284 23-3026 Uen Rev B

March 2008

WIRELESS NETWORKS FOR IN-BUILDING ENVIRONMENTS

White Paper

In-building solutions are becoming increasingly spread, as user demands for everywhere coverage is matched by the opportunity for mobile operators to offer improved services and increase traffic revenues.

ERICSSON

TAKING YOU FORWARD

Contents

1 Executive summary

In-Building Solutions, IBS, are solutions that provides mobile coverage inside buildings, where the coverage, capacity or quality otherwise would not had been satisfactory. IBS can include both cellular standards such as GSM, WCDMA, CDMA2000 and/or non-cellular standards like for example Wireless LAN and Bluetooth.

In-building solutions are increasingly deployed and introduced to mobile networks, as user demands for “everywhere coverage” are matched by the opportunity for mobile operators to offer improved services and increase traffic revenues. Site owners more frequently appreciate and recognize the value of IBS, that most often enhances the general perception and value of the property, and provide a tailor-made infrastructure that may both attract as well as retain key tenants.

Today’s mobile operator performs a profitability analysis on prospective in-building locations, based on the estimated generated traffic in a particular building. If the estimated traffic exceeds operator specific parameters at a specific in-building location, operators may justify the investment in the solution. Measurements show that up to 80% of the traffic generated from an in-building site is new traffic. If one chooses the right buildings, experience shows return on investment for an in-building solution is within two years.

Mobile operators expect that the increased usage of high-speed data services, such as mobile broadband, will require a larger number of in-building sites. This is particularly apparent in already deployed 3G mobile networks in urban areas.

In-building solutions in combination with standard and customized wireless applications will offer additional value to the buildings. Visitors and employees in the buildings may, for instance, use their mobile phones and laptops to access data that previously was not accessible via wireless devices.

Building owners, enterprises, tenants, authorities (depending of type of building) and mobile operators may all benefit from the advantages that an in-building solution provides.

People nowadays to a large extent also expect their mobile phones to work inside shopping malls, airports, metros, offices, hotels etc, and increasingly in places such as road and train tunnels, elevators and underground garages.

Present and future mobile Internet services with high data rates provide numerous opportunities for the operators where tailor-made application packages may be introduced to satisfy any end-user service requirement at for example an office, airport, exhibition centre or subway station, conference centre, hotel or shopping mall.

2 In-Building Solutions - Concepts

An in-building solution may be offered in many different ways. There is always a trade-off between quality and cost. Furthermore, there are as many tentative solutions as there are designers. One has to consider as many aspects as possible but still ensure that the In-Building Solutions, IBS, eventually meets either the return of the investment or meet the customer specific requirements, or both. In most cases, the payback time for a standard solution is less than two years. Ordinarily, coverage from the macro network via outdoor antennas penetrates into the buildings but needs for many buildings be complemented by dedicated IBS.

Greater data capacity and the ability of 3G networks to provide high-speed data services, increase the demands put on the mobile network. Subscribers have great expectations regarding 3G services. Therefore, when introduced, the new services must often be available everywhere the 2G services are accessible.

The implementation of dedicated in-building coverage enables new traffic for the mobile operators in areas that previously were “black holes” and offloads the macro system in areas with overlapping in-building and macro network coverage, thereby increasing overall system coverage and capacity.

Three important aspects to consider when designing and deploying an IBS are coverage, capacity and quality. A well-designed IBS covers the building according to the requirement specifications, i.e. mobile coverage wherever desired. The in-building cells are usually smaller then the macro cells and can thus provide greater capacity than outdoor cells. It also provides low interference levels resulting in good voice quality.

Tenants on the top floor of a high-rise building, for instance, may experience poor quality although the received signal strength from the macro network is very high. There may simply be too many interfering signals. A dedicated IBS would provide the tenants with a dedicated signal that would solve the issue of other interfering signals from other parts of the macro network.

A football stadium with good coverage from the macro network may require additional capacity to cater for the needs of thousands of spectators during big events. Again, a well-designed IBS would cater for the high capacity needs.

A number of parameters and requirements need to be considered when designing an IBS for a football stadium or an office building, such as size, internal layout, number of expected users, type of architecture, etc. Often a preliminary design is made based on blueprints of the building. The in-building solutions network engineer suggests a preliminary design based on a site

survey that complies to the building and macro specific requirements. Initial radio measurements may also be included, if needed.

To further illustrate the different needs that may be considered in a design, a few different building types and possible mobile applications are mentioned:

- **Offices/industries**: “Wireless office”, Mobile Extension, corporate Intranet, work orders, supervision, production control, etc.
- **Airports and bus/train stations**: travel information, check-in, booking, local transport information, duty free/shop advertisement, access to Internet via mobile broadband etc.
- **Conference and exhibition centres**: Portal info, info/notifications, voting, enquiries, visitor feedback, access to Internet/Intranet via mobile broadband etc.
- **Hospitals**: staff/patient communication, patient journal management, reminders/notifications to staff, patient supervision, etc.
- **Hotels**: staff and service management, booking, Internet, check-in, etc.
- **Shopping malls**: advertisement, info to visitors, item search, finding friends, staff communication etc.

