White Paper

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Wide Area File Services

Delivering on the Promise of Storage and Server Consolidation at the Branch Office

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Wide Area File Services

In an effort to regain control of mounting IT costs, ensure data integrity and security for compliance and avoid risks, enterprise IT organizations are now in the midst of widespread initiatives to consolidate the distributed servers and direct-attached storage that proliferated in the early 90s.

Unfortunately, these consolidation efforts usually stop before they reach the outermost edge of most IT organizations: Remote or branch offices. Traditionally, Branch Office IT environments have remained "the wild frontier" in IT organizations, often requiring costly investment and duplicated IT infrastructures of that found at corporate.[1] This investment can include acquisition and on-going maintenance of local file/print servers, additional tape or disk-based backup software and hardware, and significant additional management overhead.

The reason for this duplicate architecture is simple: Remote users have come to expect LAN-like access times when opening or saving files. Until recently, the inherent limitations of wide area networks made it impractical for remote users to access traditional Microsoft Office-type files housed at a consolidated datacenter location, because users are forced to wait minutes to open and save files.

Today, however, new technologies make it possible for remote users to experience LAN-like access times for files transmitted over the WAN. Wide area file services (WAFS) are one such technology that is changing the playing field for Branch Office IT.

This white paper describes how WAFS allows IT organizations to extend the benefits of centralized storage consolidation to up to hundreds of Branch Offices. A key enabler for true, global storage consolidation, WAFS solutions are already saving enterprise customers hundreds of thousands of dollars in storage, systems administration and staffing costs. In this way, they are helping overcome the problem and delivering on the promise of server and storage consolidation. They are also becoming an integral component in the push toward real-time file-based collaboration by employees at different locations.

Consolidation: Curing the Pain of Distributed IT Environments

Enterprise systems administrators are under a significant burden to manage and protect data stored in distributed file servers and in direct-attached storage (DAS) devices associated with each of a company's application servers. In these types of distributed IT environments, 25% or more of an administrator's time can be spent provisioning more storage, performing backup elated functions, or upgrading servers to accommodate exponential data growth. This cost of distributed storage and servers also extends to the need to frequently acquire new servers – often, each time a new application comes online or an existing application runs out of storage capacity.

In an effort to move away from this reactive model, many global IT organizations have undertaken widespread efforts to consolidate and centralize their dispersed servers and storage resources. New networked storage technologies, such as storage area networks (SANs) and network-attached storage (NAS), now allow a variety of file- and block-based data to be stored and managed centrally via the use of "virtual volumes."

These consolidation efforts produce a number of benefits, including:

- Lowered IT costs
- Reduced storage management burden
- Better utilization of existing assets
- Significant reductions in backup/recovery times
- Centralized data management
- An infrastructure that more easily supports the adoption of enterprise-wide best practices, policies and regulatory compliance rules regarding retention, storage, and retrieval of critical company data.
- The ability to offer higher levels of service surrounding data availability, reliability and data protection.

In all, analysts estimate that system administrators can manage as much as four to 10 times the amount of storage in NAS or SAN environments as they can in DAS environments.

Typically, many organizations that undergo storage and server consolidation also report being able to replace six to 10 servers with just one server, thanks to networked storage.

Consolidation and the Branch Office Dilemma

In an ideal world, companies undergoing global data storage or server consolidation projects would also consolidate much of their regional or Branch Office data to one central location.

After all, over 75% of corporate data now resides outside of a corporate datacenter.[2] It only makes sense that IT groups would want the option to centrally manage, store and protect the wide range of data that often exists at the periphery of their enterprise as well.

Unfortunately, this ideal consolidation scenario does not take into account the non-trivial technical challenges involved when remote users try to open or save files over a wide area network (WAN) connection. The common issues of WAN latency, WAN reliability and insufficient bandwidth typically translate into average wait times of several minutes when users attempt to open or save either a basic Microsoft Office file or even longer wait times when accessing larger, technical files like those found in typical CAD (computer-aided design), architecture and product design environments.

Let's take a closer look at a few of the most common obstacles to WAN-based file access.

