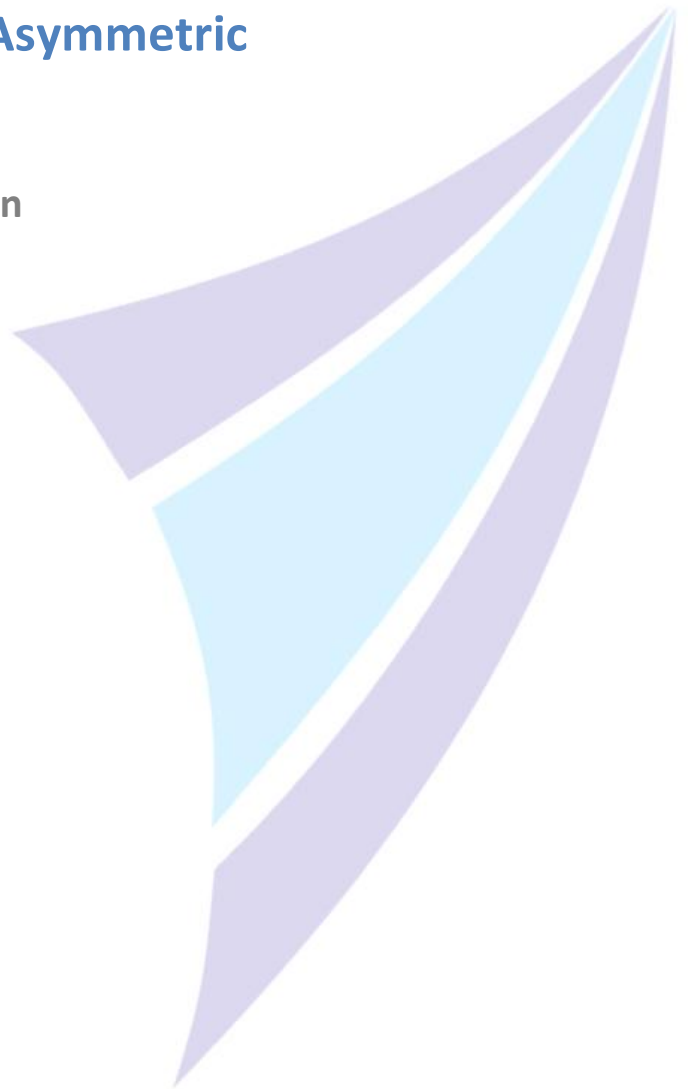


# Zeta-TCP

Intelligent, Adaptive, Asymmetric  
TCP Acceleration

AppEx Networks Corporation

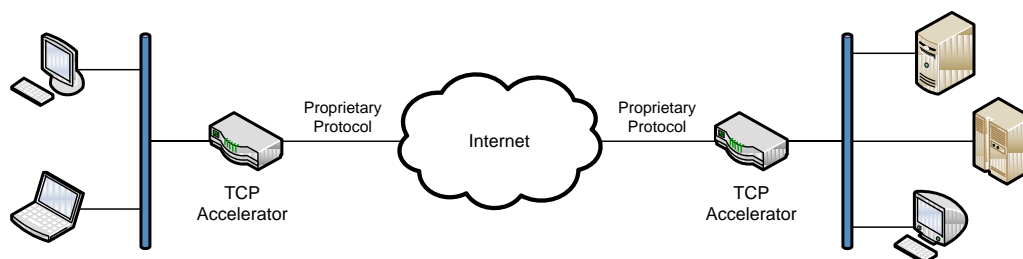


**TCP** dominates 90% of the network traffic nowadays and the trend still keeps growing. The reliable and adaptive nature of the TCP data streams has been proven to be the solid foundations for today's Internet and will continue to contribute tremendously in the future. Yet with the rapid evolvement of the media and communication technologies, as a protocol which was developed decades ago, it is facing a challenge that has never been greater before.

On one hand, the red-hot technologies such as Cloud Computing, Social Media, Mobile Personal Devices, etc., have elevated the hunger for bandwidth on both the service and the consumer ends to a whole new level; on the other hand, the current TCP algorithms and implementations are no longer well suited to the technological conditions of the networks in recent years. Some isolated, random packet losses and delays in the network will dramatically degrade the throughput of the TCP connections, lowering the network utilizations and wasting bandwidth. To make it worse, under certain situations the current TCP may retransmit unacknowledged data that the algorithm fails to identify the cause, or may refrain from retransmitting promptly for the same reason equally. All these cases either add unnecessary data traffic to the network, or introduce extra latencies on the data receiver side, deteriorating the bandwidth utilizations.