Some of the most used solutions for providing in-building coverage are described in the following subchapters.

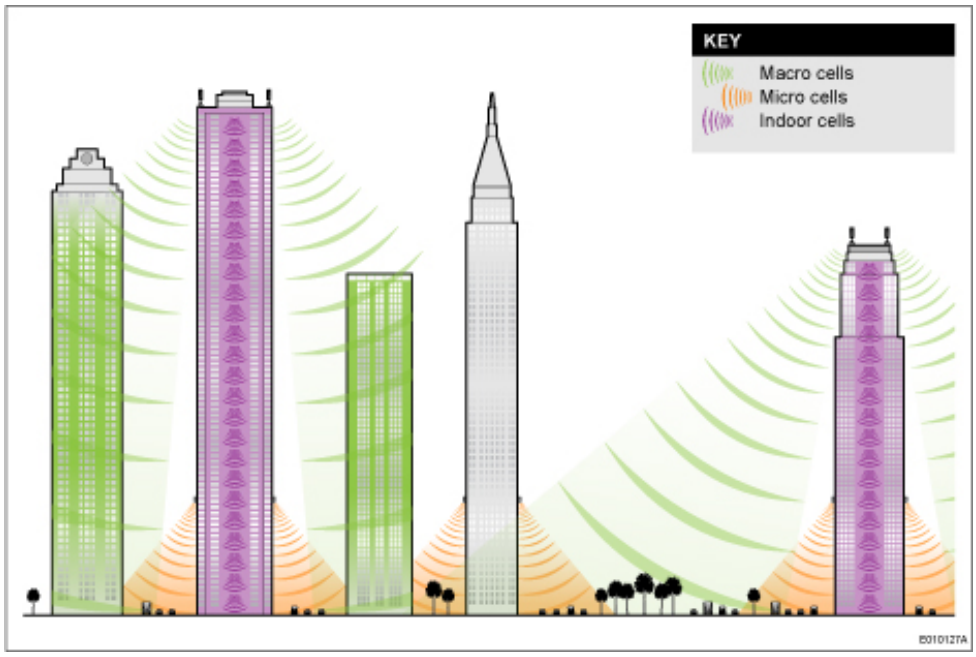

Figure 1 In-building coverage via macro, micro or indoor cells, resulting in different quality of the mobile coverage inside the different buildings.

2.1 Macro Network Coverage

The most common way of providing buildings with mobile coverage is to penetrate buildings with signals from the macro network, i.e. from outdoor Radio Base Stations, RBSs, with antennas mounted on towers. In many cases this provides a satisfactory in-building coverage, but in other cases it is far from acceptable.

Thick walls, metal-coated windows and other obstacles often hinder radio waves from penetrating inside buildings. Tunnels, metros and underground garages are obvious examples where in-building coverage generally tends to be poor, unless a dedicated in-building solution has been implemented.

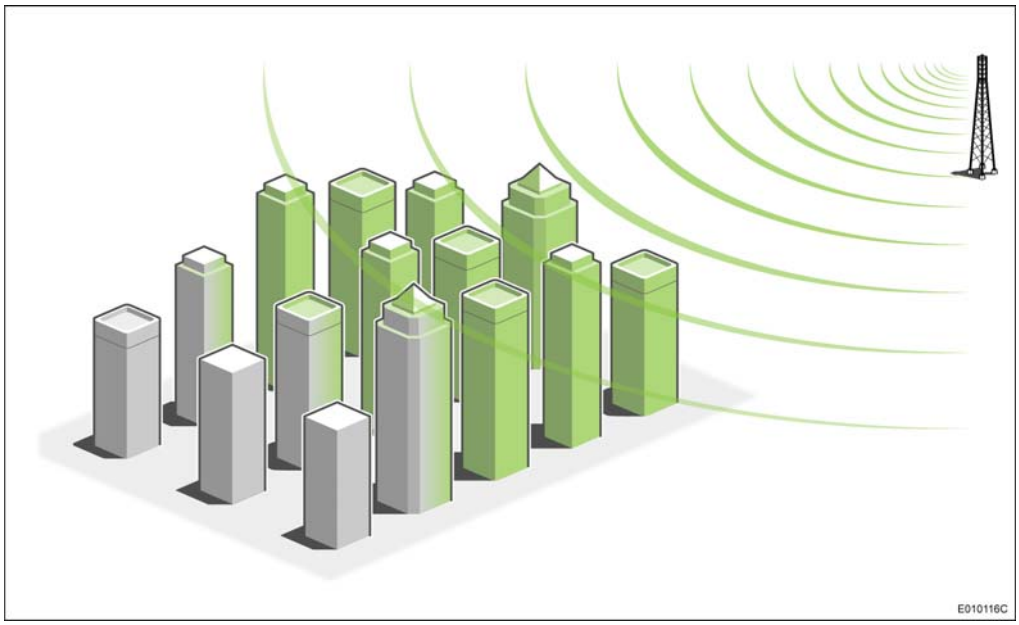

Figure 2 In-building coverage from a macro cell in the macro network.

