The business model impact of flexible spectrum management and cognitive networks

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Abstract

Purpose – *This paper aims to give a short overview of European Union policy trends towards more flexible forms of spectrum management.*

Design/methodology/approach – *The paper presents a business modelling analysis, scenario construction, policy analysis and roadmapping. It argues that both flexible spectrum management and the concept of reconfigurability do not eliminate the need for a number of centralised controlling entities, and even introduce a number of new ones, performing regulatory, commercial and technical functions of a diverse nature. One of the most prominent control entities, the Cognitive Pilot Channel (CPC), is presented, and three different configurations of the CPC are outlined. Subsequently, the potential impact of different CPC configurations on business models for wireless services making use of such a channel is explored.*

Findings – *The paper concludes that a hybrid model combining a meta-level CPC with operator-deployed channels might provide the best mix of technical and strategic control for operators, and value for users.*

Research limitations/implications – *The study undertaken here is exploratory in nature since, for example, no exact estimations of cost and revenue, or harmonisation feasibility and roadmaps can be made at this time.*

Originality/value – *The CPC is a recent and potentially crucial concept which is not yet standardised or implemented and for which no business modelling analysis has been performed yet.*

Keywords *Mobile radio systems, Mobile communication systems, Radio networks, Business analysis, Modelling*

Paper type *Research paper*

I. Introduction

The concept of flexible spectrum management (FSM) refers to a set of new and dynamic procedures and techniques for obtaining and transferring spectrum usage rights and dynamically changing the specific use of frequencies. Uncertainty currently exists concerning the way in which FSM will be implemented, both from a regulatory and a technical perspective. Without any doubt, different implementations will result in different business models for offering reconfigurable services, so it is crucial to all stakeholders to have an understanding about this relationship, and the potential business configurations it might result in.

This article seeks to provide an analytical framework for examining the influence of FSM on the business models deployed for ''Beyond 3G'' (B3G) networks and services, in the context of operational solutions currently being developed within Phase II of the European FP6 project E^{2}R (see http://e2r2.motlabs.com). This project is concerned with reconfigurability of wireless networks and devices, which can be defined as the changeable behaviour of wireless networks and associated equipment, specifically in the fields of radio spectrum, radio access technologies, protocol stacks, and application services, and usually in

response to dynamic changes in their environment. In particular, the article first outlines the current and planned regulatory framework for FSM in Europe with regard to both the introduction of secondary trading and flexible spectrum usage, and contextualises these regulatory trends with evolutions currently taking place in a number of countries. Second, it argues that, even within policy environments making increasingly more use of market-based mechanisms, and even within reconfigurable systems where decision making is highly decentralised and in which real-time mechanisms for dynamic spectrum management are used, there is a need for centralised controlling entities which may fulfil a diverse set of roles. Third, it introduces the Cognitive Pilot Channel (CPC), currently under development within the E^2R project, as such a controlling entity, and outlines a number of potential configurations for deployment of the CPC. Finally, using an analytical framework described elsewhere in this issue, it evaluates in an exploratory way the potential impact of these configurations on business models for CPC-enabled mobile and wireless services.

II. The European Union roadmap towards FSM

This section briefly discusses the main policy and regulatory evolutions in Europe towards the introduction of systems and services relying on FSM (for a more extended account, see Delaere and Ballon, 2007). While this policy domain is largely a competence of the member states, the 2002 Radio Spectrum Decision of the European Commission did create a framework for European Union (EU)-wide spectrum policy making, and various instruments for concertation have been established, such as the Radio Spectrum Policy Group (RSPG). So, despite the difficulty of defining a single ''European'' spectrum policy roadmap, a number of trends can be distinguished, both on a EU-level and on a Member State level. One of these is the introduction of spectrum trading, another is the evolution towards more dynamic forms of spectrum management.

A. The introduction of spectrum trading

Spectrum management has traditionally followed a so-called *command and control* model. In its most traditional form, this model means that administrations are both responsible for negotiating frequency allocations internationally, and deciding on precise use of the bands as well as on the users allowed to use the frequencies. In case of spectrum scarcity, a beauty contest is usually held to decide who receives a license to use the spectrum. In a market with relatively few players, this was (and still is) a system that gives administrations maximal knowledge on spectrum activity, relatively large degrees of control over spectrum usage and minimises interference between services.

