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Chair of Communication Networks
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Dynamic Bandwidth Allocation for Multiple Network Connections:

Improving User QoE and Network Usage of YouTube in Mobile Broadband

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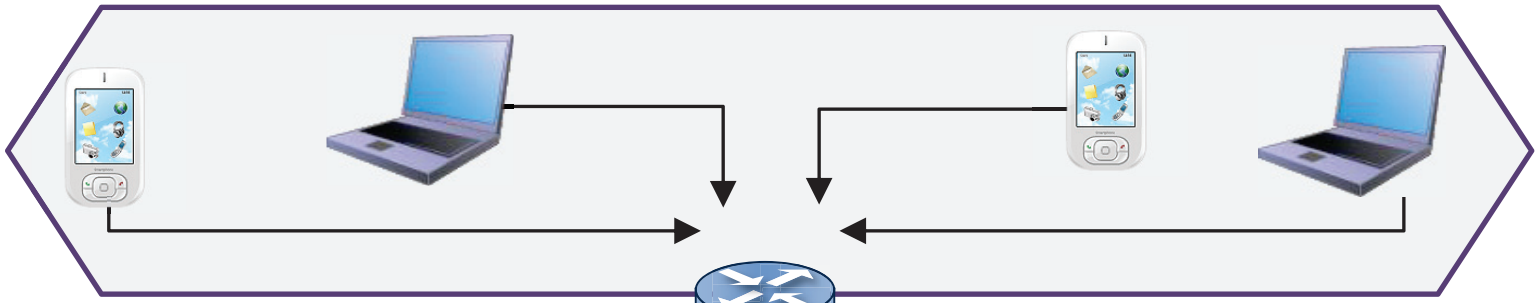
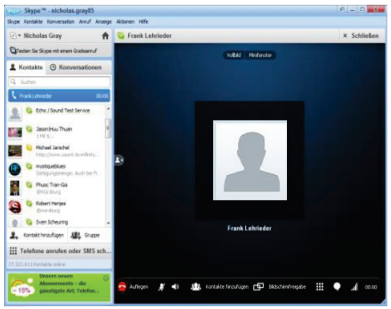
Competing Applications at a Bottleneck Link