In some cases in-building coverage from the macro network can be boosted by a dedicated RBS[1] located outside the building with antennas pointing at the building. This is often referred as hotspot either or micro cell solutions due to the smaller cell size. This solution can cover outdoor as well as indoor areas.

[1] RBS is sometimes referred to as BTS (Base Transceiver Station) or Node B.

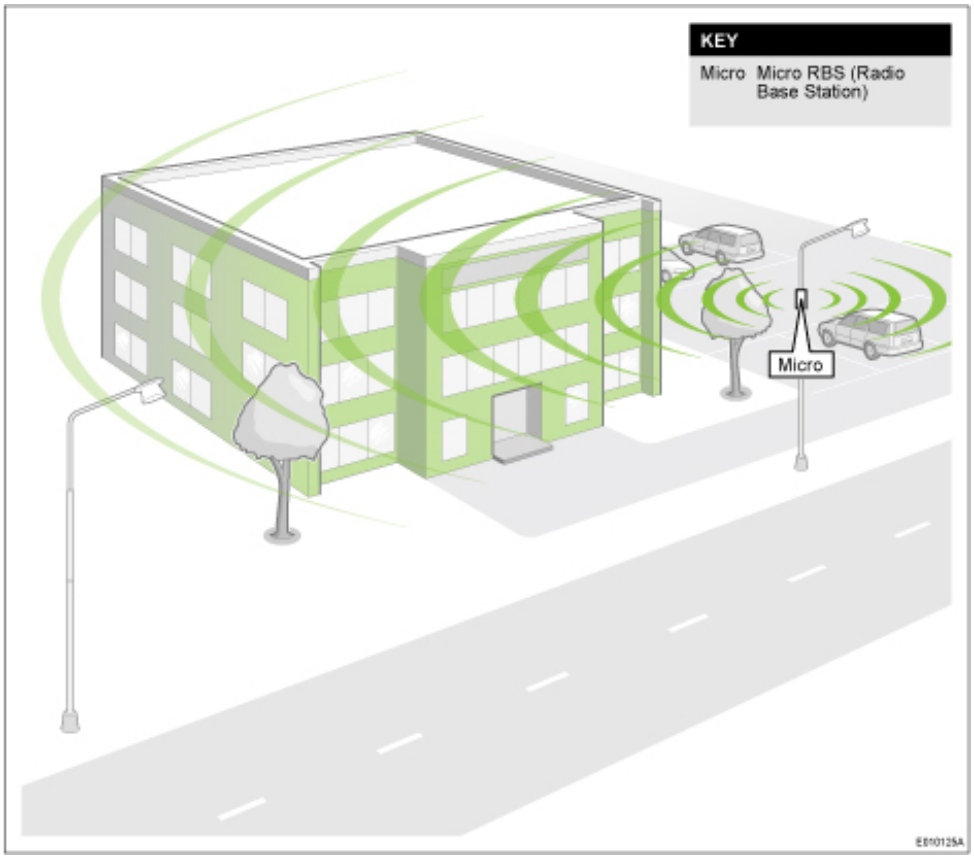

Figure 3 An RBS mounted on a lamppost penetrating into the building from outside.

The solution illustrated in the Figure 3 can provide the necessary coverage and capacity in many cases, but for bigger buildings or buildings with many users, the quality may not be adequate.

An RBS can also be mounted in trailers and vehicles that can be moved to places where there is a temporary need for coverage and/or capacity. This is similar to the solution in Figure 3, although the hotspot can be moved fairly easily. Examples include big events at exhibition centres, concert halls and sports arenas.

2.2 Coverage using Dedicated In-Building RBS

In-building coverage using one or several dedicated radio base stations, RBSs, is the most common solution for bigger in-building sites, such as airports, metros, shopping malls, offices, campuses etc, where both coverage and capacity are important issues.

A number of different RBSs are available. Macro RBSs are bigger in size and have usually a high power RF output and can handle the highest capacity. The macro base stations are placed on the floor and are available in either indoor or outdoor cabinets. The indoor cabinets are mostly used for in-building solutions, but RBSs with outdoor cabinets are sometimes used in e.g. underground garages in sites where no equipment room was available.

