Impact of deployment costs and spectrum prices on the business viability of mobile broadband using TV white space

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***Abstract* — In this paper we analyze the business feasibility of mobile broadband access services using secondary access of spectrum in the TV bands. We use a capacity-cost analysis considering costs for radio equipment, base station sites and radio spectrum. We compare network deployment by a market entrant and an existing mobile operator using either licensed spectrum or TV white spaces. In addition, we compare the impact of high and low spectrum prices using examples from Sweden and India.**

The analysis shows that market entrants will be in a more difficult position than the established actors. No matter the cost-capacity performance of cognitive radio equipment, a new operator needs to invest in a new infrastructure with sites and transmission. If the spectrum costs are "high" (like in India) the use of TW white spaces is more cost efficient for both existing operators and new operators.

Keywords - *Business feasibility, mobile broadband, network deployment; cost-structure analysis, secondary spectrum access, cognitive radio, spectrum prices*

I. Introduction

Wireless access to an increasing number of existing and new services has become a major trend in just a few years. This leads to new requirements on capacity, coverage and availability. Most of the new requirements are easier to meet with more bandwidth and use of new spectrum bands. More spectrum has been available for wireless broadband services by allocation of the 2,1 GHz, 2,6 GHz and 800 MHz bands, and in many countries auctions have taken place. This approach with exclusive usage of licensed spectrum is the common and preferred way by operators to use spectrum. Another possibility is secondary use of spectrum which primarily has been allocated for other applications, e.g. TV or radar. Several hundreds of MHz belongs to those categories. The secondary use exploits un-used spectrum in frequency, time or physical location. Such un-used spectrum in the TV bands is called TV white space (TV WS). To exploit such possibilities new technology like cognitive radio (CR) with sensing and interference management capabilities has to be developed. The opportunities related to secondary access of spectrum has been identified by national regulators leading to many initiatives and new regulatory directives. For example, 2011 the U.K. regulator Ofcom approved the use of white space spectrum and plans to make devices that connect via gaps between TV signal bands[1]: *"U.K. regulator Ofcom has approved the use of white spaces spectrum for communication services such as broadband Internet and M2M, predicting that white space technology will come to market by 2013"*.

Secondary access of spectrum is associated with a number of challenges. First, the available frequency bands need to be identified. Secondly, the secondary usage needs to be managed in order to avoid interference to the primary user and to handle interference between multiple secondary users that have detected the same "available" frequency band. There are also challenges related to the design and implementation of the system. The radio equipment must support wide band operation and the overall system needs to be cost efficient (in order to be an option).

However, in order to be commercially feasible relevant business scenarios need to be considered. It may be that spectrum is available and that a technical solution based on cognitive radio works perfectly well but that the resulting business case still not is viable. The business viability depends on specific business cases including the intended service, the demand and usage, the type of deployment and cost structure of the network. We also need to consider competing solutions.

In this paper we will analyze the business feasibility of mobile broadband access (MBBA) services using secondary access of spectrum in the TV bands. The research question is: *For what network and business scenarios can use of TV white space be a feasible solution for mobile broadband access?*

To answer this question we use a capacity-cost analysis considering costs for radio equipment, base station sites and radio spectrum. We compare network deployment costs using licensed spectrum or TV white spaces. We consider network deployment in rural and urban areas by a market entrant and an existing mobile operator.

The paper is organized as follows; related work and the intended contributions are described in section II. The research approach, deployment cases, models and assumptions are described in section III. In the results section IV total network costs are shown for different deployment cases as function of both amount of spectrum and user demand levels. Conclusions are found in section V.

[1] http://www.totaltele.com/view.aspx?ID=467424

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II. Related work and our contribution

Considering the advantages of using TVWS in terms of capacity expansion and economic viability, a growing interest in establishing new models and approaches for cellular network deployments and mobile broadband service in the TVWS bands has recently emerged [1][2]. However, most existing and ongoing research work focus on the benefits of using TVWS on the technical design (performance), interference analysis and radio wave propagation models [3] - [7].

