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The FX Series Accelerates Satellite Links to Support More Traffic & Improve Response Times

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The proliferation of diverse IP-based devices is generating more satellite link traffic than ever before. The expansion of more company branch offices and new applications such as VoIP, video, and social networking is placing even greater stress upon satellite links. Satellite-based connectivity has become an important asset to allow network managers to provide connectivity to remote sites and locations where terrestrial networks are either too expensive, or not readily available. The FX Series allows network administrators to manipulate network traffic to increase the efficiency and throughput of satellite links to allow significant increases in data throughput and reduced network response times.

When distance adversely affects satellite link performance, the increased network efficiency that WAN acceleration delivers becomes extremely important. Deploying the FX Series WAN acceleration delivers dramatic results that make the argument for spending the money on an acceleration device very convincing.

In order to be competitive and profitable, virtually every organization struggles to improve business operations and employee productivity, while keeping associated costs to a minimum. Deploying WAN acceleration can significantly reduce costs related to deploying, maintaining and supporting satellite link infrastructure, while dramatically improving network performance.

Enterprise and consumer applications are routinely delivered over satellite links to remote offices, mobile workers and individual consumers. While the number of applications increases every day, the lack of reliability, poor performance and security of these applications going over the network increases correspondingly. A primary challenge with these applications is the exponential increase of users in remote offices and on the road using mobile devices. For the IT personnel responsible for deploying, maintaining and supporting these networked applications, there is an increasing requirement to get the highest performance out of the network, while simplifying the complexity that causes excess overhead and unnecessary costs.

Problems that plague enterprise applications over satellite links:

- Many applications are competing over limited bandwidth
- Applications with chatty protocols add delay in the network
- Network congestion slows productivity for employees in remote offices
- Slow satellite link performance hampers productivity of mobile workers

For virtually all IT organizations, there are business imperatives to ensure economical utilization of Internet technology, and to provide faster delivery of applications users of all types. Hampering these business imperatives are problems due to bandwidth constraints and latency, TCP, web application and content delivery inefficiencies. There are two types of solutions that address these problems.

Application Delivery Controllers

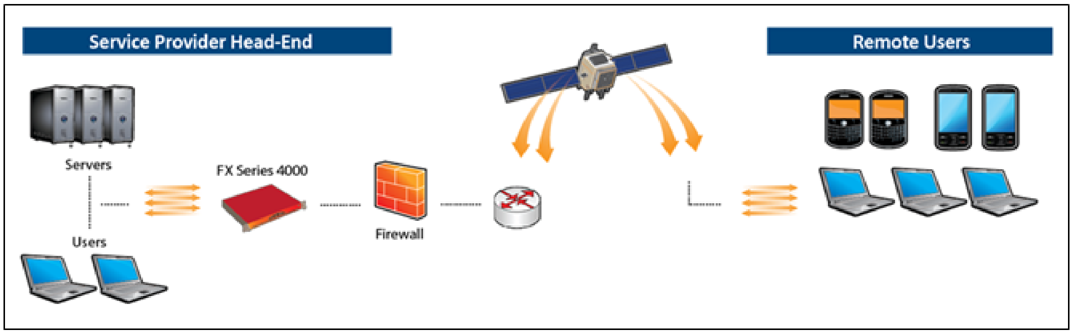
The first solution is called an Application Delivery Controller (ADC). These devices accelerate application delivery and reduce the amount of traffic over satellite links. ADCs are single-sided (asymmetric), requiring an appliance only in the head-end. The ADC serves as a proxy for TCP management, acceleration and offloading server and network resources for out-bound traffic. TCP acceleration removes the time, quantity and complexity associated with multiple short-lived connections that slow network performance and add overhead to Web server CPU resources. An ADC terminates the client-side TCP session requests, and multiplexes many short-lived sessions into a single longer-lived session between the ADC and the Web servers.