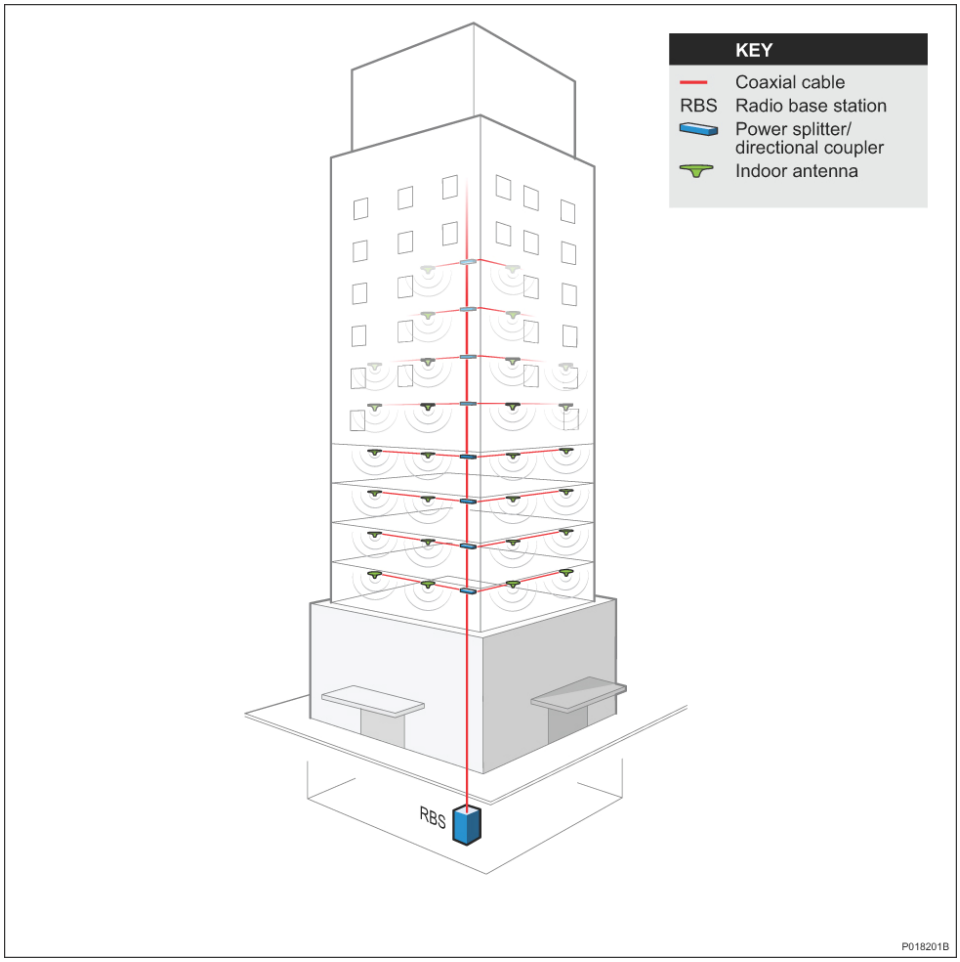

Figure 4 An in-building solution with a macro RBS connected to a passive coaxial distributed antenna system covering a large-size building.

Micro RBSs are the mid size version in regards to physical size, output power and capacity. The micro RBSs are usually mounted on a wall and therefore require only a small footprint.

