Akamai
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Akamai Briefing:

Highly Distributed Computing is Key to Quality on the HD Web

This paper outlines the basic requirements for delivering high-definition (HD) video via broadband and describes how Akamai, through highly distributed computing, is uniquely able to extend the Internet's capacity and deliver a consistent high-quality HD Web viewing experience—even as Web traffic grows exponentially.

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Are you Ready for the HD Web?
We are.

Executive Summary

Consumer demand for better content experiences continues to rise. With its high-fidelity pictures and sound, HD video offers viewers a way to experience content like never before—via television, DVD or broadband. While producing and broadcasting high definition content requires extensive re-tooling and investment by both providers and consumers, the HD Web is by comparison a simpler undertaking. No special transmitters are required, and consumers need only their broadband connections to receive it.

Viewers' expectations for HD Web content are equally straightforward: It has to look good, and it has to be available on demand. Providing this experience consistently, however, is not as simple as it appears.

Specifically, HD video files are large, and require extremely high throughput for uninterrupted, high-speed delivery. When they traverse the Internet en route from centralized infrastructures or centralized content delivery networks, these files encounter delays and failures specific to the capacity they require and the distance they have to travel to get to the viewer—namely latency, packet loss and peering problems. Files can take longer to download than they do to watch. They get interrupted; or delay for re-buffering; or the number of users that may access them is limited. In short, the experience is compromised.

Despite Internet traffic that's increasing 50% year over year, the capacity required to deliver a high-quality HD Web experience does exist. It's at the 'edge' of the Internet, leveraging the massive build-outs occurring in hundreds of networks worldwide. Only Akamai's highly distributed computing platform delivers content from within those networks, harnessing their capacity to accelerate downloads, serve HD content in its entirety, and scale to reach unlimited audiences—ultimately driving adoption of the HD Web.

Centralized Infrastructures vs. Highly Distributed Delivery

Media companies can choose a centralized or a distributed approach to deliver HD content via broadband. The centralized approach is defined by this architecture:

- A single to a few dozen data centers
- Dense deployment of Web and/or caching servers within these data centers
- Reliance on transit or peering relationships in each data center, and in some cases, a backbone network connecting the data centers

The capacity of centralized or small-footprint network architectures is limited by the number of data centers and each data center's available exit/transit bandwidth. The largest centralized content delivery network providers (CDNs) have up to 30 locations within their network footprint and can, according to published claims, provide bandwidth of up to 1.4 Terabits per second.

By contrast, Akamai's highly distributed architecture comprises a platform that resides in not a few, or even a hundred, but 1,000 data centers. As no one network in the world delivers more than 8% of total Internet traffic (in fact, the top 30 global networks combined deliver just half of total traffic), having a massive local network presence is what enables Akamai to leverage available bandwidth at its source and deliver content to users from within a few hundred miles. With 25,000 servers in 650 cities and 70 countries, Akamai is within one network hop of 90% of Internet users and can support the capacity sufficient to accommodate the HD Web and future IP needs.

The dramatic differences between these two approaches and the superiority of a highly distributed architecture become even clearer when examining the characteristics of the HD Web in detail.

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HD Web Basics: Encoding rates, file sizes, and bandwidth requirements

The amount of Internet capacity (bandwidth) required to deliver a high quality HD Web experience is based on the content's encoding rate and file size. The higher the encoding rate, the bigger the file, the more bandwidth is required to deliver it. The more bandwidth that is available, the faster the content will download.

Encoding Rates

While no definitive industry metrics are in place that specify encoding rates for HD-quality online video, 700 kilobits per second is a de facto standard for 'recreational' video quality, 2 megabits per second is the accepted standard for 'TV quality' video, and 4-6 megabits per second is the standard bit rate for 'DVD quality'. Using these figures as a guideline, a standard encoding rate for 'HD-quality' video is approximately 6-10 megabits per second, depending on content.

