Riverbed WAN Optimization Solutions

It’s Not About Bandwidth
Distributed Organizations and Their Challenges

Distributed organizations come in all sizes and shapes. Even small organizations may have multiple locations connected by data networks around the world, as well as a significant number of mobile workers. For the largest enterprises, even the simplest usable network is a complicated arrangement, while the most elaborate and sophisticated networks have unbelievable layers of replicated and interlocking functionality. Whether a distributed organization is small or large, whether its networks are simple or elaborate, each faces similar business challenges: making the distributed organization efficient and effective in its use of the wide area networks (WANs) that tie the organization together.

Often these business challenges show up as IT and WAN issues for the distributed enterprise, which includes remote offices, branch offices, mobile workers, and even data centers. Poor application performance and poor control of information at the edge of the network are both common examples of ineffective use of WANs, which leads to reduced productivity and dangerous exposure to liability. Excessive spending on network bandwidth, high administrative costs for branches and mobile workers, and slow backup processes are common examples of inefficient use of WAN resources: throwing away money that could be put to better use.

What are the underlying causes of these challenges? The network of a distributed organization typically consists of an identifiable richly-connected core and an identifiable weakly-connected fringe. The core typically includes most servers, many clients, and most of the organization’s available bandwidth. In contrast, the fringe typically includes most of the organization’s remote locations, secondary data centers, as well as mobile workers. Operations between clients and servers in the core occur at the speeds typical of local area networks (LANs), whereas operations in the fringe happen at speeds typical of WANs. Typical WAN bandwidth at the fringe is only 1% or less of the typical LAN bandwidth, while latency (the time required to take a single end-to-end round trip) is often 100 times longer or more on a WAN than on a LAN. Because the fringe has network capacity that is 100 times narrower (bandwidth) and 100 times longer (latency) than the core, it is not surprising that performance is often a problem.

With this problem in mind, we can consider how to solve the effectiveness and efficiency challenges of the distributed enterprise by making the WAN perform more like a LAN.

Distributed computing problems are converging

Previous attempts to address these challenges have been narrow, leading to deployment of a variety of local servers, various kinds of caches, and an assortment of compression or TCP-optimization devices. Today, distributed enterprise computing problems are converging – and an effective solution needs to solve storage, networking, and application problems simultaneously. (See figure above).

The Riverbed Solution

Making the WAN behave more like a LAN has two components: 1) delivering dramatic performance improvements, especially for those applications or protocols that show the worst degradation when running over a WAN, and 2) contending with a wide spectrum of protocols that are crossing the networks of a distributed organization.
Solutions that deliver this broad-spectrum improvement of WANs go by the name of WAN Optimization. With Riverbed products, enterprises can implement solutions that help them empower their distributed workforce while eliminating IT capital expenditures and simplifying IT management. With Riverbed, organizations can:

- Centralize distributed infrastructure like file servers, mail servers, network attached storage (NAS), and remote office backup systems – without affecting remote users
- Share large files among colleagues on different continents – as if they were in the same building – leading to more productive users
- Perform backup and replication over long distance WAN links – and complete them during backup windows that were unachievable just a year ago
- Deliver significantly more services on existing WANs – without upgrading bandwidth

This paper explains the multiple performance problems that affect WANs; the narrow technologies that are converging into WAN optimization; and Riverbed® Steelhead® products – the market and technology leaders in WAN optimization.

**Multiple Bottlenecks Limit WAN Performance**

Let’s consider the bottlenecks in some more detail. WAN connections typically have lower bandwidth and higher latency than LAN links, but how do those constraints actually affect application performance? There are four distinct bottlenecks, one relating to bandwidth and three relating to latency. The bandwidth bottleneck is straightforward: no application can send data faster than the available bandwidth. The three latency bottlenecks are more subtle and tend to be noticed only when there is no bandwidth bottleneck. Due to latency bottlenecks, applications may not be able to take advantage of available bandwidth, even when the bandwidth appears to be plentiful.

**Latency Bottleneck #1**

The first latency bottleneck is caused by the end-to-end acknowledgement behavior of TCP. TCP has a window of packets that can be in flight from one end to the other (i.e. between client and server). After the window is full, the sender cannot send additional packets until the destination acknowledges receipt of at least some of what has already been sent. If the maximum window is too small, the throughput of the link will be limited by the rate at which each full window can be sent to the other side and acknowledged.

