). If this mapping takes a long time, Citrix will eventually route the print to a default printer without notifying the user. (Behavior of this mapping process may also vary with different versions of Citrix Presentation Services). It is, therefore, important to retest all printers when moving to a new version of Citrix or WTS version. If print jobs are being routed to incorrect printers, incompatible drivers could be the reason. Another symptom of print driver problems is the application server freezes or hangs, which affects all WTS users on that server. In this case, off-loading the rendering process and attendant driver issues can make sense. In a fairly small environment with a limited number of printers and users, this may not be an issue.

Printer driver issues can also be avoided by using the Citrix Universal Print Driver (UPD) for those printers that do not have compatible drivers. This generally does not work well for plotters and large-format printers, but it can work well with typical office printers.

Citrix/WTS Server and Print Protocol Configuration

There are a variety of print protocols available for printing. These include

- HP LPR/LPD—Sends larger packets of data and prints fast but uses more bandwidth. It is more suitable for higher-bandwidth environments.
- Direct IP (Port 9100)—Sends smaller packets of data, prints slower, and uses less bandwidth. This may be more suitable for low-bandwidth environments.
- Socket (Raw TCP/IP).
- Enhanced IP (Port 9400).

A complete analysis of each of these is beyond the scope of this document; however, printing administrators should analyze their requirements with regard to printer functionality and performance and their network environment to determine what is best for their situation. Not all the protocols listed above may be supported in all environments.

Some users have resolved printing performance issues by modifying WTS configuration parameters. For instance, one large user who was experiencing printing performance problems fixed these problems with two configuration changes. These may not pertain to every environment, but this information is included for consideration in planning and testing. In the case of this particular user, the default printing protocol for HP was JetDirect® utilizing port 9100. This did not perform adequately over their WAN, so they switched the protocol to LPR/LPD using port 515, which dramatically improved the situation.

This same user also changed a Windows server setting on the Citrix servers because the print files were exploding across the WAN with print files five times larger than necessary. The setting was Enable MTU Discovery—Maximum Transmission Unit (MSS). The default setting is 1 and sends the print data in fewer and larger packets, which for their network environment, worked much better. If the setting is changed to zero, it sends out numerous smaller packets, which creates much more network traffic. The WAN in this environment was supported by 10 Mbps connections. With lower-bandwidth connections or different network topology, a different setting may be required.

Another user experienced major plotting performance problems with MrSID® images. The solution in this case was to turn on Opportunistic Locking (a Windows system setting) on each Windows Server file/image server and Citrix application server.

J-9577

These examples are provided to show a few types of problems that may be encountered when implementing WTS printing and to present solutions for them.

Citrix Presentation Server V3 (PS3) versus Presentation Server PS4

Citrix rebuilt its print subsystem for PS4, and for many non-GIS users, the capabilities provided will work well. The Universal Print Driver in PS4, for instance, utilizes the standard Windows EMF for print data streams, which are sent through the ICA channel. This will generally be a smaller print data stream than was utilized in PS3. For GIS, however, moving to Citrix PS4 could present the following issues:

- After some experimentation, some ESRI users have decided not to use some features of the new print subsystem as they do not work well in the ArcGIS environment. These include
  - The UPD feature does not work well with plotters or specialty printers. The full feature set of these devices is generally not supported with a UPD-style driver. (UPD can work well with typical office printers.)
  - When a user prints from ArcMap, the printer name is stored in the map document (MXD). The default PS4 Citrix printer naming scheme dynamically creates session-based printer names. If the Citrix printer name changes between sessions, the next time the user attempts to print, ArcMap will not be able to find its printer. Instead, the print job is routed to the default printer (without notifying the user). For this reason, users are using the old-style client-named printers instead of those with dynamically created session names.
  - Citrix PS3 and PS4 do not support TCP/IP-based printing, so the print drivers must be created dynamically for each session or managed on the application servers.
- The printers and drivers that worked with PS3 may well work with PS4, but it might require some driver updating or other changes. Testing should occur to determine this.
- Some administrators have noticed a dramatic decrease in the print data streams moving across the network due to the EMF-based printing scheme used with PS4.

