Mobile Multimedia Meet Cloud: Challenges and Future Directions

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Keynote Speech

ICME2012@Melbourne, Australia

July 11, 2012

**University at Buffalo** *The State University of New York*

Outline

- **Mobile multimedia: Convergence and rapid growth**

- **Coming of a new era: Cloud mobile media**

- **When mobile multimedia meet cloud – creating new class of services**

- **Sample cloud mobile media applications**

  – **Cloud-to-mobile HTTP media streaming**

  – **Distributed video decoding for cloud media**

  – **Cloud-based 3D and FVV (free viewpoint video) mobile rendering**

  – **Cloud social media learning to photograph**

- **Summary and looking ahead**

Mobile Media: Convergence and Growth

Mobile Media: Convergence of Networks

- **Wired and Wireless Convergence**

3G/4G LTE Networks

Wireless LAN

Optical Networks

Core Networks

WiMAX Networks

DSL – Telco Networks
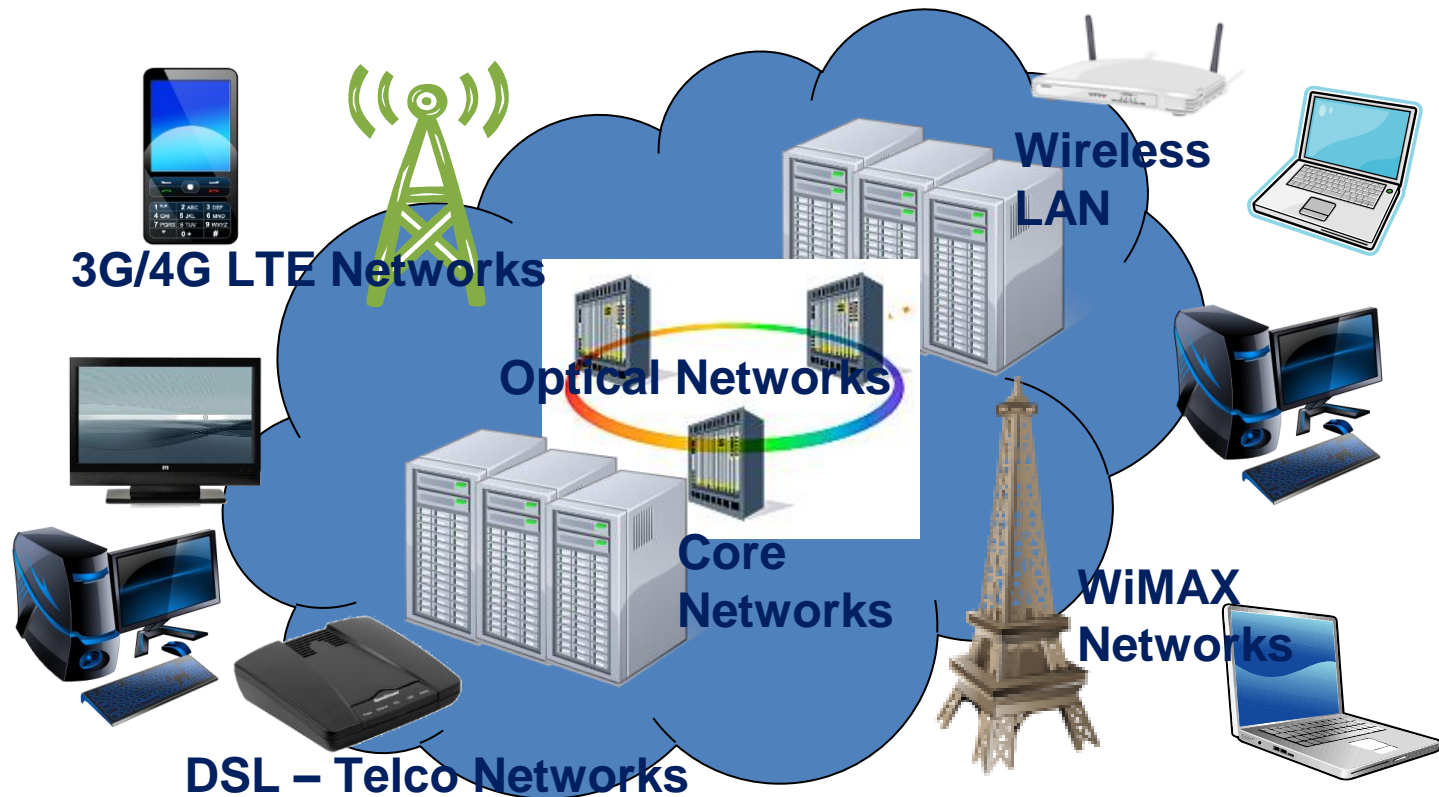
Wired and Wireless Convergence

- **Convergence of networks towards ubiquitous broadband media communications**
  - Broadband media communications are possible from Core networks to all edge networks (Telco and wireless)
  - Both media content providers (such as IPTV) and consumer media (such as YouTube) are increasing at unprecedented pace
- **Challenges in rich media network convergence**
  - Seamless roaming/switching from one network to another with vertical handoff
  - Mobility and location management for mobile media consumers on the go
  - Media content security management across network boundaries

Mobile Media: Convergence of Contents

- **Media Provider: historically – broadcasting and streaming**

Figure 1. Transporting real-time video over the Internet.

- **Media Consumer: modern days – publishing and sharing**

P2P

Convergence of Media Contents

- **Convergence of media consumer and provider demands new strategy for content administration**
  - Fundamental changes in media content flows – from few-to-many to many-to-many massive consumer servers
  - Disorganized generation of video content with diverse quality and resolution fluctuations.

- **Challenges in paradigm shifting change in mixed media networking and sharing**
  - New video communication strategy for massive mixed media sharing over heterogeneous networks and devices
  - End-to-end media content management in terms of QoS. QoE, secured access, and digital rights, especially for mobile media

Convergence of Social Networks

- **Global scale social networks**

- **Social activities via networking**

Source: kmedge.org

Convergence of Social Networks

- ## Convergence of social and technological networks
  - **Demands rich media broadband for social activities anytime, anywhere, through any network, and on any device**
  - **Results in intimate and unknown interaction between human behaviors and network behaviors**

- ## Challenges in rich media-based social networking
  - **Network management for competition between social sharing video and premier service video distributions**
  - **Novel media sharing techniques for social group sharing across global scale social networks**
  - **Intelligent retargeting of media content for individualized media consumption within and across social groups**

Mobile Media: Penetrating Everyone's Life

Any time!
Any device!
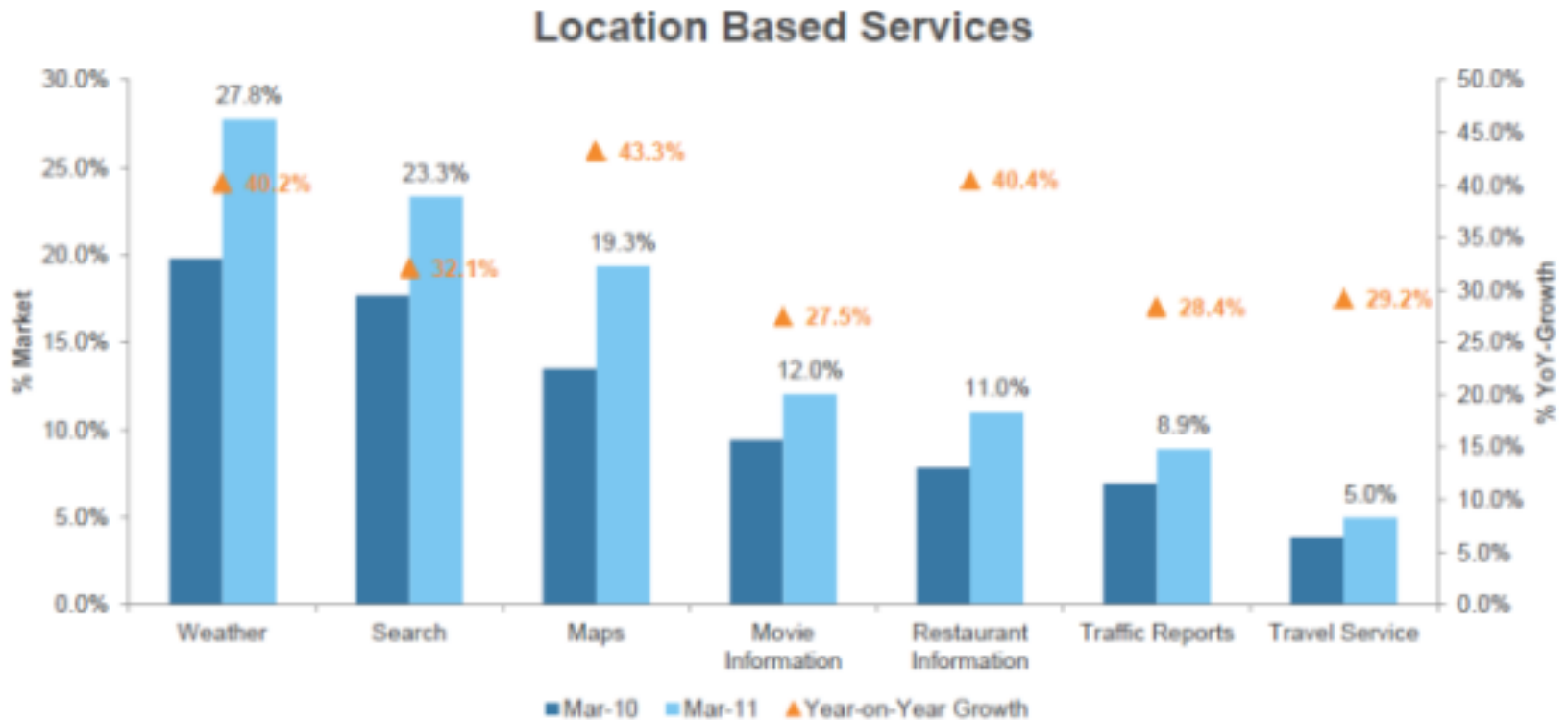**Any location!**
Any occasion!

