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**Next generation mobile networks development: technical,
regulatory and strategic issues of the roll-out of in-building
solutions in high traffic places**

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Next generation mobile networks development: technical, regulatory and strategic issues of the roll-out of in-building solutions in high traffic places

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Nowadays, mobile communications are characterized by the continuous fixed-mobile substitution and the forecasted growth of mobile data services. In fact, these new data services such as access to internet and mobile e-mail are considered as a strategic source of revenue for mobile operators to compensate for the lower projected growth rate in voice service revenues. Another characteristic of the mobile communication sector nowadays is the high use of mobile services indoor. This is not surprising if it's considered that the most productive times of our days are spent indoor. This indoor usage is particularly important in some places like airports, train stations, conference and exhibition centers, high rise office buildings or business centers, where the high concentration or the constant flow of users produces a high demand of mobile services. This high demand can't be satisfied with outdoor base stations, especially as the demand of high bit rate services grows. So the roll-out of a dedicated indoor infrastructure is needed. Moreover, this infrastructure has to be a multi-operator and multi-service (2G and 3G) solution to provide coverage without tying the tenants and customers to one particular cellular operator. In this article, the roll-out of these dedicated in-building solutions in high traffic places are analyzed from a technical, regulatory and business point of view.

1 Introduction

Nowadays, mobile communication markets in most developed countries are characterized by the continuous fixed mobile substitution and the forecasted growth of mobile data services. The ability of mobile networks to meet the needs of anytime, anywhere voice communications is the main driver of this fixed mobile substitution that is consolidating mobile phones as the primary network for voice calls. According to Analysys Research ([Analysys Research, 2007](#)), in Western Europe the proportion of voice traffic that was originated on mobile phones increased from 28% in the 1Q of 2004 to 35% in the first quarter of 2006 and would result in more than 50% by 2008. Moreover, the volume of mobile-originated voice traffic increased by 35% between the 1Q of 2004 and the 1Q of 2006, while the volume of fixed-originated voice traffic fell by 6%.

Mobile operators are looking for meeting also the needs of data communications services as e-mail and Internet browsing with their new 3G data services. Despite the growing mobile voice traffic, mobile operators forecast a lower growth rate¹ in voice service revenues as a result of the increasing competitive pressure on operators to reduce their voice prices. Therefore, these new services are considered as a strategic source of revenue to keep the growth rate of their revenues. According to Analysys Research ([Analysys Research, 2007b](#)), mobile service revenue in Western Europe is forecast to grow at a CAGR of 5.4% between 2006 and 2012 thanks to the important growth of data services (Figure 1).

¹ According to Analysys Research ([Analysys Research, 2007b](#)) voice services will show a compound annual growth rate (CAGR) of 2.3% in the period of 2006-2012

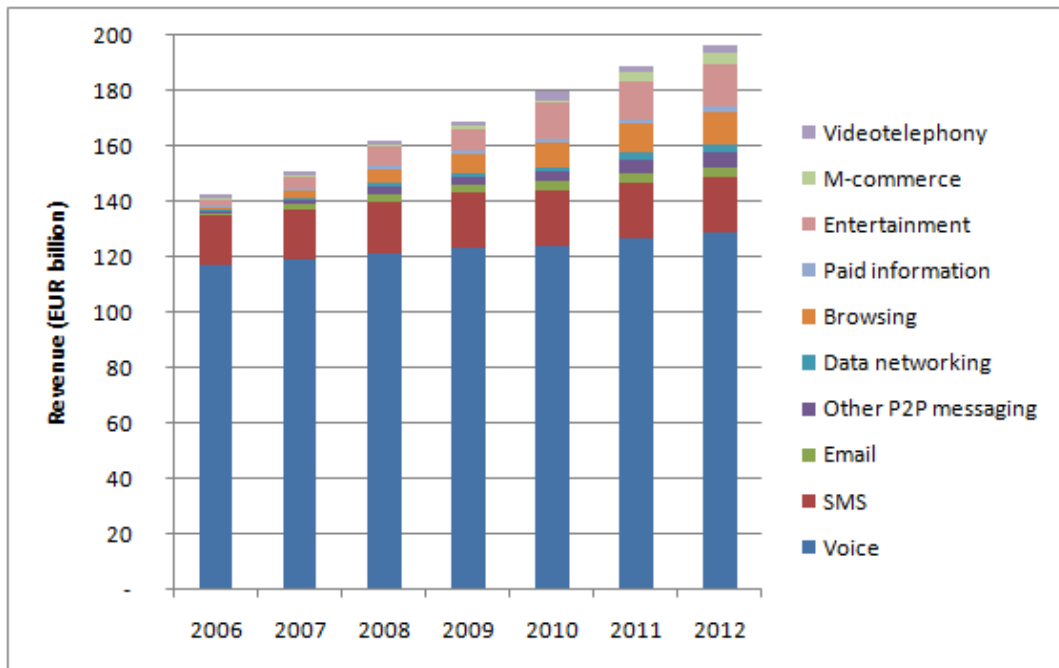


Figure 1 Revenue from mobile services in Western Europe, 2002-2012 (Source: Analysys Research, 2007b)

However, the success of mobile data services will significantly depend on the ability of mobile operators to ensure an anytime, anywhere access to their services just like happened with voice services. Especially important will be to ensure a good quality of coverage inside buildings because of the high percentage of mobile usage that is made within building. Thus, according to Deloitte, seventy percent of mobile voice calls and a similar proportion of mobile data usage were originated inside a building in 2007 (Deloitte, 2007).

