Radio Spectrum Policy in Europe: "Shared use of spectrum" as a new paradigm for spectrum management

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* *Disclaimer: the views expressed are those of the author and cannot be regarded as stating an official position of the European Commission.*

Scope of presentation

1. **Radio spectrum policy in the EU**
2. **Three trends towards rethinking spectrum management**
3. **Demand: emerging spectrum usage profiles and applications**
4. **Spectrum sharing: "Collective use of spectrum"**
5. **Responsibilities and challenges for implementing collective use**
6. **Cost / benefits of shared use ?**
7. **On-going activities and state of play in the EU**
8. **Conclusions**

References

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Section 1:
Radio spectrum policy in the EU

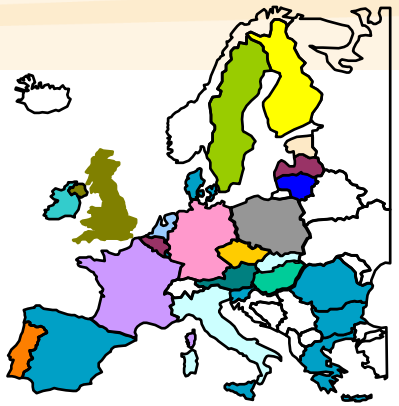
Europe's spectrum policy in context

- **EU: ~500 million inhabitants = consumers**
- **EU ICT turnover: bn€ 660**
- **Radio related electronic communications services (ECS): >250 bn € or 2.2% of EU GDP**
- **ICT sector contributes to 20% of overall GDP growth and to ~30% of the productivity growth.**
- **Radio sector is an important growth factor and offers a significant opportunity for recovery**
- **Radio applications are pervasive to all areas of modern information society and contribute to quality of life and efficiency**

Europe's spectrum policy in context

Region with *individual* countries …

- own and regulate spectrum individually
- different spectrum legacies
- issue spectrum national usage rights
- national conditions:
  economic development; cultural background; geography / demography; wireless service needs; markets; etc



… but European Union as *political and economic entity*

- integrated economies (growth, competitiveness, jobs,…); internal market →
- enabling frame:
  - coordination of spectrum policy
  - (radio) equipment regulation

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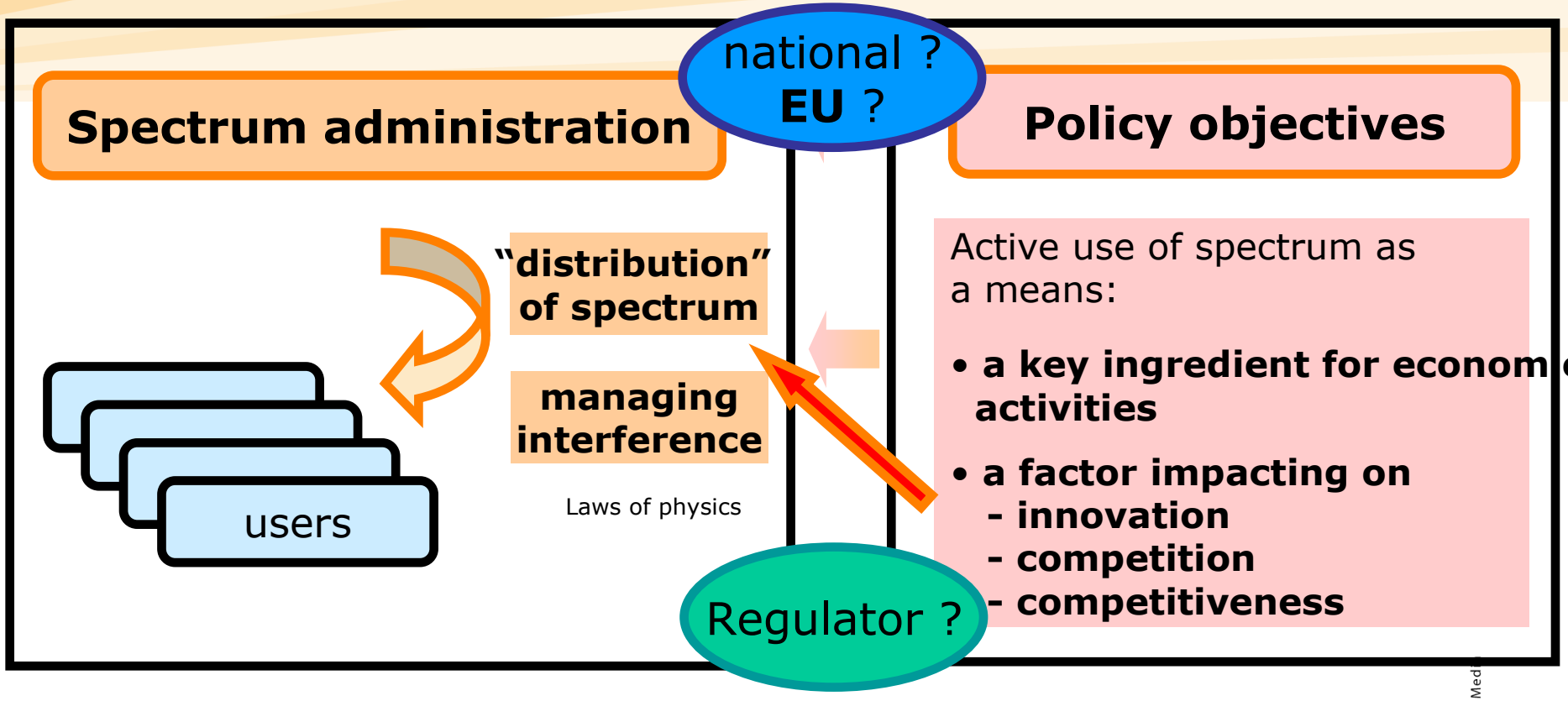
Paradigm shift: spectrum management → spectrum policy



traditional concept:
***technical spectrum management*:**
- **technical efficiency**
- **containing interference**