Mobile Applications: Dramatic Increase

- **Nearly 50% increase in 2011**
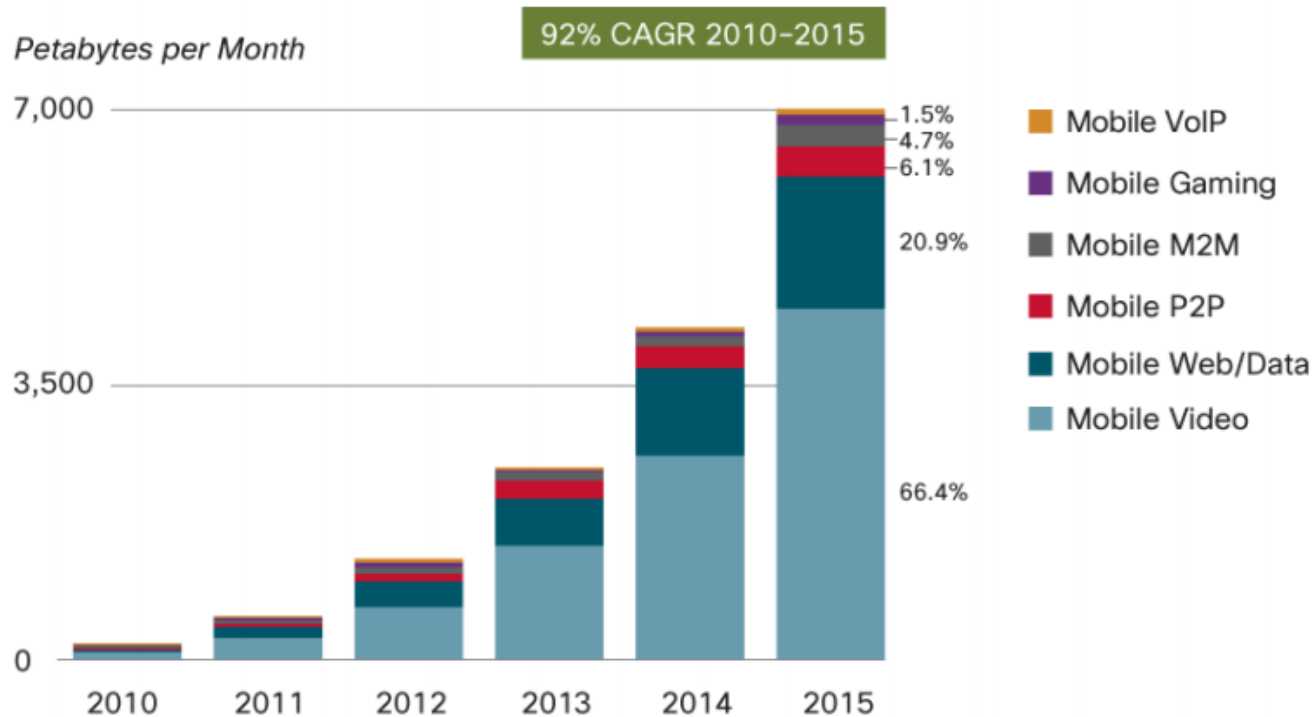
Top 10 Mobile Categories - Year-on-Year Growth

Growth in Media Rich Location Services

Location Based Services

http://www.marketingpilgrim.com/2011/06/mobile-social-media-use-nearly-doubled-in-past-year.html

Mobile Media Traffic Volume Predictions

Petabytes per Month

92% CAGR 2010–2015

7,000 — 1.5%
— 4.7%
— 6.1%

20.9%

3,500

66.4%

0

2010 2011 2012 2013 2014 2015

Mobile VoIP
Mobile Gaming
Mobile M2M
Mobile P2P
Mobile Web/Data
Mobile Video

VoIP traffic forecasted to be 0.4% of all mobile data traffic in 2015.

Source: Cisco VNI Mobile, 2011

Coming of A New Era: Cloud Mobile Media

Advances in Cloud Mobile Computing

- **Cloud mobile computing enables mobile users to engage in new and much richer media experiences**

http://www.opengardensblog.futuretext.com/archives/2010/03/mobile_cloud_co_2.html

Cloud Media System Architecture

Content Provider

Media Cloud

Content Consumer

CPU

GPU

Media Distribution
Media Streaming
Media Processing
Media Storage
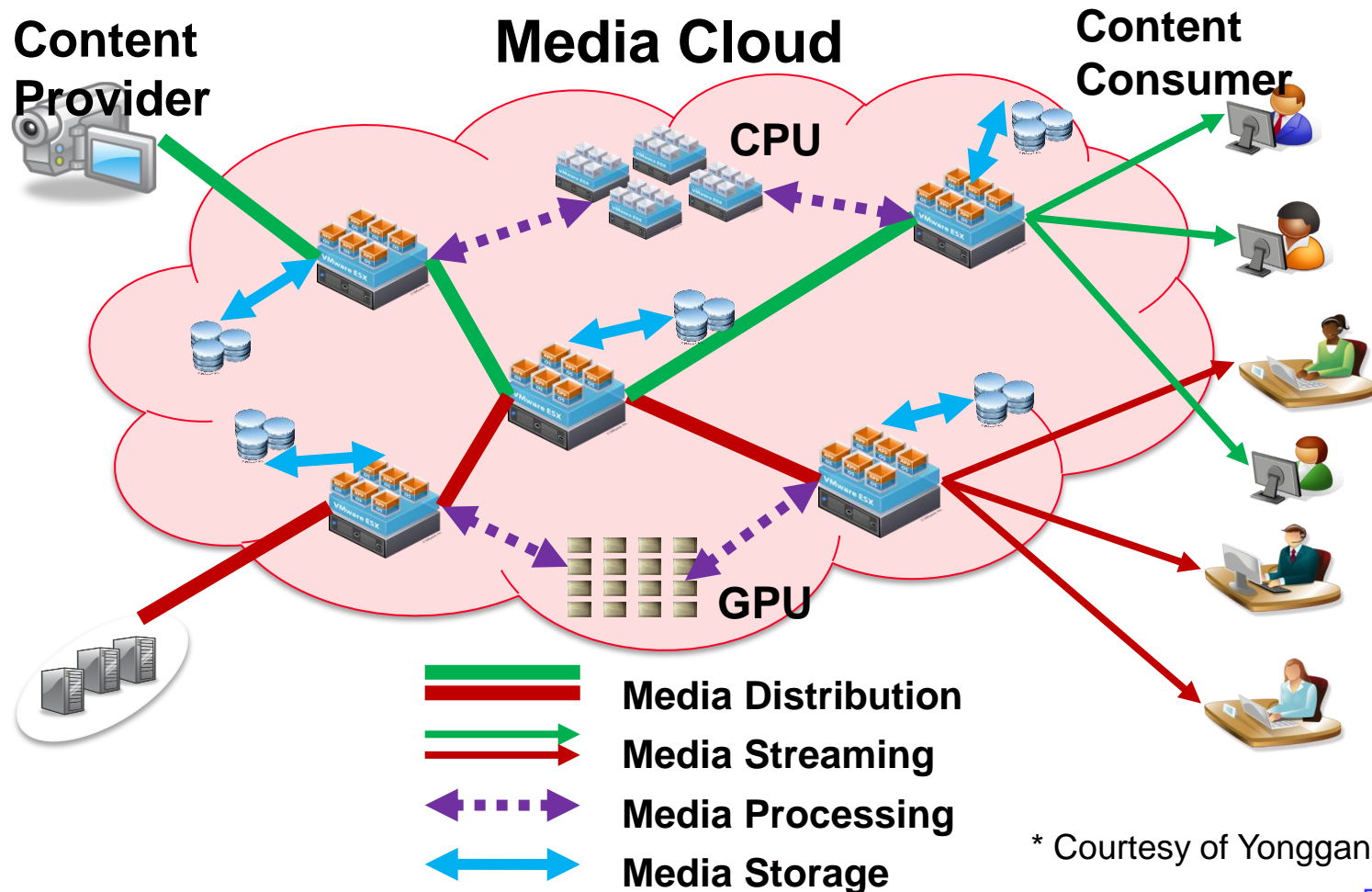
* Courtesy of Yonggang Wen

Cloud-Assisted Media Processing

- ## Cloud-Assisted Media Processing
    - ### Encoding with cloud computing resource
    - ### Transcoding with balanced cloud and edge resources
    - ### Meta data processing with media cloud architecture

- ## Research Issues
    - ### Parallel algorithm design for cloud computing
    - ### Trade-off between computation and media distortion
    - ### Trade-off between encoding performance and energy efficiency
    - ### Trade-off between distortion and delay tolerance

Cloud-Based Media Distribution

- **Cost-optimized media distribution from cloud**
  - **Distribution tree design**
  - **Distributed storage and caching**
  - **Distributed content routing**

- **Research Issues**
  - **Distribution tree algorithm, with respect to different cloud pricing models**
  - **Erasure-based cloud storage algorithm**
  - **Distributed content routing and discovery algorithm**
 - **From core storage to edge distributions**

Cloud-to-Mobile Media Rendering

- ## Context-Aware Media Rendering
  - 2D/3D content, graphical content, immersive content
  - Context: networking condition, outlet capability, user preference, device capability, environment context

- ## Research Issues
  - Distributed rendering design
  - Trade-off between energy and experience in mobile device
  - Energy-efficient media streaming over wireless network
  - Energy-efficient graphic rendering on mobile devices

Cloud Media Service Orchestration

- **Media Service Orchestration**
  - Service publishing and discovery
  - Distributed media service protocols

- **Research Issues**
  - Distributed service routing and discovery algorithm
  - Formal method for secure service orchestration
  - Universal media experience across diverse media outlets
  - Multiuser social media and hybrid traffic fairness

Cloud Media Service Platforms

Software-as-a-Service

Platform-as-a-Service

Internet | Cable | Mobile
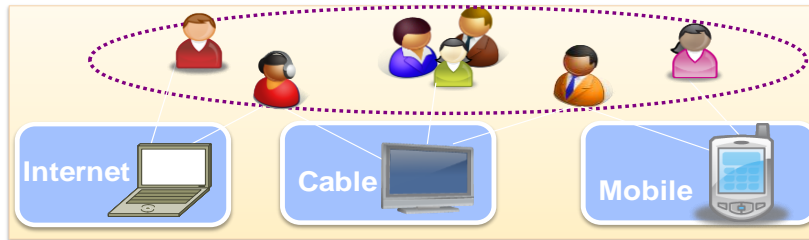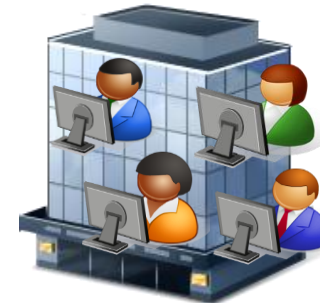
Social Media App | Content Service | 3rd Party Media App