Plotting over WANs

Given the potentially large GIS print data streams, printing across low-bandwidth WANs can be problematic. For example, moving a 112 MB plot file printed over a T-1 with a 1.54 Mbps bandwidth in a best-case scenario (i.e., when nothing else is happening on the network) would take 15 minutes and saturate the connection during that entire time. Figure 4 shows print jobs/hour and network transfer times for various combinations of bandwidth and print file sizes. These assume, of course, that no other network traffic is occurring and that the print job has access to all network bandwidth. These also assume that network latency is not an issue.

Figure 4
Printing Performance over a WAN

Wide Area Network Bandwidth	Total Possible Print Jobs/Hour (based on Average Print File Size)				
	5 MB	50 MB	100 MB	200 MB	400 MB
56 Kbps Modem	0	0	0	0	0
1.54 Mbps T-1	92	9	5	2	1
6.16 Mbps T-2	370	37	18	9	4
45 Mbps T-3	2,700	270	135	68	27
155 Mbps ATM	9,300	930	465	233	93
Note: 1 KB = 10 Kb FTP traffic					
Wide Area Network Bandwidth	Minimum Network Transport Time (secs) based on Average Print Size				
	5 MB	50 MB	100 MB	200 MB	400 MB
56 Kbps Modem	893	8,929	17,857	35,714	71,429
128 Kbps	391	3,906	7,813	15,625	31,250
256 Kbps	195	1,953	3,906	7,813	15,625
1.54 Mbps T-1	32	325	649	1,299	2,597
6.16 Mbps T-2	8	81	162	325	649
45 Mbps T-3	1	11	22	44	89
155 Mbps ATM	0	3	6	13	26

Surprisingly, a low-bandwidth network connection may not limit plotting speed. Most plotters are fairly slow devices. A T-1 connection, as shown above, could move 50 MB of data in 325 seconds (5½ minutes), yet the printer might take 20 minutes or more to print. So the network connection in this case is not the limiting factor in overall print time for the print job. These large print jobs, however, could be a major contributor to poor network performance for other users while the print data streams are moving across the network. This is especially true for printers with large input buffers and printing software, which download print data as fast as the buffer can take it. Also, other applications running concurrently across the WAN may impact the performance of the print job, dramatically lengthening the time to print. One of the goals of a sound GIS design is to minimize the size of these files, the duration of the data transfers, and the frequency of their movement across WANs.

Given the difference in size between raw and EMF print files, EMF files may be more network friendly, especially for lower-bandwidth connections. This means that generally the print spooler/server should be on the same LAN as the plotter/printer so that the smaller EMF files are crossing the WAN and the larger rendered, raw files are traversing a high-speed LAN. Citrix PS4 and some third-party print packages can compress the EMF files as well to reduce the size of the data transfer.

Another technique that some third-party packages (e.g., ZEH) employ is to send the raw print data to the plotter/printer at a speed that matches the speed of the actual printing and plotting. For many plotters commonly used in GIS, this print process is fairly slow. With this strategy, the print package intercepts print requests and spools the data (usually via TCP/IP protocol) to the printer at the speed at which the printer can consume it. This allows printing to start immediately and can be more WAN friendly, as only the amount of data that can be immediately consumed by the print process is sent over the WAN. This results in shorter/smaller bursts of print data transmission, which allows better sharing of bandwidth with other applications. Another technique that is used by some printing products is bandwidth allocation (or throttling). This allows administrators to define the amount of bandwidth that should be allocated to printing. This protects other applications from being delayed by heavy print jobs while guaranteeing that printing will occur, regardless of what else is traversing the network. One of these bandwidth-conserving techniques is often required for low-bandwidth networks.

J-9577

Plotting Management/ Performance Issues

In addition to network issues, large printing jobs offer several other challenges to GIS (and other) users. If a plotter runs out of ink or paper in the middle of a print job, the plotter or printer may not have the capability to resume the print job appropriately after the problem has been resolved. A network "hiccup" may cause an interruption in the print process as well. These events may require manually restarting the entire print job. To add insult to injury, if a print job fails, users may never know about the problem unless they physically check the printer. In an ideal situation, if a print job is interrupted, it would be able to automatically recover without having to restart. If a print job is delayed or canceled, the user would be notified and the print job would be automatically restarted if desired. These capabilities require an additional software layer; these are often referred to as enterprise print systems, or third-party print solutions.