The introduction of auctions marked the start of a second model for spectrum management, i.e. market mechanisms. The rationale is that ''efficient spectrum markets will lead to use of spectrum for the highest value end use'' (FCC, 1999, p. 32), because the parties that have identified the highest value (i.e. revenues) for the spectrum will be willing to pay the most for it. A second step in this process is to allow spectrum licenses to be traded between actors, meaning that spectrum usage rights are transferred from one party to another in a ''secondary'' market. The economic significance of this is that, apart from confronting the cost of acquiring spectrum through an auction, the licensee also needs to address the cost of retaining its spectrum (WIK, 2006, p. 12).

Several countries inside as well as outside of the EU are currently taking steps to introduce secondary trading. In the UK, for example, Ofcom has outlined a roadmap towards assigning almost three quarters of the spectrum via market mechanisms (Ofcom, 2005a, p. 12). The European Commission has also taken steps to create a regulatory framework for the introduction of spectrum trading. First of all, the (non-obligatory) possibility to introduce secondary trading was included in the new regulatory framework, which came into force in July 2003. After the publication of an RSPG Opinion the Commission issued a Communication in September 2005, entitled ''A market based approach to spectrum management in the European Union'' (European Commission, 2005). In this document, the Commission announces its target to put into practice both secondary trading and flexible spectrum usage in the entire EU by 2010. Six issues are proposed on which a European consensus is needed, including the objective of the policy initiative, the frequency bands

involved, transitory issues (e.g. existing licenses and compatibility with competition law), the definition of usage rights, the EU-wide coordination of spectrum information and increased service and technology).

B. The road to wireless access platforms for electronic communications services

Besides spectrum tradeability, the concept of technology and service neutral frequency assignment and change of use of frequencies is another significant policy evolution. In June 2004, the European Commission issued a request for opinion to the RSPG with regard to a coordinated EU spectrum policy approach concerning wireless access platforms for electronic communications services (WAPECS). This move was spurred not only by the fact that more and more wireless technologies were becoming available for which suitable spectrum needed to be found, but also by the expectation that present spectrum policies could be made more flexible, with less stringent licensing schemes attached to the particular use made of frequency bands, so as to encourage faster introduction of innovative services and to facilitate the development of the internal market.

In the UK, the regulator believes that up to 72 percent of spectrum may be liberalised in this manner, ''allowing change of use of spectrum without any intervention and with no specific restrictions, although possible usage will be limited through the use of a spectrum mask'' (Ofcom, 2005b, p. 51). In Germany, the Bundesnetzagentur (BNetzA) commissioned a study into FSM in 2005, which recommended that ''as far as possible, usage rights should be both technology- and service neutral'' and proposed a flexible re-design of the National Table of Frequency Allocations and the Frequency Usage plan, as well as the definition of clear spectrum masks (WIK, 2006, pp. 227-35).

In November 2005, the RSPG produced its Opinion on WAPECS (RSPG, 2005). It defines WAPECS as theoretically allowing any digital technology over any platform to offer any service possible (including IP access, multimedia, multicasting, interactive broadcasting and datacasting) over any frequency band (both licensed and unlicensed) and/or network, while recognising that such approach is subject to technical coexistence requirements which are tailored to each specific band.

With regard to the implementation of WAPECS, the RSPG argued that whereas a revolutionary, ''big bang'' approach would potentially distort existing services, it would be equally unwise to wait for all existing licenses to expire, and therefore proposes that specific actions and dates for implementation be set out in detail, leaving room for member states to implement ''earlier if they see fit and taking account of local circumstances''. (RSPG, 2005, pp. 14-15). Following the RSPG Opinion, the European Commission proposed a first set of bands to be further investigated by the member states. In parallel, the WAPECS concept is included in the review of the EU regulatory framework for electronic communications, which has started in 2006.

III. The need for controlling entities

The section above focused on the gradual implementation of FSM mechanisms. However, two important remarks need to be made. The first is that market mechanisms for spectrum management will not completely replace other mechanisms for reaching optimum spectrum efficiency. European regulators have not reached consensus as to how the different mechanisms ought to be balanced and what their respective contribution to spectrum efficiency and, taking a broader perspective, to mobile market innovation is. Discussions with regulators present within the E^2R II project, as well as a scan of recent literature on the subject (Analysis & Partners (2004); Ofcom (2005c); Benjamin (2003); Hazlett (2006); Xavier and Ypsilanti (2006) among others) suggests that introduction of flexible licenses will go together with so-called (unlicensed) commons or private commons models, with the sharing of spectrum between licensed operators and unlicensed users (e.g. communication below the noise floor), as well as with a certain degree of command-and-control (or more evolved, consensus-based negotiation models derived from it). Also, harmonisation of frequencies

will remain an important tool for regulators in order to promote European-wide economies of scale for the introduction of new platforms and services, which in some cases may run counter to flexible spectrum policies.