File Sizes

Given these encoding rates, a typical half-hour television show encoded for TV quality at 4-6 megabits per second results in a file size of approximately 450 Megabytes, and 2.25 Gigabytes for HD quality. A two-hour feature film encoded for DVD quality would result in a 5.4 Gigabyte file, and for HD quality would result in a file size of approximately 9 Gigabytes.

Bandwidth Requirements

That plays out in terms of capacity this way. Delivering a download of a half-hour show encoded for TV quality to a single viewer in an acceptable amount of time would require a sustained bandwidth of 2 Megabits per second. Encoded for HD quality, that same download would require 10-20 Megabits per second. Delivering that same show in TV quality to an online audience of just over one million households (the equivalent of just one Nielsen ratings point) would require 6.6 Terabits of sustained bandwidth. And delivering the show to an audience of 50 million (typical for a prime-time TV show) would require approximately 100 Terabits per second.

A key factor in how capacity is utilized is the distance between content server and viewer. The greater the distance, the slower a file will download. Even a seemingly small increase in distance can result in dramatically lower throughput due to increased latency and higher packet loss.

The Impact of Latency and Packet Loss on the HD Web

Limited access to bandwidth is not the only culprit responsible for slow or disrupted downloads. Often it's latency and packet loss that limits throughput. It's easy to discount the impact of latency on an HD download. After all, who cares about 100 milliseconds of latency when downloading a file that will take minutes or hours? While initial latency (time to the delivery of the first byte) is largely immaterial, overall latency is extremely important, since it ultimately governs the rate of throughput.

For the delivery of large files, latency matters because it affects the way underlying network protocols govern the transfer of data. A server can only send a certain number of packets before it must pause to wait for an acknowledgement from the client that all have been received successfully. The greater the distance between server and client, the longer the resultant 'round trip time'. Just a few years ago, bandwidth speeds were constrained by the last mile. Today, the distance between server and the end user is the bottleneck.

With Akamai's distributed approach, large HD video files don't travel cross-country or overseas to reach an end user. Content is delivered to end users from servers nearby, reducing round trip times to just a few milliseconds, enabling higher throughput, and reducing the opportunity for packet loss.

Distance Factors

With centralized infrastructures, servers are often far from end users. This distance, coupled with network congestion and capacity problems, reduces throughput. For a live stream, this reduction will result in poor quality, and for downloads, it essentially removes the on-demand nature of the content as the download will take longer than the time required to view it.

By distributing content from one well-chosen locale to a worldwide audience, the average distance between content and users is approximately 3,000 miles. With a network distributed in 30 locations, the average distance can close to 1,000 – 1,500 miles (delivering a 2X throughput improvement). With Akamai's highly-distributed platform in 1,000 locations, the gap closes to 250 miles, which delivers a 4X improvement in throughput vs. a centralized architecture.

Since one of consumers' two basic requirements for HD Web content is that it must be available on demand, distance, which determines time-to-download, is a critical measure of the experience.

Figure 1: *Centralized CDNs delivering from far away face download times that can be significantly slower than content delivered locally.*

Distance between server and end user	"Speed of Light" Network Latency (RTT)	Theoretically fastest possible download time using TCP	Typical Network Latency (RTT)	Typical packet loss rate	Typical download time with specified packet loss rates	Typical Throughput	Quality
Local (100 miles)	1.6 ms	6.4 minutes	4 ms	0.6%	18 minutes	29.63 Mbps	High Definition
Regional (1000 miles)	16 ms	64 minutes	50 ms	0.7%	4 hours	2.22 Mbps	DVD
Cross-continent (3000 miles)	48 ms	3.2 hours	90 ms	1.0%	9 hours	0.99 Mbps	TV
Different continent (6000 miles)	96 ms	9.6 hours	150 ms	1.4%	18.3 hours	0.49 Mbps	Thumbnail
Emerging Markets (BRIC)	96 ms	9.6 hours	300 ms	2.0%	1 day, 1 hour	0.36 Mbps	Thumbnail

The Peering Problem

Centralized content delivery networks are subject to one additional capacity challenge that highly distributed infrastructures are not. They rely on peering relationships to deliver content into end-user networks. Centralized content delivery networks have numerous peering relationships (often hundreds) with other networks to exchange and deliver traffic to end users, and count on these relationships to help them deliver their content to networks where they are not deployed. While these relationships are valuable, peering with another network is a poor substitute for deploying within that network because it can result in capacity constraints.