Very little interest has been put on the business feasibility of using TVWS for mobile broadband provisioning. As far as we are aware, no business feasibility analysis has been presented taking into account the cost-capacity performance of radio access networks using cognitive radio. For instance in [1], the authors investigate the potential of TVWS for secondary cellular use. They analyze the performance improvement of the network when upgrading its existing cell-sites to opportunistically and cost-efficiently utilize the available spectrum recourses. In [2], the authors investigate the feasibility of wireless broadband delivery using a community network architecture operating in 5GHz, 2.4GHz, and TV bands. In their model residential broadband customers share a portion of their home access-point bandwidth for outdoor public use. The viability of the inside-out TVWS network architecture in terms of achievable coverage and data-rates is given. Based on their finding, they summarize that city-wide broadband provision community networks operating in TVWS spectrum, are viable. They also claim that such network architectures are significantly less expensive. However, there is not economic analysis on how much can be gained through this new approach that validates this conclusion.

High level business and regulatory aspects for cognitive radio systems has been addressed in a number of papers. In [8][9] different scenarios and use cases are described together with models and taxonomies for classification of different scenarios. In the EU project Quasar a number of service scenarios are defined: e.g. cellular use of white spaces, Wifi-like use of white spaces, indoor broadband in aeronautical spectrum, secondary wireless backhaul, license exempt use of radar bands, and machine to machine communication using cognitive radio [10].

However, despite all the proposed use cases, scenarios and approaches for classification of scenarios there seems to be a lack of approaches for business analysis of systems and services using CR technology. The classification system in [10] is feasible for the analysis of technical performance and system design – but the approach does not include any kinds of business context or end-user service aspects. It is focused on the supply side of the service, i.e. how the networks are deployed and how the spectrum is utilized and managed.

The cost-effectiveness of broadband networks based on TVWS depends on many design, implementation factors and complexity factors. The business viability depends on the cost structure compared to competing solutions. Our contribution is to analyze the cost-capacity performance of systems using cognitive radio in an overall business and deployment context. Potential business cases can be identified by comparative analysis of different deployment scenarios.

III. Approach, models and assumptions

We consider cases for urban and rural network deployment were we compare the overall network costs for a market entrant and an existing mobile operator using either licensed spectrum or TV white spaces. The impact of spectrum prices is illustrated using examples from Europe and India.

A. User demand

The dimensioning is based on the estimated user demand per area unit (Mbps/ km^2). This number is the same in India and Sweden since the user density is assumed to be 10 times higher in India but the demand per user is assumed to be 10 times lower. We assume that the data is “consumed” during 8 (equally) busy hours 30 days per month, see table 1.

	Urban area Sweden/India	Rural area Sweden/India
#Users/km^2	2 000/20 000	100/1000
Usage GB/month/user	10/1	10/1
Demand (Mbps/Km^2)	200/200	10/10

Table 1: Assumptions of user demand

B. Coverage and capacity of base station sites

The assumptions regarding coverage is shown in table 2. The user demand is satisfied by adding sufficient capacity to each site. When the demand cannot be met with the available amount of spectrum new sites need to be deployed, i.e. the more bandwidth the fewer number of sites. In the analysis section we will show how the overall network cost depends on: i) the amount of available spectrum (for a fixed demand) and ii) the user demand (for a fixed amount of spectrum). For both the licensed spectrum and the TV white spectrum we assume that we use a LTE type of radio access technology with an average spectral efficiency of 1 bps per Hz. For the capacity estimates we assume three-sector sites and a re-use factor of 1.

	Urban environment	Rural environment
Coverage Area [Km^2]	1	100
Hex Area [km^2]	0.81	82.94
(Cell area [km^2], Radius [Km])	(1 ; 0.56)	(100; 5.65)
Sectors/base station site	3	3
Bandwidth [MHz]	20	20

Table 2: Network assumptions

C. Costs for radioequioment and base station sites

We can compare MBBA using TV white space with MBBA deployment in the 800 MHz band. Although the uncertainty is high when estimating costs for cognitive radio equipment, some insights can be gained if we consider the overall cost structure for MBBA deployment. In figure 1 we consider two main components of the cost structure for a radio access network; the radio equipment and “the sites and transmission”. In Sweden the cost for deployment of a macro base station site is typically in the range 50 – 200 k€, in figure 1 will assume a cost of 100 k€ for deployment of a new site. According to Telenor the cost for upgrading existing sites with a fiber connection is estimated to 20k€ per site [11].