WAN Optimization Controllers

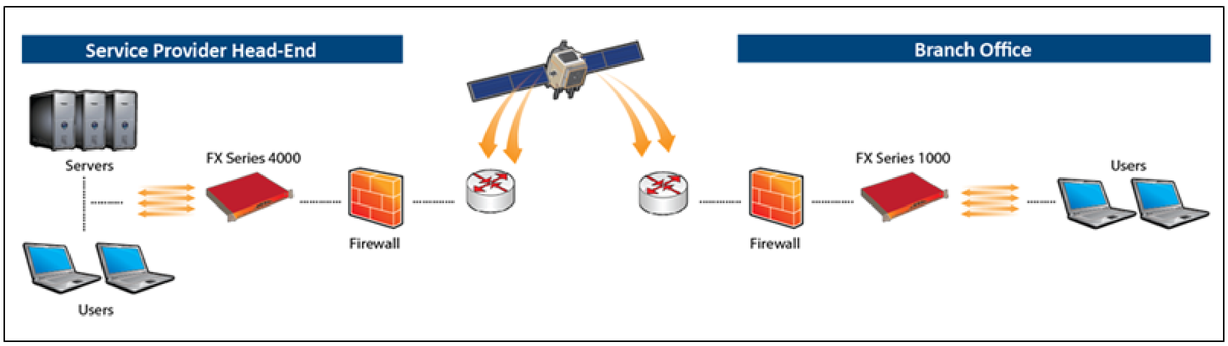
The second solution is acceleration appliances that reside at the service provider head-end, that work together with acceleration appliances located at each remote site. These products provide two-sided WAN optimization and application acceleration to alleviate the adverse effects that latency and performance errors have upon satellite network performance. They are referred to as WAN Optimization Controllers (WOCs). These solutions are symmetric (bi-directional or two-sided), and typically require an acceleration appliance at the head-end and at each remote site.

The FX Series (Integrated ADC and WOC)

The FX Series combines both Application Delivery Controller (ADC) and WAN Optimization Controllers (WOC) capabilities. The FX Series manages application interactions and applies coordinated acceleration and optimization techniques within satellite networks.



As a single-sided solution, the FX4000 Series located at the head-end, offers satellite connection management to fully utilize satellite link bandwidth.



In a two-sided implementation, The FX4000 is located at the head-end, and FX1000 Series appliances are located within the remote sites.

The FX Series WAN acceleration techniques improve satellite link performance - the ability to both fill the satellite link, and optimize traffic throughput. Some of the key benefits include:

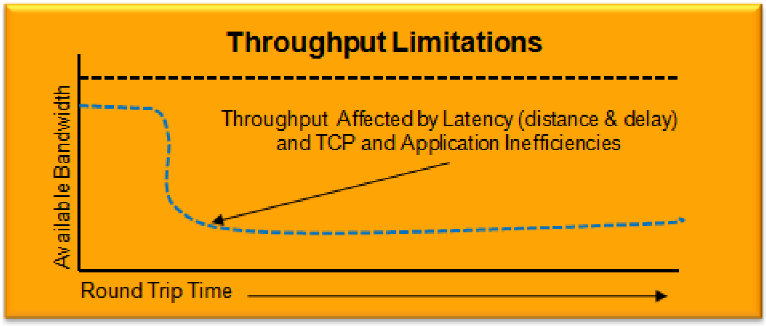
- Reduces the amount of unnecessary data sent over the satellite network
- Reduces the number of TCP and application turns (handshakes) required to complete a transaction
- Offloads computationally intensive tasks from clients and servers

Key Acceleration Technologies

Below are some of the key acceleration technologies that the FX Series provides:

TCP Optimization

Advanced protocol optimizations drive significant improvements in bandwidth efficiencies and time savings (reducing payload and latency). WAN acceleration technologies are deployed to improve satellite network performance and increase the amount of applications and users that can be delivered over the satellite link.



Satellite traffic is negatively affected by TCP and application turns, and network distance.

Stampede's FX Series manages all TCP sessions, and handles the establishing and tearing down of TCP connections locally (at LAN speeds) to avoid satellite network congestion problems. This helps to increase link utilization and improve the user experience. TCP termination offloads the responsibility from servers having to handle the overhead imposed by the volume of TCP connections from web applications.

Additionally, application level multiplexed TCP streams take advantage of all other TCP or protocol optimization done at the link level, and application-level handshakes are eliminated by consolidating transaction requests.