The second remark is that, although the final objective of FSM is a situation where market players define the best use for the spectrum they own and where licenses change owners with little or no regulatory intervention, this does not mean that all activity in the spectrum domain becomes decentralised and bilaterally negotiated. On the contrary, we argue that FSM in a reconfigurable context leads to a new set of risks and challenges, some of which will need to be met by the use of existing and the introduction of new, centralised controlling mechanisms. As an illustration, Xavier and Ypsilanti (2006) discuss a number of concerns and costs that could hamper the introduction of secondary markets. A number of these are clearly related to a lack or bad functioning of centralised (i.e. transcending operator or user level) instruments (which could be, but not necessarily are, government-run).

In Xavier and Ypsilanti's (2006) analysis, the following relevant issues are highlighted:

- Low spectrum trading activity may be caused by uncertainty regarding the future primary allocations of spectrum leading to incorrect estimations of spectrum scarcity and value. Also, the lack of a publicly searchable register of management rights and licenses contributes to this uncertainty.
- High transaction costs could, again, partly be caused by lack of information on available spectrum.
- Risk of increased interference – here also, operators and users cannot individually mitigate increased interference levels. In most countries that have implemented secondary trading, regulators have set the initial limits for interference parameters, or these have been set by industry under regulatory oversight. Also, in case of conflict between the parties involved, regulators may establish mediation and/or arbitration procedures.
- Coordination and harmonisation may hamper FSM, yet the benefits of these mechanisms – which, *per se*, transcend individual actors – renders them continually useful; it also might be necessary to harmonise some of the controlling mechanisms themselves, in order to make them useful throughout the EU.
- Anti-competitive conduct as a result of FSM – in particular concentration of spectrum and hoarding by operators to preclude potential competitors from obtaining it – need to be countered by sufficient competition safeguards, be they specifically taken by regulators or part of generic competition law.
- Disruptive effects on consumers which, for example, is taken into account by Ofcom when it makes decisions on change of use of frequencies.
- Finally, the ability to achieve public interest objectives, such as those obtained through spectrum for Public Service Broadcasting, national security, public safety and health, will continue to be taken up by central actors.

Thus, controlling entities will contribute to efficient spectrum management, primarily by:

- providing information to actors;
- mitigating interference;
- coordinating and harmonising frequencies;
- combating anti-competitive behaviour; and
- pursuing objectives of public interest and consumer protection (see also CEPT's ECC (2006) report).

Concerning the need for information resources, the BNetzA study emphasises the need for an electronically available central register of spectrum availability, license ownership and rights of use (WIK, 2006, p.131). Ofcom in its turn has developed three different databases for this purpose, while private consultancies such as Cantor Fitzgerald in the US collect and

digitise FCC license data and map it onto GIS underlays. Pleas for centralised provision of information, related to middle-to-long-term spectrum availability and usage rights or related to real-time spectrum occupancy, can also be found in Weiss (2006), and in Chapin and Lehr (forthcoming), who argue that:

> The cost and risk of characterizing spectrum use can be reduced through establishing an information registry, which could be governmental or private, for authoritative data about primary uses.

Related to this, Chapin and Lehr equally see room for a so-called spectrum distributor which, besides adding value through aggregation and re-packaging of spectrum access rights (in itself a new role), would also take up a centralised monitoring and analysis function that is needed to decide whether secondary operations are feasible in given bands and given locations. In the same vein, Falk *et al*. (2003, p. 11) argue for a ''tightly controlled supervision function that analyses relevant properties of the radio emissions (as power, frequency, bandwidth, modulation) and compares them with reference data'', having the power to deactivate radios and to perform corrective measures in case acceptable radio emission levels are surpassed.

Thus, the concepts of FSM and reconfigurability, although in themselves conducive to more decentralised methods of spectrum planning, present risks and challenges which could necessitate the introduction of central controlling entities. These mechanisms may be governmental or privately operated, and they may take the form of either human intervention or automated systems or modules. Regulatory as well as business-related arguments exist for their introduction. From a regulatory point of view, controlling entities monitor compliance with policies and regulations, take action in case of violations, and may also support public policy objectives. From a business perspective, controlling mechanisms not only are enablers for more efficient spectrum management (potentially leading to lower costs and higher revenues), but the way in which they operate also helps to define the *r*ules of the game for interacting with competitors, acquiring spectrum, getting access to users, etc. The hypothesis following from this is that there are several ''configurations'' in which these controlling entities may be deployed, and the configuration chosen has an impact on the business models developed for the different wireless services that make use of them.

