Welcome to the Dynamic Spectrum Sharing Seminar

Microsoft Innovation and Policy Center
22\textsuperscript{nd} March 2013

'The research leading to these results was derived from the European Community’s Seventh Framework Programme (FP7) under Grant Agreement number 248454 (QoSMOS)'.

Quality Of Service and MObility driven cognitive radio Systems
The QoSMOS project: overview and implications for regulation

Michael Fitch
22nd March 2013
Users are demanding more bandwidth

Orange reported 4,125% increase in traffic last year, 100% increase in last 3 months.
Cisco predict demand doubling every year for next 5 years.
What are the trends?

- Increasing data traffic, mostly from within buildings
- Increasing WiFi offload
- Cells are getting smaller
- WiFi is ‘loose’
  - suffering from increasing congestion and decreasing coverage
- LTE is ‘tight’
  - suffering from single MNO per BS, lack of spectrum
  - planning is increasingly infeasible with smaller cells
- Proposed solution is something in-between unlicensed and licensed, i.e., smart spectrum sharing
Spectrum sharing is an alternative but needs greater alignment of regulators. Planning is becoming infeasible with smaller cells.

- **Licensed**: Eg GSM, 3G
- **Unlicensed**: Eg WiFi, Bluetooth
- **Shared**: Eg TV White Space

Flexible radios and intelligent use of spectrum resources. 5-year vision is very flexible and reconfigurable user terminals. And managed use of spectrum.
TV Whititespace is the first opportunity for sharing spectrum - the UK plan...

UK post-switchover the “Digital Dividend”

- 16 channels (128MHz) of cleared spectrum for auctions (early 2013)
- 32 channels (256MHz) interleaved spectrum retained for:
  - Licensed usage for Digital TV broadcasting
  - Licensed usage for PMSE (wireless microphones)
  - Unlicensed Secondary Usage – sharing-
- 1 channel (8MHz) dedicated to Radio Microphones

Digital TV (e.g. TV)  
Auction (600MHz)  
Digital TV (e.g. TV)  
Auction (800 MHz)
Presenting QoSMOS
At a glance

• Quality of Service and MObility driven cognitive radio Systems – a part-EC funded FP7 project. January 2010 to March 2013.
• Spectrum sharing
  – Enabling technologies: Spectrum management, FBMC
  – Architecture: Reference models and interfaces
  – Business models: Use-cases, micro-trading
• Impact
  – Regulation and industry across Europe: mainly through an External Advisory Board
  – Contribution to standards: ETSI, IEEE, IETF
• Make-up
  – 15 partners across Europe
  – External Advisory Board made up of 13 representatives from broadcasters, regulators, industry and standards
  – 1200 man-months, 15.5 million Euros (9.4 million contribution from EC)
## Partners

<table>
<thead>
<tr>
<th>Partner</th>
<th>Role</th>
<th>Who’s here</th>
</tr>
</thead>
<tbody>
<tr>
<td>BT</td>
<td>Project co-ordinator, Lead on architecture</td>
<td>Michael Fitch, Richard MacKenzie</td>
</tr>
<tr>
<td>telenor</td>
<td>Lead on use-cases and business models</td>
<td></td>
</tr>
<tr>
<td>NEC</td>
<td>Cellular extension</td>
<td></td>
</tr>
<tr>
<td>NEC</td>
<td>Lead on architecture</td>
<td></td>
</tr>
<tr>
<td>Partner</td>
<td>Role</td>
<td>Who’s here</td>
</tr>
<tr>
<td>----------------------</td>
<td>--------------------------------------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Alcatel-Lucent</td>
<td>Lead on exploitation and dissemination</td>
<td></td>
</tr>
<tr>
<td>Thales</td>
<td>Lead on radio environment modelling</td>
<td></td>
</tr>
<tr>
<td>TST</td>
<td>Lead on proofs of concept</td>
<td>Arturo Medala</td>
</tr>
<tr>
<td>Agilent Technologies</td>
<td>Radio channel emulation</td>
<td>Martin Zelenak</td>
</tr>
<tr>
<td>Partner</td>
<td>Role</td>
<td>Who’s here</td>
</tr>
<tr>
<td>---------</td>
<td>---------------------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>Leti</td>
<td>Technical manager</td>
<td>Dominique Noguet</td>
</tr>
<tr>
<td>Fraunhofer</td>
<td>Spectrum portfolio manager</td>
<td>Bernd Bochow</td>
</tr>
<tr>
<td>IT</td>
<td>Sensing</td>
<td>Carlos Ribeiro</td>
</tr>
<tr>
<td>Műegyetem 1782</td>
<td>Spectrum management</td>
<td></td>
</tr>
</tbody>
</table>
# Partners