In theory, this bottleneck should be rare, because well-specified mechanisms exist to allow TCP to use large windows, and most recent operating systems implement those mechanisms. However, settings on both clients and servers are usually more attuned to LANs than WANs, and it is unusual to find clients or servers with TCP stacks matched to WAN latencies.

![Figure 1](image.png)

*Figure 1: Figure 1 illustrates the effective throughput of a T1 (1.544 Mbps) link for a TCP connection with a 6-Kbyte maximum window and increasing latency. For low latencies, the link can achieve its bandwidth-limited throughput, but for latencies larger than about 40 ms the first latency bottleneck is narrower than the bandwidth bottleneck.*

**Psomas, a leading engineering consulting firm, was having difficulty sharing large CAD documents among branches offices and mobile workers, which was causing project delays and hindering collaboration.**

Psomas deployed Steelhead products in their branch offices and Steelhead Mobile software for their mobile workers. As a result, file transfers to mobile workers were accelerated 10 - 15x, enabling Psomas to save over $1M annually by improving user productivity and eliminating wait time for engineers in the field.
Latency Bottleneck #2

The second latency bottleneck is caused by the slow-start and congestion-control behaviors of TCP. The first latency bottleneck, explained above, is a limit based on the maximum window possible. This second latency bottleneck is caused by TCP not even running at that (probably inadequate) maximum window size all the time. Instead, TCP gradually ramps up its window size when transmission appears to be successful and sharply cuts back its window size when transmission appears to be unsuccessful. In networks with both high bandwidth and high latency, this behavior leads to extended periods in which available bandwidth goes unused. However, this bottleneck is primarily an issue for users trying to fill long fat networks (LFNs), not for our example of a T1 connection.

Latency Bottleneck #3

The third latency bottleneck is caused by application protocols that are running on top of TCP. Recall that with the first latency bottleneck, the availability of bandwidth didn’t matter if TCP was limited by the size of a window of data and the need to acknowledge that data. Analogously, the availability of bandwidth and the avoidance of the first and second latency bottlenecks (at the TCP layer) doesn’t matter if the application is limited by the size of application messages and the need to acknowledge or respond to that data at the application layer. Application protocols that were originally designed for a wide-area environment—such as HTTP and FTP—generally don’t encounter this third latency bottleneck. However, application protocols originally designed for use on LANs—such as Microsoft Windows file sharing via CIFS—are often severely affected by the third latency bottleneck.

Figure 3: Figure 3 shows a similar curve for both CIFS and TCP running across a T1 link. Again, we see a sharp decline of capacity with increasing latency—but notice how CIFS is the dominant bottleneck (because it falls off more sharply). For applications with better behavior on the WAN, TCP latency may be the dominant effect. But for Windows file sharing over CIFS, even perfectly optimized TCP and plentiful bandwidth are not enough to overcome the dire effects of high latency.
The Riverbed Solution

Previous approaches to WAN improvement have chosen to deal with only a limited set of these bottlenecks, or have offered improvement for only a narrow set of protocols. Some examples of those approaches are in the following table.

<table>
<thead>
<tr>
<th>Approach</th>
<th>Bandwidth</th>
<th>TCP Latency</th>
<th>Application Latency</th>
<th>Broad Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>WAFS (File Caching)</td>
<td>Yes</td>
<td></td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Network Compression (WAN Optimization)</td>
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<td></td>
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<td>Web Caching</td>
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<td>Data Reduction</td>
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<td>Email Caching</td>
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<tr>
<td>Block Replication</td>
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<tr>
<td>Dynamic Caching</td>
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<td></td>
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<tr>
<td>QoS</td>
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<td>Yes</td>
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<tr>
<td>SSL Acceleration</td>
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</tbody>
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The table above illustrates that none of these previous approaches manage to tackle the full set of bottlenecks in a way that is valuable for a broad spectrum of protocols. The Riverbed solution combines several distinct threads that have been present in previous products but always as separate elements:

- High-performance, disk-based and memory-based data reduction
- TCP optimization
- Application- or protocol-specific optimizations
- Caching or local servers
- QoS
- Network visibility

The Riverbed solution is multi-protocol, multi-configuration, and multi-application, and it targets multiple bottlenecks simultaneously. Riverbed products are the logical combination and generalization of a number of more narrowly-focused predecessor technologies.

