

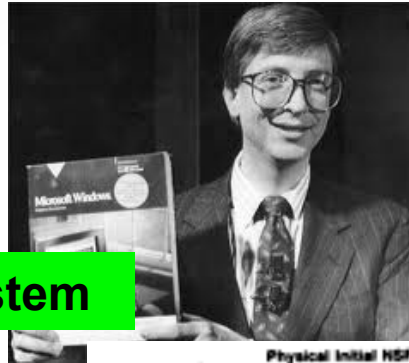
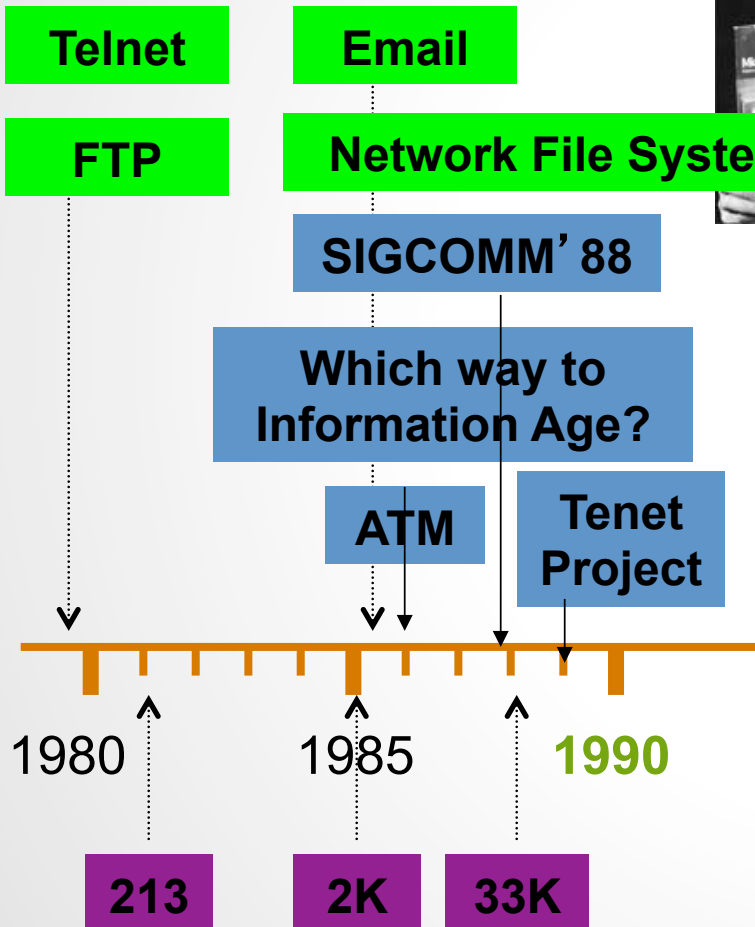
# Internet Video: The 2011 Perspective

Hui Zhang

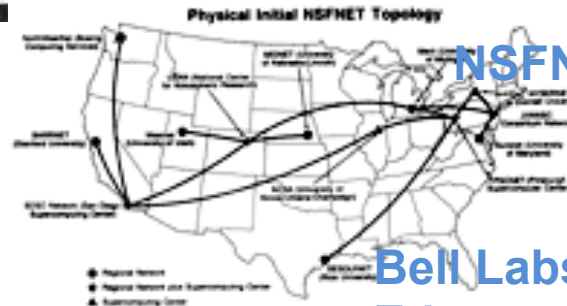


**Carnegie Mellon**

# What Questions Come To Your Mind when You Think About Future Networks? It is year 1990 ...



Windows 3.0 Released and sold 3 millions copies



NSFNet replacing Arpanet

Bell Labs designed Plan 9  
Ethernet LAN and Datakit WAN

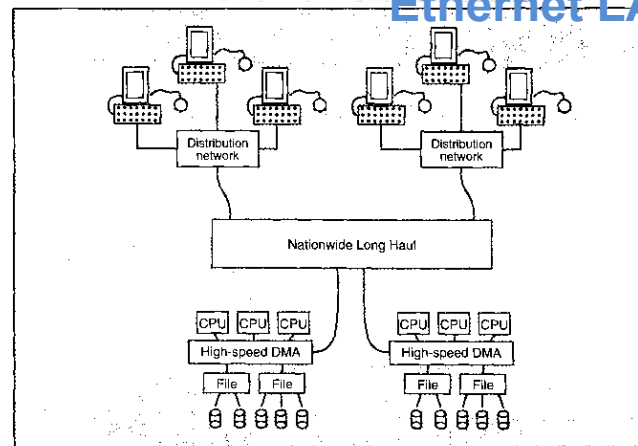


Figure 1: Plan 9 topology

# The 1990 Perspective at 1<sup>st</sup> NOSSDAV, ICSI



- ⌚ Will video traffic dominate the future Internet?
- ⌚ Do we need special Internet architectural support for video?

# Two Opposing Viewpoints



⌚ Will video traffic dominate the future Internet?

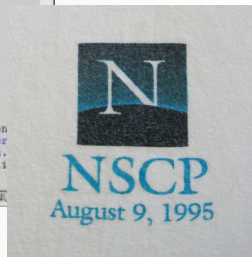
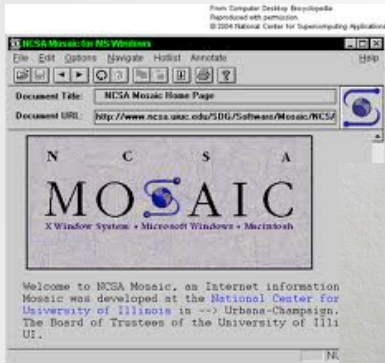
- Yes: people loves video; video has just too many bits
- No: many applications will generate more bits

⌚ Do we need special Internet architectural support for video?

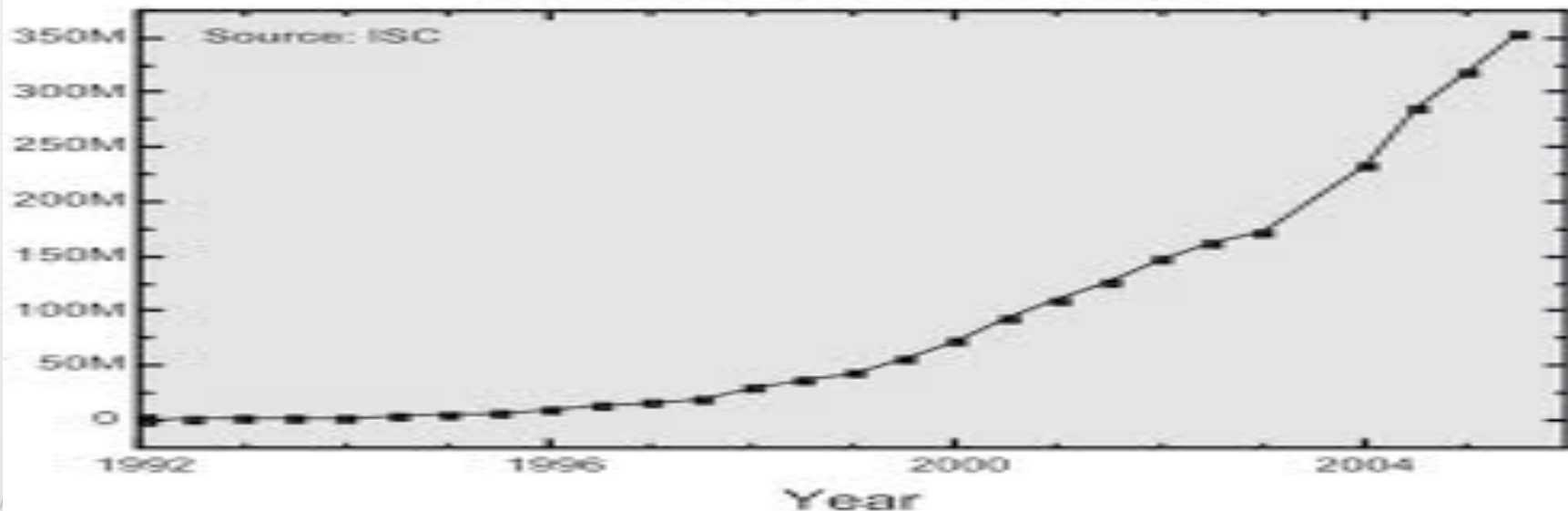
- Yes: high BW, continuous, real-time, multi-point
- No: Moore's law and clever applications will suffice