## Other Solutions

With the growth of WAN Optimization technology, some players in this field, notably Riverbed, Peribit (bought by Juniper), Orbital Data (bought by Citrix), etc., have realized the need for a better performing TCP and attempted with a variety of efforts to solve these issues. Their approaches are mostly built upon the WAN Optimization solutions of their own, labeled "TCP Optimization", "TCP Acceleration" or "Protocol Acceleration", etc. They usually transform TCP into their proprietary protocols that are better suited for the link conditions to promote the WAN bandwidth utilizations. However, since the proprietary protocols cannot interoperate directly with TCP, these solutions all require symmetric (or bilateral) deployments. In other words, the equipments supporting the same proprietary protocol must be deployed on all ends of the communication peers across the WAN. Symmetric deployments work well for the corporate scenarios with multiple branch offices, with the acceleration equipments installed at every branch. The interoffice network communication will benefit well from such solutions. However, in the most majority of the scenarios it will be impractical or impossible to require all communication peers to have these equipments. The symmetric restriction is fatal to the wide adoption of such optimizations.



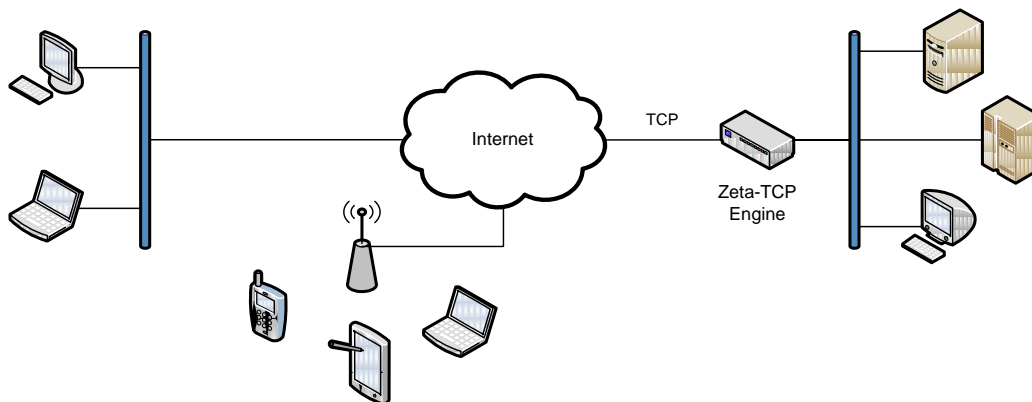
**Figure 1: Symmetric Deployment**

## Zeta-TCP in a Nutshell

### The Asymmetric Intelligence Compatible with Traditional TCP

In 2006, AppEx Networks started the development of Zeta-TCP, the new generation of TCP acceleration engine. Zeta-TCP is by-design with the following objectives in mind:

- *TCP-compatibility*: Zeta-TCP is designed to be compatible with the traditional TCP so that it is able to communicate directly with all existing TCP stacks. This enables the asymmetric (or unilateral) deployments that address a wide range of the acceleration scenarios.
- *Intelligence built-in*: By using only the existing TCP protocol primitives and options (for TCP compatibility), Zeta-TCP has a whole set of patented algorithms to study the characteristics of the TCP flow patterns on-the-fly, making accurate judgments and well-informed decisions. The intelligence injected boosts the TCP performance to the level that was previously only seen in the symmetric solutions.
- *Scalability*: The algorithms are designed to be easily scaled up and down. In the high-end, Zeta-TCP can be built into industrial grade network equipments such as routers and load balancers, supporting multiple CPUs/cores, boosting hundreds of thousands of TCP flows with gigabits of throughput; in the low-end it can be embedded into consumer mobile devices, such as phones, netbooks, tablets; or home internet routers with only a few megabytes of memory.