Given that the Internet is a network of networks, all traffic eventually reaches a peering point, which can become a bottleneck. Backups at peering links can cause some data to be dropped, resulting in packet loss for downloads, and interruptions for streaming. This capacity constraint can only get worse as more, higher-throughput media goes online. And the problem can't be solved by building capacity within any one network.

Because peering requires the cooperation of directly competing entities, capacity at peering points can lag significantly behind demand, and this situation is unlikely to be satisfactorily resolved any time soon. Network economics dictate that money "enters" the network at the first mile, from connectivity and transit fees, as well as at the last mile, from end-user subscriber fees, so network providers have little-to-no financial incentive to invest any more money than absolutely necessary in improving "middle mile" peering capacity and related infrastructure. As such, it is unlikely that peering points will grow sufficiently to be able to handle anything close to the 100 Tbps traffic loads required to deliver the HD Web.

Additionally, ISPs have a strong economic incentive to force traffic off their own networks onto peer networks as quickly as possible. This "hot potato" routing can further increase the traffic going through peering points, at a cost to overall Internet efficiency. Tier 1 ISPs, in particular, have very little incentive to peer, as they forego transit revenue by doing so, with little to gain in return. This has been demonstrated in disputes between competitors that lead to sudden de-peering, with severe consequences for end users.

Ultimately, What's Required to Deliver HD Video Online?

Akamai is highly invested in helping its customers bring the HD video experience to online audiences. As part of its effort to specify a delivery solution that lessens the impact of distance, latency, packet loss and peering, and increases capacity and throughput, Akamai has authored a basic set of criteria for the HD Web.

To even enter the playing field, a content delivery solution must support the delivery of files that:

- Achieve visual parity with broadcast video (by supporting VC-1 and MPEG-4 video standards)
- Handle the standards and resolutions of HD video (720p, 1080i and 1080p)

A number of service providers can meet those standards today. Above that, to ensure a high-quality HD Web experience a delivery platform must also comply with the following technical criteria:

- Server deployment in the world's largest high-throughput networks; and relationships established with those networks
- Support for the delivery, storage, and management of files greater than 2 Gigabytes
- Client-side technology that is deeply integrated into its delivery system to be deployed as appropriate

Akamai has architected its platform to comply, and believes that it is the first and only platform to meet all of these requirements. With these elements in place, Akamai guarantees that broadband subscribers will enjoy faster downloads and an overall positive experience that helps drive adoption of the HD Web.

Akamai serves all content, whether it is frequently or rarely requested, from the optimal server closest to the end user. Its unique technology automatically and instantly spreads popular content on-demand for better scalability. In addition, since many large HD videos are not always watched in their entirety, Akamai caches locally only the portion of a file that is most requested by end users, which on average is the beginning of the file or movie. This partial caching of HD video enables both popular and less popular content to be served from the edge to guarantee optimal performance.

With its highly-distributed architecture, Akamai is uniquely positioned among providers to deliver support for the 100 Terabits per second of sustained bandwidth required for the HD Web. The company is also committed to the long-term objective of building an ecosystem linking content owners, network providers and video platform players to ensure a superior HD Web experience wherever last-mile infrastructure permits.

About Akamai

Akamai® is the leading global service provider for accelerating content and business processes online. Thousands of organizations have formed trusted relationships with Akamai, improving their revenue and reducing costs by maximizing the performance of their online businesses. Leveraging the Akamai EdgePlatform, these organizations gain business advantage today, and have the foundation for the emerging Web solutions of tomorrow. Akamai is "The Trusted Choice for Online Business." For more information, visit www.akamai.com.

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