Remote Experimentation from Research to Education
A European Roadmap

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Acknowledgements

Sue Huan
The University of Dublin, Trinity College was founded in 1592

2015QS ranking:
- 1st in Ireland
- 77th worldwide
- Top 1% School of Engineering worldwide

Only Irish university to rank in the top 100 world universities and amongst the top 50 European universities by the Times Higher Education Supplement

Approximately 16,000 students

Approximately €154m in research income per year
Successful engineering is all about understanding how things break or fail

Henry Petroski
Engineering and experimentation

Reinforcement and demonstration through experimentation are extremely important for understanding physics and engineering phenomena, especially wireless communications and its physical properties.

The most effective way to demonstrate such physical properties and the impairments of wireless signals is through radio experimentation on top of well equipped radio testbeds.

EU Research and Innovation
Research Infrastructures (RI)

EU support for RIs in the context of its Framework Programmes (FPs)

- FP2 (1987-1991) €30 million
- FP7 (2007-2013) €1.85 billion
- Horizon 2020 (2014-2020) €2.5 billion
  - New world-class research infrastructures
  - Optimizing the use of the national facilities
  - ICT based e-infrastructures which are essential to enable access to distant resources, remote collaboration, and massive data processing in all scientific fields

FIRE initiative is a European endeavour that promotes the creation of wide-scale federations of high-performance testbed and experimentation facilities for internet and network-related research.
LARGE-SCALE EXPERIMENTAL TESTBEDS

EC budget

FUTURE INTERNET R&I in EUROPE

MAIN PROGRAMMES launched by the EUROPEAN COMMISSION*

<table>
<thead>
<tr>
<th>FP7</th>
<th>H2020</th>
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</thead>
<tbody>
<tr>
<td><strong>52</strong> PROJECTS</td>
<td><strong>18</strong> PROJECTS</td>
</tr>
<tr>
<td><strong>120 M€</strong> EU funds</td>
<td><strong>50 M€</strong> EU funds</td>
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<tr>
<td><strong>910 M€</strong> EU funds among which <strong>300 M€</strong> FI-PPP</td>
<td><strong>400 M€</strong> EU funds</td>
</tr>
</tbody>
</table>

ON FUTURE INTERNET R&I, AMONG WHICH FIRE, FI-PPP AND 5G-PPP

SmartFIRE project, ICT 2015 Conference
Experimentation-based Research
FIRE Projects

- Festival
- ORGANICITY
- WiSHFUL
- eWINE
- RAWFIE
- CREW
- 5G
- RCFIRE
- FUTEBOL
- mami
- FLEEx
- MONROE
Smart Reconfigurable Radio Testbed
Some FIRE facilities

- EPCC BonFIRE testbed
- TCD SDR radio
- UNIVBRIS OFELIA island
- iLab.t Virtual Wall
- iLab.t Wireless lab
- PlanetLab Europe
- Smart Santander facility
- Grid'5000
- i2CAT OFELIA island
- UPC community lab
- UMA LTE performance lab
- UC3M optical access testbed
- Sydney: NORBIT testbed
- Korea: KOREN testbed
- Stanford optical access testbed
- Outside EU
- Outside EU
- NORBIT testbed
- KOREN testbed
- Outside EU
- UC3M optical access testbed
- Stanford optical access testbed
- Outside EU
- UC3M optical access testbed
The focus of the FIRE Facilities

http://www.ict-fire.eu
Education & Experimentation
Learning and education

Learning underpins human society as an essential activity for societal advancement as well as personal well-being

In 2009 the European Union budget on education was 6.2% of the European Gross Domestic Product

The recent economy crash has forced a reduction in educational in several countries

Innovative solutions to provision cost-effective high quality learning are needed

Experimentation is a key component of engineering education

• Physical experimentation
  • Expensive, in particular for low-budget institutions
  • Deploying and maintaining experimental facilities is costly
  • Developing cutting edge telecommunications technologies requires massive effort and budget
  • Learners constrained by location and lab opening hours

• Online laboratories
  • Online laboratories provide remote access to experiments allowing students to access experiments without time and location restrictions
  • FORGE project’s initiative towards empowering education by enabling hands-on remote experimentation
  • Trinity College Dublin is focused on enhancing online telecommunications engineering education by enabling hands-on remote experimentation over its Smart Reconfigurable Radio Testbed