This indoor usage of mobile services is particularly important in some places where the high concentration or the constant flow of users produces a high demand of mobile services. These high traffic places are large public places such as airports, train and bus stations, conference and exhibition centers, shopping malls as well as other places such as high rise buildings or business centers. However, this high demand can't be satisfied with outdoor base stations, especially as the demand of high bit rate services grows, being compulsory the roll-out of a dedicated In-Building wireless Solution (IBwS). Moreover, a high percentage of these users are business users whose expenses in mobile services represent almost fifty percent of operator incomes and which are the main users of the new data services. Therefore, the IBwS market is expected to experience a high increase in the next years. As an example, according to ABIresearch this market will show a compound annual growth rate (CAGR) of nearly 20% in the period of 2007-2011 (ABIresearch, 2007a).

In this paper, the roll-out of these dedicated in-building wireless solutions in high traffic places are analyzed from a technical, regulatory and business point of view. Section 2 provides a description of the importance of in-building wireless solutions in next generation mobile networks. Section 3 describes the main in-building wireless solutions. The main benefits and opportunities provided for these IBwS to mobile operators and building owners are analyzed in Section 4. Section 5 provide an analysis of the regulatory issues involved in the roll-out of IBwS, mainly the conflict between the rights of mobile operators to install facilities in the public and private property and the property rights of the site owner. Section 6 describes the main exploitation

models identified from an analysis in depth of these high traffic places and from different cases identified. Finally, Section 7 presents the summary and the paper conclusions.

2 The importance of in-building wireless solutions in next generation mobile networks²

The initial roll-out of 3G mobile networks, just like happened with 2G mobile networks, was focused in providing the widest coverage with the lowest cost. The ideal architecture to achieve this objective is based on the roll-out of base stations in the roof of the buildings which provide coverage both outside and inside buildings (Beijner, 2004). However, indoor coverage is generally quite limited and mostly consists of voice services. High bit rate data services based on efficient modulation and coding schemes (MCS) are frequently not available because of the fact that there is not a good enough radio conditions (see Figure 5 in Hiltunen et al., 2005 as an example).

Therefore, nowadays mobile operators find the need of updating their networks with the aim of providing higher bit rate inside buildings where the higher percentage of services is generated. In order to provide service to indoor customers, an operator can deploy different techniques (3G America, 2006). The most straightforward would be to add new macro cellular base stations to transmit the signal into buildings. The shorter distance reduces propagation loss and coverage inside building is improved. Moreover, the use of lower frequency bands (i.e. WCDMA in 900/850 MHz) will mitigate the path loss problem getting a higher indoor penetration.

However, the roll-out of in-building wireless solutions (IBwS) in high traffic places allows mobile operators to provide services with a high quality inside these places as well as to reduce the capacity degradation that indoor traffic has in UMTS/HSDPA networks.

The negative impact of indoor traffic on the capacity of UMTS networks has been analyzed in many papers (see i.e. Pérez-Romero et al., 2004) and it is consequence of the intrinsic characteristics of the W-CDMA system where multiple users share the same base station transmitter and thus the same power resource in the downlink. As a result, the total cell capacity is affected by path loss to each user. Greater path loss is compensated for by a comparably larger proportion of the downlink resource, which leaves less of the downlink resource for other users. In essence, the system can handle more users at low power than at high power. In general, users inside buildings have greater path loss due to the building penetration loss (BPL) that can be estimated on 20dB on average (Chevalier et al., 2006). Therefore, indoors users consume a proportionately larger share of the downlink resource of the base stations. Moreover, if these indoor users demand high bit rate services, the capacity degradation will be even greater. According to Pérez-Romero et al., 2004, the capacity degradation in the downlink in a scenario with half of users indoors regarding the scenario with all users outdoor is equal to 15.3% in the case of a 64 Kbps data service and 25% in the case of 384 Kbps data service.

The case of the uplink is different because each user has his or her dedicated radio resource (user equipment) in the uplink so the former effect is not present except for the effect of noise and interference. The larger the number of indoor users, the larger the effect of noise and interference and therefore the lower the capacity in the uplink. According to Pérez-Romero et al.,

² This section is referred only to the UMTS/HSDPA technology in the aim of simplify. Many of the statements made in this chapter are also applicable for the CDMA 2000 and beyond technologies although cautiously.

2004, the capacity degradation in the uplink in a scenario with half of users indoors regarding the scenario with all users outdoor is equal to 88.4% in the case of a 64 Kbps data service.

This effect of indoor traffic is eliminated by the roll-out of a dedicated in-building solution as it shows in [Andersson et al. 2002](#) in the case of indoor pico base stations. Furthermore, [Hiltunen et al., 2005](#) shows how the roll-out of a distributed antenna system (DAS) (see Section 3) provides superior HSDPA quality of service (evaluated as the packet bit rate distribution) and capacity (measured by the cell throughput, which is defined as the total number of delivered bits during a certain time divided by the measurement time) within the high traffic place. This improvement is caused by the reduced path losses between mobiles and the serving base stations, reduced intercell interference and improved downlink orthogonality due to the narrower delay spread of the multipath channel experienced by the indoor users.

Therefore, and as a conclusion, the roll-out of dedicated in-building solutions let to increase the capacity of 3G networks by a two-fold effect. First, dedicated in-building systems offload the macro cells by reducing average downlink power levels, which in turn, releases additional system capacity for the outdoor cell. Second, in building solutions introduce additional cells that are isolated from the macro network, which result in lower interference levels, and can provide great capacity inside the building.

3 In building wireless solution overview

The provision of coverage and capacity for mobile services inside buildings may be obtained with many different solutions. The solution finally used depends on the physical characteristics of the building (size, if there are large open spaces or many obstacles and so on), the specific requirements imposed to the solution (number of communications systems, number of carriers of each system, number of operators and so on) and also economics and strategic issues.

A brief description of the main in building wireless solutions is included next. A more detailed description can be found in [Chevalier et al., 2006](#) and in [3G América, 2006](#).