One additional note: If large-format printing is required, ArcPress (or a third-party product) may be needed. ArcGIS Desktop software has limitations in the size of print jobs it can reasonably manage. ArcPress also has a number of other features for producing high-quality maps. ArcPress, however, does all EMF and raw data processing on the workstation or server, does not compress the data, and does not have print server or print management capabilities. This may not be suitable for all WTS/Citrix environments.

Enterprise Print Systems

Third-party vendors, such as IBM, DAZEL, and ZEH, provide solutions to assist in the management of printing tasks within an organization, both GIS and non-GIS, thin or thick client. Instead of printing directly to printers or to a Windows network print server, applications, such as ArcGIS Desktop, spool their output to the enterprise print system (EPS), specifying the printer to be used and other parameters required to print correctly. The EPS is responsible for managing the connections to the printers, queuing print requests, and sending the print output to printers as dictated by the user requests. An EPS can do much more than simply off-load the printing to a separate server. Some can also automatically restart failed print jobs, manage interrupted print jobs, and notify users when print jobs are canceled, interrupted, or completed. Some EPSs provide a Web interface so that users can manage their print jobs and printer queues.

Some EPS products can also print to plotter heads directly, bypassing the plotter's internal buffers. With this technique, as soon as the print subsystem starts sending data to the plotter, it can begin to print. Without this, a plotter may wait until its input buffers are full prior to printing. With the large buffers (e.g., 100 MB) available in newer plotters and printers, this can cause a significant delay in printing, especially when a large-print data stream is transported over a low-bandwidth network connection. The print-to-head technology will also utilize the network in shorter, smaller bursts, which is more network friendly. Another potential advantage is the consolidation of print queues into a single management system. Users can manage and view all their print jobs from one location. Citrix servers, which off-load printing to an enterprise print system, will not experience problems caused by low virtual memory on large print jobs since the print system generates large print images instead of the server.

Third-Party, Thin-Client Printing Solutions

There can be several significant issues with native Citrix/WTS printing in the GIS environment. These include the following:

- Printer drivers must be tested, installed, and managed on every WTS/Citrix server for each client printer in use in the environment. In a large environment, this can be very complex and time consuming.
- Client printing performance is poor, both in terms of the amount of data that must be sent across the network and the server resources required to render the print jobs.

- There are no good solutions for situations in which RDP/ICA clients and print servers are on one side of the WAN and the terminal servers are on the other.

Third-party products, however, can provide viable solutions for these printing issues by easing or removing them. These products fall into three broad categories:

- UPD-based printing
- Metafile-based (EMF and third-party) printing
- PostScript exports (or other ArcGIS exports) as a metafile

Universal print drivers do not work well with specialty devices, such as plotters, so they are generally not a good fit for those devices. This is true of the Citrix UPD solution as well as third-party products. For this reason, metafile or export-based printing products are recommended. They are technically superior to UPD-based printing products, but they are also more expensive.

