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Business Model Implications of a Cognitive Pilot Channel as enabler of Flexible Spectrum Management

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Abstract
This article argues that both flexible spectrum management and the concept of reconfigurability do not eliminate the need for certain centralized controlling entities, and even introduce a number of new entities performing regulatory, commercial and technical functions. One such entity, the Cognitive Pilot Channel (CPC), is presented, and 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. The article 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.

Keywords: business modeling, flexible spectrum management, controlling entities

1 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 flexible spectrum management will be implemented. 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 paper 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.[i] 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, this paper argues that, even within policy environments making increasingly more use of market based mechanisms, and even within reconfigurable systems where decision-making is highly decentralized and in which real-time mechanisms for dynamic spectrum management are used, there is a need for centralized *controlling entities* which may fulfill a diverse set of roles. Subsequently, it introduces the Cognitive Pilot Channel as such a controlling entity, and outlines a number of potential configurations for deployment of the CPC. Finally, it evaluates in an exploratory way the potential impact of these configurations on business models for CPC-enabled mobile and wireless services.

2 FSM and the need for controlling entities

Diverse policy and regulatory evolutions are currently taking place in the direction of more flexible forms of spectrum management. These evolutions include the introduction of secondary trading of spectrum, as well as systems for more flexible change of use of frequencies, and policies aimed at allowing and regulating the use of opportunistic devices (i.e. devices intelligently taking advantage of available spectrum) making use of software defined radio technologies (i.e. radio systems which can be reprogrammed to tune to any frequency band and receive any modulation across a large frequency spectrum) . Steps to introduce these policies are being taken in a number of countries, and the European Commission is working on a harmonised, EU-wide approach, for example through its WAPECS policy. For an extensive overview of these evolutions on a national and on a European level, we refer to Delaere and Ballon (forthcoming).

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 which 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. The most relevant of these issues are 1) the provision information to actors, 2) the mitigation of interference, 3) the coordination and harmonization of frequencies, 4) measures against anti-competitive behaviour and 5) the pursuit of objectives of public interest and consumer protection (see also CEPT’s ECC (2006) report).

Concerning the need for information resources, diverse other studies confirm its importance: a BNetzA study emphasises the need for an electronically available central register of spectrum availability, license ownership and rights of use (WIK 2006:131) while Ofcom (2007) has developed three different databases for this purpose. Pleas for centralized 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*".

Thus, the concept of Flexible Spectrum Management and reconfigurability, present risks and challenges which could necessitate the introduction of central controlling entities. 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 *rules 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 Cognitive Pilot Channel (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.

3 The Cognitive Pilot Channel as a Controlling Entity

While contributing to spectrum efficiency, new scenarios for Dynamic Spectrum Access 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, Cordier 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 flexible spectrum management. 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, technology 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 *Cognitive Pilot Channel* (CPC) (Holland, Muck et al, forthcoming; Perez-Romero 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. This way, a terminal only needs to be “pre-programmed” to look for one frequency band of the radio spectrum (contrary for example to current GSM/UMTS cellular phones looking for services in the 800/900/1800/1900 Mhz band, besides WiFi hotspots at 2.4Ghz and so on), after which a data stream on this frequency informs the device on what services are available and what frequencies these services use; the device can then switch to a specific frequency to connect to a specific network. 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 Radio Access Technology (RAT) or enhance security. This way, a CPC would eliminate the need for continuous scanning of the entire spectrum (which would be very time- and battery-consuming), while allowing services and RATs to be changed without limits. Moreover, if applied on a regional or global scale, a harmonized CPC frequency could greatly improve the cross-border functionality of devices: whatever services are deployed in a certain country or region, and whatever frequencies are locally used for these services, the CPC transmits the necessary data to the visiting terminal.