3.1 Dedicated base stations

The first solution simply consists of the roll-out of base stations inside the building (Figure 2).

Mobile operators have at their disposal a wide range of base stations³ which differ in output power, number of carrier supported, installation and conditioning requirements, etc. This solution have been used mainly in large and open indoor spaces such as large airport terminals, train stations, conference and exhibition centers, shopping malls, etc as an extension inside the building of the outside network of each operator.

This solution has been the most commonly used by mobile operators because it provide mobile operators with a fast roll-out, a low installation cost and also a greater independence with the roll-out of other operators and regarding the building owner. However, it has several drawbacks as the provision of a less homogeneous coverage, a larger radiation levels and the less infrastructure sharing in the case that multiple systems and operators have to be supported in the building.

³ Mainly micro or pico base stations and distributed base stations. Distributed base stations are characterized for having the RF section remotely from the main Node B cabinet (connected by fiber optic usually), typically at the masthead close to (or as a part of) the antenna. This architecture make easier the roll-out indoor and improve the performance having less loss between the base stations and the antenna.

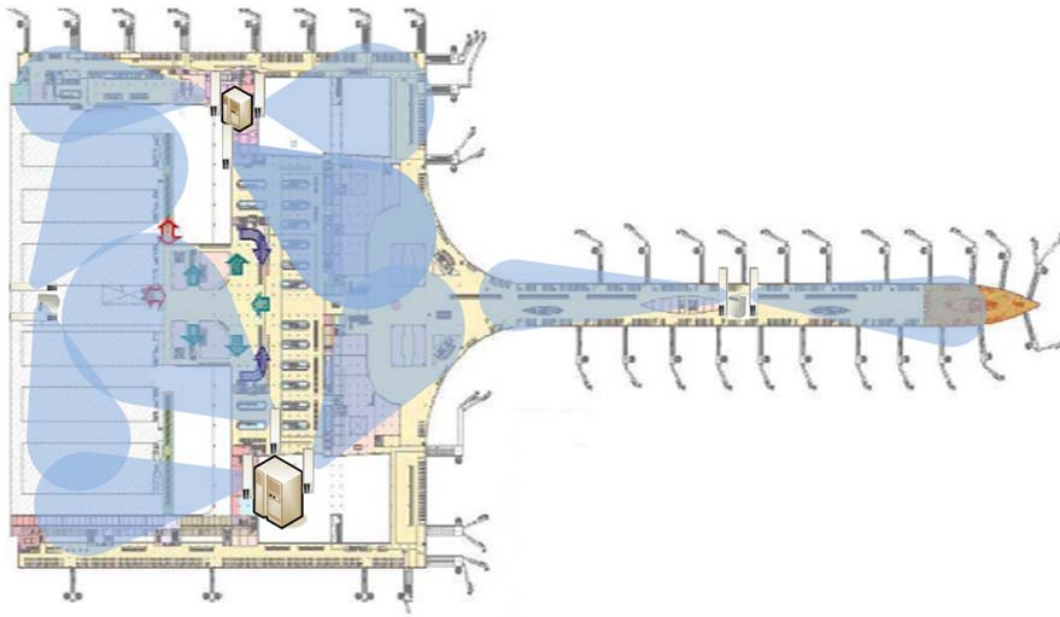


Figure 2 Illustration of the roll-out of 2 micro and 2 pico base stations to provide mobile services in an airport terminal (Source: own elaboration)

3.2 Distributed antenna systems

A Distributed Antenna Systems (DAS) is the infrastructure used to distribute radio signals from one or more base stations and access points to any number of antennas located throughout the building.

Although it can be used for the roll-out of a single system and operator (as the case of the roll-out in the Alcatel's Headquarter, [3G New, 2006](#)), the main advantages of this solution arise when this solution is used to support multiple systems of multiple operators in high traffic places such as airport terminals, subways, multi-tenant office buildings, etc. In these cases, this solution involves a higher infrastructure sharing that reduces the costs of installation and simplifies the operation and maintenance of the in-building solution against the alternative of the roll-out of different infrastructures by each operator. Moreover, DAS can be upgraded to improve capacity, coverage or to support future services without changing antenna placements. In general, DAS let the distribution of any type of technology –included but not limited to the most popular operator technologies, e.g. GSM, WCDMA, IS-95, CDMA-2000 and WLAN – operating on the 800, 850, 900, 1800, 1900 and 2.4 GHz bands.

Other advantages of DAS are that allow a better control of the service area borders of the in-building system and that provide high-quality coverage and lower interference when compared to the roll-out of base stations with integrated antennas (as in Section 3.1 and 3.3). Finally, the DAS provides better radio trunking efficiency by allowing larger portions of the building, even the entire building, to be served by a single cell. This makes easier the frequency plan requiring fewer channels to support the in-building traffic and resulting in overall higher capacity with less interference.

However, the roll-out of a distributed antenna system involves several important challenges. Firstly, due to the DAS is shared among the different operators more collaboration is needed among them especially regarding the financing model of the infrastructure. Generally, building owners preferred the cost to be borne by the wireless operator ([PRTM, 2006](#)). However, other exploitation models are emerging nowadays, which share the burden and the reward of the roll-

out of the IBwS differently (these new exploitation models are showed in Section 6). The cost of these solutions is relatively high so the roll-out of these systems is limited to buildings with a minimum size (according to ABlresearch, these systems are more economical for buildings larger than 9200 square meters; [ABlresearch, 2007b](#)). Furthermore, the costs are dominated by the installation costs so the roll-out of this solution is mainly focused on new buildings.

