AKAMAI WHITE PAPER

Streaming toward television's future: A detailed look at 4K video and how Akamai is making it a reality

Akamai
FASTER FORWARD

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IS THE WORLD READY FOR 4K? IN A RISING NUMBER OF COUNTRIES, THE ANSWER IS YES. HERE IS THE DATA TO PROVE IT.

Among the first order of business for 4K video is bandwidth, particularly the last-mile kind. Although there's quibbling about exactly how much oomph is needed to faithfully render ultra-high definition images on screens, the early consensus is that 4K will demand downstream throughput of 15-20 megabits per second, minimally – and as always, more is better. Netflix CEO Reed Hastings, for instance, said he thinks a steady rate of 15Mbps is sufficient to do the job. "It's around 15 megabits per second," Hastings said in an interview from the 2013 Copenhagen Future of TV Conference. "It's not too bad."

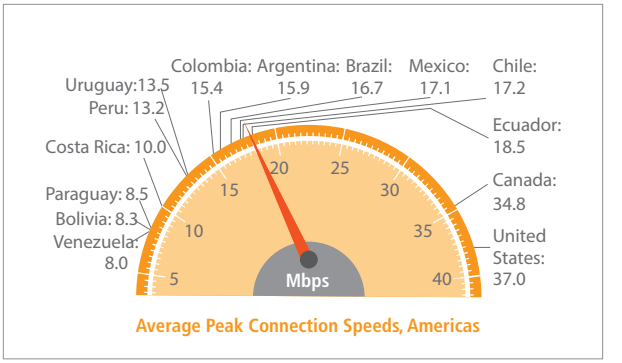
If that's the case, how 4K-ready are the world's residential broadband networks?

Akamai's latest State of the Internet Report offers some visibility. According to the Q3 2013 data drawn from traffic flows over Akamai's Intelligent Platform™, accommodating 4K video streams over last-mile access networks should be a relatively pedestrian task in places like the Pacific Rim, North/Central Europe, and in most U.S. states. Elsewhere, there are plenty of ISPs that can manage 4K delivery, although coverage is uneven. Globally, the average peak connection speed as of Q3 2013 was 17.9Mbps, and in the U.S., it was an impressive 37.9Mbps. (The average peak connection speed is a metric used by Akamai that the company believes is best representative of the capacity of an internet connection.).

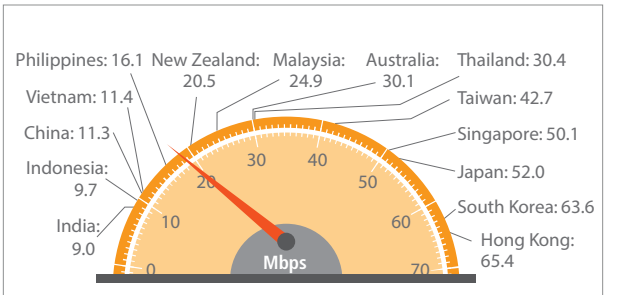
"There are a number of countries globally that are above 20Mbps, as are nearly all U.S. states," says Akamai Senior Director, Industry and Data Intelligence David Belson.

As always, some caveats apply. IP data networks operate in a highly fluid state, with bitrates plunging and rising constantly depending on a variety of influences. And as Belson notes, the presence of a high-speed network doesn't always translate to widespread usage. "Note that this doesn't mean that every subscriber has purchased a connectivity tier of 20Mbps or better, but rather that on average, the fastest speeds we're seeing from these countries and states are above 20Mbps."

Remember: The data paints a picture of the current landscape. Going forward, there are widespread expectations that networks will only improve in last-mile capability. And 4K may be one reason for it, says Belson.



Average Peak Connection Speeds, Americas



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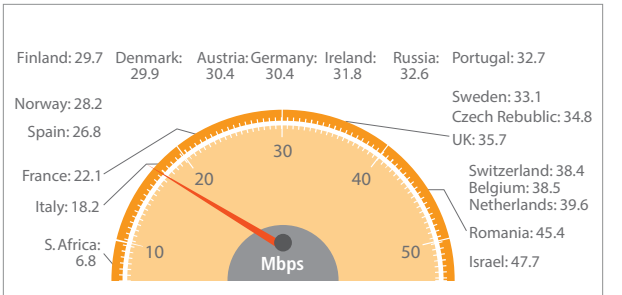

Average Peak Connection Speeds, EMEA

"It will be interesting to see if 4K ultimately drives increased bandwidth usage, leading providers to evolve the service tiers offered to customers – and ultimately improving the speeds we measure," Belson says. Similarly, he thinks 4K may spur new feats in digital video compression. Taken together, these two potential trends – rising network performance and more data squeezed into the pipe – stand to improve the prospects for widespread 4K delivery over the last mile.