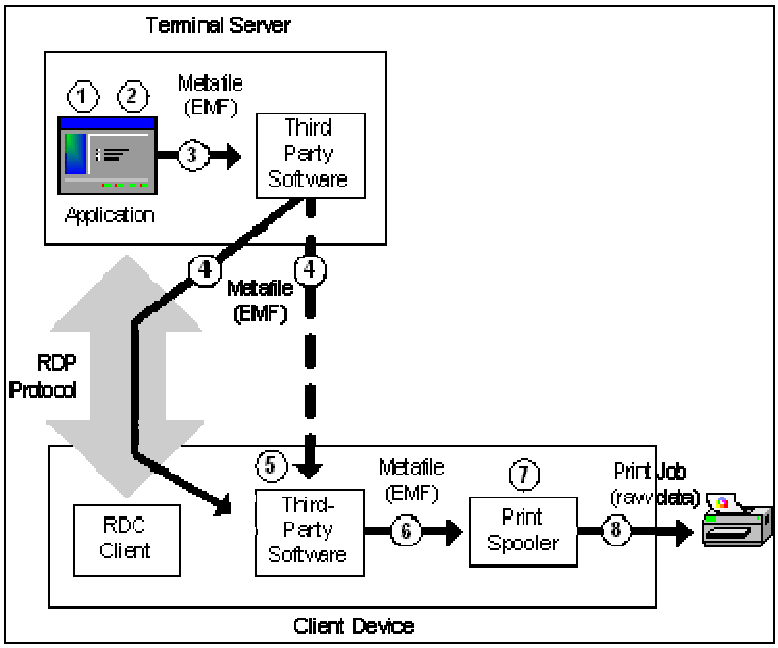
Metafile-Based Printing Products

ThinPrint and triCerat are examples of companies that provide EMF-based printing products. TriCerat has a product called ScrewDrivers®, and ThinPrint's product is called ThinPrint®. ZEH has several products as well. This market is always changing—new products are being added each year, so a detailed analysis of each product is not useful in this paper. Instead, users are encouraged to carefully research software options as part of each implementation project. Some general information about these products will be provided to show the advantages and disadvantages of various product capabilities—but this information will change over time.

Both triCerat™ ScrewDrivers and ThinPrint install a simulated print driver on the server that receives print data from the Windows GDI. This approach is similar to that of UPD-based products. However, unlike those products, these EMF-based products do not render the print job on the server. Instead, they send the device-independent EMF file to the client workstation or to a print server that has their print software installed. From there, triCerat or ThinPrint client software forwards the EMF print data to the client/server print subsystem. The client device renders the print job and sends it to the appropriate printer. Figure 5 illustrates this process.

J-9577

Figure 5
The Third-Party EMF-Based Printing Software Process



Third-Party EMF Printing Process

1. The user prints from an application on the terminal server.
2. The GDI generates an EMF file. TriCerat generates its own type of metafile, which is not a standard Windows metafile.
3. The third-party software component running on the terminal server receives the metafile.
4. The third-party software compresses and transmits the EMF file to the RDP client. It is transmitted through a virtual channel of the RDP or ICA protocol, although ThinPrint has the additional option to transmit it directly to the client via TCP/IP outside the RDP protocol. (This may be a good alternative for low-bandwidth installations.)
5. A third-party software component on the client/server receives the EMF file.
6. The third-party software transfers the EMF file to the local print spooler on the client/server device.
7. The client/server device's local print spooler spools and renders the print job.
8. The print job is transmitted to the client's printer, just like any print job in a nonterminal server environment.

Advantages of EMF-Based Printing Software

- EMF-based printing software allows printing to any printer without having to install and maintain the print drivers on WTS/Citrix servers. This eliminates the need to find Citrix-compatible drivers, test them, and manage all these drivers on Citrix servers. Printer driver management occurs on print servers or client workstations (whether local or remote) and utilizes standard Windows driver management tools.

- EMF print data can be smaller than raw print jobs, thereby increasing the speed of the printout and reducing the impact on the network; although, as explained earlier, this may not be the case with plot files for map. However, with some third-party products, the EMF print data is compressed up to 90 percent.

- EMF print data is also smaller than PDF/PCL files (used by the UPD-based products). Also, the compression ratio of EMF files may be higher than PDF/PCL files.

- Printers can be replaced or added without having to notify the terminal server administrator. This greatly reduces administrative overhead.

- Since the print job isn't rendered until it hits the remote workstation or print server (which has the native print drivers), the full capabilities of the printer or plotter can be utilized. This is especially important for specialty devices such as plotters. This capability is available in some third-party products but not in others.

- Since the print jobs are not rendered on the Citrix server (for some products), the servers will not experience as large a performance hit in heavy printing environments as UPD-based products do. This is one of the major goals of a Citrix installation.

- Documents are printed with 100 percent of the original quality since lossless compression is used. This can be important when plotting high-quality maps.

- Some third-party print products, such as ThinPrint, provide methods for throttling the print data transfer process to match the speed of the printer, thus conserving network bandwidth. This can be important in low-bandwidth infrastructures. Some products also have the capability to allocate bandwidth to printing to ensure high-quality printing performance.

- Third-party products may be better at servicing printing over unstable, low-bandwidth connections, tolerating up to 90 seconds of disconnect without canceling the print job, as in the case of ThinPrint's solution.