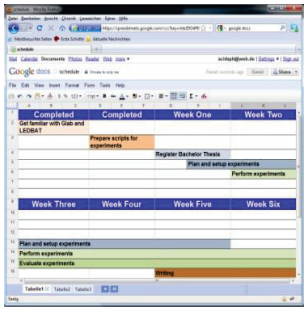


YouTube Video

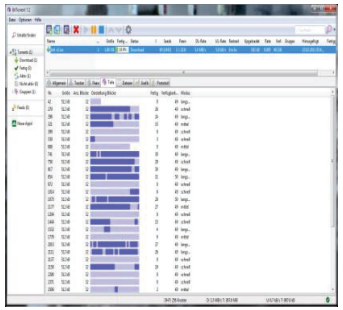
Voice over IP



Online Office

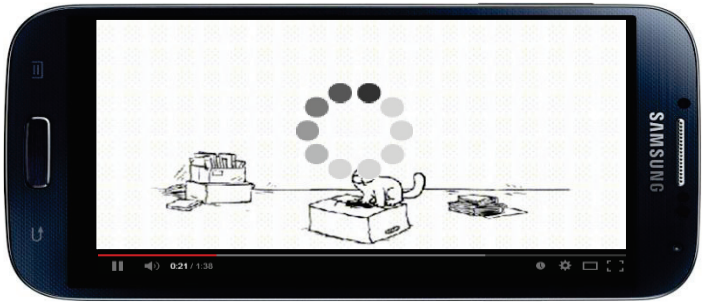


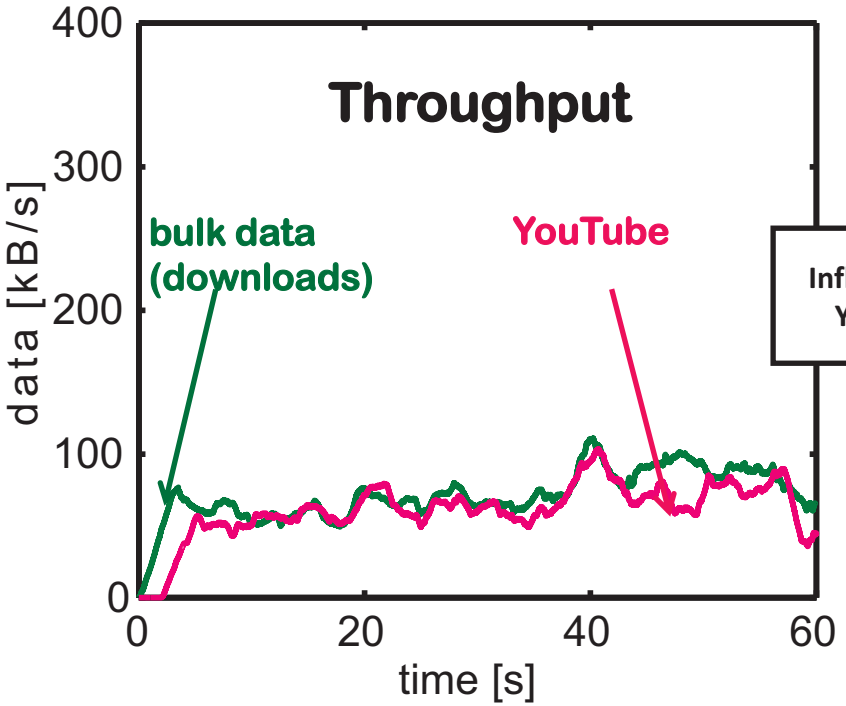
Software Download



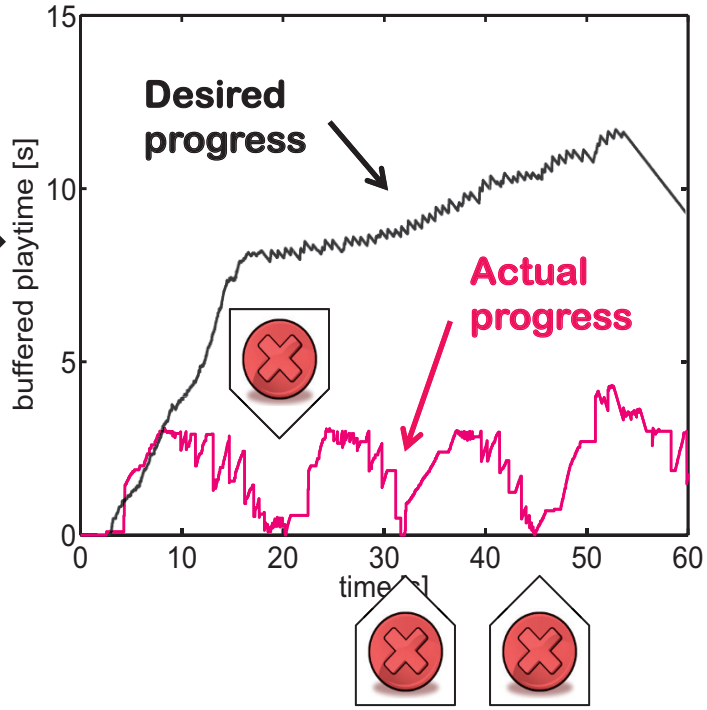
Impact on Application Quality

- **Content unaware networks**
  - Fair share with respect to QoS (throughput)
  - Bulk data download performance: good
  - YouTube quality: bad





Influence on YouTube



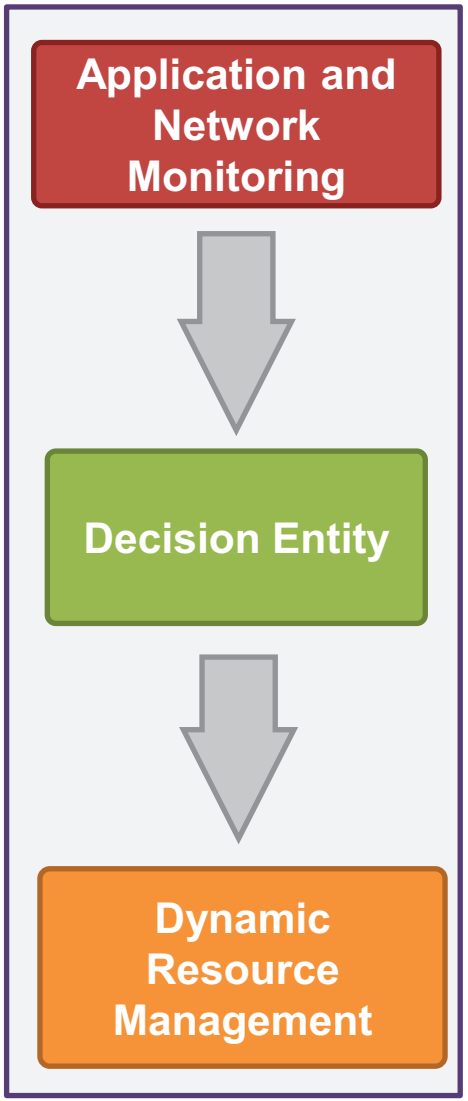
Application-Aware Networking

- **Tasks and objectives**
  - Integrating application needs' in network resource management
  - Add or re-allocate resources on demand

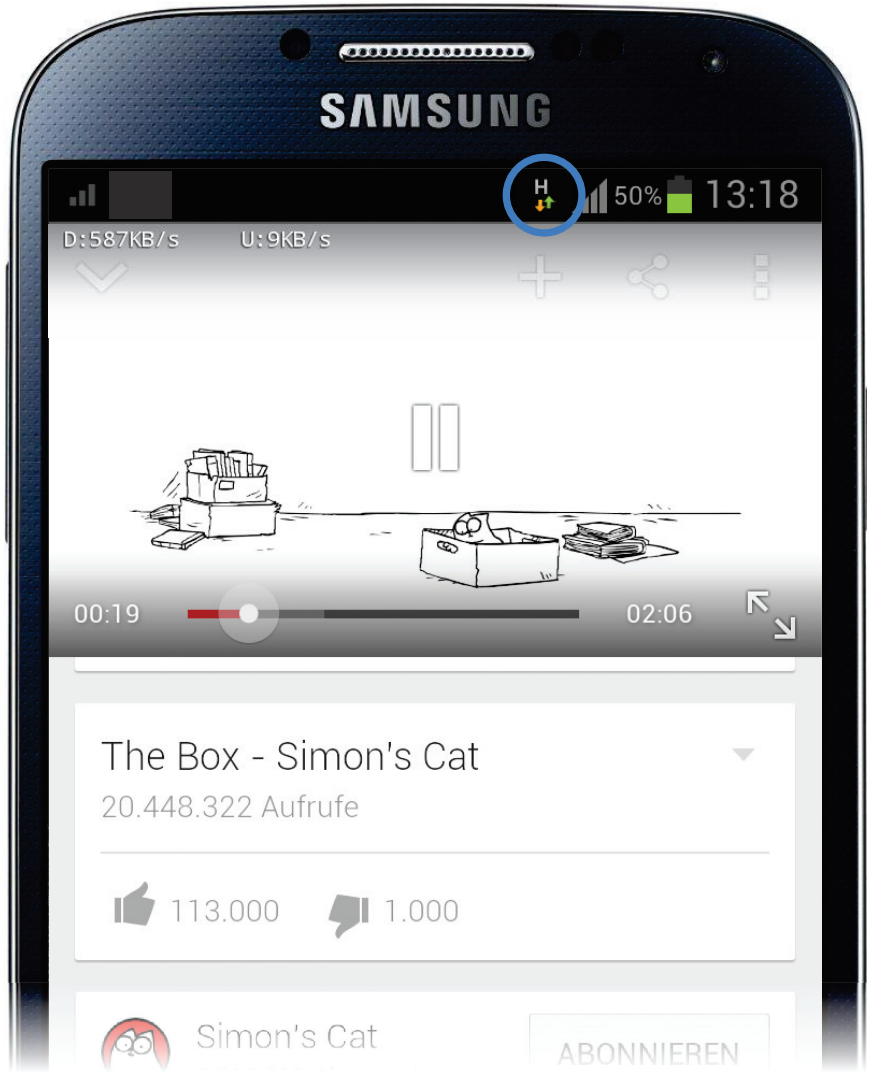
1. **Application and network monitoring**
   - Collects information with high correlation to QoE
   - Example: YouTube monitor (YoMo), browsing monitor, etc.