new concept:
spectrum policy
- **socio-economic and cultural efficiency**

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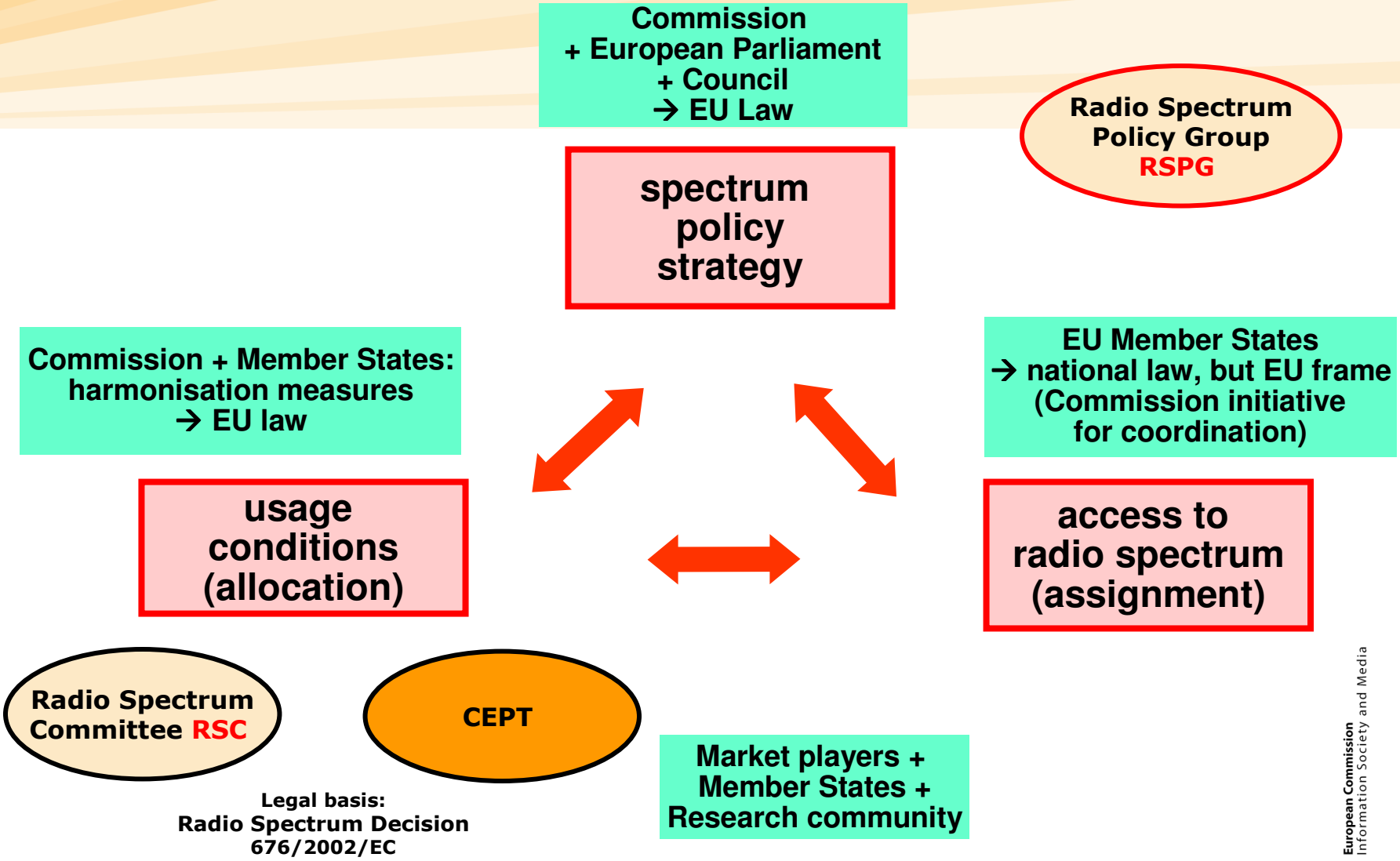
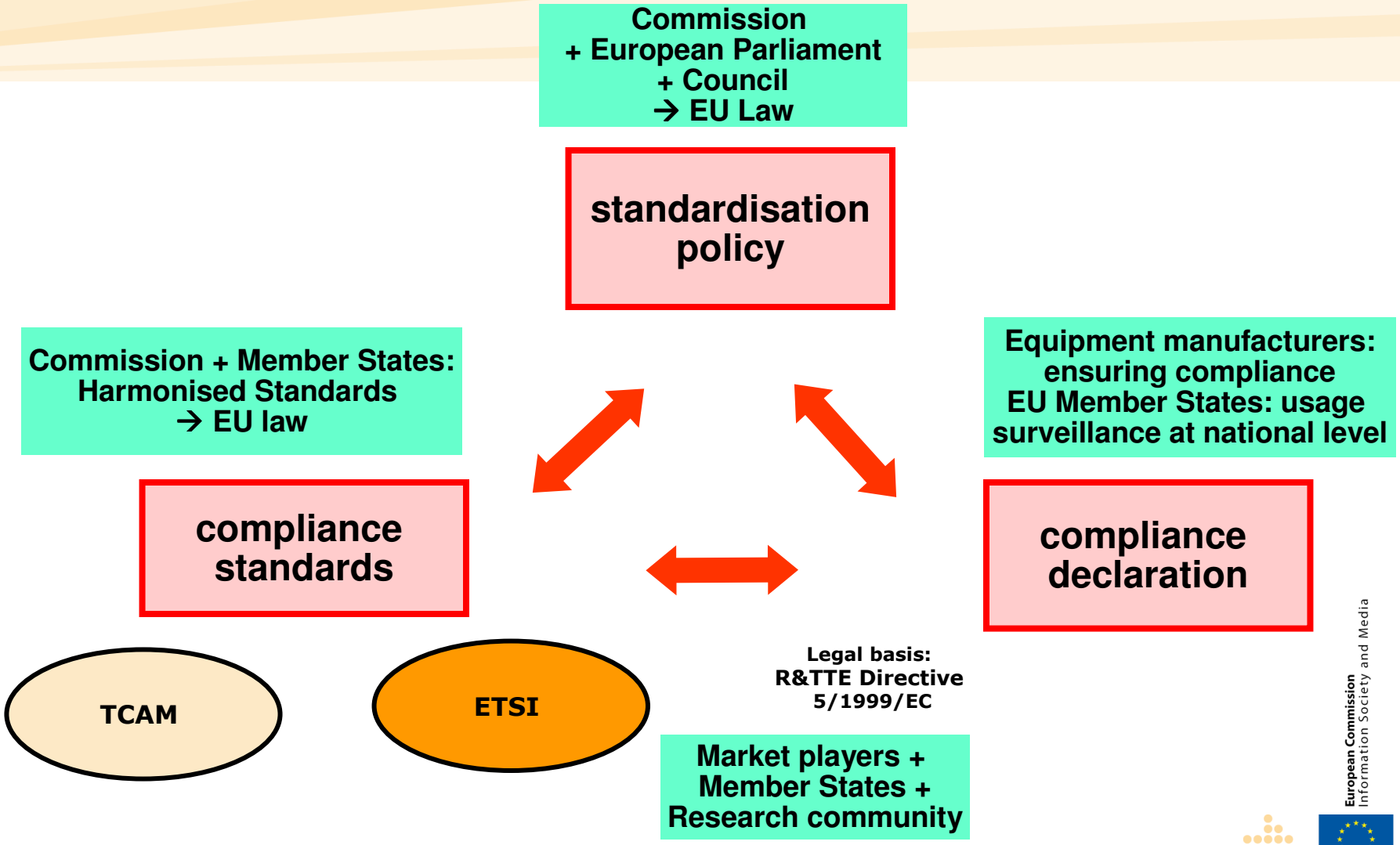
Spectrum policy at EU level: organisation



