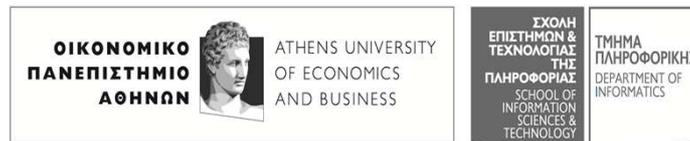


# Mobile QoE and Service Composition

**Vasilios A. Siris**

Mobile Multimedia Laboratory  
Department of Informatics  
Athens University of Economics and Business  
[vsiris@aueb.gr](mailto:vsiris@aueb.gr)  
<http://www.aueb.gr/users/vsiris/>  
COST ACROSS, Larnaca, 23-24/10/2014

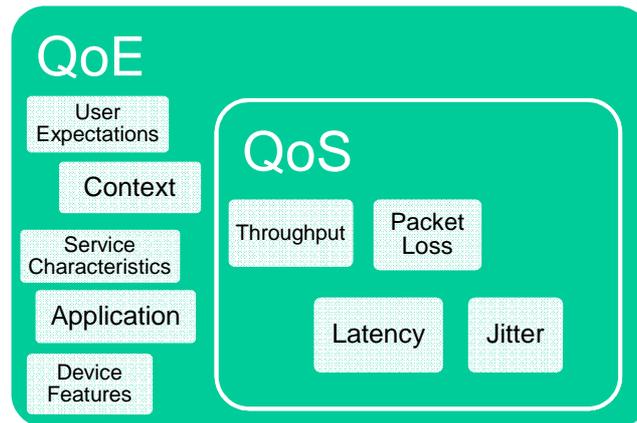


## Quality of Experience (QoE)

- Broadly defines how a user perceives the usability or degree of satisfaction of a service
- ITU-T QoE definition: the overall acceptability of an application or service, as perceived subjectively by the end user.
  - includes the complete end-to-end system effects (client, terminal, network, etc.)
  - may be influenced by user expectations and context
- Important from user perspective as well as network perspective (so that providers can improve QoE for their customers)

## QoE vs. QoS

- QoE: a user-centric characterization of service quality
- QoS: a network-centric characterization of service quality



## Why Mobile QoE?

- Important to characterize and optimize mobile QoE given:
  - increasing reliance on mobile networks
  - exponentially rising demand for mobile data services: 13-fold increase in global mobile data traffic in the period 2012-27 [Cisco VNI 2014]
- Challenging to assess QoE in mobile networks than in fixed networks due to several reasons:
  - high levels of dynamism
  - context (location, mobility)
  - diversity in terms of device characteristics, resource constraints, etc.

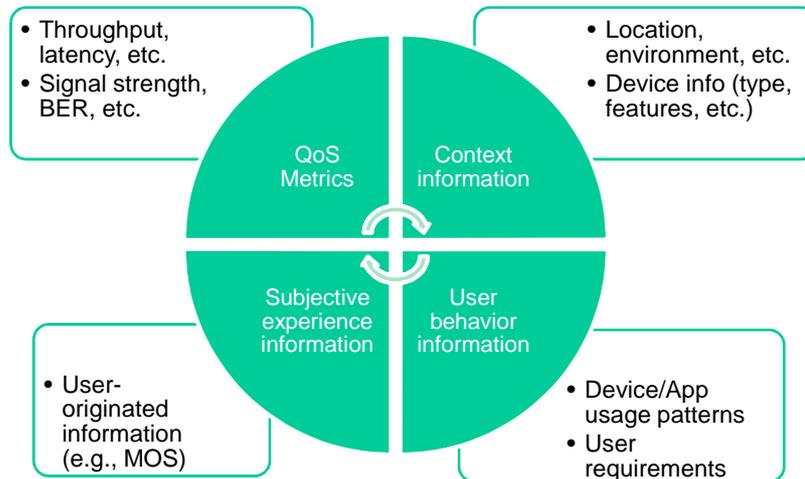
## Components of a QoE Framework

- QoE model: defines how QoE is quantified, which QoS factors influence QoE and how
- QoE measurement: involves how QoE/QoS is measured or predicted
- QoE-aware management and control

## QoE in Mobile Networks

- Mobile operators typically use theoretical models and field measurements at network planning/rollout stage to optimize coverage and performance
- But mobile performance is location and time dependent, dominated by air interface
- Relying on models leads to significant deviations between “expected” and user-perceived performance due to:
  - Device diversity
  - Context (location, environment, device placement, orientation, etc.)
  - Traffic dynamics: peak and off-peak periods
  - Performance of different applications on battery-operated mobile devices not captured via QoS metrics alone
  - Network usage profiles vary between users

## Many factors influence QoE



## QoE estimation approaches

- **Subjective Approach**
  - E.g., via Mean Opinion Score (MOS)
  - Requires user involvement
- **Objective Approach**
  - Uses a parametric model without user involvement.
  - Model is a function of the network-level QoS, and can additionally depend on application, context, etc.



