Doctoral Program in Computer and Control Engineering (XXX Cycle)

A New Modular E-Learning Platform Integrating an Enhanced Multimedia Experience

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Motivations

- Achieve an out-of-the-box **enhanced multimedia experience**
  - Analyze existing solutions and implementations
  - Study the Quality of Experience under different conditions
  - Propose an optimized framework for dynamic adaptive streaming
- **Unify** the scattered e-learning panorama
  - Develop an easy to use web approach
  - Integrate existing technologies avoiding migrations
- Allow **custom and adaptive** approaches to learning

Challenges – 1 of 2

- **Transmission of multimedia** objects (e.g. texts, images, A/V) is becoming mainstream on the Internet
- Smart devices allow **ubiquitous Internet access** forcing content providers to re-engineer the delivery infrastructures
- Addressing the **Quality of Experience** challenge becomes a key priority

Challenges – 2 of 2

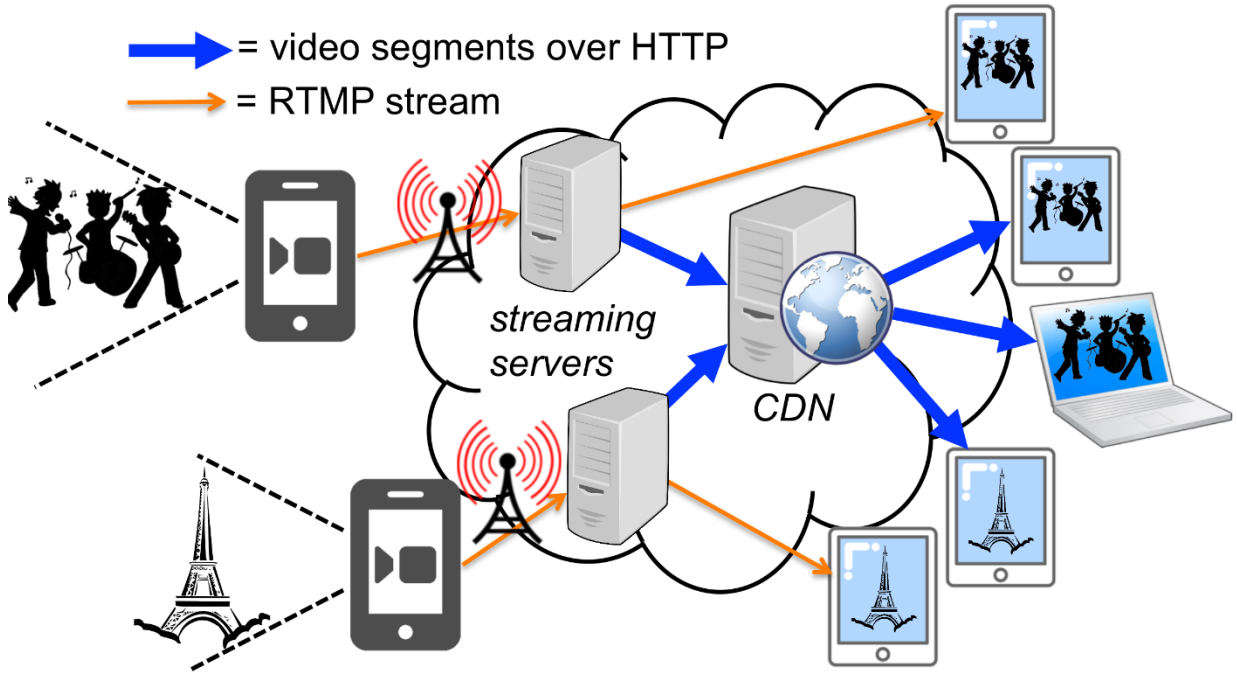
- Modern e-learning became a **browser centered** experience
- Majority of Learning Objects available in **multimedia format**
- Increasing need to **store, license and classify** them for further exploitation
- Strong dependence on **streaming technologies** to efficiently serve them around the world
- Transition towards **context aware** smart learning systems

Multimedia Communications

- **Distribution** of multimedia contents online is becoming mainstream (e.g., Youtube, Vimeo)
- Transition from the usual UDP/RTP based services to **TCP/HTTP streaming**
- Standards like **MPEG DASH** takle the adaptivity challenge
- New commercial services facilitating **mobile live streaming** are emerging

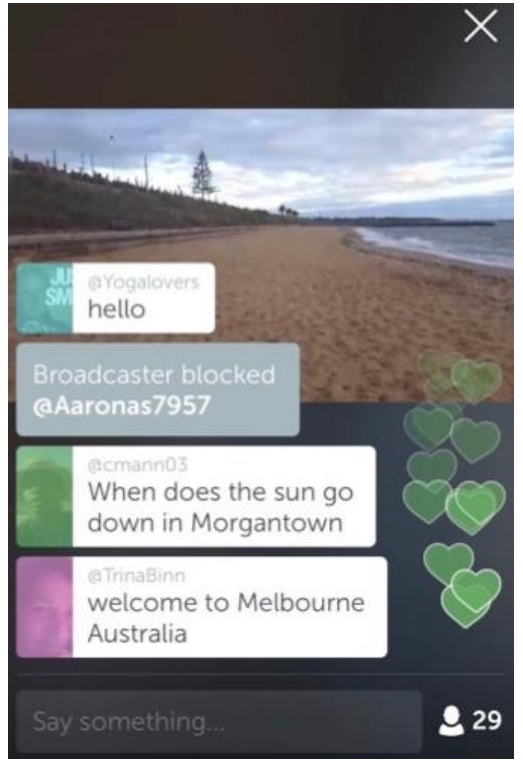
Live Streaming Systems

- **Mobile-to-mobile** live audio/video communication
- Introduces scalability issues on delivery infrastructure
- End-to-end latency relevant for **real-time feedback** delivery
- **QoE assessment** difficult seen the absence of a reference
- Periscope & FB Live most used



