QoS and Mobility Support in CRS
the QoSMOS approach

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Outline

• QoS and Mobility support in CRS
• The QoSMOS approach
• Spectrum Management
• Radio Resource Management
QoS and Mobility support in CRS

-Motivation-

• There are white or grey spaces (inefficient spectrum use)
• Centralized frequency planning and allocation cannot cater for all issues (still inefficient use)
• Use of CRs and secondary access can help, but:
  – Needs radio environment information to be really effective
  – Needs, for some services, QoS guarantees
  – Needs to support mobility of users
The QoSMOS approach
- the dual manager structure-

Two cognitive managers
- operate on different timescales and amounts of radio resource.
- One (lower) is centralised and operates on a long timescale, builds a portfolio of the available resource in a particular region.
- The other (upper) CM is distributed and operates on a shorter timescale, allocating spectrum to individual wireless links from the portfolio.
- Feedback to adjust and optimise the rules that influence the decisions.
The QoSMOS approach -reference model-

- Core role of CM-RM is to provide service to the upper layers (application)

- Resources managed are part of the portfolio provided by the CM-SM

- Primary user is actively protected, also making use of spectrum sensing
The QoSMOS approach

Clear SM $\leftrightarrow$ RM separation of tasks, functionalities and responsibilities!
Example for clarification at the QoSMOS scenario of cellular networks:

**CM-SM**
sets parameters for e.g. basestation BS (cell)

**CM-RM**
close to Resource-Scheduler e.g. in BS (cell)

**Time-Scale:**
- "semi-static" (e.g. some seconds to hours’’)
- "dynamic" (e.g. milli-seconds)

"External Info", Constraints, Repositories, Policies, …

CM-SM decides on which part of the spectrum portfolio and which transition parameters are allowed to be used by a particular CM-RM entity, it sets constraints within which the CM-RM can operate.

CM-RM assigns resources on a short (dynamic) time scale to the users within the assigned parts of the spectrum portfolio and within the parameters / constraints set by the CM-SM.
Cognitive Spectrum Manager

- Cognitive spectrum management framework specification and proof-of-concept implementation of core modules.
- Algorithms and cognitive methods to optimize spectrum utilization, e.g., for fragmented spectrum under various constraints imposed by regulation, licensing and trading of (shared) spectrum.
- Strategies and algorithms to cope with distributed cognitive decision-making contributing to cognitive spectrum management.

Mobility and QoS

- Cognitive manager architecture to implement decision-making process for cognitive allocation at link level.
- New mechanisms to support mobility and manage QoS at the radio access level in an spectrum opportunistic setting, including:
  - Policies to be shared between different decision-making entities,
  - Methods for robust and reliable end-to-end communication with intermittently available resources and with limited or erroneous feedback.
  - Derivation of algorithms to implement the proposed mechanisms.
  - Performance evaluation of the algorithms and mechanisms by simulations.
Spectrum Management - reference architecture -

Coexistence domain

Coordination domain

Network domain

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Context information:
in spectrum (SM) domain
and
in resource management (RM) domain
Opportunity modelling
-User activity models-

Incumbents activity modelling

1.) measurement
2.) quantization
3.) aggregation (multiple users) → fit a Markov model

Opportunistic user activity modelling

1.) 2 state Markov model
2.) parameters derived from internet usage
3.) aggregation (multiple users)

Supporting cognition and decision process

Result: OFF duration

Result: ON duration

Number of primary users=3
Number of primary users=10
Number of primary users=30

Number of secondary users=3
Number of secondary users=6
Number of secondary users=9

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Opportunity modelling -based on user activity models-

Low incumbents activity allows opportunistic users to utilize a channel

Incumbents OFF duration

Opportunistic users ON duration

Pr(D_{OFF} \geq 1500 \text{ sec})

Cognition

Detect opportunity

Pr(D_{ON} \geq 1500 \text{ sec})
Spectrum Management
-simplified QoSMOS hierarchical spectrum management model-