Benefits include:

- Reduces the amount of traffic sent over satellite links
- Keeps the satellite links maximized for optimum utilization
- Dramatically reduces transaction TCP turns (requests and responses) that bottleneck satellite links

Turbostreaming

Stampede's patented TurboStreaming™ (multiplexed TCP sessions, patent # 7,543,072) enables HTTP browser traffic to be intermixed across multiple "pipelines". All browser activity is optimized, including the network-intensive polling associated with Web 2.0 and AJAX applications. A key advantage of TurboStreaming is that communication resources can be shared across multiple applications, and all HTTP requests and responses from any application (including multiple browsers) are intermixed simultaneously across multiple concurrent sessions.

Multiplexing of Large Data Objects – The FX Series multiplexes large data objects using Stampede's patented TurboStreaming that enables HTTP browser traffic to be intermixed across multiple "pipelines". All browser activity is optimized, including the network-intensive polling associated with Web 2.0 and AJAX applications.

TurboStreaming serves as a platform for the consolidation and aggregation of all Web-based traffic from a given user. Multiple HTTP protocol streams are logically aggregated across a few TCP sessions. Individual objects or pieces of objects can be split into any size and then multiplexed with other object data and reconstructed as needed to deliver mixed payloads consisting of business-critical applications and data, streaming media, Voice over Internet Protocol (VoIP) and other network-intensive traffic. The end result is improved throughput and faster response time for the end-user.

Stampede enables the browser to open multiple pipelines (10's or even 100's) that communicate with the FX Series remote appliances. All of this data, from all browsers and all browser windows, is intelligently multiplexed over multiple TCP sessions back to the head-end FX Series appliance. This fully utilizes all available bandwidth, and enables the browser to function at its full potential. This is only possible because of advanced, industry leading two-sided acceleration technology.

Advanced Virtual Pipelining (AVP) – Advanced Virtual Pipelining (AVP) is a technique developed by Stampede that provides 40% performance improvements for browser-based applications. This performance improvement is on top of the FX Series industry leading performance, and is only possible because of the innovative technology of the FX Series providing two-way application acceleration. It becomes an important and standard acceleration technique used with the FX Series family of products.

AVP is a highly optimized implementation of the patented TurboStreaming (multiplexed TCP sessions, patent # 7,543,072) that enables HTTP browser traffic to be intermixed across multiple "pipelines". All browser activity is optimized, including the network-intensive polling associated with Web 2.0 and AJAX applications. A key advantage of our AVP implementation is that communication resources can be shared across multiple applications, and all HTTP requests and responses from any application (including multiple browsers) are intermixed simultaneously across multiple concurrent sessions. AVP serves as a platform for the consolidation and aggregation of all Web-based traffic from a given user. AVP logically aggregates multiple HTTP protocol streams across a few TCP sessions. Individual objects or pieces of objects can be split into any size and then multiplexed with other object data. This enhances the "Pipelining" affect of HTTP 1.1 by not restricting request data to whole objects or tying them to specific TCP sessions. Increased TCP efficiency is achieved as well as improved effectiveness of the HTTP 1.1 pipelining. The end result is improved throughput and faster response time for the end-user.

AVP enables the browser to open multiple pipelines (10's or even 10'0s) that communicate with the FX Series remote appliances. All of this data, from all browsers and all browser windows, is intelligently multiplexed over multiple TCP sessions (TurboStreaming) back to the head-end FX Series appliance. This fully utilizes all available bandwidth, and enables the browser to function at its full potential. This is only possible because of our advanced, industry leading two-sided acceleration technology.

Intelligent HTTP Turn Reduction

The FX Series uses Stampede's patented (patent # 6,012,085) "Multi-get" technology to reduce the chattiness of the HTTP protocol. In some cases, just single page retrievals will cause hundreds of HTTP "Get" requests to be issued by the browser.

A single page is returned to the browser that contains many embedded URLs needed for proper display of the original page. These URLs can be for additional HTML pages, image data such as pictures in the form of gifs and jpegs, java scripts and so on. The browser will first download the main page and then request the embedded URLs essentially one at a time. The latest browsers typically open several connections to retrieve these objects to overlap the retrieval process.