WAN Issue	Resulting Impact
Latency	Challenge: Saving or opening each file across the WAN can take minutes, or sometimes does not complete. The act of opening or saving a basic file across the WAN can involve thousands of individual "round trips" across the WAN, known as remote procedure calls, or RPCs. Network delays due to WAN latency are significantly higher (two to four orders of magnitude) than LAN access times, but file-sharing protocols like CIFS and NFS were never designed to handle high-latency environments. Every "round trip" generated by the CIFS or NFS protocol over the WAN incurs a high-latency delay, dramatically impacting performance. As distance and network contention grows between two points on the WAN, more network delay occurs, and the problem is exacerbated.

WAN Issue	Resulting Impact
Lack of Bandwidth	Challenge: Lack of network bandwidth may cause unacceptable slowness when accessing files remotely. This often forces remote users to work around the problem by copying or editing once-centralized files on a local fileshare or directory. Such workarounds can lead to problems later with multiple versions of the same file and redundant data scattered throughout the enterprise. Effective branch office WAN bandwidth to carry file requests can be 10-100 times lower than LAN bandwidth in the form of either T1, DSL or frame relay connections. Adding VPN and other network layers on top of the WAN can also further reduce WAN bandwidth.
Lack of Reliability	Challenge: File data in the process of being saved or opened can "time out" indefinitely. Newly changed files also run the risk of being lost in flight. WANs are inherently less reliable than LAN connections and may be subject to occasional packet loss and sometimes frequent network outages (especially when used with satellite or microwave link technology).

Combined, these challenges are usually enough to nix most plans to consolidate Branch Office servers and storage. The option left to IT groups who want to support their Branch Office users is usually the development of "mini silos"[3] of duplicate IT infrastructures at each Branch Office location. These include print/file servers and separate network infrastructures that support the needs of each office.

This arrangement solves remote user problems of unusually slow file access times. However, mini silos also introduce many of the same challenges experienced with LAN-based servers and their direct-attached storage. In fact, Branch Office IT environments put an even tougher management burden on central IT organizations since IT groups must now also grapple with how best to keep remote servers updated, maintained and adequately protected and IT expertise to do this may not be available on-site.

Wide Area Services (WAFS): Overcoming Branch Office Barriers to Consolidation

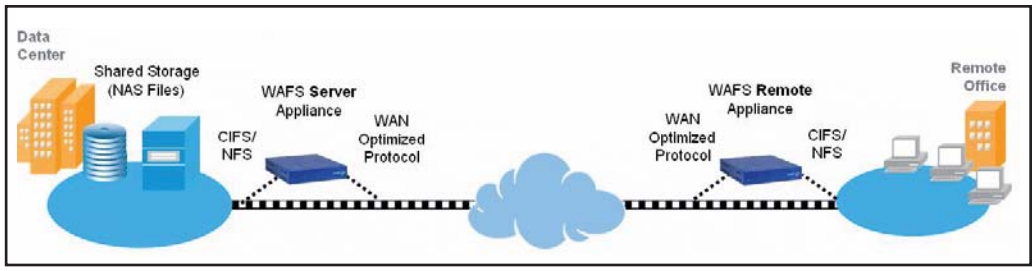
A new class of solutions, offering what's become known as Wide Area File Services (WAFS), resolves the most common WAN barriers standing in the way of remote storage consolidation.

Allowing files to be stored centrally in a shared network-attached storage (NAS) device at the main datacenter, WAFS solutions allow remote users to save or open files over the WAN at LAN-like speeds.

How WAFS Works

Typical WAFS architectures consist of two components: A Server appliance, housed at the main datacenter, and one or more Remote appliances, housed at each Branch Office location (see Figure 1).

Figure 1: Sample Configuration Using WAFS to Store Data Centrally and Access It Remotely.



Each WAFS appliance communicates with existing remote client PCs and file servers via standard protocols, such as CIFS and NFS, and communicates with each other using a custom, WAN-optimized protocol. Using this custom protocol and optimization techniques, WAFS is able to eliminate excessive WAN roundtrips, or RPCs, that are the key culprit behind WAN latency issues.