Media Portal | Admin Portal | Media Service API

Inter-Cloud Messaging Bus

Public Cloud | Private Cloud | Community Cloud

Infrastructure-as-a-Service

* Courtesy of Yonggang Wen

Mobile Media Meets Cloud Computing

- **Enables service providers and network operators to offer media services to ever increasing mobile users**
  - with much improved efficiency – leveraging omnipresent clouds
  - with lower cost and better flexibility – virtualized computing
  - with better user experience – ubiquitous broadband access
- **More and more consumers adopting mobile devices as one of their primary media experience platforms**
  - expecting new class of cloud enabled mobile media applications
- **Media rich cloud mobile media services will demand**
  - new and more powerful cloud computing platform and infrastructure capabilities to support

Mobile Cloud Media General Architecture

Media Cloud Servers

Mobile Networks

Core networks

Mobile Devices

Challenges in Cloud Mobile Media

Network Cost

Quality of Service

Expandability

Scalability

Usability

Reliability

Security
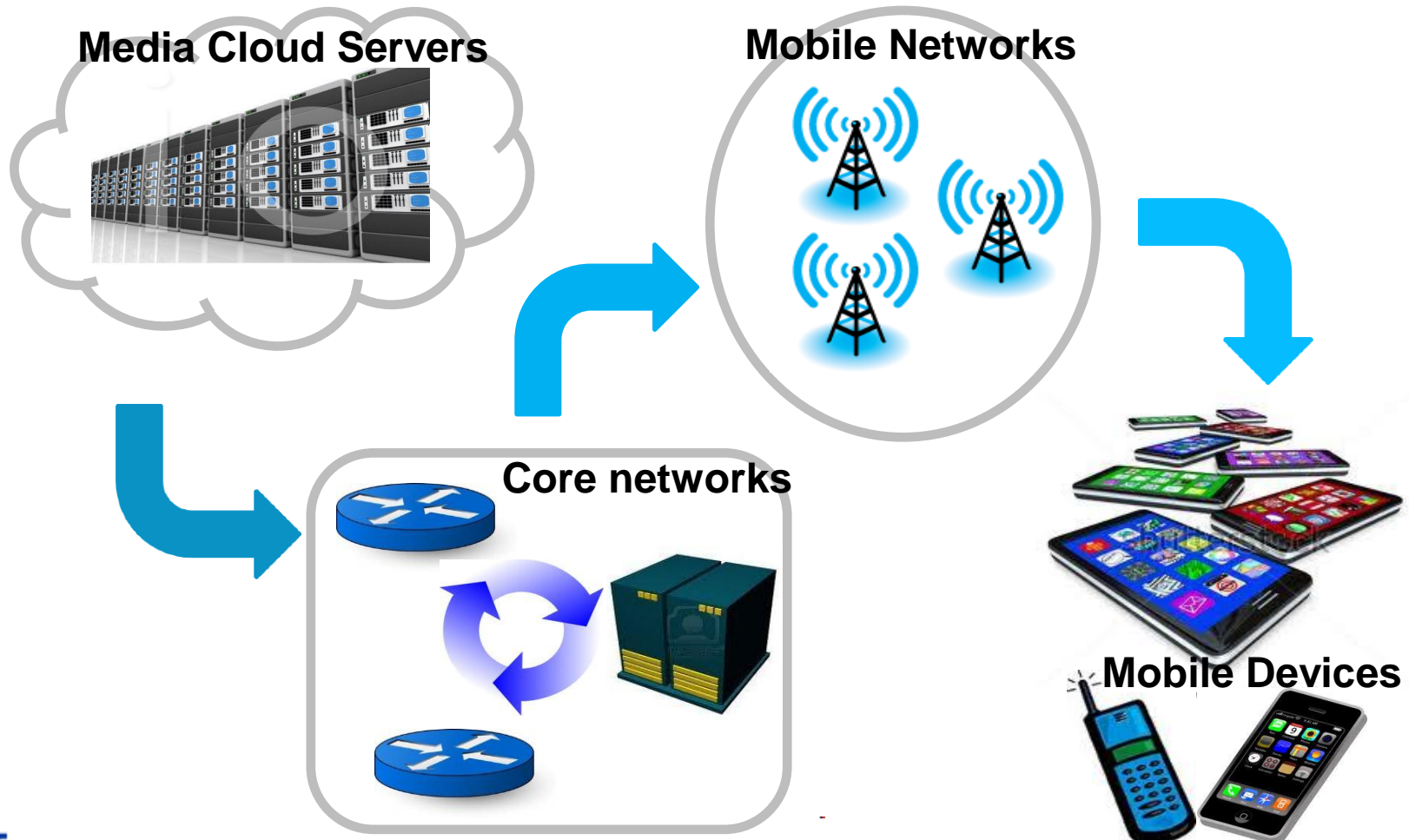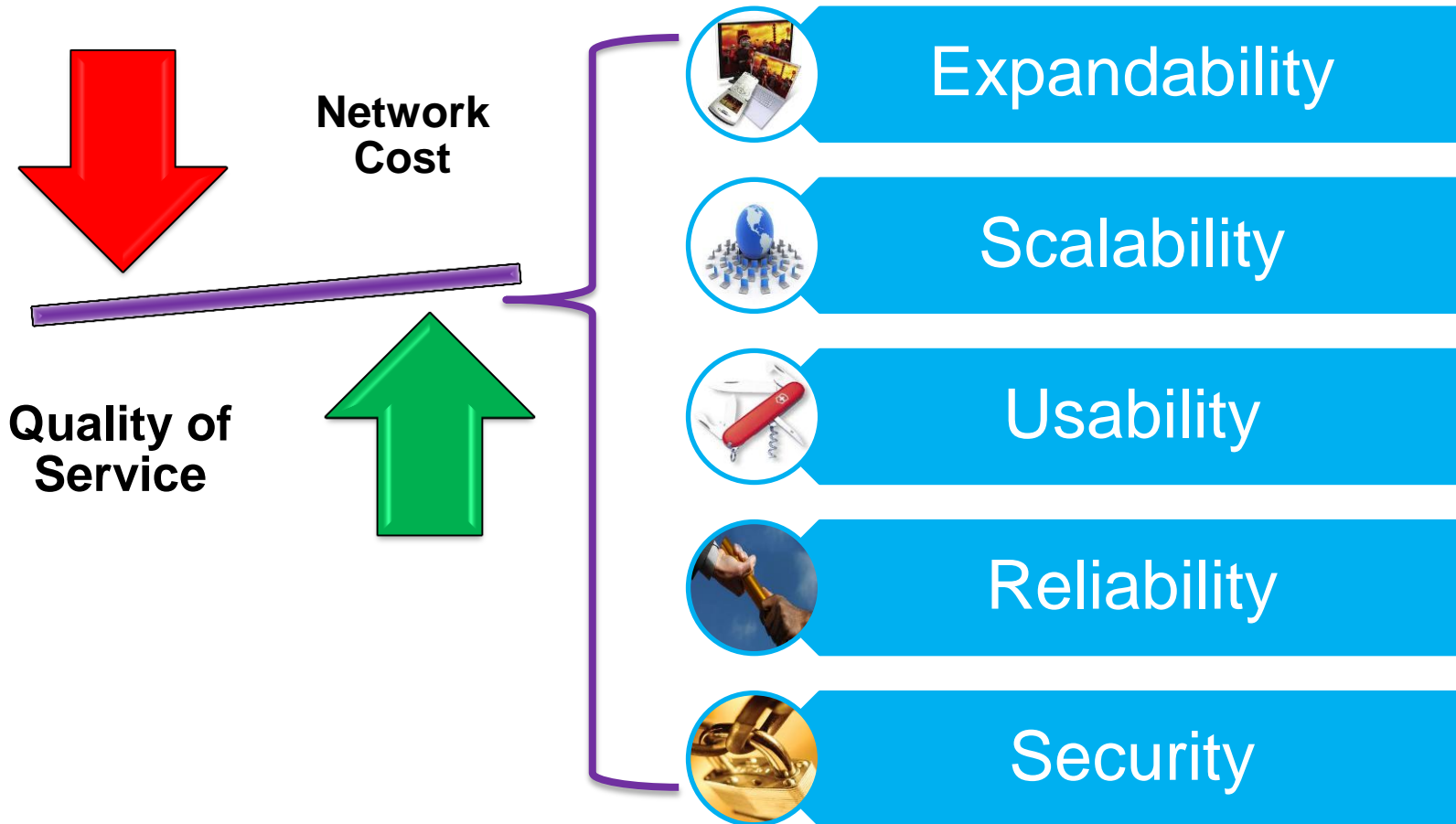
* Courtesy of Yonggang Wen

Challenges in Cloud Mobile Media

- **To ensure QoS for Cloud Mobile Media, several engineering challenges need to be tackled:**

- **Expandability to support any media format and any media outlet**

- **Scalability to support very large number of users**

- **Usability to provide seamless interactive UI design**

- **Reliability to tolerate unpredictable mobile links**

- **Security for new DRM and privacy needs.**

Sample Cloud Mobile Media Applications

Sample Cloud Mobile Media Applications

- **CloudDASH and WiDASH: DASH from cloud to mobile**

- **Distributed video decoding for cloud media**

- **Mobile free viewpoint video from cloud**

- **Cloud-based learning to photograph**

CloudDASH and WiDASH

Cloud Mobile Media Meet DASH

- **DASH – Dynamic Adaptive Streaming over HTTP**

- **Advantage of DASH**
  - **Video quality/resolution adaptation**
  - **Firewall penetration**
  - **Short start-up delay**
  - **Infrequent jitter**
  - **Web Cache, CDN**

- **Extension of DASH to both cloud servers and mobile wireless clients?**
  - **Significant challenges when Cloud Mobile Media meet DASH!**

Cloud Mobile Media Meet DASH

- **Major challenges for cloud-based DASH**
  - **Distributed storage of media contents – streaming from multiple content servers**
  - **Accurate prediction of TCP throughput – balancing the number of TCP requests and the resource reservation**

- **Major challenges for mobile wireless DASH**
  - **Balancing between client driven distributed DASH with centrally scheduling of cellular systems**
  - **Balancing between joint allocation radio spectrum with independent management of multiple DASH flows**