Akamai's State of the Internet Report, though, reflects a broadband access network environment that's becoming more robust in general. Globally, adoption of broadband network connectivity at speeds greater than 10Mbps jumped 31% from the second quarter of 2013 to the third quarter, reaching 19 percent of all measured connections worldwide.

The improvements stem from a variety of influences, including rising consumption, competition in some markets, and technology advancements. For example, some research points to the rising prominence of fiber optic networks that routinely achieve downstream data rates approaching or exceeding 1 gigabit per second. In its latest survey of broadband networks across member countries, The Organization for Economic Development and Cooperation found fiber networks accounted for 15.7% of global fixed-wire broadband connections as of June 2013, up from 13.9% a year earlier.

In this environment, 4K is a potential instigator of further advancements – but it's only one instigator. And as Belson points out, last-mile network performance alone isn't the only ingredient needed to assure the proper footing for the emerging video standard. "4K streaming may be something of a chicken-and-egg scenario," Belson observes. "Capable device availability, sufficient bandwidth, and content of interest ultimately are reliant on one another for success."

The Power Of Ping: For Assuring 4K Fidelilty, Reduced Latency Plays a Larger-Than-Life Role

In media content delivery, speed matters. It's true for low bitrate video, and it's especially paramount for 4K video, where every millisecond can impact the user experience.

The metric that matters here is Round-Trip Time Delay (RTT), or "ping time" in internet parlance. In a video delivery context, for example, RTT expresses how long it takes for an end user to send a request to launch a TV episode plus how long it takes for a server to respond with the requested information.

Ping time is especially important in the emerging world of 4K video, where proximity to the end user is a critical factor. It's a constraint brought to you by the speed of light: As an end user's distance from a server lengthens, throughput decreases. Even a small distance can result in poor performance due to lower throughput, higher packet loss, and increased latency – a more expansive cousin to ping time that also takes into account packet processing time.

All of these are issues that 4K exacerbates with its large file sizes and appetite for bandwidth. The result? Slow downloads, interruptions and the inability to serve HD content – and in particular 4K content – effectively. Latency effects, including choppy video and out-of-sync audio, can become even more irksome when available bandwidth approaches the bitrate of the video. With 4K video, which demands last-mile bandwidth of 15Mbps or greater, that scenario is far more likely to occur than with lower-resolution video that can get by at single-digit Mbps rates.

Unique Approach

Akamai, uniquely among content delivery network providers, attacks the RTT issue by injecting client media content throughout the Akamai Intelligent Platform consisting of nearly 150,000 servers co-located at network edge locations around the world. In a world of limited physical space within ISP co-location centers, it's this first-mover advantage that sets Akamai apart.

The reason: Bringing content closer to end users addresses immutable laws of physics that no software solution or cloudbased data center fix can address. "At a high level, a lot of the problems for both streaming and download delivery on the Internet stem from conditions where there's high packet loss and latency," says Bill Wishon, Akamai Senior Product Manager for Client Technology.

For 4K, whose lifeblood is all about immersive, larger-than-life entertainment experiences, getting bits to oversized TV screens quickly, with minimal loss, is imperative. That's why the model of the monolithic, centralized and distant data center is a poor fit for the emerging 4K world – it produces elongated latency that won't support the high fidelity demands associated with 4K digital video. "If the idea is to deliver these videos from the cloud, or from the core, you're going to be out of luck," said Akamai CEO Tom Leighton in an interview from the CES 2014 show floor with CNET.

Beyond leveraging its Intelligent Platform, Akamai is already exploring a next-generation approach to 4K delivery by considering ways to embed content even deeper within broadband networks – at neighborhood serving nodes, for example, or even within home gateways for still-faster access. Through joint efforts with Qualcomm, Akamai is exploring ways to leverage new home gateway technologies to provide managed access to 4K video and other types of content.

Cracking the code on 4K video: with emerging video formats, Akamai is Rewriting the Rule Book for High-Quality Online Video Preparation.

Ask a pessimist what problems afflict the modern Internet and you'll get a laundry list of woes. Cables can get cut. DNS attacks can cripple web servers. Congestion can slow streams. Demand for viral content can become overwhelming.