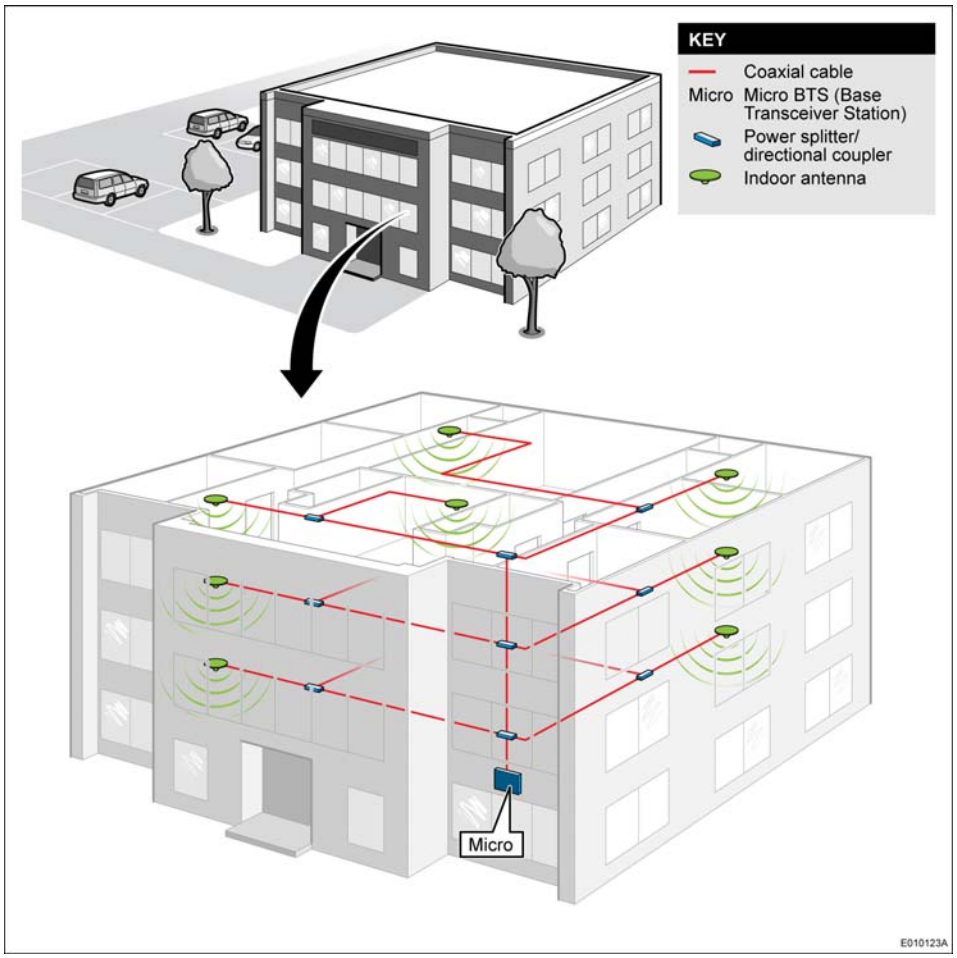

Figure 5 An in-building solution with a micro RBS connected to a passive coaxial distributed antenna system covering a mid-size building.

Examples of in-building sites include for example mid-sized building where the capacity needs are medium, but also in tunnels, metros train stations and other sites where there are limited space and maybe no equipment rooms are available.

An installation including only one micro RBS can usually be extended with one or more micro RBSs if capacity demands require this.

The second smallest RBS is usually referred to as pico RBS and has a low output power (typically a few hundred mW). A pico RBS can be equipped with an integrated antenna, but there is also a possibility to connect it to external antennas such as distributed antenna systems. The stand-alone configuration is suitable for coverage of limited parts of a building, especially open areas. Coverage of a large building is more cost efficiently achieved by connecting the pico RBSs to small distributed antenna systems.