As argued above, the primary function of central controlling entities is that of a registry. In a more advanced form, these registries could become so-called pilot channels, which not only contain all information on available networks and occupied frequencies, but transmit this data to terminals in real-time so that these can be reconfigured to connect to whatever service available on whatever frequency. In this sense, these pilot channels can be seen as the first and foremost enablers of any FSM constellation. The next section introduces the CPC as an overarching, active registry entity, evaluates the possible configurations for CPC, and analyses its potential impact on the business models of mobile services that will rely on it.

IV. The CPC as a controlling entity

As the policy trends outlined earlier have shown, new mechanisms for dynamic spectrum access (DSA) are being introduced which are meant to significantly enhance spectrum efficiency. In particular, underused frequencies can be leased or sold to parties which value these frequencies more, secondary use may be allowed if it does not cause excessive interference, radio access technologies (RATs) operating on these frequencies may be changed, and opportunistic RATs may use varying frequencies depending on their availability, e.g. by using spread spectrum techniques.

While contributing to spectrum efficiency, these scenarios for DSA make the operation of systems making use of radio frequencies much more complex. One particular issue on the terminal side is that, when services are changing frequencies and vice versa, these terminals do not know what services are available, and where they are currently located, and would therefore constantly need to scan the entire spectrum in order to determine this. Clearly, this would be excessively power and time consuming (Holland *et al*., 2006). Basically, the problem constitutes a particular instance of a lack of information, similar to the areas mentioned in the section above where this risk could compromise the take-up of

mechanisms for FSM. In the same way that insufficient data on spectrum licenses, leases, secondary use, trading activity, etc. may lead to low spectrum trading activity, high transaction costs and increased interference, it may also effectively impede users to locate and connect to services.

Equally similar to the need of central registries and supervising functions to solve the information deficit, the problems of frequency, RAT and service discovery could be solved by the establishment of another controlling entity. The E2R project has introduced a concept for this, i.e. the CPC (Holland *et al.*, 2007). In its most basic form, this would be an invariable – and, thus, easily detectable – frequency through which the availability of services in certain geographic areas as well as the frequencies used by these services can be communicated to terminals in real-time. Besides this, the CPC could potentially also communicate other data such as pricing information and (potentially time-variant) usage policies, and could even be used to transmit missing protocols needed for example to be able to connect to a new RAT or enhance security. This way, a CPC would eliminate the need for continuous scanning of the entire spectrum, while allowing services and RATs to be changed without limits. Moreover, if applied on a regional or global scale, a harmonised CPC frequency could greatly improve the cross-border functionality of devices.

Besides a number of technical design choices, which include that of a broadcast versus and on-demand CPC, the transmission network (cellular or non-cellular), the number of layers to define and the granularity of the system (whether or not to include smaller, even unlicensed operators and networks), the design of the most appropriate CPC is strongly dependent on its business model implications. From a business model design perspective, the main question is how redesigning control of the CPC (i.e. which actor will operate the CPC) will impact on the value created for its users. Three CPC controlling entities may be imagined:

1. *Every operator.* When an exclusively in-band CPC entity is chosen, every operator deploys this entity and controls the parameters for the information to be transmitted as well as the usage policies. The operator will use one of his/her own networks to distribute this information.
2. *Intermediary.* In case of an out-band CPC, the regulator could take up this centralised task as a complement to existing informational and monitoring missions (e.g. spectrum trading and secondary use registries). Transmission could happen via a network owned by the government (e.g. many terrestrial broadcasting networks), or via one or more privately operated networks (e.g. as a universal service provision). Alternatively, new actors could be added to the ecosystem which take up the role of providing an out-band CPC, and providing it as a service to operators. These could be entirely independent organisations, or a consortium of operators.
3. *Hybrid architecture.* As mentioned above, an out-band CPC operated by either the regulator or an intermediary (making use of one or more transmission networks) may be combined with an in-band CPC deployed by every operator; this implies a hierarchical system.

The section below analyses how different implementations of the CPC may impact the business models for mobile and wireless services that will operate under this controlling entity.