# ... the Next 15 Years turned out to be the Web Internet ... Not the Video Internet



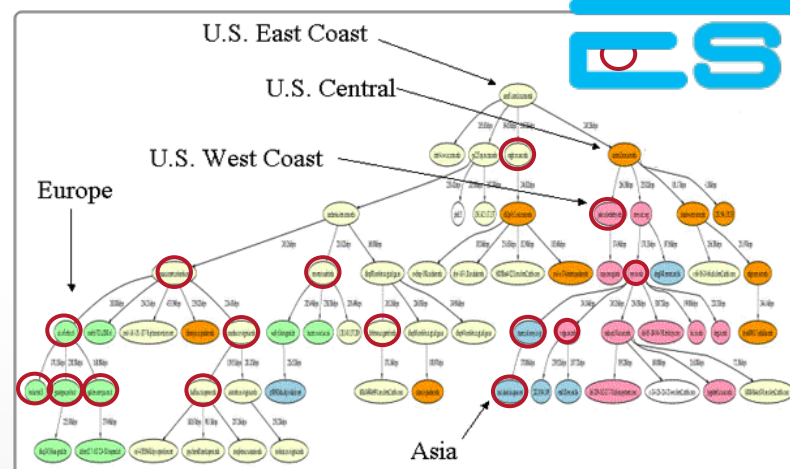
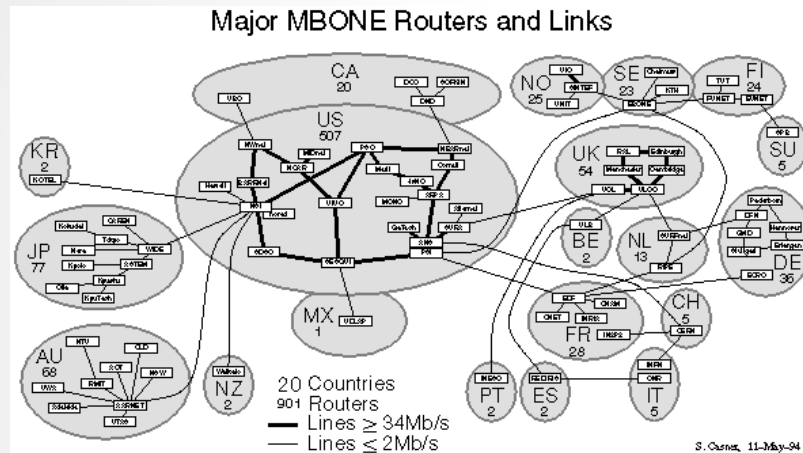
Number of Internet Hosts



# ... while Many Researchers Were Working on Video and QoS

- 🔌 Packet scheduling
- 🔌 Admission control
- 🔌 Reservation protocols
- 🔌 Intserv vs. Diffserv
- 🔌 IP Multicast vs. Application Layer Multicast
- 🔌 Content Distribution Networks
- 🔌 Layered video coding
- 🔌 Peer to Peer streaming
- 🔌 Congestion control
- 🔌 QoS routing

# ... and Multi-party Conferencing Was The Motivating Application ...



# 1990 – 2004: 1<sup>st</sup> Generation Commercial PC/Package Video Technologies



- ⌂ Simple video playback, no support for rich app
- ⌂ Not well integrated with Web browser
- ⌂ No critical mass of compelling content over Internet
- ⌂ No enough broadband penetration



# 2005: Beginning of Internet Video Era



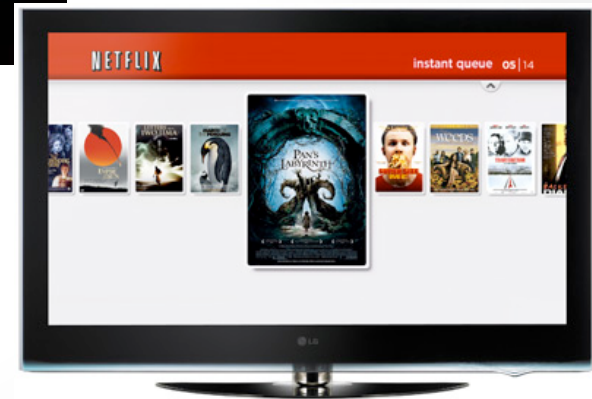
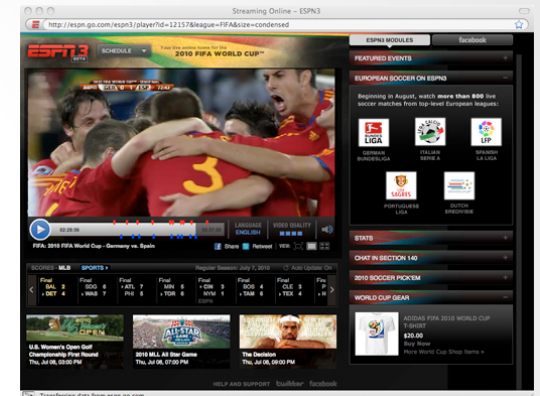
100M streams first year



Premium Sports Webcast on Line



# 2006 – 2011: Internet Video Going Prime Time



2006

2007

2008

2009

2010

2011

# Dramatic Changes to Online Video

## ⌚ Technology enablers in place

- Broadband penetration
- Standard software & hardware platforms

## ⌚ Real business model emerging

- Premium content (Hulu, NFL, HBO)
- Advertising & subscription (mlb.com, netflix, Hulu)

## ⌚ Online audiences rival broadcast for major events

- Olympics, Inauguration, Michael Jackson, World Cup

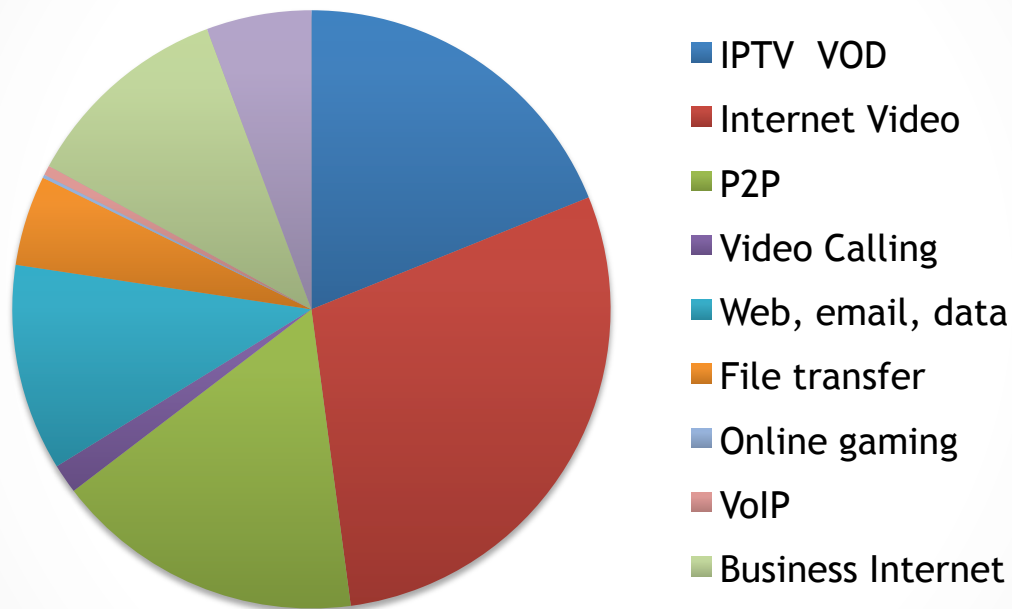
## ⌚ Convergence of TV, Internet, Mobile

- Internet connected TVs (Xbox, Playstation, AppleTV, Roku, Sony, Samsung)
- Internet connected smart mobile devices (iPad, iPhone, Android)
- “TV Everywhere” over the top (HBO, ESPN, Turner, Comcast)



# Following the Traffic ...

## 2011 Internet Traffic Distribution



66% Internet Traffic is Video

Source: Akamai

# Revisit the 1<sup>st</sup> NOSSDAV Discussion

🔊 Will video traffic dominate the future Internet?

- Yes: people loves video; video has just too many bits
- No: future applications will generate more bits

The Answer is **YES**, but holds for future?

🔊 Do we need special Internet architectural support for video?

- Yes: high BW, continuous, real-time, multi-point
- No: Moore's law and clever applications will suffice

The Answer seems to be **NO**, but is it that obvious?

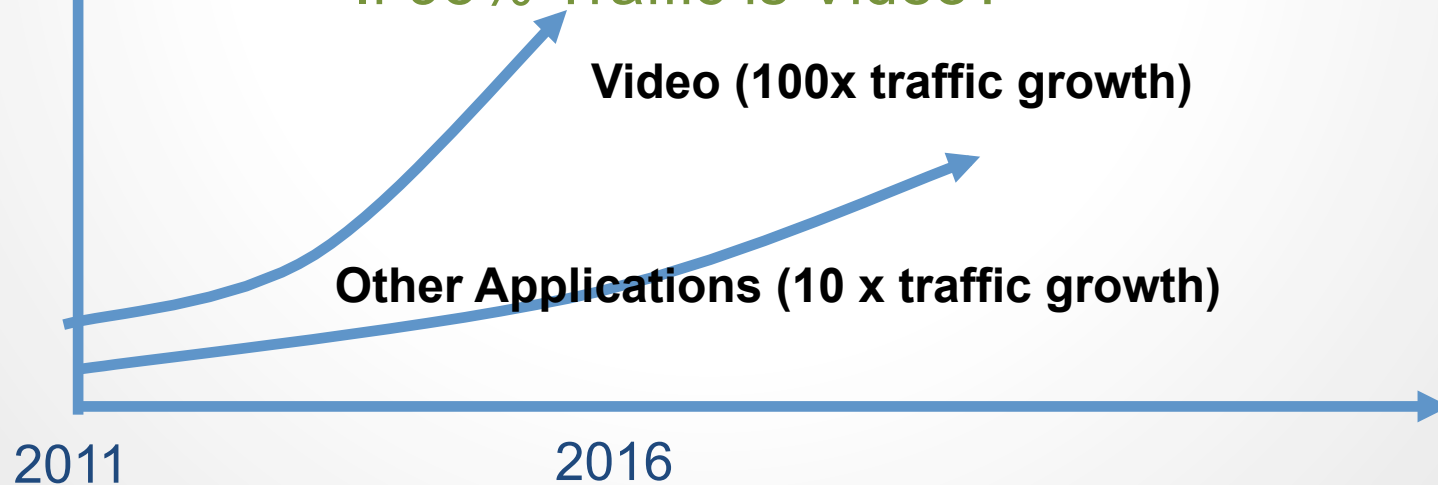
# Hui's 2011 Perspective

- 🕒 Video traffic will become an even larger fraction of the Internet traffic, reaching more than 90%
  - While all traffic types (web, cloud) continues to grow
- 🕒 High % of video in Internet traffic mix has significant implications for Internet architecture
  - Need to have mechanisms to optimize video
  - Potential to have more simplified and optimized mechanisms for other traffic

# 2011 and Beyond: A World Full of Elephants



What Does It Mean For the Internet  
If 95% Traffic is Video?