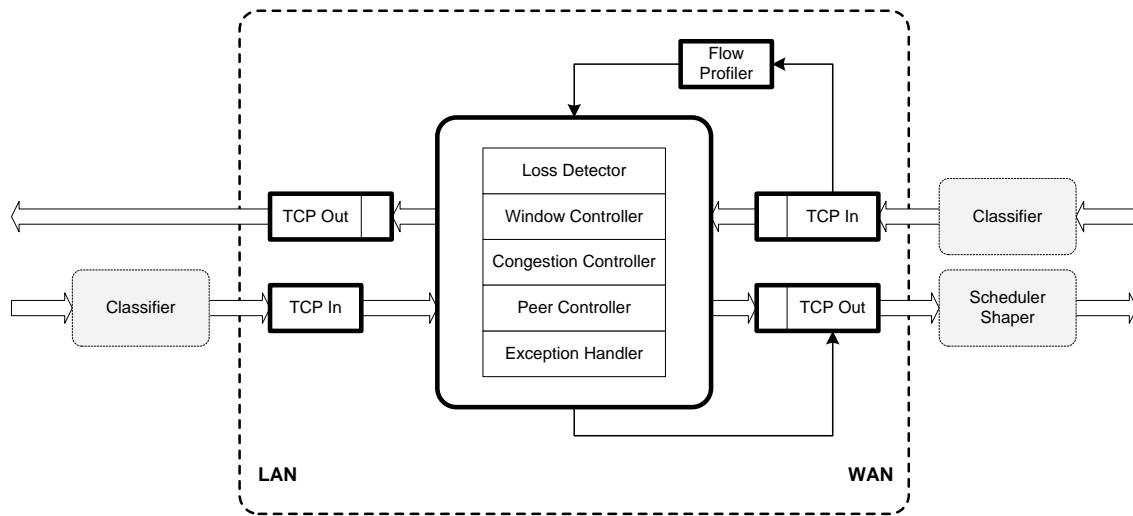
**Figure 2: Zeta-TCP Asymmetric Deployment**

- *Transparency*: The essential driving force of Zeta-TCP is an overhaul of the TCP algorithms which ideally should be implemented in the TCP stacks of the end systems. However this task would be dauntingly impractical. Instead, the Zeta-TCP engine is implemented to sit on the paths of the TCP flows. It does all the magic transparently, taking in the TCP flows, “super-charging” and pumping them out without the communication peers even realizing its existence.

These objectives ensure Zeta-TCP to be the most adoptable TCP acceleration solution that is capable of delivering an unparalleled network performance.

## How It Works

Logically the Zeta-TCP engine can be illustrated as in the following diagram:



**Figure 3: Zeta-TCP Engine**

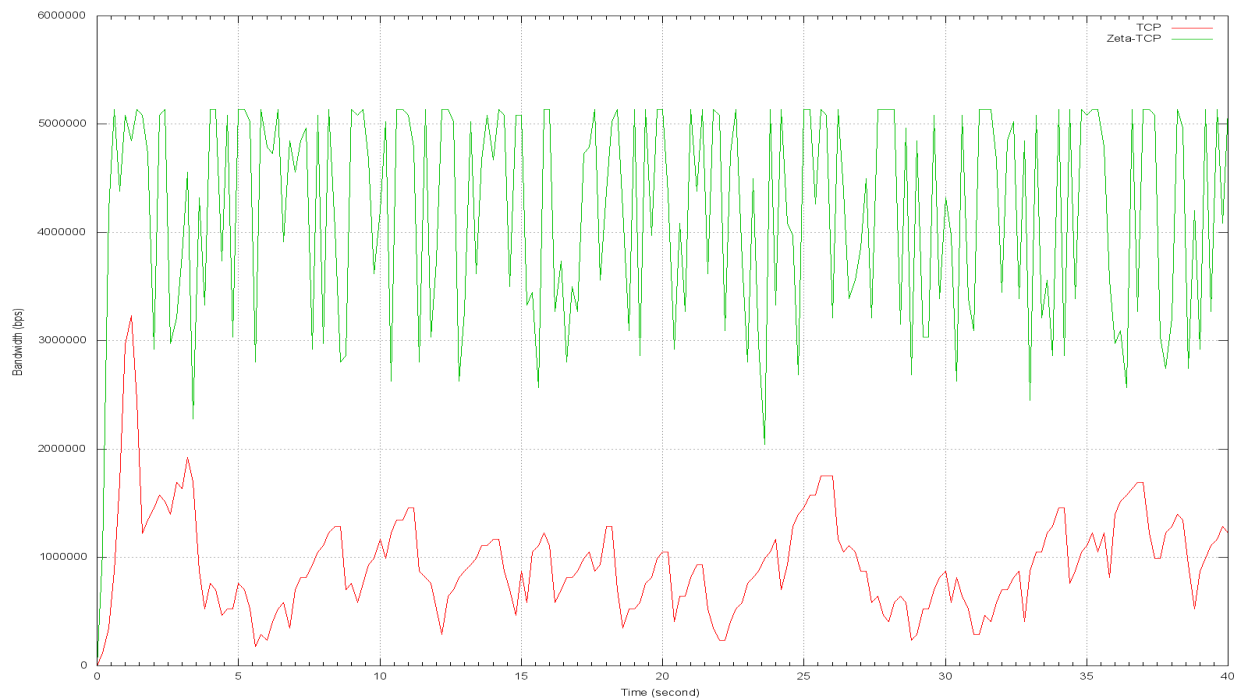
The three shaded boxes are other related AppEx modules. The Zeta-TCP engine, specifically, is the central block marked by the dashed-line box. Packets are queued at the TCP In/Out modules. Most of the logics focus on the WAN side processing. The Flow Profiler extracts the characteristics of the flows. The Loss Detector vigilantly watches for the packet losses, and calculates the most likely reason for them: whether it has been caused by simple random drops or network congestions. The Window Controller computes the TCP advertisement window size which controls the packets incoming from both the LAN and the WAN sides. The Congestion Controller executes the core TCP congestion control logics. The Peer Controller runs a series of algorithms to remotely control the sending from the WAN-side peers. Last but not least, there is the Exception Handler. Unlike other modules, it does not directly accelerate the TCP flows. It is of great importance, however, to detect the flaws in the peer TCP stacks or certain devices en route. In the real world deployments we've observed erroneous TCP implementations. Some of the problems could harm the effectiveness of the Zeta-TCP engine. This module is added to detect such scenarios and ensure the maximum acceleration.

Zeta-TCP improves the traditional TCP primarily in the following aspects:

### Loss-Scenario-Based Recovery Algorithms

The Traditional TCP's Congestion Avoidance is based on the algorithm designed decades ago. The algorithm takes the dumb assumption by treating all losses as the signal of congestions. This assumption overly simplifies what is really happening in the network and forces the traditional TCP to take the most conservative strategy against packet losses. In reality, most of the packet losses in today's networks are not congestion related. This is especially true in wireless/mobile networks, where fading channels introduces inevitable packet losses. Traditional TCP suffers greatly under such environments.

Zeta-TCP, on the other hand, introduces a number of intelligent algorithms to categorize the packet loss scenarios based on the traffic statistics such as the variations of the loss rates and latencies, etc. Therefore it is able to more accurately determine the cause of the losses and apply different recovery algorithms to different loss scenarios. In the worst case where the congestion really happens, it falls back to the traditional TCP's algorithm so as not to exasperate the congestion. In other cases it attempts to recover quickly depending on the likelihood of congestion.



**Figure 4: Zeta-TCP Under 1% Random Packet Loss**

The above comparison graph is generated from the real test data of 100-millisecond RTT and 1% random loss rate. With Receive Window size 65535 the bandwidth ceiling is about 5.24Mbps. Zeta-TCP could pretty much fill up the pipe, delivering a goodput 4 – 5 times of the traditional TCP.

### Improved Loss-Detection Accuracy

Packet losses are rarely distributed evenly across the period of the transmission. Rather they tend to happen close to each other. It is very common for more losses to happen in the fast recovery region and/or during the recovery. Traditional TCP, mostly based on NewReno (RFC 2582) and SACK supported algorithms such as RFC 3517, is rather mechanized and often fails to identify individual packet losses among clustered losses, resulting in failure to retransmit lost packets promptly, adding more round trips to the recovery cycle.

Another scenario is retransmission timeout (RTO). The last piece of logic that the tradition TCP wants to invoke is RTO retransmission. When this happens, traditional TCP will back off the transmission to the point of the last cumulative ACK. However, the dilemma here is that RTOs usually indicate the extremities in the network, such as heavy congestion, loss of connectivity, etc. Blindly falling back to

retransmit everything that has just been transmitted helps little about these scenarios, if it doesn't make the situation even worse.