Secondly, the integration of multiple communication systems involves a set of serious technical challenges. The integration of different radio systems with different link budgets forces to design the system according to the requirements of the most demanding system. It supposes in practice certain over-dimensioning for the rest of the systems. Another challenge is to maintain a suitable intermodulation performance among systems with so different output power and frequency bands. Moreover, the use of a common infrastructure has the drawback that if this infrastructure fails, all the systems will be affected. Therefore, the prevision of several contingencies such as fail in the power supplier or the installation of redundant equipment is needed. This fact makes difficult the integration of the public safety systems in the shared DAS.

Regarding the classification of DAS, it is usually considered three different types: active, passive and hybrid DAS. **Active DAS** usually transport cellular signals from the RF source across fiber cabling in risers and either fiber or Category 5 Ethernet-grade copper cabling serving each floor. Active DASs amplify, condition and adapt the signal to deliver overall consistent coverage and performance. In addition to the active RF source from the carrier, active systems make use of expansion hubs on each floor connected to remote access units (RAUs) distributed around the floor, with antennas mounted upon them. **Passive DAS** usually distribute signals using coaxial cable until the antennas or using “leaky” coaxial cabling acting as distributed antennas. Their primary advantage is their less cost and more reliability than active systems. Their main disadvantages is the attenuation over distance that constraint these systems to smaller areas. Moreover, these systems are designed to support a particular capacity and it is very difficult to adjust them for additional capacity and power requirements to improve the service.

Hybrid DAS combines active components, installed between the RF source and the floor, and usually coaxial cable for passive transmission across the last few meters on each floor. These systems offer some of the signal management and adaptation of the active system and some of the cost saving of the passive system. Figure 3 shows the architecture of a typical hybrid DAS solution.

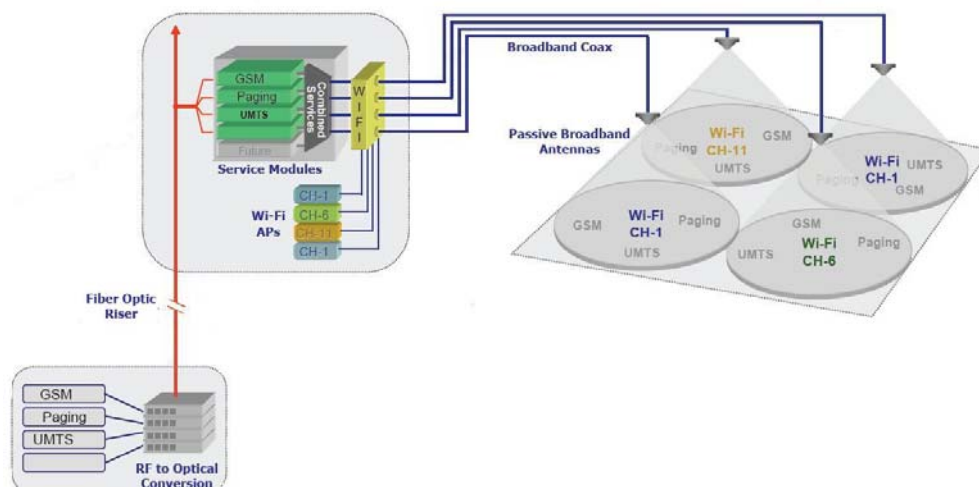


Figure 3 Architecture of a hybrid distributed antenna system (Source: MobileAccess)

3.3 3G Picocells

In addition to current base stations and DAS, nowadays a new kind of base stations (known as picocells) is emerging. The main characteristics of picocells are their low cost, small size, limited capacity, a flat IP architecture - where some radio network controller functions are integrated into picocells - and an IP-based backhaul to the mobile network (Figure 4).

Significant for picocells is their low visibility and their easy deployment as a consequence of their small size and low weight that let their installation in the wall. However, picocells have several drawbacks as well (Infonetic Research, 2007). To provide adequate coverage in large buildings, it might be necessary to use multiple picocells. Because each cell uses the same frequency, a large area within the building will receive multiple picocell signals with similar signal strengths, causing local interference issues and prohibiting high data rates. Moreover, the location of a picocell may be non optimal if this location is determined by the need of backhaul connectivity and not by the need of coverage or capacity (in contrast with DAS installations).

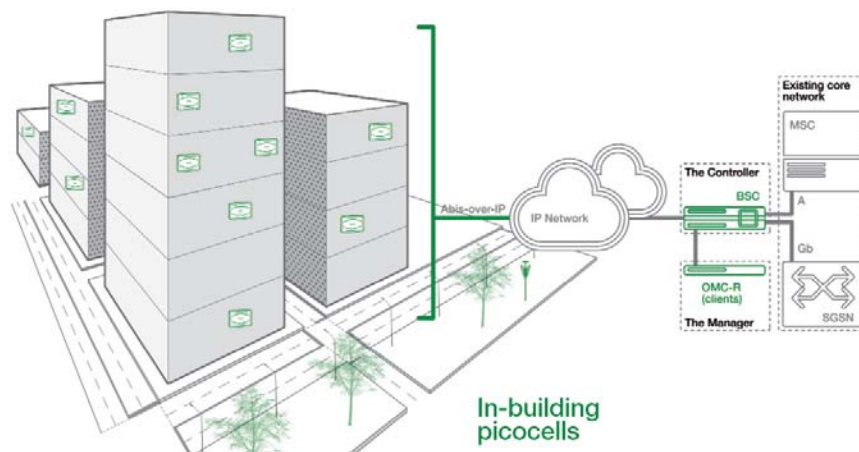


Figure 4 Illustration of the roll-out of picocells in an office building and network architecture (Source: [lp.access, 2007](#))

To summarize, although technical challenges must be overcome before IP-based 3G picocells can be widely deployed, their easy deployment and their predictable economies of scale make believe that picocells is going to play an increasingly role, not only supplementing current in-building systems but also replacing them (ABlresearch, 2007b). Moreover, their low cost makes economically viable their installation in many other different buildings in which the indoor traffic did not justify the roll-out of the current solutions.