These are all real threats, to be sure. But their actual incidence is relatively infrequent. And when it comes to streaming video, all of them take a distant backseat to a much more common culprit: poor file preparation.

Evaluations by Akamai reveal most video stream glitches stem from faults that occur well before a video asset ever gets planted on an edge server and a user clicks "play." Encoding and transcoding – the art and craft of turning video content into digital formats that are prescribed by standardized algorithms – are much overlooked contributors to poor user experiences, lousy video quality, and streams that fail to appear on command – not to mention unnecessary costs for storage and bandwidth on the part of content providers.

"In our experience, a significant percent of the problems we see have to do with content not being prepared properly," says Kurt Michel, Director of Product Marketing for Akamai's Media division.

Part of the problem has to do with skill sets, or the absence of them. Even though prevailing standards and specifications for Internet video encoding are well known and widely embraced, there's still a great deal of craftsmanship and knowledge that goes into the art of encoding and transcoding, ranging from control of VBR ratios to the synchronization of frames.

Creating multiple adaptive bitrate streaming renditions demands especially adroit handling of key frames – the establishing frames within a compression algorithm that provide color, luminance and other information for the pixels other frames will borrow from. That's true for relatively forgiving, low-bandwidth video files, and it's especially true for 4K video, where proper transcoding is essential for getting densely compressed files to play as intended.

"When you get to that level it becomes a heuristic art," says Will Law, Chief Architect in Akamai's Media Engineering Group. "There's a high level of craftsmanship required."

Akamai's Encoding Solution

Preparing for 4K video is one reason Akamai initiated its own video transcoding service in 2013. The idea behind Akamai's Media & Delivery Solutions is not only to assure excellent picture and stream performance quality across multiple bitrate renditions, but to reduce the number of discrete touch points clients must manage as they create these renditions from master or "mezzanine" files. As Michel points out, each time a new rendition is created – adaptive bitrate streaming requires a progression of multiple bitrate versions of video – there's a chance to introduce inconsistencies. Specifically, each rendition can locate key frames at slightly different points. In that case, when the stream switches to a different bitstream, the video may play poorly or not at all.

"With transcoding, there are a lot of variables – the knobs and buttons and switches – that need to be set correctly," notes Michel. "If you don't have the end in mind about a common rendition set, you're going to make changes, and some of those changes may affect the key frames. We begin with the end in mind. We know the goal is to have a clean rendition set that plays smoothly as the bitrates change."

Akamai addresses the need for rendition set integrity in part by employing simultaneous transcoding of multiple file iterations in parallel, a technique that assures consistency while enabling extremely fast turnaround times. In the typical transcoding case, a single process is used to create one rendition at a time, sequentially. In contrast, Akamai's transcoding creates all of the renditions in parallel, by leveraging multiple simultaneous transcoding processes to create all of the renditions in a single step, using common rules and settings.

That way, two important things happen. First, the processing output can scale rapidly while frame alignment is maintained – a critical requirement for smooth adaptive bitrate playback. Second, Akamai's approach future-proofs the transcoding function, because it allows a new rendition to be added easily if, for example, a new device comes on the market that warrants the addition. And if a new codec (such as High Efficiency Video Coding, or HEVC/H.265) is introduced, it can be added as a transcoding option, allowing for additive renditions with that codec – rather than recreating the entire rendition set.

Distributed Architecture

On the distribution side, quality, performance, scalability, and efficiency are the objectives of Akamai's distributed architecture. Akamai's "stream packaging" feature detects which of the various possible stream formats is required by the end device, and performs this final formatting and packaging of the video streams at the network edge servers, as the streams are being delivered. This provides a variety of benefits in contrast to the more typical approach of preparing and storing the content in all of the different formats in advance, as part of the pre-delivery preparation process, or dynamically from a centralized server array. Wrapping files into packaging formats (Apple's HTTP Live Streaming or Adobe's HTTP Dynamic Streaming for example) as content is being delivered over Akamai edge servers eliminates the need for customers to create these packaging and formatting functions further back in the network – an approach that demands big expenses for storage and content management, since each additional format requires an additional version of the rendition set. Instead, a consistent rendition set moves in a common way out to the network edge.