At the datacenter, the WAFS server appliance appears as just another client to the shared, network-attached storage (NAS) device installed at the main site. At the remote site, users see the remote WAFS appliance as a NAS device with network file shares.

WAFS solutions tend to address the three WAN issues of latency, network reliability and low bandwidth in several ways. Best-in-breed WAFS appliances typically enforce sophisticated read/write caching algorithms, along with data compression and data streaming techniques, to shield users and their files from the most common WAN challenges. Some WAFS systems also enforce distributed file locking functionality to further guarantee data integrity and consistency so that only the latest version of a centrally available file will be presented for viewing or further edit.

Combined, this functionality effectively turns the WAN into a global LAN, where employees around the world can readily access and utilize the same files.

Key Benefits of WAFS Solutions

Wide Area File Services solutions are an innovative and surprisingly cost-effective way for organizations to regain control over their distributed, Branch Office environments and enable further centralized server/storage consolidation.

According to Taneja Group research,[4] customers who apply WAFS solutions to server and storage consolidation problems tend to experience the following benefits:

- Very rapid ROI payback periods, usually in under one year
- Consolidated data protection
- Increased utilization rates
- Establishment of best practices
- Reliable collaboration architectures

A closer look at these installations also reveals that WAFS significantly reduced the amount of storage and servers required. WAFS customers also report lowered operational costs and more streamlined processes surrounding Branch Office backup/recovery, remote business continuity and enforcement of regulatory compliance procedures. A later section on WAFS ROI and TCO describes these benefits in more detail.

WAFS Evaluation

When you evaluate effectiveness of WAFS solutions for your environment, ask the vendor how the solution addresses the issues of WAN latency, network reliability and low bandwidth. Some other key areas to explore during evaluation include the following:

- WAFS performance – File access and directory lookups should be at speeds approaching the LAN.
- System reliability and resiliency – How well does the system recover from WAN disruption or other failure?
- Data integrity – How does the WAFS solution ensure that users see the latest version of the file and that file updates are not corrupted?
- Data security – How does the system protect files from unwanted access or intrusion?
- Scalability and extensibility – How many Branch Offices or concurrent users per office are supported?
- Integration and protocol support – How well does the system work with the complexities of CIFS or NFS file sharing protocols, and how well does the system integrate with existing IT and security technologies?
- System management and ease of use – How much time will it take to administer?

(Each of these areas is discussed further in the appendix to this white paper, which includes sample questions to ask during any WAFS evaluation.)

WAFS vs. the WAN: Performance Benchmarks

Before WAFS technology came on the scene, companies could not consider the prospect of storage consolidation for their Branch Offices. The painful process of accessing files over the WAN made the idea of remote storage consolidation virtually impossible. WAFS has changed this equation, however, with dramatic WAN performance characteristics for remote users who attempt to open or save centralized files.

The following subsections show WAFS in action in controlled test environments and in real world customer settings.

WAFS and Third-Party Performance Testing

The University of New Hampshire Interoperability Lab conducted independent WAFS performance tests over a period of 12 weeks within a simulated WAN environment. Using Packeteer's WAFS solution as a test case, the lab conducted a series of tests surrounding WAFS performance with a single user and under a simulated load of between 250 and 500 users. Tests were also conducted concerning reliability of the WAFS solution in the event that it encountered any WAN disruption, degradation or server failover event.

According to a report from the Taneja Group,[5] test results demonstrated "a clear and dramatic performance improvement" accessing a variety of applications with the WAFS solution versus native WAN performance. As one example, the Taneja report mentioned the WAFS solution was able to sustain "performance improvements of 78 times over the native WAN for a file save operation involving a 1.6 MB MS Word file over a U.S. continental distance." The WAFS solution also exhibited little to no change in its performance characteristics when handling hundreds of concurrent users, or when responding to WAN disruptions or potential packet loss events.

The follow table shares other findings from the UNH-IOL WAFS performance benchmarks.

Note that this table highlights initial file open and save performance characteristics with a WAFS solution. Subsequent remote read/write access times on the same files were substantially faster after initial file opens and saves had been performed.