There are two problems with this approach. First, each item request causes a separate HTTP request/response round trip. For a first time retrieval of a page this may mean up to a hundred or more round trips to the Web server. More complicated pages can cause significantly more round trips. Secondly, the extra connections the browser uses can add significant load to a Web server and to the network infrastructure.

The FX Series Multi-get technology examines the first page when it is downloaded and builds a Multi-get request that contains an optimized "GET" for all of the necessary additional objects. The FX Series appliance at the head-end parses this request and streams the objects to the remote FX Series appliance that caches them and returns them to the browser when the browser requests them.

The FX Series Multi-get/Multi-verify technology determines which objects need to be retrieved freshly and which can be conditionally retrieved. All objects are retrieved in one logical request and streamed to the FX Series appliance.

The Multi-get/Multi-verify technology virtually eliminates the "chattiness" of the HTTP protocol. However, the Multi-get technology is not limited to HTML pages and is employed wherever possible; such as with JAVA Server Pages (JSPs) and Active Server Pages (ASPs) that have embedded Java Scripts.

Advanced protocol optimizations drive significant improvements in bandwidth efficiencies and time savings, providing significant payload reductions and improved application delivery speeds. The FX Series specializes in optimizing the HTTP protocol by consolidating multiple transactions into a single transaction, which eliminates round-trips that add latency that can be responsible for up to 95% of the total application delay. Important protocols for satellite communications are HTTP (web mail, web surfing, enterprise web apps), POP3/ SMTP (email), HTTPS (enterprise accounts), and CIFS (enterprise applications).

Network Protocol Optimization

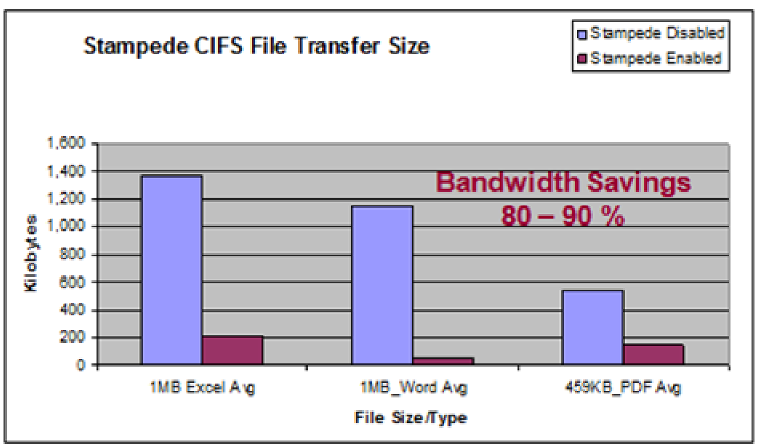
The FX Series provides application-aware modules for HTTP, HTTPS, CIFS, MAPI, POP3, SMTP, and FTP that dramatically reduce costly handshakes and intelligently apply compression to lower bandwidth consumption and reduce latency.

Stampede specializes in optimizing protocols by consolidating multiple transactions into a single transaction, which eliminates round-trips, performing cache differencing on dynamically generated content, and bi-directional data compression. In addition, our patented technology (TurboStreaming) enables the transfer of previously compressed objects up to 5 times faster through intelligent multiplexing across multiple TCP sessions.

- TCP and HTTP applications have chatty protocols that put added delay in satellite networks, as do delay-sensitive applications such as VoIP and applications such as Microsoft Exchange and CIFS.
- IT managers are placing thousands of applications on their satellite links. Many of these applications are mission-critical, and compete over a limited amount of bandwidth.

The FX Series Support for CIFS

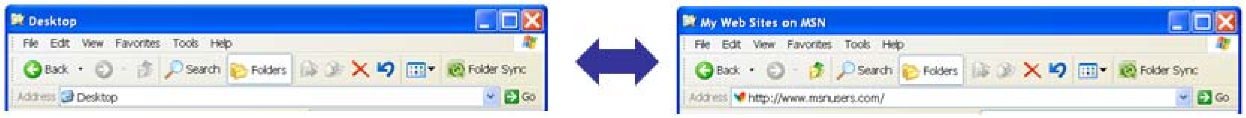
The FX Series appliances have been developed to accelerate file transfers over satellite links by getting around CIFS inefficiencies and network latency, to significantly improve file download and upload response times and directory browsing activities. In addition to CIFS, the FX Series reduces data going over satellite links for applications such as HTTP, WAFS, FTP, MAPI and others. The resulting benefits are LAN-like performance over satellite for file transfers, email delivery, remote shared file access and other applications, while delivering reliable, fast application and file delivery for users located in remote offices.