CloudDASH – Multi-Server DASH

- **CloudDASH acquires video in parallel from cloud!**
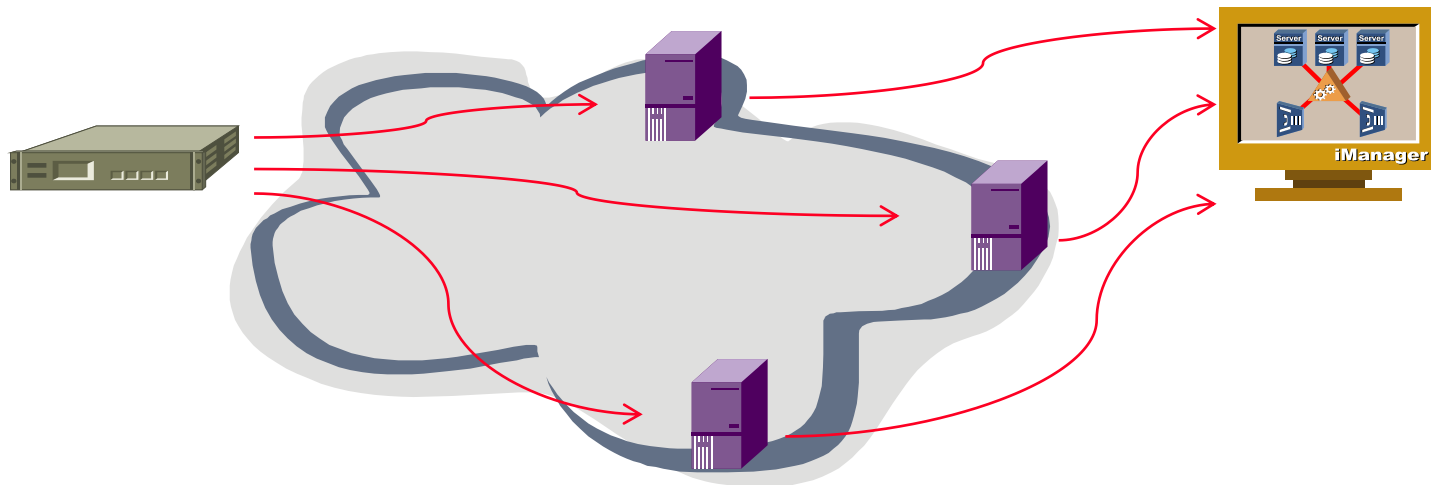
- **CloudDASH makes video 'looks like' data; Caching DASH stream is feasible**

- **Multi-source rate adaptation is enabled**

WiDASH – Mobile Wireless DASH
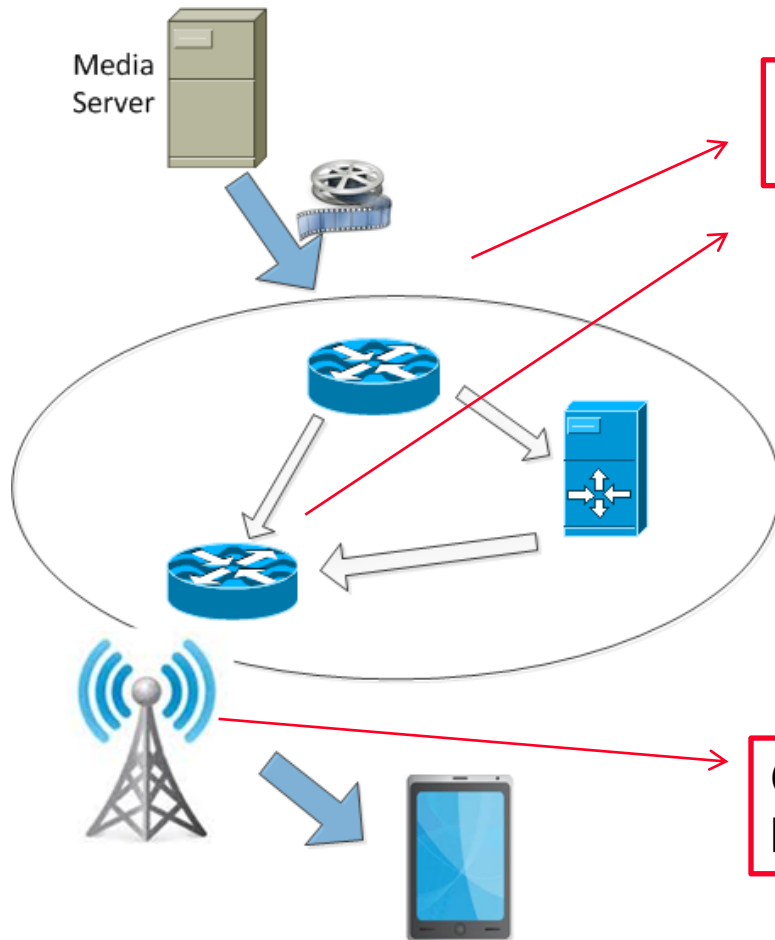
Internet is **distributed** system. DASH is **client driven**, scales well in Internet.

Mismatch #1

Cellular network is **centrally** controlled by radio resource scheduler.

WiDASH – Mobile Wireless DASH
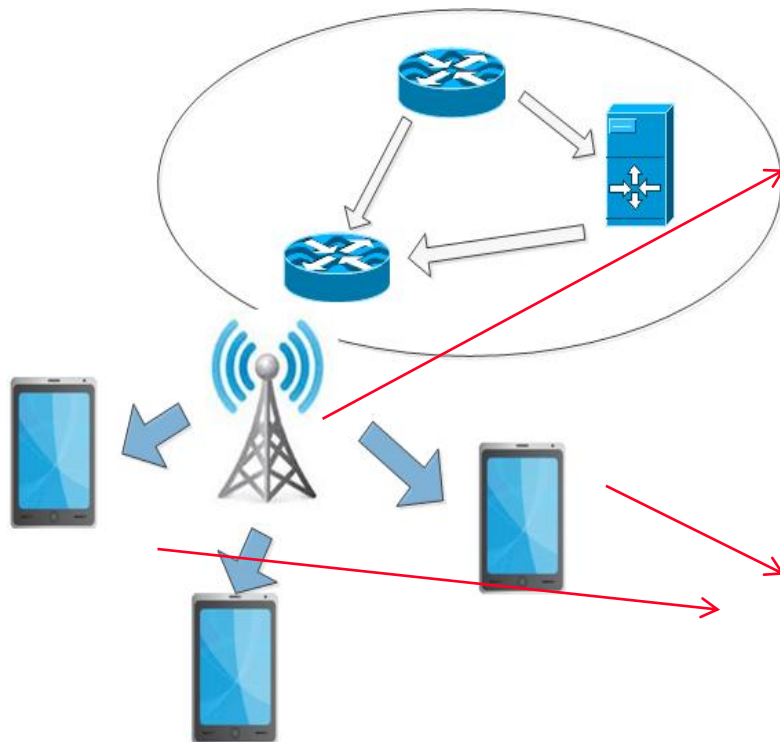
Scheduler jointly allocates spectrum based on multi-user diversity.

Mismatch #2

DASH is client driven. Multiple DASH flows adapt rate independently.
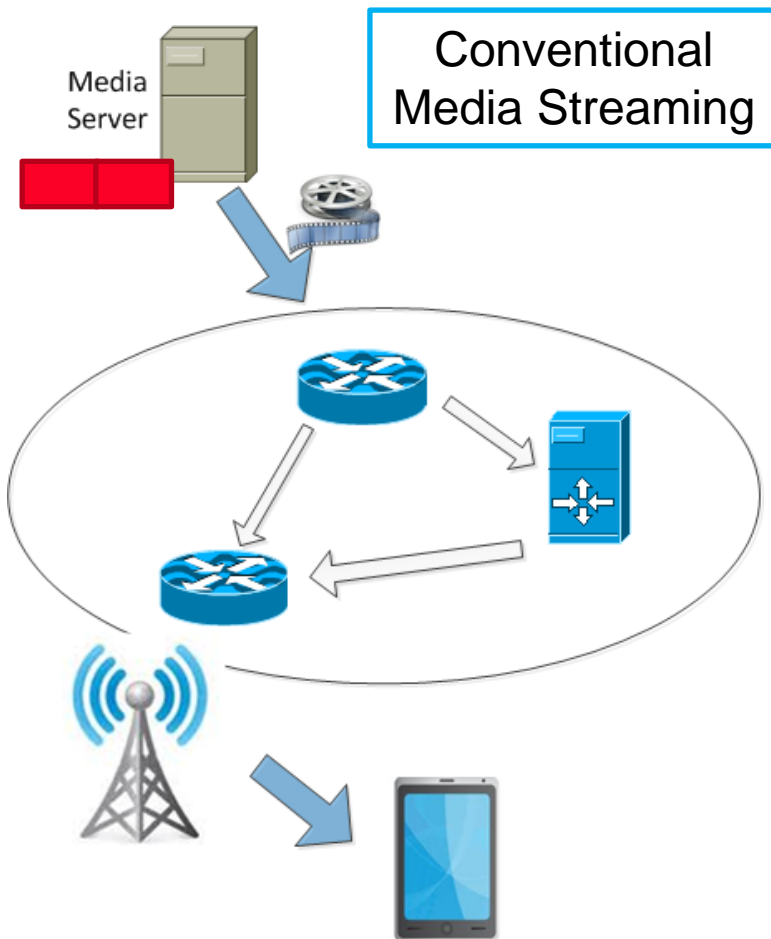
New Proxy Design in WiDASH
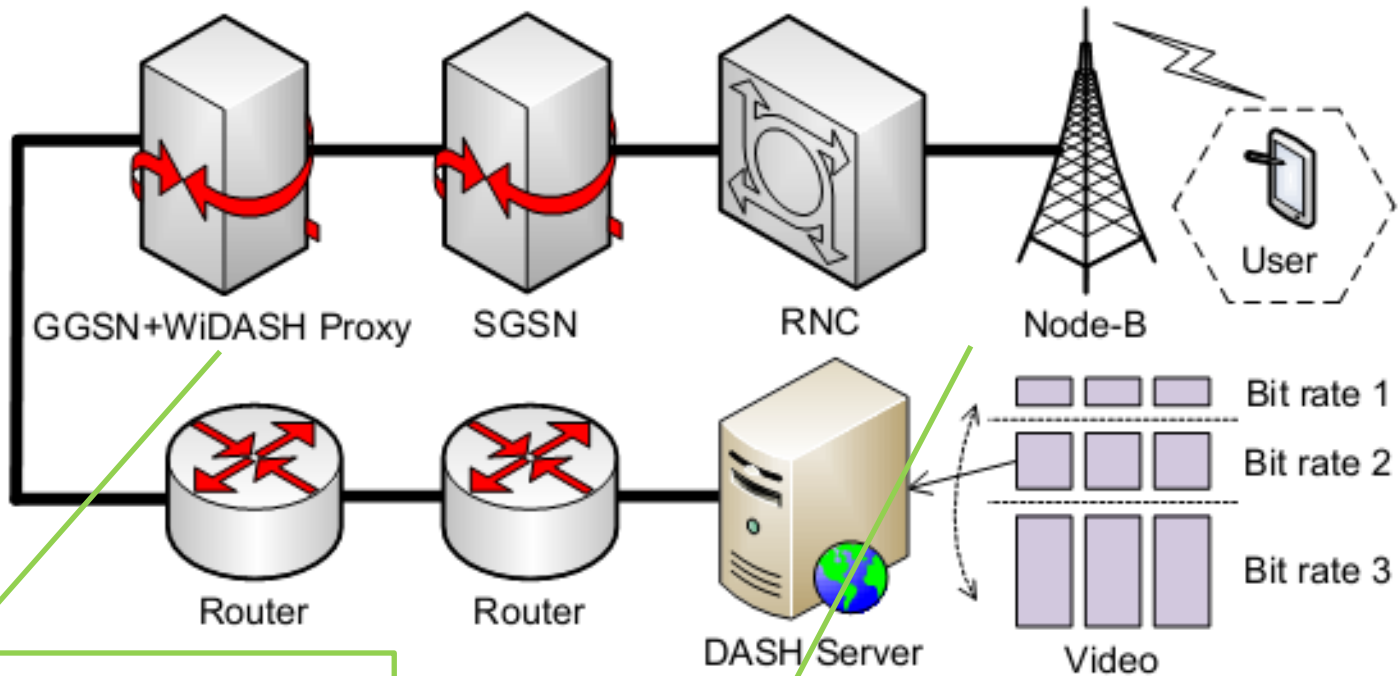
WiDASH Proxy