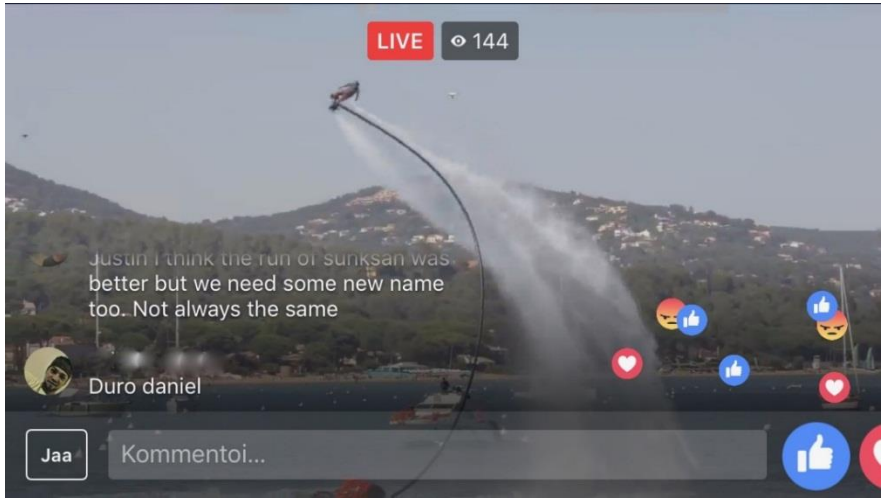
Periscope

- Commercial live streaming system
- Allows interactions (e.g. chat)
- Uses two protocols for video delivery (RTMP/HLS)
- Relies on Amazon Cloud and Fastly CDN
- Private broadcasts use TLS/SSL



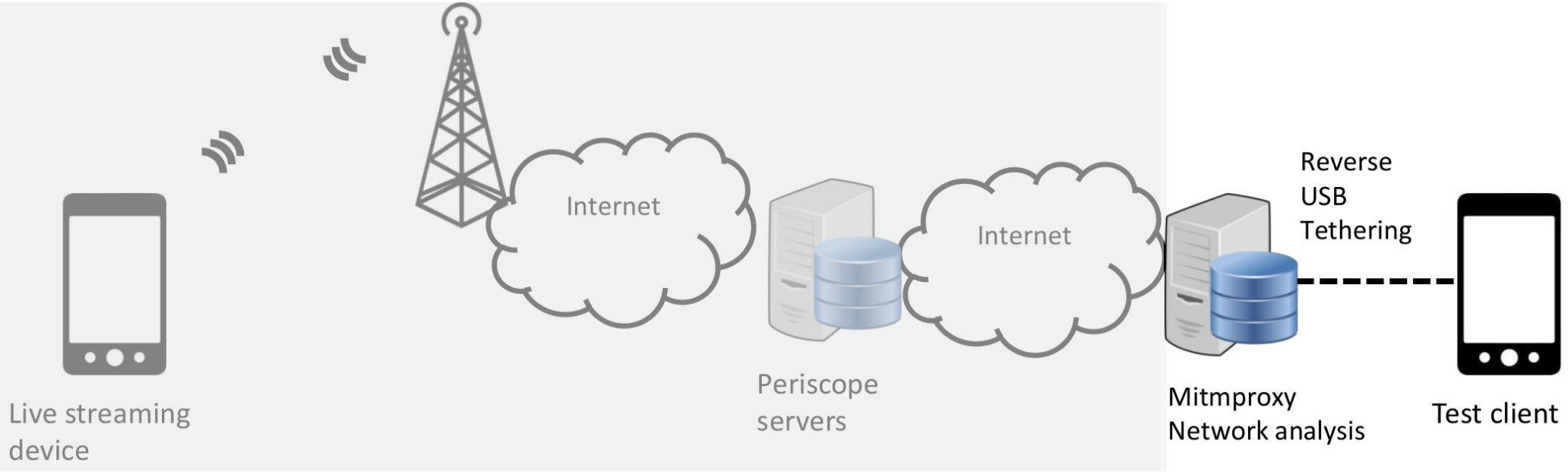
Facebook Live

- Integral part of FB application
- Allows to follow friends' broadcasts
- Uses same two protocols for video delivery
- All traffic encrypted and certificate pinning
- HTTP/2 used

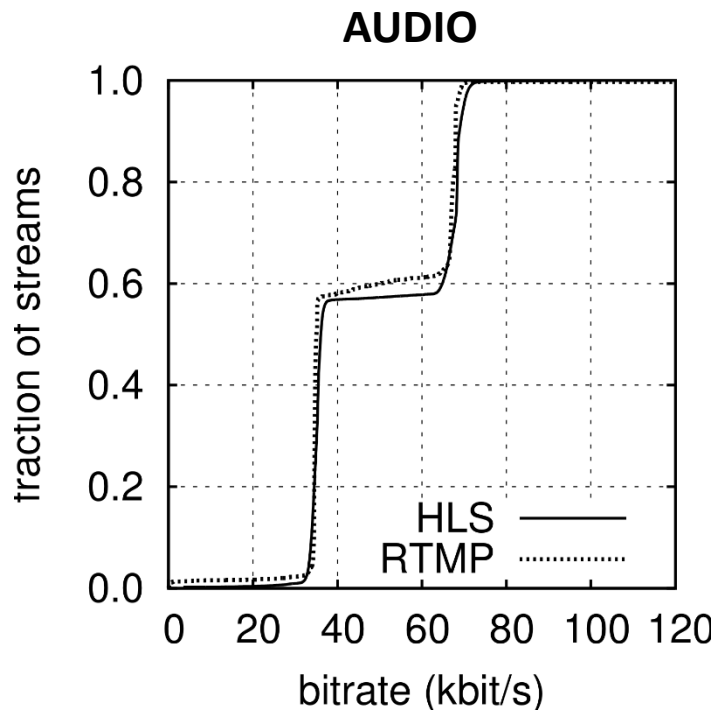


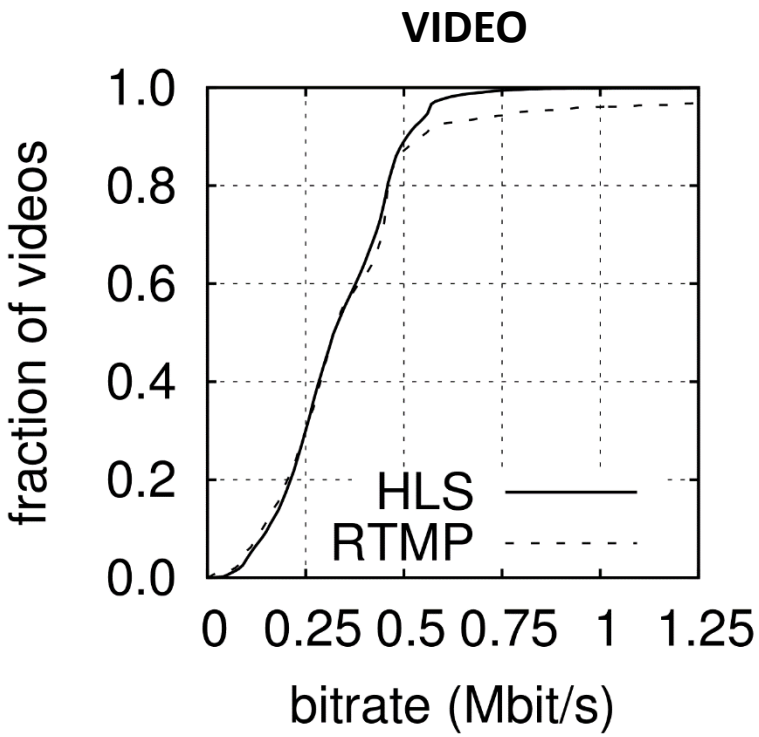
Methodology

- Mitmproxy intercepts traffic and logs it
- Genymotion emulator installed on PC
- Ad-hoc scripts to automate the crawling process