V. Business model implications of the CPC

Applying the basic business model design framework of Ballon (2007) to the concept of a CPC, we distinguish three basic business model issues from an operator and/or a user point of view. This makes sense, because it is these two actors which, in terms of the value chain, are positioned on both ends of the CPC (upstream and downstream) and on which, as a consequence, the influence of changing CPC configurations may be assumed to be the highest; here we must note, however, that the term operator in this specific context refers to more than just the classic providers of (mostly licensed) mobile services, but includes all network business owners on both local, regional and national level and deploying both licensed and unlicensed networks. The three issues are:

1. *Value network and customer control*. This parameter first, refers to the degree of control that an operator, in a certain scenario for CPC deployment, exerts onto the value network by combining essential resources, integrating roles within the production and distribution process, and controlling the different modules making up the design and deployment of their service as well as the intelligence stored in these modules. In this regard, the domain therefore refers to criteria of asset combination, vertical integration, modularity and distribution of intelligence. Second, this factor defines to what extent the customer is tied to a specific operator as a result of a particular CPC configuration (e.g. through billing relationships and CRM), and the extent to which this customer is locked into an operator's domain, i.e. whether it is possible to make use of the services of different providers both from a technological (interoperability) as from a strategic (discoverability of competing services). In this sense, the customer control domain incorporates customer ownership, interoperability and, insofar as customer information is concerned, also distribution of intelligence.
2. *Cost and revenue structure*. On the one hand, the basic question here is how the different costs associated with starting up a service (including the cost of the CPC) are divided over the different actors that make use of it, including investment costs (capital expenditure and R&D) as well as operational expenses. On the other hand, this domain also aims to identify how the CPC influences the way in which revenue is generated for operators (direct/indirect, content/transport-based) and, more importantly, whether or not revenue sharing mechanisms between operators need to be established as a result of the introduction such a CPC entity. This therefore relates to the cost sharing model, the revenue model and the revenue sharing model.
3. *User value*. This refers to the influence of the CPC on how services being delivered through market positioning (i.e. as complements or as substitutes for other services), on the degree of customer involvement in the value creation of these services, and on the type of value that operators intend to reach through CPC-enabled services, i.e. operational excellence (cost-based strategies), product leadership (quality-based strategies) or customer intimacy (lock-in). This refers to business model design criteria of user involvement and especially, positioning and intended value.

Analysing these three questions, we can now determine CPC impacts for the three deployment scenarios, i.e. the operator, intermediary and hybrid system. These three scenarios represent a specific and logical configuration of technological, architectural, strategic and regulatory choices (such as in-band/out-band, one or multiple layers, ownership of layers and degree of harmonisation).

A. Operator-based system

In this first scenario, all operators have their own in-band CPC that communicates directly with user devices. For example, an operator O1 deploys a 2G and a 3G cellular network over a given territory, as well as WLAN hotspots in selected urban meshes. The operator's SIM card contains the frequency information for the CPC of O1, to which the device always connects at start-up. Then, depending on RAT availability and the service requested, one of the three networks is automatically chosen, after which the device switches to the communicated frequency and connects to this network. Seamless handover could be provided so that, again for example, a 2G voice call could be switched to WLAN Voice-Over-IP whenever the terminal comes within the range of a WiFi hotspot. Such handovers could also be initiated by the operators when certain networks become congested. At the same time, operator O2 deploys a combination of WiFi and WiMAX access points, and has its own CPC to direct its subscribers to the frequencies used.

In this scenario, value network control as well as customer control will inherently be significantly higher than in other configurations, and comparable with the existing situation for 2G/3G services, in which SIM-cards or packages with locked terminals ensure a fixed relationship between customers and operators. Large parts of the value network (including the roles of network business owner, the network operator, the CPC itself and possibly also the device distribution) are controlled by one party, which also possesses the technical and customer-related intelligence residing within these roles. This intelligence could include data

on spectrum availability for the array of RATs offered by a specific operator, terminal usage profiles, billing history, location data, etc. Users might switch between the networks available but continuously remain within the domain of one operator; in this sense, the CPC's function is not extended to that of a marketplace or broker, but rather forms an integrated component of the operator's infrastructure which enables increasing spectrum efficiency for that one operator, thus reducing CAPEX and OPEX, and/or added value to the user by allowing the discovery of multiple RATs which may then be used either as part of an ''always best connected'' subscription service or on an ad hoc basis. This added value offered to the user is complementary: the different networks on offer are not owned by different operators and therefore do not compete with the objective of substituting each other, but are selected in view of the requirements posed by a specific service, or of efficiency considerations by the operator. The fact that the CPC resides within the domain of the operator also results in easy transmission of data to the entity (since it is controlled and trusted), eliminates negotiations and conflicts between operators and potential intermediaries, and might also make the technical infrastructure easier to maintain.