Testing Performed in Simulated WAN Environment with "Remote" Files of Medium Size[6]	Latency Values					
	120 ms			240 ms		
	Native WAN Open	WAN with WAFS "Cold" Open	WAN with WAFS "Warm" Open	Native WAN Open	WAN with WAFS "Cold" Open	WAN with WAFS "Warm" Open
Microsoft Word document	14.85	2.90	1.44	28.56	4.88	2.02
Microsoft Excel spreadsheet	24.68	2.15	< 1	44.76	3.31	< 1
Microsoft PowerPoint file	22.42	3.39	3.07	41.84	5.08	3.51
Adobe Photoshop file	33.89	4.03	2.32	54.54	5.15	3.98
Microsoft Word document	56.63	4.0	1.5	94.79	5.38	2.26
Microsoft Excel spreadsheet	15.31	10.83	6.37	27.30	15.45	9.07
Microsoft PowerPoint file	20.48	5.1	2.92	35.77	6.53	3.46
Adobe Photoshop file	44.81	8.25	5.10	74.77	12.13	7.58

WAFS and AutoCAD Benchmarks

File sharing and collaboration are common requirements among many leading architecture, engineering and construction (AEC) firms. Many of these firms create large design files, using common applications such as AutoCAD or SolidWorks. AutoCAD files, in particular, typically involve a high volume of redundant data or "scratch work" that is created by the application during the normal process of opening or saving a file. When users attempt to open or save this type of file over the WAN, the overhead involved in transferring the background scratch work usually translates into an unacceptable wait time of several minutes.

Best-in-breed WAFS solutions make it possible for geographically dispersed offices to work on the same design file in real-time, as if they were on the same LAN. Benchmark tests follow for AutoCAD file open and save procedures performed using the WAFS appliance from Packeteer as a baseline. The time saved in the following table clearly demonstrates the value WAFS can bring to distributed AutoCAD environments.

Testing Performed with AutoCAD 2004 Files of Various Sizes[7]		Seconds Required to Open/Save the File (Testing conducted at 100 ms latency, with 0.8% packet drop rate)				
Bandwidth	AutoCAD File Size	Native WAN Open	WAN with WAFS "Cold" Open	WAN with WAFS "Warm" Open	Write/Save with Native WAN	Write/Save with WAFS
1.54 Mbps (T1)	1.3 MB	47.8	8.1	5.1	72.2	9.4
	6.7 MB	80.4	26.0	9.1	154.2	11.7
512 Kbps	1.3 MB	68.1	16.2	5.6	88.5	9.4
	6.7 MB	165.6	55.2	9.5	276.6	12.0

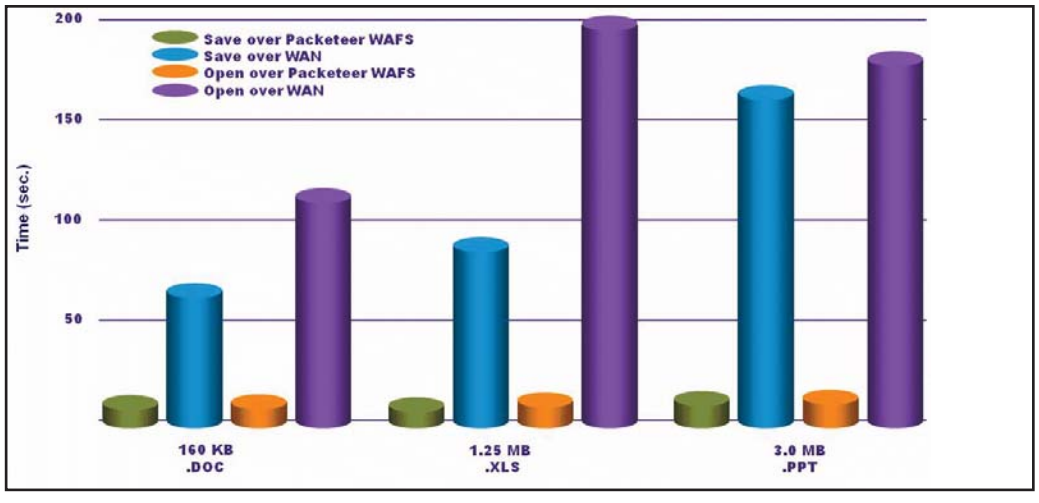
WAFS Field Performance

A large global merchandise supplier headquartered in New York recently implemented a WAFS solution at three of its regional offices in Turkey, Hong Kong and India. It was deployed to over 1,000 users on the system up to 8,000 miles away from the New York datacenter.