4 Benefits and opportunities of in-building wireless solutions

In-building wireless solutions provide benefits and opportunities for mobile operators and also for building owners.

Regarding mobile operators, the deployment of these solutions have the effect of extending their public networks into the private domain letting them achieve different objectives in the medium and long term. In the medium term, they gain greater flexibility to introduce disruptive pricing and bundling strategies. This greater flexibility allows them to accelerate fixed-mobile substitution, not only for voice but also for data services, and to be more competitive, especially in the enterprise market, a fundamental market for mobile operator that represents almost 50% of their incomes.

In the long term, these solutions are crucial for the success of their new mobile broadband service where the ubiquitous access to this service will be a key competitive advantage against offering from other operators such as fixed operators or WISP. Moreover, the roll-out of these solutions introduces a change in the architecture of mobile networks (based on macro and micro cells structure) that improves their scalability as a result of the fact that infrastructures can be placed close to the traffic it is planned to cover and being able to offer high capacity.

In addition to mobile operators, building owners or authorities that manage this high traffic places (hereinafter it will be used building owner to refer both of them) have also shown interest in the roll-out of these IBwS by several reasons.

The first reason is to satisfy the increasing demand from their tenants and customers of having high quality indoor coverage of mobile and wireless services. The roll-out of these solutions by mobile operators is based on an analysis of the return on investment (ROI). As a result, mobile operators have focused their roll-outs on high traffic public places such as airports, subways, convention and exhibition centers, etc. where the high concentrations of users justified the investment and also on building of very large companies where the roll-out is in exchange for a long term contract. However, mobile operators have shown less interest in the roll-out of IBwS in multi-tenant office buildings where they found more difficult to determine how many tenants are their costumers and how long they will reside there. In this situation, many building owners have taken the decision of rolling out these solutions themselves or share the equipment and deployment costs with the operators, especially given the increasing perception of these services as a basic amenity that increase the value of their properties (Wexler, 2007). Moreover, building owners are finding new sources of value that these IBwS can provides such as discounts on insurance premiums on the basis that a wireless communications system inside a building would make it a safer building than one without (it can be seen the case of Akridge [Realcomm Advisory, 2008](#)), development of wirelessly monitor and manage building operating systems and improvements in the provision of public safety services ([In-Building Wireless Alliance, 2006](#)) that appears as especially important in the United States; as an example, in response to the September 11 terrorist attacks, the state of New York passed a law requiring buildings with more than 30 floors to install in-building public safety systems).

The second reason is to simplify the increasingly complex scenarios that building owners have to face given the necessary roll-out of multiple communication systems of multiple operators. The difficulties of managing multiple systems rank as the second most important concern of property owners, according to a recent industry survey conducted by the In-Building Wireless Alliance (Figure 5). In this situation, building owners are taking part in or demanding the roll-out of distributed antenna systems that let a higher infrastructure sharing and simplifies the operation and maintenance.

The third reason is to try to capture the most value possible from the high traffic of mobile and wireless services that is generated in the places which own. For that, they are seeking of new exploitation models of these in-building wireless solutions taking advantage of the necessary access to their property for the roll-out of these solutions and the fact that current legislation allows them to impose conditions to this access as it is shown in next Section. This situation has lead to conflicts between building owners and mobile operators in some cases delaying significantly the availability of mobile services in some of these facilities (an example is the case of the roll-out in the Madrid subway system as can be seen in Table 1). These new exploitation models will be presented in Section 6.

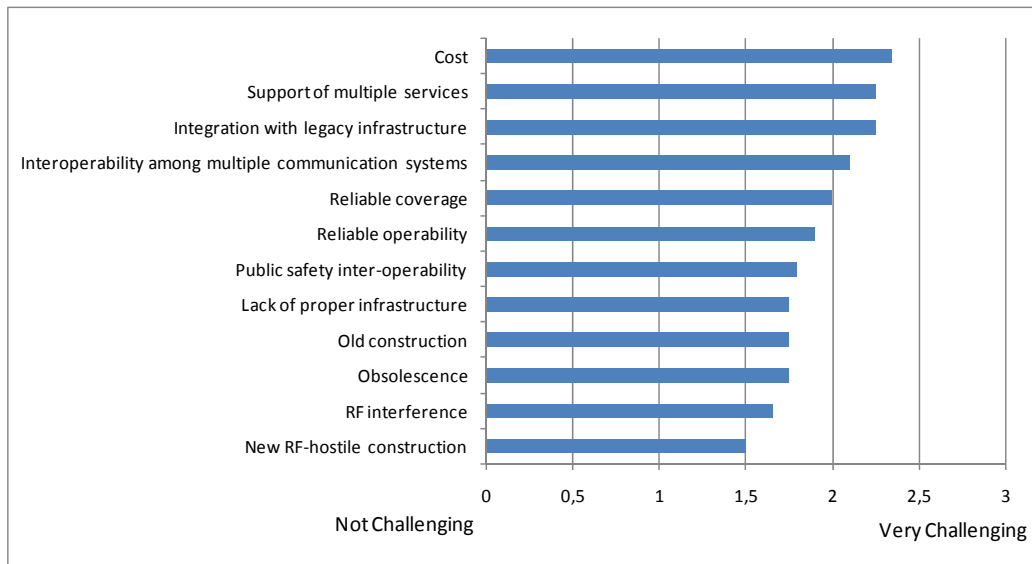


Figure 5 Ranking of Challenges to Implementing In-Building Communications. Source: In-Building Wireless Alliance, 2005 Industry Survey (PRTM, 2006)

5 Regulatory issues involved in the roll-out of in-building wireless solutions

From a regulatory point of view, the roll-out of IBwS involves a conflict between the rights of mobile operators to install facilities in the public or private property and the property rights of the site owner.