Audio and Video Bitrate/Quality

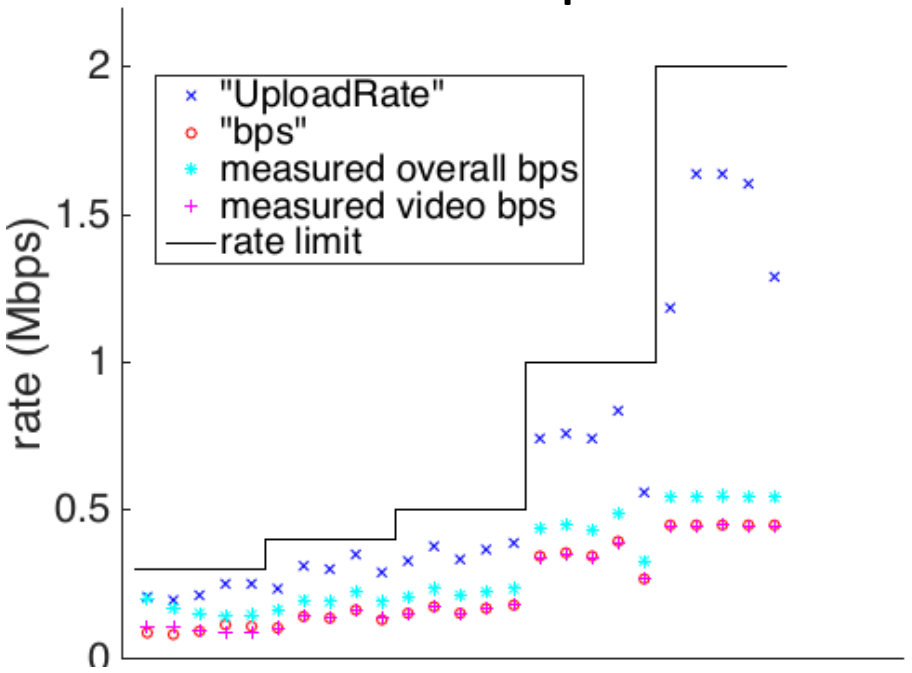




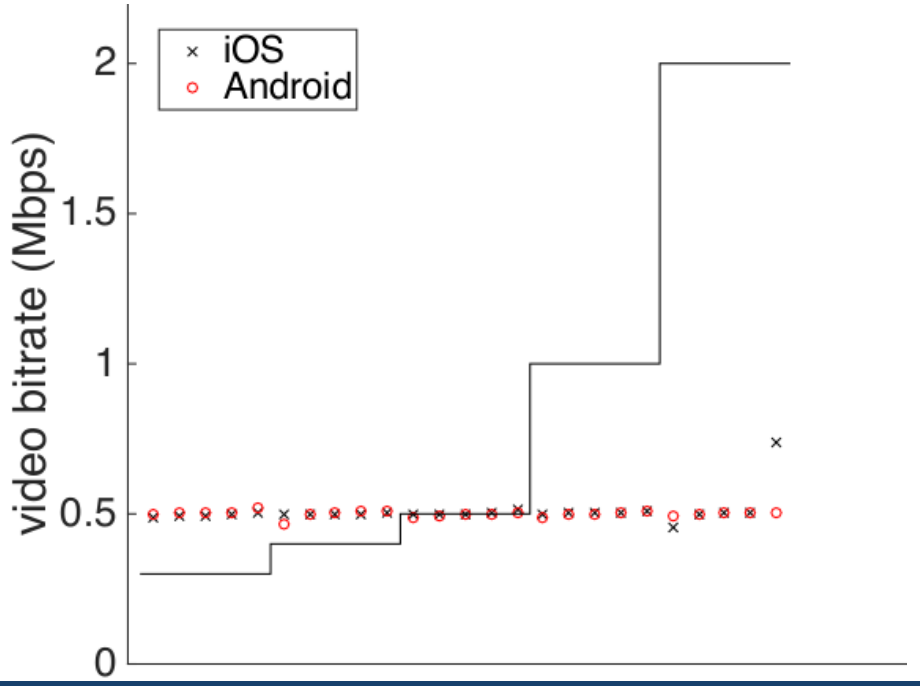
Video Bitrate Adaptation

- Understand how the video encoding bitrate gets chosen at the broadcaster and if it varies
- Bitrate measurements with constant and variable bandwidth

