SAPHYRE

Contract no. FP7-ICT-248001

Business models, cost analysis and advises for spectrum policy and regulation for scenario I (spectrum sharing)

D5.3

Contractual date:	M30
Actual date:	M30
Author:	Michał SZYDEŁKO
Participant:	WRC
Work package:	WP5
Security:	Public
Nature:	Report
Version:	1.1
Number of pages:	82

Abstract

This document focuses on spectrum sharing scenario SC2abc (i.e. inter-operator spectrum sharing in existing/additional band) that was identified and selected based on the approach presented in D5.1b. This document captures the analysis of novel spectrum sharing techniques on the service delivery chain (needs, processes and roles), discovers new business opportunities, discusses the influence on the strategy of the current key market players and makes a proposal on regulatory policies required to profit from the advantages of the novel approach to the spectrum resources allocation.

Keywords

Asset management, business model, cost analysis, spectrum assignment policy, spectrum pricing, spectrum sharing

This page has been left blank intentionally.

Contents

Abbreviations

3GPP	3rd Generation Partnership Program
4C-HSDPA	4 Carrier HSDPA
BS	Base Station
CAPEX	Capital Expenditures
CDF	Cumulative Density Function
COST	European Cooperation in Science and Technology
CR	Cognitive Radio
CRRM	Common Radio Resource Management
D#	SAPHYRE Deliverable (number)
DSA	Dynamic Spectrum Access
EAB	External Advisory Board
eNB	E-UTRAN NodeB
eTOM	enhanced Telecom Operations Map
EU	European Union
E-UTRAN	Evolved UTRAN
GBR	Guaranteed Bit Rate
GPS	Global Positioning System
HSDPA	High Speed Downlink Packet Access
HSPA	High Speed Packet Access
HW	Hardware
ICT	Information and Communication Technology
IPR	Intellectual Property Rights
ITU	International Telecommunication Union
ITU-R	ITU radio communication sector
KPI	Key Performance Indicator
LTE	Long Term Evolution
LTE-A	LTE Advanced
M2M	Machine to Machine
MNO	Mobile Network Operator
MVNO	Mobile Virtual Network Operator

OPEX	Operating Expenditures
O&M	Operation and Maintenance
PLMN	Public Land Mobile Network
QoS	Quality of Service
QoE	Quality of Experience
RAN	Radio Access Network
RB	Resource Block
RF	Radio Frequency
RRM	Radio Resource Management
RRS	Reconfigurable Radio Systems
SA	System Architecture
SI	Study Item
SINR	Signal to Interference and Noise Ratio
SLA	Service Level Agreement
SLS	Service Level Specification
SW	Software
SWOT	Strengths, Weaknesses, Opportunities and Threats
TSG	Technical Specification Group
TTI	Transmit Time Interval
TR	Technical Report
UE	User Equipment
UMTS	Universal Mobile Telecommunication Service
UTRAN	Universal Terrestrial Radio Access
VCG	Vickrey–Clarke–Groves (auctioning scheme)
WP#	SAPHYRE Work Package (number)
X2	E-UTRAN interface between eNBs

1 Executive summary

In this document, we identify key modifications to the market and business model, required by the spectrum sharing scenario implementation, with the focus on the business case related aspects. Due to the fact, that the spectrum usage in the current markets is subject to various constraints coming from regulatory, standardisation bodies, as well as hardware limitations point of view, various market players and their positions within described spectrum sharing scenarios are considered and analysed.

Starting with the methodology developed in Deliverable D5.2 [1] for the reference market model characterisation, this document presents a business analysis of spectrum sharing scenarios with the breakdown into four sub-scenarios as identified in D5.1b [2] and described in Section 5.

In the analysis presented in this document, we consider spectrum resources as goods being required for the mobile network subscriber value delivery. Therefore, spectrum valuation aspects as well as the end user requirements and expectations are incorporated in the discussion. Furthermore, the mobile market roles and processes required to address spectrum sharing scenario are covered, with the focus on the value chain creation and its delivery to the end users. Finally, cost aspects are analysed, where the required investments are identified for particular spectrum sharing sub-scenario.

The aim is to evaluate, whether the spectrum sharing extended by appropriate, novel resource allocation techniques, might be able to generate new services for mobile subscribers, at the same time enabling new revenue streams for mobile network operators. Considering various aspects of the end user value perception, possibility of cost and complexity of the services delivery is also addressed.

The subject of the analysis covers also the regulatory policy aspects, trying to generate advices for novel spectrum allocation policies, based on the analysis of the spectrum sharing scenarios.

2 Business scenarios – general overview

A challenging task both for the mobile network operators as well as for national regulators is the creation of mobile services market, which is competitive, being able to offer low rates for end users, at the same time stimulating the investments in innovations and research branches.

What has been proved by several trials, exclusive spectrum usage being motivated by the required interference avoidance results in sub-optimal spectrum efficiency and its utilisation. Based on the results found in [3], [4], spectrum utilisation of the spectrum bands was less than 17% in urban deployments and in range of 5% in other deployment scenarios. Therefore, spectrum sharing has great potential for the future networks and their service delivery quality improvements. Anyway, what is uncertain, is how the spectrum sharing might shape the future networks, what would be the outcome of such evolution, and how the evolution could be stimulated.

The successful introduction of the smartphones, as well as the progressing development of the packet data services and radio access technologies being their background showed, that the discrepancy between the increasing cost of the network architecture as well as mobile services delivery and lack of revenue from the network extension investments is growing. Booming demand for mobile services observed during past years caused higher demand for the spectrum, what makes the spectrum resources to be a crucial aspect of the successful service delivery chain. Mobile data traffic increase observed over the year 2011 was doubled, keeping same trend as for previous four years globally [5]. It is expected that the booming increase in the mobile data traffic will keep the pace. As the costly network upgrades will be required in order to fulfil the traffic demands, the flat rate model revenues might not provide sufficient profits for network operators. Therefore, trying to force pure flat rate charging in the future mobile networks might cause the risk of higher discrepancy between cost and the generated revenue, not being suitable for fruitful business development.

Due to the radio resources limitation, novel and innovative spectrum access techniques are gathering more interest in the industry as well as among regulators, paving the way for (possibly) new definitions of the business models for the mobile services market, being dependant on the evolved spectrum usage regulations to come. This observation leads to the conclusion, that the economics of the mobile data market might need serious modifications and adaptation to the evolving situation on the market. Network operators may need to consider less restrictive and less exclusive business models. For that reason, we are proposing in this document number of modified market models from the spectrum sharing point of view, proposing various solutions in four of selected sub-scenarios (refer to Section 5), where the focus is set on the mobile network operator and his motivation to participate in such business model.

During earlier work in SAPHYRE on the business related aspects of the spectrum and infrastructure sharing in cellular networks, report presenting ten initial candidate scenarios was created [2], looking at details of various cooperation schemes between infrastructure and radio resources owners, where feedback obtained by interaction with the External Advisory Board (EAB) was captured, as well as the internal SAPHYRE

WP5 discussions and findings were considered. For the scenario selection purposes, a set of measures was constructed, consisting of seven key aspects ranging from market-related to the technology/cost benefit related as well as other related to the innovation speed. For the described spectrum sharing scenario, the following feedback was received from industry and regulatory EAB members, as presented in Table 1.

Based on the above, selection of three sharing scenarios was performed out of initial ten candidates. The selection was based on the total scores comparison among candidate sharing scenarios. The resulting selection is as follows:

- Spectrum sharing scenario, i.e. inter-operator spectrum sharing with separate network infrastructure consideration;
- Network sharing, i.e. network infrastructure sharing with and without shared relaying nodes;
- Full sharing scenario, i.e. sharing of network and spectrum.

Based on the working procedures applied in WP5, this deliverable covers only the spectrum sharing scenario. Within this work, we will look at various inter-operator relations with respect to the spectrum sharing aspect, where the reference case will be the current market with the spectrum exclusively licensed to operators for a decade or more duration [6]. Business, standardisation and regulatory aspects of this scenario are covered within this work.

Table 1: Outcome of the EAB meeting pool for spectrum sharing scenario (SC2abc) [2]

Key aspects		**SC2abc***	**Comments from the EAB**
Entry barriers	Does SC2abc have an influence on the entry barriers? Can new entrants also enter existing sharing coalition? Is entry made easier because of lower sunk cost?	No/Yes	In this case the investment needed to start the activity could be reduced but it depends on the regulatory policy (e.g. higher pricing for shared spectrum resources). Also, in principle the entry barrier is reduced because a new entrant can obtain spectrum access even if no new spectrum is made available, through a spectrum sharing deal with an existing player.
Dominant positions	Is there any risk of monopoly situations? Does SC2abc lead to more potential for a coordinated behaviour of the parties that share network or spectrum resources? Is there scope for abuse of dominant position by sharing coalition that harms competition at network or services level?	Yes	Depending on the prior distribution of spectrum, perhaps some players can enhance their position strategically.
Homogeneity	Does SC2abc lead to a change in the homogeneity of the product offerings, as multiple parties share a number of crucial resources? Is the freedom in product development, QoS differentiation, coverage etc. of individual participants in sharing coalition reduced?	No	Where spectrum is shared, service homogeneity is likely to be increased. However, there is only a limited potential for change in homogeneity in this scenario (far smaller than with RAN sharing and full sharing).
Spectral efficiency gain	Does SC2abc lead to a higher spectral efficiency for the mobile market as a whole? How much is gained in spectrum efficiency? (Explicit policy goal) How many additional Mb/MHz?	No/Yes	The "No" depends on the fact that a distributed processing is used, so performance could get worse due to the interference. Realistic algorithms to solve this problem are not available at the moment. The "Yes" depends on a long-term availability of efficient distributed algorithms, which are under study in WP2 and WP3, see D3.1a.
Cost efficiency	Does SC2abc lead to a lower CAPEX+OPEX? How much is gained in investment efficiency? (Explicit policy goal)	Yes	Spectrum sharing can lead to a lower CAPEX/OPEX, e.g. it could allow a higher spectral efficiency without the need of a network update.
Innovation in networks	Does SC2abc influence the speed of rollout of new generations of networks? Is innovation in networks promoted or slowed down by sharing? Alignment of discrepancies in technology roadmaps of sharing partners?	No/Yes	NO (no spectrum trader): Since each of the two operators would own its own chunk of spectrum, we do not think that SC2abc would have an influence on the speed of roll-out of new generation networks. YES (with spectrum trader): The operators could rent the spectrum from the spectrum broker → lower CAPEX.
Availability of technical solution	Is the solution close to be found for the major technical challenges?	No	SC2abc relies on distributed techniques: at the moment we detect problems due to convergence, problems due to the need of information exchange, restrictions due to bandwidth for information exchange, restrictions due to latency for information exchange. Moreover, this scenario requires interface extensions for existing standards e.g. X2 in 3GPP E-UTRAN.
Total score		**2/5**	* Inter-operator spectrum sharing in existing/additional band

3 Business modelling tools

In this section, we briefly describe the tools which are used in this document for the business models creation and description. The rationale behind the introduction of this section is to familiarise the readers with the selected business case related analyses and to ease understanding of the subsequent work.

3.1 Market model based on eTOM

Based on the eTOM analysis performed in [1], we attempt the description of the spectrum sharing case, by identification of the delta approach on top of the reference market model as presented in [2]. The aim of this analysis is to identify the influence of the spectrum sharing scenario specifics on the reference market model with the consideration of the value chain and positioning of the current business entities in this model. In case of new market entrants being identified in certain spectrum sharing cases (as detailed in Section 5), the market model will be extended accordingly.

3.2 Business case evaluation by the SWOT analysis

For each of the described cases of the spectrum sharing presented in this deliverable, we have performed the SWOT analysis, i.e. the Strengths, Weaknesses, Opportunities and Threats analysis, which is seen as a valuable tool for new business case evaluations, being able to provide answers for general questions and to show tendencies related to the evaluated case. The SWOT analysis is carried out from the Mobile Network Operator (MNO) point of view, i.e. not for all market players in the considered spectrum sharing scenarios.

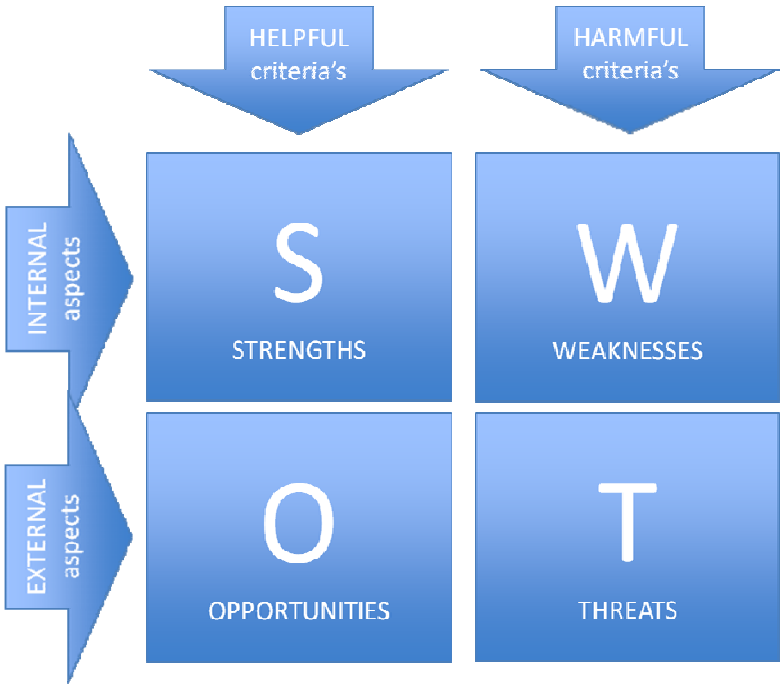

Figure 1: SWOT matrix

This analysis is constructed of four main building blocks (Strengths, Weaknesses, Opportunities and Threats), where many criteria might be applicable in more than one of the four blocks. Furthermore, in the vertical analysis of the SWOT matrix (as presented in Figure 1, Strengths and Opportunities boxes are collecting criteria which are helpful for the objective achievement. On the other hand, Weaknesses and Threats are to capture all the harmful issues, which might appear in certain business cases. For the horizontal analysis of the SWOT matrix, Strengths and Weaknesses are related to internally originated aspects of the analysed concept. For external aspects, which are considered as the environmental attributes of the analysed business case, the Opportunities and Threats construct another horizontal domain.

All four measures are used for the evaluation of the spectrum sharing sub-scenarios are briefly described in the subsequent sections.

3.2.1 Strengths measures

For the strengths of the possible business case, all envisioned advantages of the proposed solution should be captured, covering its capabilities as well as the advantages over the competitive solutions and products already available on the market. Various kinds of resources shall be accounted here, covering human resources accompanied by the experience and knowledge gained, as well as the hardware resources of the network equipment. On top of the hardware resource, IT tools, systems and processes being implemented within HW for smooth products rollout, are to be accounted as well.

Considering the specific case being analysed by the SWOT, the value chain shall be analysed from the product or service delivery point of view, considering such elements like product selling points, their locations, product's distribution and the market penetration of the product.

More importantly, the financial aspects are to be covered, including financial reserves and the expected returns from the business case, based on the pricing and valuation of the product, considering its quality and competitiveness.

Furthermore, the innovation and novelty of the concept being analysed belong to the strengths measures as well.

For the product itself, accreditations, certifications and licenses might be considered as well.

As the analysed product is targeted at certain subscribers group, their feelings and views to the planned product might be also analysed, possibly considering also brand perception on the market. Following this argumentation, philosophy, as well as the high level social values related to the analysed case shall be addressed, e.g. ecology, social aspects, energy consumption, etc.

3.2.2 Weaknesses measures

For the weaknesses of the business case, all kinds of disadvantages of the proposition have to be accounted, covering the identified gaps in the capabilities of the product, as well as lacks of the competitiveness. As far as it is possible, own known vulnerabilities shall be considered.

Furthermore, possible reputation related risks should be considered, including the risk of not being present on certain market, as well as the risk by the introduction of not suitable product or its limited penetration of the market.

What might be seen as one of the most obvious risks in the product creation process, is the timeline of the product development. Deadlines and the time pressure are belonging to weaknesses in the SWOT analysis. Furthermore, the product planning and the reliability of the assumptions and data taken for the product planning can be extremely risky for the successful business establishment.

Similar to the strengths analysis, for weaknesses the financial aspects are to be considered as well, especially focusing on the cash flow and cash requirements of the product development. This aspect is critical in case of start-ups. On the other hand, in case of well established market players, the risk might arise from the lack of focus and from possible distractions in the company's strategy, leading to negative effect on the core business activities of particular company.

After finalisation of the product creation phase, another possible source of problems might arise from the insufficiently robust supply chain, possibly causing gaps in the product/service delivery chain.

As all products are forced to rely on the human resources (development, maintenance, management, delivery, etc.) the team's morale and their commitment to the planned tasks and foreseen workload shall be considered, securing proper leadership and management. Furthermore, stable management over the duration of the whole process shall be verified, also considering possible successions, in case of position rotations, etc.

This analysis shall also consider possible accreditation or licensing being required for fruitful deployment of the product.

3.2.3 Opportunities measures

This part of the SWOT analysis is closely related to the reliability of the data and assumptions, which are mentioned in the weaknesses part. In this part of the analysis, market development trends have to be taken under consideration, covering competitors, products, and offers. Furthermore, in case of the products, which are hardware based, the technology development and innovative techniques play a major role, being able to broaden the scope of the product, and attract more customers – this is clearly an opportunity. Following the above argument the lifestyle trends shall be closely tracked, as they might easily become an issue for the threats, if not considered early enough.

Referring to the weaknesses analysis above, the vulnerabilities of the competitors might be seen as opportunities for our products, if the knowledge on the competitor's product can be considered as stable and reliable enough.

In case of innovative solutions under planning, niche markets might be considered as the target markets, which were not attracted by the solutions and products currently available.

Depending on the market coverage of the company analysing the products or service by the SWOT analysis, global influence might be also considered as the opportunity, based

on the unification of the offer over multiple markets globally (horizontal market). Furthermore, the question on the possible new markets shall be asked, also considering niche, or vertical markets. All the aspects above shall be extended by the logistics consideration, which does not necessarily belong to the opportunities block and might be considered in many cases as the threat or weakness, depending on the expected product's coverage.

What might become a major opportunity for the successful business is the appropriate tactic in the product/service introduction to the market (e.g. appropriate intensity of the advertisement, surprise approach vs. market expectations). Furthermore, finalisation of major contracts might stimulate further business partners to be attracted by the offer, considering various business partners (e.g. distribution chain companies, virtual service providers, various kinds of partnerships etc.).

In most cases, the analysis will not be related to the start-up initiative, but rather to the evolution, or revolution of the current product offer. From this point of view, further offer development can be also seen as the opportunity, being supported by the gained experience.

What might be equally considered as opportunity, as well as the threat, is the possible seasoning of the offer due to the weather, market condition locally or globally, as well as trends, which might be very strong in niche markets.

3.2.4 Threats measures

Consideration of the external aspects for the mobile network operator perspective business case shall cover political, regulatory, as well as environmental aspects. MNO, as being part of the market, shall attempt estimation of the competitor's intentions and possible plans, as far as this can be done based on the available market information. Furthermore, the considered business case shall be evaluated from the market demand point of view, including all possible obstacles in the business establishment.

In case of the software related products, all the software development management threats shall be considered as well, considering timelines, resources and cost of the software creation. Resources mentioned in the previous statement shall especially consider human resources, as being the weakest element of the chain, which might require replacement due to the market competition, or poor quality delivery.

Not only related to the software development, the financial shortage seems to be one of the most obvious threats. In contrary, sustainable financial background can easily be considered as the strength of the business case.

In case of new technologies and services, it might happen that the market is not mature enough to assimilate with the product of service. It seems to happen from time to time, that innovations need to wait couple of years, before the market gets familiar and mature enough for the product to succeed.

For the external threats, credibility of the business partners and related contracts shall be analysed. Similar, it shall be performed with respect to the internal team members, who might put the project into the risk, when leaving company. In general, all kinds of the internal capabilities and their sustainability shall be accounted.

Referring to the market considerations in the opportunities discussion above, those markets economy shall be verified against possible weaknesses, with consideration of their geographical aspects.

The seasonal aspects being indicated as the opportunity will have also consequence by becoming a threat, if the seasonality is identified as an issue for particular product or service.

3.3 Business model canvas creation

Another tool used for the analysis of the spectrum sharing scenarios is the business model canvas [7], being currently considered as one of the most used frameworks for business model elements description, covering such aspects like infrastructure, offer, customers, finances, etc.

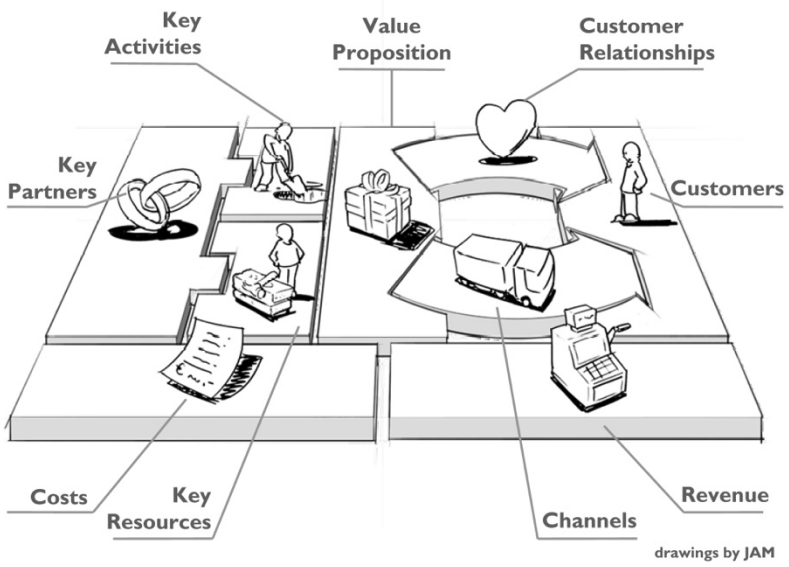

Figure 2: Business model canvas template [7]

The canvas consists of nine block elements, which are briefly described below, being the basis for sub-scenario specific business model canvas, as presented in Section 6.3.4, 7.3.4, 8.3.4 and 9.3.4 for each of the sub-scenarios, respectively.