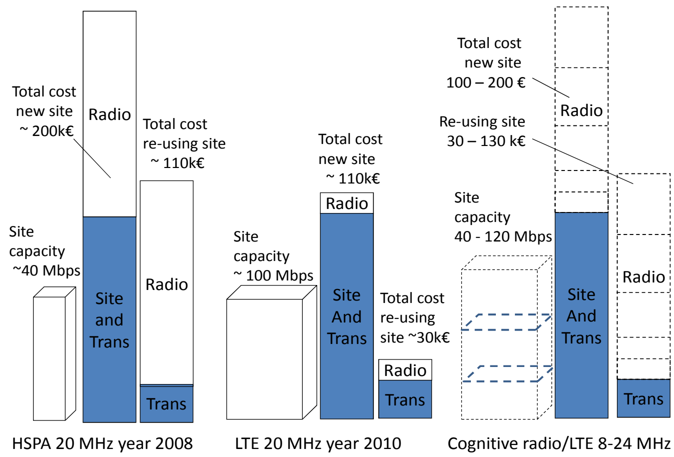


Figure 1 Example of capacity and cost structure for different types of radio access technologies. For the cognitive radio solution the indicated variations for capacity and radio costs depends on the amount of available bandwidth and uncertainty about radio complexity and implementation, from [13].

The cost-capacity ratio of commercial radio equipment has improved more than 20 times the last few years. This is illustrated in figure 1 where HSPA and LTE are compared. For cognitive radio we still do not have any cost numbers, in then analysis we assume twice the cost for the same spectral efficiency as LTE, i.e. 20 k€. Factors that may drive costs for cognitive radio are: large system bandwidth, additional systems for sensing, interference management, data bases, etc and no large scale production.

From figure 1 we can draw another conclusion: even if the cost for cognitive radio equipment would be the same as for standard LTE base stations, the key issue is if new sites need to be deployed or not. In this case the problem is mostly a matter of market entry. In addition to deploying a totally new infrastructure, a new actor needs to invest in marketing, customers, customer care, service and billing platforms, and to build up the operation.

D. *Spectrum costs*

It is often claimed that one driver for secondary use of spectrum is that the cost of spectrum can be avoided. This is only partly true; it depends on the spectrum price in relation to other network costs. Comparing recent auctions in different countries we can identify large differences. In Table 3 we can see that the spectrum cost per site for the Swedish case is in the same range as the radio equipment whereas in India the spectrum cost per site is of the same order of magnitude as the site cost. This will be further described in the analysis section.

Case	**Bandwidth**	**Paid price (€ /MHz/pop)**	**Spectrum cost /site**
Germany 2.6 GHz	20 MHz	~0,05	~1k€
Sweden 800 MHz	10 MHz	~0,50	~10 k€
India Metro 2.1 GHz	5 MHz	~5	~100 k€

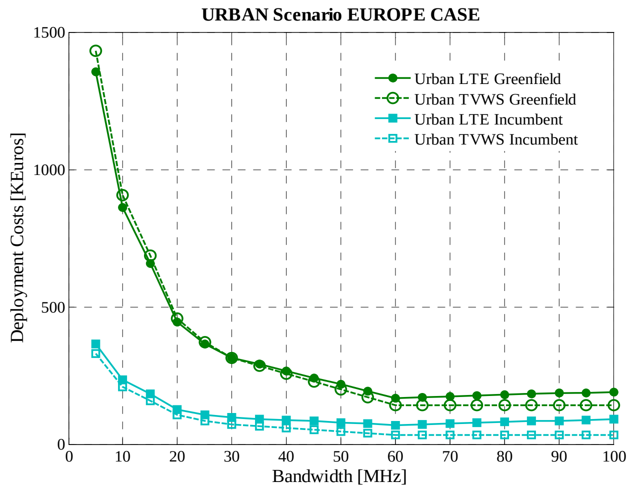
Table 3. Example of spectrum prices, data from [12]

IV. PERFORMANCE ANALYSIS–COSTS STRUCTURE

In this section, graphical illustrations of our analysis are presented. Details on specific assumptions for each case study are also introduced.