# Video and Internet Architecture

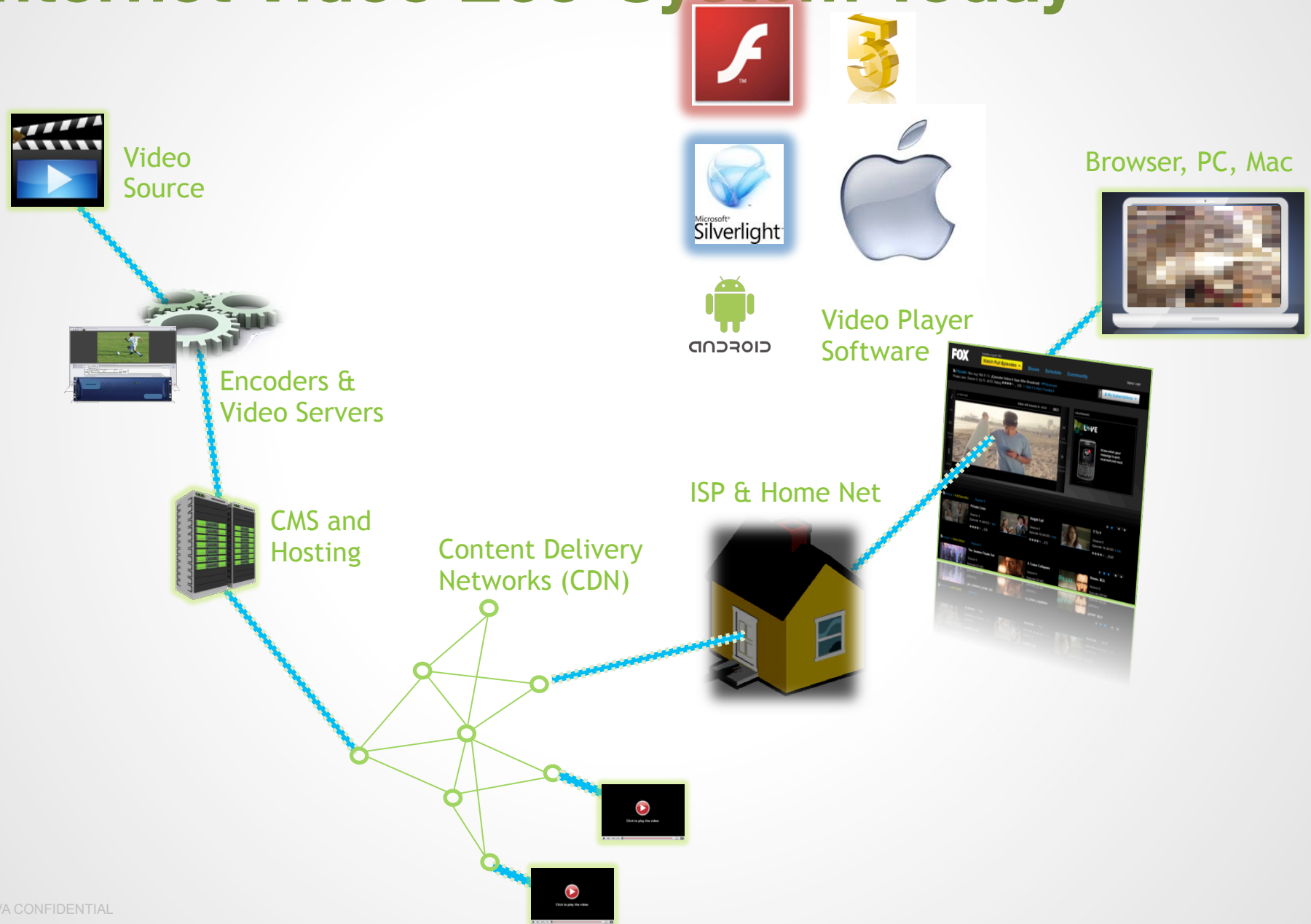
## 🕒 What we have learned since 1990

- Live broadcast & VOD are driving applications
- Video conferencing is a niche application (traffic % wise)
- Incremental deployment of new architecture elements is key

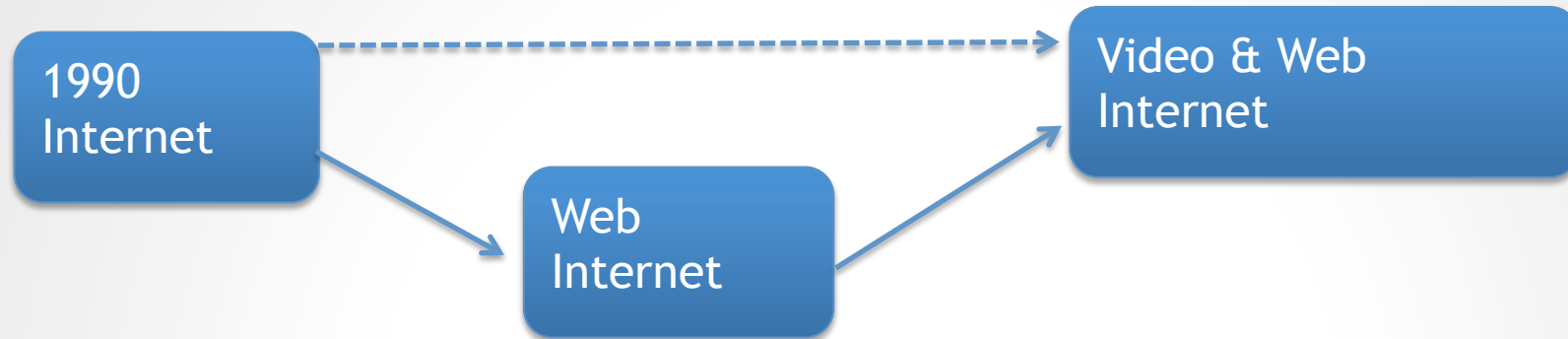
## 🕒 Key elements of the new architecture emerging

- Borrow ideas from 20 years networking research, but will take different form
- Separate control and data plane
- HTTP is the new convergence data plane layer
- Diverse device and network access speed have to be supported
- QoS & Scalability remain key challenges

# Internet Video Eco-System Today



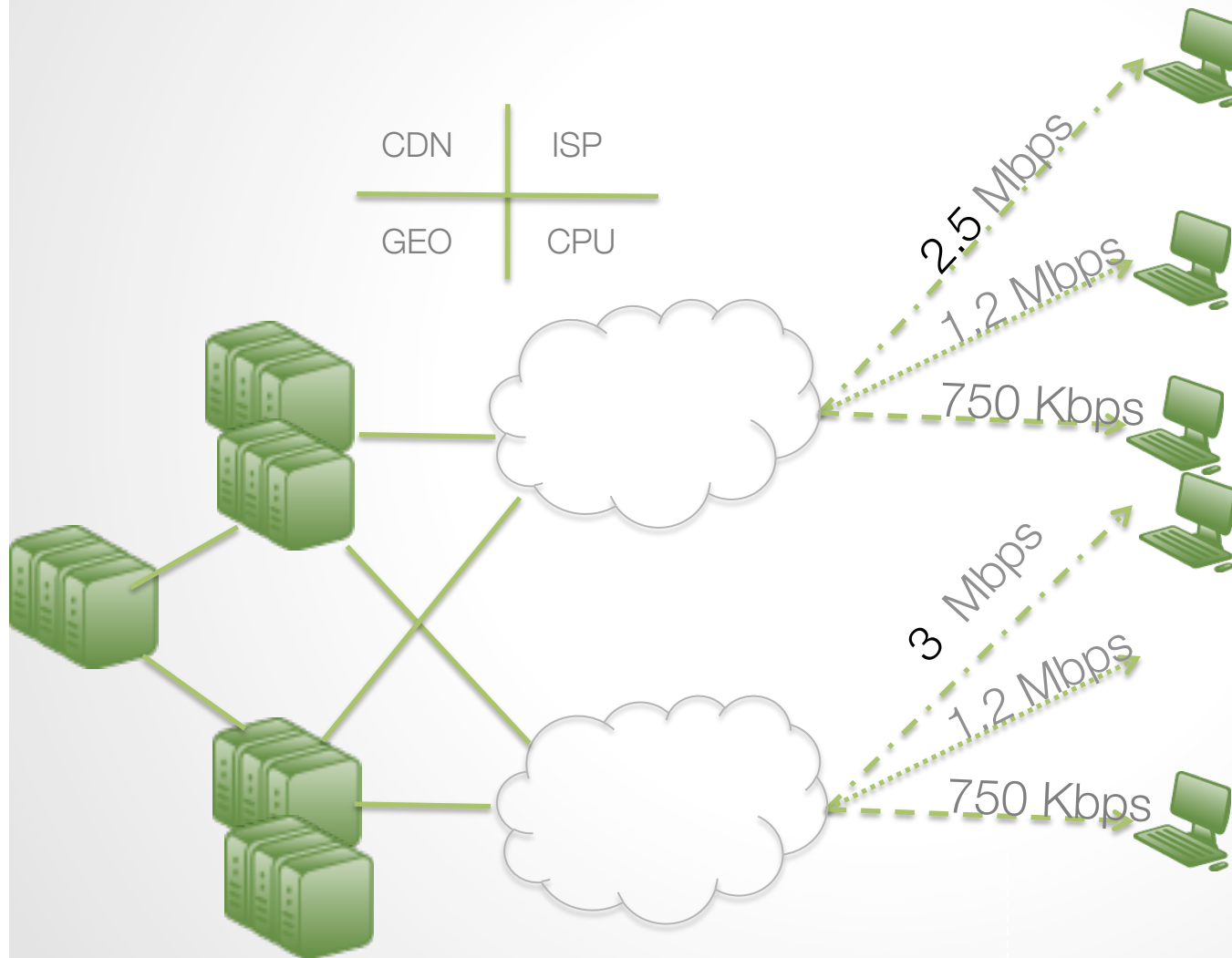
# HTTP is the New Convergence Data Plane Layer