Note: Some third-party products reduce print file sizes and processing loads by requesting a low-resolution EMF file, then "faking" a higher-resolution print and making certain assumptions. This may not work well for higher-quality GIS maps.

TriCerat builds the print device drivers dynamically on the application server at session initialization time and creates its own type of metafile, which is then rendered and sent through the ICA or RDP virtual channel to the client device. In cases where off-loading the rendering process from the application server is important, TriCerat would not be a good choice because it does not provide this capability. The product also currently does not support TCP/IP print connections; the print streams go through the same virtual channel as Citrix/WTS traffic.

The third method of printing, which uses PostScript exports from ArcGIS, is utilized by ZEH. The PostScript export serves as the metafile for the printing process. The ZEH print server renders the exported file in RTL, PCL, or PS format to match the capabilities of the plotter including color and resolution.

J-9577

Third-Party PostScript-Export Printing Process

1. The user requests a print from ArcGIS on the terminal server using the ArcGIS ZEH plug-in extension to ArcMap.
2. ZEH requests a PostScript export from ArcGIS, and ArcGIS produces this file and sends it to the ZEH print server located in the data center (or to a remote server).
3. The print server renders the PostScript file, correcting and modifying the data stream to match the full capabilities of the target printer/plotter.
4. As the rendering occurs, the raw data stream is immediately sent to the printer via TCP/IP. This allows plotting/printing to start immediately without waiting for the rendering process to complete. This also effectively throttles the network utilization by sending smaller, more frequent packets of print data rather than a single large data stream.

Advantages of PDF-Based Metafile Printing Software

- This software allows printing without having to install and maintain the print drivers on WTS/Citrix servers. This eliminates the need to find Citrix-compatible drivers, test them, and manage them on Citrix servers. Printer driver management occurs on the ZEH print servers, and the software uses its own print drivers.
- Printers can be replaced or added without having to notify the terminal server administrator. This reduces a great deal of administrative overhead.
- This printing process is more WAN friendly since TCP/IP-based printing typically sends smaller packets of print data over the network.
- Printing/Plotting starts immediately without waiting for the entire data stream to find its way over the WAN or for the printer buffers to fill. This can dramatically shorten print times.
- Since print jobs are not rendered on the Citrix server (for some products), the servers will not experience as large a performance hit compared to UPD-based products. This is one of the major goals of a Citrix installation.
- Documents are printed with 100 percent of the original quality since compression is not used and high-function printer/plotter drivers are used. This can be important when plotting high-quality maps.
- No client-side software is required other than the ZEH plug-in to ArcGIS Desktop software.

Other Considerations

- Compression is not utilized for the raw data stream. Network utilization is lowered by using TCP/IP-based printing.
- ZEH uses its own print drivers, so all printers or plotters may not be supported. However, ZEH supports most HP plotters including many older plotters that are still in use.
- ZEH does not have a method for managing network utilization other than the TCP/IP-based printing process itself.
- PDF exports can be heavy consumers of application server resources and, in some cases, may fail due to shortage of system resources. There are workarounds for this.

PDF exports may place higher CPU and memory loads on application servers than EMF-based printing products.

Third-Party Product Summary

Third-party solutions can offer significant advantages to a GIS WAN implementation in the areas of print management, print quality, and printing and network performance. Some low-bandwidth implementations may actually require a third-party solution to be successful. Not all third-party solutions have the same capabilities, however, so their functionality should be carefully assessed according to specific requirements.

Case Studies

This section examines several real-world experiences with users implementing ArcGIS Desktop in the Citrix/WTS environment.

Large Government Agency

A Canadian government organization consolidated its 1,400 ArcGIS Desktop users into a centrally managed Citrix environment, containing more than 30 Citrix servers. With more than 15 remote locations serviced by low-bandwidth connections and hundreds of printers and plotters of various types scattered around the region, printing was a major concern. The organization initially implemented early versions of Citrix and it took many months for printing to work properly. No third-party solutions were used. The issues and solutions were

- Not all Citrix-certified drivers worked properly in this environment. Drivers had to be updated or, in some cases, printers/plotters were not supported or did not perform well and required replacement.
- Network connections with T-1 or below did not perform adequately for Citrix traffic, printing, and the other uses it needed to support. Most of these connections had to be upgraded; 10 Mbps was implemented in most locations.
- Some application server settings and default printing protocols had to be adjusted to provide workable printing.