Riverbed Steelhead Products

Riverbed is the pioneer and market and technology leader in WAN optimization – the first comprehensive solution to a host of problems that plague enterprise applications operating across the WAN. Using solutions from Riverbed, enterprises can improve application performance across the network typically by five to 50 times and in some cases up to 100 times, and can simultaneously reduce WAN bandwidth utilization by 65 to 95%. These dramatic results allow businesses to take advantage of their networks, infrastructure, and applications in ways they had never imagined possible.

Riverbed products improve the performance of all applications running over TCP and also have application-specific modules that address chatty application protocols. This combination enables Riverbed solutions to accelerate the applications that enterprises care about most, and provides the ability to easily add more functionality over time.

Riverbed products are architected to scale all the way from the largest data centers with clustered products down to software on a single user’s laptop (or desktop). For organizations looking to optimize branch office operations, Riverbed offers a full line of Steelhead products that can be easily integrated into a customer’s network. There are thirteen models of Steelhead products to choose from, based on the bandwidth to the site in question, the amount of data being used, and the number of desired TCP connections (roughly proportional to the number of users). For enterprises that want to improve productivity for their mobile workers, Riverbed also offers Steelhead Mobile software, which can be installed on a user’s laptop to optimize that mobile user’s communications with the data center. In effect, Steelhead Mobile software turns a user’s laptop into a Steelhead product, so that mobile users can enjoy the same performance benefits as workers in a Steelhead product-enabled branch office.
The Riverbed Architecture

The Riverbed Steelhead product architecture has several key elements that differentiate it from other approaches. Some of these features are highlighted below.

Disk-Based System

From the beginning, Riverbed Steelhead products were built upon a disk-based architecture. Using a disk to store network traffic affords a vast capability to go back in time to find old repeated data patterns, even when the data in question last traversed the network days or even months earlier. Devices using only RAM are easily overran by typical traffic levels and file sizes, leading to much lower performance. With Riverbed’s dramatic success, other vendors are also rushing to add disks; but Riverbed offers the most mature implementation.

Universal Data Store

Building on top of its disk-based architecture, the Riverbed universal data store allows the data reduction process to efficiently scale across multiple peers. By avoiding the inherent scalability and performance limitations of per-peer data stores, organizations can save costs on WAN optimization storage and leverage the data reduction benefits of multiple peers feeding a universal store.

Application-Independent Foundation

Unlike a cache, Steelhead products are built on two key application-independent pieces of technology: Scalable Data Referencing (SDR) and Virtual Window Expansion (VWE) which remove all redundant TCP traffic and reduce TCP round trips, respectively. The benefit of this approach is that any application running on TCP sees a significant reduction in WAN traffic and an increase in throughput. Unlike a compression product, Riverbed TCP optimization accounts for the effect of high latency on TCP-based applications, which when combined with SDR, can have a dramatic improvement on applications like CIFS, Lotus Notes, FTP, backup and replication traffic as well as on web-based applications.

Application Specific Latency Optimizations

On top of the application-independent foundation (SDR + VWE), Riverbed has built a set of application-specific optimizations, including elements specialized for MAPI, CIFS, HTTP and FTP. The most important application-specific optimizations are latency optimizations called Transaction Prediction. These Transaction Prediction modules offer incremental optimizations for those applications above and beyond those provided by SDR and VWE.

Integrated Solution for Mobile Workers

Riverbed Steelhead Mobile delivers leading-edge application acceleration to mobile or home-based workers, wherever they connect to the network. Providing support for the broad range of applications that enterprises use the most, Steelhead Mobile enables remote workers to collaborate and access applications as if they were in the office. The software is easy to install and manage with no user intervention required. Steelhead Mobile extends virtually the same functionality found in the Riverbed award winning Steelhead products to mobile workers everywhere. Steelhead Mobile software leverages the same data center infrastructure as Steelhead products, and uses the same technologies as the products for auto-discovery, latency optimization, and data reduction – making it a truly integrated solution.

