Optimizing Media Delivery in the Future Mobile Cloud

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Agenda

• Motivation
• Industry Trends
• Media Optimization Opportunities – University Research
• Adaptive Streaming over LTE networks
• Content-based adaptive video compression & streaming
• Summary & Future Challenges
Motivation
Mobile & Video Traffic Are Exploding

2011 Mobile Traffic*

52% Video

7M paid video subscribers

597 PB/month

2016 Mobile Traffic*

70% Video

10.8 EB/month

700M paid video subscribers

* Cisco, ABI

Emerging Applications

Video entertainment

Video conferencing

Video sharing

Live streaming

Mobility + video + social media driving new experiences and new challenges
Network Operators Are Challenged

“Network as a Service”

“Mobile Video will be a killer 4G service”, ABI

Video Quality, Network Efficiency, and Cost/Revenue ($$/bit) are Critical for Service Providers
Quality of Experience Matters

By the year 2014, 77% of U.S. online activity will be video streaming.*

*According to the eMarketer.com study, Video Content and Syndication: Long-Form Content on the Rise.

Of all video disruptions, buffering* has been found to have the largest impact on viewer engagement.

240%

In live events, viewers watch 240% more video when they don’t experience buffering.

1% 3 mins

A 1% increase in buffering leads to an average decrease of 3 minutes in viewing time.

Viewers who experience a single video start-up failure return 54% less.

In long form, Video on Demand content, viewers watch 32% more video when they don’t experience buffering.

*While any amount of buffering impacts engagement, for this infographic buffering was defined as 5 seconds or 2% of total length of viewing session.
Industry Trends
Consumer Usage and Industry Trends

Trends:
- Real-time entertainment is big - “25% of U.S. mobile phone owners watch video at least once a week on their phone”
- Consumers are willing to pay more for quality
- Tablet users like long-form content
- Multiple screens are important
- Video is far from slowing down

* Source: Yankee Group Research

<table>
<thead>
<tr>
<th>Investment</th>
<th>Network Opex Savings</th>
<th>Creation of New Revenue Streams</th>
<th>Perceived Increase of QoE</th>
<th>Capital Investment</th>
<th>Vendors</th>
<th>Comments</th>
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</thead>
<tbody>
<tr>
<td>Increased Network Bandwidth</td>
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<td></td>
<td></td>
<td></td>
<td>Alcatel-Lucent, Cisco, Juniper, Ciena, Ericsson, NSN, Tellabs, Huawei, ZTE, Samsung, Fujitsu</td>
<td>Capital-intensive but necessary evolution of RAN, access, aggregation, edge and core networks with high-capacity IP networks. Needs to be combined with network optimization and policy management.</td>
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<td>Policy and Traffic Management</td>
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<td>Amdocs (Bridgewater), NSN, Alcatel-Lucent, Openet, Cisco, Tekelco, Ericsson, Orga Systems, Juniper, Huawei, Tango</td>
<td>Important for sustained business model viability. Limited impact on QoE.</td>
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<td>Wi-Fi Offloading</td>
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<td>Ruckus Wireless, Kineto Wireless, Aptilo Networks, Stoke Networks, Intellicom Technologies</td>
<td>Reduces traffic load on macro RAN by invoking reliable offload to available Wi-Fi networks in a secure manner that is virtually seamless to end-users. Requires presence of Wi-Fi-enabled devices and additional gateway equipment; introduces additional security and network management challenges.</td>
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<td>Off-Peak Content Distribution</td>
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<td>Alcatel-Lucent (Bell Labs)</td>
<td>Client/server architecture that uses intelligence on network availability, device constraints and user behavior to optimize mobile content placement and delivery.</td>
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<td>Partnership with CDN Provider</td>
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<td>Edgecast, Akamai, Limelight, Level 3, Amazon</td>
<td>Partnering with a traditional CDN player is a normal first step that helps operators get familiar with the CDN business. Tier 2/3 providers without the resources to build their own CDNs will continue to partner given scale disadvantages.</td>
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<td>Network Optimization (General or Video-Specific)</td>
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<td></td>
<td>Bytemobile, Vantrix, Openwave, Mobixell, Dialogic, Smith Micro, Opana, Flash Networks</td>
<td>Includes optimization of video content, as well as transcoding of the content to fit each specific device and compression of files to create less traffic and fit the network’s availability. Introduces potential conflicts with content owners due quality manipulations, which could negatively impact perceived QoE.</td>
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<td>Internal CDN Deployment</td>
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<td>Cisco, Juniper, Edgeware, Verivue, Huawei, ZTE, Alcatel-Lucent, Azuki Systems, Skytide</td>
<td>Most Tier 1 network operators are pursing internal CDN strategies to lower opex costs to deliver their own rich media services and position themselves to offer CDN services to enterprise customers.</td>
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<td>Transparent Caching</td>
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<td></td>
<td></td>
<td>PeerApp, Oversi, Blue Coat, Juniper Networks, Verivue</td>
<td>Fast ROI for Tier 2/3 operators with expensive IP transit costs. Growing importance for Tier 1 operators seeking opex reductions and better QoE.</td>
</tr>
</tbody>
</table>
Optimization Deployment - Terms & Conditions (2011)