2. **Decision entity**
   - Evaluates the information and decides about appropriate resource management action

3. **Dynamic resource management**
   - Enforces resource management actions
   - Example: resource allocation, scheduling, traffic prioritization, access technology selection, …



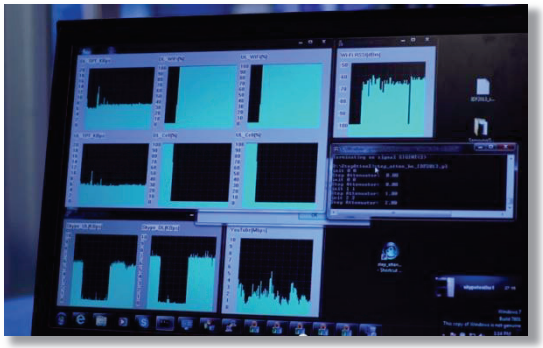
Resource Management: Dual Connectivity of Devices

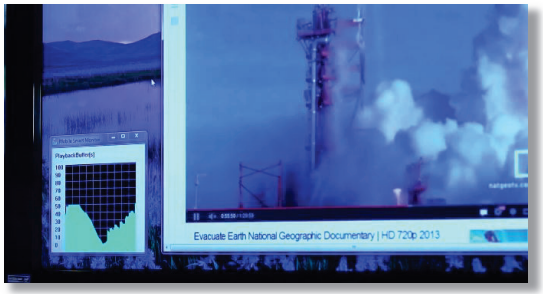


- More than just one transmission technology is available at current mobile devices
  - Wi-Fi Communications
  - Cellular Communications

Framework for Intelligent Bandwidth Aggregation

- Virtual access network (VAN) to aggregate multiple networks into single IP pipe
- Technical implementation: TCP/IP over UDP tunneling (mobile IP-like approach)
- Features of Intel‘s OTT VAN
  - Configurable bandwidth aggregation for multiple networks
  - (TCP) packet reordering (re-sequencing)
- Missing features
  - Smart algorithms for dynamic offloading
  - Application specific guidelines





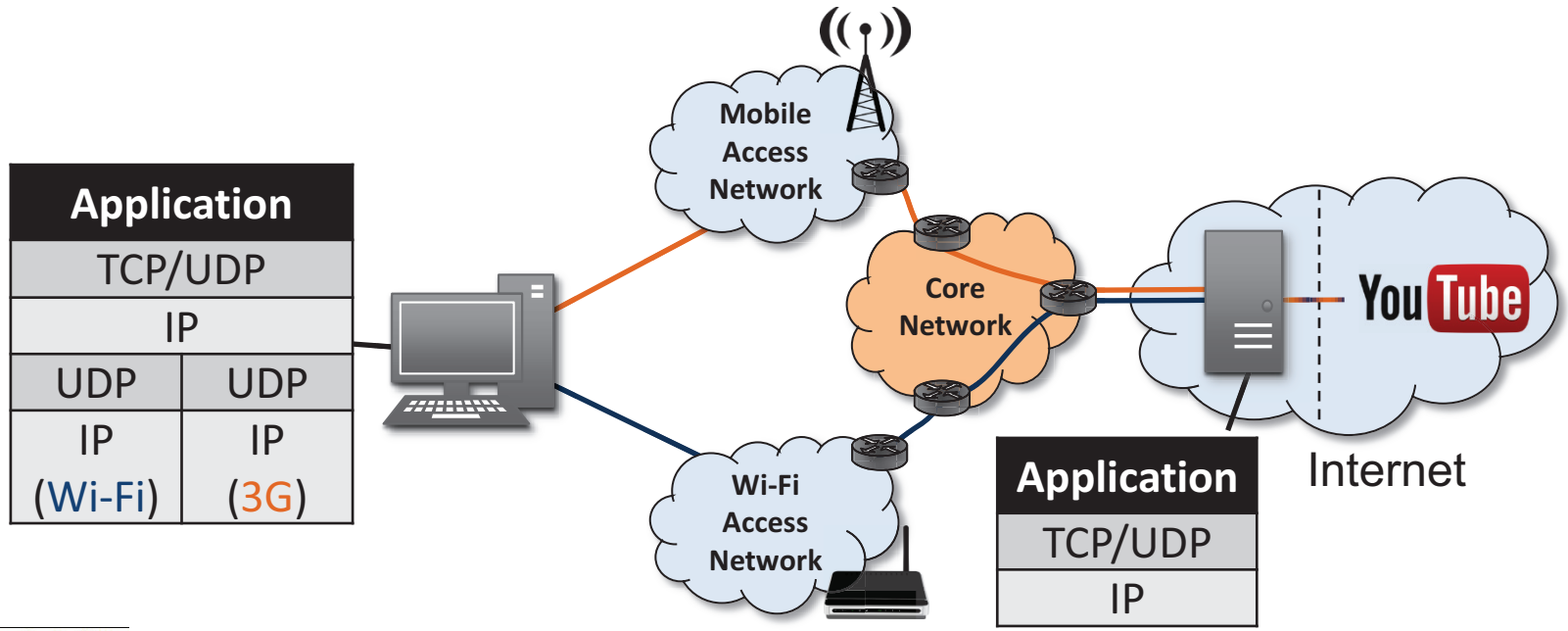
Intel's OTT VAN Testbed: Hardware and Software

Client

- Virtual network device provides tunneling functionality
- Access technologies
  - Wi-Fi communications (limited to max. 2 Mbps)
  - Mobile communications (limited to 4 Mbps)

Server

- Tunnel endpoint
- Implements re-sequencing buffer
- Enforces resource management



Resource Management Algorithms

- Adjust offload ratio between Wi-Fi and 3G cellular traffic, based on a **required throughput**