Equipment regulation at EU level: organisation



Main stream policy lines of EU spectrum policy

Maximising socio-economic /cultural potential of spectrum

- balancing **coordination at EU level vs national flexibility**
- **empowering spectrum user** (less "command and control")
- no dogmatic approach, **mix of management paradigms**:
  market based assignment for exclusive usage rights / license exempt approach non-exclusive rights / "command & control"
- **facilitating access** to spectrum resources
- promoting **efficient spectrum usage**
- wireless access policy ("WAPECS"): **technology and service neutrality** for spectrum usage (electronic communications services)
- **Synergy of research efforts and spectrum policy**

Section 2:

Three trends towards rethinking spectrum management

Rethinking spectrum management ?

3 key drivers tentatively identified:

- "surging demand for spectrum creates **scarcity**"
- "**technological progress** changes the way we use and manage spectrum"
- "**new spectrum usages** changes demand for spectrum"

"Scarcity"

- **Spectrum "quality"** varies according frequencies
- Key **"physical factors" vs. user demand**:
  - **transmission bandwidth**
  - **penetration capability**
  - **coverage range**
- Key challenge:
  - definition **optimum "cell architecture"** per usage
  - **making spectrum available**
    (key issue: legacy spectrum usage rights)
- **Today's perception**
  - **scarcity < 1 GHz**
  - **higher frequencies exploitable ?**

"technological trends"

- **usage higher spectrum range**
  becomes increasingly technically feasible
- **from "dumb" to intelligent receivers**
  improved interference resistance technically feasible
- major (disruptive ?) technical break through:
  adaptive radio
  - **possibility of sharing usage between different users**
  - **possibility for individual right holder to optimise the usage of spectrum assigned to him**

adaptive techniques

Software defined radio (SDR)

***Radio controllable* by software → flexibility**

A radio transmitter and/or receiver employing a technology that allows RF operating parameters including, bit not limited to, frequency range, modulation type, or output power to be set or altered by software (…)

Cognitive radio system (CR)

***Control strategy* through sensing → "intelligence"**

A radio system employing technology that allows the system to obtain knowledge of its operational and geographical environment, established policies and its internal state; to dynamically and autonomously adjust its operational parameters; and to learn from the results obtained.

ITU-R Study Group 1

Section 3:

Demand: emerging usage profiles and application candidates

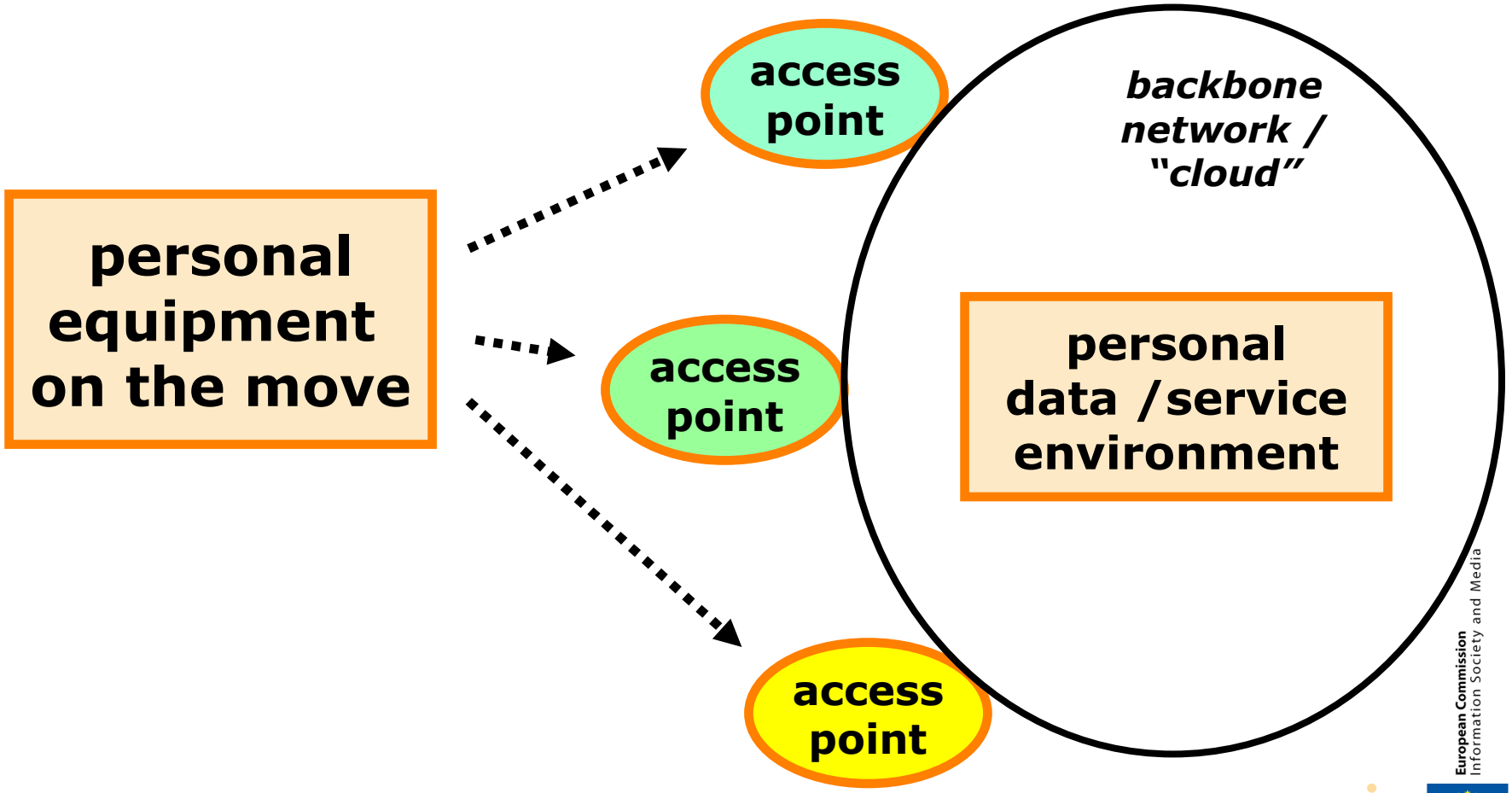
Trends in new spectrum usage patterns

- **"global" use → "local" → "personal" use**

WAN	LAN	PAN
• high-power • wide coverage • infrastructure shared by many users	• low-power • small coverage • infrastructure shared by several users	• low-power • small coverage • individual / personal use