Example of bandwidth savings using the FX Series for CIFS applications

Remote users who access files from servers located in head-end most likely use Common Internet File System (CIFS), a de facto standard protocol for remote file access with Windows file sharing.

Remote clients (e.g. Windows Explorer and Web browsers) access and download files on a file server, transfer files, and search through file directories. If you have remotely copied files using Windows Explorer, you have used the CIFS protocol.



This screen shot shows a remote client using Windows Explorer to download a file from a server using the CIFS protocol.

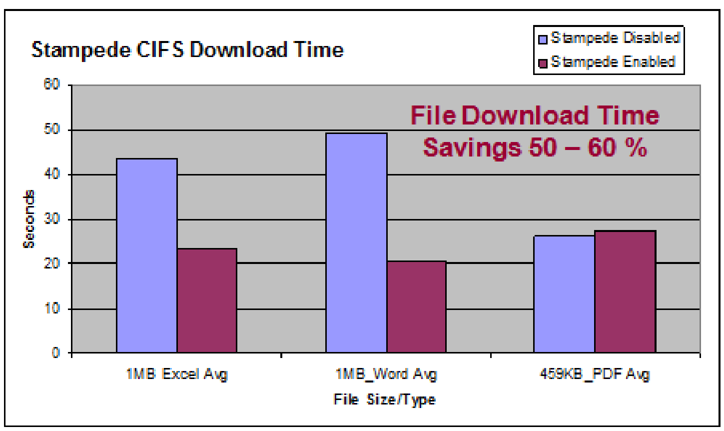
CIFS Performance over Satellite Links

CIFS is an exceptionally "chatty" protocol that requires many client and server transactions in order to complete a file request. Latency also has a considerable adverse impact on the performance of CIFS file transfers over satellite links as it was originally created for LAN environments, and has a block size limit of 64KB. Compounding the 64KB block size limit is SMB signing that generates additional overhead, and the fact that the TCP Window size is not well-tuned for satellite links.

The FX Series Solves CIFS Inefficiencies over Satellite Links

FX Series appliances address the inefficiencies of the CIFS protocol and satellite link latency. They act as a proxy for CIFS clients and servers to optimize and accelerate their communication. The FX Series significantly improves transaction performance for remote file downloads, uploads and searching through directory listings.

The FX Series maintains the status of clients and servers for CIFS actions to reliably anticipate upload and download payloads within a transaction. If the FX Series anticipates that a specific CIFS transaction has a high probability, it pre-fetches data (e.g. byte-level data from a file) and temporarily stores it in memory for future extraction. Rather than doing entire file caching, the FX Series uses byte-level temporary storage to improve file response time.



This example shows the time savings that the FX Series CIFS acceleration provides by reducing latency over a satellite link.

The FX Series Accelerates CIFS File Downloads

The sequence of events that occur when the FX Series accelerates a CIFS file download request is as follows: the client opens a file for reading, the file server responds with a file signature. The client issues the first read request, and server responds with data. This first transaction may take a relatively long time because the read request and response are hampered by network latency. When the FX Series appliances see the initial transactions, they establish that the client is attempting a file download. At this point, the FX Series located where the server resides pre-fetches data by generating read requests locally to the server which keeps the satellite connection filled for optimal bandwidth utilization. For repeat transfers, the server-side FX Series will transfer small amounts of data across the satellite connection – reducing the CIFS transfer time further.
The pre-fetched data is temporality stored on the FX Series where the remote client is located for future requests. As the client requests the file data, rather than retrieving every 64k bytes from the server over the satellite link, the client receives the replies locally from the FX Series at LAN speeds.