- Customers – building block comprised by group or different groups of customers being served or targeted by the organisation. In order to better address customer needs and expectations, company might want to create distinctive segments of customers, being characterised by common attributes. For the offer complexity reduction of for the cost reductions, the company might need to ignore certain segments of the market and customers. Customer segments might differ by the specific customer needs and expectations, distribution channels, specific customer relationships or different profitability.
- Value proposition – this element describes how the company is planning to attract customers, either by solving their problems or covering their expectations. Aim of this building block is to capture the value for specific customer segment.

In the competitive market, value proposition is the reason for the customer to choose particular company out of many available.

- Channels – describe the way, how the value propositions are delivered to the customers and how the company is communicating with subscribers, covering sales channels, distribution and communication itself. Is shall not be underestimated as this is the actual interface with customers, keeping them aware of the current offer.
- Customer relationships – covers the relationship types, the company establishes with customer segments, being e.g. personal or automated. Customer relationship can be driven by the customers acquisition or customers retention strategies, depending e.g. on the market development stage.
- Revenue streams – this element of the business model canvas is collecting all possible cash generation sources of the business, being a consequence of the value proposition that is delivered to the customer segments. This is the place, where it shall be estimated for what kind of the value proposition the customers are willing to pay extra money, or to pay at all. Each of the revenue streams might have different pricing mechanism (e.g. fixed pricing, bargaining, auctioning, market dependent etc.). Furthermore, the revenue might be a onetime payment or being regular, recurring payment.
- Key resources – covers the most important assets, which are needed for fruitful business implementation (i.e. to deliver the value proposition to the customer segment and receive the revenue stream). It can consist of human resources, hardware, software, IPR or experience. Moreover, the key resources may be leased or acquired from key partners of the business.
- Key activities – those are the required activities for the delivery of the elements described in the previous elements. This is set of most important actions needed for successful business creation. Its relevance is as high as the relevance of the key resources described earlier.
- Key partners – include external entities (suppliers and business partners) that are delivering key resources and key activities. There are four different types of partnerships, which are strategic alliances among non-competing companies, partnerships among competitors, joint-ventures or buyer–supplier relations.
- Cost structure – this element covers cost generated by the business implementation and operation. In general, the cost structure of the business can be value or cost driven.

4 Business modelling

By the business model, we understand the way in which the potential business case might be constructed, considering possible revenue channels, description of the current business entities positioning in the value chain, as well as mobile services delivery to the subscribers and related processes analysis. The spectrum sharing oriented business modelling covered by the following elements:

- Technical aspects of the spectrum sharing sub-scenarios with proposed sharing mechanisms are described in Section 6.1, 7.1, 8.1 and 9.1, respectively).
- Construction of the business analyses based on the tools proposed in Section 3, i.e. the eTOM model, SWOT analysis, as well as the business model canvas.
- Creation of the appropriate pricing mechanism description for the traded goods being the basis for the cost analysis, for all four spectrum sharing sub-scenarios (Section 6.3.1, 7.3.1, 8.3.1 and **Fehler! Verweisquelle konnte nicht gefunden werden.**, respectively). As the business involves multiple entities, it shall be clarified that MNO focus is kept.
- Identification of the market players (current and possibly new ones) as well as their roles in the value chain. This is covered for all four sub-scenarios in Section 6.4, 7.4, 8.4 and 9.4, respectively.

Furthermore, the following aspects are also covered:

- Identification of the possible monopoly threats and their consequences in the analysed scenarios, covered in Section 4.3.1.
- Mobile services and their value creation analysis due to the spectrum sharing consideration on the market, is covered for all four sub-scenarios in Section 10.1.

The work towards the creation of business models for mobile network operators is based on the reference case scenario, i.e. no spectrum sharing case. At the same time, the regulatory aspects are tracked, in order to identify possible recommendations for the spectrum access and spectrum policies regulations for sharing of the radio resources, in order to enable optimal utilisation of the sharing concept, as well as to stimulate competition on the market of mobile services. Furthermore, market roles of the scenario players are analysed, looking into possible new parties and innovative roles on the market.

The focus is set on qualitative analysis and description of the business cases modelling in the presented spectrum sharing scenarios.

4.1 Pricing mechanism and cost analysis

As it was presented in WP3 [8], [9], [10] and WP4 [11] deliverables, the radio resources may be shared and distributed in much more flexible way (referring to the current market situation) on relatively short-term period basis. The pricing mechanism is seen as the enabler for the novel spectrum sharing techniques in the inter-operator (near to) real-time environment, based on the appropriate mechanism for the information

exchange among sharing participants for the proper charging. Development of novel mechanisms and solutions for the charging of spectrum usage is equally important as the sharing mechanism itself. Consequently, the required pricing and charging solutions would require transactions on similar or same time scales.

Furthermore, pricing mechanism should benefit voluntary spectrum sharing for the market players participating in the coalition, at the same time being able to stimulate sharing initiatives. What is of high importance, is to how to keep the MNO interest, which is the revenue maximisation from the owned spectrum, at the same time, being in line with the national regulations, focusing on the market fairness and competition stimulation.

It can be easily predicted, that the pricing details will depend on number of factors, starting from the scenario itself, traffic demands and their relations among coalition participants, as well as the amount of available spectrum resources and the granularity of the resources under the sharing mechanism. Consideration of the achievable capacity associated with the spectrum resources under the sharing principles, might not be trivial task, due to the physical layer radio channel characteristics, especially under the fast fading conditions, resulting from the multi-path propagation. Therefore, multi-layer optimisation model might be required to be formulated in order to create meaningful pricing mechanism. Therefore, we will refer to the system level simulation campaigns and to the spectrum sharing mechanisms introduced it WP4 work [11], [12]. Furthermore, certain level of technical aspects will be also introduced in the spectrum sharing scenario descriptions in further park of the work.

Based on the pricing aspects, more general cost analysis extension is formulated for the described spectrum sharing cases, trying to capture the whole picture of the investments required for the business finalisation.

What can be expected is that the novel pricing mechanism will be most successful in case of state-of-the-art technology, which can more easily assimilate with novel techniques and mechanisms, which are still under development and maintenance phases (i.e. trying to force novelty of the spectrum sharing to be implemented in the old-fashioned, even though profitable RATs, might be too expensive). Therefore, it is seen that the E-UTRAN might be the most suitable environment for application of spectrum sharing schemes.

In general, the following aspects can be identified for the pricing mechanism definition:

- Selection of the factors impacting the value of certain resources. In case of this analysis, such technical aspects as the frequency bands (low, high, etc.), carrier's quality (i.e. considering propagation conditions) or bandwidth size might influence the final resources valuation. WP4 simulation assumptions will be a valuable input in this part of the analysis.
- Identification of the model, describing instantaneous valuation of particular time–frequency resources for the spectrum user, based on his priorities (e.g. throughput maximisation, coverage extension, etc.).
- Definition of the real-time trading mechanism principles, linking cross-layer mechanism with the work performed in other work packages, especially in WP4,

where system level simulations were performed for various spectrum sharing and trading concepts. What is of high importance is the identification of most optimum space/time/frequency granularities, not causing exhausting overhead from the signalling overhead point of view, at the same time being flexible enough for efficient sharing gain exploitation.

- Consideration of the inter-operator differences and their business goals, with an attempt to balance possible pains caused by the proposed pricing model and to create appropriate compensation mechanisms.

What has to be stressed is that the coverage of this document might not be able to capture all the above listed aspects in sufficiently detailed manner due to the scenarios and problem complexity.

4.2 Current market situation and migration towards flexible services delivery framework

In this section we discuss market implications of the spectrum sharing which are found to be an attractive opportunity being able to open new markets and generate new mobile services. Based on simulation results from the WP4 presented in [11], [13], [14], using a game theoretic approach to the spectrum sharing, it was observed that there is a sharing gain achieved in terms of the total sum rate of the cell goodputs[1] of both MNOs cooperating, who are partially sharing their spectrum resources. Nevertheless, in the referred solution, which was based on the spectrum valuations being modelled by the cell specific buffer states, it was further observed that a load imbalance between sharing participants is the key aspect. When the load imbalance is high enough, the less loaded network is not gaining from the participation in the sharing. It has to be noted, that those described auction based sharing players are not aware of the valuation functions of other auction participants. This meant that any risk-free network operator might not be attracted by such cooperation mechanism. For that reason, it was found that appropriate motivation for potential players has to be formulated in order to stimulate their willingness to participate in such sharing mechanism. In order to find solution for the identified concern, we can think of the mechanism, where the sharing MNO is modifying his utility function in order to improve the sharing outcome (e.g. from proportional fair to throughput maximisation). Alternatively, the coalition participants could introduce less restrictive regulation on their strategies, in order to allow more predictable sharing outcomes for potential entrants (e.g. based on the probabilities of the utility functions).

Based on the telecom market analysis, it is not difficult to notice, that the fruitful deployment of the cellular network depends on the availability of the spectrum resources, which are a scarce resource and can be allocated only by the national regulator grant. Due to limited availability of this medium, in most cases the allocation is based on the long-term auctioning process, in order to maximise the revenue from the spectrum and allocate it to the network operator, which values particular spectrum band the most. For all the reasoning mentioned earlier, the auctioned spectrum bands in many

[1] Goodput: throughput without protocol overheads and retransmissions

cases generated bids, which were much higher than expected by the national regulators. The simple conclusion is that in order to be able to provide mobile services, one has to consider high investment to obtain the spectrum resources.

It comes as no surprise that after successful acquisition of spectrum band, every mobile network operator tries to cover the market as wide as possible (by means of the amount of the subscribers) in order to compensate expenses from the spectrum resources acquisition, by possibly largest revenue flow. What it means, is that MNOs are not focusing on too granular users definitions and are targeting their offer at high population of users. In such case, it is not very likely that the offer will cover very specific end-users requirements. If the MNO would like to serve as many customers as possible, he would need to cover all possible end-user requirements.

From the economical point of view, the most optimal offer creation process shall be constructed from as little building blocks as possible. At the same time, this process should allow to cover the market as wide as possible. In other words, for the Operational Expenses (OPEX) reduction, company would be interested in maintaining as little product lines as possible and at the same time, for the revenue maximisation purposes, the company's goal would be to generate as many product variants as possible, in order to satisfy possibly widest range of customers.

In relation to the cellular networks and mobile services, this can be translated into an offer, which is constructed from limited number of basic services (limitation of costs of services provisioning and maintenance), being able to attract certain population of subscribers. Due to the granularity of the service offer, it is likely to happen, that it will not be possible to offer sufficiently large number of various subscription plans and respective mobile services to certain, well defined group of end users having specific demands, or not willing to pay for the subscription which is not suited for their needs and expectations.

Trying to attempt this problem from the standpoint of the new market entrant, we feel that the situation presented in the previous paragraph might give the opportunity for new mobile services creation, but cannot attract the current MNOs due to relatively low (in reference to their expectations) revenues forecast. What is the most important observation, is that in contrary to the MNOs, the presented case might be highly attractive for new market players (e.g. virtual operators, mobile service providers, etc.), who's cost structure is much less complicated and which is not being affected by high investments in the spectrum and infrastructure. The enabler for this to happen is the modification of the spectrum access regulations for bands that are not yet allocated, as well as for the re-use of spectrum resources, which is already in the possession of the MNOs (e.g. short-term auctioning, leasing, etc.). Reusing TV white spaces is another attractive target for the application of the proposed approach, but due to its relation with the Cognitive Radio applications (e.g. [15]), this case will not be further evaluated in this work.

Looking back at the referred simulation results, the observation on the sharing gains as a function of the load imbalance has to be highlighted, i.e. the higher packet load imbalance was considered between operators, the higher sum rate throughput gains were observed. That brought us to the conclusion, that the most optimal spectrum

utilisation (irrespective of the radio access technology consideration) shall be met in case of services generating highly uncorrelated (in terms of the generated data traffic) packet load over particular areas in case of shared spectrum or full network sharing.

Thinking of the relaxed spectrum regulations, which would allow dynamic (i.e. variable timeline) and flexible (i.e. variable amount) spectrum allocation grants, well suited and flexible services would emerge on the market being provided by new market entrants, as there would be much lower entry barrier, i.e. no need for long-term spectrum band acquisition. For the current market players owning already acquired spectrum bands, which would open new revenue generation possibilities, at the same time, allowing them to decide on the competitiveness of the emerging offer being delivered via their radio access network. Such kind of possible revenue streams are considered in the business analyses covered in further part of the work (e.g. Section 7.3 and 9.3). The proposed model differs from the Mobile Virtual Network Operator (MVNO) business case, which allows new market players not owning spectrum bands, but does not allow spectrum allocation flexibility and its dynamics – only medium to long-term contracts are considered. Furthermore, new market entrants not owning the spectrum are considered in the scenario presented in Section 9.

From the current market stage, novel spectrum sharing techniques are expected to arise on the market, gaining from the opportunistic spectrum availability. Frequency, time and space specific network capabilities boosts coming from spectrum sharing will materialise only in case of the matching UE needs, as well as available scheduling grants. From the business point of view, authors are in the opinion that the current market of mobile services is too generous. With the users expected flat rate, network operator agrees to offer cell's peak rate (of course with no guarantees). Spectrum sharing will make the cell's peak rate even higher, but it is not guaranteed that the revenue will increase for the operator(s).

The missing element is the definition of the SLA being signed between market players who are providing radio access and the mobile services. System level agreement contains the Service Level Specifications (SLS), which defined the radio access bearer as well as the services, including definition of the bearer throughput, its availability and quality of service, which should be specified independent from the network provider and RAT being used. Moreover, SLA might cover the traffic volume being guaranteed for the service provider, possibly being time and geographical location specific. Depending on the volume of the SLA and its parameters, the consideration of the service provider requirements in certain radio access network might be considerable high, requiring appropriate network planning and dimensioning actions, or capacity extensions.

We believe that the spectrum utilisation, as well as network sharing gains for the operators will follow the path as presented in Figure 3 below.

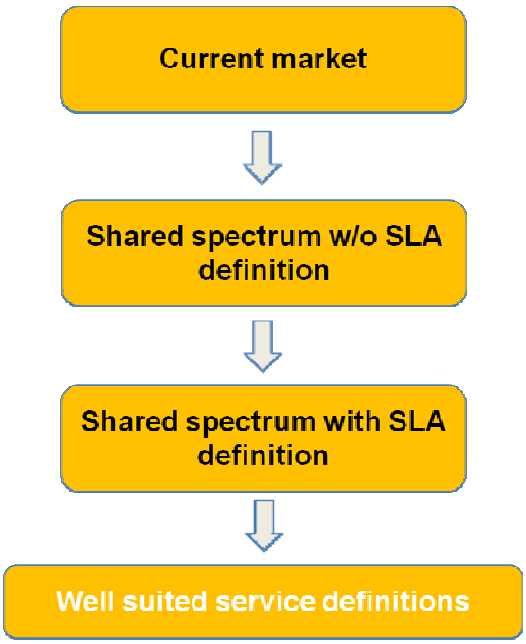

Figure 3: Possible market evolution towards more flexible spectrum usage

4.3 Regulatory aspects

From the business and regulatory point of view, the dynamic spectrum sharing together with the Dynamic Spectrum Access (DSA) with all possible innovations and technical aspects behind such solution, might not be seen as equally attractive for the networks and mobile services evolution. What is meant here is that the business goal of the mobile network operators, are not equal to the goals of the national regulators. Business players might prefer to keep fixed and exclusive spectrum usage policies, while the regulators of the mobile service market might see the need for more dynamic and flexible regulations.

What has to be highlighted in the regulatory aspects discussion is the fact, that one of the most important factors shaping the current market of mobile services is the spectrum assignment policy, which is governed by the regulatory bodies across countries. Furthermore, in case of European market and from the European Commission point of view, there is no way to force national regulators to implement certain (relaxed) regulations, as the only output from the EC might be the recommendation formulation, which is not mandatory.

Furthermore, looking at the current market, it is worth to notice, that its definition is not perfect either. Both the network operators as well as the regulatory bodies have risk factors. In case of network operators, these factors can be summarised by the following bullets:

- Risk of not winning the spectrum band license;
- Risk of artificially high price for the spectrum band;
- Risk of the frequency band cost much higher that for the competitors.

At the same time, the regulatory bodies might face the following risks:

- Risk of causing market competition reduction, or monopoly situation;
- Risk of low price for the auctioned spectrum resources;
- Risk of situation, where the frequency bands are under-utilised.

The main driver for spectrum access policies and their distribution is the mobile market stimulation towards provision of competitive services, as well as infrastructure investments. At the same time monopoly situations shall be avoided, which are seen as destructive and not attractive for subscribers. Considering current market situation, we are looking into novel spectrum assignment policies, investigating their impact on the homogenisation of the mobile services offer on the market, at the same time looking the how such trends can be stimulated and implemented. Despite of the regulatory focus on the spectrum utilisation, its spectral efficiency improvements as well as the social welfare, evenly important is the economy benefit from targeted spectrum policy.

One more aspect, which has to be accounted, is the financial consideration on the national level. In case of the current market, the spectrum long-term leasing process generates significantly high revenue to the national budgets. Finding sufficiently good justification for adaptation of a model, which gives up such revenue, might not be easy. Secondly, the currently deployed networks might not be able to easily benefit from new market regulations due to limited hardware capabilities. Therefore, the recommendation is to start consideration of the described market evolution in step-wise manner, starting from the spectrum bands that are not yet allocated to the cellular services.

Based on the above observations, we will try to formulate recommendations on the beneficial or required modification in the regulatory framework with respect to the spectrum management, which will be derived from the spectrum sharing scenarios analyses.

4.3.1 Monopoly situation risk

Based on the feedback received during series of the discussions with various national EU regulators [16], [17], the main concern was not to limit the competition on the mobile market, by introduction of sharing in the cellular networks (even though this concern starts to become less visible in face of spectrum sharing benefits gaining more attention). These discussions as well as the presented concerns and doubts brought our attention. We feel that the competition will not be degraded by the spectrum sharing in case, where new, uncovered market sectors will be revealed by the mobile services offer. This will be secured in case, where the spectrum access will be de-regulated to certain extend, allowing new market entrants to offer services to well defined, specific target groups, not focused on large scale flooding of the market. The proposed market coverage limitation shall be sufficiently large, in order to convince current MNOs to lease/rent certain percentage of their owned spectrum resources for the “gap fillers”.

It can be observed, that in case of higher degree of competition in the mobile services market being enabled by a higher number of the service and radio access providers, less regulation would be required, what increases the end user benefits. Looking further into the offer details, market players can specialise their offers, looking for niche markers,

not covered yet, due to the current offer not being attractive enough for potential subscribers. What leads to interesting observation is that the service provider can benefit by the discovery of the niche market, where in turn, they can be considered as the monopoly players.

Another observation with respect to the risk of monopoly is the potential spectrum hoarding by the market players [18], which might simply block the implementation of the flexible spectrum regulations due to limited spectrum resources availability.

5 Spectrum sharing scenarios – general overview

Spectrum sharing scenario being identified and selected in the previous WP5 work as covered in deliverable D5.1b [2], is presented in Figure 4 (SC2abc, according to D5.1b naming convention). In this scenario no RAN sharing is considered, focusing purely on the radio resources sharing issues, which in some cases, cannot be treated without the hardware aspects consideration. This scenario is taken as the starting point of work, with the assumption there are Mobile Network Operators (MNO) considered to be interested in certain form of cooperation with respect to the spectrum resources utilisation, taking into account the business relations among them as well as the regulatory body, which plays mayor role in the spectrum distribution and delivery chain. As presented further, we also allow third party units to appear in the analysis, e.g. for the spectrum sharing negotiations purposes, or for regulatory monitoring for the spectrum usage.

Consideration of the non-exclusive spectrum usage and introduction of the shared spectrum bands, is seen as a solution to obtain significant improvements in the spectrum efficiency and spectrum usage. This in turn is expected to generate gains in the cost efficiency of the business maintenance and operational profitability in the mobile networks industry. In the further part of the work, we address the already running networks point of view, as well as the newcomer's situation.

Besides the spectrum resources consideration, another reason for the growing interest in the spectrum sharing scenario is the cost saving. For example, what has been studied and shown in [19], [20], is that the possible cost saving achieved by the network sharing was estimated to be in the range of 10–15% for the long term perspective. Those savings stem from the network CAPEX and OPEX reductions, being in range of 40% of the total cost, where the remaining 60% of the cost is generated by licensing, billing, administrative issues and marketing [21].