Trends in new spectrum usage patterns

- **nomadic / occasional use**

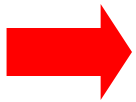


Trends in new spectrum usage patterns

- **"mass" applications**
- **"democratisation" of spectrum access**

trend

- Many new "individual" applications emerging
- Demand for quick set up of communication infrastructure
- Innovative momentum dependent on spectrum availability and easy access



impact

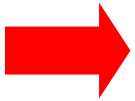
- demand for sufficient spectrum
- flexible spectrum usage needed
- easy spectrum access (licensing)

Trends in new spectrum usage patterns

- **Quality of service (QoS) depends on application, but:**

trend

- New "individual" applications allow for compromises on ***quality in transmission*** reliability without endangering significantly the ***quality of service***



impact

- higher interference tolerance
- opens up "polluted" spectrum bands for new usages

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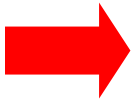
Trends in new spectrum usage patterns

- **Dynamic economies of spectrum usage**

trend

- a single application is characterised by demand of spectrum varying over time
- Examples of variables : bandwidth, transmission QoS, usage time and range, price of spectrum access vs. business case revenues



impact

- More efficient spectrum usage in technical and economic terms possible
- Flexible reuse on spectrum feasible reduces scarcity

Examples of "new" usages

- **home automation**
- **local wireless extension of broadband access**
- **local media streaming**
- **communications needs for towns / local communities**
- **transport applications**
- **remote metering, energy consumption surveillance**
- **security applications, remote surveillance**
- **medical telemetry, social alarms**
- **"internet of things"**
- **mobile communications (reconfigurable networks)**

Section 4: Spectrum sharing: "Collective use of spectrum"

Shared use of spectrum: potential benefits and models

- **Innovation driver**
  - shared use of spectrum stimulates development of technologies for advanced interference mitigation
  - dynamic use of spectrum facilitates adaptive network deployment
- **Sharing of spectrum serves policy objectives**
  - new and diverse services to the citizen;
  - overcoming digital divide
  - enabler for sectorial policy objectives (environment, transport,…)
  - wireless communications benefit the ICT sector, hence represents a significant growth driver
  - flexible usage conditions lowers barrier to small scale business cases: potential benefits to SMEs, service innovators, etc.
- **Increasing spectrum supply through shared use:**
  - drives spectrum prices down
  - lowering the barrier to access spectrum increases competition

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Shared use of spectrum: potential benefits and models

shared spectrum usage

collective usage of spectrum (CUS)

- unknown number of users
- dynamic usage

planned coexistence of spectrum usages

- known number of users
- static usage

"Collective use of spectrum"

An attempt to clarify "language" and to set the context:

"*Collective Use of Spectrum allows an undetermined number of independent users and / or devices to access spectrum in the same range of frequencies at the same time and in a particular geographic area under a well-defined set of conditions"*

RSPG Report RSGP08-244, November 2008

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"Collective use of spectrum" Sharing models

collective usage of spectrum (CUS)

- unknown / varying number of users

"ISM band" model	**"white space" model**	**"access right arbitration"**
• **band availability: static** ***(specs to protect legacy users)***	• **band availability dynamic "vertical sharing"** ***(specs to ensure priority use for legacy users)***	• **access rights dynamically attributed on demand: "horizontal" or "vertical sharing"**
• **all users compete dynamically for access: "horizontal sharing"** ***(specs to determine sharing conditions)***	• **all users compete dynamically for access: "horizontal sharing"** ***(specs to determine sharing conditions)***	• ***common technical usage frame*** • ***arbitration rules***

"Collective use of spectrum": Techniques to avoid interference

Interference mitigation remains the central issue:

- **Setting static technical usage parameters:**
  - **Power limits, indoor constraint, modulation / coding specs etc. guaranteeing a determined static level on non-interference**

  → rigid, suboptimal approach

  → simple / cheap radio equipment

- **Using adaptive techniques parameters:**
  - **allowing spectrum usage under less restrictive parameters, but imposing to take the actual spectrum occupancy into account.**

  → increased spectrum usage efficiency through dynamic approach

  → costs of more sophisticated radio equipment

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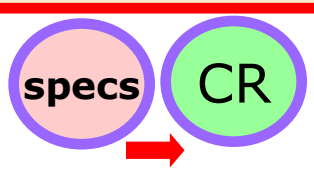
Collective use of spectrum: The role of CR techniques

collective usage of spectrum (CUS)

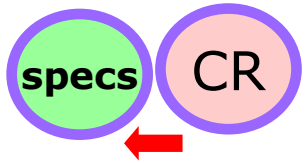
- **unknown varying number of users**

"ISM band" model



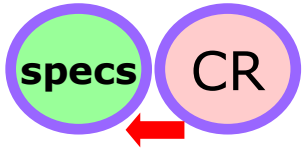
- **surviving in a crowded environment**
- **politeness rules**

"white space" model



- **determine whether usage of spectrum is permitted**

"usage arbitration"



- **acquire "suitable" usage right (amount / quality / price of spectrum)**

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Collective use of spectrum: usage rights / protection

collective usage of spectrum (CUS)

- **unknown number of users**
- **dynamic usage**

"ISM band"	**"white space"**	**"usage arbitration"**
• **license exempt !** (general authorisation)	• **license exempt ?** (general authorisation)	• **individual license !** • **market based assignment** • **private management**

protection variable depending on usage right

"Collective usage of spectrum"
Radio spectrum available matching needs ?

- **"ISM band" model**
  - exists and has offered good results
  - spectrum is available under this model
  - test bed for simple forms of CR
- **"white space" model**
  - the "next step", driven by scarcity
  - costs ? which bands ?
- **"arbitration of exclusive rights"**
  - futuristic concept, new approach of sharing
  - applicable to bands which apply individual rights
  - not used so far, intensive research
  - "concept driver": optimise networks using dynamic spectrum usage approaches

evolutionary process
usage efficiency, innovation

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"White Spaces" approach untested

- **"white spaces" opportunity**
  - potentially offering new resources of "prime spectrum"
- **candidate bands ?**
  - demand: *the "right" spectrum band*
  - > call for "low" frequencies: covering local area, good penetration
    > call for "high" frequencies /offering aggregated spectrum blocks: high transmission bandwidth
  - supply: *bands with "white space potential"*
    > broadcasting
    > defence