Telecommunications operators' access to rights of way is often reflected in telecommunications legislation. These rights were already in force before the liberalization as a consequence of the fact that operators were in need of installing facilities on, over or under public or private property to be able to provide the telecommunication services. The liberalization process of most countries established the principle of competition in the provision of electronic communications networks and services and kept operators' access to rights of way as a necessary condition for a positive development of the infrastructure-based competition in the electronic communications market (see as an example [EU-Commission, 1995](#)).

Nevertheless, in addition to operators' rights of way, there are other rights and public interests involved that also have to be protected such as property rights or the interests of protection the environment, public health, public security or town and country planning objectives.

Therefore, telecommunications legislation of most countries recognizes on the one hand operators' rights to install facilities in the public or private property but on the other, imposes certain conditions to these rights. These conditions try to avoid the damages that could be made to those other rights and interests by the proliferation of telecommunications networks. As a consequence and in practice, operators' access to private property is normally very complicated because depends on the property laws of each country.

In the case of the installation of facilities in the public property, telecommunications legislation usually gives to Administrations with competences in matters affected by these facilities – such as town planning, public health, public security and so on- the authority to establish conditions and requirements to these installations. At the same time, telecommunications legislation also

establishes that these conditions cannot prohibit or have the effect of prohibiting the access to the public property and cannot unreasonably discriminate among providers of functionally equivalent services in order to protect the normal development of competition.

The main aspects of both the European and the American legislation regarding access to private and public property are presented next.

5.1 European legislation regarding the access to the private and public property

In the case of Europe, the Framework Directive⁴ tackles the topic of rights of way in whereas statements 22 and 23 and in articles 11 and 12. The Directive sets that Member States shall ensure that procedures exist for the granting of rights to install facilities on, over or under public or private property that are timely, non-discriminatory and transparent, in order to guarantee the conditions for fair and effective competition. The Directive also sets that the provisions of this Directive are without prejudice to national provisions governing the expropriation or use of property, the normal exercise of property rights or the normal use of the public domain.

Moreover, the Directive also recognizes that facility sharing can be of benefit for town planning, public health or environmental reasons so the Directive establishes that national regulatory authorities shall encourage the sharing of facilities or property on the basis of voluntary agreements. In particular where undertakings are deprived of access to viable alternatives because of the need to protect the environment, public health, public security or to meet town and country planning objectives, Member States may impose the sharing of facilities or property. It covers inter alia: physical co-location and duct, building, mast, antenna or antenna system sharing. Such sharing or coordination arrangements may include rules for apportioning the costs of facility or property sharing and should be imposed on undertakings only after full public consultation.

The issue of the charge of fees for rights to install facilities is tackled in article 13 of the Authorisation Directive⁵. According to this article, Member States may allow the relevant authority to impose fees for the rights to install facilities on, over or under public or private property which reflect the need to ensure the optimal use of these resources. Member States shall ensure that such fees shall be objectively justified, transparent, non-discriminatory and proportionate in relation to their intended purpose and shall take into account the objectives in Article 8 of Framework Directive.

5.2 United States legislation regarding the access to the private and public property

In the case of the United States, the Telecommunications Act of 1996 governs federal, state and local government powers regarding the location of wireless communication facilities (Kim, 2007) in the amending 47 U.S.C. Section 322, entitled “NATIONAL WIRELESS TELECOMMUNICATIONS SITING POLICY”. This amending to the Act gives to different Administrations (State or local government and instrumentality) the authority to make decisions regarding the placement of operators’ base stations and I quote: “*Except as provided in this paragraph, nothing in this Act*

⁴ Directive 2002/21/EC of the European Parliament and of the Council of 7 March 2002 on a common regulatory framework for electronic communications networks and services (Framework Directive)

⁵ Directive 2002/20/EC of the European Parliament and of the Council of 7 March 2002 on the authorisation of electronic communications networks and services (Authorisation Directive)

shall limit or affect the authority of a State or local government or instrumentality thereof over decisions regarding the placement, construction, and modification of personal wireless service facilities”.

However, the Act provides five separate and substantial protections for the applicants in the *section B Limitations*. The effect of this legislation has been analyzed in depth by Tryniecki (Tryniecki, 2002). These protections are the regulation of the placement, construction and modification of personal wireless service facilities by any State or local government or instrumentally shall not unreasonably discriminate among providers of functionally equivalent services and shall not prohibit or have the effect of prohibiting the provision of personal wireless services. Moreover, a state or local government shall act on any request of authorization to place, construct or modify within a reasonable period of time and the deny of a request shall be in writing and supported by substantial evidence contained in a written record.

Moreover, section 704 c) entitled “AVAILABILITY OF PROPERTY” encourage to Federal departments and agencies to *make available on a fair reasonable, and nondiscriminatory basis, property, rights-of-way, and easements under their control for the placement of new telecommunications services that are dependent, in whole or in part, upon the utilization of Federal spectrum rights for the transmission or reception of such services*. This section also encourages States to make property, rights-of-way, and easements under their jurisdiction available for such purposes and establish that *reasonable fees may be charged to providers of such telecommunications services for use of property, rights-of-way, and easements*.

5.3 Negotiation scenario in the roll-out of IBwS

To summarize and despite the rights recognized by the telecommunications legislation, the access to public and private property by telecommunications operators have been very difficult in practice. The problems faced by mobile operators to obtain the authorization for installing base stations are well known.