Furthermore, the concept behind the newly proposed business models for the spectrum sharing scenarios is the observation, that there is no need to keep technical aspects and economical roles of the mobile services provider being bundled and closely related, what was captured also in [22]. It is seen, that the currently used vertical value chain model, where the MNO is covering all functionalities from the spectrum management, infrastructure extensions to the mobile service offering and the customer service, does not need to be assumed as the basis for the future networks and potential spectrum sharing scenarios. The challenging aspect of such transformation is the identification of the roles, responsibilities and business relations between future market participants, creating the value chain for the mobile services delivery. Such evolution requires modification in the way of thinking among the considered, current market entities, including the regulators and governments.

Looking at the spectrum sharing, the following categories of the sharing mechanisms can be identified:

- Orthogonal spectrum sharing: radio resources are assigned to the sharing agreement participants based on certain spectrum granularity (usually RAT

specific) and considering the TDMA allocation principle: two MNOs cannot be granted the same radio channel at the same time, not allowing subscribers belonging to different MNO to be allocated in the same time/spectrum resources (e.g. utilising multi-antenna techniques).

- Non-orthogonal spectrum sharing: radio resources are assigned to the sharing agreement participants based on certain spectrum granularity (usually RAT specific) and without any strict TDMA allocation principle: two MNOs can be granted the same radio channel at the same time (by using multi-antenna techniques), thus allowing subscribers belonging to different MNO to be allocated in the same time/spectrum resources.
- Vertical spectrum sharing: considers sharing of the licensed band with the primary user of the spectrum.
- Horizontal spectrum sharing: sharing participants are considered to have same priority to access the spectrum resources, like in case of unlicensed bands.

Based on the above classification, it is seen, that the sharing mechanisms proposed in further sections are well suitable for the orthogonal spectrum sharing techniques. For the non-orthogonal spectrum sharing consideration in the presented analysis, further complication of the mechanism would be required. Moreover, it is expected, that the network operators preference would favour the orthogonal sharing mechanisms. Therefore, the orthogonal spectrum sharing will be assumed throughout the work. Anyway, it has to be captured, that some of the analysis parts are applicable to both variants of the sharing (e.g. regulatory aspects, end user perception).

In general, we allow in this scenario each of the considered MNOs to share certain part of their frequency spectrum, while keeping the exclusive usage over the remaining resources. Furthermore, the shared spectrum resources can be also provided by external entities, or being purchased for the non-exclusive usage among interested market entities, while focusing on the licensed spectrum bands only. Therefore, mix of vertical and horizontal spectrum sharing strategies is considered. Detailed summary of the described sharing scenario is presented in Table 15.

By the cooperative spectrum sharing we consider the case where the frequency channels are granted in the (near to) real-time based on the resource requests coming from the operators participating in the sharing agreement, being managed and scheduled in the coordinated and dynamic manner.

Complexity of the considered spectrum sharing scenario depends on many factors, such as:

- Number of network operators;
- Independent infrastructure sets and their development plans;
- Availability of various RATs;
- Backhaul technologies used, their bandwidth and capabilities;
- Market competitiveness pressure;

- Traffic structure on the market and its forecasts;
- Spectrum resources availability, etc.

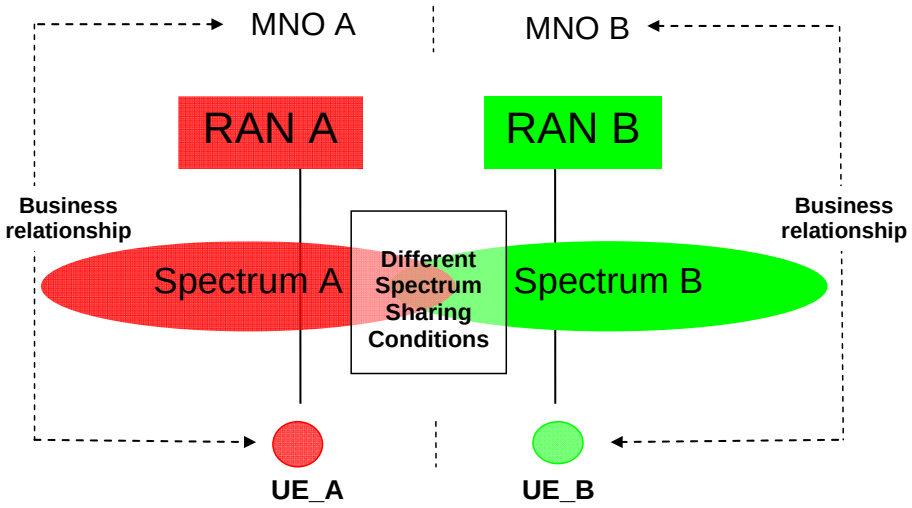

Figure 4: High level spectrum sharing scenario model [2]

Due to the complexity of the analysis, it is assumed, that only two network operators are considered in each of the proposed scenarios. Nevertheless, it is expected that the described models can be extended to the multi-operator case, with relatively low complexity to the whole process. Furthermore, the analysis presented in this document aims at the RAT independent study, unless otherwise stated.

To analyse its business implications with the cost and benefits analysis, the author proposed to perform a more detailed analysis of four business cases belonging to the spectrum sharing scenario, for accurate analysis and business model creation in further part of the document. These cases are presented in Figure 5, which are:

- Collaborative spectrum sharing in existing spectrum band, where Operator A and Operator B decide to share spectrum block which belongs to Operator B (in Figure 5 marked as ①),
- Collaborative spectrum sharing in additional spectrum band, where Operator A and Operator B decide to buy a dedicated spectrum block which will be a subject of sharing (in Figure 5 marked as ②),
- Inter-operator spectrum sharing with spectrum broker, where Operator A and Operator B access the same part of the spectrum resources they have usage rights for. The spectrum is owned by a wholesaler, who sells the access rights in real-time (in Figure 5 marked as ③),
- Spectrum spot market, where Regulatory Body changes the spectrum policy and sells the spectrum chunks on the spot market, making de facto pay per use policy possible (in Figure 5 marked as ④).

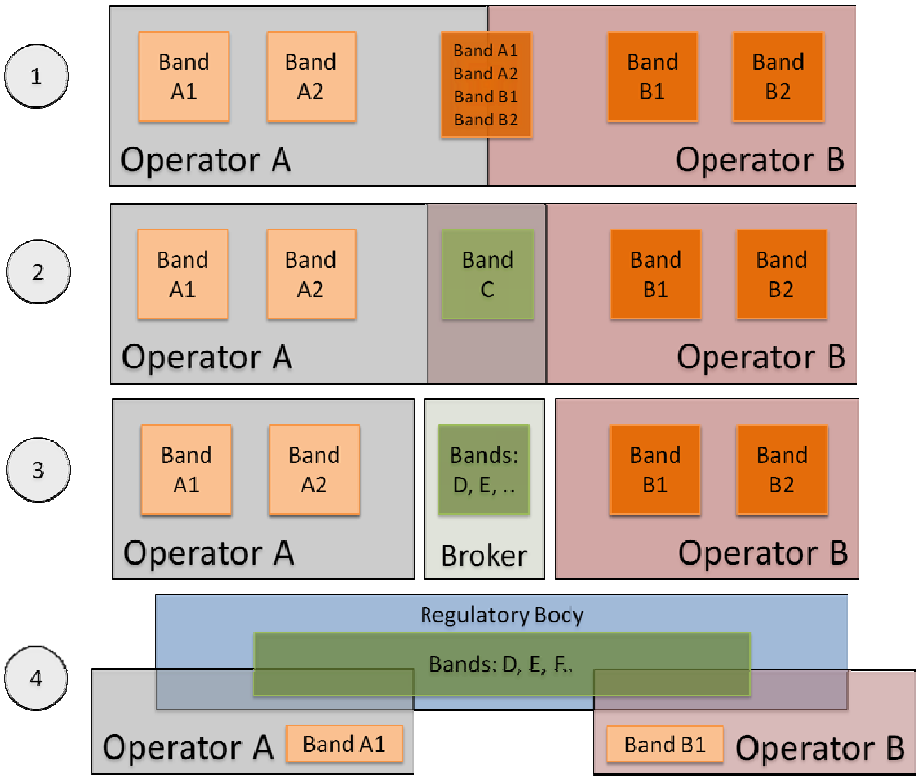

Figure 5: Four business cases belonging to the spectrum sharing scenario

The main criterion for differentiation of the above listed scenarios is the MNO's approach to the investment risk. This aspect was clearly observed during the 3G networks license distribution followed by delayed network deployments over the world. Furthermore, not only the financial aspect might be considered as the risk factor, but entering the sharing agreement itself. Both above mentioned aspects will cause the potential sharing benefits and cost reductions to be valid in specific cases only:

- In case of sub-scenario #1 Operator A and Operator B offer not fully utilised resources, to get additional benefits from the own asset;
- In case of sub-scenario #2 Operator A and Operator B decide to invest jointly, buying additional spectrum band as none of them is able to utilise the spectrum block individually as efficient as in the coalition, reducing the investment risk at the same time;
- In case of sub-scenario #3 the spectrum broker, or wholesaler takes the investments risk related to investment in spectral resources;
- In case of sub-scenario #4 the regulatory body eliminates the investment risk related to spectral resources, by introduction of the spot market manager which is additionally allowing MNOs to re-sale their own spectrum resources.

From the coalition formation point of view, the following aspects of the spectrum sharing might require detailed analysis for scenario implementation:

- Trustful network load monitoring in spectrum sharing scenario;

- Compatibility issues between the sharing partners (e.g. RAT, backbone, RF frontends);
- Mobile market competition reduction risk;
- Differentiation among operators considering spectrum sharing and their willingness to enter the coalition.

In Table 2, we present the high level differentiation of the proposed sub-scenarios, which will be further detailed on the following part of the document.

Table 2: High level sub-scenario comparison

Spectrum sharing sub-scenario	**Additional bands considered**	**Spectrum amount and availability**	**Spectrum related cost**	**Market set-up, new market units**
#1 Collaborative spectrum sharing in existing spectrum band	No	More spectrum, not guaranteed, opportunity based	No spectrum cost (in case of money-free variant)	Inter-operator deal
#2 Collaborative spectrum sharing in additional spectrum band	Yes	More spectrum, guaranteed	Reduced investment into guaranteed spectrum, medium cost	Inter-operator deal
#3 Inter-operator spectrum sharing with spectrum broker	Yes	More spectrum, guaranteed (up to broker capacity), pay-per-use	Pay-per-use, Low cost in case of capacity shortage, Timescale dependant cost	Spectrum broker unit
#4 Spectrum spot market	Yes	More spectrum, guaranteed, pay-per-use	Pay-per-use, Demand based cost, additional revenues from own spectrum possible	Spot manager unit

Based on the above proposed spectrum sharing cases, we will approach the formulation of the business models for mobile network operators, at the same time trying to identify the opportunities coming from the novel spectrum allocation methodologies for current, as well as for new market players, e.g. spectrum broker. This analysis will consider the cost and pricing aspects, proposing certain mechanisms being identified during the study of the spectrum sharing scenarios.

6 Collaborative spectrum sharing in existing spectrum band

In this section, we analyse first of the proposed variants of the spectrum sharing scenario, which is the collaborative spectrum sharing in the existing spectrum bands.

6.1 Scenario description

By this scenario, we understand a coalition of (at least two) cooperating mobile network operators, who agree to dynamically share a certain percentage of their own spectrum in the already deployed network under the condition, that traffic demands originated from their own subscribers, were already covered and served by appropriate radio channel allocations. The scenario graph is depicted in Figure 6, indicating that we do not consider any additional spectrum resources to be introduced to the reference, non-sharing scenario. In other words, this case of the spectrum sharing aims to improve the spectrum utilisation of the spectrum bands currently owned by the MNOs participating in the cooperative spectrum sharing, by filling the spectrum gaps with the traffic coming from the other operator's network, i.e. so called statistical multiplexing phenomenon is targeted to be the main source of the sharing gain (example presented in Figure 7). The spectrum access grants are assigned in the real-time, in fully operator controlled manner, so that the spectrum band owners can allow the other MNO subscribers to be served by part of own radio channels, on top of RAT specific TDMA scheme, i.e. the opportunity based spectrum sharing will grant access for limited time duration. For more details on the time scale of the spectrum sharing, refer to [11], where short-, medium- and long-scale spectrum sharing variants were simulated and analysed.

The legacy radio network planning is not expected to be impacted by implementation of this scheme. Moreover, this scheme would most feasible and beneficial in case, when both considered MNOs have already rolled out in their networks the frequency bands which are under consideration for sharing.

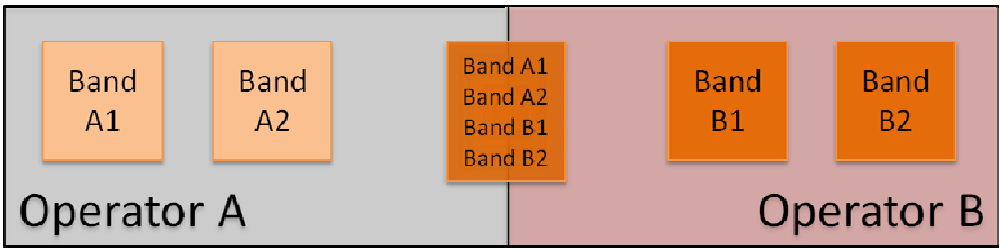

Figure 6: Spectrum sharing sub-scenario #1: Collaborative spectrum sharing in existing spectrum bands

Due to the formulated condition, we can conclude that this access scheme will not be able to guarantee fully equal spectrum usage balance between the operators spectrum grant requests from the other MNO (i.e. Operator B access to the Operator A spectrum, and vice versa), due to e.g. location and time specific variations of the traffic demands. Furthermore, in order for the mechanism to work, supply on one side, and the demand on the other has to occur simultaneously. Therefore, the expected gains might be limited.

In the presented scenario, Operator A is licensed to use frequency bands A1 and A2, while the Operator B owns license to serve his subscribers on bands B1 and B2. The spectrum sharing mechanism can be explained by the following rules:

- Operator A shares part of his own radio channels belonging to bands A1 and A2, and allows Operator B;
- Operator B does the same kind of sharing of his radio channels from bands B1 and B2;
- Operator A subscribers can utilise band A1, A2 and shared part of B1 and/or B2;
- Operator B subscribers can utilise band B1, B2 and shared part of A1 and/or A2;
- Operator A users have priority over the Operator B users on band A1 and A2;
- Operator B users have priority over the Operator A users on band B1 and B2;
- Radio channels sharing is opportunity driven and the other operators are not able to force others to share more spectrum resources;
- Bands A1, A2, B1 and B2 are disjoint, but might create continuous spectrum.

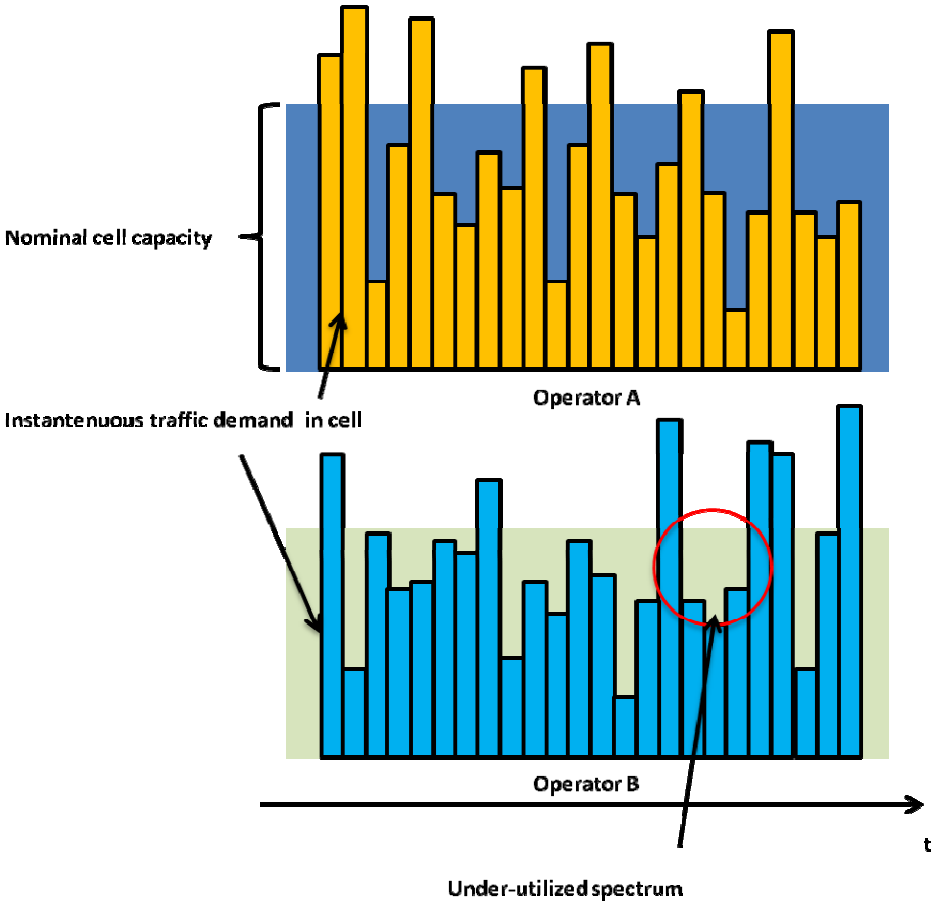

Figure 7: Example of the uncorrelated traffic demand over time in the inter-operator scenario, with multiplexing gain opportunities; RAT specific TDMA scheme applies

In order to enable such cooperation between MNOs, a certain agreement would be required to be established, but due to the fact, that this kind of spectrum sharing is seen as opportunistic and not being able to guarantee certain level of the availability and quality of the additional spectrum resources, it is not seen feasible to introduce service level and capacity assurance agreement (i.e. SLA management). In other words, in this case it is not possible to define the sharing rule among MNOs in the reliable way, i.e. to guarantee quantitative spectrum availability.

In order to keep fairness of the sharing, it is proposed to construct the so called clearance function, which aims to keep balanced gains and charging of the spectrum sharing in the coalition of operators. The goal is not to let the Operator B permanently use Operator A radio channels, while at the same time not serving the Operator A subscribers as a payback (such situation might occur e.g. due to statistically unfitted traffic demands and spectrum availability). The proposed clearance function can consider the shared spectrum usage reporting to be applicable in many variants, depending on the operator's preference:

- Time-dependant, e.g. Operator A might be interested in getting extra cell capacity only in certain time periods during the day;
- Spectrum-selective, e.g. network operator might be interested in acquiring only radio channels from particular spectrum bands, due to coverage issue in certain deployment scenario in his network;
- Location-specific, e.g. we can imagine, that network operators will not be interested in deploying the described sharing mechanism in full network (e.g. in order to limit complication and deployment costs), focusing on specific areas, like hot-spot areas.

Furthermore, in this case, as in all other cases considering multiple cooperating entities, certain amount of feedback information is required to be exchanged between MNOs in order to e.g. provide the time/band/location dependant spectrum availability notifications. The available spectrum resources reporting would be needed, in order to notify the potential operator(s) on the availability of the un-allocated radio channels. This problem is similar to one existing in the interweave Cognitive Radio (CR) systems, where the secondary users have to sense the spectrum in order not to interfere with the primary spectrum users, or other feedback systems have to be established, e.g. database based. Considering limited amount of the radio channels being under consideration in this scenario, it is seen that the periodic signalling might be used via the backbone network between the Operator A and Operator B infrastructure, for the under-utilised spectrum resources notifications, on the location specific manner. Depending on the network infrastructure relations between involved MNOs as well as depending on the considered RATs being deployed, realisation of such feedback exchange might generate various levels of complication in the network. For example in case of the infrastructure sharing and LTE radio access network, such interface might be established based on the standardised X2 interface between eNB entities, even in case of eNB's hardware from different vendors [23]. Optionally, consideration of the 3rd party entity for security and anti-trust reasons can be considered as well. Possible scheduling flow realisation for cell specific inter-operator spectrum sharing is depicted in Figure 8.