When a remote file is requested a sequence of actions take place. Before the file is actually moved, there is a log-in, the directory listing is viewed, the file is copied, and finally, the file is closed. Using Stampede's Dynamic Data Suppression (DDS), a combination of byte-level caching (transferring data signatures, rather than entire files) and data compression, as well as response time acceleration techniques, the FX Series accelerates each aspect of the sequences involved in the file request process.

Additionally, while not specific to CIFS, the file data is multiplexed to optimize the round-trip processing between the remote client and head-end to speed the data delivery over the satellite link. The FX Series takes one or more client TCP connections and consolidates them to minimize transfers over the satellite link. This results in fuller packets for more optimal utilization of the satellite link.

Byte-level temporary data storage – Rather than caching entire files, when a file is requested, the FX Series examines the data at a byte-level and temporarily stores file attributes within memory. If the file is requested again, the FX Series will identify the file and only transmit the signature representing the data bytes of the file. This reduces the amount of round trips, and eliminates having to send the entire file over the satellite network. For example, the FX Series examines the data sequences of an 8000KB file that has been received and temporarily stored. Rather than transferring the entire 8000KB, the FX Series will transfer only a 16 byte signature that represents the 8000 bytes.

Transferring data from a remote file server to a local client computer – **Reading ahead** – Copying a file from a remote server to a client computer, the FX Series issues read requests on behalf of the client to the server. This removes delays associated with having to wait for the replies to be completed. The FX Series spoofs the acknowledgments to the read requests, allowing the client computer to send the data transmissions more quickly to the FX Series.

Transferring data from a local client computer to a remote file server – This is similar to a file download, but, in this case a client writes a file to a server, rather than reading a file. The remote client-side FX Series appliance responds locally to the client's write requests and passes the data to the FX Series appliance at the head-end to complete the write operation to the server. The FX Series spoofs the acknowledgments to the write requests to accelerate this operation. Because of CIFS inefficiencies, when a client wants to read a file, they can only receive 64KB of data at a time. Therefore, in order to read a 1000KB file, the client will make 16 requests to read the entire file. To speed up this process, as soon as the FX Series receives the first request from the client, it interprets the action, and identifies it as the start of a file copy operation. Rather than waiting for the subsequent requests to come from the client (and the responses from the remote file server), it sequentially sends out all 16 requests to the file server. This acceleration technique eliminates delays and significantly speeds up the file transferring process.

It can take 250MS (1/4 of a second) for the client to make a request to a file server and get a response back. If it requires 16 requests to complete the file process for a 1000kb file, then it will take 4 seconds to copy the entire file. The FX Series eliminates the additional 4 seconds of delay - improving the user experience and productivity.

Write-through – When a client requests a file from the server; makes changes to the file; and then uploads the file back to the server, the FX Series will acknowledge the write requests (protocol messages) locally; and simultaneously communicate those actions with the FX Series at the head-end. This process speeds up the file transfer process.

Real-time CIFS performance enhancement – The FX Series takes advantage of Stampede's deep level of understanding of the CIFS protocol and its inherent inefficiencies. For example, when a client copies a file they may actually make two requests for the same file. The FX Series temporarily stores this data and optimizes the data flow to eliminate round trips.

Wide-Area File Services (WAFS) enhancement – WAFS is used for remote clients to access (read/write) shared files located on remote servers. An underlying communication protocol used by WAFS is CIFS. Similar to the benefits that the FX Series provides for CIFS, the FX Series optimizes WAFS data access patterns for editing files remotely.

Remote access for Microsoft Office files – Microsoft office files such as Word, Excel, PowerPoint, etc. that are accessed from remote clients can experience long delays due to satellite link latency and CIFS inefficiencies. When remote clients open files, browse directories and save files they can lose valuable time and productivity waiting for files to open and save. The FX Series addresses these problems by pre-fetching file data on a byte-level on the remote client-side FX Series. All client requests for the file data can be served from the remote client-side FX Series - at LAN speeds.

The FX Series Support for MAPI

Remote clients use Messaging Application Programming Interface (MAPI), a messaging architecture for Microsoft Windows applications, for clients running Outlook to interface with Microsoft Exchange servers. In large part due to MAPI, Microsoft Exchange performance runs slow over the satellite links, requiring many enterprises to distribute Exchange servers beyond their headquarters; within remote branch offices to support remote users. Maintaining and supporting distributed Exchange servers can be a complex and expensive proposition, and one that opens up a greater risk of confidential data theft.