With these changes in place, printing and plotting has been working well with few remaining issues. The Citrix PS4 printing subsystem naming scheme is not being utilized because of the previously mentioned issue with dynamic printer names. Also, Citrix UPD was not implemented because it did not work for the organization's plotters and printers. Bandwidth management schemes could not be used, as most of the organization's network segments entered into a common network cloud that was not managed.

U.S. Government Agency State Office

A U.S. government office servicing offices in a large state began consolidation of its ArcGIS Desktop users into a centrally managed Citrix environment. This office supported hundreds of GIS users at dozens of remote locations serviced by T-1 or better connections. Remote printing requirements included 30 plotters and several hundred printers. Initially, printing performance was the major concern; however, since making several adjustments to the infrastructure, performance has not been an issue. In general, printing is working well, and users are satisfied with performance. The basic architecture is as follows:

Print drivers are mapped from client workstations at Citrix session initialization. A logon script maps each printer defined to the workstation prior to starting ArcMap. Citrix PS4 print subsystem is used with the old-style hard-coded printer names to avoid the ArcMap printer name problem mentioned earlier. EMF print streams are generated on the application server and sent over the WAN to the workstation (compressed via the ICA channel), which forwards the print job to a print server servicing the local office. The

print server then renders the print job and sends it to the printer. Lessons learned through this implementation were the following:

- Not all Citrix-certified drivers worked properly in this environment. Getting the right drivers in place and restricting print drivers (through Citrix policies) to those defined on the application servers were important. This organization dedicated one person to printer and print driver management so that it had tight control over the process. Once this was done, printing problems were dramatically reduced.
- Some printers did not perform well or did not have appropriate Citrix/WTS drivers. For most of these, using the Citrix UPD was a good solution. However, this did not work with plotters or large-format printers, which required the use of native drivers.
- Exporting maps to PDF files, then zipping and shipping them via e-mail or FTP is a common technique.
- Initially, the agency experienced issues in plotting performance with MrSID images. The solution for this was to turn on Opportunistic Locking on each Windows file/image server and Citrix application server.
- ArcPress is used by some for printing, which works well.
- The agency recognizes that printer administration is a major task for this architecture. For an organization of its size, this is manageable, but for a regional or nationwide architecture with many thousands of users and hundreds of printers, this task could be overwhelming. The agency could have looked into third-party products that do not require application server-based drivers if its environment were substantially larger.

With these changes in place, printing and plotting have been working well with few remaining issues. The agency will not utilize the Citrix PS4 printing subsystem naming scheme because of the previously mentioned issue with dynamic printer names. Also, the Citrix UPD did not work for some of the plotters and printers.

Large Utility Company

A large U.S. utility company utilizes Miner & Miner's ArcFM™ product (which is based on ESRI GIS desktop software). It consolidated its application software several years ago onto Citrix servers. Because it does not often use orthoimagery or other raster data, the print and plotting jobs for its maps and other printed products are considerably more lightweight than most other GIS maps. Most of the company's printing occurs in the data center, so high-frequency printing over low-bandwidth connections is not a concern. For these reasons, there were few issues in implementing Citrix-based GIS printing.

Small Government Agency

This agency has 100 concurrent GIS users scattered throughout a number of remote sites serviced by T-1 and fractional T-1 network links. Five years ago, it began planning and implementing a centrally hosted Citrix environment and identified plotting as its main obstacle. Citrix and WTS did not provide solutions for the low-bandwidth situation, so the agency looked at third-party solutions. At that point, ThinPrint was the only solution that met its criteria, which were the following:

- Provide a way to throttle/manage network utilization for printing and print outside the RDP/ICA channel.
- PDF-based printing did not meet legal requirements for map production.

ThinPrint was implemented successfully, but it took more than a year to perform testing, run a pilot program, and obtain permission to buy and use the product and implement it. It took four to six months to properly configure the agency's environment, including determining the amount of bandwidth throttling to use and tweaking the HPGL2 drivers on the ThinPrint server to provide the correct colors and other parameters required to mimic PostScript drivers.

Printing has been working well, even in the low-bandwidth (256 KB) environments, and some users actually get faster prints than with local printing.