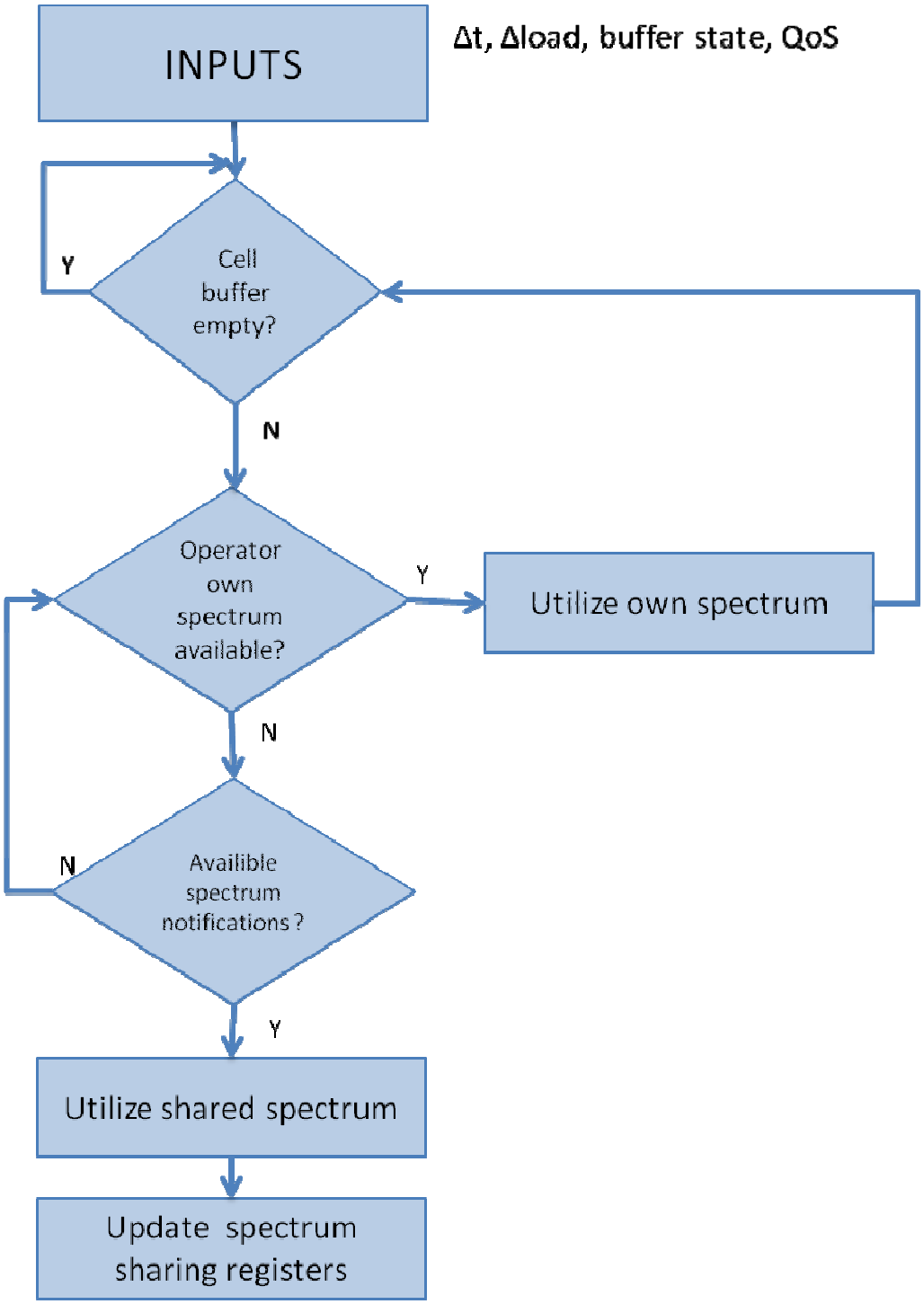

Figure 8: Sub-scenario #1 scheduling flow for cell specific inter-operator spectrum sharing (run per operator)

The input values defined in this flow are describing the traffic arrival process:

- Δt: denotes the time duration, for which the sharing decision will be valid among the cooperating operators; this duration might be RAT specific;

- Δload: denoted the amount of the traffic, which is under consideration at certain time instant, e.g. based on the delay requirements;
- Buffer state: denotes the local (e.g. cell specific) level of the incoming traffic to be served, e.g. MNO might be interested in the spectrum sharing only in case of the overload indications.
- QoS: the incoming traffic might have various delay or throughput requirements, therefore its consideration will impact the scheduling process, as well as the requests for the shared spectrum usage.

Another functionality considered as required for the scenario implementation, is the monitoring of the spectrum usage, which is granted by different sharing partner. One possible realisation of such monitoring can be done based on the offline tracking of the log files from the O&M units. More sophisticated solutions might allow online tracking of those performance indicators, or even allow dynamic "on the fly" modifications of the sharing mechanism, e.g. dynamic modification of the areas covered by the counters (example depicted in Figure 9), for the optimisation purposes of the subsequent inter-operator charging.

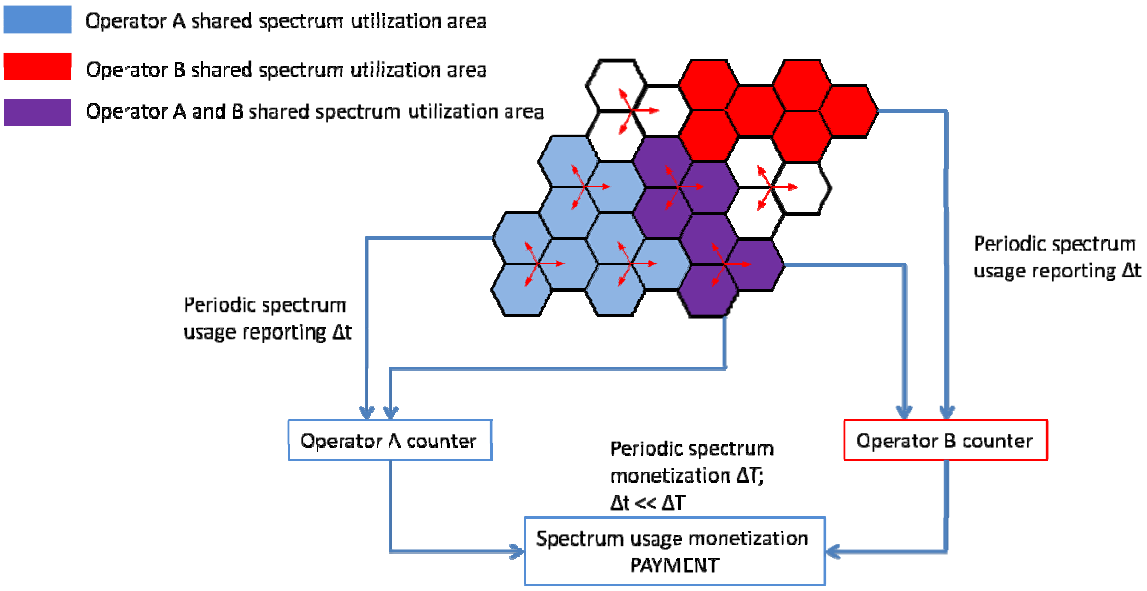

Figure 9: Example of the location specific spectrum sharing enabling; network coverage provided by both operators

As in the cellular network we cannot ignore the mobility issues, for the roaming users, the handovers will have to be covered considering possible usage of the spectrum belonging to the other operator (e.g. multi-operator CRRM), what will introduce certain level of complexity to the RRM procedures, as well. Because of the competitive entities cooperation, as well as in order to ease the procedures execution, the information exchange between operators will have to be minimised.

6.2 Reference to the system level simulations

System level simulation campaigns were performed for the SAPHYRE project purposes, simulating various radio resource allocations and sharing schemes in various cellular network configurations, for the concepts verification purposes. Highlights from this work were captured in deliverable D4.1 [11], with inputs from SAPHYRE project members involved in system level simulations. Based on the mentioned work, we try to link the spectrum sharing sub-scenario #1 with the simulations results obtained in previous work.

One of the simulation campaigns was simulating the case, where two MNOs operating over the same area and providing mobile services using HSPA radio access technology, are cooperating using game theory based decision mechanism for the resource allocation, from the radio channels being pooled for sharing [14]. In order to obtain the situation as proposed in the spectrum sharing sub-scenario #1 (i.e. Operator B can access Operator's A channel, only when A does not need them, and vice versa) the Poisson process based traffic generators were configured to generate same traffic patterns for both network operators, where the subscribers were randomly located in each of the network. Such set-up has stimulated situation, where time and space specific radio channels demand occurred. Based on the obtained Cumulative Density Function (CDF) of the cell goodput, only limited sharing gain of ~2% was observed, which can be considered as being derived from the statistically uncorrelated traffic demands in both considered networks.

Please note, that the above case does not completely depict the sharing case as in the sub-scenario #1, therefore above referred case shall not be considered as the final qualitative conclusion of the described scenario. Therefore, despite of the referred simulation results, we have continued the business analysis of this sharing scenario.

What can be concluded is that this sharing scheme will provide limited gains over the non-sharing scenarios and the remaining sharing schemes shall be considered for more promising gains.

6.3 Business model

In this sub-scenario, we do consider only the spectrum bands, which are currently owned by the mobile network operators, which are limited in the initial analysis to two MNOs, being interested in the cooperation for the spectrum resources sharing for the network capacity and subscriber perception improvements. Furthermore, those operators are providing mobile services over the same geographical area.

We assume that, on top of operator specific frequency plans, both operators will have the opportunity to utilise the other MNO spectrum resources. To certain extent, this mechanism might be seen as the Cognitive Radio, which is employed within the licensed bands, being an opportunity based spectrum access service.

Despite of the possible gains for the network operators, there is number of weakness and threats of the proposed scenario. One of the weaknesses of the inter-operator spectrum in the existing spectrum bands, is lack of the guarantees for the additional spectrum availability in the time/space/frequency domain. In order to address this

concern, it is proposed to introduce certain level of the QoS into the proposed scenario, by definition of time domain granularity into the sharing mechanism, i.e. once you get access to the shared spectrum, you have it granted at lease for Δt, irrespective of the load in the donor's network.

As this scenario is allowing usage of the competitors resources, appropriate spectrum valuation mechanism is needed in order to keep the unused spectrum exchange cooperation fair to all participants, as well as being still attractive feature. The approach presented in Figure 9 might be used for the monitoring of the spectrum usage. The implementation of this idea might have few variants:

- Online: the spectrum usage is monitored continuously and online in the own network via O&M functionality, using KPIs. The other operator will do the same in his network. Based on the legacy frequency allocation plan, it will be known who's radio resources are used (Operator A shall be able to determine which radio channels belonging to Operator B are used, as well as, which channels belonging to Operator A are used by the Operator B users, same applies for the other sharing partner).
- Static: the earlier mentioned balancing function limitation might be set in static manner, per cell/site/area, without possibility to react in case of continuous network overload. Static version of this mechanism is possible in both, offline and online variant.
- Dynamic: in this variant, MNOs are able to dynamically adjust their settings in the balancing mechanism, staring from the load balance volume, as well as the mechanism coverage and its geographical applicability. Dynamic variant of the mechanism is possible only in the online variant of the implementation.

Furthermore, is it proposed that in the default case, operators might simply apply the balanced resources valuation, namely, only the amount of the time/frequency units would be calculated and being compared on the central level in relatively non-frequent manner (e.g. days, weeks, months), in order to minimise the maintenance effort. This concept is illustrated in Figure 9.

The spectrum usage balance monetisation would then apply only to one of the cooperating MNOs, based on the outcome of the usage reporting from the KPI counters from the considered time period and their comparison between considered operators. Afterwards the monetised is performed and the performance counters are reset and the process is repeated. The payment valuation might be based on the initial agreement among MNOs, being defined for time/frequency unit (e.g. per ms, per RB, in case of E-UTRAN).

What is further observed, is that various network operators might require additional spectrum resources in different geographical regions. Therefore, it would be most beneficial, to allow flexible set-up of the mechanism, in terms of the spatial domain.

Based on the observed interaction between network operators, there might be beneficial for both parties to formulate long-term spectrum usage agreement (possibly time and space specific), providing more controlled level of the quality of service being able to be offered to the subscribers.

Another speculation is on the potential formation of the cooperating MNOs. Due to the structure of the proposed mechanism and the sharing gains availability being dependant on the opportunistic radio channels availability, it is expected that the spectrum sharing coalition formation will not be equally attractive in all market scenarios, e.g. depending on the MNO's market penetration and their market shares. In case of small MNO, it is expected that he might be attracted by the availability of the additional spectrum resources availability, but at the same time, he might not be able to offer too much for the sharing purposes. On the other hand, in case of large MNO, more spectrum resources owned by him would allow to assign more carriers to the sharing algorithm. For the same reason, such MNO might consider coalition formation, only with equally large market player.

In order to ease further business models comparison for each of the sub-scenarios, we introduce a high level categorisation of the model, as presented in Table 3.

Table 3: Main factors for the MNO business modelling

Business case purpose	Cell capacity improvements and additional spectrum resources without expensive long-term spectrum acquisition
Mobile services offer impact	Offer to be kept the same, with additional opportunity for service availability extensions
Strategy related to the business case	Introduction of the inter-operator agreement (win-win strategy)
Infrastructure impact	No direct impact on HW, but RAT specific issues might arise. Software seen to cover required functionalities
Network operator structure impact	MNO functionality structure to be unchanged
Goods/services trading	Based on the cooperation strategy, spectrum resources are considered as the good which will be exchanged for more efficient utilisation, improving both sharing partners
Market related cooperation processes	Cooperation process with other network operator will require certain information exchange – possible mediating unit consideration. Relations with subscribers to be kept unchanged
Spectrum policies	Due to much more flexible spectrum usage consideration, spectrum regulations might limit the cooperation's scope – subject to national regulations

6.3.1 Pricing mechanism and cost analysis

For the efficient implementation of the business case, we need to consider the inter-operator money flows. These flows are considered to represent the payback mechanism in their cooperation in the spectrum resources re-use. As presented in Figure 10, it is proposed to realise the spectrum usage monetisation in the periodic time instants, where the network operators are accounting usage of the radio channels, which are granted by the other operators.

Despite of the proposed mechanism above, one can also imagine, that the spectrum sharing in the existing bands might be also realised with no monetisation at all, in form of money–free variant. The voluntary spectrum sharing in this case can be stimulated by

simple approach *"the more you give, the more you get"*. Such variant might be considered as the starting point for the cooperation, i.e. less risk for potential entrants.

The participants of this scenario presented in Figure 9, are able to receive additional revenue from the owned spectrum resources. The big question is how to evaluate the unused spectrum resources. In order to stimulate and advertise this kind of cooperation, it would be more efficient to set the price according to the input from the capacity limited network side, which is suffering from the spectrum resources shortage.

From the subscriber point of view, spectrum sharing mechanism would be transparent, therefore there would be no additional, dedicated charging for the end-users due to the inter-operators radio channel handovers. This is justified by the fact that sub-scenario #1 would aim at the end-user perception improvements and cell capacity boosts. Therefore it is assumed, that potential costs and investments would be covered by the MNO with no direct impact on the end user bill.

6.3.2 Definition of the modified map of the market

eTOM based market and role analysis is covered for all four sub-scenarios in Section 10.1.

6.3.3 SWOT analysis

In Table 4 we present the SWOT analysis, based on the theoretical introduction to the four analysis fields as presented in Section 3.2.

6.3.4 Business model canvas

Based on the business model canvas approach [7] and its description in Section 3.3, Table 5 contains the analysis of the spectrum sharing sub-scenario #1, from the MNO point of view, who is considering the implementation of the proposed sharing scheme.

Table 4: SWOT analysis for collaborative spectrum sharing in existing spectrum band

STRENGTHS	**WEAKNESSES**
• Relaxed requirements for capacity limited cells (opportunistic and to limited extend) • No need for extra spectrum long-term license purchase (to limited extend) • Improved spectrum utilisation and efficiency • Due to larger amount of channels, more flexible resources assignment and scheduling • Possibility to employ this scheme in the current frequency plan • Utilisation of the current employees experience • Operator's own subscribers service shall not be impacted • Seamless adaptation to the current offer • Possibility to obtain new revenue flow • Operators cooperative dynamic spectrum allocation might generate new services and applications • Allows provision of extra, non-QoS services	• Depending on the spectrum band regulations, RAT specific limitations might apply • Possible gains will be visible only in case of capacity limitation only • Scenario might require case specific set-ups, due to operator specific frequency planning • Lack of the guarantees for the additional spectrum availability in the time/space/frequency domain • Provides only opportunistic capacity improvements (i.e. depend on the other operator network load) • Considered additional spectrum from other operator might not be sufficient for QoS demanding services • Increased complexity in the scheduling process – TDMA access to the extra bands • Higher signalling overhead required in order to signal additional spectrum availability • Appropriate coordination mechanism might be required in order to secure spectrum owner subscribers service • Possible concern for MNO to enter the cooperative action with the competition
OPPORTUNITIES	**THREATS**
• In long-term, might enable much more cooperation between competitors, once initial gains being identified • Opening new approach to the spectrum, being considered as good which can be exchanged between MNOs • Possibility to reach higher peak data rates per cell, depending on the load balance between two considered MNOs • Possibility to obtain new revenue flow • Potential extension for multi-operator cooperation scheme for more flexible additional spectrum allocations • MNO coalition formation might be seen as attractive tool against operator not participating in such cooperative spectrum sharing (subject to regulatory monitoring)	• Might require third entity, in order to avoid speculative actions from the another operator, e.g. blocking the unused spectrum • The expected gains might be limited, depending on the load the other network • Potential regulatory limitations of such sharing coalition formation due to monopoly risk

Table 5: Business model canvas analysis for sub-scenario #1

<table>
<tr>
<td rowspan="2">KEY PARTNERS
• Strategic partnership between MNOs as business case enablers: cooperation motivated by the extra radio resources acquisition, while MNOs are competing entities
• Telecom equipment vendors for possible extensions in the BS (e.g. RF front ends) – buyer–supplier relation
• SW developers (internal resources or outsourcing) for implementation of the spectrum trading functionalities</td>
<td>KEY ACTIVITIES
• Identification of the potential MNOs interested in cooperation
• Creation of the inter-MNO alliance
• Formulation of the potential inter-operator charging mechanism and pricing
• Identification of possible network infrastructure issues with regard to planned spectrum sharing</td>
<td rowspan="2">VALUE PROPOSITION
• Improved service availability, but non-guaranteed
• Improved network coverage, but non-guaranteed
• Reduced risk of “no-coverage” situation
• Overall subscriber experience enhancement (applicable for all MNOs participating in sharing)
• Potential for the subscription cost reductions</td>
<td>CUSTOMER RELATIONSHIP
• Focus on customer retention by their service perception improvements
• Customer relationships to focus on the automation
• Possibility to create new target market for low-end service delivery, at lower cost</td>
<td rowspan="2">CUSTOMER SEGMENT
• Current customer segmentation to be targeted and current segmentation kept as reference
• Potential of new, low-end customer segment, mostly relying on the service delivery based on the additional, shared spectrum resources
• Potential current segmentation extension in case of new services offer, based on additional spectrum</td>
</tr>
<tr>
<td>KEY RESOURCES
• Running networks
• Current delivery chains
• Experienced employees
• Spectrum resources (own + shared)
• Inter-operator partnership</td>
<td>DISTRIBUTION CHANNELS
• Mobile service distribution channels to be unchanged
• In case of extension of the offer, same channels can be utilised</td>
</tr>
<tr>
<td colspan="3">COST STRUCTURE
• Business case mainly being value-driven, with cost awareness
• Network OPEX costs expected at current level (many elements being the fixed cost)
• Case specific HW/SW investments might apply for functionality implementation (depending on the spectrum band under consideration)
• Potentially, inter-operator charges based on the additional spectrum usage (based on the internal agreement between operators) – variable cost
• In case of low-end service enabling: advertising cost</td>
<td colspan="3">REVENUE STREAMS
• Regular revenue from the subscriptions fees, being customer segment dependant – mostly fixed prices
• Potential to extend the subscription generated revenue, by low-end customer segment – this might be onetime payment model
• Potential, variable revenues generated by the shared spectrum from other MNOs, as the usage fee for “spectrum leasing”</td>
</tr>
</table>

6.4 Description of scenario players and roles

In this section we attempt to describe and analyse the spectrum sharing influence on the roles and on the assignment of the market players, leading to possibly new business models for mobile services delivery, where the regulatory and business relations are considered.

6.4.1 Standardisation

The analysis of the standardisation impact from the proposed scenario point of view shall be RAT specific, following the way of the 3GPP technologies standardisation. For that reason, detailed analysis of various scenario configurations might be very extensive. Therefore, we only attempt to identify the requirements from high level point of view, not looking in too detailed analysis of the RAT specific protocols and architectures.

The proposed scenario requires inter-operator feedback exchange, which might be subject for standardisation actions. For example in case of the infrastructure sharing among operators and the E-UTRA radio access network, such interface might be established based on the already standardised X2 interface between eNB entities. This interface can be established also in case of the eNB's hardware coming from different vendors [23].

From the RF perspective, it is seen that the proposed opportunity based radio channels reuse shall be doable, assuming BS capabilities of the shared radio channel generation for particular RAT. In case of the various RAT's consideration (GSM, UTRA, E-UTRA), the Multi-Standard Radio capable base station might be required [24].

6.4.2 National regulator

This sub-scenario, is seen as the one which requires no regulatory interaction for the inter-operator spectrum exchange and re-use, as long as we can assume that no monopoly issues will be identified against market players, not participating in the described cooperation, e.g. the coalitions formations, might limit the market's competitiveness, being against other marker player not participating in the sharing coalition.

Role of the national regulator in this scenario is limited, as the spectrum sharing is performed between cooperating entities, which already were granted the long-term spectrum license. The issues of strict spectrum policies, not allowing such spectrum reuse practices might arise.

6.4.3 Telecom equipment vendors

Depending on the relation between the network infrastructures of both MNOs (e.g. collocated, or separate infrastructure), there will be various requirements for the un-occupied spectrum resources signalling.

Hardware vendors role in this scenario is not directly seen and depends on the possible implementation issues, which might require e.g. software upgrades in the currently existing infrastructure for the spectrum sharing scenario implementation, e.g. upgrade of

the maintenance software, in order to monitor the shared spectrum usage – on the other hand, such action might not require HW vendor intervention, being in the capabilities of the network operator itself.

In case of unfitted RF frontends capabilities in base stations over the interest area, there might be also need for some HW upgrades (e.g. power amplifiers, antennas). Such case might become main bottleneck for proposed scenario implementation due to the cost issue.

For the terminal devices, there are no additional requirements for the scenario implementation, other that the support of spectrum bands, which are the subject of the considered scenario.

6.4.4 Network operators

In this spectrum sharing case, both MNOs are operating and manage their own networks, based on the exclusively owned spectrum resources. Their goal is to improve the availability of the radio resources, with no investment in the long term spectrum lease. The prerequisite is the identification of the interested coalition of the MNOs and consideration of the spectrum bands, RATs and geographical areas for the spectrum sharing scenario implementation.