Scheduler

New Proxy Design in WiDASH

- **New split-parallel TCP architecture for WiDASH**

Parallel TCP

Split TCP
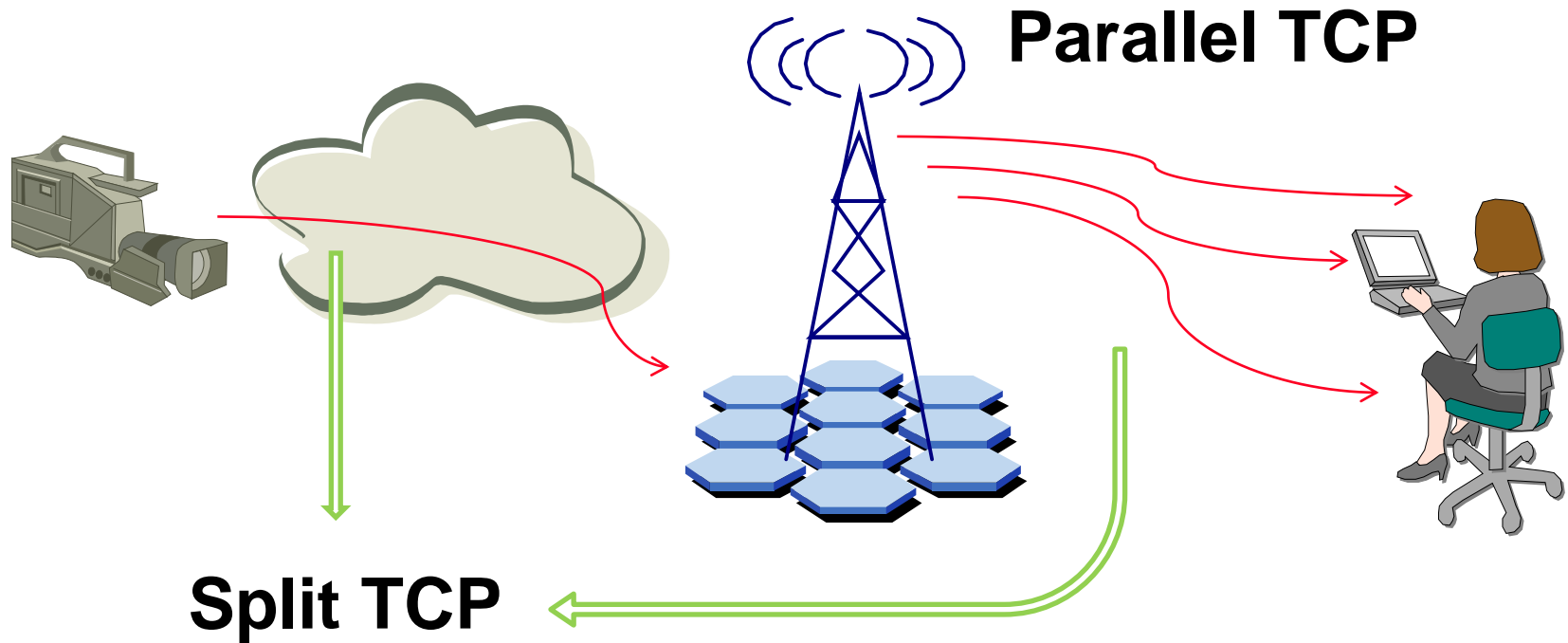
Distributed Decoding for Cloud Media

Cloud Aware Distributed Decoding

Media Server

Conventional Media Streaming

Cloud Media

Distributed Decoding for Cloud Media

Conventional Media Streaming
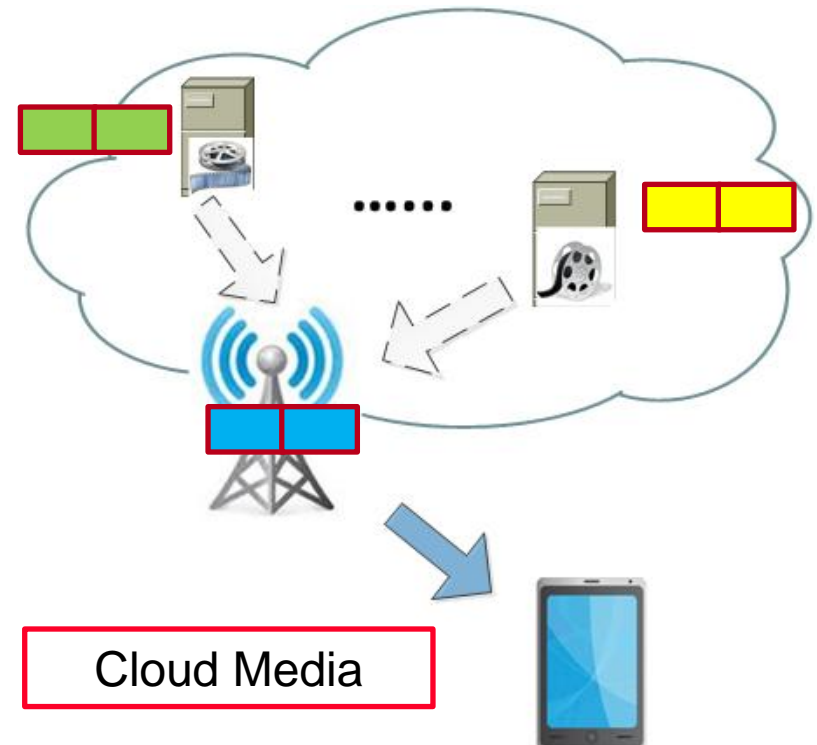
Cloud Media
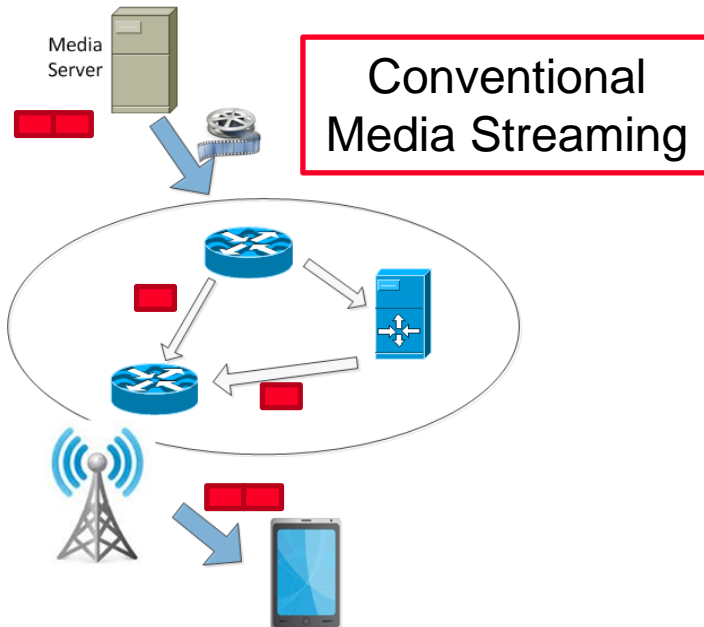
Single Compressed Version for a single video sequence is transmitted

Router obtains different fragments from multiple sources and mobile device will receive a merged bitstream
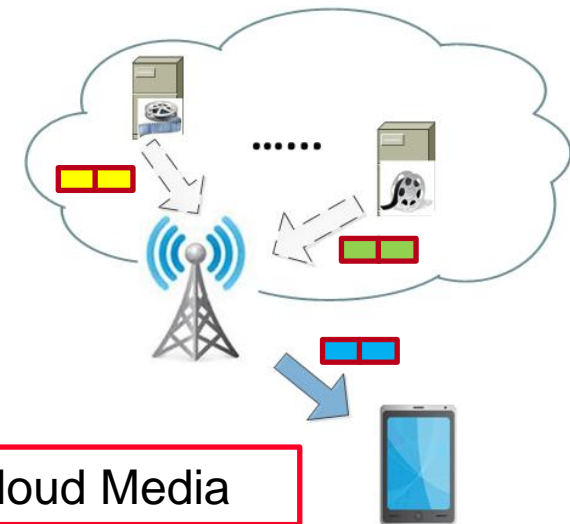
Multiple Compressed Versions for a single video sequence are transmitted

Base station obtains multiple versions from multiple sources but mobile device can only decode a single bitstream