Summary of Strategies

ArcGIS Desktop printing with Citrix over a WAN inherits all the issues of Windows and Citrix printing over a WAN. Because GIS print/plot files are so large, however, these issues are important to resolve. Unfortunately, there is no magic bullet for remote printing of these large files, and organizations must usually experiment with a variety of methods, settling on several that satisfy the basic requirements. With bandwidths less than 10 Mbps (such as T-1 or fractional T-1), plotting becomes much more problematic and requires careful planning, sometimes taking months to implement. This is especially true if the connections are not stable. Some users have had success in printing over T-1 connections, while others have not. There are, however, several implementation strategies that can minimize the impact of printing on application servers and networks and increase the chances of a successful WTS/Citrix implementation.

- Carefully define the printing requirements for the various locations and users that will be involved.

  For each location, list the printers that will be supported and the frequency and types of printing/plotting that will occur. Gather network bandwidth and utilization information about the networks connecting the remote locations. Analyze the user needs and decide what is most and least important to the users and to the organization. With this information, examine the available strategies and technologies and identify those that are appropriate for each situation. A sample Enterprise Printing Requirements Form is included in appendix A. A Sample Product Strategy Comparison Chart, which allows side-by-side comparison of different products or options, is included in appendix B.

- If application server-based driver printing products are used, the selection of printers/plotters and drivers is very important to Citrix (or third-party) printing functionality and performance.

  Not all print drivers work in the WTS and Citrix environments. Using Citrix-friendly drivers is equally important. Start with Citrix-certified printers and drivers and thoroughly test printing configurations prior to production. Some third-party products are not driver sensitive and will support virtually any Windows printer driver, while others may be driver sensitive. For some printers, Citrix UPD can be used if native drivers do not work well. In some cases, it might be necessary to replace printers or plotters that either do not work or perform poorly in the Citrix environment over a WAN.

- Make sure that the Citrix/WTS server configuration settings and print protocol types are optimized for WAN printing.

  As mentioned earlier, there are several server and protocol parameters that can affect performance across a WAN.

J-9577

- Off-load print rendering (raw print data file creation) from the Citrix/WTS application servers whenever possible.

  If possible, do not attach printers directly to Citrix boxes; instead, use a network print server located at the remote locations, or if that is not possible, use data center-based printer servers. Printing large maps directly from application servers can create performance problems on the servers (memory and CPU utilization). Rendering on application servers can also cause the server or server processes to freeze or hang if driver problems are encountered. These issues affect all the users on the application server. Utilizing third-party software solutions that off-load the rendering may be a viable solution for this as well.

- When appropriate, instead of printing maps (especially large-format plotting) directly from ArcMap, export PDF files, zip them, and move these to the remote print server for unzipping and printing where possible.

  The PDF print files can be much smaller than the Windows print files (by a factor of 10 or more). For plotting, the default printer settings will need to be adjusted manually to accommodate the larger formats.

- Use print formats that create smaller data streams. PostScript, for instance, often creates large file sizes compared to other formats.

- Consider direct print technology such as that offered by ZEH print subsystem. This could reduce network congestion by synchronizing the transfer of information over the network to the speed of the printing process, which is usually fairly slow, especially for plotters.

- Consider using a third-party print system—enterprise print subsystem—that allows off-loading of printing from the application servers and provides better print management functions.

- ArcPress may not be a viable choice for some Citrix/WTS installations.

  ArcPress (which is included with ArcGIS 9.1 Desktop and subsequent versions) renders the raw print data stream at the client workstation (or application server) so that the printer does not have to do any translation or storage of data. While this enables high-performance plotting, the processing will occur on the Citrix server. This is not desirable, as it will generate heavy processing and memory loads on the Citrix server and the large, raw print data streams must traverse the WAN. ArcPress also supports a limited set of printers, and the drivers would need to be installed and maintained on the application servers.

- Managing the bandwidth available to printing and to Citrix/WTS client traffic through bandwidth allocation schemes can provide better and more predictable performance for all users of the WAN. Printing can consume a large percentage of network capacity, especially over low-bandwidth connections such as T-1 or less. Print jobs can also be heavily impacted by other network traffic.