In terms of cost and revenue, this scenario is highly concentrated. Being the sole owner and user of a CPC, the operator will need to have the necessary usage rights for CPC spectrum as well as possess (or at least, in the case of a mobile virtual network operator (MVNO), have access to) a transmission network with wide area coverage. As far as mechanisms such as administrative incentive pricing are effectively used, recurrent operational costs must also be met by the operators. Moreover, it needs to be noted that, if all operators have their own CPC, investment and operational costs, as well as the costs associated with harmonisation, are to be multiplied by the number of CPCs to be deployed. This might render these costs prohibitive, in particular for smaller operators that do not have a large customer base and/or national coverage, such as WLAN hotspot operators, and therefore result in CPC-enabled dynamic spectrum access only being used by existing large-scale operators that in many cases already offer a mix of licensed and unlicensed RATs to their customers. On the other hand, revenues are also concentrated within one actor, since the CPC is an integrated part of the operator, so that no intermediary needs to be compensated.

It is clear that such a CPC deployment would be part of an operator's strategy aimed at intimacy with the consumer: it will give the demanding user no opportunity to subscribe to competitors, but instead offer him increased connectivity, with an in-house RAT available for the different types of service requirements the user might have. To conclude, the CPC in an operator-based context will not increase direct competition between actors, but enables operators to streamline spectrum efficiency between their different networks, and to offer ''always best connected'' subscriptions to their consumers, which in turn see their existing 2G/3G ties to their operator extended to one or more other networks. Established, wide coverage, multi-RAT operators would reinforce their position in this scenario.

B. Intermediary-based system

In the second scenario, an intermediary party deploys an out-band CPC. Two variants are possible for this configuration. In a first one, the government takes up the role of administering a single CPC covering the entire territory. A new agency could perform this task, however it is more likely that the existing regulatory authority for spectrum administration adds it to its existing portfolio of structuring, monitoring, arbitrating and informing roles. In a second variant, several out-band CPCs are launched as independent, commercial services by new actors. Subsequently, operators may have their networks with the respective frequencies listed on the CPC of one or more intermediaries, in order to reach as many potential customers as possible. In the case of private intermediaries, different marketing strategies could thereby be imagined, for example the use of premium fees for top listings or the grouping of different RATs by one operator under one heading. This is also reflected in the different strategies that an intermediary can adopt towards the user: besides just offering a real-time list of available networks, premium packages may also be proposed to subscribing users, in which the broker actively looks for, suggests and (for example with the help of a software agent installed onto the terminal) even reconfigures the device to use the network that best meets certain pre-set requirements such as price, bandwidth, QoS, etc.

Logically, the controlling entity would in this case be either a single, or multiple out-band CPCs operating on a frequencies which are harmonised at least locally but, if international CPC-enabled roaming is to be facilitated, most probably also on a regional or even a global basis. In case of multiple intermediaries, the need for multiple CPCs will make international harmonisation of these frequencies difficult, and will therefore make international roaming harder, especially as national CPC frequencies change over time.

In this scenario, the CPC would contain essential information on different RATs available from different operators in a specific mesh. Since it is not a hierarchical system, the user's device would switch directly from the meta-CPC to a specific service S1 by operator O1 on frequency F1 or alternatively, for example, to S2 by O2 on F2. With only one level and limited capacity on the CPC, this implies that choices will need to be made with regard to the granularity of the system: on the one hand, an efficient channel aimed at maximising competition between operators and technologies would contain not only the different licensed and unlicensed RATs deployed by major network business owners, but also local hotspots for (mostly unlicensed) technologies operated by small, independent providers. However, this may crowd the CPC with information on relatively small networks with a mixed degree of capacity, accessibility and reliability, so clearly a trade-off will need to be made here; a well-balanced participation fee to the CPC which would exclude single WiFi hotspots but would be affordable for better-organised local or regional scale networks would be a solution, albeit certainly an imperfect one – because it would still impede the user to get automatic access to the well-functioning, free local wireless network of, for example, his local hotel or sports club.

Contrary to the operator-based system, value network control and customer control are low when regulators or private intermediaries administer the CPC. First, the CPC is not vertically integrated but resides outside the domain of the operators, acting as an intermediary role between customers and operators and thus as the first point of contact for these customers. Since the operators do not own the CPC, they are bound to transmit only that information which the intermediary requires from them, and have to offer this information on the CPC together with data from other operators. This makes it difficult for operators to lock in subscribers to their services. A way for operators to solve this would be to programme the device such that it filters out from the CPC only those networks offered by a certain operator, thereby significantly increasing customer control. However, this implies that an a priori customer relationship exists between operator and consumer, that the operator is still able to lock terminals in the same way that it does today, and that the consumer is willing to accept that any RAT available on the meta-CPC but not belonging to its operator is unavailable, even though his device would support the technology.