- Always use Wi-Fi and dynamically add 3G

  If current throughput < required throughput

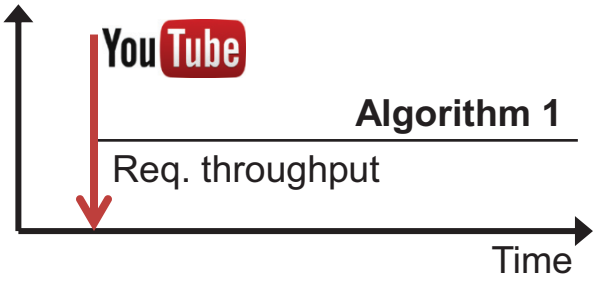
  → Increase 3G bandwidth 

  If current throughput > required throughput

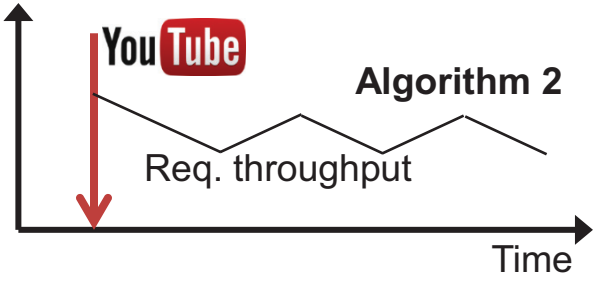
  → Decrease 3G bandwidth 

Resource Management Algorithms for YouTube

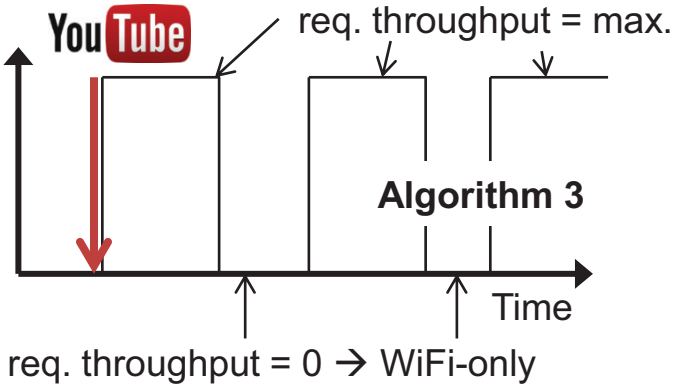
- **Algorithm 1:** *Static* Offloading Based on Video Request
  - Defines required throughput based on requested video quality
  - Detects uplink request by YouTube with DPI



- **Algorithm 2:** Dynamic Offloading Based on Buffer Estimation
  - Constant monitoring of the buffer level
  - Adaption of the required throughput based on the buffer level

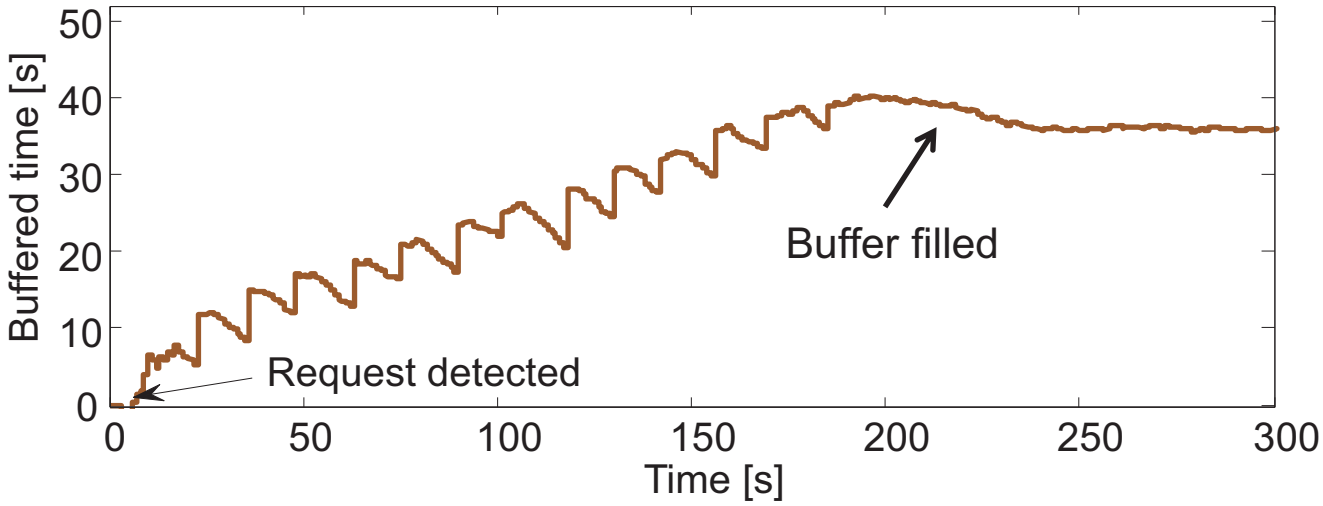


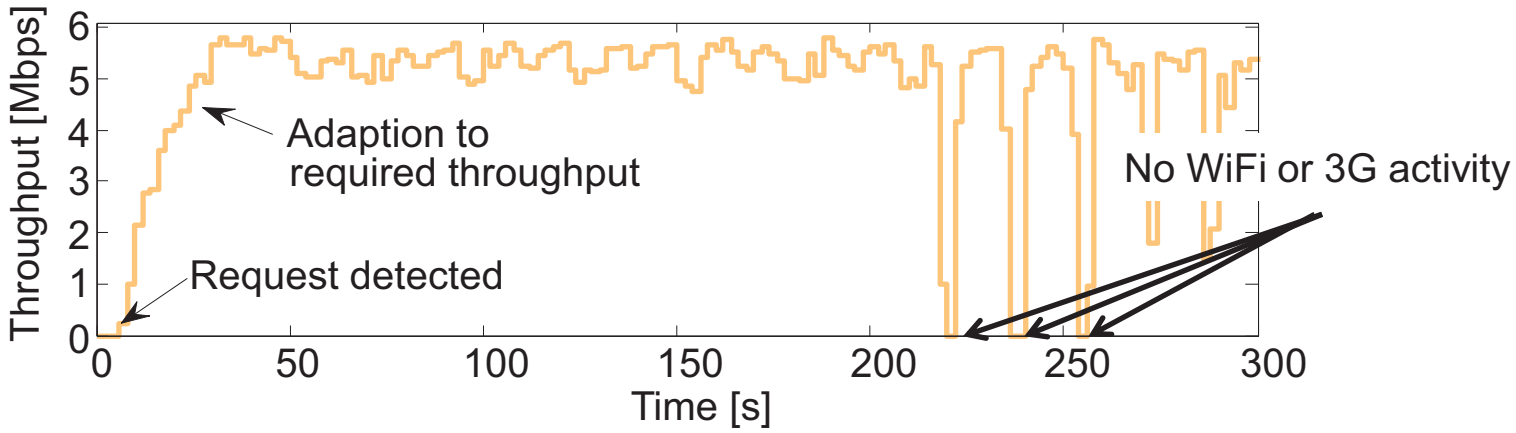
- **Algorithm 3:** Burst-wise Offloading Based on Buffer Estimation
  - Make use of the complete bandwidth until the buffer is filled
  - Disables 3G link until the buffer gets low