6.4.5 End users

End user role is same as is the non-sharing scenario, where the subscribers are using the mobile services. From the subscriber point of view, this scenario might improve the service delivery and its quality, but this depends on the traffic, spectral and special relations among operators. Nevertheless, introduction of the described scheme shall not degrade the service quality, with respect to the reference non-sharing case.

For the end user being the market player, spectrum sharing is considered general enough to be together for all four cases considered in this document. Therefore, the end user perspective analysis is performed in Section 11, where the analysis is covering mobile services impact by the introduction of the spectrum sharing. Moreover, we make an attempt to the identification of possibly new mobile services, which might appear thanks to the new radio resources management rules and regulations.

7 Collaborative spectrum sharing in additional spectrum band

7.1 Scenario description

In this section, we analyse second of the proposed variants of the spectrum sharing scenario, which is the collaborative spectrum sharing in additional spectrum band.

In this case we consider at least two mobile network operators, who are interested in acquiring additional spectrum band(s), while at the same time being interested in lowering the network investment costs. This sub-scenario can be modelled as the coalition of operators, whose spectrum demand is lower than the spectrum bands granularity in the long-term radio frequency offer. Those operators have an internal agreement, reflecting their percentage investment in the additional spectrum band. Each of the operators keeps the right for the exclusive usage of the frequency bands being assigned previously (e.g. band A1, A2 for Operator A and band B1, B2 for Operator B respectively, as depicted in Figure 10). The shared frequency band (i.e. band C) constitutes an additional spectrum band, that none of the considered operators involved in the spectrum sharing is licensed to use before the sharing agreement. Moreover, there is no active legacy network operating on the band considered here as the shared band.

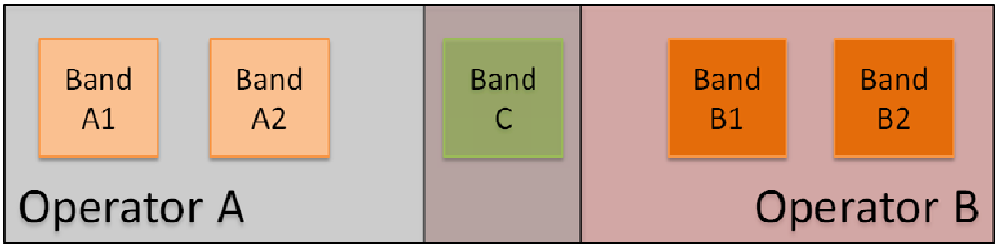

Figure 10: Spectrum sharing sub-scenario #2: Collaborative spectrum sharing in additional spectrum band

The spectrum sharing mechanism can be explained by the following rules:

- Operator A subscribers can utilise band A1, A2 and shared part of band C;
- Operator B subscribers can utilise band B1, B2 and shared part of band C;
- Operator A and Operator B usage of the band C is complementary;
- Bands A1, A2, B1, B2 and C are disjoint, but can create continuous spectrum.

Comparing to the previously described sub-scenario #1, the relation between two considered network operators is modified. Both MNOs have invested in additional spectrum band which they decided to share, based on spectrum acquisition cost sharing (e.g. 50/50). For the scenario differentiation, we do not consider any sharing within A# and B# bands.

For the implementation of this sharing scenario, it is required to introduce functionality, which will maintain and control the sharing balance over the band C (i.e. will not allow one user to use more spectrum that initially agreed). Furthermore, the band might be decided not to be shared equally over the whole network or sharing agreement duration, allowing each of the operators, to improve their network capacities in various locations,

being dependant on their network topologies and frequency plans. The sharing mechanism applicability issues (time, spectrum, location) as covered in Section 6 are seen to be equally applicable also in the sub-scenario #2. Therefore, they will not be covered in this section.

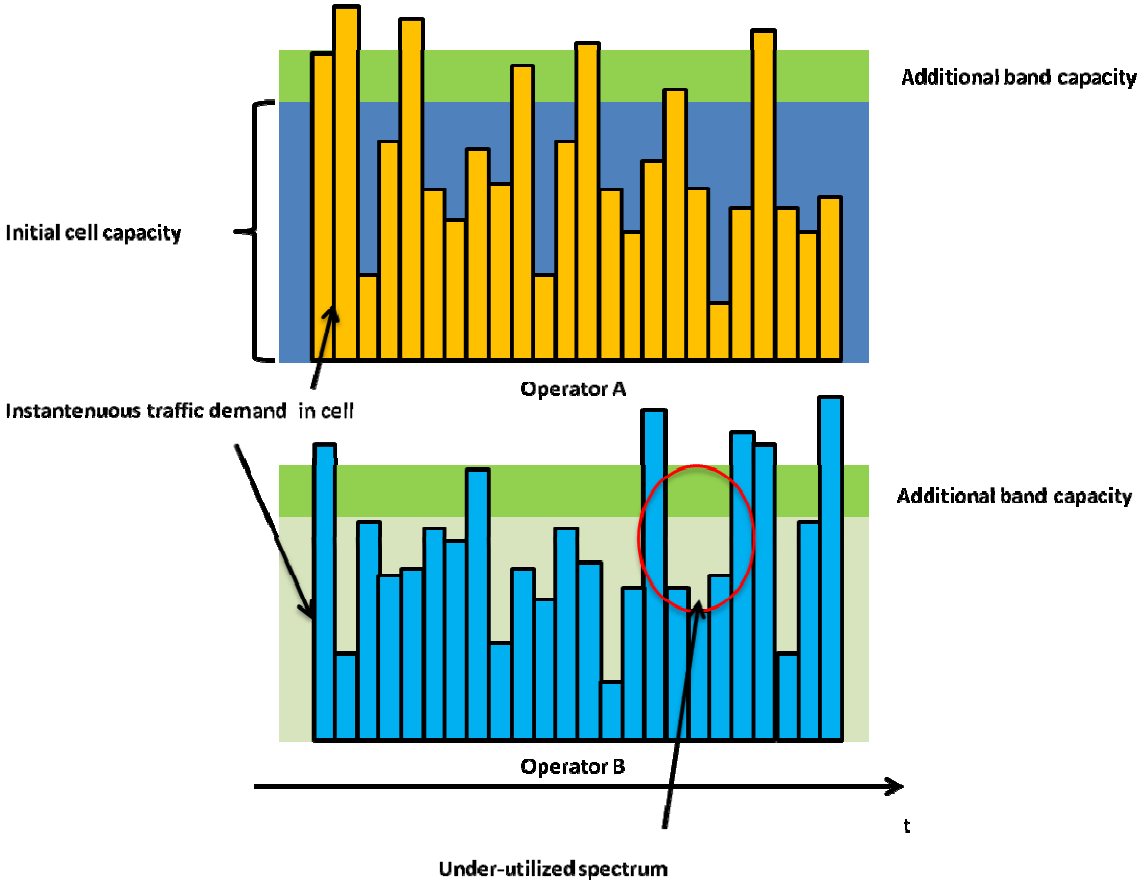

Figure 11: Example of the additional, shared spectrum band capacity in the inter-operator scenario (default capacity share: 50/50); RAT specific TDMA scheme applies

For the implementation of this sub-scenario, functionality for the additional band usage monitoring is required, in order to secure the fairness of the agreed spectrum sharing percentage (i.e. sharing of band C as in Figure 10). For the basic variant of this scenario, kind of *watch-dog* functionality would be only required, keeping the share percentage at certain limit (e.g. 50/50), not allowing any of the participating operators to exceed the capacity share. Based on the recent standardisation activities monitoring, a new Study Item (SI) was recently accepted in the 3GPP TSG SA group, called "RAN sharing enhancements". This SI will be covered be the Technical Report TR22.852 [25]. In the initial phase of this work, it was proposed by the industry partners, to consider studies on the load balancing among share LTE cells, as in the current networks, the load balancing between cells does not take into account the allowed percentage of shared RAN resources per operator. Such functionality would be useful in the described spectrum sharing case.

The above proposed watch-dog functionality is an attractive opportunity to enhance the sharing scenario by the addition of the dynamic adaptation of the additional band sharing percentage. The idea is to, on top of the reference band C share and the related MNO investment in the spectrum resources, to allow extended capacity requests (within band C capacity), with the appropriate payback mechanism to the hosting operator. Proposed mechanism is presented in Figure 12. The inputs for the presented flow are same as for the sub-scenario #1 flow, as described in Figure 8. Moreover, the following parameters are introduced:

- A1, A2: Operator A bands;
- B1, B2: Operator B bands;
- C: shared band;
- β: band C sharing factor; range of [0;1].

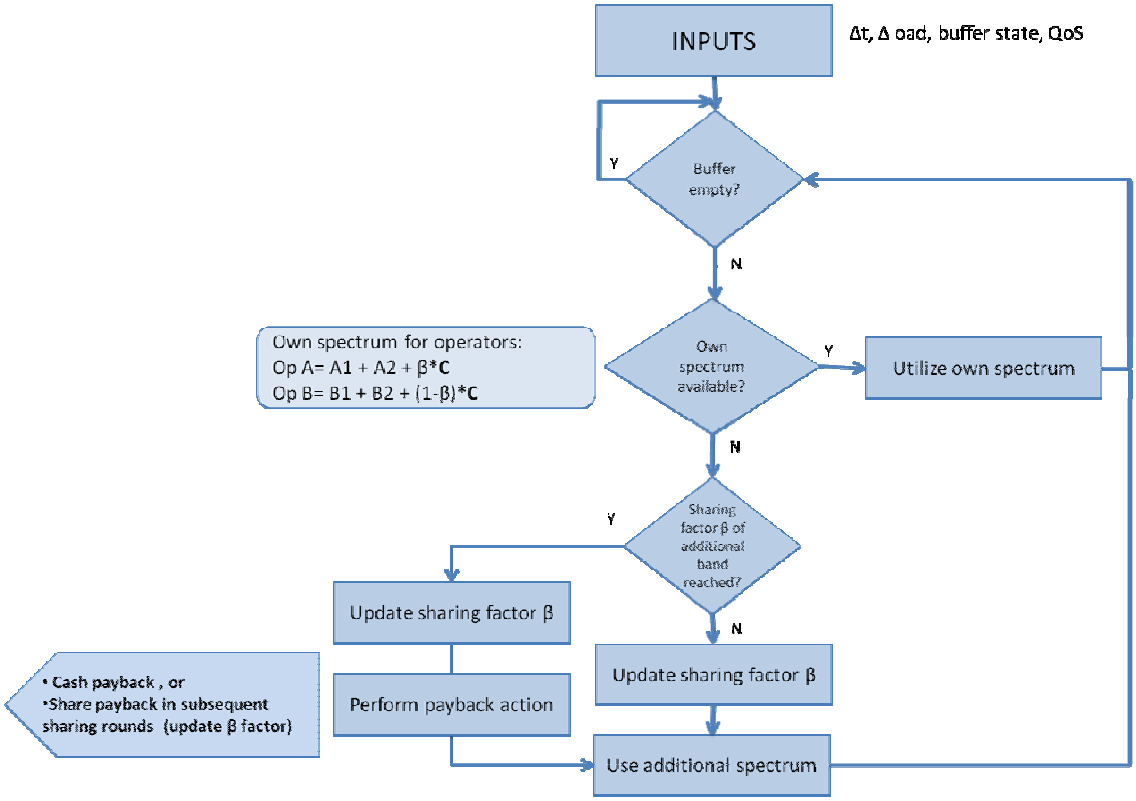

Figure 12: Sub-scenario #2 scheduling flow with dynamic band share and spectrum monetisation

In order to keep the level of implementation complexity relatively low, it is proposed not to affect the spectrum bands already owned by the network operators. Proposed spectrum sharing mechanism would be applicable only within limits of the additional spectrum band, commonly acquired by coalition of MNOs.

Mechanism starts with the default share of the additional band (β factor in Figure 12). Depending on the radio resources demand in each operator's network, the shared band

utilisation might reach limit derived from the β factor, which in case of two operators would be defined as follows:

- Operator A: A1 + A2 + β*C;
- Operator B: B1 + B2 + (1- β)*C.

Referring back to the example case depicted on the [26], the meaning of the proposed mechanism would be allow dynamic and complementary modifications of the additional cell specific capacities (depicted by green bars).

7.2 Reference to the system level simulations

System level simulation campaigns were performed for the SAPHYRE project purposes, simulating various radio resource allocation schemes in various cellular network configurations, for the concepts verification purposes. Highlights from this work were captured in deliverable D4.1 [11], with inputs from SAPHYRE project members involved in system level simulations. Based on the mentioned work, we try to link the spectrum sharing sub-scenario #2 with the simulations results obtained in previous work.

The spectrum sharing sub-scenario #2 was not directly simulated within WP4, as such sharing scheme does not need simulation to prove its benefits in the cell throughput or improved cell edge performance, i.e. additional spectrum band consideration over the reference scenario. Spectrum sharing sub-scenario #2 is based on the consideration of additional spectrum resources, which are shared among investing MNOs – this can be directly mapped to the gains obtained in both considered networks, with the reference to the non-sharing scenarios.

Please note, that the above case does not directly depict the sharing case as in the sub-scenario #2, therefore above referred case shall not be considered as the final qualitative conclusion of the described scenario.

7.3 Business model

In this spectrum sharing configuration, the consideration of additional spectrum resources being purchased by the coalition of network operators creates basis for the value delivery for the current end users, being served by all considered MNOs. This is based on top of the currently running networks, with already established market penetration, not necessarily equal for both considered MNOs. Moreover, it is assumed that the service perception for current subscribers shall not be degraded after implementation of the sharing scheme. The delivery of the mobile services will not be modified due to the implementation of this sharing scheme, as far as we can assume, that the terminal devices will support the shared spectrum band.

Based on the additional, MNO guaranteed spectrum resources, it is expected that operators will have capabilities to offer more capacity demanding mobile services. Furthermore, we have proposed to allow spectrum share modification being applied on the MNO demand basis, in order to allow more flexibility in the radio channels allocations. As usage of the competitor’s resources is considered here, appropriate spectrum valuation or payback scheme mechanism is required in order to motivate

spectrum exchange among all participants. Depending on the preferred option, the donor MNO will receive cash payback, or might be granted with more spectrum share from the spectrum band under the cooperative sharing.

Due to the nature of this kind of cooperation, it is expected that the sharing agreement would be formulated for long-term periods (in range of years).

In order to ease further business models comparison for each of the sub-scenarios, we introduce a high level categorisation of the model, as presented in Table 6 below.

Table 6: Main factors for the MNO business modelling

Business case purpose	Cell capacity improvements based on the long-term spectrum band purchase, with reduced investment costs
Mobile services offer impact	Main purpose is to secure current offer, with possible extensions based on the availability of additional spectrum resources (e.g. high capacity demanding services, not possible at the current stage)
Strategy related to the business case	Introduction of the inter-operator agreement and spectrum investment share
Infrastructure impact	HW capability to cover the new spectrum band is needed (especially the RF chains capabilities have to be checked). Software expected to cover required functionalities
Network operator structure impact	MNO functionality structure to be unchanged, despite of the inter-operator interface for spectrum usage tracking
Goods/services trading	Based on the cooperation strategy, spectrum resources are considered as the goods, which will be shared. Sharing percentage might vary, appropriate inter-operator payback mechanisms are needed
Market related cooperation processes	Cooperation process with other network operator will require certain information exchange. Relations with subscribers to be kept unchanged
Spectrum policies	Due to more flexible spectrum usage consideration, spectrum regulations might limit the cooperation scope – subject to national regulations

7.3.1 Pricing mechanism and cost analysis

In sub-scenario #2, the most evident cost is the investment in the additional spectrum band. The investment will depend on the desired bandwidth share acquisition, which will be the subject for agreement with the other MNO, participating in the shared purchase of spectrum.

The introduction of the additional spectrum resources shall not impact the subscribers. Therefore, there will be no additional charging for the end users – possible charging is only allowed on the inter-operator interface. Such case might happen when one of the considered operators is willing to acquire more capacity from band C (see Figure 13), i.e. more than was considered in the initial investment during the acquisition and inter-operator agreement. In order to stimulate such mechanism, attractive payback for the donor MNO has to be constructed. Namely, in case depicted in Figure 13, Operator A has to receive payback which is more valuable for him, than potential temporal spectrum capacity reduction and potential subsequent degradation of the service delivery quality for his own subscribers. It is expected, that the most

straightforward mechanism shall be based on the RAT specific granularity of the resources. In case of E-UTRA, time-frequency granularity would apply (e.g. 2 RB per 10 TTI). Moreover, such trading mechanism shall be self-organised and triggered based on the local scheduling entity in the Base Station. For that purpose, predefined charging database or calculation formula would be required to be implemented. After expiration of the resources trading time period, the default band C share would be applied (case I, in Figure 13).

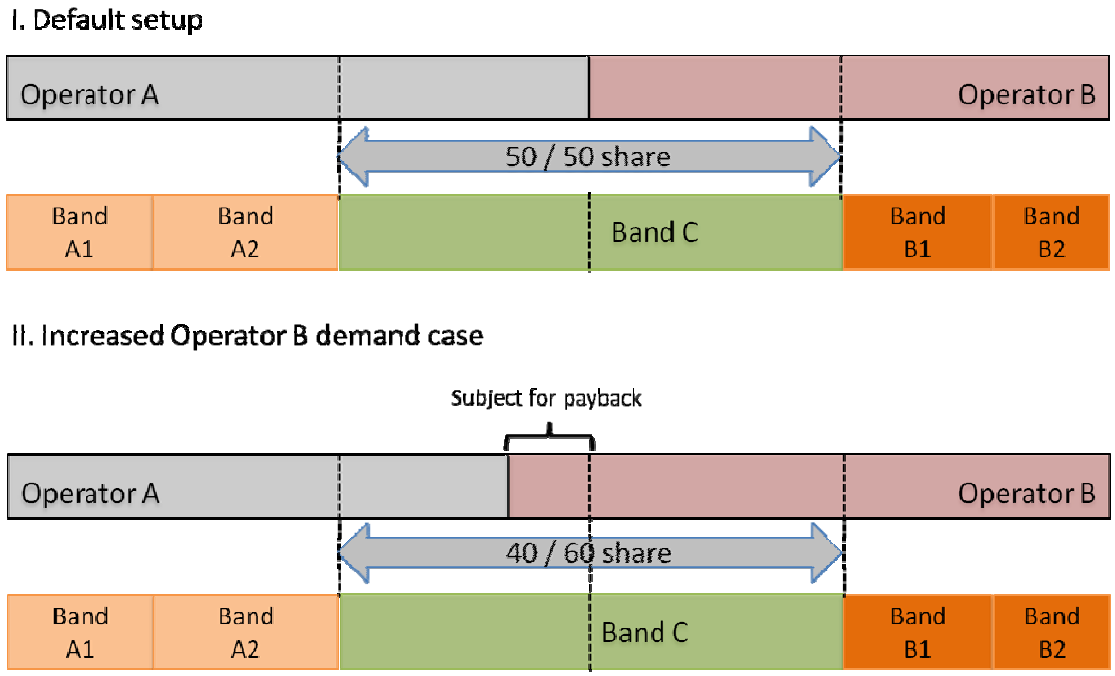

Figure 13: Explanation of the demand driven spectrum sharing among cooperating operators

7.3.2 Definition of the modified map of the market

eTOM based market and role analysis is covered for all four sub-scenarios in Section 10.1.

7.3.3 SWOT analysis

In Table 7 we present the SWOT analysis, based on the theoretical introduction to the four analysis fields as presented in Section 3.2.

7.3.4 Business model canvas

Based on the business model canvas approach [7] and its description in Section 3.3, in Table 8 we present the analysis for spectrum sharing sub-scenario #2, from the MNO point of view, who is considering the implementation of the proposed sharing scheme.