Distributed Decoding for Cloud Media

Many To One Mapping

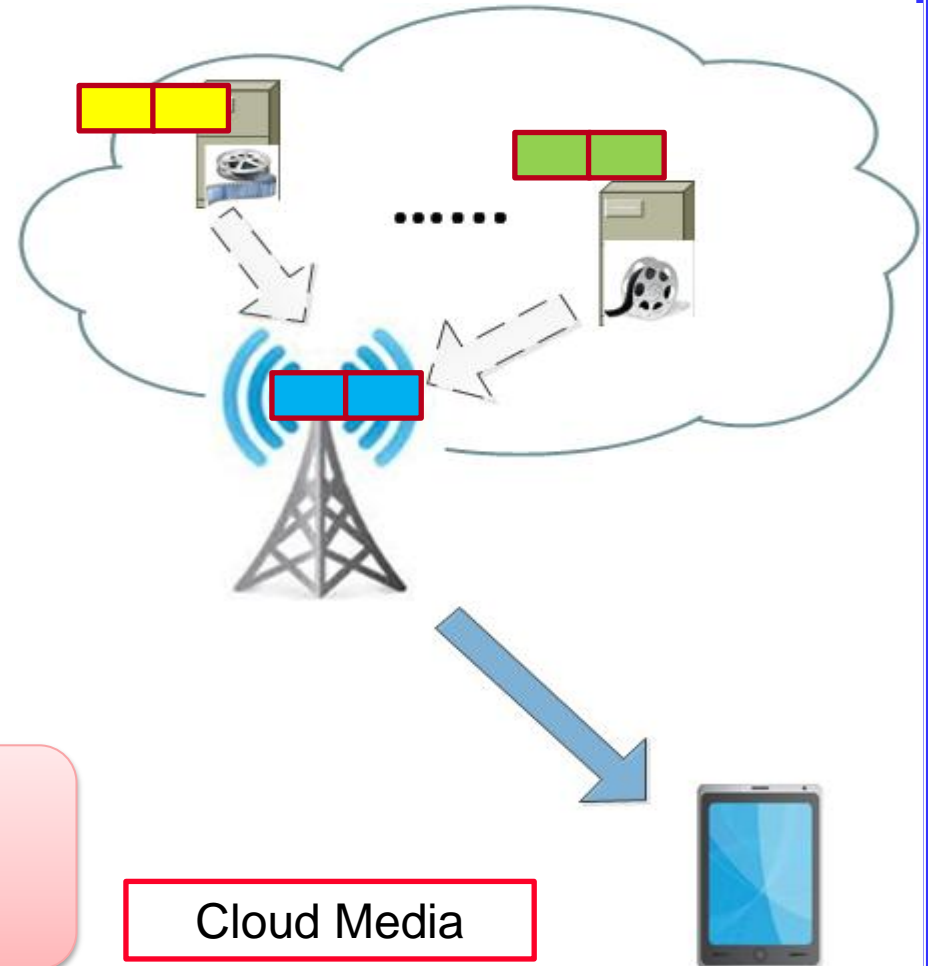Select the one with the best quality (*w. or w/o bandwidth constraints*)
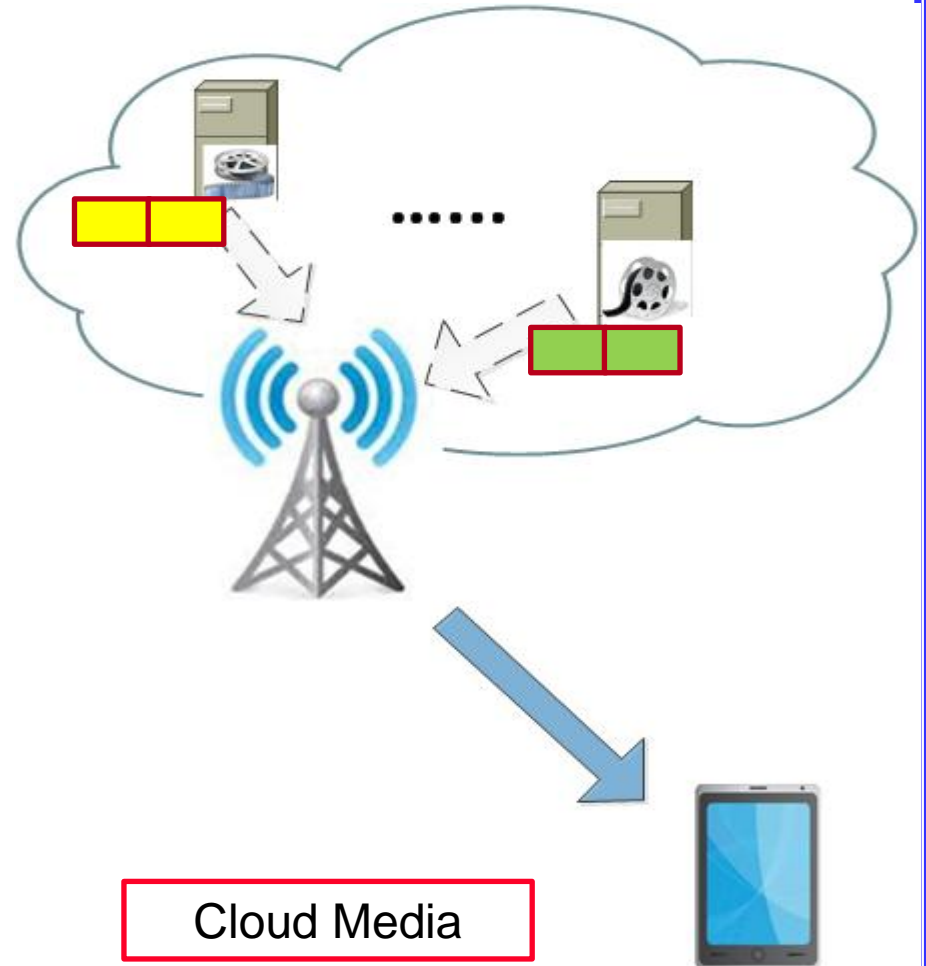
Cloud Media