By not being part of the operator's infrastructure, the CPC is also not a source of customer intelligence for the operators, but on the contrary acts as a data flow barrier between subscribers and business owners; therefore intelligence (both technical and customer related) is distributed. For the user, the CPC – if unfiltered – acts as a neutral regulated marketplace of services; however, as any other market the CPC will function imperfectly if consumers do not have the information needed to make a rational choice – implying that data are not only needed on RATs and services but also on their functionality, reliability and price – and/or if barriers to market entry (i.e. CPC access) are too high. This again refers to the degree of granularity wanted, and the measures to obtain it. Also, a fragmentation of intelligence might create an information deficit for users, comparable to searching any other service that is available via different brokers. Finally, CPC data will need to be gathered from different operators, transmitted in real-time to one or more CPC entities, transformed into a single CPC data stream and then again transmitted over a separate CPC network. Given the sensitivity of the data, this fragmentation of intelligence – and responsibility – is likely to increase conflicts.

As far as cost is concerned, it is the intermediary which needs to procure the necessary funds for the establishment of the CPC as well as provide a budget for its operational expenses; in case the regulator acts as the only intermediary, no spectrum rights need to be purchased and maintained for different operators, and no license needs to be obtained and

financially maintained for the out-band CPC. In terms of revenue sharing, the case is different for the two variants. If the intermediary is the government, it will not need to be compensated for the advantages provided by a CPC, because it can reasonably be expected that the government will not perform this task as a profit-making undertaking. So while the costs for a CPC are administered externally – be it that they have to be recovered in some way, additional revenues – if any – are concentrated within the operator. However, if one or more private identities cover costs associated with running the service (second variant), these intermediaries will need to earn back these costs by taking a share of the revenues realised by its customers. These customers might be end users, who pass part of their savings on operator and service fees onto the broker. Alternatively or concurrently customers might be operators, who pay simply to be listed onto the intermediary's CPC platform and/or to occupy premium spots on that platform. In both variants, however, this scenario makes the CPC more interesting to smaller operators than a decentralised system, and are likely to spur competition between a large number of operators with diverging networks and services, to the point even where this may become detrimental to the quality of the CPC service.

Another clear difference from the operator-based model lies in the nature of the value that is proposed to users. Having to compete with various other operators on the CPC with often duplicate technologies and services, the value will be defined in terms of how they could substitute rather than complement competing RATs and services. For example, a user can consult the CPC for available WLAN networks and select the operator which best suits his/her requirements (cost-per-second, cost-per-bit, signal strength, speed, or a combination of these). As a result, operator strategies cannot solely be based on increasing intimacy. Instead, they will more likely be positioned as being cost-effective (the VoIP example) or quality ensuring (for example by stressing the guaranteed quality of service offered by 2G voice connections). In short, because of decreasing customer and network control, an intermediary-operated CPC would create a marketplace that allows for entry of a varied set of players with a diverse array of strategies to attract consumers. However, the foreseeable management complexities and associated conflicts are clear disadvantages of this scenario. The difference between the regulator and private intermediary variants of this configuration lies in the potential added value of active brokers to consumers, the additional level of competition between intermediaries, the revenue sharing models to be developed and the costs and potential problems inherent to the deployment of multiple out-band CPCs.

C. Hybrid system

As mentioned, a third and final possible configuration of the CPC could be a hybrid system, consisting of one out-band meta-CPC combined with different, operator-level in-band channels. In this hierarchical scenario the out-band CPC, operated by either the government or by an intermediary private party, communicates to devices only the location in the spectrum of the operators' in-band pilot channels. After having scanned the meta-CPC for the locations of the different operators, the user selects a specific operator, whose in-band CPC is then consulted for the networks on offer, or the device autonomously receives network and frequency information from multiple in-band CPCs to increase the choice of networks. One of the main advantages of this configuration is that, while giving operators full control over their own pilot channel, only one CPC channel needs to be harmonised and known a priori by the device; all the other frequencies, including that of the different in-band CPCs and of the networks that they list, may change dynamically as allocations and assignments are altered.

Because of the hybrid architecture, value network control and customer ownership are on an intermediate level. By keeping part of the CPC entity within its own domain, the operator has the flexibility to communicate any information desired to the customer – a freedom which is restricted in regulator or intermediary-led scenarios – and, from the moment that its CPC has been selected, has a direct relationship with this customer. However, the upper hierarchical level resides outside of the operator's domain and may function as an open marketplace. As in the regulator-based system, operators could still lock in users by reaching contractual

agreements which allow them to have the terminals filter out only their CPC from the meta-channel; however, the same conditions of a priori subscription, device control and technology exclusion apply and it remains to be seen to what degree customers as well as terminal manufacturers will allow such control. In any case, modularity and distribution of intelligence are higher, making the system as a whole more complex to handle than a single-CPC model (since one level is rendered useless on failure of the other, and the control over both levels resides with different actors), while giving more control to the operators than in the regulator or intermediary-based models to manage their own channel.