Time Series of Algorithm 1

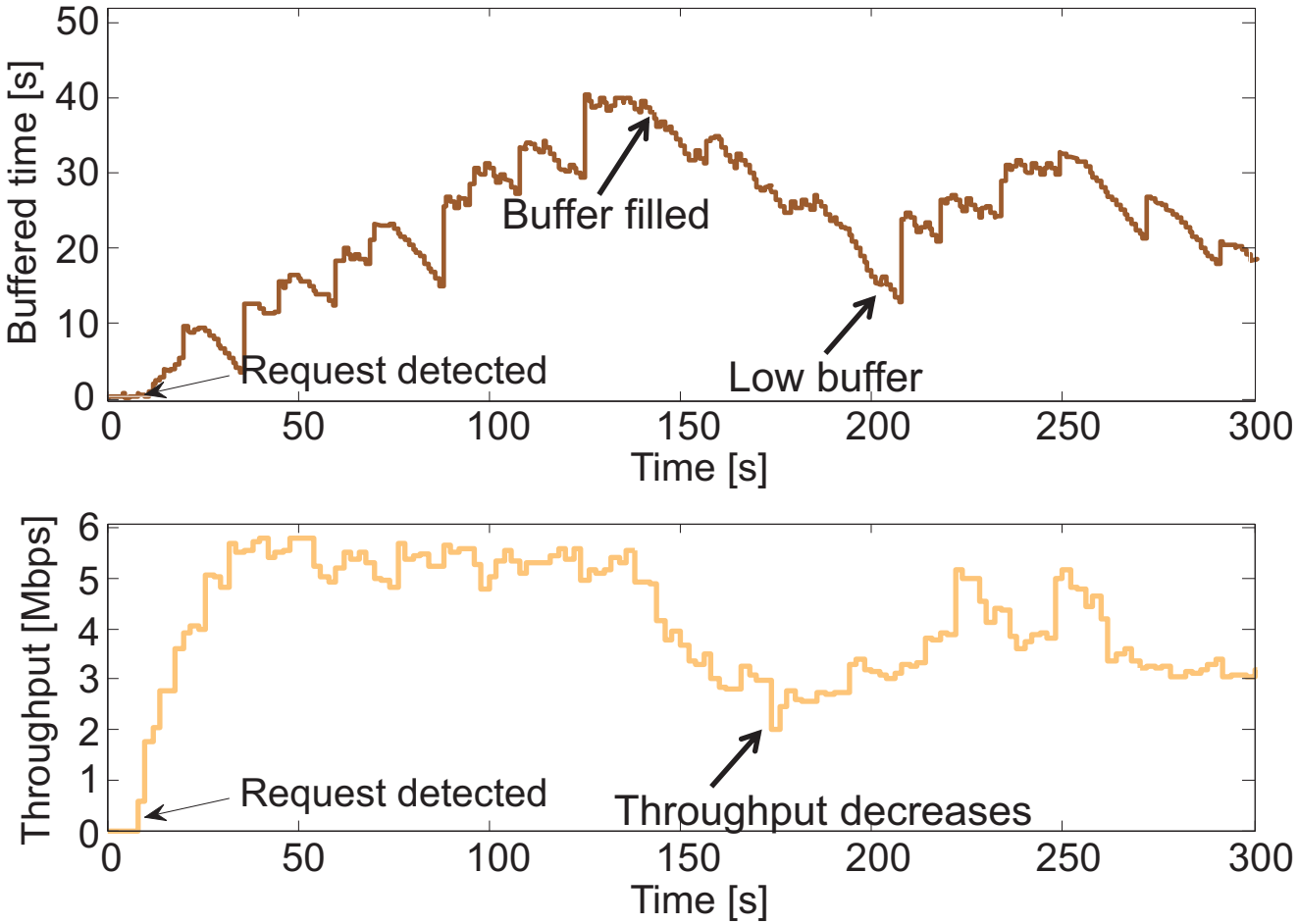
- Time series of one video with 1080p resolution
  - Wi-Fi and 3G available
  - Static req. throughput = 6 Mbps