Flexible Network Integration

Riverbed products support virtually any network topology and/or technology capable of handling TCP traffic. Riverbed products use a TCP proxy approach to network deployment that does not require the use of tunnels. This methodology allows customers to easily deploy Steelhead products and mobile software without modifications to the infrastructure. Organizations can also use Web Cache Communications Protocol (WCCP), Policy-Based Routing (PBR), or other out-of-path deployment options if these methods are desired as well. The absence of tunnels enables Riverbed products to auto-discover peers and support full mesh environments such as MPLS with minimal configuration, as well as scale efficiently in the largest enterprise environments. Riverbed products also works easily with existing QoS, VoIP, and video conferencing, and provide the ability to mark and enforce QoS traffic on Steelhead products based on both latency and bandwidth.

Quality of Service (QoS)

Riverbed products also allow customers to use quality-of-service (QoS) management in the way that best fits their network. For customers already using QoS to support VoIP and other bandwidth sensitive traffic, Riverbed products can easily pass QoS DSCP markings to an enforcing device in a completely transparent hand-off. For cases where the environment remains bandwidth constrained, Riverbed products provide customers with the ability to leverage extensive QoS capabilities with Steelhead products themselves. Users can employ Hierarchical Fair Service Curve (HFSC) class-of-service marking and enforcement at the “edge” of their network on Steelhead products, for both optimized and pass-through traffic. HFSC supports prioritization based on both bandwidth and latency, meaning that real-time traffic such as VoIP and video is protected against congestion and latency.
In addition, Riverbed products offer hierarchical QoS capabilities to address QoS requirements for customers with multiple sites and diverse WAN link speeds. Hierarchical QoS enables the creation of QoS parent and sub-classes allowing customers to shape traffic by site, priority and traffic type. Riverbed products can apply QoS traffic based on IP address, subnet and port and also lists classes in a tree view to simplify configuration and administration for enterprise deployments.

**Riverbed Services Platform (RSP)**

Riverbed provides customers with the capability to run additional services and applications in a protected zone on Steelhead products. This revolutionary approach, called the Riverbed Services Platform (RSP), provides dedicated resource instances for certified software modules to run on. The RSP offers software vendors a unique development platform and easy interoperability with data and applications at the network level. For customers, the RSP is a protected partition on the Steelhead product to run best-of-breed virtualized services and applications on VMware while minimizing the branch office hardware infrastructure.

The RSP creates an extensible platform for multiple technology partners to deploy their services without the need for an additional dedicated server or product in remote offices. The RSP helps customers by enabling branch services such as IP address management (IPAM), video streaming, and local print server capabilities. Software providers will continue to develop modules for the RSP going forward to expand functionality to include unified threat management, directory and authentication services, virtual machine deployment and customized applications.

**Applicability of Riverbed solutions**

Riverbed solutions can be applied to many areas affecting enterprise networks today. Because WANs are such an integral part of a distributed organization’s infrastructure, they affect many critical business processes and in some cases stand as a real obstacle to the plans and goals of the organization. Here are a few of the key ways that Riverbed’s solution can help you:

**Application Acceleration**

Many business processes are dependent on applications deployed on WANs. The application can be as simple as sharing Windows files, or as complex as a custom-built application. In either case, if a WAN is in the middle, it’s almost guaranteed that the application won’t work as well as it was intended. Riverbed’s Steelhead products can accelerate many applications, like Windows file sharing, Exchange, FTP, backup and others by as much as 100 times. With LAN-like performance, users can work together no matter where they are located. Riverbed products also optimize SSL traffic without compromising the end-to-end trust model. Companies subject to compliance regulations such as SOX, HIPAA or PCI can deliver both performance and security for applications.
Riverbed’s approach accelerates all TCP applications

Remote Office Data Backup

Backing up remote office servers requires the transfer of what normally wouldn’t be too much data. But, when it needs to be sent over a low bandwidth, high latency WAN link, the throughput drops dramatically as we’ve seen, and what was a quick job can easily stretch out to take longer than the available backup window. For this reason, most IT managers rely on local tape autoloaders or other backup schemes in the branch office. Of course, local backup is fraught with poor execution, equipment failure, and operational difficulty. With Riverbed solutions, backups can be completed in a fraction of the time they currently take, which lets you take a different approach to protecting your company’s data.