For clients that are dealing with a library of hundreds or thousands of titles, that's a huge efficiency gain. In addition, notes Michel, on-demand formatting preserves the sanctity of the original encoding process by allowing for additions and alterations in formats without ever having to touch the original rendition set. For example, as new formats such as MPEG-DASH emerge, and Akamai adds stream packaging support for the new format, customers can deliver their existing content library in the new format by simply checking the box for that format in the management user interface. With this approach, the new format can be provided dynamically, precluding the need to produce a new rendition set for the additional format. "We're future-proofing the rendition set," Michel says. "We do it all at the edge of the network."

Adapting to a New Video World: How Adaptive Bitrate Streaming Offers a Proven Path for 4K Content Delivery

For several years now, the content delivery technique known as adaptive bitrate streaming has been a star of the online media scene. Adaptive streaming conquers the challenge of sustained media delivery by dividing a particular television show, clip, or movie into multiple encoded segments, each expressed by an associated bitrate. Tablets, smart phones, smart TVs, and other media devices fetch and play the optimal video stream from the available segment pool based on network conditions and device capabilities, switching to a higher or lower bitrate as conditions change.

Adaptive bitrate streaming is a smart solution to the vexing problem of delivering large media files over the Internet without demanding that users wait patiently for a one-size-fits-all file to buffer. For popular video streaming services like MLB.com, HBO GO, and others, it's a key to rising marketplace acceptance. And there's more to come. The development of Dynamic Adaptive Streaming over HTTP (MPEG-DASH) promises to further advance the craft by creating the first international standard for adaptive bitrate HTTP-based streaming.

For 4K video, adaptive bitrate streaming offers a remedy for seamlessly integrating 4K streams and segments into the broader bitrate set while accounting for the higher bandwidth demands 4K will involve.

A quick exercise in digital media math illustrates why 4K segments will sit at the high end of the ABR progression. Using the 4K specifications of 3,840 pixels x 2,160 lines (8.3 megapixels per frame), a 90-minute movie encoded using H.264 at 20Mbps can weigh in at close to 14 gigabytes, nearly 5x the size of the same film encoded for 1080p delivery over the internet. Although the emerging H.265 codec promises to squeeze more bits into a smaller file, 4K movies will still pose delivery challenges that adaptive streaming can help to accommodate.

The idea here is to layer multiple bitrates, just as video providers currently do for standard resolution and HD videos. With 4K content, however, the progression will expand to encompass a higher bitrate layer that produces Ultra HD resolution for TV sets that can display it. As available bandwidth and network conditions permit, users with Ultra HD-capable sets will select and display the highest bitrate stream, delivering 4K resolution. In the event that the network won't support the 4K stream, the next-best variation will appear.

Pioneering Role

Akamai has been a pioneer in helping media companies leverage the power of adaptive streaming to reliably serve video content over the internet. In the emerging 4K world, Akamai has staked out an early leadership position, evidenced by its collaboration with Elemental Technologies at the 2014 CES. There, Akamai hosted 4K/HEVC/DASH content in Akamai's cloud-based Net Storage and streamed the content in real time over the Akamai Intelligent Platform's high-performance network at bitrates ranging from 10 to 20 megabits per second.

The demonstration was emblematic of Akamai's ability to enhance 4K delivery by enabling its customers to take advantage of Akamai's highly distributed Intelligent Platform, which spans nearly 150,000 globally distributed media servers that are co-located at network edge points, literally sitting side-by-side with servers maintained by "last mile" internet service providers.

"We use our efficient edge server network and on top of it overlay some client enhancements to improve the flow to your device," explains Akamai's Law. For content providers that have embraced adaptive streaming, Akamai's distributed architecture means faster, lower-latency access to content and speedier stream access at large.

In addition to adaptive streaming, Akamai also supports an alternative 4K delivery approach, progressive download, which enables users to trigger playback of large media files before the entirety of a file has been completely downloaded. Platforms like Apple TV have reached critical consumer mass in part by leveraging the capabilities of progressive download. Akamai's progressive media download solution may be suitable for 4K video-on-demand implementations where providers are pursuing a store-and-forward or in-home caching approach for content delivery and playback.

Either way, the value of a market-ready download solution for 4K is apparent when you consider the strong interest in 4K among consumers. A 2014 survey of 1,231 U.S. adults by media researcher Leichtman Media Research found that 30% of adults have heard of 4K Ultra HDTV, and about one-third of this group has seen a 4K Ultra HDTV. Moreover, 28% of those who have seen a 4K Ultra HDTV said they are very interested in getting it, while 15% of all who have heard of 4K are very interested in getting it.