MAPI Performance over Satellite Links

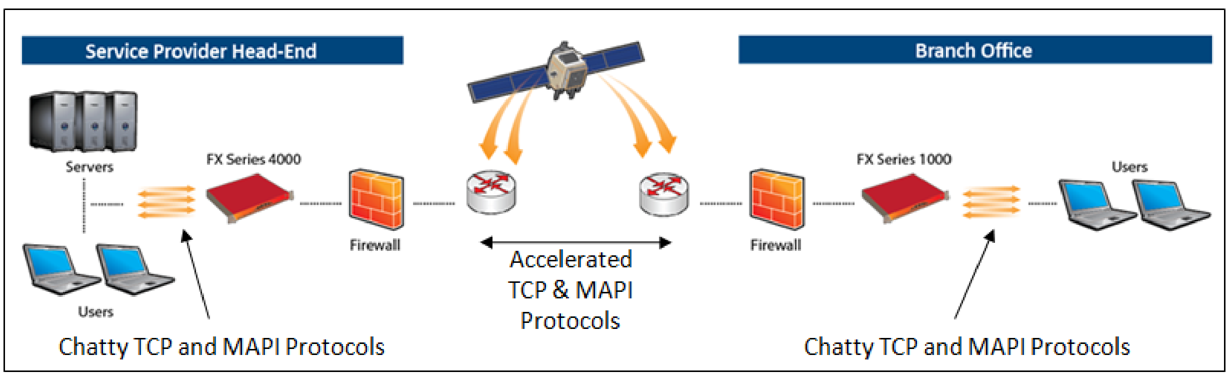
MAPI is a "chatty" protocol that requires many client and server transactions in order to complete a single transmission. Latency also creates considerable adverse impact on the performance of MAPI transmissions over satellite links.

Email has inherent data redundancy problems when used over satellite links. Two examples include - sending email to an alias that goes to many different individuals simultaneously; and using the "Reply to All" button that sends multiple emails (with large attachments) to many individuals.

Whether the issues stem from data redundancy, link latency, MAPI inefficiencies such as excessive client/server transactions (send/receive turns), or excessive data being sent, any one of these problems will slow MAPI traffic over satellite links.

The FX Series solves MAPI inefficiencies over satellite links – Stampede has in-depth understanding of the MAPI Protocol, and has developed acceleration technologies to speed up user response time. The FX Series appliances address the inefficiencies of the MAPI protocol and network latency. They act as a proxy between the email client and server, and anticipate user requests, resulting in ultra-fast data retrieval. These appliances terminate user requests locally (at the remote site) and, going across the satellite link, initiate connections to the FX Series appliance located at the head-end. MAPI-based email performance is able to excel with this two-sided (symmetrical) implementation.

The FX Series maintains the status of clients and servers for MAPI actions to reliably anticipate upload and download payloads within a transaction. If the FX Series anticipates that a specific MAPI transaction has a high probability, it pre-fetches byte-level data and temporarily stores it in memory for future extraction. Rather than doing entire file attachment caching, the FX Series uses byte-level temporary storage to improve response time.



This diagram shows the primary goal of the FX Series MAPI acceleration by reducing latency over a satellite link.

The FX Series accelerates MAPI transmissions – When the FX Series appliances see the initial MAPI transactions, they understand that the client is attempting to send an email. At this point, the FX Series located where the server resides pre-fetches data by generating read requests locally to the Exchange server which keeps the satellite link filled for optimal bandwidth utilization. For repeat data transfers, the server-side FX Series will transfer small amounts of data across the satellite link– reducing the MAPI response time further.

The pre-fetched data is temporarily stored on the FX Series where the remote client is located for future requests. As the client requests the file data, rather than retrieving every 32k bytes from the server over the satellite link, the client receives the replies locally from the FX Series at LAN speeds.

When an email is sent a sequence of actions take place. Before the file is actually moved, there is a log-in, the mail directory list may be viewed, the file attachment is copied, and finally the email and attached file is sent. Using Stampede's Dynamic Data Suppression (DDS), a combination of byte-level caching (transferring data signatures, rather than entire files) and data compression, as well as response time acceleration techniques, the FX Series accelerates each aspect of the sequences involved in the MAPI process.