"White Spaces" approach untested

- **alternative solutions to "white spaces" exist :**
  - "low" frequency ISM bands: 2.4 GHz band very successful
  - UWB technology so far not commercially very widely used
  - other alternative access modes:
    - > power line
    - > exploiting high frequencies (e.g. 60 GHz)
    - > mobile cellular networks (machine to machine communication)
    - > femto cells to bridge the gap to fixed broad band access (no "fresh" spectrum needed, convergence fixed/mobile)
- **challenges of regulatory, technological nature**
- **implementation costs vs. benefits ?**

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Section 5:

Responsibilities and challenges for implementing collective use

"Collective usage of spectrum" responsibilities involved

- **Regulators**:
  - selecting candidate bands and determining sharing model
  - defining usage conditions
  - regulating equipment (receiver characteristics ?)
  - overall responsibility for "predictable interference environment"
  - monitoring actual usage of spectrum and maintaining information
  - Defining liabilities
  - ensuring equitable access to radio resources
- **Equipment manufacturers**:
  - developing interference resistant receivers
  - developing software defined radio
  - designing cognitive radio capable equipment as solution to satisfy usage conditions set by regulation
  - standardisation effort
  - equipment conformance
- **Spectrum users**:
  - adhering to static parameters and to sharing protocol discipline

Challenges to exploit "ISM bands"

- **Regulatory challenges**
  - identifying suitable ISM bands (across the whole spectrum range; according to demand, new usages; global coordination)
  - setting least constraining general usage parameters (TN, SN)
  - Making bands effectively available
    > legal certainty over usage rights,
    > defining new interference models
    > protection of legacy usages
    > defining liabilities
  - ensuring conformance compliance of equipment, enforcement
  - usage monitoring

- **Technology challenges**
  - interference resistance receivers
  - standardisation of interference mitigation techniques (CR such as "listen before talk" LBT, "detect and avoid" DAA)
  - reducing cost of equipment

Challenges to exploit "white spaces"

- **Identifying white space bands**
  - what is the definition of "unused" spectrum ?
    → How much spectrum becomes available through white spaces ?
  - difficulty to define the usage of spectrum to be protected (frequency / geography / time space)
  - anticipation of future development of legacy usages to be protected

- **Linking CR technology to permitted usage conditions**
  - today's approach: principle of "zero tolerance" as for interference of white space secondary user on legacy user
  - new approach: mutually tolerated interference ?
  - new challenge: trust in CR and its performance determine operational radio parameters and the format of usage right.
  - liability

Challenges to exploit "white spaces" CR specific issues

- **CR technology: how to sense the radio environment ?**
  - **direct sensing of environment**
    - > the hidden node problem (communication between CR radios)
    - > setting levels of emission signals to be detected
    - > signature of signal to be protected
    - > periodicity of sensing
  - **pilot channel / sensing networks approach**:
    - > spectrum for the pilot ?
    - > where does the information of the pilot come from ?
    - > who "owns" and runs the pilot ? Who bears the costs ?
    - > standardisation of the pilot (cross border ?)
  - "**geolocation**"
    - > defining the database structure and information it contains
    - > updating the database
    - > who "owns" and operates the database ? Who bears the costs ?
    - > security issues

Challenges to implement "usage right arbitration" model

- **potential supply: "spot spectrum environment" definition**
  - amount of spectrum / usage area / availability over time / interference to be tolerated / max permitted interference generation / applicable transmission parameters / spectrum price / etc.

- **technology**
  - monitoring spectrum usage on-line
  - making information on available spectrum environment available (geolocation ? pilot ?)
  - organising and realising on-line arbitration (e.g. spot or leasing market, peer to peer or band manager, etc.)
  - standardisation of procedures

Challenges to implement "usage right arbitration" model

- **missing elements**
  - availability of CR capable equipment
  - monitoring spectrum usage
  - running real-time spectrum arbitration

- **regulatory challenges**
  - new approach to usage rights assignment (on-line trading)
  - spectrum pooling concepts
  - defining usage rights in terms of interference
  - setting rules for fair access to spectrum, competition aspects
  - ensuring conformance of CR equipment
  - defining liabilities
  - security

Section 6:
cost / benefits of collective use ?

Cost / benefits: a tentative assessment

- **"ISM model" in many cases viable (CR already introduced)**
  - RLAN in 2.4 and 5 GHz: LBT technology for shared use, incl. protection of radar application
  - UWB in 3.5-9.5 GHz: DAA technique
  - SRR UWB in 24 GHz: geolocation based switch off (radio astronomy sites)

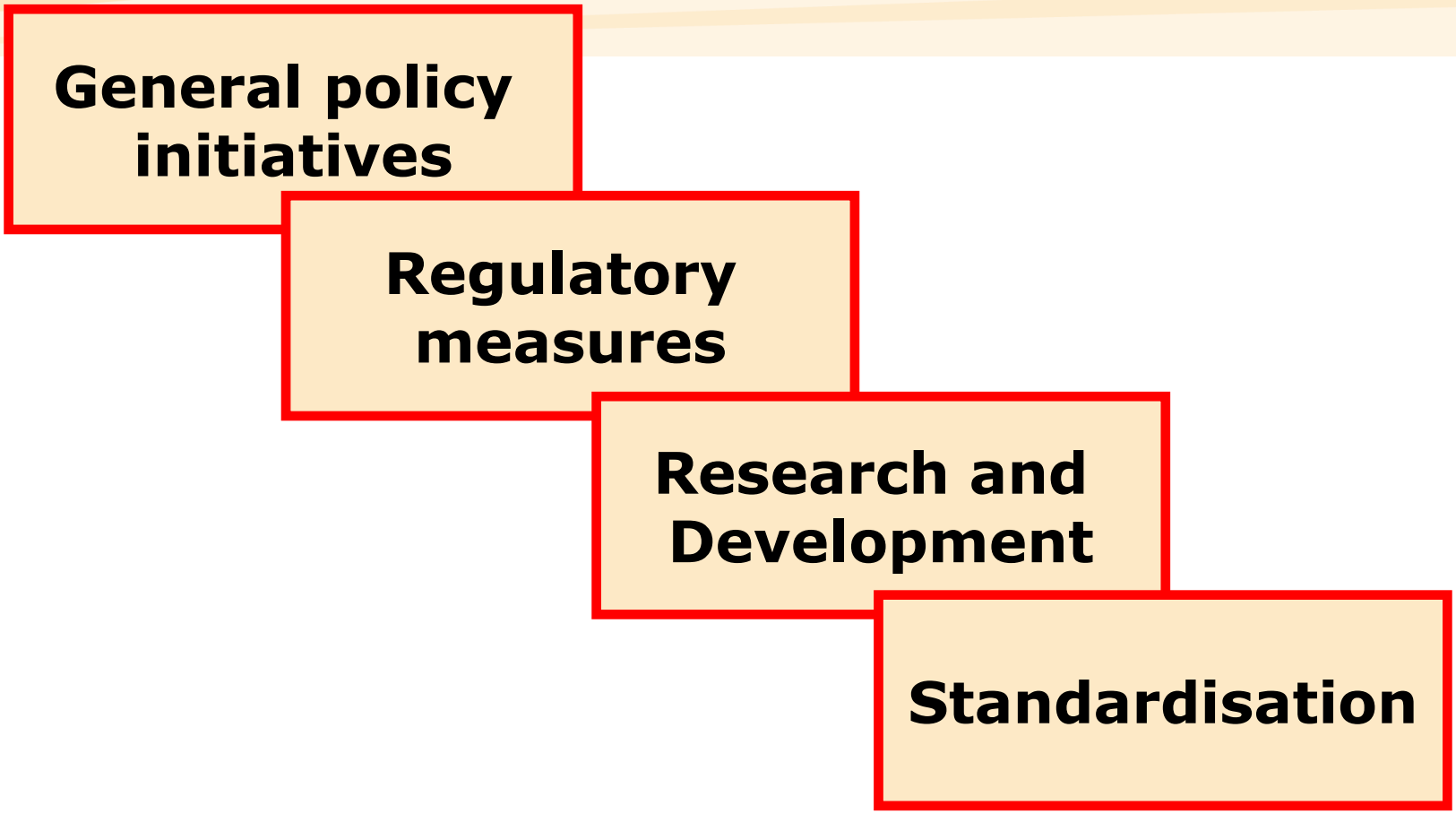
- **More sophisticated shared use so far unproven to deliver viable business models**
  - technical stable and standardised CR solutions still under progress for "white spaces", only beginning for "arbitration of usage rights" model
  - cost of sophisticated CR equipment not tested
  - time to market uncertain
  - uncertainty over amount of "unused spectrum" and over regulatory environment