“Verizon Wireless is deploying optimization technology in parts of its 3G mobile broadband network. This network management technology is designed to transmit data more efficiently, ease capacity burdens on the network, primarily from video files, and improve the user experience with faster downloads and decreased Internet latency.”

“Several optimization techniques are applied to video files: transcoding, caching, and buffer tuning. All are agnostic as to the source or content of the video.”

Verizon Talks High-Res Unicast Delivery at CES
Verizon Digital Media Services is in the middle of its rollout, offering a way around the web’s distribution limitations.

Verizon may limit FaceTime to tiered data plans, in an attempt to manage traffic on its network at the risk of displeasing the iPhone maker.

Viewdini: Could this app be Verizon’s first pass at toll-free mobile data?

Netflix has unveiled a new feature that lets mobile users change their video quality as a way to manage how much bandwidth they use under their mobile data plans.

*Good, Better, Best

By leveraging Akamai’s Cloud Network and Ericsson’s Technology Leadership in Mobile Broadband networks, Akamai and Ericsson plan to offer an end-to-end solution for delivery across the Internet AND mobile networks - from the content owners all the way to the end user device!
Intelligent Edge Infrastructure

Service Edge Network
- Premium content served from edge
- Less latency and jitter
- Opportunity for new services

Cloud RAN on Intel Architecture
Source: CMCC white paper

Intel Architecture at the Edge for Greater Flexibility and Scalability
Source: Intel white paper

Cisco ‘Fog’
Microsoft Research ‘Cloudlets’
Alcatel-Lucent ‘Distributed Cloud’

Future: Comms + Media + CPU + Storage at the Edge
Intelligent Edge Server: PoC Demo

- Xeon E3 Sandy Bridge Server
- Expression Encoder w. QSV support
- IIS Live Smooth Streaming (HTTP Adaptive Streaming)
- Wi-Fi Router
- 1 Ge Switch
- iPhone
- Simultaneous streams rendered at any one of 8 different adaptive bitrates: 200 kbps – 4.5 Mbps (~15% CPU utilization)
- Silverlight-enabled Clients

Example: Live Streaming with Time-shifting

Real-time, Content-aware Transcoding using Integrated graphics
What’s New? Why Now?

Industry trends (‘Perfect storm’)  
- Powerful devices, larger screens, good graphics  
- Higher capacity wireless networks [good enough]  
- Internet video and accepted social video usage models

Technology trends  
- Running into limits in wireless network improvements  
- Adaptive streaming solutions gaining traction (HTTP-based)  
- Improved video quality understanding (visual perception)  
- Fundamental changes in network infrastructure  
- Improved video processing, more memory in mobile devices  
- 3D, stereoscopic video coming
Media Optimization Opportunities – University Research
Adaptive Streaming over LTE networks
Video Rate Adaptation is Being Realized Today

BUT, what are implications for mobile networks?
End-to-End Real-Time Wireless Test-bed

Real Application Servers

Real devices (WLAN)

Real devices (LAN)

Intel MEMIC (Middle East Mobility Innovation Center)

Simulated Environment

OPNET®
Making Networks and Applications Perform™

Real Application Servers

Live Video
Streaming

YouTube
skype

Facebook
Twitter

Intel
Measurements, Statistics & Analysis Platform

1. OPNET has a set of tools that can change and/or monitor network behavior

2. Client applications can provide additional statistics

3. QoE measurements & Statistics

4. Validate, modify, or create new algorithms

Real-time adaptive video streaming example
Example: 4 HTTP AS users sharing same channel
HTTP Adaptive Streaming - Mobility

Mobile User Trajectory
Mobile client takes some time to get the requested stream.

For good conditions for mobile client: Two clients competing for the available resources and get served fairly.

Mobile client gets out of the coverage area, took longer time there and lost the connectivity to the streaming server.