Data Replication

Whether data needs to be replicated to support data replication plans, or to mirror data so it’s available for users around the world, data replication is critical. Riverbed solutions can accelerate data replication processes by a factor of 10 or more, even those using already optimized products like SnapMirror™. Steelhead products remove all the redundant traffic from the WAN, and optimize TCP. The two together make a huge difference in the time required to complete a replication.

IT Consolidation

While there have been many tools available for consolidation within the data center, until now there have not been any that allow an enterprise to consolidate infrastructure from remote offices into data centers. Riverbed’s Steelhead products enable the successful consolidation of file servers, email servers, NAS, and local tape backup. Deployments can start by consolidating only a single type of infrastructure with incremental consolidation of other infrastructure thereafter. In addition, with the Riverbed Services Platform (RSP), organizations can further consolidate their infrastructure in the branch office to achieve a true serverless office. The RSP is a protected partition on a Steelhead product on which customers can run best-of-breed third party services. With the RSP, customers no longer need to deploy separate servers in their branches to run services such as IP address management and print services.

In-sourcing

Distributed organizations doing knowledge work often find that they have spare capacity in some locations and insufficient capacity in others. By enabling more flexible sharing of information and applications across geographic boundaries, Riverbed’s Steelhead products make it possible to use idle internal resources to assist in situations that might otherwise require additional local consultants or other temporary help. This in-sourcing saves money and helps lower the volatility of work life by spreading work more evenly across locations.
**Bandwidth Optimization**

Sometimes the goal is as simple as avoiding a WAN upgrade, and Riverbed products can help with that too. Riverbed Steelhead products typically reduce existing WAN traffic by 60% to 98%, which means that an existing WAN can often support many more users, new applications like VOIP can be rolled out, and an expensive WAN upgrade can be delayed or avoided.

**Riverbed Generates Strong ROI**

Because of the benefits mentioned above, investments in Riverbed solutions generate a strong ROI. In fact, a study by IDC found that the average payback period for a Riverbed implementation is 7.3 months.1 Savings are typically generated from user productivity improvements, hardware and software savings, and bandwidth savings.

In addition to significant user productivity improvements, investments in Riverbed technology can also generate substantial hard cost savings by helping customers do the following:

- **Reduce bandwidth costs.** Using Riverbed to improve network performance, many organizations can defer WAN bandwidth upgrades. Riverbed projects can often be justified solely on bandwidth savings.

- **Consolidate infrastructure into the data center.** With Riverbed products, enterprises can remove much of the IT infrastructure (such as file and email servers, SMS servers, SharePoint servers, tape auto-loaders, and so forth) that sits in branch offices —without impacting performance.

- **Simplify branch office infrastructure.** Riverbed offers the RiOS™ Services Platform (RSP), which enables customers to run best-of-breed services on the Steelhead product (such as print, IP address management, and other services). This allows customers to consolidate their IT even further, making a true “serverless” branch office a reality.

- **Optimize disaster recovery.** By improving the performance of a disaster recovery site, Riverbed solutions can help organizations save money and backup their data in a more frequent and reliable manner.

**Summary**

Riverbed Steelhead products are a key tool for distributed organizations. Riverbed provides a single solution that can reduce WAN traffic, ensure high application performance, enable successful site consolidation projects and ensure effective data protection. No other product offers the complete set of optimizations; only Riverbed delivers a solution that can change your business.

**About Riverbed**

Riverbed Technology is the IT infrastructure performance company. The Riverbed family of wide area network (WAN) optimization solutions liberates businesses from common IT constraints by increasing application performance, enabling consolidation, and providing enterprise-wide network and application visibility — all while eliminating the need to increase bandwidth, storage or servers. Thousands of companies with distributed operations use Riverbed to make their IT infrastructure faster, less expensive and more responsive. Additional information about Riverbed (NASDAQ: RVBD) is available at [www.riverbed.com](http://www.riverbed.com)

1 IDC Whitepaper, “Adding Business Value with Wide-area Data Services,” August 2007