Coexistence Domain
- Spectrum Manager (CM-SM)
- Global Spectrum Portfolio Repository
- Geolocation Database

Coordination Domain
- Spectrum Manager (CM-SM)
- Local Spectrum Portfolio Repository
- Spectrum Manager (CM-SM)

Networking Domain
- Resource Manager (CM-RM)
- Basestation Controllers
- Spectrum Sensors / Sensor Network

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Spectrum Management
-Requesting and Obtaining Spectrum-

• CM-SM entities perform: multi-purpose optimization on spectrum portfolios (e.g. utilization, interference ...).
• CM-SM entities may obtain spectrum portfolios from other CM-SM entities (e.g. from a spectrum trader).
• Portfolio repositories contain deployment history and may act as a cache.
• Spectrum requests may refer to a specific realisation (e.g. existing portfolios) or to abstract bands (e.g. a portion of a frequency band).
• Basic procedures are
  – Request / deploy portfolio.
  – Revoke / release / update portfolios.
• CM-SM entities may request geo-location databases to create and optimize spectrum portfolios.
Spectrum Management - Req. and Obtaining Portfolio: showcase

Illustrates the initial SM implementation beyond PoC.

Focus set on real-time interaction between managers, portfolio communication and spatially constrained spectrum portfolios.

Enables to validate, verify and optimize spectrum portfolios in a real-world set-up.

U.K. Geolocation Database (BT)

Spectrum Manager (Fraunhofer)

Resource Manager (Fraunhofer)

Spectrum Sensor (IT, TST)

HTTP / HTML5 Client

HTTP / HTML5 Client

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Radio Resource Management

- Mechanisms to **support mobility and manage QoS at the radio access level** when using spectrum opportunistically.
- Identification of QoS class at the MAC from Network layer and corresponding differentiated processing of the data flows.
- **Policies** (scheduling, etc.) for QoS support in QoSMOS opportunistic environment, i.e., with mobility and scattered available spectrum.
- **Methods and protocols** for robust and reliable end-to-end communication with intermittently available resources.
CM-RM architecture

Networking domain
Resource Control

Terminating domain
Resource Use

- RESOURCE ALLOCATION
- REPORTING TO CM-SM

- METRICS
- MANAGEMENT

CONTEXT ACQUISITION

CM-SM

QoS
MAINTENANCE
TRIGGERS (DROP, HO)

SERVICE PROVISION
MAC/PHY CONFIGURATION

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Cellular extension in white spaces

Rationale:
• Operators use “free” portions of radio spectrum in addition to their licensed bands to increase their operational bandwidths i.e. capacity.

Basis:
• The use of the “free” spectrum must be shared among the different operators.
• CM-RM is in charge of optimizing the exploitation of the information provided by CM-SM regarding the availability of free spectrum.
• CM-RM is also responsible for combining information of both licensed and opportunistic bands in order to maximize the QoS of the users of each Mobile Operator.
Cellular extension in white spaces

Scope:
• Improve “experienced QoS”
• Expand coverage area through these extra bands.
• Trade-off to be evaluated based on the requirements of users in each cell.

Operators must deal with $\alpha$ and $\beta$ in order to fulfill the QoS requirements of as many users as possible.

Mobility management in this scenario
- Physical mobility, change of cell due to movement of UE.
- Frequency band mobility, primary users appearance implies shifting opportunistic users to other bands.
conclusions

• Regulation has dramatically changed and spectrum sharing, or secondary use become viable.

• Spectrum and Resource Management framework defined, specified, and PoC implemented and tested.

• There is no “one size fits all” solution, but the QoSMOS framework can adapt its policies to what is needed in a particular application case and context.

• Instantiations of the QoSMOS cognitive manager model can be applied and tailored to different cases and can ensure QoS for secondary users, within the limits of given policies and constraints.
Thank you!