Zeta-TCP has introduced advanced intelligence to the loss detection. It is able to detect packet loss more accurately and promptly than the traditional TCP, especially under heavy losses. For RTO, Zeta-TCP will first attempt to figure out what's really missing before it happens. It makes all efforts to prevent from falling into RTO in early stages. Even if RTO finally happens, it doesn't simply blindly fall back. Instead, it will start from heuristic retransmission. As a result, Zeta-TCP on average generates less retransmission traffic than traditional TCP, which is more obvious under heavy loss.

	Zeta-TCP	TCP
<b>Lost Transmitted (bytes)</b>	6395494	6395494
<b>Retransmitted (bytes)</b>	6612340	6969728
<b>Over-retransmitted (bytes)</b>	216846	574234

**Table 1: Over-retransmission under 5% Loss Rate**

This advantage is especially valuable in the explosive growth of the wireless networks. The flaky last mile fading channel to the mobile devices could create frequent bulk packet losses. Such losses could trigger the traditional TCP jamming more packets into the network. Zeta-TCP, however, will analyze the situation smartly to boost the overall performance.

### Reverse Control & Stimulus

Zeta-TCP introduces a series of unique mechanisms to stimulate or control the peer's sending, with which it is capable of accelerating the inbound TCP flows. Unlike the outbound acceleration explained above, the real control of the speed of the inbound flow lies in the data sender, i.e., the peer. What Zeta-TCP does is to send feedbacks to the peer, which is understandable to the traditional TCP hosts, to encourage or hint it to send in more data and avoid unnecessary retransmissions.

Compared with the outbound, the inbound acceleration is not a sure shot. It is more of a best-effort improvement to increase the inbound flow statistically. Zeta-TCP's attempts include explicit or clearer indications to the sender to prevent it from unnecessarily falling into recovery mode, and retransmit promptly if a real loss is detected. It hints the sender about the detected end-to-end bandwidth so that the peer can potentially send as fast as the bandwidth allows, increasing the sending speed while avoiding introducing congestions. It also makes all efforts to prevent the sender from falling into RTO retransmission.

The reverse control mechanism to accelerate the inbound flow as described above, on the contrary, can be applied very effectively to decelerate the inbound flows. These algorithms lay the foundations for AppEx Network's Inbound Shaping feature.

## Bench Marks

### Gomez Reports

Gomez provides the platforms for Web performance and quality tests which are well recognized by the industry. The following are the test reports of the unilateral installation with Zeta-TCP device deployed in the web server side. The test was performed over almost 2000 different time slots, accessing from a variety of client sites.