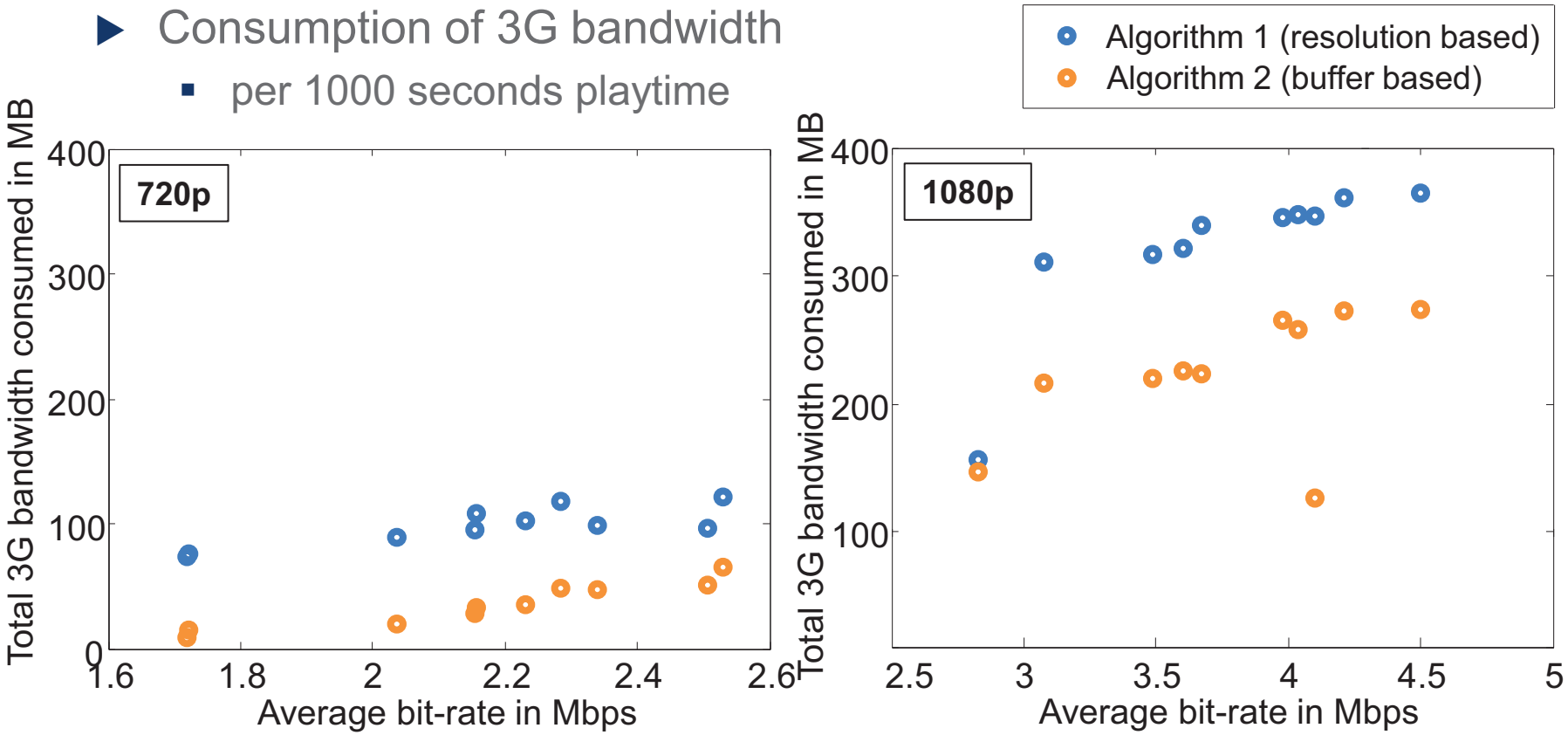
Time Series of Algorithm 2

- Algorithm 2 dynamically adjusts required throughput according to video playback buffer