Table 7: SWOT analysis for collaborative spectrum sharing in additional spectrum band

STRENGTHS • Relaxed requirements for capacity limited cells – more spectrum available • Improved subscribers experience due to higher availability of the spectrum • Due to larger amount of channels, more flexible resources assignment and scheduling • Reduced risk of the capacity limitation • Utilisation of the current employees experience • Possibility to employ this scheme with the current frequency plan • Seamless adaptation to the current offer • Guaranteed spectrum resources availability, up to the contracted percentage among operators • Operators cooperative dynamic spectrum allocation might generate new services and applications • Allows provision of additional QoS based services	**WEAKNESSES** • Depending on the spectrum band regulations, RAT specific limitations might apply, limiting the interest from operators • Scenario might require case specific set-ups, due to operator specific frequency planning • Increased complexity in the scheduling process – need for the spectrum band division coordination • Higher signalling overhead required • Possible concern for MNO to enter the cooperative action with the competition
OPPORTUNITIES • Possibility to reach higher peak data rates per cell • Potential extension for multi-operator cooperation scheme (cheaper spectrum acquisition) • MNO coalition formation might be seen as attractive tool against operator not participating in such cooperative spectrum sharing for the network cost limitation (subject to regulatory monitoring)	**THREATS** • Might require third entity, in order to control the spectrum usage percentage • Operators might not be interested, as they have sufficiently high amount of spectrum which is under-utilised • Potential regulatory limitations of such sharing coalition formation due to monopoly risk

Table 8: Business model canvas analysis for sub-scenario #2

<table>
<tr>
<td rowspan="2">KEY PARTNERS
Strategic partnership between MNOs as business case enablers: cooperation motivated by the additional, guaranteed radio resources acquisition, while MNOs are competing entities
Telecom equipment vendors for possible extensions in the BS (e.g. RF front ends) – buyer–supplier relation
SW developers (internal resources or outsourcing) for implementation of the mechanism for “spectrum leasing” on top of the sharing agreement</td>
<td>KEY ACTIVITIES
Identification of the potential MNOs interested in shared band purchase
Creation of the inter-MNO alliance, with the band share reflecting the investment
Formulation of potential inter-operator charging mechanism and pricing
Identification of possible network infrastructure issues with regard to planned spectrum sharing</td>
<td rowspan="2">VALUE PROPOSITION
Improved, guaranteed service availability for subscribers
Improved, guaranteed network coverage for subscribers
Reduced risk of “no-coverage” situation
Risk reduction for “always online” subscribers
Overall subscriber experience enhancement (applicable for all MNOs participating in sharing)
Ability to address high-end subscribers expectations of improved service availability
In case of extended spectrum granting to other operators, potential offer of additional spectrum resources</td>
<td>CUSTOMER RELATIONSHIP
Focus on additional customers acquisition (extra network capacity available)
Customer relationships to focus on the automation
Possibility to create new target market for high-end service delivery</td>
<td rowspan="2">CUSTOMER SEGMENT
Current customers segmentation to be extended by additional capacity from the acquired band
Furthermore, possibility to obtain extra capacity on the demand basis, allowing to focus on high-end group of users expecting improved service availability
Potential current segmentation extension in case of new services offer, based on additional spectrum
In case of extended spectrum granting to other operators, they also became a separate group of customers</td>
</tr>
<tr>
<td>KEY RESOURCES
Running networks
Current delivery chains
Experienced employees
Spectrum resources (own + shared)
Inter-operator partnership</td>
<td>DISTRIBUTION CHANNELS
Mobile service distribution channels to be unchanged
In case of extension of the offer, same channels can be utilised</td>
</tr>
<tr>
<td colspan="3">COST STRUCTURE
Investment in the additional spectrum band, together with another MNO
Business case mainly being value-driven, with cost awareness
Network OPEX costs expected at current level (many elements at fixed cost)
Case specific HW/SW investments might apply for functionality implementation (depending on the spectrum band under consideration)
Potentially, inter-operator charges based on the additional spectrum usage (based on the internal agreement between operators) – variable cost
In case of extension of the service offer: advertising cost</td>
<td colspan="3">REVENUE STREAMS
Regular revenue from the subscriptions fees, being customer segment dependant – mostly fixed prices
Expected increase of the above subscription fees, based on the focus on the new customers acquisition – volume dependant
High-end subscribers expected to be willing to pay more for improved service delivery – must be guaranteed by certain performance measures
Potential, variable revenues generated by the shared spectrum from other MNOs, as the usage fee for “spectrum leasing”. Pricing might be real-time based, depending on the supply and demand</td>
</tr>
</table>

7.4 Description of scenario players and roles

7.4.1 Standardisation

From the 3GPP point of view, Network Sharing was already considered in the previous work, allowing more than one PLMN to be connected to one RAN. Anyway, there was no possibility to control and to balance in the controlled way the capacity of the radio network, or in particular, spectrum band.

A new Study Item was recently accepted in the 3GPP TSG SA group, called "RAN sharing enhancements". This SI will be covered be the Technical Report TR22.852 [25]. In the initial phase of this work, it was proposed by the industry partners, to consider studies on the load balancing among share LTE cells, as in the current networks, the load balancing between cells does not take into account the allowed percentage of shared RAN resources per operator. In pre-Rel-12 load balancing between cells does not take into account the allowed percentage of shared RAN resources per PLMN of each Hosting Operator. Thus the number of UEs from each Hosting Operator that move from the more congested cell towards the less congested cell will be roughly proportional the total number of UEs from the PLMN of each Hosting Operator in that cell. This could result in a situation where one Hosting Operator exceeds its share of RAN resources in a cell. As the work on this study item has been recently started, it is not possible to predict the final outcome and industry's decision.

7.4.2 National regulator

Regulatory policy has to allow spectrum band purchase by consortium of network operators, which are planning to share these resources based on internal agreement. Similar to the previous sub-scenario #1, the national regulations have to allow spectrum sharing as well as trading, as described in the mechanism above.

In this sub-scenario, the national regulator plays much more crucial role than in the previously described case. This is due to the reason, that the regulator is able to prioritise the sharing agreements in the long-term spectrum auctions for the additional bands. This might play important role in the future market shaping, towards more flexible spectrum usage regulations.

7.4.3 Telecom equipment vendors

Similar to the sub-scenario #1, the HW vendor role in this case depends on the possible implementation issues, as well as on the considered RATs.

It is envisioned, that the implementation of the described case might be doable by software upgrade. In case of unfitted RF frontends capabilities in base stations, there might be also need for some HW upgrades.

The optimal solution selection might strongly depend on the expected anti-trust functionalities requirements, which might be required in certain MNO coalitions.

For terminal devices, there are no additional requirements for the scenario implementation other than the support of spectrum bands, which are the subject of the considered scenario.

7.4.4 Network operators

Similar to the sub-scenario #1, in this spectrum sharing case, both MNOs are operating and manage their own networks. The modification to the previous scenario is in the spectrum resources considered for mobile services delivery, which comprise form two parts:

- Exclusively owned spectrum resources (e.g. bands A1 and A2 for Operator A, as in Figure 10), and
- Additional spectrum resources being shared among cooperating MNOs. Sharing balance reflects the initial investments percentage of each of the operators. Nevertheless, additional band usage share might be dynamically tuned, based on the spectrum demand from each of MNOs, where appropriate payback the other sharing partners is considered. These spectrum resources are assumed to be jointly managed by the cooperating, which might require certain type of the mediating unit between the operators.

In this sub-scenario the goal for MNO is to improve the availability of the spectrum resources, with reduced investment cost. The prerequisite is the identification of the interested coalition of the MNOs.

7.4.5 End user

The subscriber role is expected to be the same as covered for the sub-scenario #1, in Section 6.4.5.

8 Inter-operator spectrum sharing with spectrum broker

8.1 Scenario description

In this section, we analyse third of the proposed variants of the spectrum sharing scenario, which is the inter-operator spectrum sharing with spectrum broker. This sub-scenario involves at least one network operator being involved in the cooperation with the new market entity, which is the spectrum broker.

Spectrum broker is distributing spectrum resources grants from the owned spectrum bands using appropriate trading and charging mechanism for the spectrum usage. This may be realised by a trading mechanism building on the principle of auctioning transmission capacity or spectrum on a short time-basis. The role of the broker is to act as mediator between the market players interested in the on-demand radio resources acquisition, namely buyers who are the network operators. This scenario assumes, that the spectrum sharing is done in the real-time and the spectrum grants are assigned to the operators by the spectrum trading entity, which is selling the spectrum chunks in the location specific, time and demand based manner.

Referring to the previously described sub-scenarios, in this case we do consider that each MNO can have also its own spectrum resources and the spectrum broker granted resources are obtained on the demand basis.

What has to be clarified, is that for this case implementation, only one network operators is sufficient, in contrary to the previous sub-scenarios, where at least two MNOs are required for the cooperating coalition formation (two MNOs depicted in Figure 14 are kept for reference only).

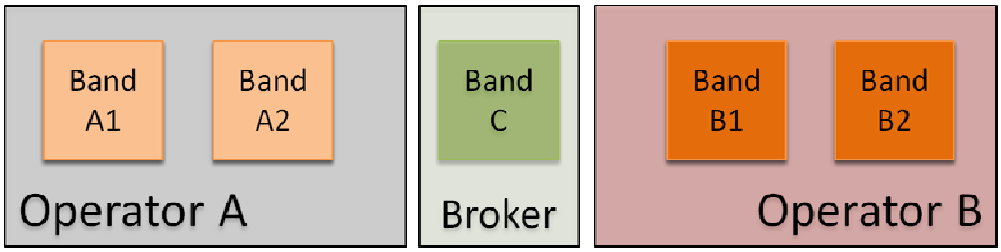

Figure 14: Spectrum sharing sub-scenario #3: Inter-operator spectrum sharing with spectrum broker

In the presented scenario, Operator A is licensed to use frequency bands A1 and A2, while the Operator B owns license to serve his subscribers on bands B1 and B2. The spectrum sharing mechanism can be explained by the following example:

- Operator A subscribers can utilise band A1, A2 and shared part of band C;
- Operator B subscribers can utilise band B1, B2 and shared part of band C;
- Operator A and Operator B usage of the band C is dynamic, complementary and not guaranteed;
- Bands A1, A2, B1, B2 and C are disjoint, but can create continuous spectrum.

The proposed scenario configuration means, that new entity on the market would appear, i.e. the spectrum broker, who aims to generate maximum revenue from the spectrum band under his management. Therefore, the radio access is granted to the highest bidding operator.

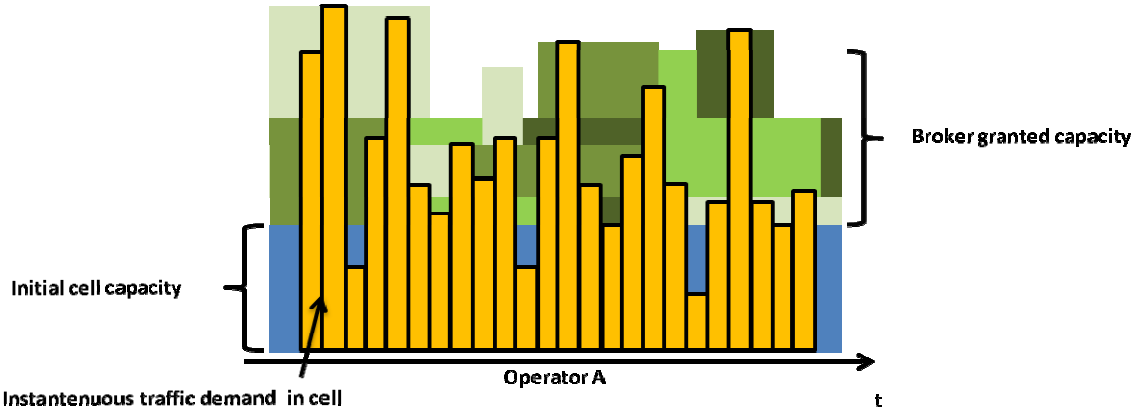

Figure 15: Example of the broker granted spectrum resources. Variable capacity and duration of grants depicted; RAT specific TDMA scheme applies

Considering the introduction of the spectrum broker as new market entity, the question has to be asked, whether this functionality shall be implemented as central or distributed solution. As the RAT specific aspects might apply, observe that for example in case of the E-UTRAN network, it would be beneficial to utilise its flat network architecture and not to introduce any centralised functionality. Moreover, it is seen, that due to uneven traffic demands in the network, it would be much more beneficial to allow the network operator to utilise such functionality in the location specific approach. Therefore, the suggestion would be to allow distributed and dynamic enabling of such kind of spectrum sharing, similar to the approach presented in Figure 9, where location specific application of the mechanism is depicted.

8.2 Reference to the system level simulations

System level simulation campaigns were performed for the SAPHYRE project purposes, simulating various radio resource allocation schemes in different cellular network configurations, for concepts verification purposes. Highlights from this work were captured in deliverable D4.1 [11], with inputs from SAPHYRE project members involved in system level simulations. Based on the mentioned work, we try to link the spectrum sharing sub-scenario #3 with the simulation results obtained in previous work.

The broker based scenarios were simulated in the HSPA scenario with two MNOs considered. As the consideration of additional, broker owned spectrum resources is not too interesting from the system level simulations point of view (gains are easily predictable), the simulated case assumed that two network operators would compete for the pool of shared radio channels. The radio resources assignment rule was based on the VCG auction [13], where network operators were indicating by the bids to the spectrum broker, how much do they need additional spectrum resources. This scheme was considering that one MNO can benefit from the sharing on expense of the other MNO –

this relation depends on the spectrum resources amount declared to be shared in the pool, as well as on the traffic parent set-ups among MNOs. The sharing gain results were function of the amount of shared spectrum. In the highest spectrum configuration considered (i.e. 4C-HSDPA in both network implemented, with 75% spectrum sharing) the gains observed for total cell throughput (i.e. served traffic in both networks) were reaching 27%, for the 5%-tile of the cell throughput CDF. It has to be highlighted, that the traffic pattern generation played here crucial role. For more details please refer to[13].

Please note, that the above case does not directly depict the sharing case as in the sub-scenario #3, therefore above referred case shall not be considered as the final qualitative conclusion of the described scenario.

8.3 Business model

Appearance of the spectrum broker on the market might be very difficult, if his goal would be to acquire spectrum band from the national regulator and try to sell radio resources on demand. Due to the fact, that the appearance of new market entrant being interested in acquisition of the spectrum bands which are scarce resources, might not be welcomed by current market players (especially competing MNOs), it is seen that the spectrum broker functionality might require special attention from the spectrum policy point of view.

In order to stimulate market migration towards this model, question shall be asked, who might become the spectrum broker. Much more realistic would be the situation, where spectrum broker functionality is based on the spectrum resources which are already "on-the-air" and do not require extra investments and fighting to acquire the spectrum – that would ease appearance of the broker functionality. Such observation might lead to some of the following conclusions:

- Spectrum broker needs business connection/dependency with (at least one) network operator. That would address the concerns related to the vertical market of mobile services, where the MNO is providing full service, from the radio and infrastructure ownership to the mobile services delivery itself,
- Moreover, it would be an interesting extension to the discussion, to consider any of the classical MNOs as the spectrum broker functionality owner. That would trigger further market evolution of competing spectrum brokers, potentially leading to the situation, where radio access providers are competing in the near to real-time manner, to serve subscribers for the revenue generation,
- Spectrum broker needs to be managed by the national regulator, who grants him spectrum band with the aim of optimal spectrum resources utilisation and social welfare maximisation of the scheduling process,
- Spectrum broker needs to offer more than just pure spectrum resources, e.g. network infrastructure that is using the considered bands, being able to offer the wholesale radio access to the mobile content providers. Such business model was already attempted by the Lightsquared, who will operate wholesale-only

business model, offering the LTE radio access, making it the sole wireless provider of its kind in the U.S. market [27].

Despite of the identified threats and ideas of the initial broker based scheme, we continue the scenario analysis, with the assumption, that the spectrum broker has already access to the licensed spectrum band and is an independent entity on the market.

It is seen, that implementation of the broker functionality can be location and time specific, being limited by the nature of the radio environment. Appearance of the spectrum broker functionality might be seen as attractive form of the cell capacity boosting in case of special events or hot spot areas. That might be another alternative for the free of change Wi-Fi access, not being controlled by the MNOs.

In order to ease further business models comparison for each of the sub-scenarios, we introduce a high level categorisation of the model, as presented in Table 9 below.

Table 9: Main factors for the MNO business modelling

Business case purpose	Cell capacity improvements on demand basis without expensive long-term spectrum acquisition and without creation of coalition with the competitive entities.
Mobile services offer impact	Aim to enhance the service availability in case of high network congestion and capacity limitations. Possibility to create new services on the broker acquired spectrum resources.
Strategy related to the business case	Enabling of the safety exit for the high traffic demand locations, in case of no possibility to improve currently owned spectrum utilisation. Business relation formation with the spectrum broker, against the competitive MNOs.
Infrastructure impact	No direct impact on HW, but RAT specific issues might arise. Software seen to cover required functionalities. Standardisation actions required.
Network operator structure impact	Additional interface towards the spectrum broker will be required, with appropriate process of payments for the spectrum usage.
Goods/services trading	The goods, which are the spectrum bands, for the services delivery in case of capacity limitations, can be granted for short-term periods from the broker entity.
Market related cooperation processes	Cooperation process with spectrum broker will require certain information exchange (e.g. spectrum grant size). Relations with subscribers to be kept unchanged.
Spectrum policies	Spectrum policies as well as the national market regulations might play mayor role in this scenario, as novel policy for the flexible spectrum usage is considered, as well as new market entity for the spectrum distribution.

8.3.1 Pricing mechanism and cost analysis

In this scenario, the network operator investment for acquisition of the spectrum resources for mobile services delivery would be limited to the charge for the short-time, location and spectrum band specific frequency grant allocations from the broker. Furthermore, the indirect cost of the functionality implementation has to be considered.

Network operators might also own other spectrum bands for exclusive usage, as in previous sub-scenarios.

The spectrum broker offer will have to consider the RAT specific radio channels structure. Furthermore, the customers, which are in this case network operators or service providers, would be able to declare their requirements for the spectrum resources (further translated into the radio channels, transport channels etc.).

It is expected that broker based scenario would attract mostly the market players with limited spectrum availability, or new market entrants, who cannot afford participation in the long-term spectrum auctions. That would have the following consequences:

- Enhanced mobile services offer;
- Increased competition on the market. Furthermore, it is expected, that the competition on the marker of the spectrum brokers would increase with time, as multiple broker entities would be possible.
- Higher interest in the radio resources access via broker entity.
- This might be motivating for the players, to become the first broker on the market.

8.3.2 Definition of the modified map of the market

eTOM based market and role analysis is covered for all four sub-scenarios in Section 10.1.

8.3.3 SWOT analysis

In Table 10 we present the SWOT analysis, based on the theoretical introduction to the four analysis fields as presented in Section 3.2.

8.3.4 Business model canvas

Based on the business model canvas approach [7] and its description in Section 3.3, in Table 11 we present the analysis for spectrum sharing sub-scenario #4, from the MNO point of view, who is considering the implementation of the proposed sharing scheme.

Table 10: SWOT analysis for inter-operator spectrum sharing with spectrum broker

STRENGTHS	**WEAKNESSES**
• Relaxed requirements for capacity limited cells, due to potential of higher spectrum availability, acquired on-demand • No need for extra spectrum long-term license – possibility to on demand spectrum grants from broker • Improved spectrum utilisation and efficiency • Due to larger amount of available radio channels, more flexible resources assignment and scheduling • Utilisation of the current employees experience • Possibility to employ this scheme in the current frequency plan • Operator's own subscribers service shall not be impacted • Seamless adaptation to the current services offer • Spectrum broker might be seen as the mediator in the inter-operator cooperation establishment • Allows provision of extra, QoS services • Broker based dynamic spectrum allocation might generate new services and applications • Possibility to reach higher peak data rates in cell	• Additional spectrum resources will generate more network operation costs – broker fees • Depending on the spectrum band regulations, RAT specific limitations might apply • Possible gains will be visible only in case of capacity limitation • Scenario might require case specific set-ups, due to operator specific frequency planning • Additional spectrum from broker might still not be sufficient for QoS demanding services • Increased complexity in the scheduling process • Higher signalling overhead might be required in order to signal additional spectrum availability • Appropriate coordination mechanism might be required • Possible concern for MNO to enter the cooperative action with the competition • Broker offered spectrum availability might be time/location dependant and subject to limitations
OPPORTUNITIES	**THREATS**
• In the long-term, might enable much more cooperation on the market, between competitors, once initial gains being identified • Competition might motivate network operators to cooperate with the spectrum broker • Opening new approach to the spectrum, being considered as good which can be dynamically traded • Scenario might be very attractive for new market entrants, not owning (sufficient) spectrum resources • MNO cooperation with the broker might be seen as attractive tool against operator not participating in such cooperative spectrum sharing (subject to regulatory monitoring)	• Spectrum broker might be considered as competitor on the mobile services market • Other competing network operators might also start implementing similar mechanisms, reducing novelty and competitiveness of our offer • Potential regulatory limitations of such sharing coalition formation due to monopoly risk

Table 11: Business model canvas analysis for sub-scenario #3

<table>
<tr>
<td rowspan="2">KEY PARTNERS
• Strategic cooperation with spectrum broker
• Cooperation motivated by the additional, guaranteed radio resources acquisition
• Telecom equipment vendors for possible extensions in the BS (e.g. RF front ends) – buyer–supplier relation
• SW developers (internal resources or outsourcing) for implementation of the short-term spectrum sharing mechanism</td>
<td>KEY ACTIVITIES
• Creation of the business link with the spectrum broker
• Negotiations of most beneficial pricing scheme with the spectrum broker
• Identification of possible network infrastructure and UE issues with regard to planned spectrum usage extensions
• Market research for possible new services offer, being enabled by the broker cooperation</td>
<td rowspan="2">VALUE PROPOSITION
Current customers segmentation:
• Improved, guaranteed service availability for subscribers
• Improved, guaranteed network coverage for subscribers
• Reduced risk of “no-coverage” situation
• Risk reduction for “always online” subscribers
“Smartphone” users:
• Ability to improve guaranteed data-rates
High-end users:
• Ability to improve QoE by higher flexibility in resources scheduling
• Possible extension by dedicated branding for high-end users
Low-end users:
• Ability to offer low-cost rate plans, based on non-guaranteed quality</td>
<td>CUSTOMER RELATIONSHIP
• Focus on acquisition of additional customers (network capacity on-demand)
• Ability for the current users retention by availability of additional value of the offer
• Customer relationships to focus on the automation
• Possibility to create new target markets, enabled by higher flexibility in the spectrum usage</td>
<td rowspan="2">CUSTOMER SEGMENT
Current customers segmentation to be extended by additional capacity from the acquired spectrum, e.g.:
a. current segmentation (legacy users) – mass market
b. users relying only on broker spectrum – segmented market:
• additional rate plan, e.g. smartphones oriented due to high data traffic demand
• opportunistic access, low-end service users
c. high-end users, demanding highest service continuity and quality (own + broker spectrum utilised) – niche market</td>
</tr>
<tr>
<td>KEY RESOURCES
• Running networks
• Current delivery chains
• Experienced employees
• Spectrum resources (own + acquired on demand basis)
• Spectrum broker business link</td>
<td>DISTRIBUTION CHANNELS
• Mobile service distribution channels to be unchanged
• In case of extension of the offer, same channels can be utilised</td>
</tr>
<tr>
<td colspan="3">COST STRUCTURE
• Investment in the additional spectrum band, requested on demand basis – cost might be expected to be variable (supply and demand based) – brokerage fee can be auctioning based
• Business case mainly being value-driven; in case of low-end subscribers group – cost-driven
• Network OPEX costs expected at current level (many elements being the fixed cost)
• Case specific HW/SW investments might apply for functionality implementation
• Advertisement costs of new services, enabled by the on-demand spectrum acquisition by MNO</td>
<td colspan="3">REVENUE STREAMS
• Regular revenue from the subscriptions fees, being customer segment dependant – mostly fixed prices
• Expected increase of the above subscription fees, based on the ability to acquire additional capacity on demand basis: new customers acquisition – volume dependant revenue
• High-end subscribers expected to be willing to pay more for improved service delivery – must be guaranteed by certain performance measures; subscription rate might be dependant of the real cost of the service provision (i.e. due to flexible brokerage fees)</td>
</tr>
</table>

8.4 Description of scenario players and roles

8.4.1 Standardisation

The main expectation from the standardisation bodies would be to create broadly supported spectrum broker standard, being available for possibly highest percentage of the subscriber's locations, networks and radio technologies (3GPP specifications are RAT specific). Such trading mechanism would require dynamic distribution of spectrum access rights, for which technical mechanisms might not be available soon. Appropriate signalling mechanism would be needed, for the spectrum grant requirement indication, acknowledgement procedures, possible retransmissions, charging, etc.