This company wanted to avoid implementing file servers at each office, and extend the benefits of its own centralized storage consolidation efforts out to its Branch Offices. Yet, IT staff knew that the company's existing WAN connection latencies and limits to its global frame relay network made it virtually impossible to share Microsoft Office files among offices. The datacenter team had also been trying, unsuccessfully, to replicate files to the regional offices when they learned about WAFS.

The company installed a WAFS server appliance at the datacenter, providing access to its shared Windows-based NAS storage. It then installed one WAFS appliance at each of its three offices. Before shipping the WAFS systems to each office, the systems were "pre-populated" with the files the supplier thought would be most likely to be accessed on a regular basis. This is a performance-enhancing technique deployed with some WAFS solutions that can reduce the time it initially takes to open files from remote locations.[8]

Figure 2 displays initial WAFS deployment results for sample file opens and saves performed across the WAN from within the company's Hong Kong office.



WAFS ROI and TCO: An Easy Answer for Remote Storage Consolidation

This section takes a closer look at the fast track to ROI and the low TCO currently experienced by today's WAFS users as they extend centralized storage to Branch Offices.

In as little as three to nine months after WAFS deployment, many sites report having already gained a significant return on investment.

In fact, one large enterprise customer who has had WAFS deployed for over a year at its Branch Offices reported yearly savings in the range of several hundred thousand dollars.

This is money that would have been otherwise earmarked toward additional remote storage, systems and related labor and administration costs.

The following table demonstrates the key areas where WAFS users report the largest ROI.

Key Areas of ROI from WAFS Deployment	Description of WAFS Benefit
Replacement or reduction in existing remote storage servers, hardware and software.	One WAFS appliance can replace remote file servers, remote backup hardware (tape drives, etc.), backup tapes, backup software, management software, DNS/DHCP domain servers, Web cache servers,* print servers,* server-related operating system license/upgrade protection plans, and server-related anti-virus software licenses. This enables better consolidation of remote islands of storage to the primary datacenter.
More centralized management of all corporate data means: Faster, more comprehensive data protection and business continuity for Branch Offices. Better adherence to regulatory compliance standards.	IT staff no longer need to oversee remote backups and remote server hardware or software upgrades. Additionally, by eliminating dependencies on Branch Office file storage, WAFS also allows organizations to simplify Branch Office-related compliance strategies and ensure higher data availability. With edge data residing centrally, IT organizations can also apply more widespread policy-based management and archiving practices.
Reduction in IT infrastructure and maintenance costs associated with Branch Offices.	Since WAFS installations no longer need to support such robust silos of remote IT operation, they tend to report significant savings in remote IT labor and travel costs, Branch Office space now available for other use and reductions in use of power to run remote systems. Sites also are able to eliminate many of the maintenance contracts associated with prior remote hardware and software.
Significant improvements in remote user productivity.	Remote users accustomed to waiting for WAN access to files are now able to gain nearly real-time access to documents and files as if they were being accessed from within the corporate LAN.
Improved collaboration through global file sharing.	For key industries that require close collaboration, such as the production of sets of detailed CAD designs of drawings, WAFS allows members of teams based at different company locations to more rapidly update and work on the same files. IT organizations who implement WAFS also seem more able to transform the WAN into a unified, global LAN where they can now share the same data worldwide, in real-time.

* Some WAFS appliances support print serving and Web caching functionality. Check with WAFS vendors to see if the solution you are evaluating offers these capabilities.

Conclusion

The use of wide area file services technology represents a significant paradigm shift for today's distributed enterprise that has been accustomed to supporting the data needs of Branch Offices with investments in redundant file servers, backup hardware, and software.