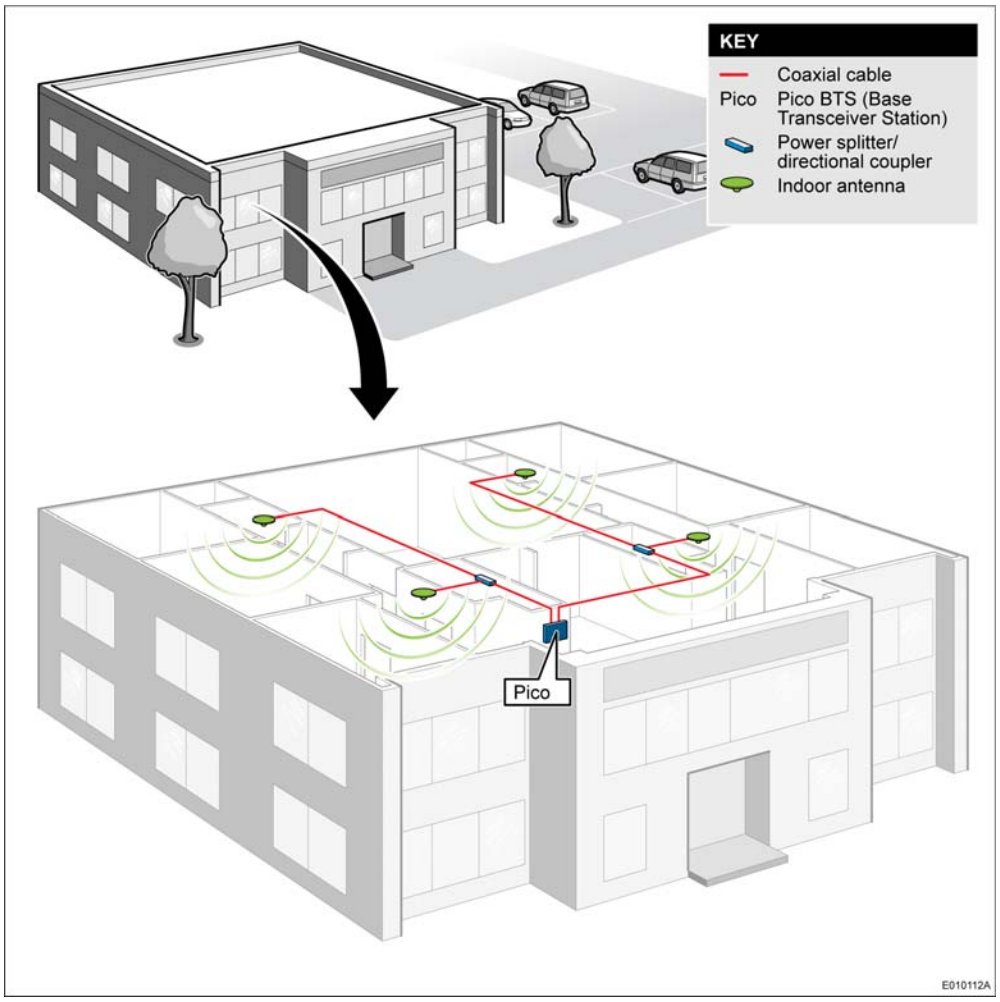

Figure 6 A pico RBS connected to a small coaxial distributed antenna system covering a small-size building (or part of a building).

Typical sites where pico RBSs are used include smaller buildings and offices for small to medium sized companies. The transmission lines between the pico RBSs and the mobile networks are often based of xDSL conections.

Some RBSs are implemented with the traditional RBS functionality distributed in several separate cabinets. In the so-called Main-Remote RBS the radio specific HW for each sector is contained in a Remote Radio Unit, RRU. The rest of the RBS functionality is contained in a Main Unit.

The main unit can be stored in a central equipment room while one or several RRUs, connected via optical fibres to the main unit, can be installed far away from the main unit. The RRUs can be connected to antenna systems in e.g. both a main building as well as some satellite buildings, high up in skyscrapers etc, which are impossible to reach via coaxial cables from a centralized traditional RBS because of the feeder losses.

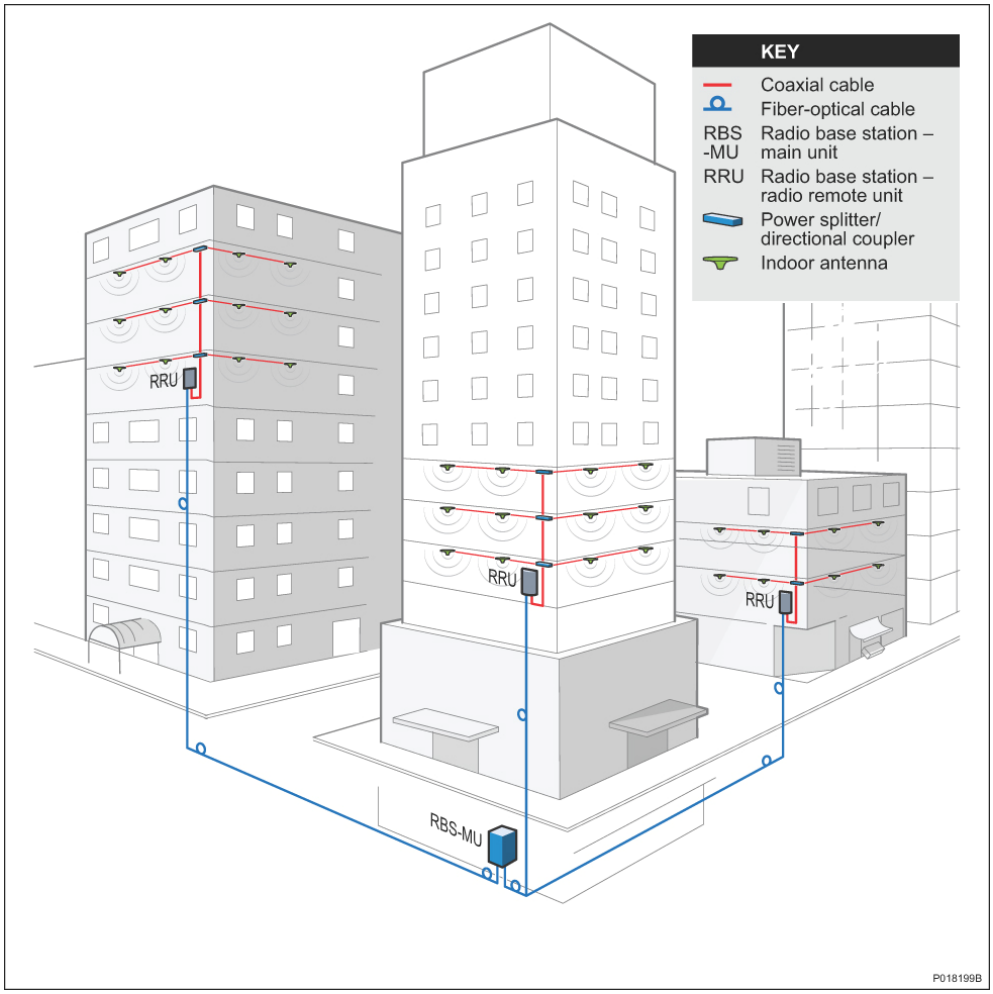

Figure 7 An in-building solution with one main-remote RBS covering two different buildings. The radio remote units, RRUs, are connected to the main unit via optical fibres.