"At the same time that consumers are acquiring an increasing number of devices that allow them to watch video anywhere and anytime, television sets in the home are getting bigger and better," said Bruce Leichtman, the firm's President and Principal Analyst

Back to the Protocol Future: As Higher-Resolution Video Puts More Strain on the Internet, A Once-Embraced Transport Protocol is Making a Comeback

In the early days of video streaming, a behind-the-scenes hero was User Datagram Protocol, or UDP. A core component of the broader internet protocol, UDP was well-suited for what seemed like a daunting task: transforming the internet from a static world of text-and-images to a full-blown multimedia environment.

Unlike protocols associated with the other workhorse of the internet, Transmission Data Protocol (or TCP), UDP-based protocols don't divide and reassemble data units into sequenced packets. Instead, protocols that speak UDP treat a data element (or datagram, per the moniker) as a thing unto itself. That means less computational power and network resources have to be devoted to processing tasks. And in the case of pioneering video streaming providers like RealNetworks, UDP helped to neatly solve issues around stream performance – particularly nettlesome problems of latency that frustrated early streaming enthusiasts.

Over time, though, UDP has taken a back seat to TCP-based protocols, including HTTP, even for bandwidth-intensive tasks like streaming video. The internet's broad embrace of TCP, and the scale economies associated with it, have led to widespread adoption of TCP as the transport protocol of choice for video streaming – packet management and all. But that's beginning to change, and Akamai is among the pioneers gearing up for a new sort of TV sequel: the return of UDP.

Development Team

In 2012, a small team at Akamai began work on a project to create a new breed of protocol, a hybrid of HTTP and UDP. Among its goals: to harness the power of UDP transport as a means to make 4K video move faster over the Internet.

One of the goals is to improve a core behavior of TCP transport: throttling down the data rate associated with a stream when the network senses there's trouble, as evidenced by a mounting number of missed packets. This is exactly what TCP is designed to do, of course, as a way to assure bits get to where they're supposed to go. But in the case of video streaming, it results in degradation of stream quality as the network slows down the send rate to play catch-up, says Akamai's Wishon. And when people have paid thousands of dollars to outfit living rooms and media rooms with giant, 4K-capable screens, that's a problem.

Wishon thinks UDP can help. "By switching to UDP, we're able to implement a different form of congestion control and packet loss recovery. We're basically creating a protocol more resilient to packet loss and latency in the network," says Wishon.

Actually, check that. Akamai's Hybrid HTTP/UDP effort isn't so much about "switching" to UDP as incorporating the transport protocol into a broader hybrid solution that leverages TCP-speaking rule sets such as HTTP Live Streaming (HLS) while allowing for forward error-correction and for congestion relief. The architecture creates a UDP transport connection from an Akamai server at the network edge to a client application that plays on a TV set, tablet, or other video device. "This technology optimizes that last mile," Wishon says. But it also preserves HTTP as the method by which a video player requests and manages a session from an Akamai client.

"The clever thing is that the video player is still receiving an HTTP/HLS stream," Wishon explains. That means many of the cool tricks of internet streaming still work: "If you have fancy ad overlays, multiple viewpoints, and DVR technology, you don't change that at all."

The migration to UDP isn't simple. Algorithms baked into Akamai's hybrid solution include allowances for discerning, for example, whether signs of packet failure are caused by network congestion or by something else, like RF interference from an external device. Each evokes a different remedy. Wishon notes that it's critical to avoid trampling over TCP traffic. "Being fair to TCP traffic is a whole different ballgame," Wishon says. "It's trivially easy to make a UDP blaster. It's very easy to get great performance gains against TCP. But to respect the fact there are TCP flows in the network, which also should get some bandwidth – that's really hard."

Now Appearing Live: In Collaboration With Elemental Technologies, Akamai Sets The Stage For Real-Time 4K Delivery

A revolution is quietly building in the video sector around a big leap forward for 4K: live television. Over the past few months, early efforts in live 4K streaming have included delivery of several large events:

- **The Osaka Marathon.** In October 2013 Live 4K/59.94p content acquired from Sony CineAlta 4K cameras and streamed over a K-Opticom fiber optic network to an NTT Docomo decoder displayed on an 84-inch Sony 4K Bravia TV.
- **The Sochi Winter Games.** Russian pay-TV provider NTV Plus transmitted live coverage of the opening ceremony and other events over a satellite network to selected receive sites using technology that included Broadcom real-time decoders and Sony PMW-F55 Cine Alta 4K cameras.
- **Major League Soccer.** In November 2013, a Major League Soccer game was acquired with a RED Epic 4K camera and delivered to a Planar 4K TV using encoding at less than 20Mbps.