Comparison of Algorithm 1 and 2

- Consumption of 3G bandwidth
  - per 1000 seconds playtime

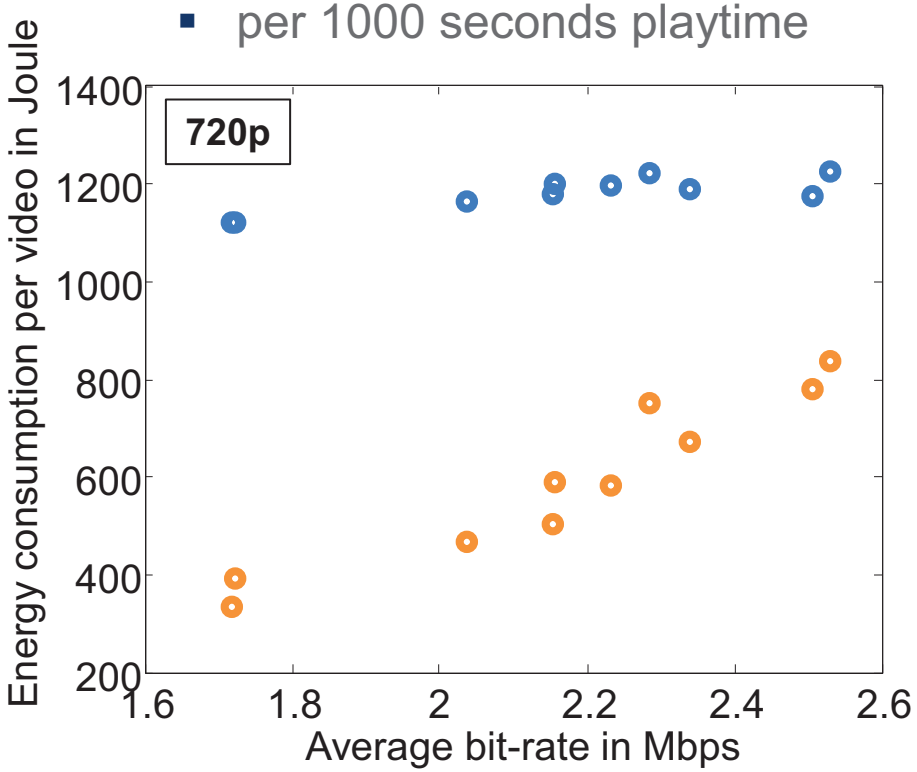


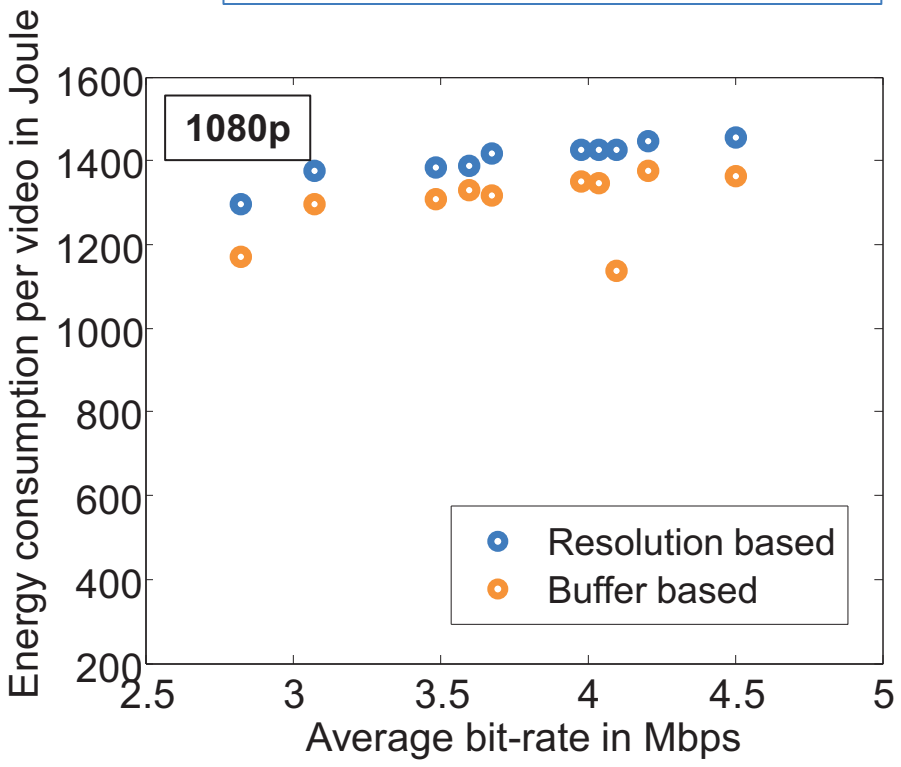
	Resolution based		Buffer based
720p	98 MB	-64,3%	35 MB
1080p	321 MB	-30,5%	223 MB

Comparison of Algorithm 1 and 2

- Average amount of consumed energy
  - per 1000 seconds playtime

J. Huang et al. „A close examination of performance and power characteristics of 4g lte networks"

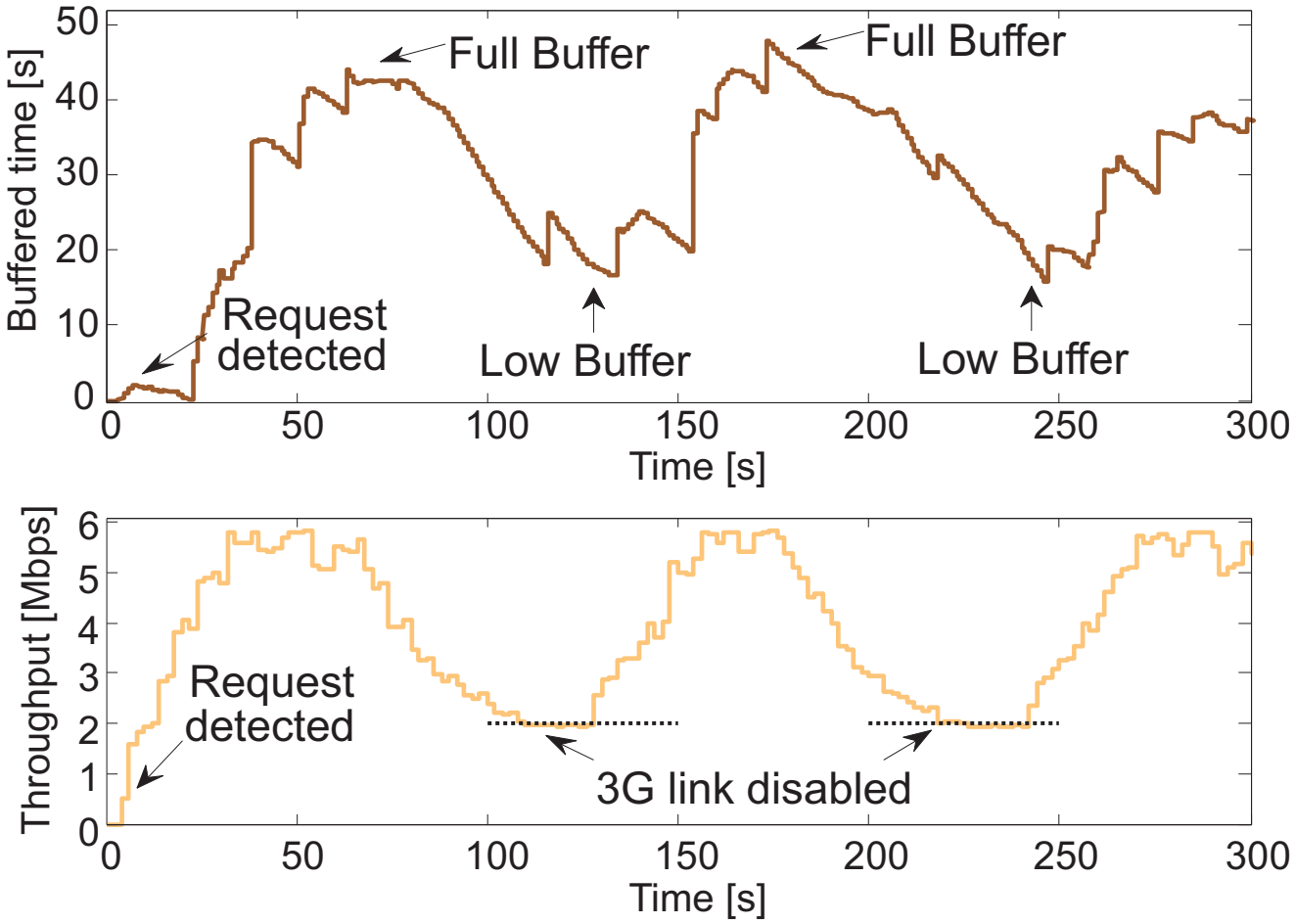




	Resolution based		Buffer based
720p	1180 J	-49,9% →	591 J
1080p	1404 J	-7,5% →	1299 J