Typically removed from consideration in IT storage consolidation efforts, it's become an accepted practice to keep Branch Offices as islands of separate storage and IT infrastructures.

WAFS technology effectively challenges this practice, and offers a compelling way to extend the reach of centralized storage to the outer edges of today's enterprise.

This white paper clearly demonstrates the performance benefits, fast ROI and low TCO WAFS is bringing many top enterprise customers who have already adopted WAFS technology. Their move to a WAFS-enabled storage consolidation architecture is resulting in lower backup costs, more centralized data protection and remote users who can be more productive while plugged into a global, LAN-like environment.

Appendix:
Key Considerations When Evaluating a WAFS Solution

Industry analysts such as the Taneja Group and Forrester Research have carefully assessed the key criteria customers should consider when evaluating wide area file services technology offered from any vendor. The following checklist combines some of these high-level criteria with questions Packeteer routinely receives from potential customers. This table should serve as a starting point for further research into any WAFS solution under evaluation.

WAFS Performance

The WAFS solution should be able to demonstrate consistent operation at LAN-like speeds over the WAN. Sample questions surrounding performance include:

- How well does the system perform when opening/saving single files across the WAN?
- How well does it perform with very large files?
- How well does the system handle metadata or CIFS/NFS directory listings?
- How does the system perform with "cold" vs. "warm" file open and save attempts?[9]
- What mechanisms or algorithms does the system use to reduce the size of data sent across the WAN or reduce the amount of Remote Procedure Calls required to complete a save or open exercise?
- How well does the solution perform with the types of files most used at my organization?
- Does the solution handle all file types in the same way?

System Reliability and Resiliency

Wide area networks are prone to disruption and frequent poor link quality that can seriously degrade performance. This area of questioning should help you determine how reliable the WAFS system will be when it encounters WAN issues. It should also help you learn how well the WAFS vendor has taken various failure scenarios into account. Sample questions include:

- How does the WAFS system handle WAN disruptions or poor link quality so that remote users or files remain unaffected?
- Can remote users still access remote files when the link to the main WAFS server is not available? If so, how?
- What happens to a file in the process of being opened or saved across the WAN when a
- WAN disruption event occurs?
- How does any file caching or compression functionality improve the system's ability to recover from WAN failures? How does this functionality differ from that of competing products?
- In the event that a component in the WAFS hardware fails, what availability safeguards are in place to ensure on-going access to the system (clustering capabilities, RAID functionality, support for rapid failover, etc.)?
- WAFS vendors have come up with a variety of methods to survive common WAN disruptions and shield users from potential data loss as they attempt to open, close or save a file across the WAN.

- Data Integrity Of special interest when sharing the same files with multiple locations across the WAN is the topic of data integrity. In short, the WAFS solution must be engineered to guarantee that files are up to date and cannot be edited by more than one person at the same time. Here are a few questions to consider in this area:
- How does the system ensure that consistent views of the data are seen at all locations?
- What type of file-locking mechanism does the system use to ensure only one person can edit a file at a given time?
- Can others read a file from various locations when a file is being edited by someone else?
- If so, does this degrade file access at all?
- How does the system prevent file corruption if a file is open and in use by a remote user when a network disruption or downtime event occurs?

Data Security

Because file access will be occurring from the edge locations of the enterprise, WAFS systems need to have built-in security features that ensure only those users with a genuine need for the files will be granted access. They also may need to adequately secure the data packets being transmitted across the WAN. A few lines of questioning in the area of security include:

- What type of encryption exists with the WAFS solution?
- How well will the WAFS system support any role-based access control rules I already have in place for certain files in my environment?
- Are security rules administered only from the central WAFS server or do I need to perform administration from the remote WAFS appliances as well?
- How does the WAFS system help authenticate and authorize users when accessing files?
- Is this an automated process? Where does the process take place?
- What type of logging or auditing functionality does the WAFS system offer to track file access patterns?