- ⌚ The detour to Web Internet has a key positive legacy
  - HTTP chunk will be the new Datagram for Internet video
  - HTTP chunk switches are the new switches/CDN servers
- ⌚ Many practical problems solved for HTTP after years of evolution
  - Middle-box support, authentication, firewall penetration, anycast



# Diversity and HD Drives Multi-Bit-Rate



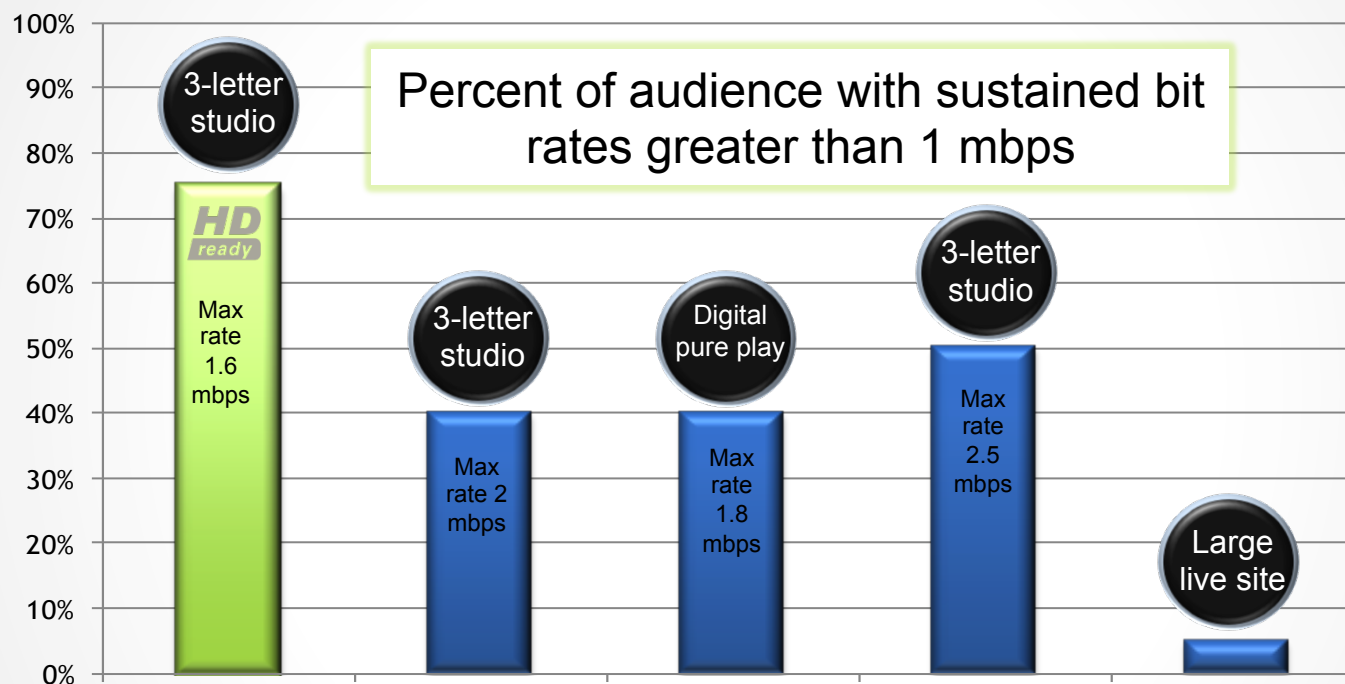
# Industry Status

- ⦿ Basic mechanism of adaptive multi-bit rate support with HTTP chunking is supported



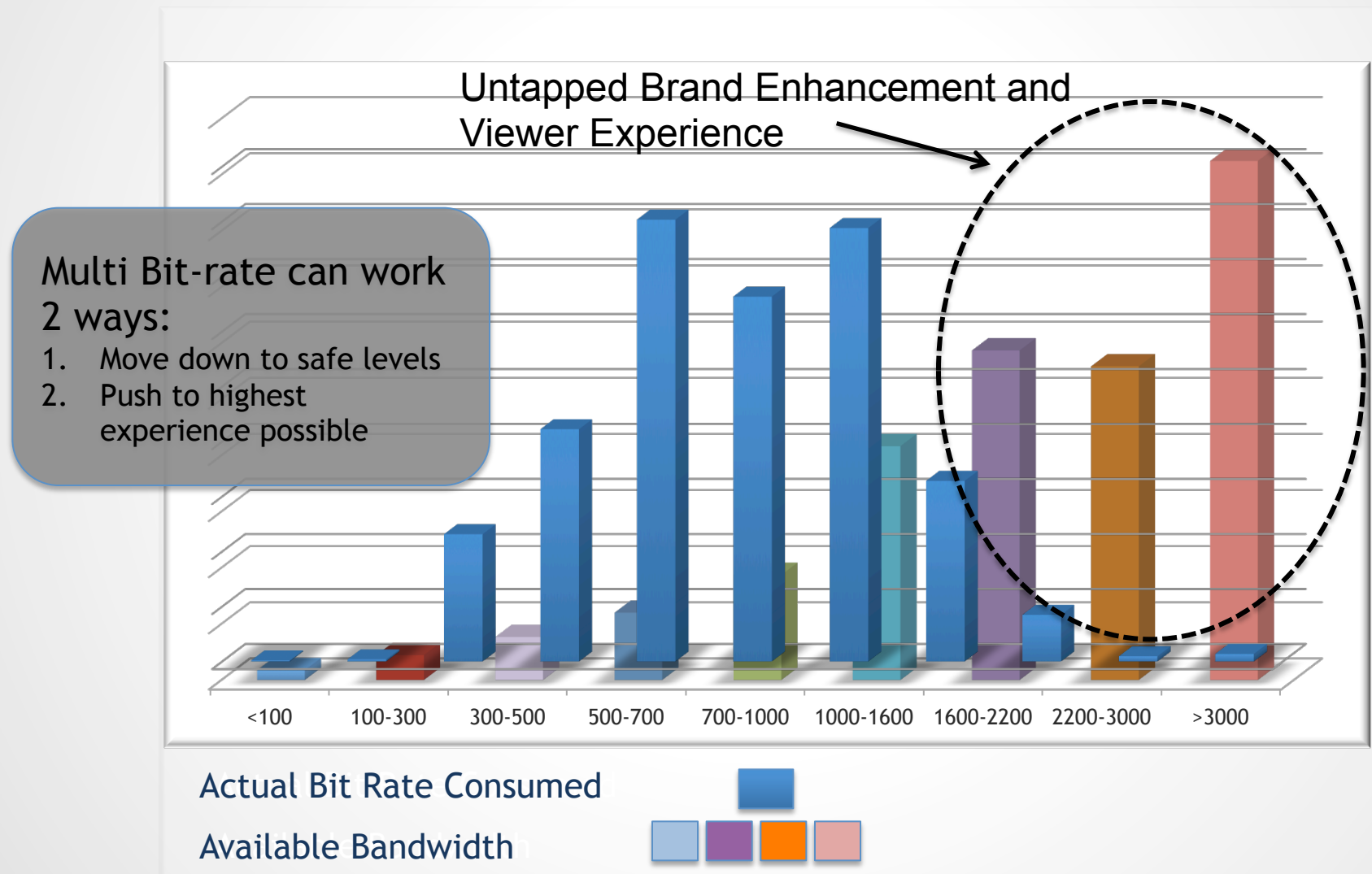
- ⦿ The performance across different algorithms do differ

# Comparison of Different Adaptive Multi Bit Rate Algorithms



How To Achieve High Bit Rate and Lower Buffering Ratio?