Yellow Line: With Zeta-TCP  
Blue Line: Without Zeta-TCP

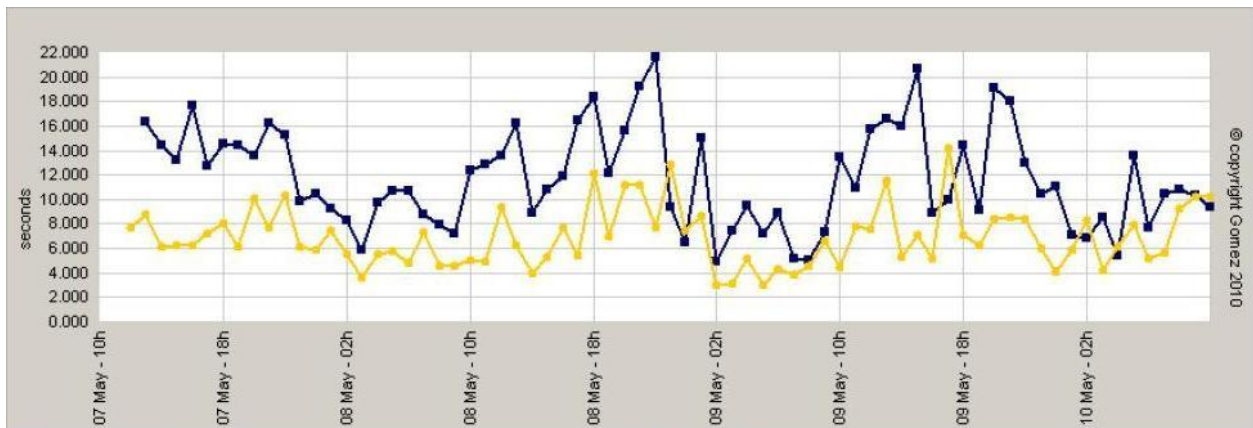


Figure 5: Gomez Test - Dynamic Web Page Loading Time

Gomez Tests	Total Tests	Total Errors	Availability	Avg Response Time
With Zeta-TCP	1948	45	97.69%	6.921 (seconds)
Without Zeta-TCP	1951	68	96.51%	11.774 (seconds)

Table 2: Gomez Test – Statistics

From the real-world test result above, Zeta-TCP is able to eliminate 34% of web page access failures and shorten the total loading time by 40%.

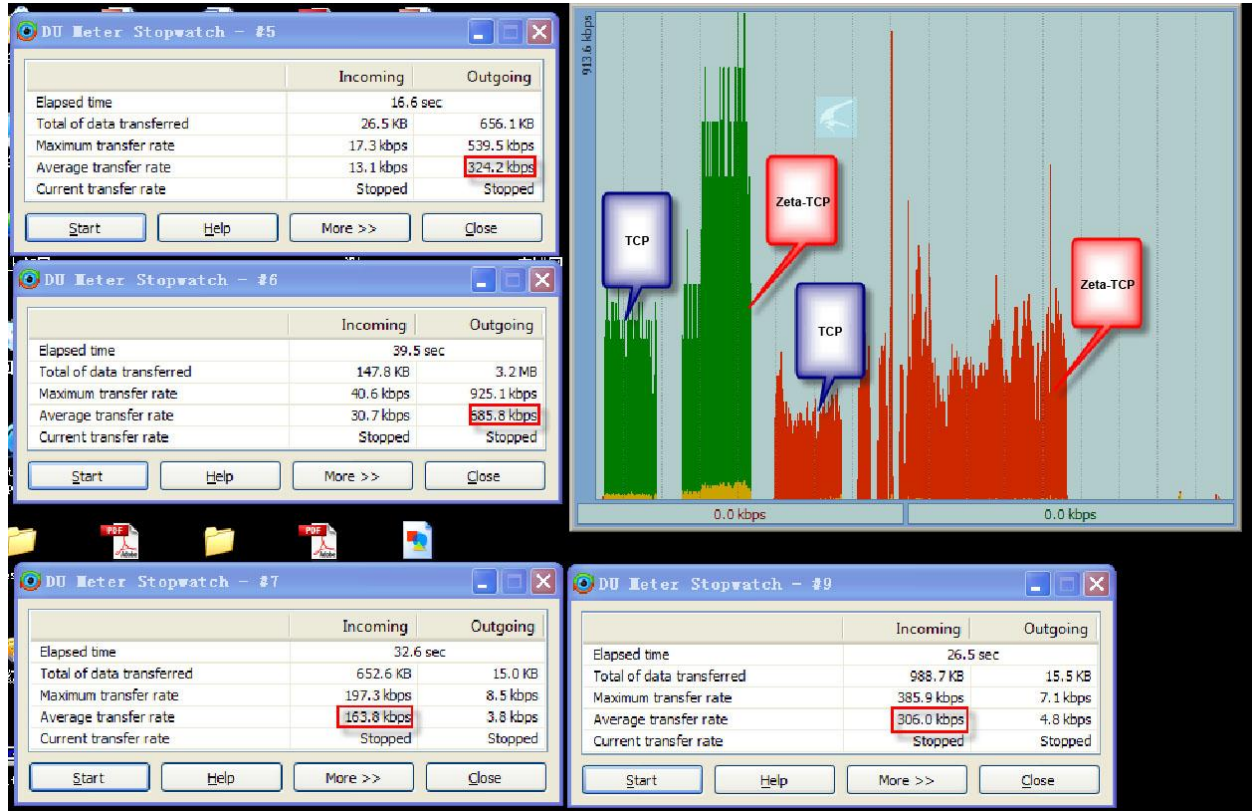
## The All-in-One Acceleration Solution

Designed with great flexibility and scalability, Zeta-TCP has a very wide variety of applications to boost the performance of network transport and improve the user experiences.