Introduction of the new entity into the mobile services delivery chain is expected to bring attention and generate a lot of interest in the industry, especially from the IPR point of view. This is expected to happen despite of the possible standard creation for the broker entity and its functionalities.

The other side of the story is that it is not about technology in the standards creation, but it is all about supporting the business. That is why, main leading force in pushing the standards forward are the network operators, who are demanding constant development from the hardware vendors. Another showstopper for possible spectrum broker standardisation is the current stage of development in the standards bodies, and their roadmap.

8.4.2 National regulator

It is seen, that similar to the MNOs, spectrum broker appearance on the market might be controlled and regulated by the national regulator. Moreover, the spectrum re-sale mechanism might not be allowed by the spectrum policies in some cases, being considered as the monopoly risk increase. One can imagine, that the large MNO, suffering from the lack of spectrum resources, is constantly cooperating with the spectrum broker(s) and acquiring large part of the radio resources from this pool. Moreover, the regulatory bodies might treat this as the anti-competitive action (i.e. intentional spectrum blocking, being forced even in case of the spectrum charging application).

8.4.3 Telecom equipment vendors

Referring to the discussion in Section 8.4.1, it is expected that the hardware vendors will participate in the (possible) standardisation process. Depending on their focus and products, also the IPRs are expected to attract the research department within those companies.

8.4.4 Mobile network operators

Similar to the sub-scenario #1, in this spectrum sharing case, MNOs operate and manage their own networks. In this scenario, MNO might consider the following spectrum resources for the mobile services delivery:

- Exclusively owned spectrum resources (e.g. bands A1 and A2 for Operator A, as in Figure 14);
- Additional spectrum resources being acquired from the spectrum broker.

In this sub-scenario the goal for MNO is to improve the availability of the spectrum resources, with reduced investment cost. The prerequisite is the availability of the spectrum broker on the market, or at least in certain deployment scenario.

8.4.5 MVNO

MVNO existence on the market depends on the MNO business interest and his capabilities to host virtual operator within own infrastructure. This kind of the business relation generates additional revenue for MNO, but at the same time, increases competition on the market (assuming that both parties are targeting at the same customer segments).

From the MVNO point of view, the spectrum brokerage of the spectrum resources creates an opportunity of acquiring the spectrum resources for the mobile services delivery, which are not generating huge investments requirements. On the other hand, the availability of those radio resources cannot be guaranteed, what makes the scenario less attractive. Furthermore, even in case of the radio resource availability for virtual operator, there is still need for the MVNO to have access to the RAT and the network infrastructure. Therefore, such spectrum broker scenario might not be sufficiently attractive from the virtual operator point of view. This scenario would be much more attractive in case, where spectrum, as well as the RAT access could be granted at the same time.

8.4.6 Spectrum broker

As the spectrum sharing scenario is expected to involve multiple competing market players, we might face situation, that there will be lack of trust or good will for the current spectrum owners to participate in any form of coalitions for the spectrum sharing. In such case, third party negotiator, or mediator entity might be the enabler for the flexible spectrum marker. We call such entity as the spectrum broker.

Furthermore, it is expected, that the competition on the market of the spectrum brokers would increase with time, as multiple broker entities would be possible. Similar to the MNOs, their appearance on the market might be controlled and regulated by the national regulator.

It has to be considered, that the spectrum broker might also serve the new market entrants, who are willing to utilise MNO's infrastructure and pay-per-use for the broker's spectrum.

8.4.7 End user

The subscriber's role is expected to be the same as covered for the sub-scenario #1, in Section 6.4.5.

9 Spectrum spot market

9.1 Scenario description

In this section, we analyse fourth of the proposed variants of the spectrum sharing scenario, which is the spectrum spot market management. By the spectrum spot market scenario we consider a market set-up, where certain amount of radio resources, e.g. certain standardised frequency band(s), are:

- Not exclusively allocated by the regulatory body to MNOs for long term periods (like in case of the current market set-up) but instead, can be obtained and shared between spectrum users directly from the national regulatory body on the demand basis, where the charging is based on the spectrum chunks usage. Therefore, the spot market manager, on behalf of the national regulator, distributes the spectrum bands, or
- Legacy MNOs own resources are assigned back to the spot manager for certain duration, allowing better spectrum utilisation of the MNO owned spectrum. Motivation for MNO would be additional revenue from such spectrum leasing.

The regulatory body is considered here as the spectrum owner, who is allowing spectrum users to obtain radio resources for relatively short periods of time, which are in the order of particular mobile service duration, where multiple various services might be assigned to the subscriber in parallel. The spectrum users are granted the spectrum from the spot market manager under certain conditions, which might be derived from the incentive maximisation, as well as from the market fairness principles, depending on the current market situation. It has to be noted, that the considered network operators might also own spectrum resources, obtained previously according to the current market regulations and still participate in the spot market.

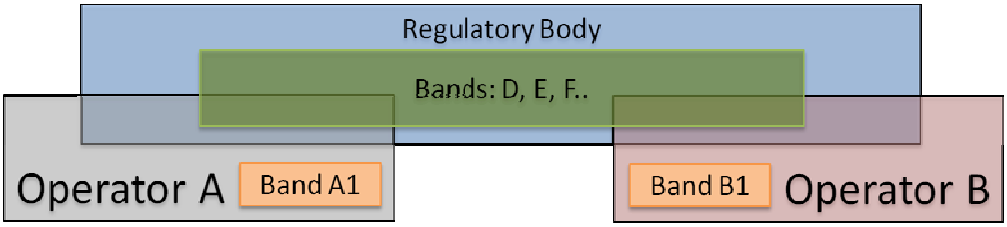

Figure 16: Spectrum sharing sub-scenario #4: Spectrum spot market

Spot market manager can be considered as the central unit for spectrum resources distribution among interested parties across the mobile services market. Moreover, it is observed, that the enabling of the MNOs to resell or lease the under-utilised spectrum resources back to the spot market manager might even further enhance the scenario flexibility. In such case, the MNO would receive corresponding revenue from the spot market manager. In consequence the operator would be allowed to exchange the radio channels on the spot market, e.g. lease radio channel from one band, at the same time borrowing spectrum resources from another frequency band/bands.

For sure, such flexibility would generate relatively high complexity in the scheduling and signalling domains, but we silently assume that those aspects will not be considered as showstoppers for the proposed spectrum management model, in order to allow business aspects analysis of the scheme.

The following spectrum resource categories might be identified, from the spot market manager point of view:

- Spectrum bands, which are not yet declared for long-term auctions. This category might be potentially extended by TV white spaces spectrum.
- MNO owned spectrum leased to the spot market manager, i.e. temporal spectrum availability declaration of particular radio resources (e.g. based on the 3GPP RAT specific radio channels grid). In order to ease this kind of spectrum trading case, it might be worth to consider spectrum + RAN access leasing, meaning that the MNO would offer its network capacity.

From the MNO point of view, the following spectrum resource categories are considered in this scenario:

- MNO owned spectrum bands;
- Spot market granted radio resources, being assigned to the spectrum user, on the request basis. Spectrum user would be the network operator, who is claiming spectrum resources requirements, based on predefined performance measures, e.g. cell buffer state, traffic demand patterns. Spectrum grants would be assigned directly and automatically without human intervention, by the regulatory virtual entity. The granularity of the assignment will be defined based on the based on the Radio Access Technology specific resource allocation units.

In the presented scenario, Operator A is licensed to use frequency band A1, while the Operator B owns license to serve his subscribers on band B1. The spectrum sharing mechanism can be explained by the following example:

- Operator A subscribers can utilise band A1 and granted resources from bands D, E, F;
- Operator B subscribers can utilise band B1 and granted resources from bands D, E, F;
- Operator A and Operator B usage of bands D, E, F is dynamic and their availability might be limited;
- Bands A1, B1, and D, E, F are disjoint, but can create continuous spectrum.

The advantage of such market set-up over the previously described spectrum broker based regulations is expected to lead to an optimal social welfare and spectrum utilisation.

Moreover, such kind of spectrum market would be an interesting opportunity for new market entrants, like MVNO, as well as mobile service and content providers, who do not own sufficiently large amount of the spectrum or radio access capacity.

9.2 Reference to the system level simulations

System level simulation campaigns were performed for the SAPHYRE project purposes, simulating various radio resource allocation schemes in various cellular network configurations, for the concepts verification purposes. Highlights from this work were captured in deliverable D4.1 [11], with inputs from SAPHYRE project members involved in system level simulations. Based on the mentioned work, we try to link the spectrum sharing sub-scenario #4 with the simulations results obtained in previous work.

The spot manager scenario was not directly simulated within WP4. Nevertheless, the channel trading mechanism was analysed in [11], where two E-UTRAN network operators were cooperating by exchanging the radio channels. In this cooperation mechanism, MNOs were not able to increase the availability of the spectrum resources for their exclusive usage. This channel exchange was rather exploiting the instantaneous frequency diversity gain. Sharing gains expressed in the total sum rate capacity, were reaching even 50% for the corner case, and were function of the shared spectrum percentage and network load.

Please note, that the above case does not directly depict the sharing case as in the sub-scenario #4, therefore above referred case shall not be considered as the final qualitative conclusion of the described scenario.

9.3 Business model

In order to ease further business models comparison for each of the sub-scenarios, we introduce a high level categorisation of the model, as presented in Table 12 below.

9.3.1 Pricing mechanism and cost analysis

It is required to construct the valuation mechanism, which will provide fair and consistent rules for all spot market participants.

In this scenario, the network operator investment for acquisition of the spectrum resources for mobile services delivery would be limited to the charge for the short-time, location and spectrum band specific frequency grant allocations. Furthermore, the indirect cost of the functionality implementation has to be considered.

On the other hand, network operators are allowed in this scenario to lease their own spectrum resources back to the spot manager, in order to acquire additional revenue from the spectrum usage, based on the requests coming to the spot manager.

Network operators might also own other spectrum bands for exclusive usage, as in previous sub-scenarios.

9.3.2 Definition of the modified map of the market

eTOM based market and role analysis is covered for all four sub-scenarios in Section 10.1.

Table 12: Main factors for the MNO business modelling

Business case purpose	Cell capacity improvements on the demand basis, without expensive long-term spectrum acquisition and without creation of coalition with the competitive entities. Additional revenue flow generation from the owned spectrum.
Mobile services offer impact	Offer not to be degraded, with additional opportunity for service availability extensions, as well as their capabilities. Additional revenue flows might allow investments in the offer extensions.
Strategy related to the business case	Business relation formation with the spot manager, against the competitive MNOs. Enabling of the safety exit for the high traffic demand locations, in case of no possibility to improve currently owned spectrum utilisation.
Infrastructure impact	No direct impact on HW, but RAT specific issues might arise. Software seen to cover required functionalities. Standardisation actions required.
Network operator structure impact	Additional interface towards the spot manager will be required, with appropriate process of payments for the spectrum usage, as well as the spectrum charging for the MNO own spectrum.
Goods/services trading	Two directional spectrum trading will be allowed in this scenario. As multiple market players will participate, resources pricing might vary not only based on the offer and demand, but also depending on the spectrum owner.
Market related cooperation processes	Cooperation process with spot manager will require bi-directional information exchange (e.g. spectrum grant size). Relations with subscribers to be kept unchanged.
Spectrum policies	Spectrum policies as well as the national market regulations might play mayor role in this scenario, as novel policy for the flexible spectrum usage is considered, as well as new market entity for the spectrum distribution. Furthermore, the spectrum re-use on the spot market might require special attention.

9.3.3 SWOT analysis

In Table 13 we present the SWOT analysis, based on the theoretical introduction to the four analysis fields as presented in Section 3.2.

9.3.4 Business model canvas

Based on the business model canvas approach [7] and its description in Section 3.3, in Table 14 we present the analysis for spectrum sharing sub-scenario #4, from the MNO point of view, who is considering the implementation of the proposed sharing scheme.

Table 13: SWOT analysis for spectrum spot market

STRENGTHS	**WEAKNESSES**
• Relaxed requirements for capacity limited cells, due to potential of higher spectrum availability • No need for extra spectrum resources long-term license – possibility to on demand spectrum grants from broker • Improved spectrum utilisation and efficiency • Due to larger amount of channels, more flexible resources assignment and scheduling • Utilisation of the current employees experience • Possibility to employ this scheme in the current frequency plan • Operator's own subscribers service shall not be impacted • Seamless adaptation to the current services offer • Allows provision of extra, QoS services • Spot market based dynamic spectrum allocation might generate new services and applications • Possibility to reach higher peak data rates per cell, depending on the load balance between two considered MNOs	• Additional spectrum resources will generate more network operation costs • Depending on the spectrum band regulations, RAT specific limitations might apply • Possible gains will be visible only in case of capacity limitation (i.e. owned spectrum fully occupied in certain cell) • Scenario might require case specific set-ups, due to operator specific frequency planning • Considered additional spectrum from spot market might still not be sufficient for high-end QoS demanding services • Increased complexity in the scheduling process – TDMA access to the extra channels/bands • Higher signalling overhead might be required in order to signal additional, time-variant spectrum availability • Appropriate coordination mechanism might be required • Spot market offered spectrum availability might be time/location dependant
OPPORTUNITIES	**THREATS**
• In long-term, might enable much more cooperation on the market, between competitors, once initial gains being identified • Competition might motivate network operators to join the spot market • Opening new approach to the spectrum, being considered as good which can be exchanged between MNOs • Potential extension for multi-operator cooperation scheme for more flexible additional spectrum allocations • Scenario might be very attractive for new market entrants, not owning (sufficient) spectrum resources • MNO participation in the spot market might be seen as attractive tool against operator not participating in such cooperative spectrum sharing (subject to regulatory monitoring)	• Spot market might be considered as competitive for regular MNOs • Might require third entity, in order to avoid speculative actions from the another operator • Other competing network operators might also start implementing similar mechanisms, reducing novelty and competitiveness of our offer • Potential regulatory limitations of such sharing coalition formation due to monopoly risk

Table 14: Business model canvas analysis for sub-scenario #4

<table>
<tr>
<td rowspan="2">KEY PARTNERS
• Strategic cooperation with the spot market manager
• Cooperation motivated by the additional, radio resources acquisition
• Telecom equip-ment vendors for possible extensions in the BS (e.g. RF front ends) – buyer–supplier relation
• SW developers (internal resources or outsourcing) for implementation of the short-term spectrum sharing mechanism</td>
<td>KEY ACTIVITIES
• Creation of the business link with the spot market manager
• Negotiations of most beneficial pricing scheme with the spot market manager, if possible
• Identification of possible network infrastructure and UE issues with regard to planned spectrum usage extensions
• Market research for possible new services offer, being enabled by the spot market
• Identification of own capabilities to release a certain amount of spectrum to the spot market</td>
<td rowspan="2">VALUE PROPOSITION
Current customers segmentation:
• Improved, guaranteed service availability for subscribers
• Improved, guaranteed network coverage for subscribers
• Reduced risk of “no-coverage” situation
• Risk reduction for “always online” subscribers
“Smartphone” users:
• Ability to improve guaranteed data-rates
High-end users:
• Ability to improve QoE by higher flexibility in the resources scheduling
• Possible extension by the dedicated branding for high-end users
Low-end users:
• Ability to offer low-cost rate plans, based on non-guaranteed quality
Spot market:
• Spectrum resources might be offered by MNO</td>
<td>CUSTOMER RELATIONSHIP
• Focus on acquisition of additional customers (network capacity on-demand)
• Ability for the current users retention by availability of additional value of the offer
• Customer relationships to focus on the automation
• Possibility to create new target markets, enabled by higher flexibility in the spectrum usage
• Spot market as special case of MNOs customers</td>
<td rowspan="2">CUSTOMER SEGMENT
Current customers segmentation to be extended by additional capacity from the acquired spectrum, e.g.:
a. Current segmentation (legacy users) – mass market
b. Users relying only on spot market spectrum – segmented market:
• additional rate plan, e.g. smartphones oriented due to high data traffic demand
• opportunistic access, low-end service users
c. High-end users, demanding highest service continuity and quality (own + spot market spectrum utilised) – niche market
d. Spot market being considered as customer as well, as it will also generate revenues for MNO, for the spectrum leasing</td>
</tr>
<tr>
<td>KEY RESOURCES
• Running networks
• Current delivery chains
• Experienced employees
• Spectrum resources (own + acquired on demand basis)
• Spot manager business link</td>
<td>DISTRIBUTION CHANNELS
• Mobile service distribution channels to be unchanged for subscribers
• In case of extension of the offer, same channels can be utilised
• In case of spot market cooperation, spectrum grants to be exchanged by automated mechanisms, e.g. X2 interface</td>
</tr>
<tr>
<td colspan="3">COST STRUCTURE
• Investment in the additional spectrum bands from the spot market, requested on demand basis – cost might be expected to be variable (supply and demand based)
• Business case mainly being value-driven; in case of low-end subscribers group – cost-driven
• Network OPEX costs expected at current level (many elements being fixed costs)
• Case specific HW/SW investments might apply for functionality implementation
• Advertisement costs of new services, enabled by the on-demand spectrum acquisition by MNO</td>
<td colspan="3">REVENUE STREAMS
• Regular revenue from the subscriptions fees, being customer segment dependant – mostly fixed prices
• Expected increase of the above subscription fees, based on the ability to acquire extra capacity on demand basis: new customers acquisition – volume dependant revenue
• High-end subscribers expected to be willing to pay more for improved service delivery – must be guaranteed by certain performance measures; subscription rate might be dependant of the real cost of the service provision (i.e. due to flexible brokerage fees)
• Additional revenue possible from the spot market, by the MNO own spectrum resources leasing</td>
</tr>
</table>

9.4 Description of scenario players and roles

9.4.1 Standardisation

From the standards point of view, most observations captured in Section 8.4.1 are applicable also for the spot market manager case.

The main expectation from the standardisation bodies would be to create broadly supported spot manager standard. In order to allow possibly widest exploitation of such feature, it has to provide sufficiently wide flexibility (time, space). At the same time, the legacy UEs shall support the functionality as well – otherwise, implementation of this spectrum sharing functionality would be significantly delayed.

Obviously, signalling mechanism would be required for flexible spectrum availability indications, as well as for the MNO own spectrum leasing purposes. Furthermore, the charging functionality is expected to require standardisation as well.

Similar to the spectrum broker case, the spot manager functionality is expected to attract the IPR focused companies from the telecom industry, because of its novelty.

Trying to identify the standardisation bodies being possibly interested in such kind of spectrum management mechanism, despite the 3GPP, also the COST RRS group is expected to be interested to investigate the proposed scheme.

9.4.2 National regulator

In this spectrum sharing variant, the national regulator plays mayor role due to the fact, that he would become the active member of the value chain, as spectrum bands would be subject to the sharing enabling, case by case. Of course, this decision process is the subject for optimisation and automation, in order to minimise the effort required.

In practice, it would be required to crate certain linkage between the regulatory bodies providing the radio resources, the network operator owning the hardware and physical layer access technology, and between the end terminals, which are requesting the services requiring spectrum owned and managed by the regulatory body.

The question is how to convince spectrum owners (i.e. national government) to give up significant money income from the long-term spectrum band auctions.

9.4.3 MVNO

In the spot market scenario, the MVNO perspective is seen to be the same in covered in Section 8.4.5, for the spectrum broker case.

9.4.4 Telecom equipment vendors

Due to completely novel market model proposed, hardware vendors would be involved in this scenario in verification actions of the technical feasibility and further standardisation process.

Mayor modifications would be required in the scheduler and its implementation in the base stations.

The simplest foreseen scenario would be to have just one set of the hardware infrastructure covering the area, without overlapping networks. Alternatively, such scenario could be migrated towards the model, where all overlapping networks are accessible by the spot market manager for most optimal spectrum utilisation, as well as for avoidance of the signalling multiplication (as in case of overlapping networks).