Looking at the traditional value chain for wireless services, the CPC is located as a new segment in between the *user/subscriber* and the *operator* (including 2G/3G, WiFi access point, WiMAX operators etc., and possibly also broadcasters using Digital Terrestrial Television, DVB-H, 3G or other platforms) mediating information between these two roles. For the sake of clarity, the business roles of the operator (the offer of services to consumers with the associated functions) and the logistic management of the physical network are taken together in the term ‘operator’ as it is used throughout this paper, even though these may be separated in real life (e.g. in the case of Mobile Virtual Network Operators or MVNOs). A role that may coincide with the CPC but can also be separate from it, is that of a *spectrum broker,* which –with either the subscriber of an operator as a customer– respectively provides retail and wholesale access to different Radio Access Technologies. Finally, the *regulator* may also play an important role in the ecosystem as it may incorporate the CPC role. Although other segments of the value chain are, of course, equally crucial in the eventual build-out of CPC-enabled services -not in the least those of content provider/aggregator/store and of manufacturer (enabling devices to contact the CPC and to reconfigure themselves)- the following, exploratory business impact analysis of the CPC will mainly be centered about the relationships between these five roles: *user/subscriber, CPC, spectrum broker, operator* and *regulator.*

The design of the most appropriate CPC is strongly dependent upon its business model implications. From a business model design perspective, the main question is how the design of CPC control (i.e. which actor will operate the CPC) will impact on the value created for its users. Three CPC controlling entities may be imagined:

- *Every operator*: when an exclusively *in-band (*i.e. making use of one channel withing one of the existing RATs of an operator, e.g. its GSM network) *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 own networks to distribute this information;
- *Intermediary:* in case of an *out-band CPC (*i.e. a dedicated frequency not linked to a specific RAT), the regulator could take up this centralized 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 organizations, or a consortium of operators.
- *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 Cognitive Pilot Channel may impact the business models for mobile and wireless services that will operate under this controlling entity.

4 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. The three issues are:

- *Value network and customer control*: this parameter firstly 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 module. Secondly, 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) viewpoint.
- *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.

- *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).

Although the limited length of this paper does not allow us to deeply present the theoretical foundation of the different concepts mentioned above (again we refer to Ballon 2007 for this), it is clear that an extensive body of academic literature exists exploring and analyzing these concepts. Some key works on these topics, on the basis of which the above classification was made, are Hawkins (2001), Faber et al (2003), Bouwman & MacInnes (2006), Haaker et al (2004), Osterwalder (2004), Wehn de Montalvo et al (2005), Robertson & Langlois (1994), Lee (2006), Shapiro & Varian (1999), Treacy & Wiersema (1993), Bouwman (2003) and Porter (1979, 1985).

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).

4.1 Operator-based system

In this first scenario, all operators have their own in-band CPC which 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 Wireless Local Area Network (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 (VoIP) 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 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 A) increasing spectrum efficiency for that one operator, thus reducing Capital and Operational Expenditure (CAPEX/OPEX), and/or B) 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 have access a transmission network with wide area coverage. 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 harmonization, 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.

4.2 Intermediary-based system

In the second scenario, an intermediary party deploys an out-band CPC. Two variants are possible: in a first one, the government takes up the role of administering a single CPC covering the entire territory, while in a second variant, several *out-band* CPCs are launched as 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, 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.

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 on a particular frequency. 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 maximizing 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.

Contrary to the operator-based system, *value network control* as well as *customer control* are low when regulators or private intermediaries administer the CPC. Firstly, the CPC is not vertically integrated but resides outside the domain of the operators, acting as an intermediary role between customers and operators. 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. 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 is 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. 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 realized 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 decentralized system, and are likely to spur competition between a large number of operators with diverging networks and services.

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 requirements (cost-per-second, cost-per-bit, signal strength, speed, or a combination of these). As a result, operator strategies cannot solely be based upon increasing *intimacy*. Instead, they will more likely be positioned as being *cost-effective* or *quality-ensuring.*

4.3 Hybrid system

As mentioned, a fourth 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 harmonized 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 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, 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, 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 harmonized 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 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.

5 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 flexible spectrum management and the concept of reconfigurability, although distributing decision-making and intelligence on spectrum allocation and assignment, do not eliminate the need for certain centralized controlling entities, and even introduce a number of new ones. One such entity, the Cognitive Pilot Channel, 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 Cognitive Pilot Channel. The three domains of analysis and the respective values for the different CPC configurations can be found in Table 1.

Table 1: 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 optimize 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, harmonization 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 harmonization 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 harmonization 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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