A. *Impact of amount of spectrum on deployment costs*

We have assumed scenarios where a Greenfield and an Incumbent operator have decided to deploy a network in order to provide mobile broadband services. Two options are available for the operators; first, it is to run their networks by using licensed spectrum (this means to acquire new spectrum licenses) and second, to use TVWS and only upgrade the network sites with cognitive radio equipment. Assuming a fixed demand for MBB services and varying the amount of bandwidth that each operator gets, we analyze the impact of this additional spectrum bandwidth on deployment costs.



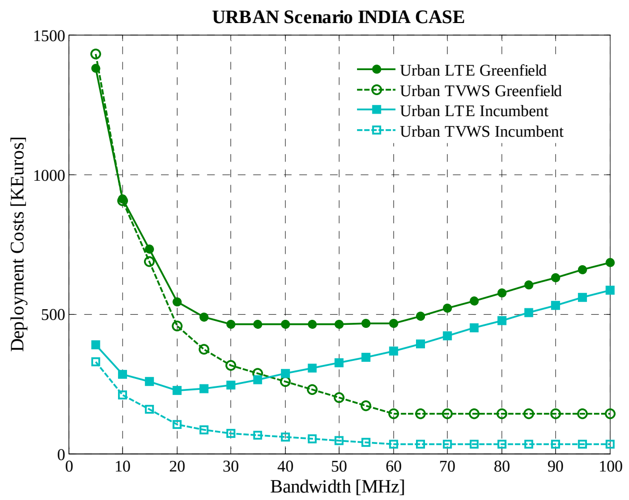
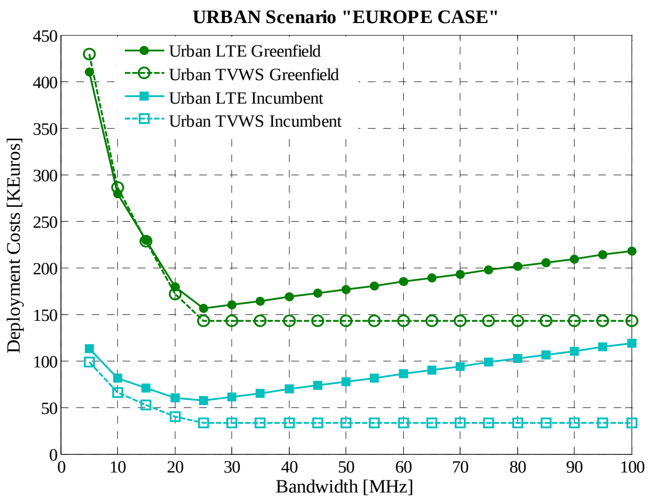


Figure 2 Examples of deployment costs as a function of system bandwidth assuming "low" and "high" spectrum prices (Europe and India respectively) and an urban environment with demand of *200Mbps/km^2* and a base station coverage area of *1km^2*.

The more spectrum the less sites are needed. Hence the sites costs decrease with increasing bandwidth, this is clearly visible for low bandwidths. The impact of spectrum price can be seen for higher levels of bandwidth, see Figure 2. For the low spectrum price levels (European case) a small increase can be observed but for the high price levels (India case) the networks costs increase dramatically.

Besides the costs for sites, radio equipment and spectrum the result depends on the demand levels and the assumed coverage areas. Hence, we present a sensitivity analysis where we vary the user demand and the base station coverage. In Figure 3 we illustrate the impact of lower demand. In Figure 4 we show the cost assuming a smaller coverage area for "high" spectrum prices. In this case a large number of sites are needed and hence the site cost is dominating. For the European cases with lower spectrum prices, the graphs with lower demand levels and smaller coverage areas are similar to Figure 4.