Additionally, while not specific to MAPI, the file data is multiplexed to optimize the round-trip processing between the remote client and Exchange server at the head-end to speed the data delivery over the satellite link. The FX Series takes one or more client TCP connections and consolidates them to minimize transfers over the satellite link. This results in fuller packets for more optimal utilization of the satellite link.

Examining the email payload – Using DDS, the FX Series distinguishes between MAPI protocol headers and the payload data. For example, when reading a file attachment, large portions of data are transferred over the satellite link. Read requests and/or responses have headers - variable data that is continually changing, and are not appropriate for storing. The FX Series avoids checking stored headers and by recognizing the difference between headers and payload data, the FX Series is able to get better matching percentages for DDS, in order to improve MAPI file transmissions. For example, to read an Excel spreadsheet attachment, requires the FX Series to send multiple file requests, with each request having an identifier that describes the request and its payload. The ability to identify the payload apart from the header allows the FX Series to temporarily store just the payload (email copy and file attachments), and not the headers.

Byte-level temporary data storage – The FX Series removes data redundancy from the satellite link, specifically for e-mail when the message is sent to multiple individuals using the "Reply to All" button, which can adversely affect satellite links by producing multiple copies of an email (and large attachments). This is also the case when sending emails to an alias. The email and attachments will be simultaneously sent over the satellite link, putting unnecessary congestion on the satellite link.
E-mails sent to aliases that include multiple recipients at the same site will result in the same e-mail being sent over the satellite link repeatedly, at least once per recipient. With the FX Series appliances, the byte-level data within the e-mails will be sent over the satellite link one time, no matter how many recipients. This will optimize the satellite link by removing redundant data and reducing the amount of congestion-causing transmissions required.

Reading ahead – When receiving file attachments from a remote server to a client computer, the FX Series issues read requests on behalf of the client to the server. The FX Series spoofs the acknowledgments to the read requests, allowing the client computer to send the data transmissions more quickly to the FX Series.

Sending file attachments is similar to reading them. In this case, the remote client-side FX Series appliance responds locally to the client's write requests and passes the data to the FX Series appliance at the head-end to complete the write operation to the server. To accelerate this operation, the FX Series spoofs the acknowledgments to the write requests. Due to MAPI inefficiencies, when a client wants to read a file attachment, they can only receive 32KB of data at a time. Therefore, in order to read a 10,000KB file, the client will make 312 requests to read the entire file. To speed up this process, as soon as the FX Series receives the first request from the client, it interprets the action, and identifies it as the start of an attachment transfer operation. Rather than waiting for the subsequent requests to come from the client (and the responses from the remote Exchange server), it sequentially sends out all 312 requests to the server. This acceleration technique eliminates delays and significantly speeds up the attachment transfer process.

It can take 250MS (1/4 of a second) for the client to make a single request to a server and get a response back. If it requires 312 requests to complete the file process for a 10,000KB file, then it will take 78 seconds to copy the entire file attachment. The FX Series eliminates the additional 78 seconds of delay - improving the user experience and productivity.

Write-through – When a client requests a file from the server; makes changes to the file, and then uploads the file back to the server, the FX Series will acknowledge the write requests (protocol messages) locally and simultaneously communicate those actions to the FX Series at the head-end. This process speeds up the file transfer process.

Real-time MAPI performance enhancement – The FX Series takes advantage of Stampede's deep level of understanding of the MAPI protocol and its inherent inefficiencies. For example, when a client sends a file attachment they may actually make two requests for the same file. The FX Series temporarily stores this data and optimizes the data flow to eliminate round trips.

Summary

Stampede's WAN acceleration significantly lowers costs associated with satellite link connectivity, saving money by making the optimum use of existing bandwidth to support more users and applications. Both enterprises and satellite Internet service providers are under continuous pressure to reduce operational expenses and to improve profitability. Significant areas that can benefit from satellite link efficiency gains include improved support for IT consolidation, expansion of branch offices, improved response times for mobile workers and consumers.