Therefore, the analysis of the current legislation shows that the roll-out of IBwS by mobile operators is not possible without a previous agreement with the building owner as a consequence of the necessary access to their property. This situation gives building owners a strong negotiation power in a negotiation scenario with the mobile operators to fix the conditions of the access to these places. However, the pressure from the tenants and consumers of these places to have available mobile voice services together with the unavailability of substitutive technologies⁶ and the necessity of having a spectrum license to use these services⁷ force to building owners to achieve agreements with mobile operators. Therefore, this situation drive to a **win-win negotiation scenario** that is resolved with cooperative agreements between the multiple operators and the building owner at least for the mobile voice services. Moreover, these agreements should not contain unreasonably discrimination among the different mobile operators to avoid possible conflicts with national regulatory authorities.

In the case of high bit rate data services, building owners have at their disposal a competitive technology to the 3G services (the Wi-Fi technology) and many of these building owners are already exploited these services with very interested business models such as a shared benefits

⁶ The technology of Voice over Wi-Fi (VoWi-Fi) is not available in many places at the moment and there is also a important problem with the lack of dual terminal that could support this service

⁷ The concessions to the use of spectrum in the case of mobile services provides to the mobile operators the rights to exploit these services in the whole country

agreements with *Wireless Internet Service Providers*. Therefore, building owner could fix harder conditions to the roll-out of these services or even place obstacles to the roll-out of 3G networks if they consider these networks as a threat to their Wi-Fi services profits. Nevertheless, it has not been found any real-life cases of this situation.

In the case of private property, the situation is similar to the case of public property except for the fact that building owners have a greater freedom to achieve agreements with mobile operators. As a result building owners could establish different conditions and prices to the different mobile operators and even give the rights of access to their property to one operator. In this situation, the other mobile operators could claim their rights of access to this property according with the telecommunications legislation and start an expropriation process that will be long and difficult.

6 Main exploitation models

Most of the literature about the roll-out of IBwS is focus on the technological issues having not identified papers that define the main exploitation models of these solutions.

In this paper three different models of exploitation of these IBwS have been identified. These models are based in an analysis in depth of these high traffic places and in different real-life cases identified⁸ (a summary of the most relevant ones are included in Table 1 in next page). The main characteristic that is going to differentiate the different models is who gains the right of access to the building for the roll-out of the dedicated in-building solution.

6.1.1 The model of the public ownership provider

This model has been the more frequently used so far because of the fact that it is the favorite model of the mobile operators letting them a total control of their infrastructures also in these high traffic places. Under this model, the building owners of the high traffic place allow the different mobile operators to access to their property for the roll-out of infrastructures necessary to provide the mobile services. The different operators are therefore responsible of the infrastructure roll-out assuming the risk of the investment as well as the operation and maintenance costs. The operators' return on investment is achieved with the incomes obtained by the services provision inside the building.

Regarding the technical solution used, it is very different from one building to another. In some places, especially in subways and airports, it is increasingly common to roll out DAS in order to avoid the duplication of infrastructure, to share the investment cost and to simplify the operation and maintenance (as it can be seen in the case of Suvarnabhumi Airport; Table 1).

The participation of the building owners in the infrastructure roll-out is limited to provide the access to the building as well as certain facilities needed by mobile operators such as optical fibers, conditioning spaces where install their network equipments, etc. Therefore, the participation and the risk assumed by building owners are quite limited. This model also reduces the possibility of conflicts with the mobile operators.

⁸ It is important to clarify that the models identified in this paper are theoretical and do not correspond completely with none of the real case identifies

Case	Description	Phase
Suvarnabhumi Airport (Bangkok, Thailand)	The country's top five mobile operators have gained the right to roll out an IBwS inside the airport. The five operators have achieved an agreement to roll out a shared Distributed Antenna System that let them to provide mobile services based on second and third generation technologies (Ericsson, 2006).	Operational
Hartsfield-Jackson Atlanta International Airport (HJIA)	The airport's operator (The City of Atlanta's Department of Aviation) has built, owns and manages its own IBwS designed to accommodate all major wireless standards and protocols (both mobile services and Wi-Fi access to the Internet) in the Atlanta International Airport. The system has also enhance airport operations with a completely separate layer to support Public Safety and other operations groups that rely on dependable wireless coverage and service to communicate under regular and emergency circumstances. The main objectives pursued by Department of Aviation with this neutral host system are the following: improve wireless radio coverage for mobile and Wi-Fi throughout the airport, ensure equal opportunities among all the operators, encourage the roll-out of new services and applications in the airport and have an integrated infrastructure that can support all new cellular devices and handheld technology that will be introduced in the market place during the next 10-15 years (HJIA, 2006; HJIA, 2008).	Operational
Madrid Subway System	The project to provide mobile services in the Madrid's subway system was launched in the year 2000 with the set up of Metrocall, a neutral host provider partly participated by the subway's owner Comunidad de Madrid. The plan of Comunidad de Madrid was that Metrocall was responsible of the infrastructure roll-out inside the subway. However, the different proposals of Comunidad de Madrid (first trying to get a spectrum license for the use of GSM inside the subway system and then making an exclusive agreement with one mobile operator that would provide roaming services to the rest of operators) was rejected by mobile operators and some of them by the Spanish National Regulatory Authority. Finally, the agreement was achieved in 2005. Mobile operators accepted that Metrocall was responsible of the DAS inside the subway in exchange for an annual fee that let Metrocall to finance the infrastructure in addition to the operation and maintenance costs (Cinco Días, 2006). Despite the agreement, mobile services are only available in a few lines nowadays what shows that mobile operators do not completely agree with the actual exploitation model	Operational/ Roll-out
Nueva York Subway System	Metropolitan Transportation Authority invited tenders to send proposals for wiring the 277 underground stations in the New York subway system to provide cellular and Wi-Fi services. The company that finally have won the right to wire the stations is Transit Wireless, a joint venture involving Nab Construction, Q-Wireless, Dianet Communications and Transit Technologies, will pay New York City Transit a minimum of \$46.8 million over 10 years. The company will also pay the full cost of building the wireless network in the underground stations, estimated at \$150 million to \$200 million. Under the agreement, mobile operators would pay the company a fee to carry their signals on the network (New York Times, 2007).	Roll-out
Aéroports de Paris	Aéroports de Paris has taken advantage of its experience in the airport sector and in the telecommunication services provision to its own employees to set up Hub Télécom. Hub Télécom is a new telecommunications operator that provide services as a specialized operator in certain sites characterized by a high concentration of business traffic, a need for (and a habit of) mobility, which is a real added value especially for large sites and a community dimension, providing the possibility to share resources in the general interest of all concerned. Hub Télécom is expanding its business providing services to tenants of Aéroports de Paris' airports first and then moving to other places such as business center, convention and exhibition center, business hotels, etc (Hubmag, 2005a, 2005b). Moreover, a consortium that include this company ⁹ has been awarded with 12 regional WiMAX licenses including the region of Paris (Hub Télécom, 2007) and Hub Télécom has reached an agreement with Orange to provide a mobile voice service together for Hub Télécom's customers (Hub Télécom, 2006).	Operational