The RBSs are usually connected to the mobile operators' networks via copper wires, optical fibres or microwave link connections, but also satellite links are sometimes used. The output ports of the RBSs are connected to one or several antennas. An antenna system with several antennas is usually named Distributed Antenna System, DAS.

Depending on the implementation, the DAS can serve one or several operators and one/or several bands (e.g. GSM 900, GSM 1800 and WCDMA). In some cases the DASs can be used to concurrently distribute both cellular and non-cellular bands, e.g. both GSM and WLAN in one and the same antenna system.

The DASs can consist of either passive or active components. When both active and passive components are used in a DAS, it is often referred to as a hybrid solution.

Some advantages of a dedicated RBS connected to a distributed antenna system, DAS, are that it is possible to ensure both dedicated coverage and capacity, confine the signals, prevent spillage and interference and thus enhance the quality for both speech and data services. In addition for enabling new traffic in previous non-covered areas, the solution also off-loads the macro network in overlapping coverage areas. The RBSs are normally owned by mobile operators.

2.3 Coverage using Repeaters

In-building solutions with repeaters (radio frequency repeaters) are widely used for coverage of e.g. road and train tunnels, but can also be used for other types of buildings or parts of buildings.

A repeater has a donor antenna that is used for communicating with a radio base station, RBS. The repeater amplifies the received signals from the RBS and transmits it via a service antenna. The signal amplification enables mobile users to receive a better signal strength and thus quality in their mobile phones.

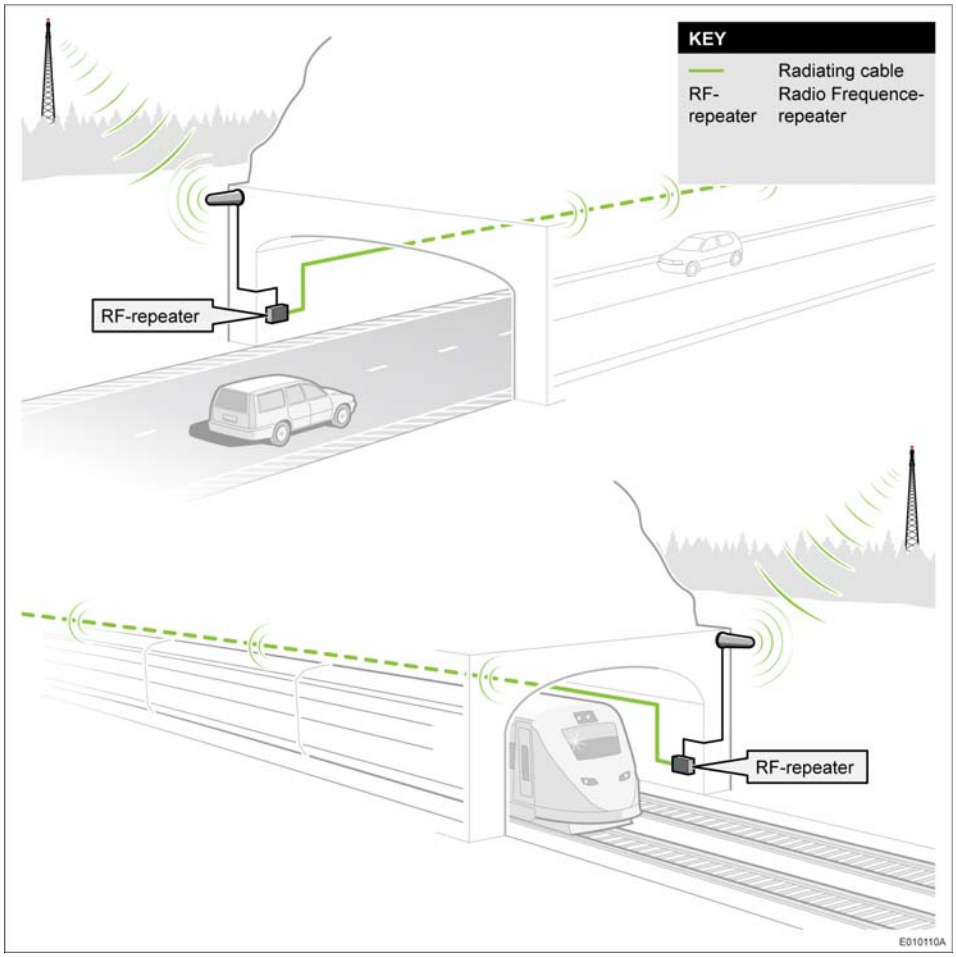

Figure 8 In-building coverage using repeaters (with the donor antennas visible on top of each tunnel entrance).