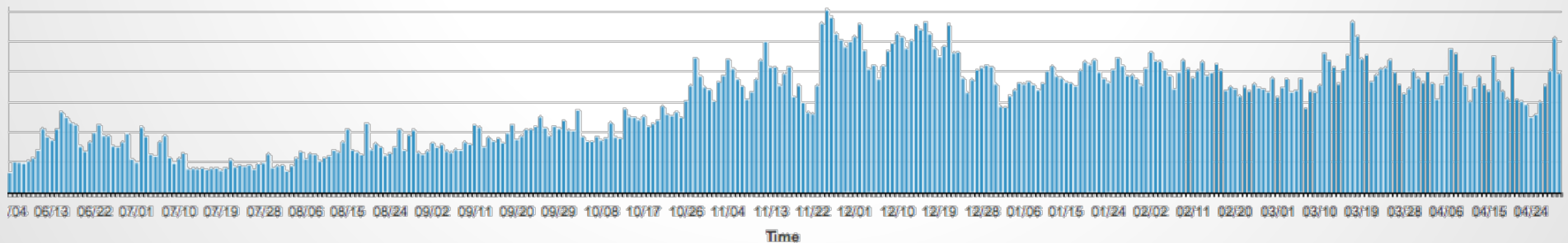
# Opportunity of Going Higher Speed



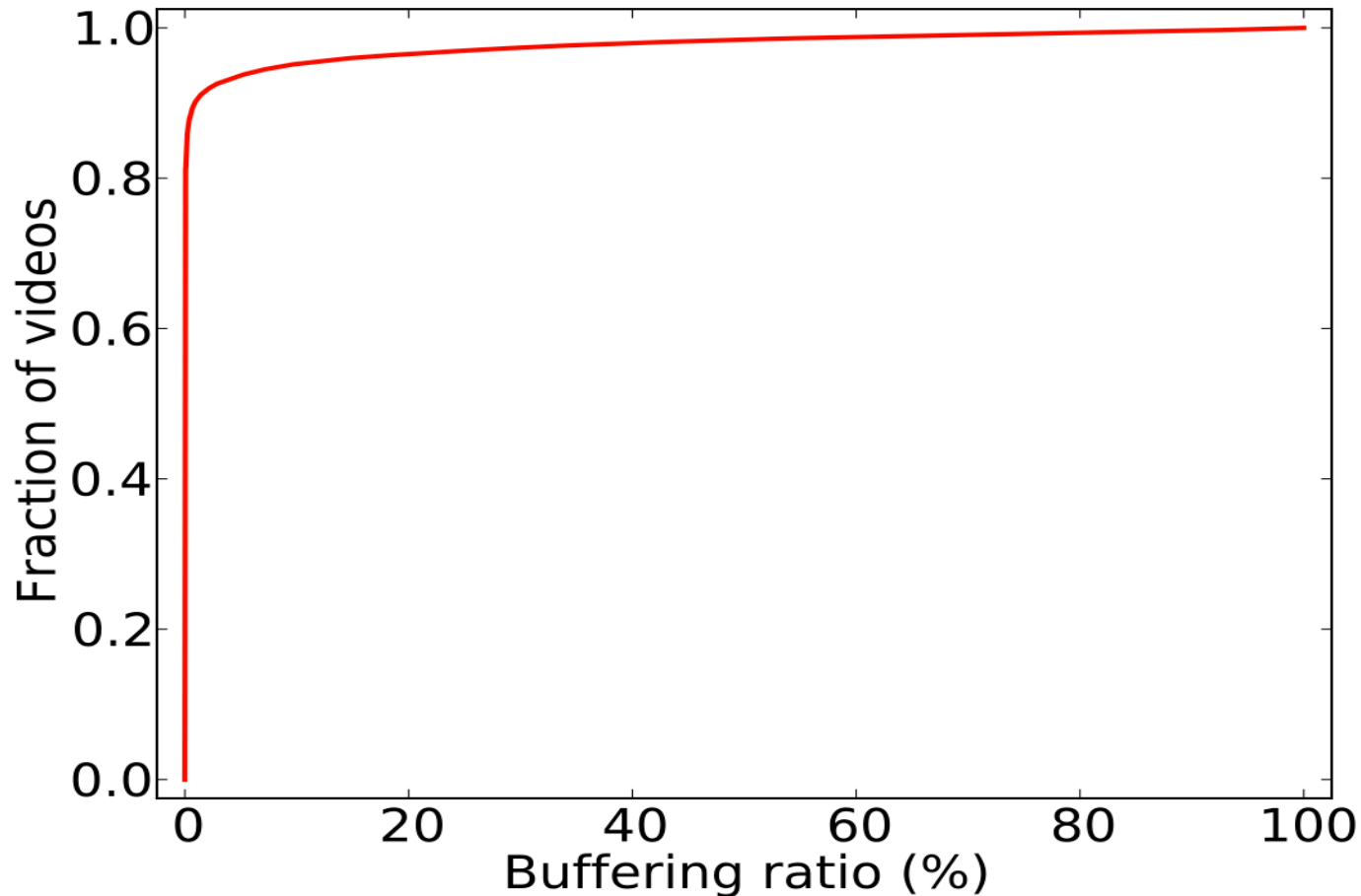
# What is the State-of-Art of Internet Video Quality?



# We've seen a pattern across many sites.... and billions of streams



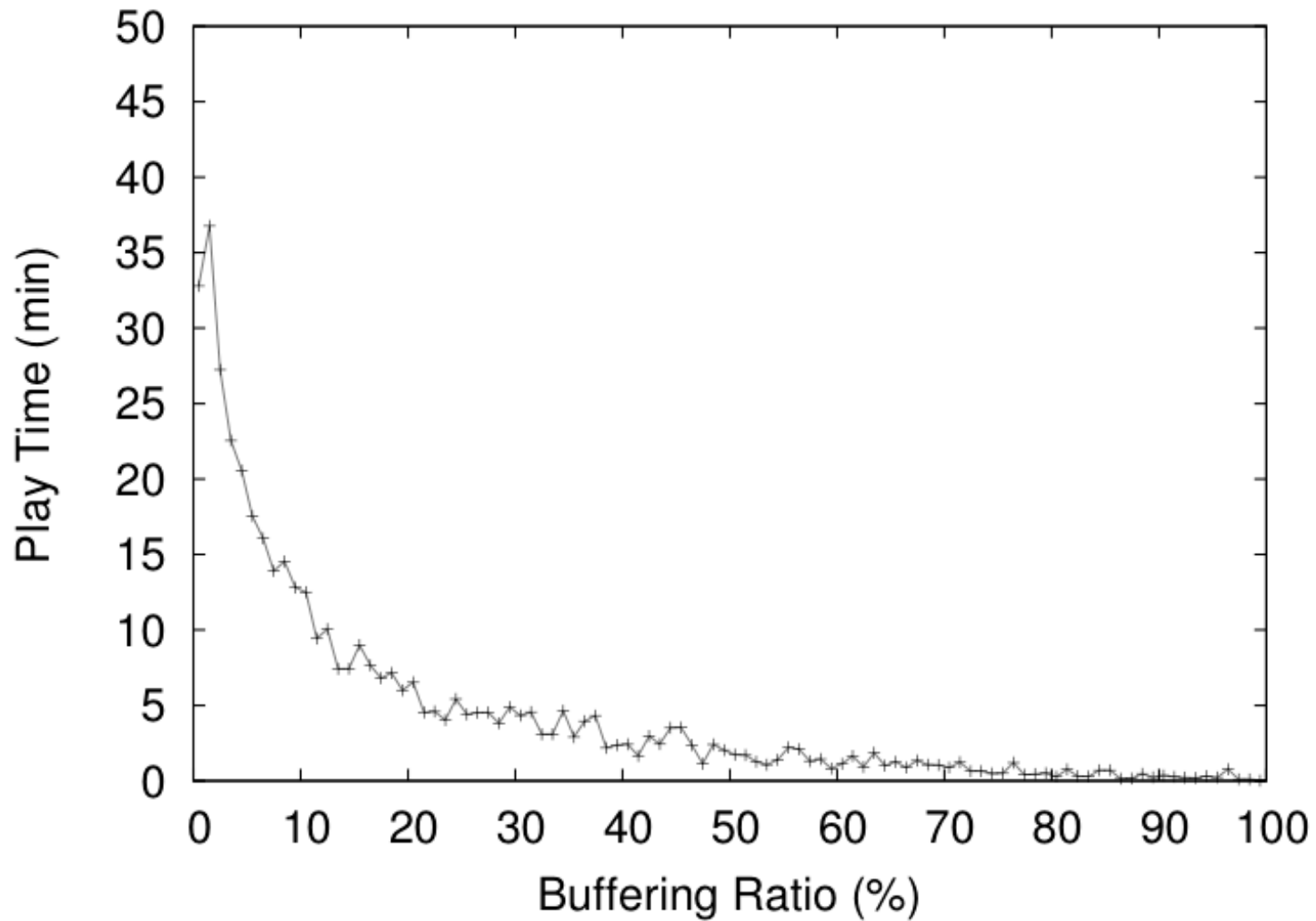
# Buffering Ratio As A Performance Metric