A similar evaluation can be made for cost and revenue models. Both will be mixed, as investments and operational expenses will need to be made on two CPC levels, of which one will reside within and the other outside of the operator's responsibility. Therefore, as in the operator-based model, operators will have to bear the cost of setting up and maintaining a CPC, which plays to the advantage of larger actors with have more financial resources and more RATs to advertise via a single in-band channel. An advantage over the operator-based model, however, is that these in-band CPCs do not need to be harmonised and may be located on whatever suitable frequency band that is available, probably rendering these frequencies more affordable for smaller operators. As for revenues, these may be entirely transferred to the operators, or may have to be shared with an intermediary if this actor is responsible for setting up the meta-CPC. Therefore, both the regulator-based, operator-based and intermediary-based financial analysis with regard to revenue models may be valid, depending on the type of hybrid model selected.

A variety of possible strategies can also be noted with regard to the proposed value. For example, an operator could use SIM locking to lead customers to their in-band CPC (intimacy strategy), and subsequently promote different RATs as complements to each other: GSM for QoS-guaranteed voice and SMS applications, WLAN for low coverage, high bit-rate data transmission and seamless handover to UMTS in case the connection with the WLAN network is lost. Alternatively, users could purchase a device without any a priori subscription to an operator, and use a combination of out-band CPC and several in-band CPCs to discover substituting services within (e.g. competing WLAN networks) or across technologies (e.g. GSM voice services versus VoIP over WLAN) based on quality and/or price considerations. If the meta-CPC is deployed by an intermediary, users could subscribe to an active brokerage service by this intermediary, in order to always be redirected, via one of the operator's CPCs, to the cheapest or best network available for the desired service; operators could in their turn make agreements with intermediaries to get top-of-list advertisements. In short, this hybrid model may be more complex to manage, and necessitates the setting up of an in-band CPC by different parties, but in return allows for a varied number of opportunities for both consumers (to find the best deal among competing operators or conclude package subscriptions with trusted operators), operators (to flexibly manage their own CPC, compete on a technology and service level, or tie consumers into their own networks) and regulators (to steer competition levels by allowing or disallowing lock-in, determining the type of information to be included in in-band and out-band CPC, etc.).

6. Conclusions

In this article, a short overview has been given of policy trends towards more flexible forms of spectrum management. We have argued that both FSM and the concept of reconfigurability, although distributing decision making and intelligence on spectrum allocation and assignment, do not eliminate the need for certain centralised controlling entities, and even introduce a number of new ones, performing regulatory, commercial and technical functions of a diverse nature.

One such entity, the CPC, has been presented here, and three different configurations of the CPC have been outlined. Subsequently, we have explored the potential impact of different CPC configurations on business models for wireless services making use of such a CPC. The three domains of analysis and the respective values for the different CPC configurations can be found in Table I.

Table I Overview of CPC domains of analysis

	Domain of analysis	*Domain aspects*	*Operator*	*Intermediary*	*Hybrid*
1.	Control	Value network control	High	Low	Medium
		Customer control	High	Low	Medium
2.	Cost and revenue structure	Cost distribution	Centralised	Centralised	Both
		Revenue distribution	Concentrated	Both	Both
3.	User value	Product positioning	Complement	Substitute	Both
		Intended value type	Intimacy	Mix	Mix

This analysis has shown that, while giving large scale, multi-RAT operators significant advantages in terms of value chain and customer control, product positioning and revenue concentration, the operator-based scenario does not seem to optimise value for customers and create a maximal degree of competition between actors and technologies. Such degree of competition (inter-broker, inter-operator, and inter-technology) and of user value types is clearly present in the intermediary-based model, however operators might have too little control over the architecture and of their customers, and the practical complexity of the system might be too high for them to support this configuration. Also, harmonisation of the necessary frequencies might be problematic in both the operator and the private intermediary configurations. For these reasons, a hybrid model might perhaps be the best choice, because it limits harmonisation issues and allows a competitive market of CPC-enabled services to develop, while also giving operators sufficient technical and strategic control. However, as the evaluation made in this study is exploratory in nature (since, for example, no exact estimations of cost and revenue, or harmonisation feasibility and roadmaps can be made at this time), further research in all three domains of analysis as well as policy and regulatory analysis will need to be undertaken.

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