Cost / benefits of "shared usage" approach a tentative assessment

- **Drivers to new forms of collective use such as "white spaces" and "arbitration of rights":**
  - **technological experience driven by need to optimise networks, (allow for a more efficient use of the rights holder's own spectrum asset)**
  - **push for using lower frequencies usage focuses attention on using "white spaces" in broadcasting bands**
  - **other opportunities for white spaces to be explored: defence spectrum**

Section 7: On-going activities and state of play in the EU

EU spectrum policy: building blocks related to collective use of spectrum



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EU spectrum policy: general policy initiatives related to collective use of spectrum

area	*issue*	*RSPG*	*Commission*
Secondary trading	**usage rights secondary trading**	**Opinion**	***Communication***
Collective use of spectrum	**applications, needs**	**Opinion**	***Study***
WAPECS	**flexible use of spectrum (TN,SN)**	**Opinion**	***Communication; regul. Framework ECS***
Interference models	**definition of interference**		***Study***
Digital Switchover / Digital Dividend	**spectrum aspects, reorganisation of UHF band, white spaces**	**2 Opinions on Digital Dividend Opinion on Multimedia**	***Communication RRC06; WRC-07 Communication; Communication Dig.Div.; Digital Dividend Roadmap***
Broadband wireless	**spectrum needs for broadband**	**Report**	***I2010 → European Digital Agenda, broadband strategy***
Cognitive radio	**analysing issues, state of play, perspectives**	**Report**	
WRC-11	**AI 1.19 on CR**	**Opinion**	***[WRC-11 Communication]***

EU spectrum policy: RSPG report on collective use of spectrum

RSPG CUS Report (2008)

- **expects increasing importance of the collective use (CUS) model, but the concrete demand difficult to predict; the CUS model seen as particularly suited for "smaller users", mainly short range (but not only)**
- **spectrum should be made available in whole range; emphasis of underused opportunities in high spectrum bands; need to be *pro-active* on availability of CUS spectrum (e.g. 40 GHz, experimental spectrum)**
- **"markers" for deciding of suitability for CUS model: "range" / "power level" / "specific spectrum band needed" / "type of usage"**
- **suggests to group different groups of usages following CUS, to ease the issue of mixing very different usage in a same band.**
- **suggests to explore the possibility of setting a power threshold below which devices can operate at any frequency on a CUS basis**
- **dynamic spectrum access becoming more important, needs to be supported by suitable regulation; impact of cognitive radio acknowledged;**
- **emphasises need to allocate spectrum flexibly for exclusive usage (incl. overcoming legacy constraints) for the usage based on the CUS model**

Complementary: Study on Collective Use 2006

EU spectrum policy:
RSPG report on cognitive radio

RSPG CR Report

- **Identifies cognitive radio as key element to move from static to dynamic spectrum management**
- **Clarifies terminology and components of CR**
- **Notes usage of CR for sharing but also optimising networks and its spectrum consumption**
- **Emphasises that CR is not confined to license exempt spectrum usage, but can benefit also in case of exclusive right usage arbitration**
- **Analyses the usage of CR in the case of white spaces and identifies issues to solve**
- **Emphasises need for a harmonised approach to CR**

To be followed up by an RSPG Opinion identifying necessary regulatory measures to be taken to facilitate the introduction of CR (delivery end 2010)

Digital Dividend / White Spaces

The digital dividend roadmap (October 2009)

- **Immediate actions:**
  - **> accelerating the switch-off date for all Member States: 1/1/2012**
    (note: to date: 6 MS have already switched off, 26 out of 27 will switch off in the course of 2012)
  - **> mandatory usage conditions for wireless broadband services in the 790-862MHz ("800MHz band"), no date for making available**
    (note: Austria, Czech Republic, Finland, France, Germany, Spain, Sweden, Netherlands and UK already on track for assigning this band)
- **Actions to be proposed (Radio Spectrum Policy Programme)**
  - **> mandatory availability of the 790-862 MHz band**
  - **> minimum efficiency level for the use of the digital dividend in the EU**
  - **> establishing common position for coordination with third countries**
- **Long term actions to improve the usage of the digital dividend**
  - **> preparing for next generation transmission or compression**
  - **> ensuring minimum receiver interference resistance**
  - **> frequency agile wireless communication technology development**
  - **> migration of wireless microphones**
  - **> usage of white spaces**

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Digital Dividend / White Spaces

- **Amount of white spaces varies in MSs**
  - **> example UK estimate: 50% of all locations offer 100-150 MHz white space**
  - **> increased usage of bands <790MHz by broadcasting; also: more channels, HDTV, 3D TV; higher packing of channels**
  - **→ spectrum available through White spaces tend to shrink**
- **Services to be protected when opening white space usage:**
  - **> broadcasting**
  - **> PMSE equipment ("wireless microphones")**
  - **> other usages (in certain Member States)**
- **Commission initiatives to be expected:**
  - **> support technical studies (in cooperation with CEPT)**
  - **> examine socio-economics**
  - **> plan for PMSE equipment**
- **Member States initiatives:**
  - **> UK public consultation on CR applied to UHF white spaces**
  - **> experimental spectrum in IRL**
  - **> trials in FIN, etc.**