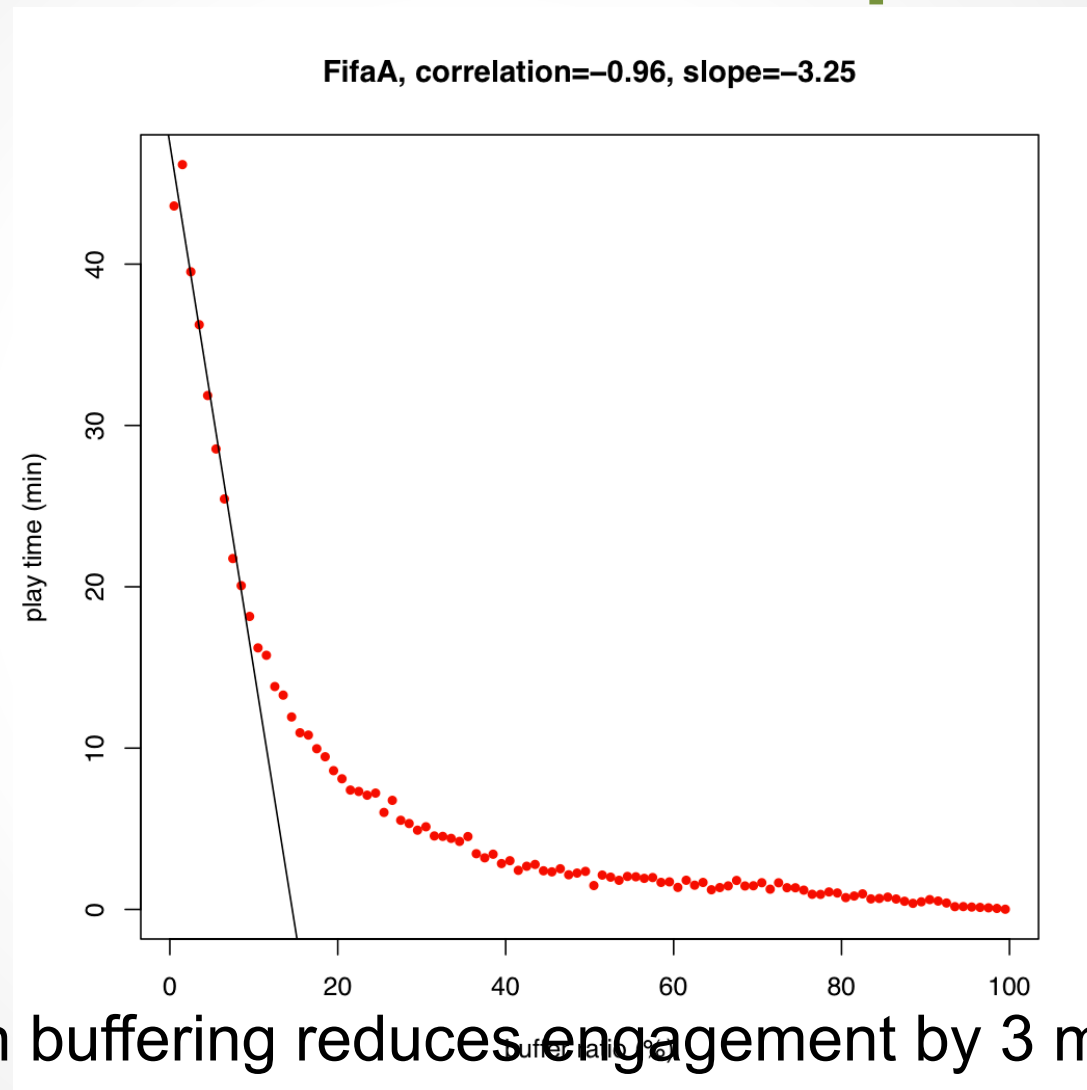
Non-trivial fraction of users suffer quality issues!



# Poor Quality Impacts Engagements



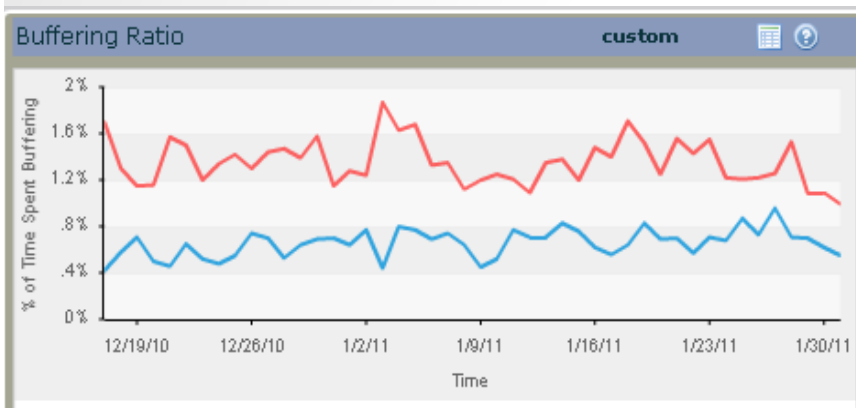
# Example of Quantitative Impact



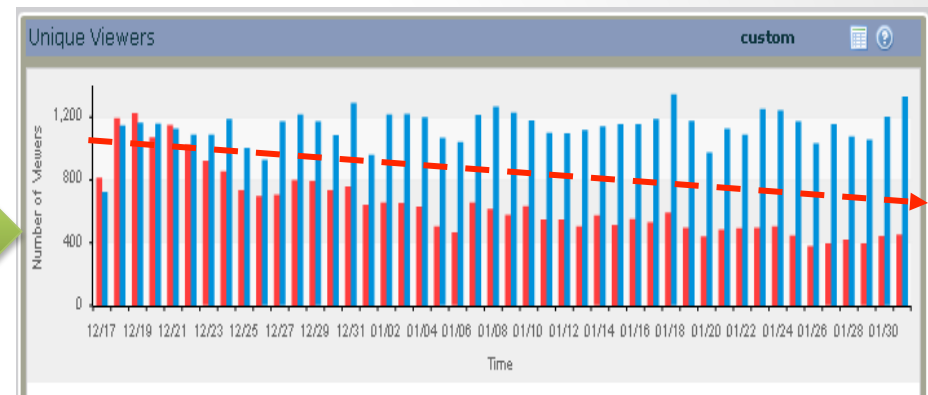
1% increase in buffering reduces engagement by 3 minutes

[More Details in upcoming SIGCOMM'11 Paper ]

# Viewers React to Poor Video Quality by Clicking Away



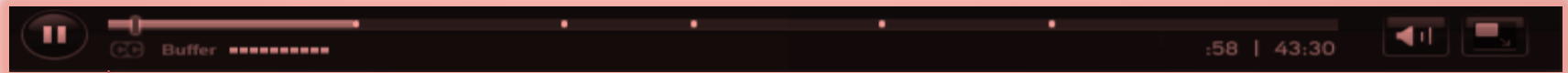
**1% difference in buffering  
between two ISPs**



**68% monthly loss in uniques for ISP  
with poor performance**

**Even 1% increase in buffering leads to more than 60% loss in audience**

# Why CDN Video Solution Is Not Good Enough



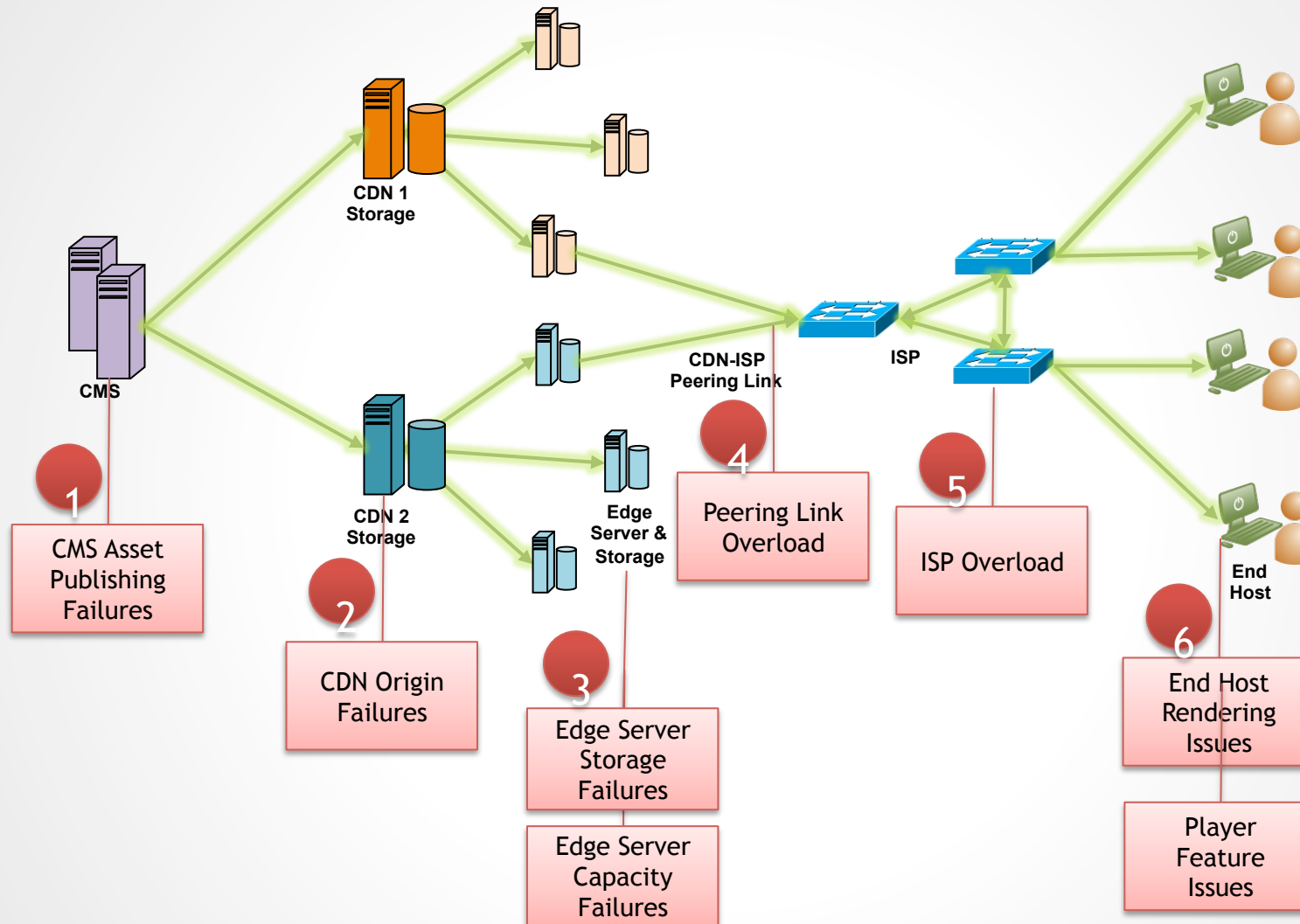
**Select a server intelligently at start time**