Fixed client gets the maximum.
Capacity Improvements From Adaptive Streaming

- Stored Video
- HTTP/TCP/IP
- 3GPP-based multi-cell simulation

Capacity = # satisfied users meeting rebuffering % in 95% of cellular area

- Capacity-quality-rebuffering - coverage trade-off

- Content-specific resource management = + 20-25% add. gain
3GPP DASH / HAS

Make Adaptation:
- Device-Aware
- Link-Aware
- Content-Aware
- QoE-Aware
Content-based adaptive video compression & streaming
Content-aware Adaptation

- 3 layer adaptation
  - Adaptation based on metadata, e.g. movie, sports, etc.
  - Adaptation based on video characteristics, e.g. extract video features such as motion, texture, to preset coding parameters
  - Adaptation based on quality assessment, e.g. objective quality output during compression and QoE monitoring/feedback from users

*content attributes, content description, etc.*

Layer 1

Video → Metadata Analyzer → Feature Extractor → Category-based Presets → Video Adaptor → Quality Assessment

Layer 2

*motion, texture, etc.*

Layer 3

objective quality output, user QoE feedback

User QoE feedback

Objective Quality
Content-aware Adaptation

• Key Challenges
  - How to extract video characteristics? Motion, texture, spatial complexity, etc.
  - How to design a learning classifier system using feature and metadata info.?
  - What objective quality metrics to use for quality assessment? MS-SSIM, VQM, etc.
  - How to collect user QoE feedback?
  - How to refine coding parameters automatically? Bitrate, resolution, frame rate, fragment size, etc.
Content-aware Adaptation Benefits

- **Save bandwidth**
  - Find proper bitrate bound/range based on content
- **Improve QoE**
  - Optimize encoding options to achieve better QoE
- **Enable tier services with QoE guarantee**
  - Provide different tiers of video quality

Example: Comparison of Subjective Results
Summary & Future Challenges
Summary

• Video content is quickly dominating mobile network traffic
• Need to minimize $$/bit (e.g., reduce # of bits to deliver the same experience)
• Cross-layer & content-based adaptation show tangible benefits for system capacity and end-user QoE (more results needed!)
• Alternative network architectures → opportunity for QoE metrics
  • Heterogeneous networks (macro, pico, femto, WiFi)
  • Intelligent network edge; Caching at the edge
  • Peer-to-peer
• Need to optimize the future mobile cloud for:
  • Content (packet loss visibility, prioritization, content characteristics)
  • Devices (handheld, tablet, laptop, auto)
  • Wireless networks (multi-user scheduling, QoE optimized, dynamic adaptation)
  • Overall QoE (visual perception, latency, interactivity, re-buffering)
Challenges

• Content-specific adaptations & streaming solutions
  • Objective video quality techniques at different points in network
  • Tighter link between video quality analysis & adaptation
  • Method for sharing video quality across layers & network elements

• Methods to analyze video quality at mobile device
  • Non-reference metrics
  • Key data/stats for feedback

• Methods to analyze impact of video post processing (scaling)
  • Quality metrics which objectively quantify VPP enhancements

• 3D video adaptation
  • 3D perceptual quality assessment techniques
  • 3D rate-quality trade-offs & important quality characteristics
Thank You
Back-up
Limitations of Existing Solutions

Use pre-determined encoding parameters regardless of video content

<table>
<thead>
<tr>
<th>Technology Provider</th>
<th>Service Provider</th>
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<tbody>
<tr>
<td>Microsoft</td>
<td>Netflix</td>
</tr>
<tr>
<td>224x128@230kbps</td>
<td>375kbps</td>
</tr>
<tr>
<td>284x160@331kbps</td>
<td>500kbps</td>
</tr>
<tr>
<td>368x208@477kbps</td>
<td>1Mbps</td>
</tr>
<tr>
<td>448x252@688kbps</td>
<td>1.5Mbps</td>
</tr>
<tr>
<td>592x332@991kbps</td>
<td><a href="mailto:720p@2.6Mbps">720p@2.6Mbps</a></td>
</tr>
<tr>
<td><a href="mailto:768x432@1.4Mbps">768x432@1.4Mbps</a></td>
<td><a href="mailto:720p@3.8Mbps">720p@3.8Mbps</a></td>
</tr>
<tr>
<td>992x560@2Mbps</td>
<td><a href="mailto:1920x1080@5.5Mbps">1920x1080@5.5Mbps</a></td>
</tr>
<tr>
<td>1280x720@3Mbps</td>
<td></td>
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</table>

\[
\text{FRAME HEIGHT} \times \text{FRAME WIDTH} \times \text{FRAME RATE} / \text{MOTION FACTOR} / 1024 = \text{baseline Kbps}
\]

Where MOTION FACTOR is:
- 7 for high-motion, high scene-change clips
- 15 for standard clips
- 20 for low-motion (talking head clips)

Limited encoding option can lead to inefficient use of bandwidth or reduced user experience.