9.4.5 Network operators

Two variants of the network operator might be considered, differentiated by the volume of the already owned spectrum and network infrastructure:

- Legacy network operator: in this analysis, we foresee that the operator would be allowed to lease certain amount of his own spectrum back to the spot manager, in order to acquire additional revenue flows, once his own spectrum demands are already secured;
- Greenfield network operator: in this case, the new market entrant might not have any other spectrum resources, despite of those acquired under the spot market agreement.

9.4.6 Spot market manager

The spot market manager entity proposed in this scenario may be realised under the national regulator management, being realised in the centralised manner for the spectrum usage coordination purposes.

Main task of the spot manager would be the distribution of the spectrum resources under its management as described in Section 9.1.

This new market entity might be also extended by the functionality of "spectrum garbage collector", which aims to improve the spectrum utilisation, collecting the under-utilised spectrum chunks from spectrum owners, who are leasing or selling spectrum to other market players, via the spot manager who acts as the market mediator.

9.4.7 End user

In the proposed model, end user will be able to directly benefit from the additional spectrum resources being provided by national regulator.

The subscriber's role is expected to be the same as covered for the sub-scenario #1 in Section 6.4.5.

10 Spectrum sharing scenarios comparison

Based on the description and analyses of four spectrum sharing sub-scenarios as presented in Section 5, we attempt to compare all cases in Table 15. This comparison aims to help identify the differences between proposed scenarios, as well as to highlight the main advantages of proposed solutions.

Table 15: Spectrum sharing sub-scenarios comparison

Spectrum sharing sub-scenario	Cooperation timescale	Shared spectrum grant duration	Shared spectrum availability	Shared spectrum amount to obtain	Sharing rule enforcement	Scenario's applicability	Spectrum sharing category
#1 Collaborative spectrum sharing in existing spectrum band	Long-term	Opportunistic, with guaranteed allocation duration	More spectrum resources, not guaranteed, opportunity based	Not guaranteed	Not possible in direct form, balancing function needed	Limited due to non guaranteed gains and relatively flat implementation cost	Vertical in own spectrum
#2 Collaborative spectrum sharing in additional spectrum band	Long-term	Same as for own band, traffic driven	More spectrum resources, guaranteed	Depends on the agreement among MNOs (e.g. 50/50)	Possible, default share division with possible dynamic adaptation	General applicability, capacity improvement	Vertical in own spectrum; Horizontal in shared band
#3 Inter-operator spectrum sharing with spectrum broker	Variable, real-time	On-demand, depending on the broker capacity	More spectrum resources, guaranteed, pay-per-use	Up to the amount managed by the broker	Not possible in direct form, depends on online investment in broker managed resources	General applicability, especially for capacity limited cases and hot-spots	Vertical in own spectrum; Horizontal in spectrum broker spectrum
#4 Spectrum spot market	Variable, real-time	On demand, depending on the instantaneous spectrum availability	More spectrum resources, pay-per-use	Variable, depending on supply and demand	Not possible in direct form, depending on the spectrum demand and own spectrum	General applicability, especially for capacity limited cases and hot-spots	Vertical in own spectrum; Horizontal in spot market spectrum

10.1 Definition of the modified map of the market

Due to the already mentioned spectrum policy being the possible bottleneck for spectrum sharing mechanisms, it is seen, that in the spectrum sharing market, spectrum policy owner in the eTOM based analysis (as presented in Table 16) will be influencing the mobile services quality assurance. This relation is seen to be applicable to all spectrum sharing cases discussed in this paper. Furthermore, the spectrum owner is seen to be also responsible for the quality assurance, which applies to all considered sharing partners. The above statement is based on the understanding, that the spectrum policies and regulations are enablers for flexible and dynamic spectrum access, being the prerequisite for enhanced subscriber's satisfaction, e.g. spectrum sharing as the service coverage enhancement, or throughput improvement in the hot-spot deployment scenario. Still, it remains clear, that the network operator, as the infrastructure owner, is responsible for optimal network configuration, keeping the service quality assurance by appropriate KPI monitoring and parameters tuning.

The spectrum broker has been added to the market model for sub-scenario #3. This entity is expected to influence the quality assurance. Moreover, due to the business relation, also the billing related activities will be influenced. These two aspects are seen to be equally relevant in case of sub-scenario #4 and the Spot market manager. Furthermore, it is expected, that the possible standardisation process might influence the billing aspects, in case of sub-scenario #3 and #4, which then will be reflected in the infrastructure and its functionality.

In case of sub-scenario #1 and #2, MNO agreement is required. Since MNOs are considered as the RAN owners, they (as RAN owners) will have impact on the quality assurance for the mobile services delivery for end users (i.e. MNO coalition formation is expected to improve this quality due to more flexible spectrum management).

NOTE: Modifications to the reference matrix on the current market model (cf. Table 16) are introduced in red, indicating to which spectrum sharing sub-scenario they are applicable. In case of optional applicability, brackets are used.

Table 16: Roles and needs matrix for spectrum sharing sub-scenarios

	Service delivery	Quality assurance	End user device	Billing	Support	Product and service mix	Pre-sales
Spectrum policy owner	x	all					
Spectrum owner	x	all					
Spectrum supplier	x						
Spectrum user	x						
Standardisation body – infrastructure	x		x	(3, 4)			
Vendor of end user devices			x				
Vendor of infrastructure	x			(3, 4)			
Owner of infrastructure – RAN	x	1, 2					
Owner of infrastructure – other	x						
Supplier of configuration and optimisation services	x	x			x		
Supplier of monitoring and troubleshooting services	x	x	x		x		
Service business developer and planner	x						
Resource manager	x	x			x		
Supplier of product quality assurance and monitoring services		x			x		
Software vendor	x						
Software owner	x						
Product business developer and planner		x	x			x	
Product configuration manager		x	x			x	
Product lifecycle manager		x	x			x	
Inquirer o billing information				x			
Invoice and payment manager				x			
Supplier of customer support services	x	x	x	x	x		
Supplier of information about product and technology							x
Market developer							x
Spectrum broker		3		3			
Spot market manager		4		4			

11 End user perception

The subscribers needs and their analyses shall be the basis for the market description and its forecasting. This analysis allows understanding, what are the triggers for the behaviour of main market players. It is important to consider which mobile communication services may be successful and which demand can be expected, as well as how much end users will be willing to pay for the services.

One of the strongest drivers for new, value-added mobile services is high expectation coming from subscribers side, who were attracted already by the booming smartphones and tablets offer, causing many users being much longer in the CONNECTED state (breathing applications, online monitoring, regular information updates, online gaming, online health monitoring, etc.) than in IDLE state. Furthermore, the rapid development of new software platforms (e.g. Android) created new traffic sources by generation on thousands of applications being able to benefit from the broadband capabilities offered by radio access technologies these days.

As already indicated in the previous part of the document, discussing the standardisation issues of the novel market modelling, it was highlighted, that the technology evolution is not the goal itself – but the business case is, which simply requires new tools to satisfy customer and meet their expectations. Therefore, with the consideration of the spectrum sharing, the question shall be asked: how the spectrum sharing could create or improve the mobile services and subscribers demand. Furthermore, consideration of the customer segment needs to be considered (as covered in the business model canvas analyses, Section 6.3.4, 7.3.4, 8.3.4 and 9.3.4, respectively), as the value of the new service will be different for various customer groups. Based on the discussion in Section 4.2, we need to also consider the aspect of the more suited subscription plan creation, for well defined customer needs, not being the current approach of flat rate for all subscribers, irrespective of their needs.

Looking at new, or currently not supported, customer needs and desires in the area of mobile services, we can identify few high-level example ideas being enabled by the spectrum sharing:

- “Fast lane” – users are queued in the scheduling process based on various performance metrics like buffer state, delay, QoS etc. We propose to define premium subscriber category, having higher priority in the queuing, based on certain metrics. This scheduling concept, would benefit from more flexible spectrum regulations by the fact, that once needed, the network operator would be able to cover the burst of the traffic demand, by the pooled spectrum resources (not being forced to dimension his network with the consideration of the load level as high as in case of typical network planning).
- Low rate, non-real time data link – the use case would be application to any kind of regular reporting services, considering also the M2M scenarios; no voice, SMS nor web browsing.
- Low rate, highly robust link – the use case would be application to any online payment services, no voice, SMS nor web browsing. From the technical point of

view, the high link robustness requirement would be supported (at least) by the improved frequency diversity of the available radio channels, i.e. “buy better channel, once needed”. In this case, coverage would be the critical aspect of the service provision.

Trying to be a bit self-criticising, one can say that all of the above provided examples can be covered already today by the current MNOs’ subscription plans. Such solution might work, but in a very inefficient manner, both for MNO as well as for the end user, for the following reasoning:

- For MNO, an attempt to serve the above example classes of subscribers by regular flat rate subscriptions might not be able due to lack of proper quality measures available. MNO might not be willing to spend extra network capacity for more demanding subscribers, still dimensioning the network according to the average subscribers traffic models. Furthermore, such approach might lead to the overestimation of the network capacity requirements in situation, where low bitrates subscribers are assigned the regular flat rate subscription plans – in consequence the network spectral and hardware resources might be under-utilised.
- For subscribers characterised by one of the bullets above, regular flat rate subscription would mean, that they would pay for what is not required by their profile, or what does not fulfil their requirements.

We are in the opinion, that the mobile services market is similar to many other markets, which gives the opportunity to adopt the evolution paths also to the described case of cellular networks. What can be concluded, is that the mobile services are missing the guaranteed service quality definitions, giving the ability to define both, lower and upper bounds of the service specific quality measures, in order to allow network operators to be able to perform much more granular and exact network dimensioning, leading to improved utilisation of the spectrum bands, also in case of frequency reuse schemes.

Referring to the quality measures of the mobile packet data services, we attempt to analyse the high level gains coming from the spectrum sharing for the end-user. It has to be emphasised, that the money flow aspects require similar analysis in order to enable (some of) below described cases.

Capacity

For the services, whose quality is perceived mostly by the capacity measure, spectrum sharing is expected to provide visible gains for subscribers. The quantitative gain will be limited by the amount of the shared spectrum. This measure is closely related to the peak rate measure, which is the upper bound of the capacity measure.

Coverage

Due to different propagation capabilities of different frequency bands (e.g. 36.101, 25.101) it is expected that coverage gains are possible in cases, where carriers belonging to different bands will be in the pooled spectrum resources.

Delay

For the delay sensitive services, it is expected that short term leasing of additional spectrum resources might improve the delay sensitive services availability. On the other hand, for services with large delay acceptance, spectrum sharing might not be attractive at all, as the end user can accept additional service delivery delay, not being forced to pay additional fees for the access to the shared spectrum resources. What has to be additionally accounted in this case is the possible additional delay in the service delivery, being caused by the shearing mechanism itself.

Guaranteed bitrates

This quality measure is expected to be operator specific, therefore it will not evaluate possible spectrum sharing gain in the say way. In general, GBR measure is a special case of the capacity measure, as described above. In this case, end user is assured to receive what the MNO agreed to deliver for the money paid.

Peak rate

Spectrum sharing gain in terms of the possible peak rate seems to be the straightforward gain. Nevertheless, this aspect might be the subject to the inter-operator agreements (in case of sub-scenario #1 and #2), which might be set up in order to limit greedy users behaviour. One of the most important aspects of the peak rate consideration is its marketing significance: it seems to be desirable by the operators to be able to attract potential customers with high, not necessarily achievable, bitrates. Spectrum sharing will definitely open new possibilities in this area.

Service continuity and availability

Based on the spectrum sharing schemes proposed in this document, it is seen, that these schemes will allow network operators to provide enhanced service continuity and availability. This is basically justified by the availability of additional radio channels and their capacity, as well as additional frequency diversity. This measure is related to the service coverage, as described above.

It has to be emphasised, that there might be hardware aspects (e.g. power amplifiers bandwidth, capacity limits etc.) causing limitations in the spectrum sharing enabling.

More importantly, above described relations might vary in case of different valuation functions applied by the operators in the scheduling process.

12 Advices and recommendations

Based on the discussion and observations on the spectrum sharing aspects and business related implications, in this section we attempt to formulate the advices for the spectrum policy and regulations, being aware that in many cases they will not be feasible for implementation in real market due to complexity of the spectrum policies.

The identified issues are listed below, covering also recommendations to the further work within the project:

- It is expected that spectrum regulation might be the limiting factor for flexible spectrum usage, including spectrum sharing mechanisms – subject to national regulations.
- Consolidation of the national regulations would ease the implementation of novel spectrum management mechanisms.
- Appearance of the spectrum broker on the market might be very difficult, if his goal would be to buy spectrum bands and try to offer radio resources on demand. Much more realistic is the situation, where the spectrum broker functionality is based on the spectrum resources which do not require extra investments. That might lead to the conclusion, that either:
  - Spectrum broker needs business connection/dependency with (at least one) network operator. That would address the concerns related to the vertical market of mobile services, where the MNO is providing full service, from the radio and infrastructure ownership to the mobile services delivery itself;
  - Moreover, it would be an interesting extension to the discussion, to consider any of the classical MNOs as the spectrum broker functionality owner. That would trigger further market evolution of competing spectrum brokers, potentially leading to the situation, where radio access providers are competing in the near to real-time manner, to serve subscribers for the revenue generation.
  - Spectrum broker needs to be managed by the national regulator, who grants him spectrum band with the aim of optimal spectrum resources utilisation and social welfare maximisation of the scheduling process.
  - Spectrum broker needs to offer more than just pure spectrum resources, e.g. network infrastructure that is using the considered bands, being able to offer the wholesale radio access to the mobile content providers. Such a business model was already attempted by the Lightsquared, who will operate wholesale-only business model, offering the LTE radio access, making it the sole wireless provider of its kind in the U.S. market [27].
- It is suggested to consider modified spectrum bands allocation policies, after expiration of current spectrum bands usage agreements. It might be socially beneficial not to give exclusive spectrum usage to only one MNO, or at least, to give exclusive spectrum usage only to part of the most attractive spectrum bands.

- Furthermore, modification to the unallocated spectrum bands is seen as another alternative to stimulate more flexible and more efficient spectrum usage.
- Based on the simulation campaigns performed in the WP4, it is suggested not to consider schemes, which are decreasing the subscriber's experience, even if those schemes are justified by the business cases (e.g. by the cash payback from other spectrum users).
- Considering possible interest in the location/time/band specific implementation of the described sharing mechanisms, it would be beneficial to utilise the state of the art technologies. Therefore, based on the available radio access technologies, it is seen that the E-UTRAN would be natural choice for further consideration. The advantage of this RAT is the X2 interface, which might ease the coordination of the sharing mechanism functionality.
- More focus on the sharing cases, where the MNOs might have real interest (i.e. new revenues), at the same time, leading to improved spectrum utilisation. This would allow much easier and faster implementation of the sharing cases.

Conclusions

We have studied the spectrum sharing scenarios, being differentiated by the investment risk for the mobile network operator to implement the sharing scenario in the market. Four sub-scenarios were generated for that purpose, considering various relations between current as well as new market entrants:

- Collaborative spectrum sharing in existing spectrum band;
- Collaborative spectrum sharing in additional spectrum band;
- Inter-operator spectrum sharing with spectrum broker;
- Spectrum spot market.

Inter-operator relations were considered in the analysis, with the aim to identify the stimulating aspects in the spectrum sharing mechanisms, for the MNOs to create the coalitions.

Based on the proposed scenarios, mechanisms and their descriptions, business aspects analysis was performed, using various tools, like SWOT and business model canvases.

The analysis was extended by the current market analysis, with decomposition of the mobile services offer and observations on the possible migration path towards the flexible spectrum usage and well suited mobile services offer, being beneficial for the market, operators and users.

After the analysis of all scenarios above, it was found difficult to forecast the future shape of the mobile service market, due to complicated structure of the spectrum usage policies and regulations. It was not possible to judge, how liberal the national specific spectrum regulations might become and how fast the flexible spectrum usage might evolve on the market, also considering the hardware developments and the level of innovations within the standardisation bodies.

Bibliography

[1] Rafał Pisz, Krzysztof Przybylski, Dominik Hamera (WRC), Osman Aydin (ALUD), Peter Trommelen, Thom Janssen, Pieter Nooren, Ioanna Chatzicharistou (TNO): "SAPHYRE D5.2: Reference business scenario and reference regulatory situation"

[2] Federico Boccardi, Osman Aydin (ALUD), Thom Janssen (TNO), Rafał Pisz (WRC): "SAPHYRE D5.1b: Initial reference scenarios for resource sharing"

[3] Frank Berggren, Olav Queseth, Jens Zander, Börje Asp, Christian Jönsson, Peter Stenumgaard, Niklas Z. Kviselius, Bertil Thorngren, Urban Landmark, Jonas Wessel: "Dynamic Spectrum Access – Phase 1: Scenarios and research challenges", Wireless@KTH Report, 2004

[4] ABI Research: "Software Radio and Dynamic Spectrum Access", ABI Research Report, 2007

[5] CISCO: "Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2011–2016", White Paper, February 2012

[6] Martin Cave, Chris Doyle, William Webb: "Essentials of Modern Spectrum Management", Cambridge University Press, 2007

[7] Alexander Osterwalder, Yves Pigneur, Alan Smith: "Business model generation", self published, 2009

[8] Martin Haardt (TUIL), Zuleita Ka Ming Ho (TUD), Eduard Jorswieck (TUD), Eleftherios Karipidis (LiU), Jacek Kibilda (WRC), Jianhui Li (TUIL), Johannes Lindblom (LiU), Christian Scheunert (TUD), Jan Sýkora (CTU), David Gesbert (ECM), Erik G. Larsson (LiU), Jianshu Zhang (TUIL): "SAPHYRE D3.1a: Adaptive and robust signal processing in multi-user and multi-cellular environments"

[9] Jan Sýkora, Miroslav Hekrdla, Pavel Procházka, Tomáš Uřičář (CTU): "SAPHYRE D3.2a: Network, resource, and interference aware coding and decoding"

[10] David Gesbert (ECM), Zuleita Ka Ming Ho (TUD), Jacek Kibiłda (WRC), Martin Haardt (TUIL), Dominik Hamera (WRC), Eduard Jorswieck (TUD), Eleftherios Karipidis (LiU), Jan Sýkora (CTU), Jianhui Li (TUIL), Radosław Piesiewicz (WRC), Jianshu Zhang (TUIL): "SAPHYRE D3.3b: Reference scenario parameters and novel interference models"

[11] Torsten Fahldieck (ALUD), Michał Szydełko (WRC), Haibin Zhang (TNO), Martin Schubert (FhG), Luca Anchora (CFR), Jianshu Zhang (TUIL): "SAPHYRE D4.1: Resource allocation and interference management strategies"

[12] Haibin Zhang (TNO), Jianhui Li (TUIL), Lars Thiele, Leonardo Badia (CFR), Ljupčo Jorgušeski (TNO), Luca Ancora (CFR), Martin Schubert (FhG), Michał Szydełko (WRC): "SAPHYRE D4.3: System level evaluation methodology and asymptotic analysis assessment"

[13] Michał Szydełko, Jarosław Byrka, Jakub Oszmianski (WRC): "Dynamic valuation function based definition of the primary spectrum user in colocated cellular networks", to appear in proceedings, CROWNCOM 2012

[14] Michał Szydełko, Jarosław Byrka, Radosław Piesiewicz, Jakub Oszmianski (WRFC): "Local spectrum redistribution techniques for spectral efficiency improvements in cellular networks", submitted to GlobeCom 2012

[15] Lars Berlemann, Stefan Mangold, Andreas Jarosch: "Operator Assisted Cognitive Radio for Dynamic Spectrum Access and Spectrum Sharing", Comsware 2006

[16] SAPHYRE EAB meeting #2, September 2011, NGMN office, Frankfurt/Main, Germany

[17] SAPHYRE EAB meeting #3, March 2012, TNO office, Hoofddorp, The Netherlands

[18] Xavier, Patrick, Ypsilanti, Dimitri: "Policy issues in spectrum trading", The journal of policy, regulation and strategy for telecommunications, volume 8, number 2, pp. 34–61(28), 2006

[19] Ericsson AB: "Shared Networks – White Paper: An operator alternative to reduce initial investments, increase coverage and reduce Time To Market for WCDMA by sharing infrastructure", http://www.ericsson.com

[20] INFORMA: "Industry Outlook – 2011", 9th edition, www.informatm.com

[21] Klas Johansson, Anders Furuskär, Peter Karlsson, Jens Zander: "Relation between base station characteristics and cost structure in cellular networks", Proceedings of the IEEE Personal, Indoor and Mobile Communications (PIMRC), 2004

[22] Pieter Ballon: "Business Modelling as the Configuration of Control and Value", 20th Bled eConference eMergence, 2007

[23] 3GPP TSG RAN: "TS 36.420: Evolved Universal Terrestrial Radio Access Network (E-UTRAN); X2 general aspects and principles", Technical Specification

[24] 3GPP TSG RAN: "TS 37.104: Multi-Standard Radio (MSR) Base Station (BS) radio transmission and reception", Technical Specification

[25] 3GPP TSG SA: "TR 22.852: RAN sharing enhancements", Study Item

[26] Johan Hultell, Klas Johansson, Jan Markendahl: "Business models and resource management for shared wireless networks", VTC 2004-Fall

[27] LightSquared operating model description, www.lightsquared.com

[28] Rafał Pisz, Krzysztof Przybylski (WRC): "SAPHYRE D5.3a: Business models, pricing mechanism and advices for spectrum policy and regulation for scenario I" (initial version)

[29] Nikhil Kelkar, Yaling Yang, Dilip Shome, George Morgan: "A Business Model Framework for Dynamic Spectrum Access in Cognitive Networks", GlobeCom 2008