In each instance, the encoding work was performed by Oregon's Elemental Technologies Inc., an early leader in applying H.265 encoding to 4K content to enable live transmission of 4K video. As onlookers in Japan, Russia and the U.S. gazed at stunning Ultra HD images on big-screen TV displays, they were witnessing the dawning of a new way to experience live television.

It's no coincidence that each of these demonstrations revolved around live sports, which are seen as a prime 4K draw for sports enthusiasts who crave an immersive, you-are-there, big-screen experience. Live sports in 4K "is sort of like a Ford F-150 truck: You don't necessarily need it to get from point A to point B," says Akamai's Law. "But guys are really going to like it."

Elemental agrees. Although on-demand streaming services are likely to be first to market with 4K video offerings, "the real value in 4K TV lies in live broadcasting of high-profile sporting and tent pole events," the company points out in a 2013 white paper about 4K encoding.

Elemental has teamed with Akamai to expand the market for live 4K by pairing Elemental's ground-breaking encoding platform with Akamai's highly distributed media delivery network to support an end-to-end delivery system for live 4K video over the internet. The arrangement, branded "Pass Through LIVE," allows for 4K video content processed in realtime to be streamed to Akamai ingest points, where it's transferred to Akamai edge servers for rapid delivery to end users.

The Akamai-Elemental collaboration traces back to 2011, when Elemental joined Akamai's Digital Media NetAlliance Partner program, which assists in certifying and promoting solutions that integrate with Akamai's network.

Akamai and Elemental have already demonstrated the ability to connect in 4K delivery. At the 2014 International CES, Akamai, Elemental and Qualcomm demonstrated how 4K content can be encoded with HEVC/H.265 using MPEG-DASH and streamed to a large video screen. For the breakthrough demonstration, Elemental encoded 4K master files at 10, 15, and 20Mbps renditions, uploading the output to Akamai's cloud-based storage network. From there, it was streamed to Qualcomm's exhibit booth, where it was displayed on a tablet and simultaneously mirrored to a large-screen 4K television.

Akamai's collaboration with Elemental represents one of the first efforts to distribute video material encoded in Internet using H.265, the presumed successor to the H.264 standard that's now used to process high-bitrate video for internet streaming.

Akamai envisions a bright future for HEVC as a solution for managing storage and distribution costs for bandwidth intensive 4K video streams. "The trick is to devote the least amount of bandwidth you can for the most satisfying result," says Akamai's Law.

One of the key implications of the Elemental-Akamai collaboration is the realization that the internet – not broadcast, cable or satellite TV – is poised to become the go-to delivery medium for a revolutionary live television image standard.

For an Internet video category that has long been seen as an adjunct to the legacy TV ecosystem, the new role is exciting. "Broadcast is going to take a while to be ready for 4K," says Law. "The Internet can do this tomorrow."

Akamai

Over the last 15 years, Akamai has grown to become the leading cloud platform for helping media companies provide secure, high-performing user experiences on any device, anywhere. Our Intelligent Platform removes the complexities of connecting the increasingly mobile world, supporting 24/7 consumer demand and enabling enterprises to securely leverage the cloud.

At Akamai, we're fiercely committed to helping our customers engage audiences of any size with superior-quality live and on-demand video and solve the challenges of multi-device consumption. In delivering some the world's leading online entertainment services, most important media events, highest profile sporting championships, major awards ceremonies and global product launches, Akamai is constantly striving to help our customers reach its viewers on a global scale with a relentless dedication to quality, simplicity and scale across networks and devices.

That dedication is reflected in our customers, which include the top 30 media & entertainment companies, more than 150 of the world's leading news portals, 9 of the top 10 largest newspapers, 8 of the top 10 online publishers and 9 of the top 10 social media sites. We are proud to be an integral part of daily Internet life, delivering up to 30% of all web traffic and more than 2 trillion transactions.

As the global leader in Content Delivery Network (CDN) services, Akamai makes the Internet fast, reliable and secure for its customers. The company's advanced web performance, mobile performance, cloud security and media delivery solutions are revolutionizing how businesses optimize consumer, enterprise and entertainment experiences for any device, anywhere. To learn how Akamai solutions and its team of Internet experts are helping businesses move faster forward, please visit www.akamai.com or blogs.akamai.com, and follow @Akamai on Twitter.

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