Periscope



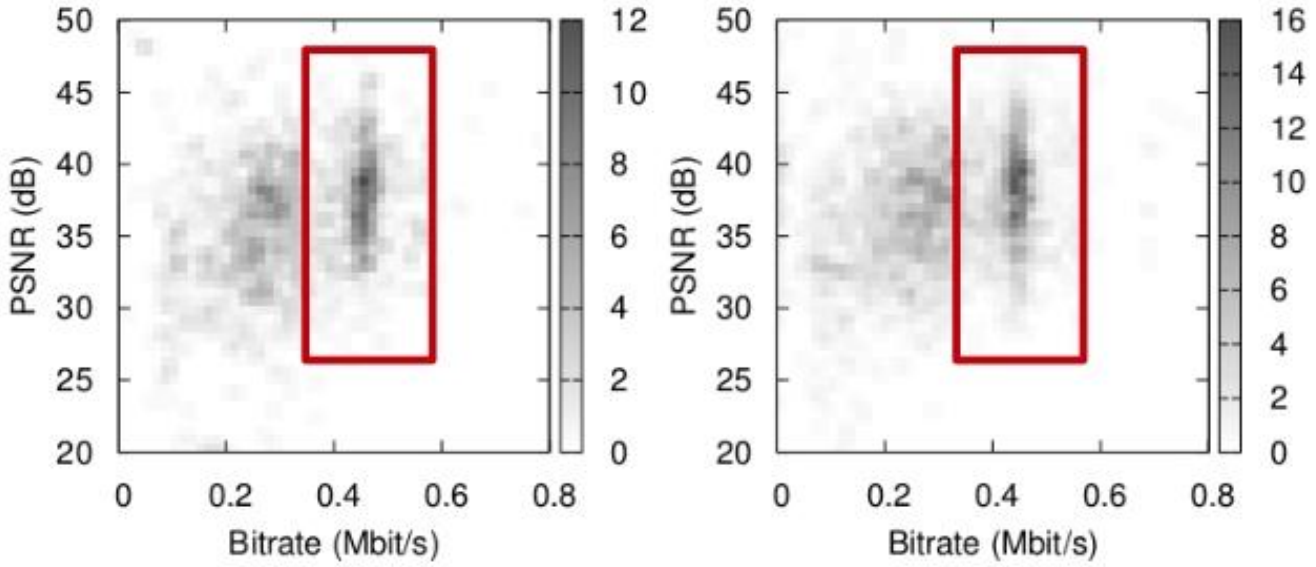
FB Live



Quality Assessment – No Reference

- Analyze the quality of videos recorded
- No reference to the original source available
- A no reference algorithm has been implemented to:
  - **Extract** the quantized coefficients from the received video
  - Perform **statistical analysis** to determine parameters of pdf
  - Estimate **MSE** and **PSNR** using those coefficients

Quality Assessment – No Reference



(a) RTMP (b) HLS

Lessons Learned

- Large difference in broadcast **popularity**
- Different protocols lead to **different end-to-end latencies**
- **Limited** rate adaptation strategies both during download and upload
- **Significant** QoE variations over time

Adaptive Streaming

Transition from UDP/RTP to TCP/HTTP requires **new** adaptation of communication to the channel conditions.

- **Client in control** by means of its requests
- **Optimization** is currently target of several research efforts
- MPEG DASH **standardizes description** of multimedia resources
- Client side parameters: **buffer** level and **estimate** of channel condition

MPEG DASH

- Covers interoperability aspects, in particular the Media Presentation Description (MPD)
- Resources split in aligned segments which can be **individually addressed** and requested by client
- **Easy switch** from one representation to other
- **Flexible standard** but implementing a good adaptation is non trivial

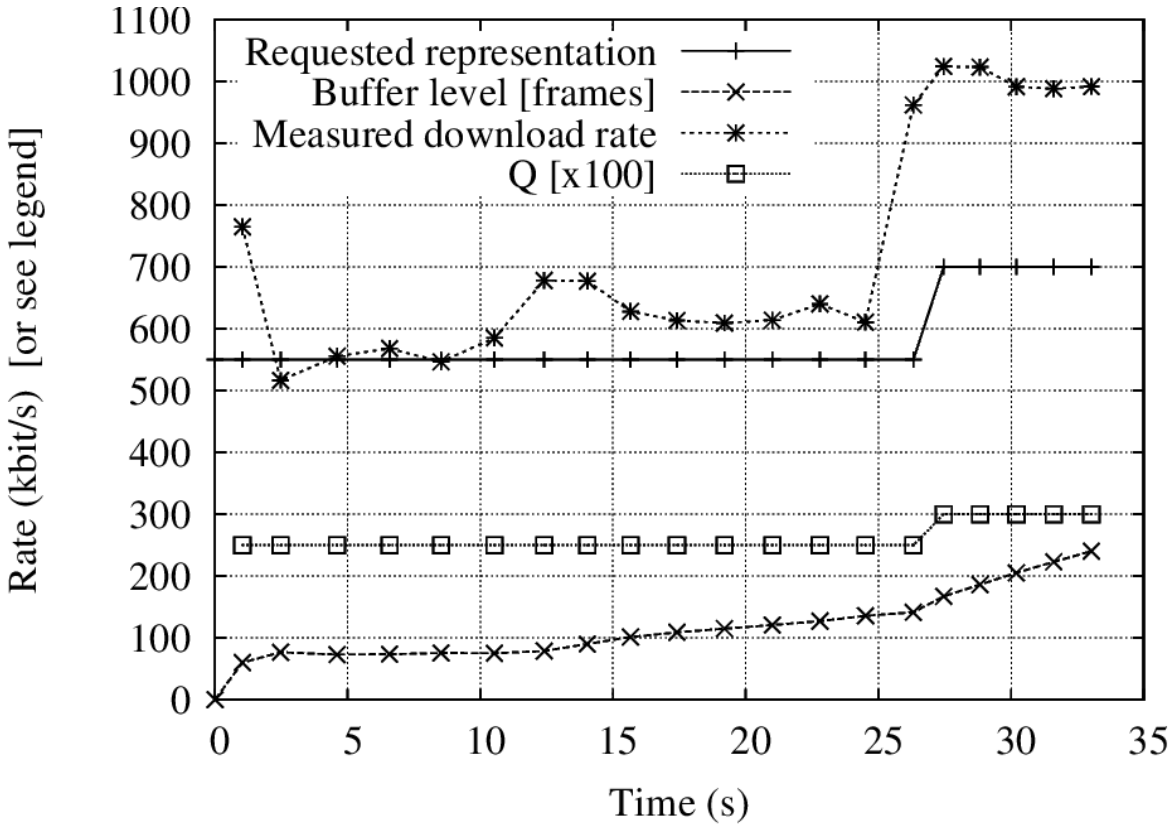
Optimization Framework

Tune trade-off between the quality of received content and the freeze probability

- **Analytical** formulation to estimate the bandwitdth and the probability of freezes
- **Simulation** using real download rate traces of 3G channels
- **Comparison** with other bandwidth-adaptive algorithm