**May still incur connection or streaming failure or missing asset**

**• Does not know anything about the state of the video stream for the next 45 minutes**

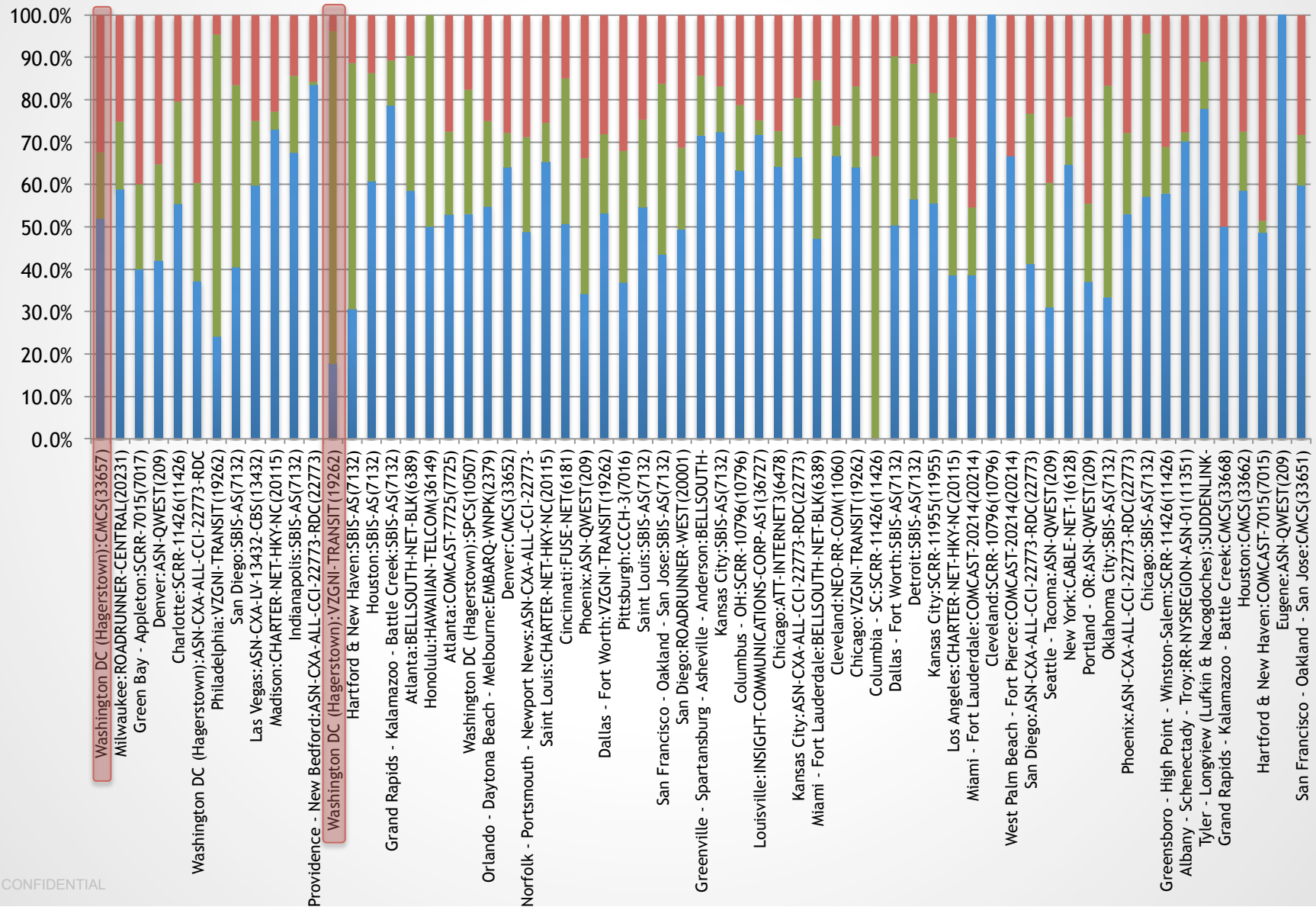
- 🕒 CDNs are architected for the web Internet
  - 🕒 Make a single decision on first object request
  - 🕒 Use server-side load monitoring & intelligence

# Internet Video Delivery Has Many Points of Failure

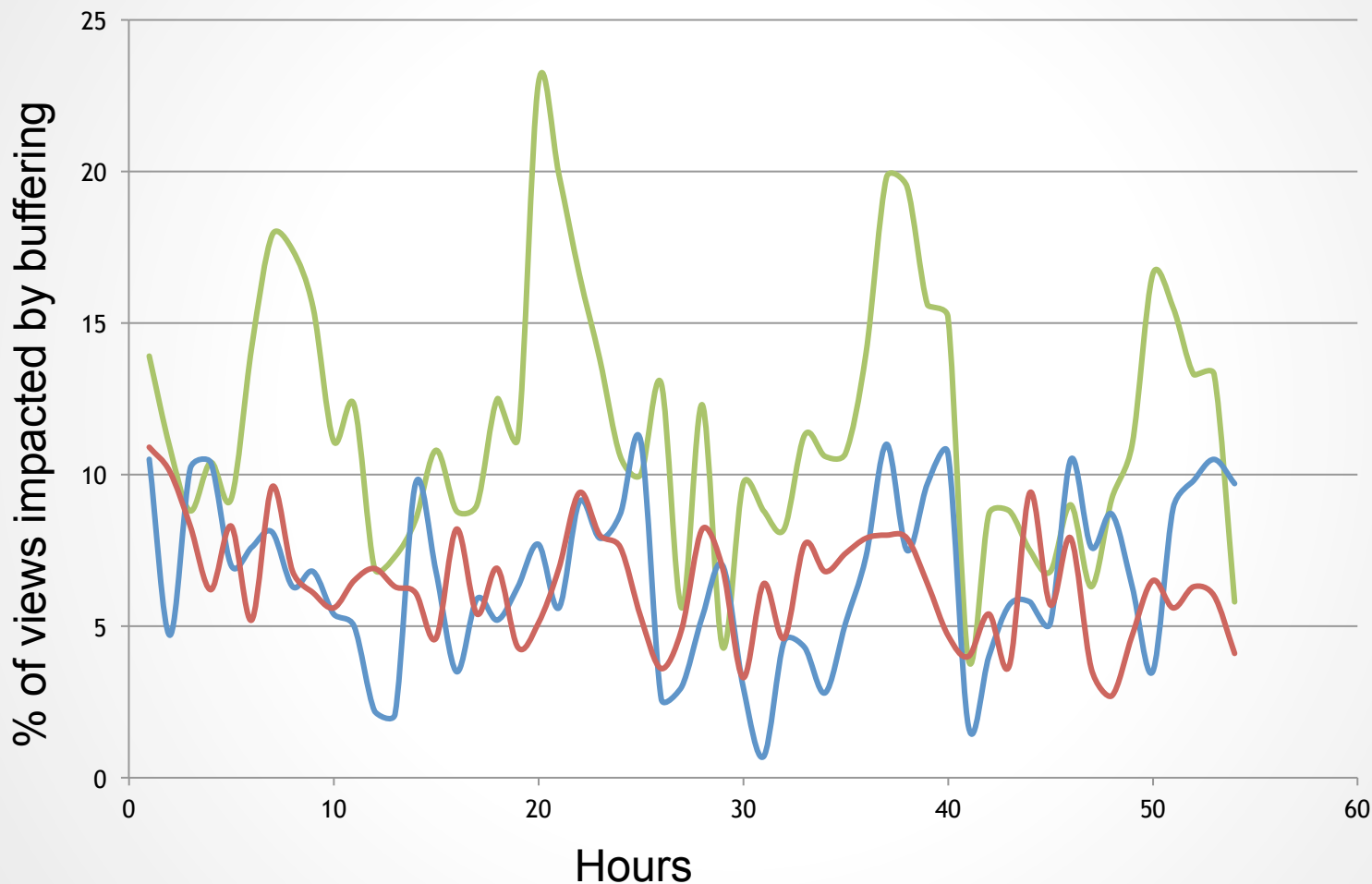


There is a very high probability that a viewer watching even a 15 minute video will experience visible quality degradation due to one of these issues ...