Table 1 Summary of the most relevant real-life cases of the roll-out of IBwS identified

⁹ Bolloré Télécom, the consortium bringing together Hub télécom, Bolloré and Antalis-TV

Nevertheless, it reduces the control that the building owners have on the roll-out of infrastructures inside their buildings as well as the incomes they can obtain from these services. These incomes will be basically associated to a tax for the occupation of physical space inside the building, the several facilities provided to the mobile operators and a fee for the right of access to their property. The amount of the latter fee is based on a negotiation between the building owner and each operator and could be fixed in function of the number of base stations, carriers, users that are or passed by these places, etc.

6.1.2 The model of the neutral host provider

Under this second model, building owners grant the right of access to their property as well as the design, roll-out, exploitation, operation and maintenance of the in-building wireless solution needed to provide all the mobile and wireless services inside the building to an undertaking who will be a neutral host provider.

The business model of this host provider is based on the provision of a wholesale service of access to the IBwS to the different mobile operators and Wireless Internet Service Providers (WISP) who want to provide their retail services inside the high traffic place. The incomes from these wholesale services should allow the host provider to cover the investment and the operation and maintenance costs of the IBwS, the fee to be paid to the building owner for the right to exploit the IBwS as well as to provide a sufficient operating profit.

The building owners could decide to become themselves in the host provider in their buildings by many reasons (see Section 4). For example they could decide to include these IBwS in their investment plan as another facility once recognized the high value that a good quality of mobile and wireless coverage has for their tenants and users. This decision allows them to ensure a good quality of services for the different mobile and wireless services as well as to facilitate a competitive pricing structure by establishing a truly neutral host system (see the case of the Hartsfield-Jackson Atlanta International Airport in Table 1). Being the neutral host also provides other advantages to the building owners as keeping a major control of the infrastructures roll-out in their buildings and larger incomes for the provisioning of mobile and wireless services in their buildings. In exchange, it involves a greater risk for them due to they have to assume the investment, the operation and maintenance of the IBwS as well as the coordination with the different operators.

On the other hand, building owners could choose the neutral host provider by means of an open request for tenders as it has happened in the case of the New York subway (Table 1). In addition to the mobile operators, other companies with different backgrounds could be interested in being a neutral host providers mainly providers of in-building solutions, tower companies and even construction and real estate companies. The main challenge to be faced by this neutral host provider will be the negotiation of the prices of their wholesale services with mobile operators. The case of the Metro de Madrid showed as this negotiation may lead to great conflicts between the mobile operators and the neutral host provider (Table 1).

6.1.3 Model of the operator specialized in complex sites

The last model arises from the previous one in which the neutral host provider not only provides wholesale services of access to the IBwS but also retail services by means of a strategic alliance with the building owner and taking advantages of the available technologies.

This model is especially interesting in high traffic places such as airports, office buildings, enterprise centers, etc. where there are a high number of tenants with specific and common

needs. In these places, the host provider can take advantage of his control on the infrastructure inside the building as well as his knowledge of the characteristics and needs of the tenants to provide services to the tenants and users of these places.

This operator could provide voice and data services using the Wi-Fi technology as well as could benefit from the imminent apparition of the WiMAX technology to offer truly mobile services either acquiring the corresponding spectrum license or using WiMAX in the license-exempt frequency bands.

Nevertheless, the success of this operator will be dependent on the capacity of this operator to ensure the provision of these services also outside these high traffic places that can be achieved either seeking an alliance with a mobile operator or taking advantage of the current legislation of many countries to become a Virtual Mobile Network Operator (VMNO). The main real case that can be used as an example of this exploitation model is the case of Hub Télécom in spite of not being a neutral host provider but only a retail service provider (Table 1).

7 Conclusions

The high demand of mobile and wireless services that is generated in some specific places such as airports, subways, conference and exhibition centers, etc. make necessary the roll-out of dedicated in-building solutions.

These solutions offer important benefits for mobile operators who gain greater flexibility to introduce disruptive pricing and bundling strategies, ensure the access to their mobile broadband services and improves the scalability of their public networks. In addition to mobile operators, IBwS also offer opportunities for those building owners who want to take part in the roll-out of these solutions. As a result, new exploitation models of these IBwS are emerging in which building owners are taking advantage of the necessary access to their property to capture the most value possible from the provision of mobile and wireless services in their building.

However, mobile operators and building owners should recognize the value of each part to avoid conflicts that delay the availability of the new high bit rate data services in these places.

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