Optimization Framework

REFERENCE



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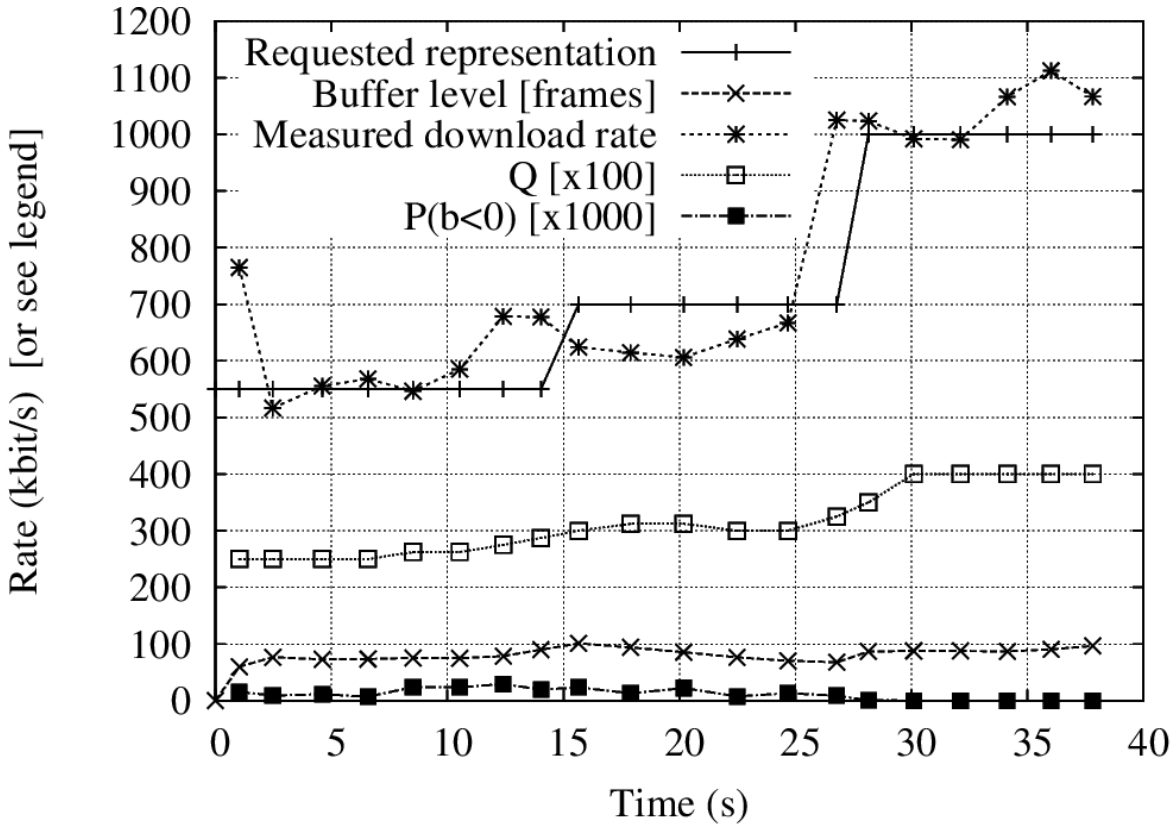


E-Learning Panorama

Increase in general interest followed by creation of many different approaches

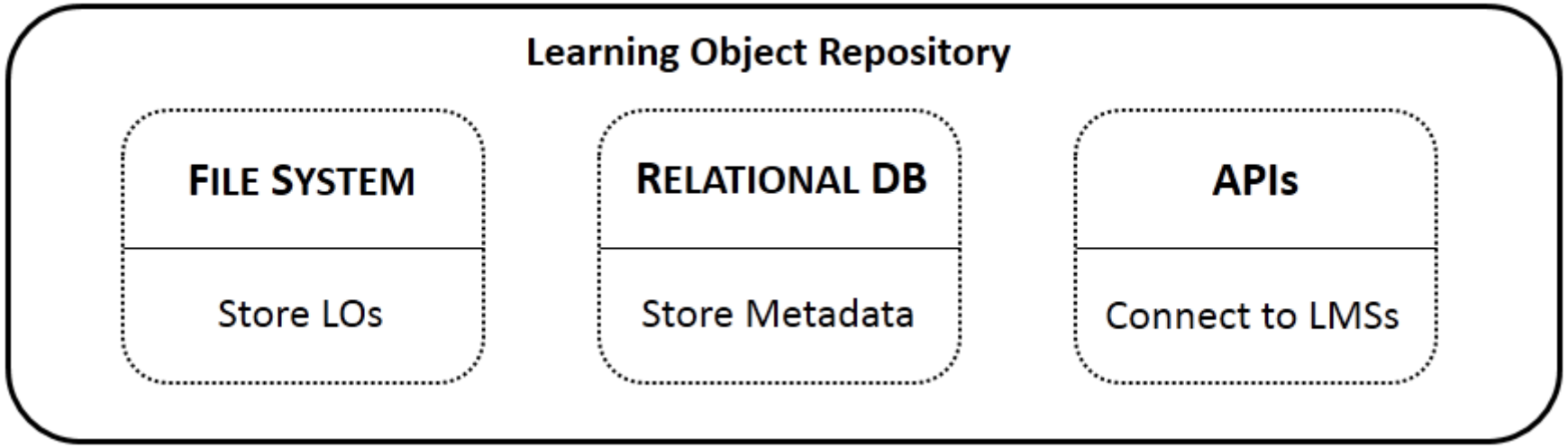
- Highly **scattered** panorama both for contents and solutions
- Fragmentation leads to **abandon** by faculty members
- Need for **unified solutions** to increase the quality of experience
- **Multimedia** approaches play a key role

Learning Object (LO)

- Simple Learning Object: the **elementary** didactic unit
- In digital form (file)
- Stored somewhere (**repository**) together with its description (**metadata**)
- Different licensing; **Open Educational Resources (OER)** if license is **permissive**
- Merging several SLOs together to create a **Complex Learning Object**

Learning Object Repository

- Specialized vs General Purpose
- Compatible with different Metadata Schemas
- API endpoints available for interconnection of Learning Management Systems (LMS)



Requirements

Need for a solution respecting the following:

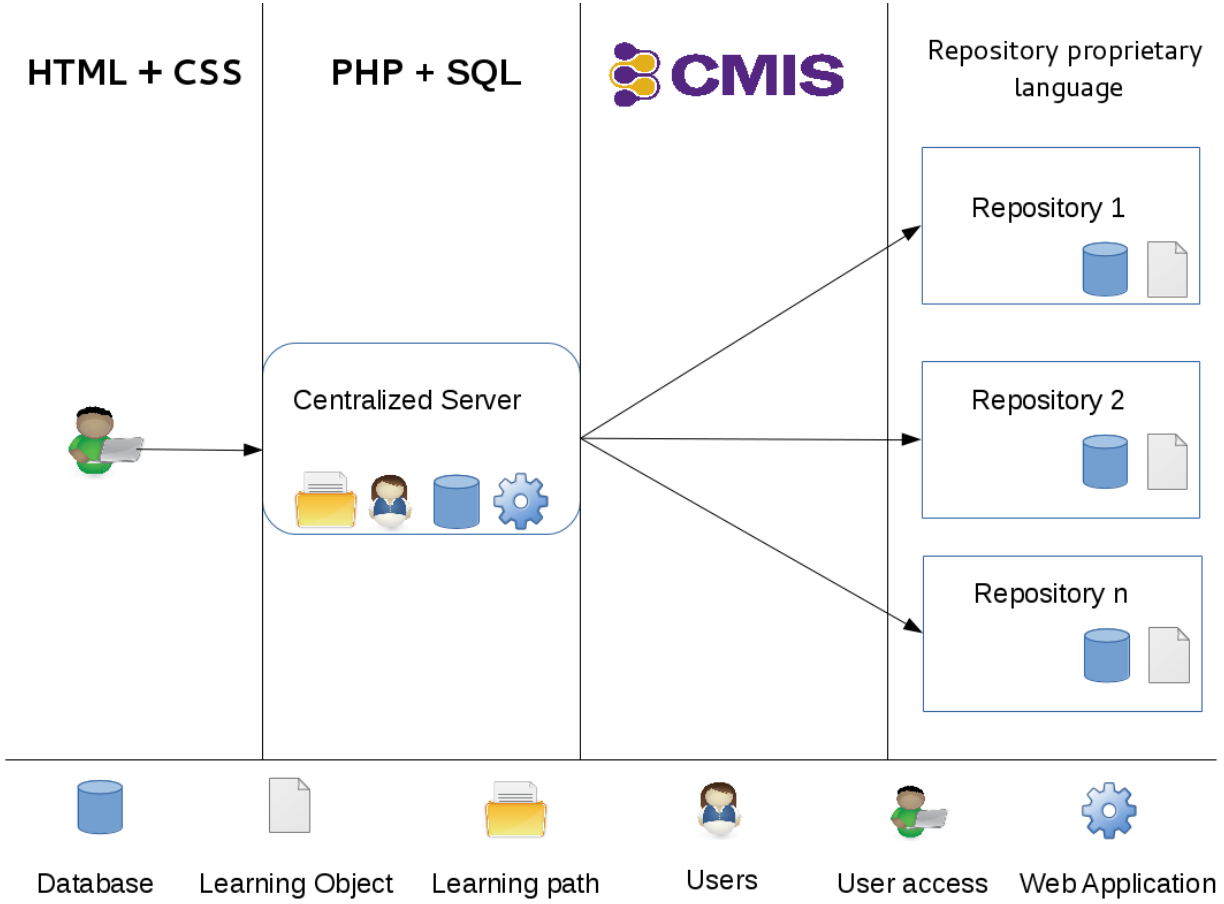
1. **Permissive licenses** both for code and contents
2. **Simple** web user interfaces
3. **Transparent** manipulation of LOs
4. Ensure **quality** of contents
5. Guarantee a **multimedia** experience

FARE - Architecture

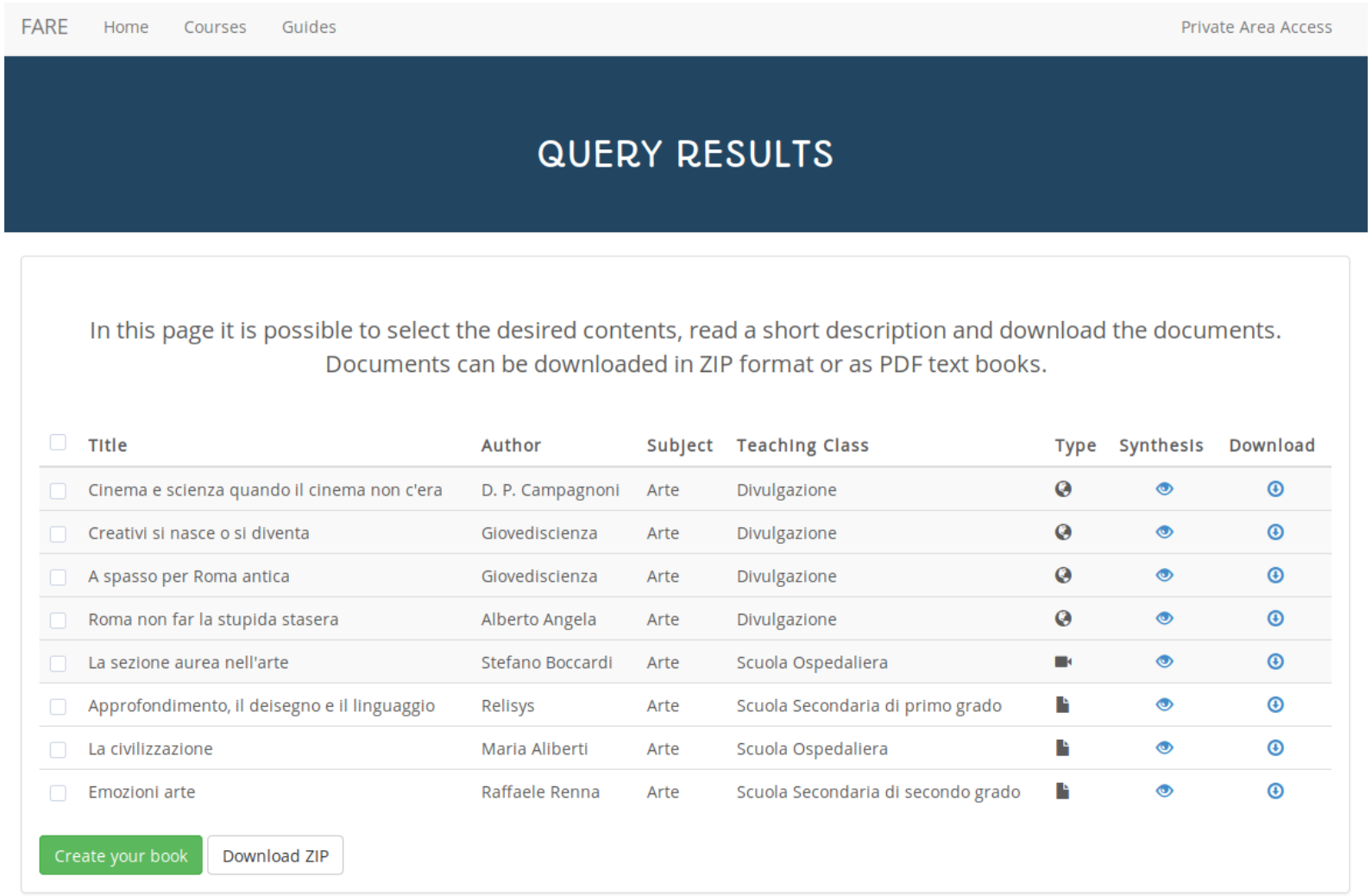
To address such requirements, FARE leverages:

1. AGPLv3 for code, CC BY-SA for contents
2. **Mobile first** frontend and modular design
3. Exploits **CMIS** specifications
4. **Reviewers** committee
5. **Integration** of different multimedia technologies