## Mapping of Network-Level QoS to QoE

- **Logarithmic:** a multiplicative change of the QoS has a linear influence on the QoE
  - E.g., video streaming QoE logarithmically dependent on bit-rate
- **Exponential:** an additive change of the QoS has a multiplicative influence on the QoE
  - E.g., VoIP QoE exponentially dependent on loss
- **Linear:** an additive change of the QoS has a linear influence on the QoE
- **Power:** a multiplicative change of the QoS has an exponential influence on the QoE

## Key disadvantages...

- Schemes require subjective testing
  - Even most the parametric models
  - Rating screens usually skipped
- They target to capture typical/average user
  - There is no “average” mobile user
  - Very high variation in how mobiles are used, in addition to variation in context

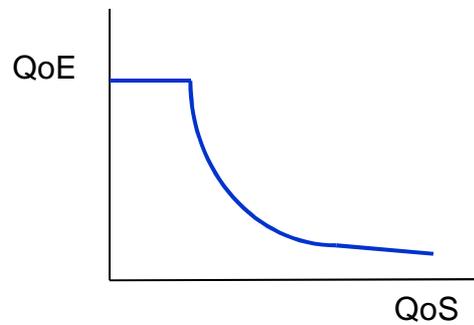
## Mobile QoE = Personalized QoE

- There is no “average” mobile user
- Cannot use existing models without adjustment/personalization
- Alternative: use indirect *user engagement* (user behaviour) metrics that are influenced by QoE
  - Does **not require explicit user involvement**

## User engagement / behavior

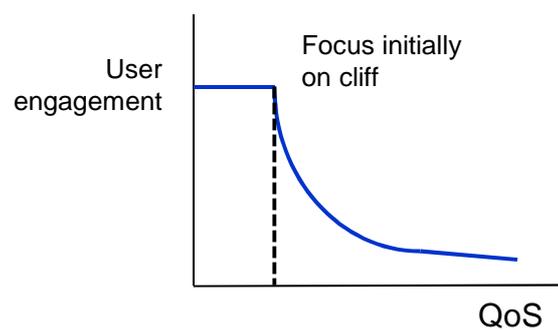
- Video user engagement metrics
  - Video pausing, abandonment, skipping
  - Percentage of video viewed
- Web user engagement metrics
  - Abandonment, revisits
- Service user engagement metrics
  - Abandonment, percentage experienced, revisits
- Important to have **causal relation** between user engagement metric and QoE
  - Correlation not enough

## From QoE



- Examples:
  - VoIP QoE versus pkt loss
  - Web QoE versus delay

## From QoE to user engagement/behavior

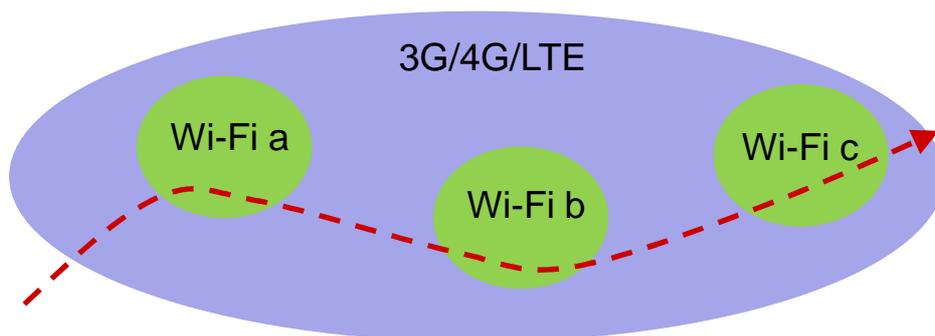


- Key advantage: user engagement can be implicitly measured
  - modified app or client-side traffic analysis
  - **non-intrusive**