CEPT work on White Spaces

- **Investigating cognitive radio for white spaces in UHF:**
  - **CEPT reports 24 (June 2008) recommends**
    > white space usage on non-protected non interfering basis
    > to undertake further studies (activities on-going in ECC SE43)
  - **ECC Spectrum Engineering Group (SE43):**
    > geolocation method: database specifications
    > sensing: performance specification
  - **report due mid 2010**
- **Related work:**
  - **Investigating candidate bands for CR based usage**
    ECC Frequency management Group (FM)
  - **Preparing for WRC-11 (agenda item 1.19):**
    ECC Conference Preparatory Group (CPG)

Open regulatory questions in the EU

- **Interference models:**
  - present regulation: interference defined in terms of avoiding "harmful interference", i.e. a worst case scenario
  - alternative: interference defined through impact on spectrum users, i.e. through tolerable interference
  - possible new approach: usage rights defined by applicable interference conditions
  - option for spectrum users to negotiate usage agreements bilaterally setting individual mutually agreed interference constraints
  - Commission Study "Interference Models" undertaken in 2008
- **Receiver specifications**
  - regulatory option of setting receiver parameters ? Other incentives ?
- **Equipment regulation**
  - European system of self-compliance may raise issues on CR context
  - Formal certification of CR equipment (incl. software) needed

EU spectrum policy: Harmonisation measures

area	*application*	*CR ?*	*assignment mode*
Short range devices	**large variety of applications**	***(x)***	***unlicensed***
RFID	**object tagging**	***(x)***	***unlicensed***
SRR 24 GHz and 79 GHz ITS	**road safety**	***x***	***unlicensed***
Ultra wide band (UWB)	**high bit-rate communication; specific applications**	***x***	***unlicensed***
5GHz R-LAN	**ECS**	***x***	***unlicensed***
Mobile communications on planes and vessels	**ECS**	***x***	***licensed + unlicensed***

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Regulatory action on short range devices (SRD)

- **CEPT: traditionally developing consensus on voluntary common technical parameters for a number of bands (SRD MG producing ECR REC70-03)**
- **European Commission SRD Decision (2006): legally binding harmonised usage parameters, annual updates**
- **Approach:**
  - least constraining usage parameters (technological and service neutral approach; power emission limits, duty cycles, possibility for channel aggregation, etc.)
  - interference mitigation techniques base on simple CR used in certain bands (mitigation *performance* objective by reference to standards where available)
  - investigate approach to introduce generic emission thresholds below which transmission would be unregulated
  - increasing number of bands harmonised at EU level
  - link to standardisation (compliance)

UWB Regulation

- **regulation based on technical studies undertaken by CEPT**
- **initial UWB regulation (2007)**
  - indoor - short range/high data rate type of applications
  - Spectrum mask for usable range between 3.5 -9.5 GHz
  - Imposing "detect and avoid" (simple CR) in certain parts of the band
- **extended UWB regulation (2009)**
  - extend to use in 'road and rail' vehicles
  - special conditions for wall penetrating radar

Regulation for mobile communications on planes and ships

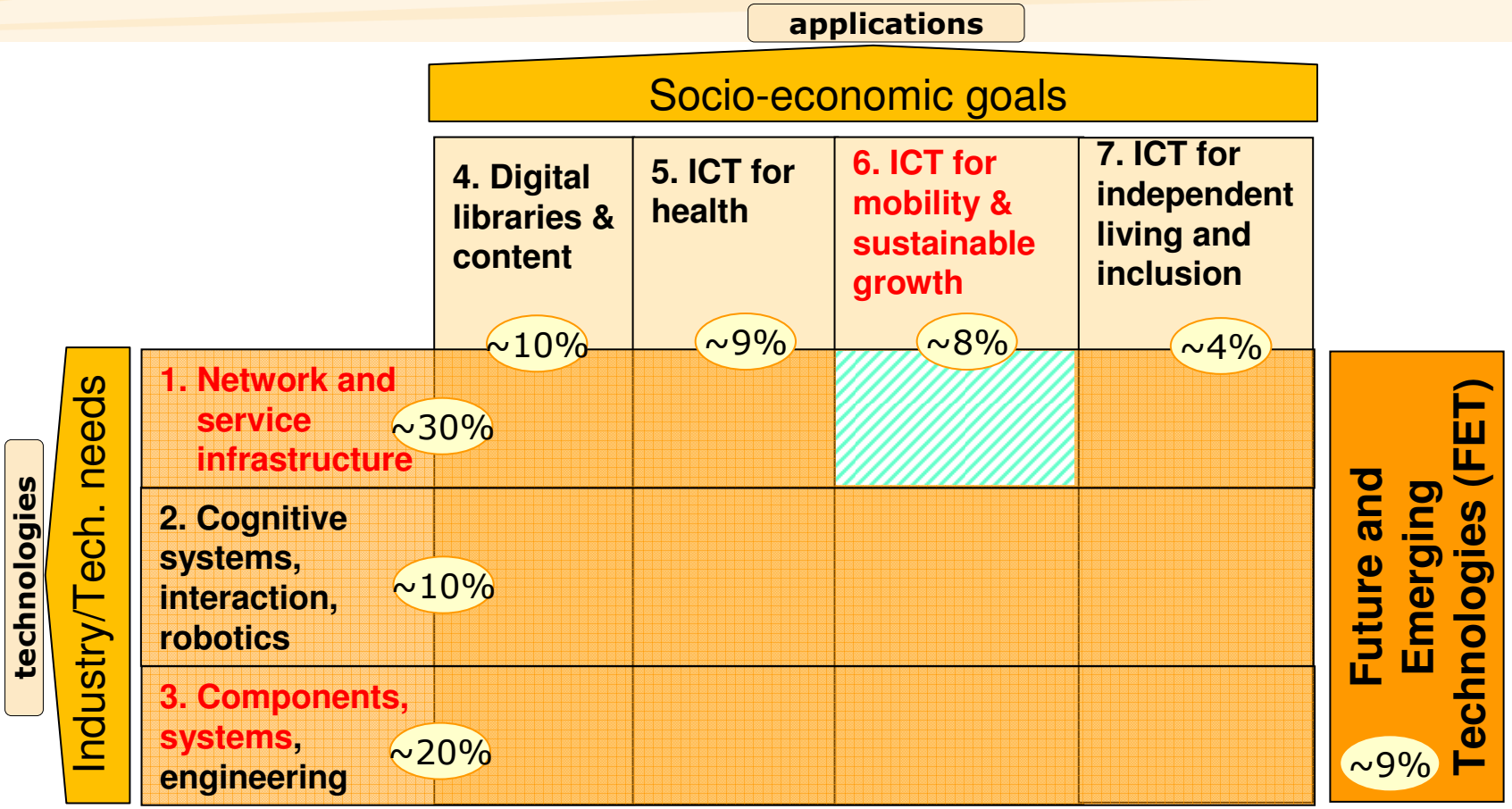
- **Regulation based on technical studies undertaken by CEPT**
- **Mobile communications on airplanes**
  - Shared spectrum 1800 MHz
  - Issue is separation of terrestrial from on-board usage
  - On-board base station:
    > geolocation": switching off depending on altitude
    > controling mobile terminals on board: noise floor to hide terrestrial networks
- **Mobile communications on vessels**
  - Shared spectrum 1800 MHz
  - Issue is separation of land base terrestrial networks from on-board usage
  - On-board base station:
    > geolocation": switching off depending on ship position
    > in-door" only