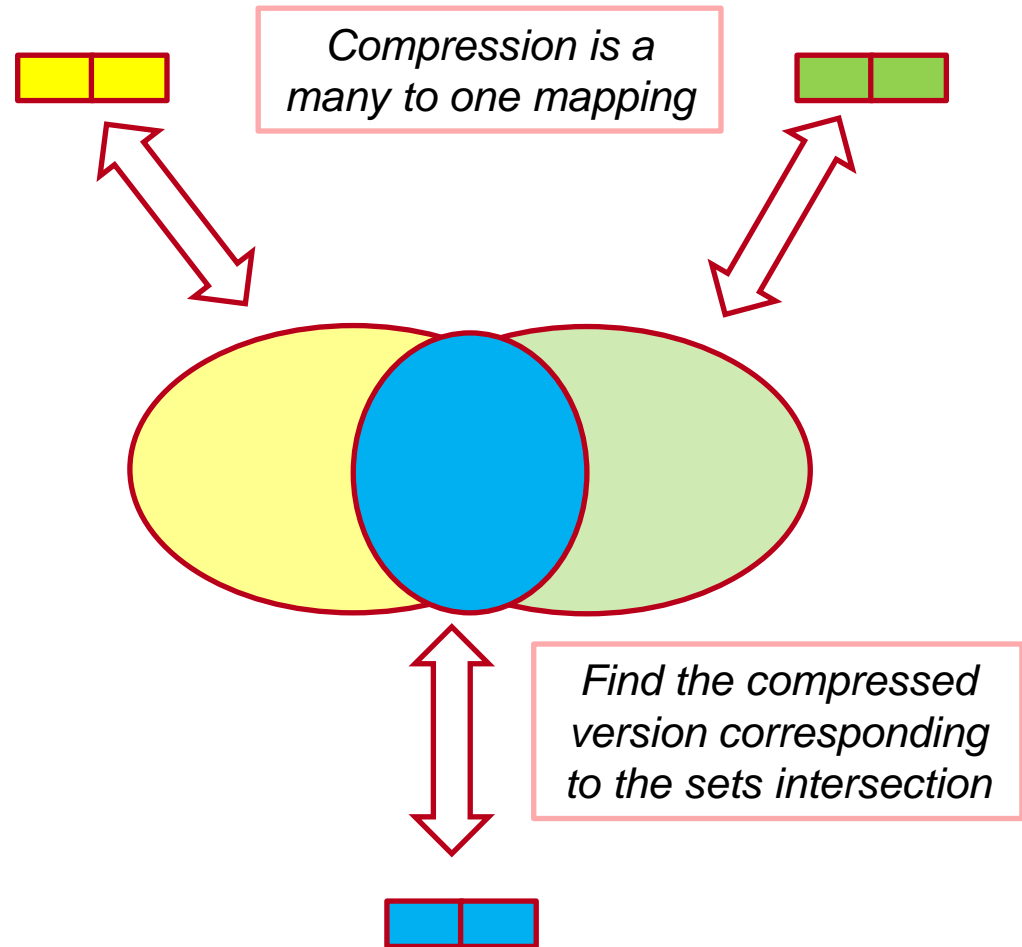# Distributed Decoding for Cloud Media

Many To One Mapping

Select the one with the best quality (*w. or w/o bandwidth constraints*)
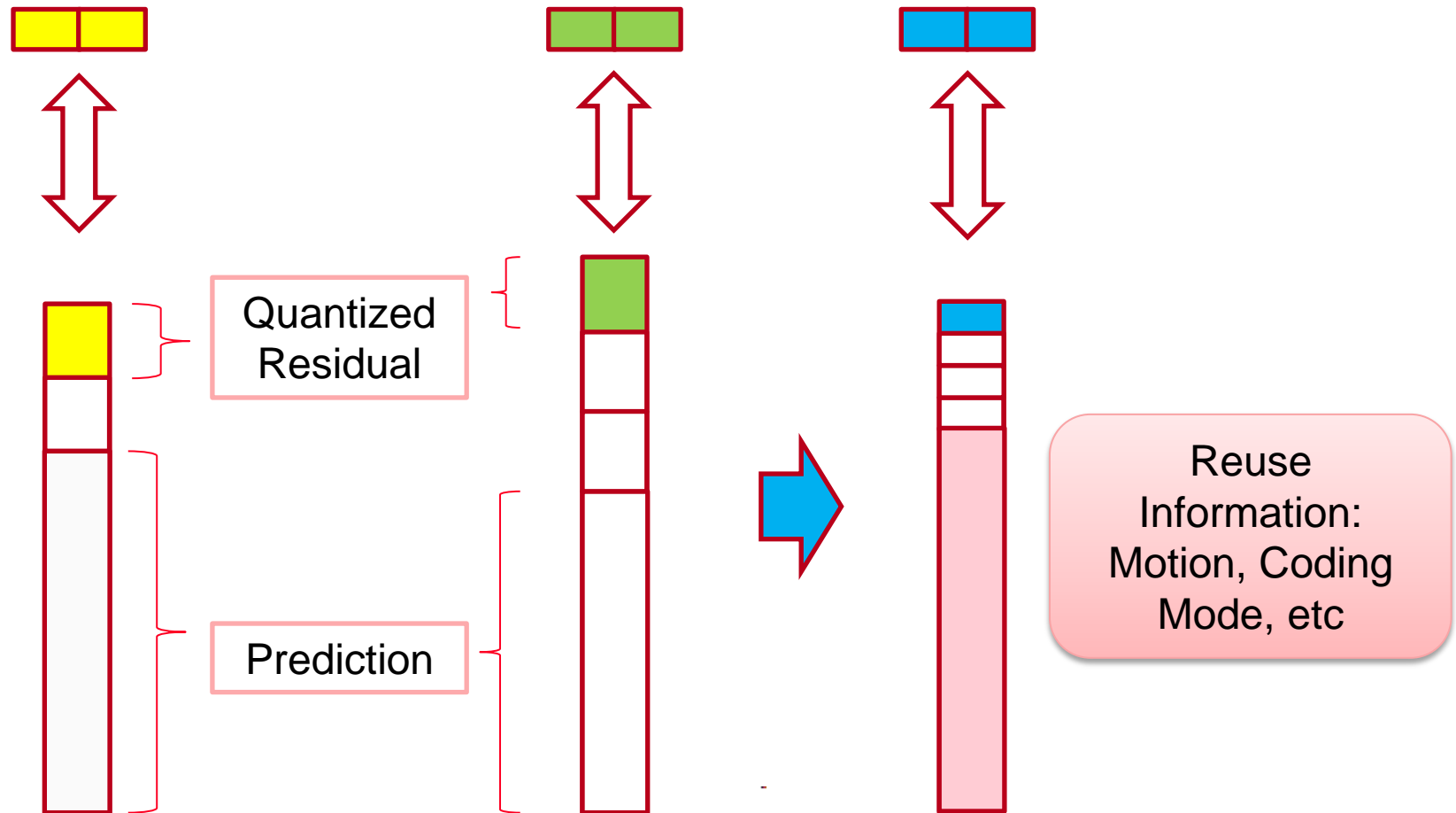
Can we get a better quality?

Cloud Media

Distributed Decoding for Cloud Media
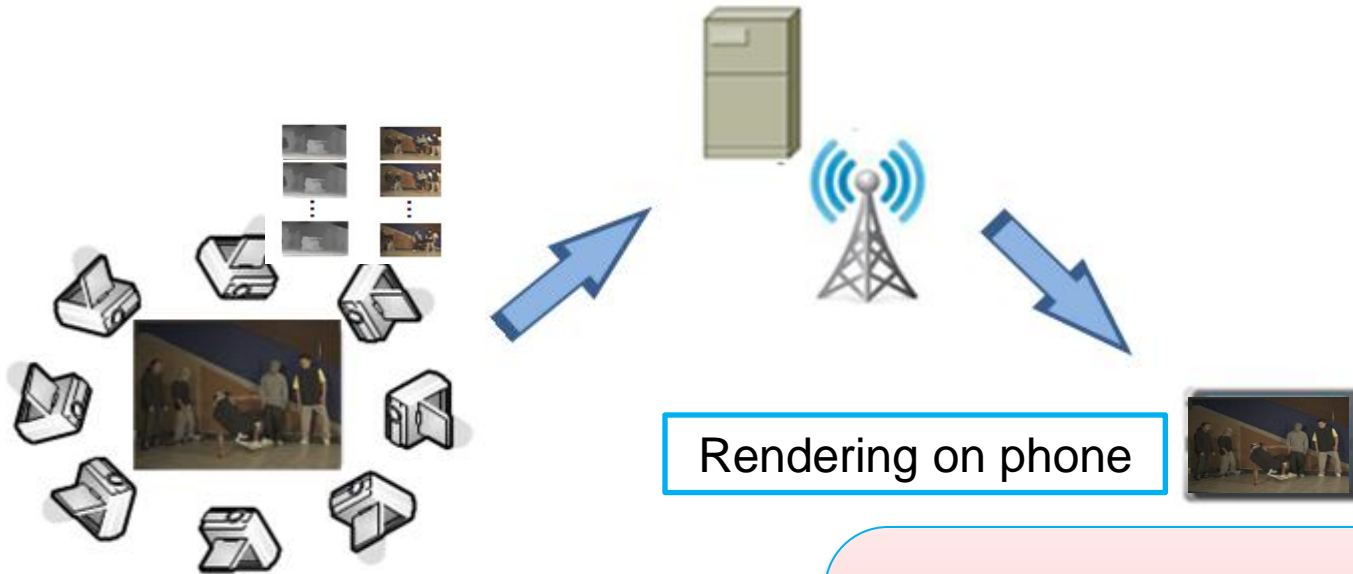
Merge multiple bitstream→Obtain sets intersection

Compression is a many to one mapping

Find the compressed version corresponding to the sets intersection

Transcoder Design - Many to One Mapping

Quantized Residual

Prediction

Reuse Information: Motion, Coding Mode, etc

Mobile Free Viewpoint Video from Cloud

Challenges of FVV on Mobile Phone

Rendering on phone

FVV
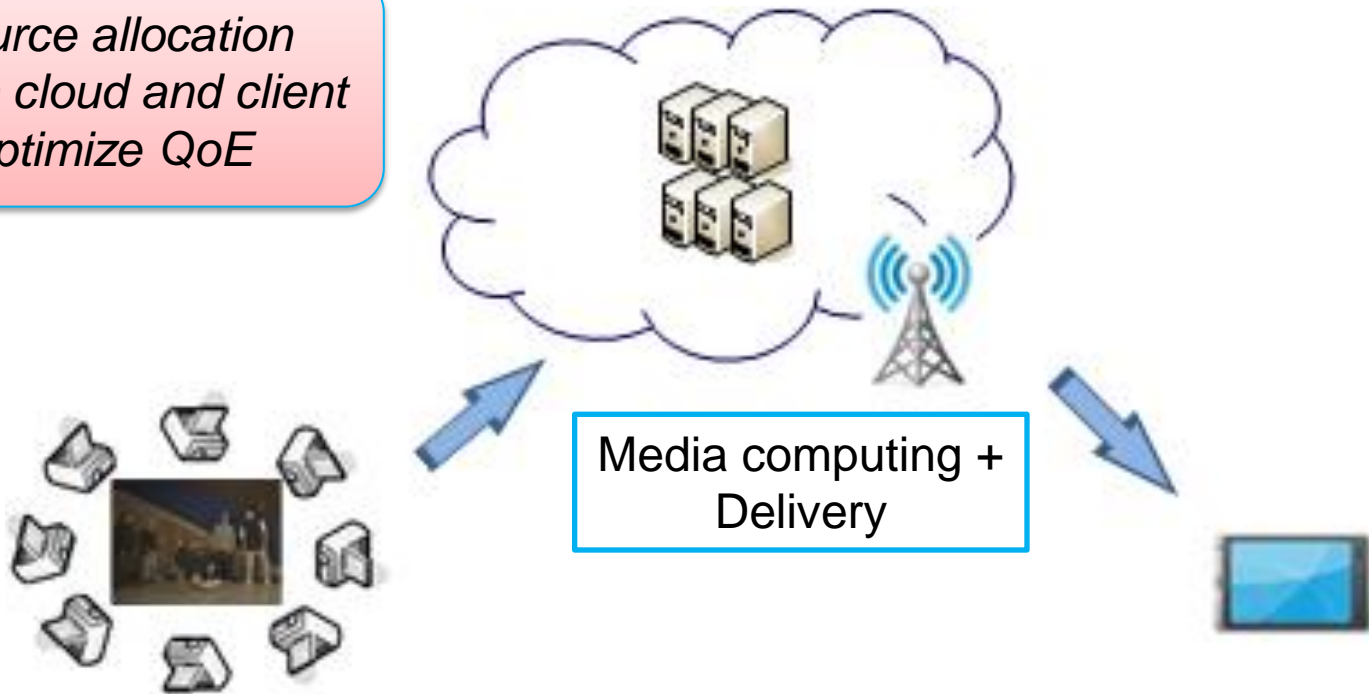- Large data size: N GRB + N depth
- High computation cost: rendering for synthesis views
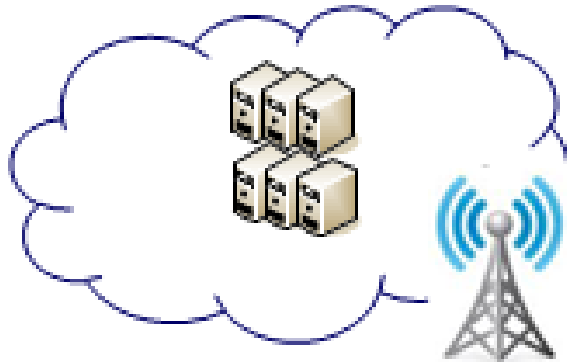
Wireless & Mobile Phone
- Limited bandwidth and dynamic link condition
- Limited computation resource on mobile phone

Cloud based FVV for Mobile Phone

Resource allocation between cloud and client to optimize QoE

Media computing + Delivery

Cloud based FVV for Mobile Phone

Current view request
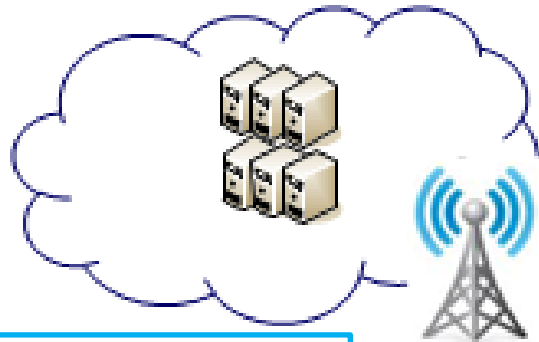
Current stream

Rendering on Cloud

Rendering allocation: quality-optimal cloud rendering
- All rendering will be conducted in cloud according to the request viewpoint