"Assessing the impact of remote hands-on experimentation on engineering students", Johann M. Marquez-Barja, Nicholas Kaminski, Guillaume Jourjon, Jono Vanhie-Van Gerwen, Daan Pareit, Luiz A. DaSilva. IEEE Transactions on Education. [In preparation], 2015.
Online laboratories
Summarized taxonomy

- **Virtual labs**
  - software-based laboratories
  - simulation tools
- **Remote labs**
  - Experimentation on real lab equipment
- **Hybrid labs**
  - Output data from real measurements/equipment
  - Processed by simulation tools

Education and experimentation
Experimentation-based projects
Forging Online Education through FIRE (FORGE)

FORGE is a project bringing the FIRE and eLearning worlds together. In particular, FORGE aligns FIRE (Future Internet Research and Experimentation) with the ongoing education revolution.

FORGE specifies development methodologies and best practices for offering FIRE experimentation facilities to learners and to the learning community in general

The project leads to a strong connection between the learning community and existing FIRE platforms and supporting tools

FORGE objectives

FORGE is transforming the FIRE facilities, already vital for European research, into a learning resource for higher education, enabling educators to easily create experiment-based learning resources.

FORGE allows educators to create, use and re-use FIRE-based learning experiences through our tools and techniques.

FORGE enables equity of access to the latest ICT systems and tools independent of location and at low cost. Experimental facilities are expensive!!!
Resulting web widgets + iBook

Cross-platform: virtually any platform

- Modern web browser
- FORGEBBox
- Any LMS supporting iframes
- Apple iBook
- EPUB3
FORGE Methodology
FORGE Methodology

Creating FIRE courseware

Two main stages

- Course preparation
- FORGE supported activities

Specifying course requirements
Dynamic spectrum access & wireless signalling – Use case

• Lab sessions within a master course on wireless networks and communications systems
• Basic knowledge of wireless comms systems is a pre-requisite for this lab
• Learning outcomes:
  • Understanding of the impairments to wireless comms
  • Gaining tangible experience with interference and interference-avoidance techniques
  • Understanding OFDM modulation
  • Understanding of Dynamic Spectrum Access techniques
  • Appreciation of realistic wireless applications
Identifying FIRE facilities
Dynamic spectrum access & wireless signalling – Use case

- Smart Reconfigurable Radio Testbed @ CONNECT, Trinity College Dublin, Ireland
  - USRPs in a grid configuration
  - Cloud-based computing VMs
  - Dedicated indoor testing environment
Authoring educational content
Dynamic spectrum access & wireless signalling – Use case

Reuse content of lecture slides
Multimedia material

OFDM Remote Laboratory
This remote laboratory is provided by CONNECT / Trinity College Dublin within the EU FORGE project.

Introduction

Testbed configuration
Integration of FIRE facilities and content
Dynamic spectrum access & wireless signalling – Use case

Interaction via widgets and FIRE adapters

- Control widgets
- Visualization widgets
- Adaptions for the specific testbed management system
Integration of FIRE facilities and content
Dynamic spectrum access & wireless signalling – Use case

www.ict-forge.eu
www.fed4fire.eu
www.ict-fire.eu
www.crew-project.eu
Deployment and impact
Dynamic spectrum access & wireless signalling – Use case

- Trinity College Dublin, Ireland (March 2015)
- University of Brasilia, Brazil (July 2015)
- Federal University of Rio de Janeiro, Brazil (July 2015)
- Federal University of Rio de Janeiro, Brazil (Sept. 2015)
- IT Mexicali, Mexico (October 2015)
- Trinity College Dublin, Ireland (March 2016)
- University of Brasilia, Brazil (May 2016)
- IT Mexicali, Mexico (October 2016)
Evaluation and reflection
Dynamic spectrum access & wireless signalling – Use case

Questionnaires used to inquire student perception (Qualitative)
- Surveymonkey.com (anonymize)
- Google forms

Learning analytics integrated into the widgets xAPI (Quantitative)
- Learning Locker

Remote experimentation in your pockets...
Thank you

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