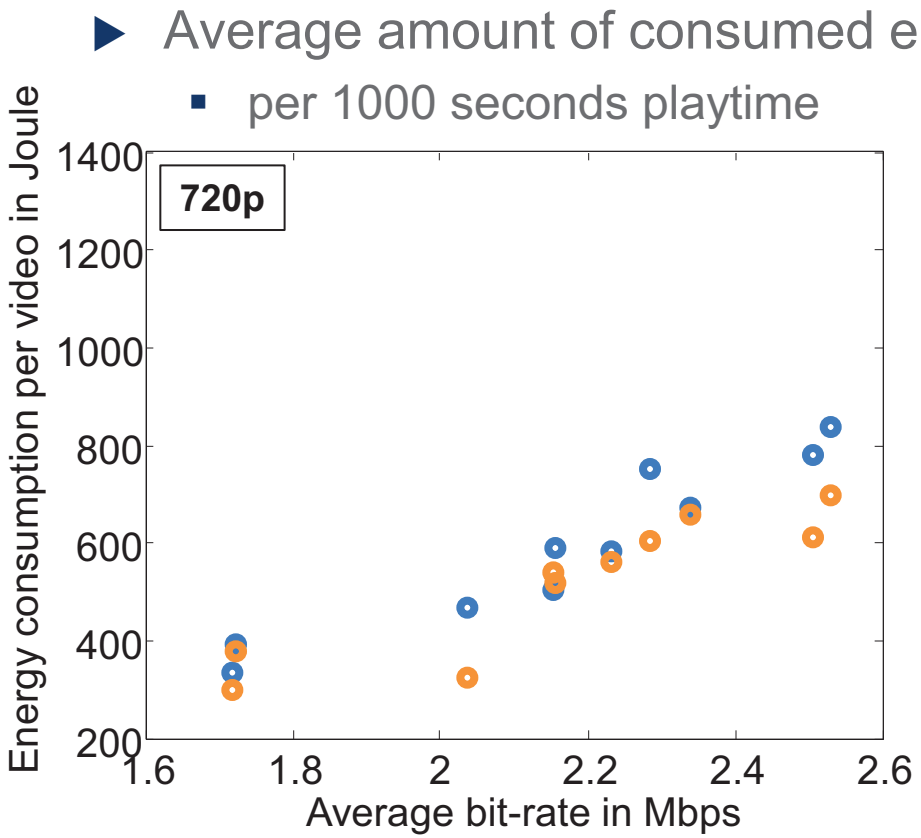
Time Series of Algorithm 3

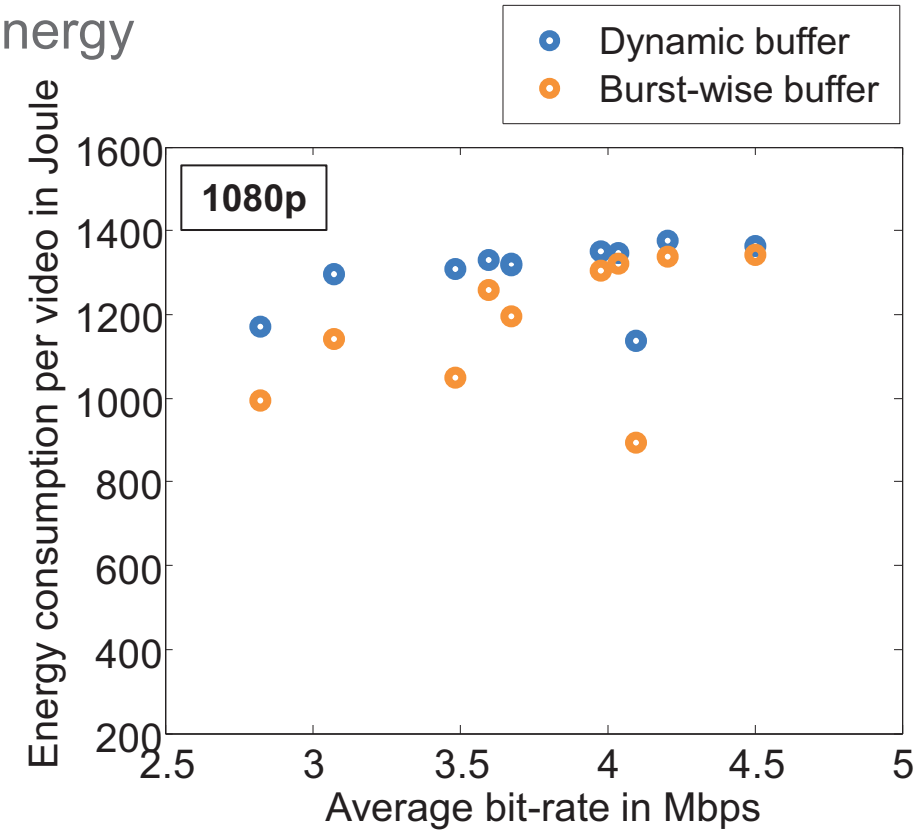
- Algorithm 3 activates 3G link in bursts



Comparison of Algorithm 2 and 3

- Average amount of consumed energy
  - per 1000 seconds playtime





	Dynamic buffer		Burst-wise buffer
720p	591 J	-12,2% →	519 J
1080p	1299 J	-8,9% →	1183 J

Conclusion and Outlook

- **Contribution of the work**
  - Assessment and quantification of the benefits of cross-layer resource management on the example of YouTube
  - Analysis of three application-aware algorithms which differ in complexity and impact on user and network

- **Results of the evaluation**
  - The application-aware algorithms can
    - enhance the QoE level for end users (if both networks provide enough resources)
    - save costs in terms of energy & Cellular resources

- **Future work**
  - Investigations on scalability of our approach and field trials with many users
  - Providing a holistic resource allocation for popular applications with respect to their instaneneous needs

http://dl.acm.org/authorize?N71341

Florian Wamser, Thomas Zinner, Phuoc Tran-Gia and Jing Zhu

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ACM SIGCOMM Capacity Sharing Workshop (CSWS 2014)

In conjunction with ACM SIGCOMM 2014 conference, on August 18, Chicago, USA.

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Demonstrating the Prospects of Dynamic Application-Aware Networking in a Home Environment

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Steffen Gebert, David Hock, Thomas Zinner, Phuoc Tran-Gia (University of Würzburg); Marco Hoffmann, Michael Jarschel, Ernst-Dieter Schmidt (Nokia); Ralf-Peter Braun (Deutsche Telekom T-Labs), Christian Banse (Fraunhofer AISEC); Andreas Kopsel (BISDN)

Demonstrating the Optimal Placement of Virtualized Cellular Network Functions in Case of Large Crowd Events

BISDN
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ACM SIGCOMM 2014

SIGCOMM is the flagship annual conference of the ACM Special Interest Group on Data Communication (SIGCOMM) on the applications, technologies, architectures, and protocols for computer communication.