## Mobile service composition

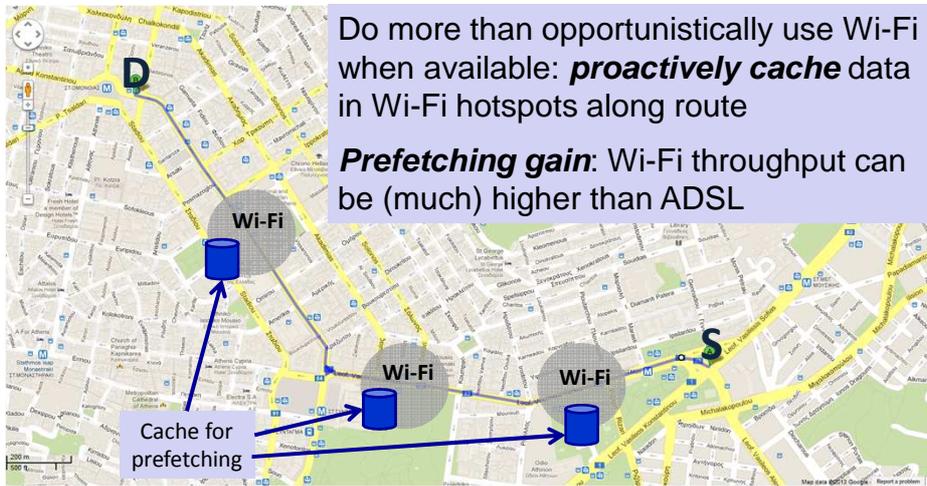
- QoE/QoS: availability & reliability are important
- Mobile context:
  - Location
  - **Mobility (i.e. route a mobile follows)**

## Exploiting mobile route prediction



- Different characteristics of cellular and Wi-Fi
  - Cellular: wide coverage, higher cost
  - Wi-Fi: higher throughput (sometimes), more energy efficient
- Mobile route prediction:
  - Wi-Fi networks encountered, when and how long
  - Can be used for improved **quality prediction**
  - Can be used to take **proactive actions**

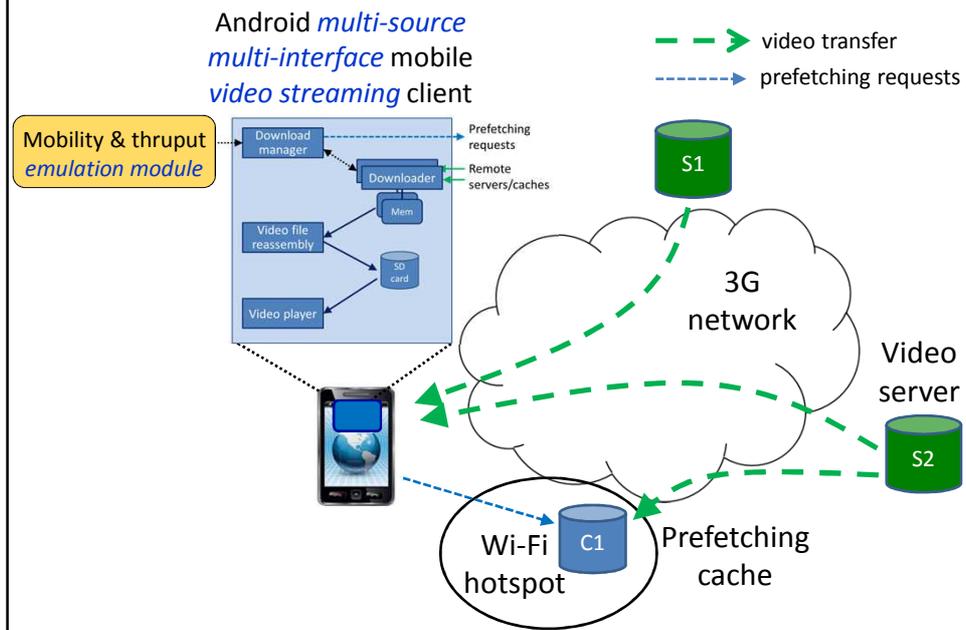
## Proactive caching can exploit mobility/throughput information



Key issue: **scheduling data transfer**

## Multi-source mobile video streaming

Android *multi-source multi-interface* mobile video streaming client



## Take-away points

- Mobile QoE = **Personalized** QoE
  - **individual user** QoE rather than **aggregate users** QoE
- **User engagement / behavior** metrics
  - has been considered for **aggregate users QoE**
  - measured **without user involvement**
- Mobile context: **mobile route prediction** is possible and can assist in
  - **quality prediction**
  - **mobile service composition/adaptation**

## Collaborates

- Mahesh K. Marina, Konstantinos Balampekos, The Univ. of Edinburgh
- Dimitris Mimopoulos, Christos Boursinos, Athens Univ. of Economics and Business

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