FARE, the Free Architecture for Remote Education



FARE, the Free Architecture for Remote Education

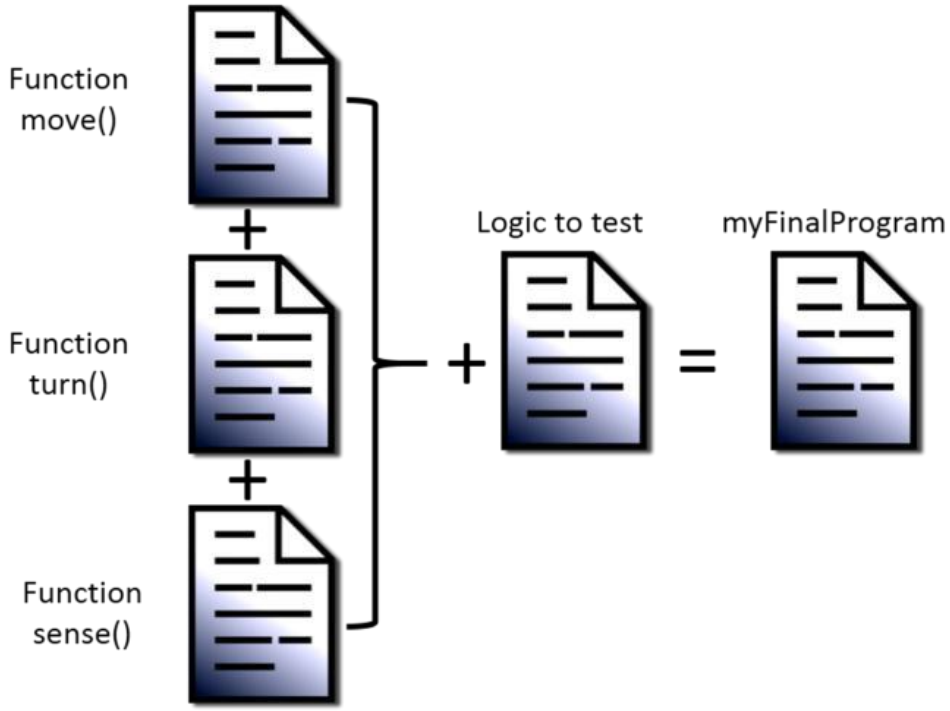


Modules

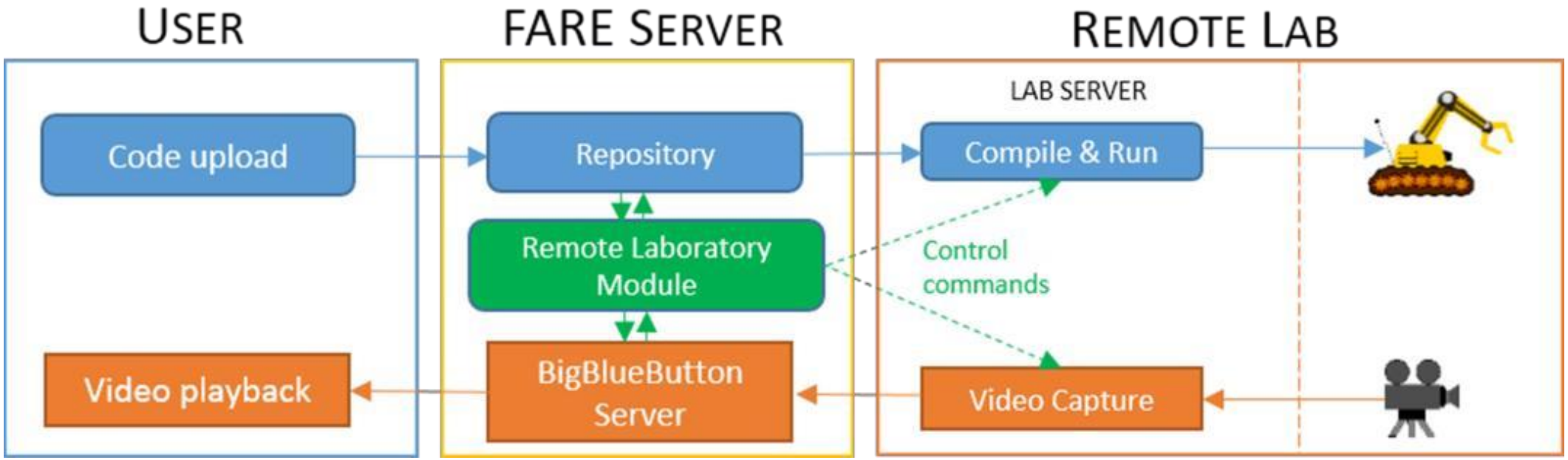
- **Distributed** query (natural language and filtered)
- Results **selection** and **save** in personal dashboard
- Content **remix** functionalities; creation of CLO
- **Export** in different formats
- **Upload** and referee approval process
- **Videoconferencing** tool