# Measurements of 3 Leading CDN Show Significant Variation Over Geo and ISP



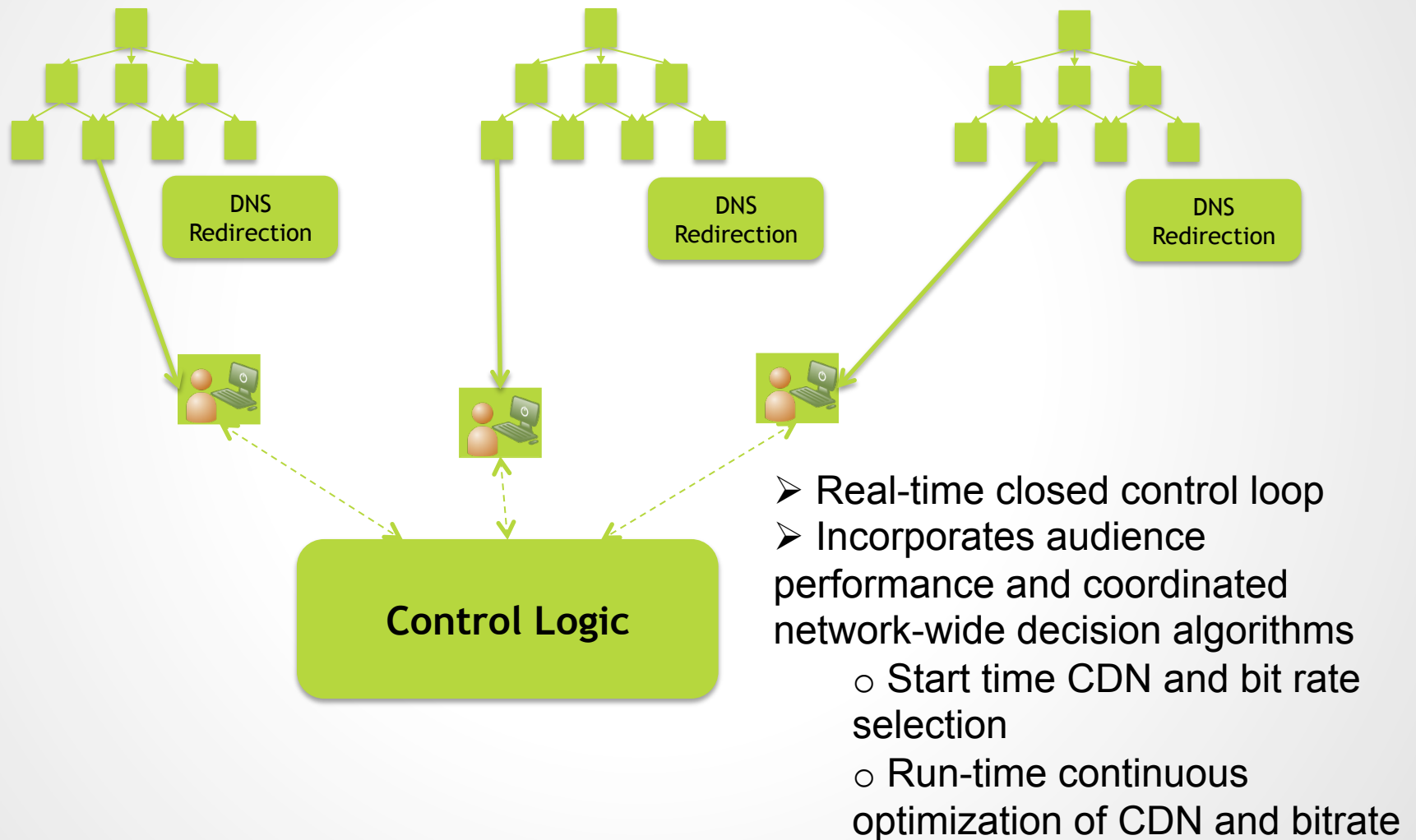
# CDN performance varies across time



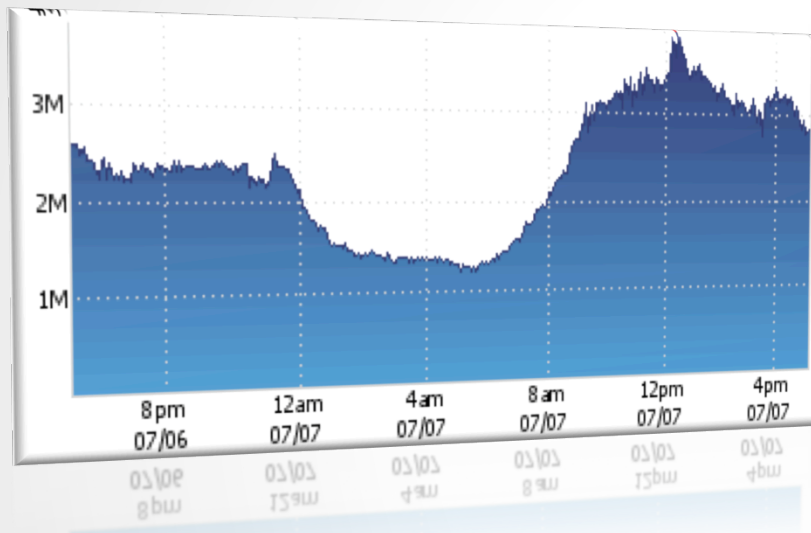
New York:COMCAST-33287



# The Case For Receiver-Based Multi-CDN Control



# Flash Crowd



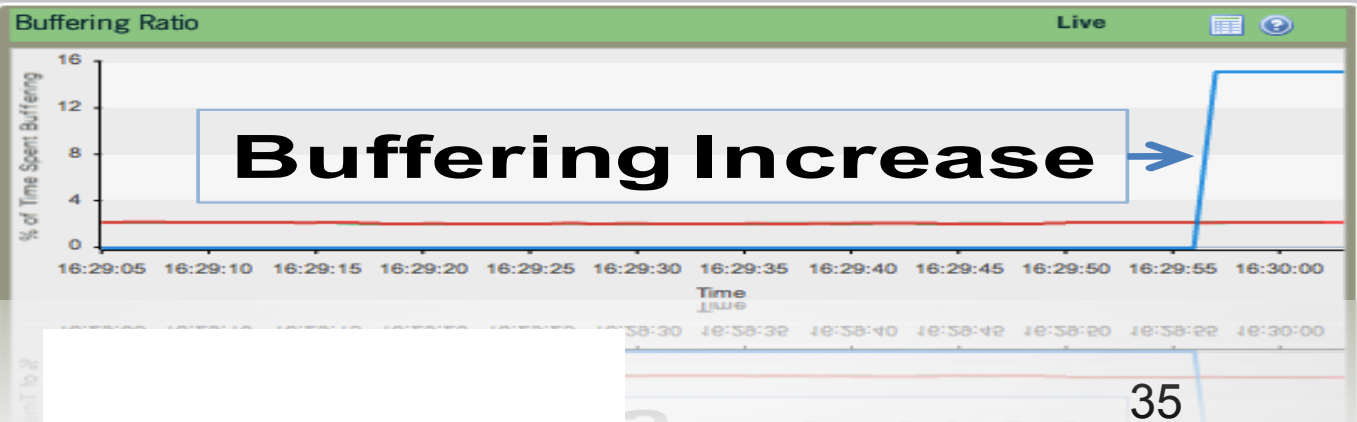
## MICHAEL JACKSON MEMORIAL

Live stream from the Staples Center  
July 7th, 2009  
12:55PM ET/ 9:55AM PT

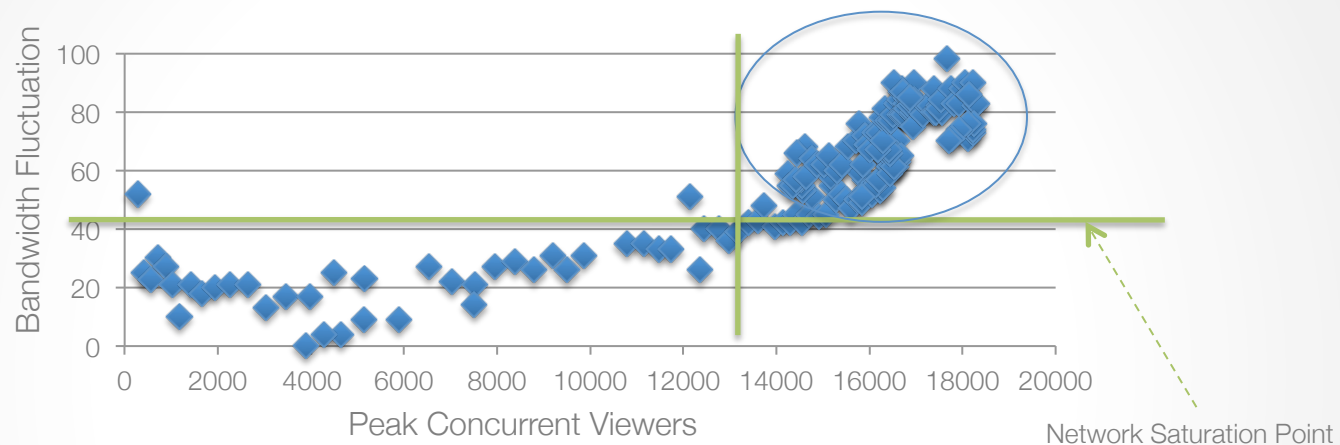


- Ⓢ 19% spike in global Internet
- Ⓢ Over 2Tbps traffic and 3.3 M visitors/min

# Flash Crowd Impacts Quality



# May Need Global Adaptive or Admission Control Algorithm to Deal with Flash Crowd



One DMA (all ISPs) became saturated once the PCV in the DMA crossed 13,000

The saturation caused heavy fluctuation in the bandwidth available to viewers to stream video

Immediate action was to cap the bit rate available to viewers in the DMA

# Elements of Emerging Architecture

- Ⓢ HTTP chunk is the new Datagram for Internet video
- Ⓢ HTTP chunk switches are the new switches/CDN servers
  - Support both pull-based multicast (cache miss and request) and push-based multicast
- Ⓢ Peer-to-peer need to be incorporated
  - Scaling is still a key challenge
  - Video bits are most unprofitable (\$/bit)
- Ⓢ Key innovation may happen in out-of-band control plane (unlike RTSP and RTMP) for
  - Video streaming control
  - Multicast path control
  - Peer-to-peer management
  - Congestion control (bit rate adjustment and admission control)
  - Quality of Service

# Concluding Remarks

## 🔌 Follow the traffic

- the Age of Internet Video has arrived
- Internet video will fundamentally change TV, entertainment, social networking, games

## 🔌 Video requires architectural support

- yes, it was said 20 years ago, but this time could be real

## 🔌 Quality of video experience does matter

## 🔌 Scalability requires federation of server resources

- Multi-CDN, hybrid CDN-P2P, integrated ISP/CDN

## 🔌 Architectural elements emerging

- many research ideas are bearing fruit