### Mobile Networks

The volatile characteristics of the fading channels make loss and delay the eternal topics of the wireless networks. Fueled with the exponential growth of the mobile applications in recent years, the hunger for bandwidth is now worse than ever before. Regardless of the costly upgrades in both the service provider and the consumer camps, the user experiences are still far from satisfactory.

Zeta-TCP's advanced loss detection and recovery algorithms not only improve the bandwidth utilization, boost the communication speed, but also make the flows more robust against the loss and delay. In addition, it is able to reduce the unnecessary retransmissions and lower the pressure in the carrier networks.



**Figure 6: Zeta-TCP Wireless 3G Acceleration**

The above screenshot shows a test performed in a notebook computer with Zeta-TCP engine installed in Windows XP. The network connections were established via a 3G Wireless PC-Card. The upload speed was promoted from 324Kbps to 685Kbps while the download from 164Kbps to 306Kbps.

Zeta-TCP can be easily built into smart mobile devices, such as phones, tablets, netbooks, etc., with very low resource consumptions. This type of client-side deployment greatly benefits applications such as email clients, social media, IM, video/voice communications, VPN, etc. The download direction will also be improved statistically. It can also be deployed at the server / content provider side as an industry-class acceleration device, which benefits both the wired and wireless clients.

### Dynamic or Uncacheable Content Providers

Web Content Caching plays an important role in accelerating web browsing and reducing trunk traffic. The caching technology works very effectively for static web contents. However, the recent new trend in Social Media Networks, Cloud / SaaS, etc., swamps the Internet with dynamic web contents. Although many of the child objects of the dynamic content may be static, the delivery of the dynamic object itself

is often the bottleneck to load the entire page. Besides, certain applications may not allow the contents to be cached at all for security, privacy or other considerations. The effectiveness of Web Caching is greatly impacted for these scenarios.

With the Zeta-TCP acceleration devices deployed at the content provider sites, the serving speed of such contents can be dramatically improved. Furthermore, the provider-side deployment is completely transparent to the clients and the servers. The deployment cost is therefore very low. But the user experience improvements would be tremendous.

## **Businesses and Organizations**

Zeta-TCP is able to address a wide range of network acceleration and flow control needs of the businesses and organizations that provide group network accesses. Zeta-TCP enables them to maximize the network utilizations and control the flows on both outbound and inbound directions. Especially worth mentioning is that the inbound traffic can be effectively controlled and restricted. Zeta-TCP will offer cost savings in a variety of scenarios such as Internet access, inter-branch communications (especially long distance/high loss such as international and/or satellite links), VPN and Road Warrior, etc.

## **Internet Service Providers**

Likewise, the ISPs can deploy Zeta-TCP to improve the user experience or as a value-added service to the subscribers. The improved bandwidth utilization and intelligent retransmission means cost savings for the ISP themselves as well.

## **Personal / Home / SOHO Use**

If the ISP doesn't have it yet, the users can simply install the Zeta-TCP acceleration software to their home computers. The PC versions of AppEx Networks Accelerator support Windows XP all the way up to the latest Windows 7. Or they can choose to buy a home-use Internet Router with Zeta-TCP built-in. The portability and scalability of Zeta-TCP makes it easily adopted by all kinds of computer systems.

## **Conclusions**

Traditional TCP, which is largely based on NewReno and a few other related RFCs, is no longer performing well in the networks nowadays. Some WAN Optimization vendors attempted to provide their own proprietary protocols to address the issue, however, required bilateral deployment which restricted the scope of users / scenarios that may benefit from them.

Armed with a series of algorithms to overcome the inefficiency of the traditional TCP, Zeta-TCP is fully compatible with the existing TCP stacks, which makes the unilateral deployment possible. Its unique Reverse Control algorithm is capable of accelerating inbound flows, in addition to the outbound acceleration. This boosts the network performance to the same level only seen before in the bilateral deployment.

Engineering wise, the deliberate design and implementation make Zeta-TCP the most portable and scalable TCP acceleration solution in the industry. It can be seamlessly deployed and integrated in a very

wide variety of scenarios, notably among them, wireless / mobile networks, SaaS and dynamic content delivery, and other hotspots in today's network applications.

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