<table>
<thead>
<tr>
<th>Partner</th>
<th>Role</th>
<th>Who’s here</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="University of Surrey" /></td>
<td>Lead on spectrum portfolio management</td>
<td>Klaus Moessner</td>
</tr>
<tr>
<td><img src="image" alt="University of Oulu" /></td>
<td>Radio resource management</td>
<td></td>
</tr>
<tr>
<td><img src="image" alt="Technische Universität Dresden" /></td>
<td>Lead on transceiver design</td>
<td></td>
</tr>
</tbody>
</table>
External Advisory Board

Regulators:
ANFR
BNetzA
RA-NL
Ofcom UK
Ofcom Swiss

Broadcasters:
BBC
SWR

Industry:
Airspan
NXP
Microsoft
Bosch (representing PMSE)

Others:
Wireless Innovation forum
ETSI RRS

QoSMOS

Steering and deliverable reviews

Five review meetings aligned with project milestones

Dissemination route

EAB
Position in eco-system

- Spectrum rules
- Spectrum management
- Services
- Network management
- Network elements
- Network elements
- Base-stations and user equipment
- QoS MOS processes
- Legacy NW processes
- New from regulator
QoSMOS concept

Cognitive Manager-
Resource manager
(CM-RM)

Cognitive Manager-
Spectrum manager
(CM-SM)
Determining TVWS power in UK

Reference: Ofcom: Access to white spaces in the UHF band: Protection of digital terrestrial television and calculation of TV white space availability
20 October 2011
QoSMOS manager as WSDB
Relation of QoSMOS concept to its architecture

Deliverable report D2.3 is a full description of QoSMOS architecture
Hierarchy of Objectives

Main driver: shared use of spectrum

Scientific and Technical Objectives

Efficient Radio Access to Future Networks

Cognitive Wireless Access Provision

Network Support Provision

Platform

Use of aggregate spectrum

Environmental Modelling

Protocols

Cognitive Manager

Security Aspects

Design of Transceivers

WP4

WP5

WP3

WP2,3,5

WP5,6

WP6

WP1

WP8

Integration and proof of concepts ➔ WP7

Use-cases and economic analyses

Impact Regulation, Standards, Industry

Non S & T objectives
Challenges, architecture and WPs

**Challenges**

- **QoS and Mobility Management**
  - WP2

- **Spectrum Management**
  - WP6

- **Technology-agnostic approach**

- **Context Management**

- **Optimized data transfer in opportunistic band**
  - WP4

**Architecture**

- **CN Mngt**
  - End-user Application
    - CM-RM
      - Adaptation Layer
        - Spectrum Sensing
          - WP3
        - AL
          - Regulation Policies
            - Common Portfolio Repository
              - AL

- **Transceiver**

**Work Packages**

- WP2
- WP3
- WP4
- WP5
- WP6
One-slide summary of what we have achieved…

• Use-cases defined and business modelling tools developed
  – We have looked at the most viable markets and sensitivities
  – Allows more efficient spectrum sharing, through protocols and less wastage

• Radio environment modelling and awareness
  – Performance limits are now known for a wide range of sensing methods

• Spectrum management architecture
  – System solution for QoS and mobility, including a prototype database -> ETSI RRS, IETF PAWS

• Fundamental radio technology
  – Allows more efficient spectrum sharing, through reduction in interference -> IEEE P.1900-7

• Made proof of concept demonstrations of critical technologies
  – To downstream to stakeholders, you will see some of these today
Spectrum trading and business models

- Work has taken place on:
  - Framework for spectrum trading model
    - Including micro-trading models
  - Business modelling
    - Cash flow and NPV models for rural broadband, cellular extension, cognitive femtocell and machine to machine use-cases
**Scenarios and use-cases**

Public deliverable reports D1.2 (December 2010) and D1.6 (December 2012) contain process and results that lead to these three scenarios:

- **Cellular extension**
- **Cognitive Femto-cell**
- **Cognitive Ad-hoc**

Rural broadband, Cellular Extension and M2M are example use-cases

**IMPACT:** Operators and vendors know most viable markets
Base values used were 50 million connected devices in the UK and 0.31 Euro per month each. The curve is very sensitive to both of these numbers.

