The Economics of Content Delivery

Bruce Maggs
Duke University
Emerald Innovations
(and formerly Akamai Technologies)
In the beginning…

• Akamai deployed servers around the world and offered to deliver images that appeared on web pages.
• The goal was to speed up page load times
• … and reduce infrastructure investment for content providers.
Impact of PLT on conversion for e-commerce web sites

Impact of page load times on conversion rates for desktop, mobile, and tablet.

Source: Akamai, State of Online Retail Performance, 2017 Holiday Perspective
New Fortnite Release Downloads Shatter Record for Internet Traffic

By CHRIS MORRIS July 15, 2018

Obama’s Inauguration? The 2016 presidential election? They’ve got nothing on Fortnite.

The release of the game’s fifth season, a notable update that players have been anxiously awaiting, broke Internet game traffic records, according to Akamai. Actually, no ... it shattered those records.

37Tbps

To put things in perspective, the 2016 U.S. Presidential election saw peak traffic on Akamai’s platform of 7.5 Tbps. Yesterday’s Fortnite update peaked at 37 Tbps. That’s nearly five times the bandwidth.
Embedded Image Delivery

Embedded URLs are Converted to ARLs

<html>
<head>
<title>Welcome to xyz.com!</title>
</head>
<body>
<img src="http://www.xyz.com/logos/logo.gif">
<img src="http://www.xyz.com/jpgs/background.jpg">
<h1>Welcome to our Web site!</h1>
<a href="page2.html">Click here to enter</a>
</body>
</html>
Move to Full-Site Delivery
88 of Alexa top 500 home pages delivered by Akamai

Motivated in part by split-TCP/TLS optimization

Motivated in part to protect web site

Akamai operates DNS for main domain, holds private keys!
The Akamai Platform and Services

A Global Platform:
- 240,000+ Servers
- 1,700+ Networks
- 3,300+ Physical Locations
- 750+ Cities
- 130+ Countries

Delivering Content for 130,000+ Domains
- All top 20 global ecommerce sites
- All top 30 media & entertainment companies
- 16 of the top 20 global banks
- All major anti-virus software vendors

Daily Statistics:
- 80+ Tbps traffic served
- 600+ million IPv4 addresses seen
- 3+ trillion HTTP requests served
- 260+ terabytes compressed logs
Flow of Payments

- content provider
- content delivery network
- ISP
- colocation provider / IXP
- Hardware vendor
Cost of Goods Sold (CoGS)

25% bandwidth (95/5 rule)
25% colocation
25% server depreciation (now over 4 years)
25% other

colocation breakdown:
40% rack space
40% energy (now metered)
20% other (e.g., interconnect within facility)
Mapping Clients to Akamai Clusters

- Many “no brainers” – servers co-located with clients, e.g., on university campuses

- Otherwise, make decisions based on active measurements
Wide Area Network Measurement

- Traceroute to all important name servers
- Core point X is the first router at which all paths to name servers 1, 2, 3, and 4 intersect.
- X can be viewed as the straddling the core and the edge of the network.
Identifying Core Points

500,000 nameservers
Reduced to
30,000 core points
7,000 account for 95% end-user load
ping these continuously
Bandwidth Breakdown

40% free from edge servers to clients
40% paid from edge servers to clients
20% from edge servers to origin servers
Next Service: Streaming Media

- Proprietary servers and players
  Real, Windows Media, Quicktime, Flash
- UDP-based protocols
- Network for live streaming built for Steve Jobs.
Live Streaming Architecture

- Satellite Uplink
- Entry Point
- Encoding
- Top-level reflectors
- Clusters of edge servers

Satellite Downlink
Streaming Today

- Everything delivered over TCP/HTTP(S)
- Client (typically JavaScript) makes all decisions
- “Brokers” may choose from multiple CDNs
- Vast majority of bytes served by CDN
- Highly commoditized, low margin business
High Margin Services

Low latency content delivery

Bells & whistles (e.g., automatic A/B testing)

Protection from denial of service attacks
Defending Web-Based Services from Attacks

Two Architectures:

Traditional CDN protects web sites

Packet filtering data centers provide generic protection for network-based services
Distributed Denial of Service (DDOS) Attacks

The attacker hopes to overwhelm the content provider’s resources with requests for service.

Sometimes the attacker issues requests through a “bot army” of compromised or rented machines.

The attacker looks for “amplification” where an easy-to-generate request requires a large or difficult-to-generate response.
Largest DDOS Attacks by Year

Gbps

GitHub

Krebs
Akamai Kona Site Defender

Origin Traffic
10000
1000
100
10
1

Akamai Traffic
10000
1000
100
10
1

Origin Server

End User

Traffic
Malicious login attempts
Prolexic IP Anycast Scrubbing Centers
Moving Web Applications to the Edge

Standard three-tiered architecture
Original CDN Application

Clients

Internet core

CDN nodes

Content providers
But... high latency to database server, and for data-intensive applications database server becomes the bottleneck.
Peer-to-Peer Assisted Content Delivery

Hybrid between a fixed-infrastructure CDN and a pure peer-to-peer delivery system

Based on technology developed by Red Swoosh (acquired by Akamai in 2007)

Goal is to deliver large files at lower cost
BitTorrent-like protocol with control nodes serving as “trackers” and assigning peers
CDN acts as a backstop
Growth in Number of Installations

- Sep 2010: 12.0 x 10^6
- Oct 2010: 15.0 x 10^6
- Nov 2010: 16.0 x 10^6
- Dec 2010: 17.0 x 10^6
- Jan 2011: 19.0 x 10^6
- Feb 2011: 20.0 x 10^6
- Mar 2011: 21.0 x 10^6
Locations of Clients per EdgeScape
P2P Efficiency for Largest Enabled Customers

% of bytes delivered

Infrastructure

P2P

Customer

B  C  D  F  H  I
Performance

![Graph showing download speeds for different services with P2P usage variations.]

- **comcast.net / edge only**
- **comcast.net / >50% p2p**
- **rr.com / edge only**
- **rr.com / >50% p2p**
Implications for ICN

Incentives and costs must be aligned.

Performance benefits from caching:
  Reducing latency is valuable to content providers.
  Reducing network load is valuable to ISPs.

Caching in the core in addition to caching at the edge – how much additional benefit, and who pays?

Delivering everything over HTTPS/TLS makes traffic opaque, but recent history demonstrates that new protocols (e.g., QUIC) can be introduced.