Remote Robotic Laboratory

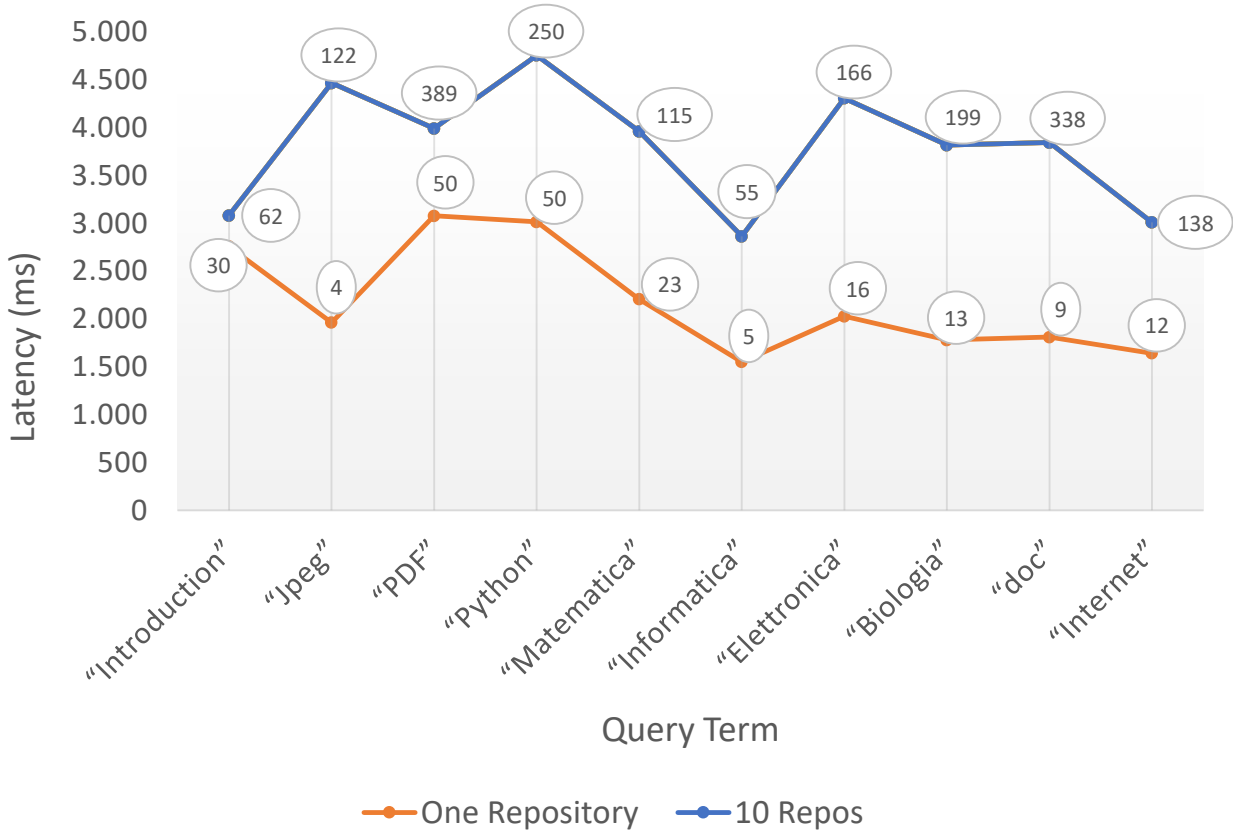
- Allows lab access also to online courses
- Practical approach to programming
- Live feedback shows results
- Reuse of contents is encouraged
- New functions stored as LOs



Remote Robotic Laboratory

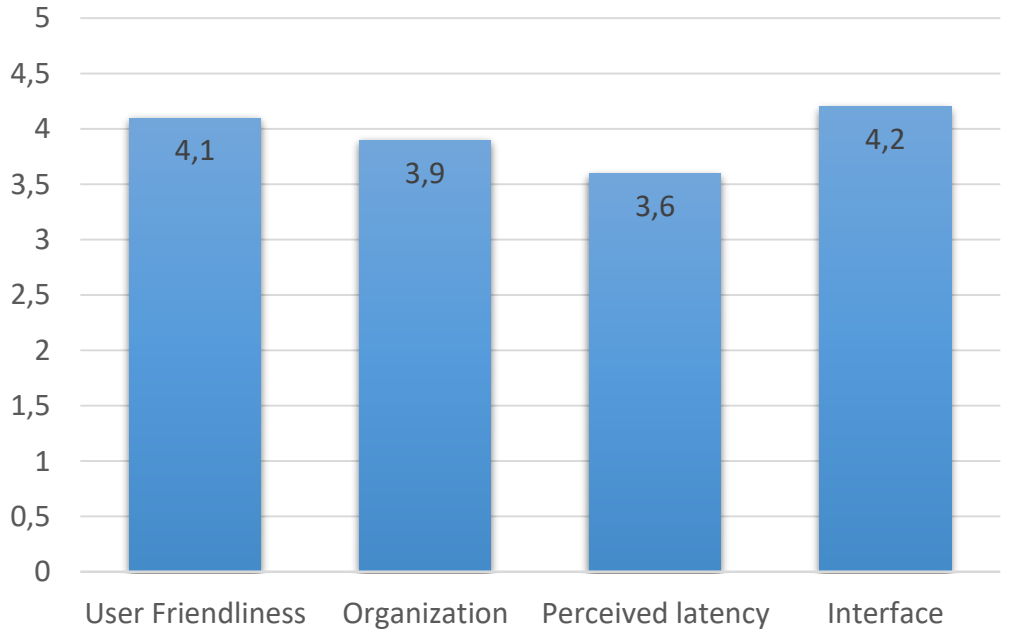


Objective Evaluation



Qualitative Evalutation

- Questionnaire submitted to early adapters
- Evaluation of the subjective feelings on QoE
- Informal feedback also important during the development phases



Discussion

- Novel e-learning platforms **rely** on multimedia streaming technologies
- Ubiquitous access implies the need of **ad-hoc solutions**
- The commercial streaming services analyzed show how **optimization** work is **still needed**
- Standards like MPEG DASH do not specify how to handle the client adaptation layer so optimization work can be done in this regard

Contributions

The research output has been presented in international conferences and journals, i.e., IEEE MMSP, IEEE ICME, IEEE FIE, IEEE EDUCON, IEEE COMPSAC, iJET and ACM TOMM.

Apart from papers, the following contributions are made available to the public:

- A working deployment of FARE and the other web applications
- FARE's complete source code, both for the platform and the modules
- A no-reference quality assessement algorithm implementation

Publications List

- [j3] M. Siekkinen, T. Kamarainen, L. Favario, E. Masala, *Can You See What I See? Quality of Experience Measurements of Mobile Live Video Broadcasting*, ACM Transactions on Multimedia Computing, Communications and Applications, 2018
- [j2] L. Favario, E. Masala, *A new architecture for cross-repository creation and sharing of educational resources*, INTERNATIONAL JOURNAL ON EMERGING TECHNOLOGIES IN LEARNING, 2017
- [c5] L. Favario, M. Siekkinen, E. Masala, *Mobile Live Streaming: Insights from the Periscope Service*, IEEE Workshop on Multimedia Signal Processing (MMSP), 2016
- [c4] L. Favario, E. Masala, *Work-in-Progress: Integrating a Remote Laboratory System in an Online Learning Environment*, IEEE Global Engineering Education Conference EDUCON), 2016
- [j1] L. Favario, A.R. Meo, E. Masala, *FARE: A New Free Architecture for Remote Education*, MONDO DIGITALE, 2015
- [c3] L. Favario, A.R. Meo, E. Masala, *Seamless Cross-Platform Integration of Educational Resources for Improved Learning Experiences*, IEEE Frontiers in Education (FIE), 2015
- [c2] L. Favario, E. Masala, A.R. Meo, *A New Platform for Cross-Repository Creation of Educational Paths: Architecture and a Case Study*, IEEE 39th Annual International Computers, Software & Applications Conference, 2015
- [c1] L. Favario, E. Masala, *A New Quality Optimization Framework for DASH Streaming over Wireless Channels*, IEEE Intl. Conference on Multimedia and Expo, 2015

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