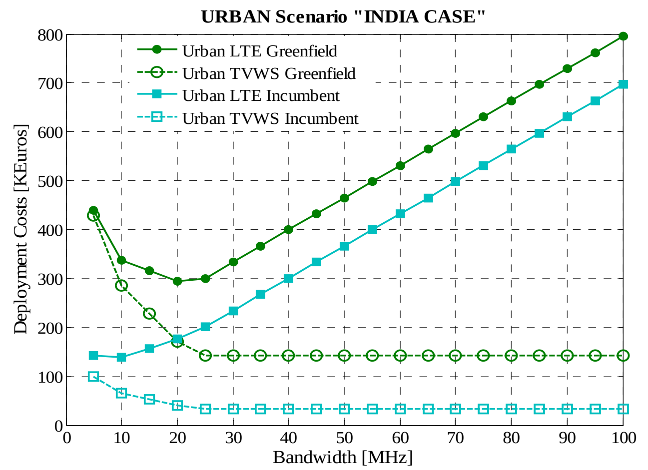


Figure 3 Examples of deployment costs as a function of system bandwidth assuming "low" and "high" spectrum prices (Europe and India respectively) and an urban environment with demand of 50 *Mbps/km²* and a base station coverage area of 1,0 *km²*.

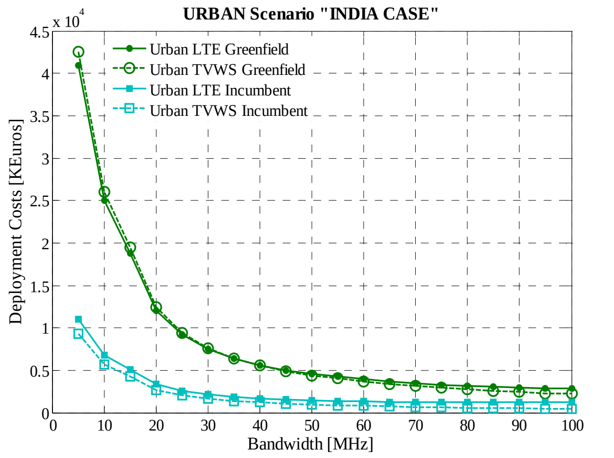


Figure 4 Examples of deployment costs as a function of system bandwidth assuming "low" and "high" spectrum prices (Europe and India respectively) and an urban environment with demand of *200 Mbps/km²* and a base station coverage area of 0,2 *km²*.

B. Impact of user demand on deployment costs

Above we illustrated the impact of amount of spectrum on deployment costs for two fixed levels of user demand. Now we will vary the demand for a fixed bandwitdh, 20 MHz. The costs will increase with demand but the interesting thing is to identify the differnces between different deployment cases.

Figure 5 illustrates how a Greenfield operator building up its network from scratch has higher costs than the incumbent operator. The difference is largest for the low demand levels where the incumbent can make use of existing sites. For the assumed levels of site costs, radio costs and spectrum price the Greenfield operator always has higher network costs, even when cognitive radio and TV white spaces are used.

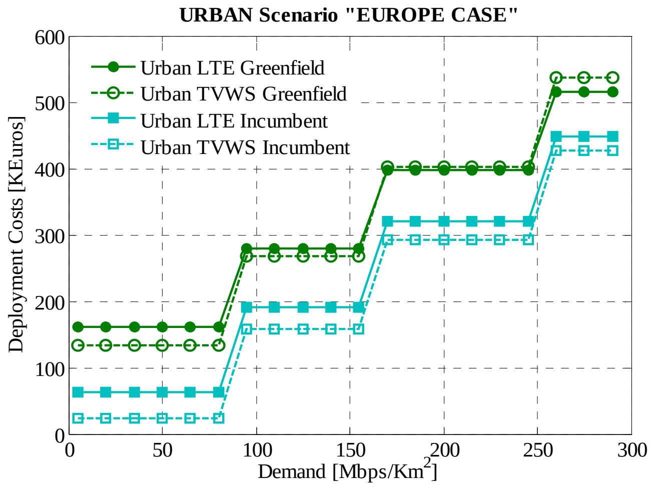


Figure 5 Network costs as a function of a varying demand in an urban environment assuming "European" level of spectrum cost, 20 MHz of spectrum and coverage area of *1km²* per site.