Switch delay exists. Can we conceal the delay?
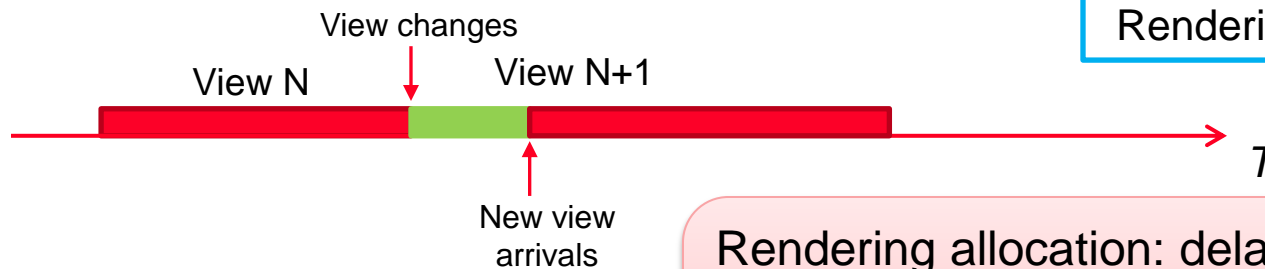
Cloud based FVV for Mobile Phone

Current view request

Current view stream

Rendering on cloud

Rendering on phone

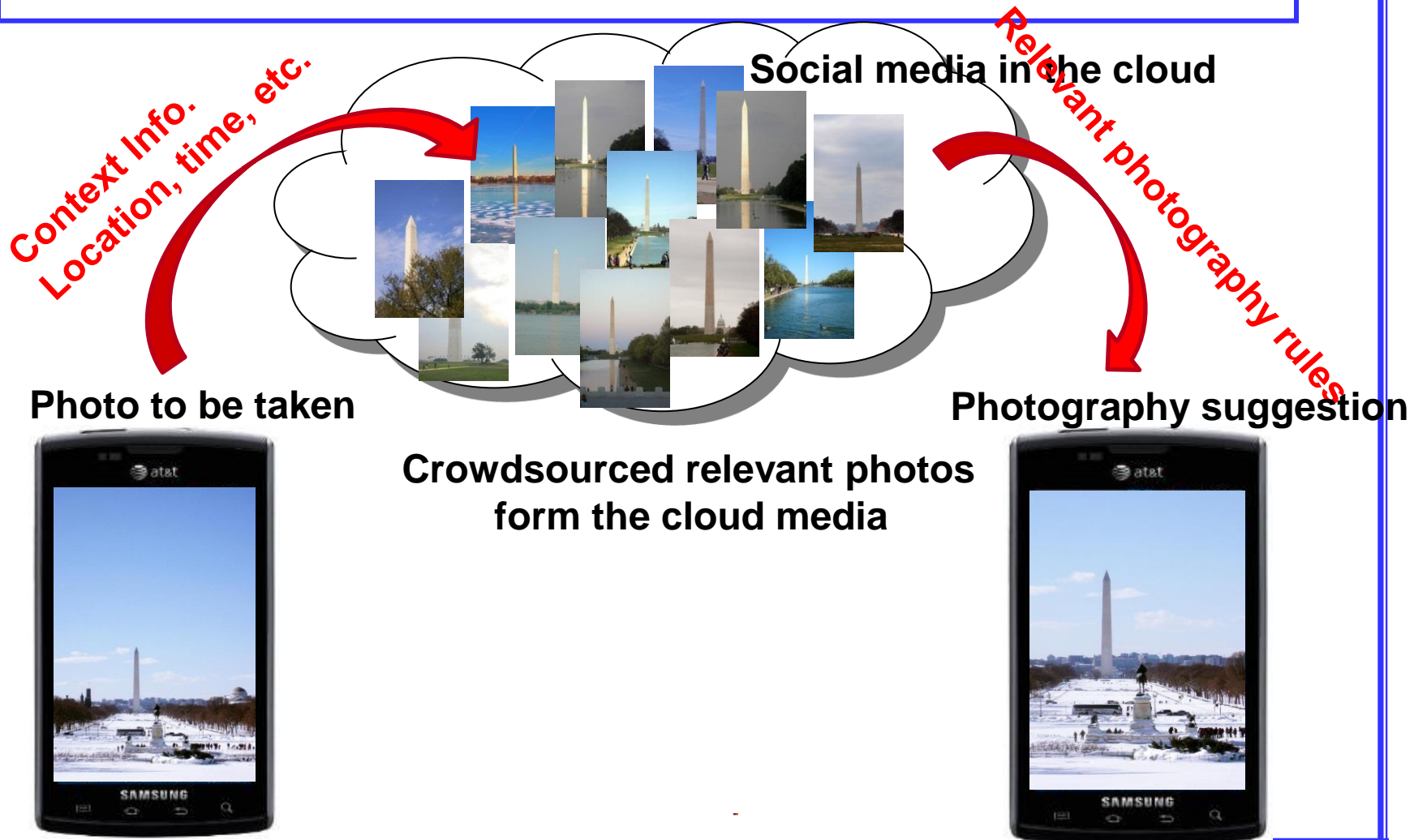View changes

View N

View N+1

New view arrivals

T

Rendering allocation: delay-optimal cloud rendering
- Local rendering to minimize the switch delay

Cloud-based Learning to Photograph

Cloud-Based Learning To Photograph

Context Info.
Location, time, etc.

Social media in the cloud

Relevant photography rules

Photo to be taken

Crowdsourced relevant photos form the cloud media

Photography suggestion

Cloud-Based Learning To Photograph

Scene Context:
GPS: (37.809333,-122.475667)
Time: 10:10:33 am

Input Scene

GPS: 37.809333 - 122.475667
Time: 2009-11-08 10:29:01am
Number of favors: 0
Number of views: 19

GPS: 37.809333 - 122.475667
Time: 2009-11-08 10:05:44am
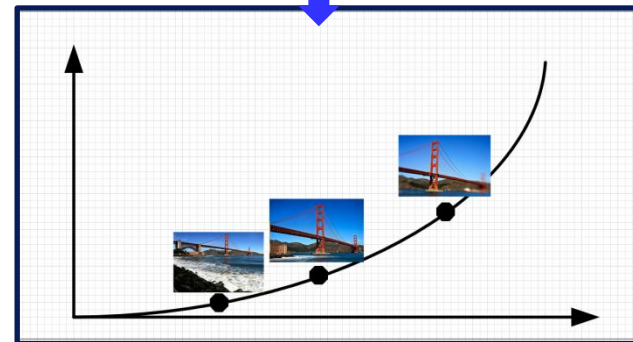**Number of favors:** 1
Number of views: 34

GPS: 37.809333 - 122.475667
Time: 2009-11-08 10:03:14am
Number of favors: 1
Number of views: 77

Contextual Image Search

Composition Learning

Photographing Suggestion

Cloud-Based Learning To Photograph

- **Examples of photograph suggestions**

(a) input scene (b) suggested view by our proposed approach (c) suggested view by visual attention

Cloud-Based Learning To Photograph

- **Examples of photograph suggestions**

(a) input scene (b) suggested view by our proposed approach (c) suggested view by visual attention
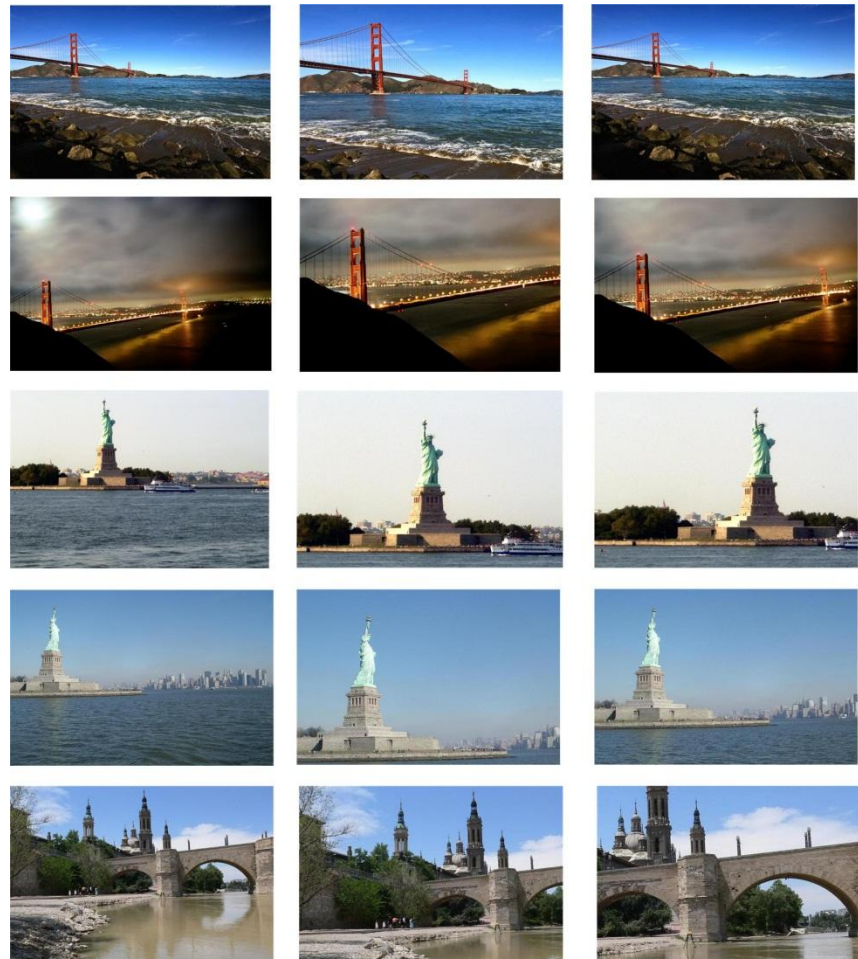
(a)   (b)   (c)

Summary and Looking Ahead

- **Cloud Mobile Media is an emerging research area which will have significant impact in both technology advancement and people's daily life**

- **There are numerous research opportunities in cloud mobile media as they tend to cross the boundary between multiple engineering disciplines**

- **New technical barriers will need to be overcome as we build up:**
  - **better cloud infrastructures for media services**
  - **enhanced networking capabilities for media delivery**
  - **enriched mobile devices for media access and rendering**

Acknowledgements

- **Several research projects presented in this talk are carried out by my PhD students:**
  - **Wei Pu**
  - **Shujie Liu**
  - **Dan Miao**
  - **Wenyuan Yin**
- **My research has been supported by:**
  - **NSF**
  - **Microsoft**
  - **Intel**
  - **Kodak**
  - **Huawei**

Thank You!

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