**IMPACT:** Tool for operators and vendors to assess money viability
Spectrum micro-trading

Magenta = 1
Blue = 2
Green = 4
Red = 8

The efficiency increases as the block sizes decrease, because bids are made only for what is needed (less waste)

Time of allocation also important

A sample plot from public deliverable D1.5, July 2012

IMPACT: More efficient sharing. Towards operators / regulators?
Example of sensing results….we evaluated energy detection, cyclo-stationary, hybrids, co-operative sensing…single and multiple antennas… fixed and moving users etc
Spectrum management, we have:

- System specifications considering functional blocks and interactions (eg CM-SM and CM-RM)
- Adaptation layer defined with associated Message Sequence Charts, primitive layouts and data structures
- Basic functions such as load balancing and interference measurements also defined with MSCs and data structures
- Link budgets and selection of channel models
- A reference incumbent environment of DTT and PMSE, to be used for performance evaluation in each scenario
Spectrum management architecture: interaction of CM-SM and CM-RM
Illustration of signalling between CM-RM and CM-SM

CM-RM

Request Infos

Filtered (averaged) status information.
Wishes for getting (e.g. more) resources

Decision

settings are overtaken

Configurations (spectrum portfolio etc.)

CM-SM

Alternatively previously obtained and stored information is used

Request for infos

Response with infos

“External Infos", Constraints, Repositories, Policies, ...

SD SS ...

Optionally:
other CM-SMs
other entities, ...

Optionally:
Exchanges with other entities
Either here now or using previously obtained and stored infos

Request Infos

SD = Spectrum Databases (Repositories, etc.)
SS = Spectrum Sensing

Wishes for getting (e.g. more) resources Configurations (spectrum portfolio etc.)
Example system solution for rural broadband
QoS and mobility framework - admission / eviction

Step 1: Context observation
Step 2: Elaboration of the operating rules
Step 3: Evaluation of the alternatives
Step 4: Selection of the decisions
Step 5: Execution of the decisions
PHY layer

- Techniques have been evaluated to enable fragmented use of spectrum.
- Filter Bank Multiple-Carrier (FBMC) emerged as a strong contender and has as been developed and prototyped in the context of the TVWS
- FBMC is here benchmarked against OFDM (incl. 3GPP LTE PHY)

**FBMC vs OFDM with 480 active carriers of LTE**

**Fragmented spectrum usage with FBMC**
QoSMOS has built a prototype transceiver using FBMC
Regulatory impact

In UK, TVWS could go live this year, if statutory instruments can be put in place. There have been trials already
Currently discussing vanilla / special cases (ie how much can the volume be increased ?)
Ofcom have started a work item in ETSI BRAN for radio parameters

Position in other European countries is lumpy
(some European regulators are members of QoSMOS EAB)
German / French very cautious for a number of reasons
Swiss /Dutch / Finnish / Polish more open and looking to FCC / Ofcom for lead

Considerably more effort will be needed to establish trust with regulators and with primary users of the spectrum (DTV and Wireless Microphones) – through trials / standards

Ofcom being lobbied by BBC and Mobile Network Operators to be cautious,
MNOs see this as a dangerous precedent,
BBC lobbying to protect non-preferred DTT and indoor sets
Some relevant information on transmitters is not available (eg antenna patterns)

Every band that is opened up to sharing will encounter a similar set of issues from existing users.
QoSMOS legacy

- Standardisation – ETSI RRS and DySPAN and IETF PAWS
- EAB to continue as an industry body, anchored on a future project
- RF Hardware, Adaptation layer, spectrum manager, business cases
- Contributing to responses to regulator consultations
- Spectrum policy statement from EC – free up a further 700MHz spectrum for fair sharing, QoSMOS results will continue to contribute
Thank you for listening

For more information on QoSMOS and to access the public deliverables, visit www.ict-qosmos.eu

or email michael.fitch@bt.com
Today’s demonstrations

- Radio environment and sensing
  - Radio emulation – Agilent (Belgium)
  - Sensing – IT (Portugal)
- Phy layer technology
  - FBMC – CEA (France)
- QoSMOS spectrum manager
  - Database / Portfolio – Fraunhofer (Germany)
- QoS and Mobility
  - Adaptation layer – TST (Spain)
- TVWS equipment with Telcordia database – Adaptrum (US)
- Enhanced WiFi in TVWS – Interdigital (Canada)
- FCC certified spectrum manager database including PCAST SAS – SpectrumBridge (US)
Demonstration 1: Flexible Transceiver for DSA (Using FBMC)

Flexible hardware design controlled by Software interface

Tuneable 40MHz RF window centred from 470MHz to 860MHz

FBMC Spectrum pooling for channelization within 40MHz window

Provides high rejection for adjacent incumbent protection required by regulators
Demonstration 2 – Spectrum manager
Demonstration 3 – Adaptation Layer

- Transceiver
- Spectrum Sensing
- Regulatory Database
- Common Portfolio Repository
- Remote AL
- CM - SM
- CM - RM
- Network Coordinator
Demonstration 4 – Sensing and radio environment