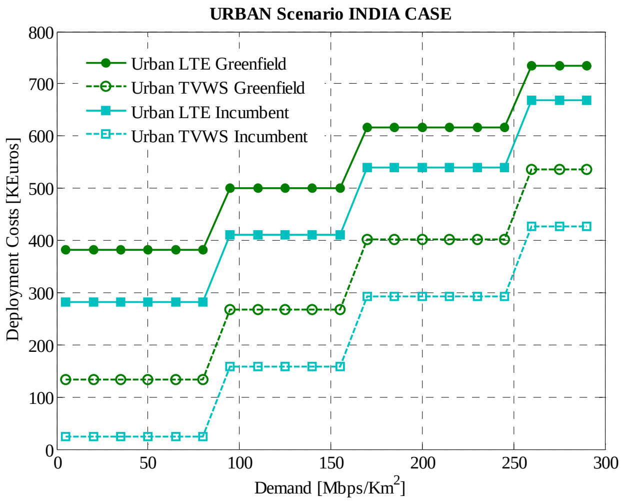


Figure 6 Network costs as a function of a varying demand in an urban environment assuming the high "Indian" level of spectrum cost, 20 MHz of spectrum and coverage area of *1km²* per site.

For the case where the spectrum prices are "high", the situation is different, see Figure 6. Use of TV white spaces (i.e. no spectrum cost) results in lower costs for both the incumbent and the Greenfield operator. The incumbent has lower costs.

C. Spectrum costs and other network costs

When spectrum prices are small compared to sites etc, then the overall network costs decrease the more spectrum an operator has since the base station sites can be re-used. When spectrum prices are "much higher" the situation is different, there is a trade-off between deployment and spectrum costs.

Figure 7 present a graphical illustration of this trade-off between network cost and spectrum costs and the total deployment cost incurred by an operator. For all combinations of network and spectrum costs there is an optimum point with lowest total costs.

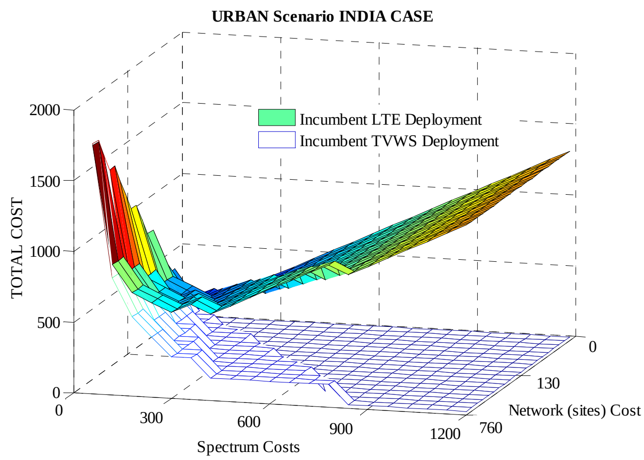


Figure 7. Trade-off between different costs incurred by the incumbent when providing MBB services; total deployment cost, spectrum cost and site costs.

V. CONCLUSIONS

This work is a continuation of the business feasibility analysis of secondary spectrum access introduced in [13]. The analysis is extended taking into account additional deployment scenarios and both network deployment and spectrum costs. We compare network deployment for mobile broadband access by a Greenfield and an Incumbent operator. The operators use either licensed spectrum or TV white space spectrum using radio technology with cost-capacity performance of LTE type.

Due to the need to deploy new base station sites the market entrant will be in a more difficult position than the established actor. No matter the cost-capacity performance of cognitive radio equipment, a new operator needs to invest in a new infrastructure with sites and transmission. This is true when the spectrum prices are at a level typical for Europe. However, if the spectrum costs are "high" (like in India) the use of TW white spaces is more cost efficient for both existing operators and new operators compared to use of licensed spectrum.

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