  Citrix and third-party print products provide management tools for this purpose, and there are other quality of service (QOS) network management tools that can be used as well. These do not work well if the private WAN connects to shared network "clouds" where bandwidth cannot be managed.

- If printing is still a problem, look at the maps themselves, especially the print quality, resolution, colors, complexity, and so forth, and see if these can be modified to reduce print stream sizes. Using rasters dramatically increases file sizes, so if some maps can be created without rasters, these will have much less impact on the printing environment.

- If remote printing still does not work well in some situations, consider installing one or more shared copies of ArcGIS Desktop software (possibly with Citrix) at the remote locations, which can be used to generate local prints/plots. This may require moving the data to produce the map across the WAN. If possible, arrange for this to occur in the evening when network utilization is low. This should be a last resort.

Appendix A: Enterprise Printing Requirements Form

Purpose

To gather printing/plotting requirements for printing architecture planning

Server-Side Information

- Will your organization consider an integrated printing solution for both GIS and non-GIS applications, or should a solution be developed strictly for GIS?
- Number of GIS Terminal Servers:
- Server Model, OS, and Service Pack:
- Version of Citrix Presentation Server and/or Microsoft® TS used:
- Is there a dedicated print server local to the terminal servers that will be used for printing (same subnet)? If so, please describe and indicate how many plotters/printers will be supported.
- Is there NAT or firewall between remote offices and data center servers?
- Can remote servers or workstations be set up to communicate with the Citrix servers in the data center with static (real) IP addresses? (Additional software expense may be incurred if this cannot be provided.)
- Any third-party servers (SAP®, Linux®, AS/400®, etc.) involved:
- Are there any third-party printing solutions that are being used or need to be supported?

Client-Side/Remote Site Information

- Are there any home users that need to be supported?
- How many remote offices/home users will be supported?
- What is the effective bandwidth to each remote office/home user?
- Are there any known network issues (performance, stability, high utilization) with any of the connections to the remote offices?
- For each remote site, are there (or will there be) any Quality of Service or bandwidth allocation systems being used between the data center and the remote sites? If so, please describe and note if there is a GIS or other suballocation that will affect bandwidth availability.
- How many users are at each office/home including the data center?
- How many printers are used at each office/home (including the data center)?
- Do you use PCs, thin clients, or both?
- Client types, OS, and Service Pack:

- Version of Citrix client used:
- Version of Microsoft RDP client used:
- Are there (or will there be) any dedicated print servers at the remote offices?
- How are the printers integrated into the network?
  - Locally attached: LPT, USB.
  - Network printers: IP or netshare.
  - If IP, are they print boxes?
  - Other.
- Make/Model of printers/plotters used at each location:
- Please describe the main type and frequency of printing/plotting at each location:
  - Microsoft application printing
  - GIS map printing
  - GIS map plotting
  - Other applications (Please list.)

Project Information

- Please describe any other technical or organizational constraints or requirements that would affect a printing/plotting architecture solution.
- Is a centralized printing management function (drivers installed on all application servers) feasible given your expected infrastructure and system support resources and skills? Please describe.
- Is the IT architecture going to change over the next several years in ways that would affect printing and application server architecture or support? Please describe.

Appendix B: Sample Product Strategy Comparison Chart

Printing Product Strategy Comparison				
	Strategy 1	**Strategy 2**	**Strategy 3**	**Strategy 4**
Printer Management				
Supports all Windows Printers/Plotters				
Drivers managed on application servers				
Supports dynamic driver installs on application server from client printers				
Uses native printer drivers				
Uses proprietary printer drivers				
Printing Architecture				
Supports UPD-based printing				
Supports EMF-based printing				
Requires rendering on application server				
Supports rendering on client or print server				
Requires software on client				
Supports print server-based printing				
Supports 'direct print' function				
Printing Process Mgmt				
Supports automatic restarts of failed print jobs				
Supports user notification if print job fails				
Provides a single point for queue mgmt				
Provides a web application for user and administrator print queue mgmt				
Network Architecture				
Supports bandwidth management for printing				
Supports printing outside of WTS virtual channels				
Tolerates network disconnects				
Supports RDP protocol				
Supports ICA protocol				
Supports TCP/IP printer connections				
Supports EMFcompression				
Supports raw print data stream compression				