Spectrum policy: EU research action

- **Community funding of R&D**:
  - collaborative R&D
  - networks of excellence
  - coordination and support action
  - Infrastructure building
- 7th Framework Programme: 2006-13, 32.4bn €
- **IST programme (9.1bn €)**
  - 7 "challenges"
  - Future emerging technologies (FET)

Spectrum policy: EU research action

ICT R&D / spectrum policy:



Spectrum policy:
EU research action on cognitive radio

- E^2R: End-to-end reconfigurable networks
- **E^3 ("Ecube"): framing project for cognitive radio**
  End-to-end efficiency cognitive wireless networks technologies
  - ***Objective:***
    > To transform current wireless system infrastructures into integrated, scaleable and efficient managed ' cognitive system framework beyond 3G'
    > to introduce cognitive systems in the wireless world
  - ***Tasks:***
    > reference architectures (including mapping on LTE)
    > reference techniques
    > identifying regulatory needs
    > contributing to standardisation IEEE (P9100.4, P100.6) and ETSI RRS
    > advising CEPT, national regulators, EC; input to ITU disucssions
  - ***Budget: 2008-2009, 18.6 m€***

Follow-up project under evaluation

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Spectrum policy:
EU research action on cognitive radio

- **Projects on ISM model related issues**
  - **PHYDAS: cognitive radio and opportunistic access scenarios**
  - **ARAGORN: CR applied to "ISM band" model**
  - **FARIMIR: developing behavioural rules used by CR in the "ISM model"**

- **Projects focusing on "White Spaces" related issues**
  - **QOMOS: potential applications for white spaces, cognitive wireless access**
  - **COGEU: enabling technologies based allowing commons or trading usage model in white spaces**
  - **PHYDAS: opportunistic use of white spaces, "good neighbourhood" approach**

- **Projects looking into specific technological**
  - **SENDORA: CR via wireless sensor networks, nomadic broadband access**
  - **SACRA: spectrum and energy efficiency using CR in multi-band environment**
  - **SAPHYRE: spectrum / cost / energy efficiency using CR for resource sharing**
  - **QUASAR: modelling spectrum sharing opportunities and assessing benefits**

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Spectrum policy:
EU research action on Ultra-wide Band

- PULSERS: Pervasive ultra-wideband low spectral energy radio systems

- **EUWB : framing project for UWB technologies**
  Coexisting short range radio by advanced ultra-wideband radio technology

  - ***Objectives:***
    > explore the enormous economic potential of the ground-breaking Ultra-Wideband (UWB) radio technology
    > extend the UWB concept with advanced cognitive radio, multi-band/multimode networking, and multiple antenna system concepts
    > enable the introduction of advanced services and competitive applications using the radio spectrum in a sophisticated manner

  - ***Tasks: inter alia***
    > WP2: Cognitive UWB radio and coexistence
    > WP8: applications (public transport, automotive environment, home environment)
    > contributing to standardisation IEEE and ETSI
    > advising CEPT, national regulators, EC; input to ITU discussions

  - ***Budget: 2008-2011, 20.7 m€***

- **WALTER: reference activities on**

  > specifying, testing, and improving interoperability of UWB
  > ensuring coexistence of UWB with other radio technologies

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Standardisation

- **ETSI responsible:** SDR and CR related activities in
  - the Technical Committee **Reconfigurable Radio systems (RSS)**
  - working groups:
    > system aspects: developing SRD/CR scenarios
    > radio equipment architecture: defining functional blocks for reconfigurable base stations and mobile devices
    > functional architecture and CPC: studying functions of reconfigurable networks and the cognitive pilot channel functions
    > public safety: certification of software modules used in reconfigurable systems, CR in security and defence systems
  - link between research and standardisation via the E^3 project
  - focus on standards (no test beds or own simulations)
  - two phases:
    > delivery of technical reports and ETSI Guides (currently ending)
    > normative work (starting)
  - work on white spaces to be included, taking EU needs into account

Section 8: Conclusions

Conclusions

- **Collective use of spectrum: potential for improved efficiency in spectrum use.**
- **Dynamic spectrum usage : a possibly significant change of paradigm in spectrum management including handling access rights**
- **Innovation potential, attractive and diversified services for the citizen, increased competition, realising important policy objectives**
- **Concurring trends: technology facilitates sharing, the scarcity of radio resources forces to be efficient, and new trends in spectrum usage.**
- **Simple forms of shared use already practised and are viable.**
- **New sophisticated approaches are tried out, but with so far unproven record of economic viability , many technical questions unsolved.**
- **All players are solicited to developing a stable ecosystem for collective use**
- **Shared use will require an adaptation of regulation: usage right definition / ownership, interference models, and responsibilities / liability regarding spectrum usage.**
- **Regulators should become (pro)active to gradually offer an enabling regulatory environment,**
- **Research on technical is still necessary. Standardisation efforts will be key, and global cooperation is called for.**
- **White spaces in the broadcasting bands are likely to become the next test case.**

References

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Legal , economic and technical aspects of collective use of spectrum in the EU: Study by Mott McDonald et alt., 2006

Radio Interference regulatory models in the EU: Study by Eurostrategies et alt. 2007

Workshop on cognitive radio/regulation: proceedings of event 28/2/2020

Directorate General for Information Society and Media: central website

Radio Spectrum policy: dedicated DG INFSO policy webpage
(legislative reference documents, activities, general information)

Radio Spectrum Policy Group (RSPG) : official website
(RSPG reference documents, activities etc.)

CEPT / ECC : central website
(access points for CEPT / ECC documents)

ETSI RRS Technical Committee: dedicated webpage
(terms of Reference and activities)

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