WAFS Scalability and Extensibility

Of special note when investigating WAFS is how well any solution will grow to accommodate more concurrent remote users and more remote sites. Potential customers must also learn whether or not the WAFS solution can be extended beyond its initial use for centralized file sharing and consolidation. Here are a few questions that speak to these topics:

- How many remote sites can be consolidated to the datacenter using the WAFS solution? In other words, how many remote sites can a central WAFS server support?
- Do I need to install any additional per-office or per-file storage at the datacenter as I add remote sites to the WAFS system?
- How many remote sites can be consolidated to the datacenter using the WAFS solution?
- Is there a limit to the amount of shared storage at the datacenter a Branch Office can access?
- How many concurrent users at any given remote site can the WAFS system support?
- Since the WAFS system may replace other remote servers, can it also support other branch office services, such as print services, web caching services, management services, or DNS/DHCP services?

Integration and Protocol Compatibility with Current IT Environment

Any robust WAFS solution should be able to communicate flawlessly with the standard file transport protocols used by all main operating system platforms. Sample questions in this area include:

- Does the system comply fully with Security methods inherent in your IT System (for example, Windows SMB Signing)?
- How well does the system support file access from either Linux or Microsoft Windows environments?
- How has the system been engineered to integrate with the native CIFS or NFS protocols already in use in my environment?
- For Microsoft Windows environments, how well does the WAFS system support Domain Controller and naming resolution functionality (via NetBIOS, WNS, DNS)? How well does it support DFS, SMS and Active Directory or Kerberos features?

System Management and Ease of Use

Ease of WAFS system administration should also enter into any evaluation. A few questions you may want to ask in this area include:

- How easy is the system to install?
- What types of routine management functions need to be performed? How much time should they take?
- Does the system offer centralized management controls of all remote WAFS appliances?
- What, if any, administration is required at the Branch Office level?
- How well does the central WAFS system integrate with larger systems management tools that may be in use at the datacenter (IBM/Tivoli, HP OpenView, Microsoft SMS, etc.)?
- For Microsoft Windows environments, how well does the WAFS system integrate with Microsoft management tools such as Active Directory, Systems Management Server (SMS), Microsoft Management Console (MMC), and Microsoft Operations Manager (MoM)?

End Notes

[1] "Wide area file services tame the distributed enterprise," by Brad O'Neill, InfoStor magazine, April 2004, http://is.pennnet.com/Articles/Article_Display.cfm?Section=Archi&Subsection=Display&P=23&ARTICLE_ID=203175&KEYWORD=tame%20the%20distributed%20enterprise

[2] Source: Enterprise Strategy Group.

[3] Source: Brad O'Neill, Senior Analyst and Consultant, The Taneja Group, as described in InformationWeek TechWebcast, "Storage Consolidation for the Distributed Enterprise," original airing Dec. 8, 2004, https://www.cmpnetseminars.com/BTG/default.asp?K=TWTEVTPG&Q=177

[4] Ibid.

[5] "Taneja Group and University of New Hampshire Interoperability Lab (UNH-IOL) Product Validation Report for Tacit Networks," July 2004.

[6] Test results excerpted from the "Tacit Networks Functionality and Operations Device Test Report," prepared by the Interoperability Laboratory Research Computing Center, University of New Hampshire (UNH-IOL), June 25, 2004.

[7] Testing results excerpted from "iShared AutoCAD Optimization," an application note from Tacit Networks, http://www.tacitnetworks.com/M06_03-Application-Notes.php

[8] See a later section in this paper for more information on WAFS performance characteristics and techniques, including the ability to prepopulate data for faster read/write operation across the WAN.

[9] Some WAFS systems may implement a form of file caching that allows them to retain information about prior files accessed over the WAN. Then, if the same file is accessed again, the WAFS system can improve its read/write performance by accessing the information from its cache. For this reason, it's important to ask WAFS solution vendors about the read/write performance of their systems when a file is first opened or saved across the WAN. This may be referred to as either the initial open or save exercise, or a "Cold Open/Cold Save." Subsequent file opens or saves are referred to as "Warm Open" or "Warm Save." Some WAFS systems are engineered to help minimize the performance impact of "Cold Opens" by letting customers preload or prepopulate the remote systems with the most commonly accessed files, thereby making any subsequent opens "warm."

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