Repeaters can be connected to external antennas or other repeaters if the task is to cover bigger areas. Some of the advantages with repeaters for in-building solutions include the fairly easiness these may be installed (e.g. no transmission equipment are needed) and that one promptly may get enhanced coverage in a certain area. Repeaters can also be used for coverage inside trains, on ferries when near costal areas and in other moving vehicles.

One of the main disadvantages with repeaters for in-building solutions is that they do provide no or a very limited additional capacity and downloads the macro network cell from which the donor antenna picks up the signals. The inability of accurate mobile positioning can also be an issue when using repeater solutions.

Repeaters are usually owned by mobile operators. Many different types of repeaters are available, from small low power repeaters (for e.g. smaller shops) to high power repeaters that can be connected to antenna systems. Repeaters are available for most systems and frequency bands.

2.4 Coverage using Femto Cell Solutions

The Femto cell solutions consist of a low power RBS that can be installed in the end-users homes and connected to the mobile operators' networks via e.g. ADSL connections. These are the smallest RBSs and can be installed by the end-users themselves.

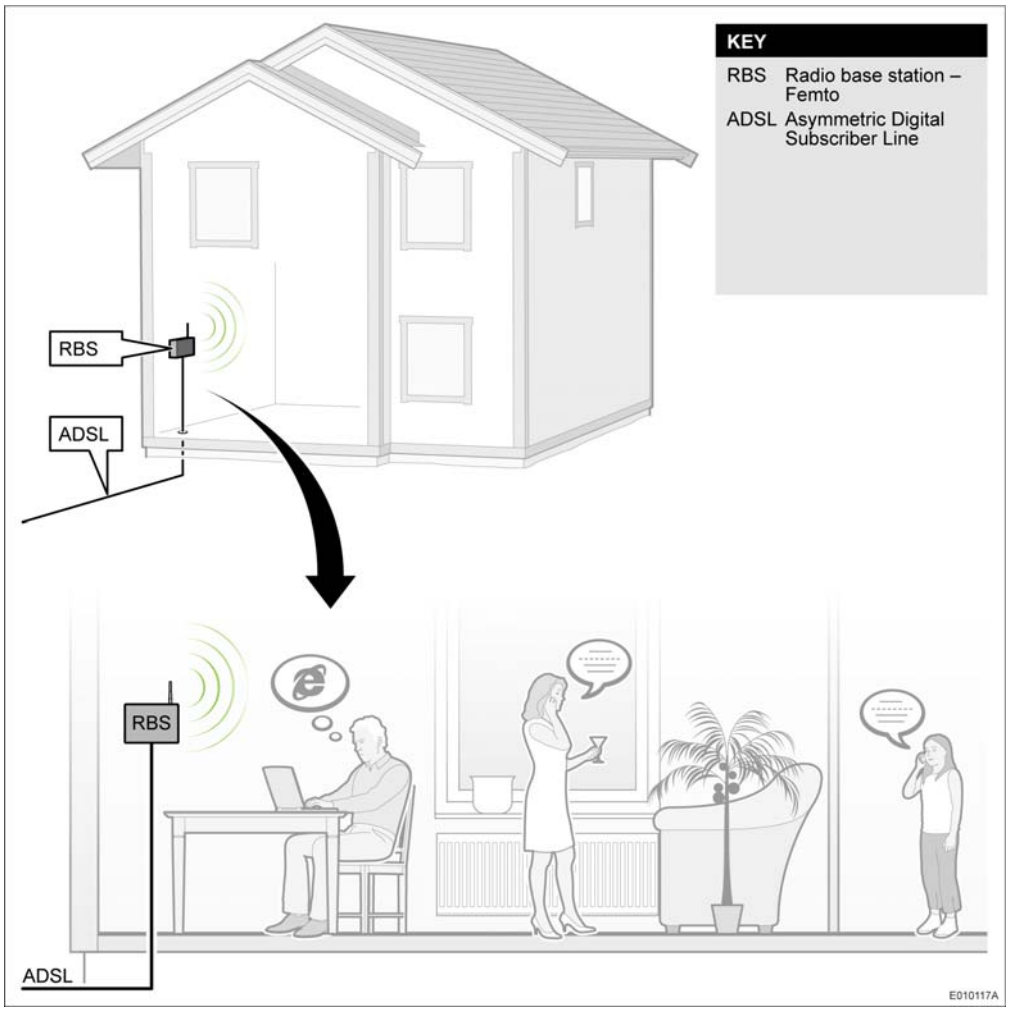

Figure 9 An example of a Femto Cell solution.

Typical examples of sites for Femto cell solutions are private homes. This include both houses and apartments, either where the mobile coverage penetrated from the macro networks perhaps is poor or to for example get hold of special family & friends tariffs offers from the operators.

2.5 Distributed Antenna Systems

As already mentioned, a distributed antenna system, DAS, consists of either passive or active components or a mix of passive and active components. The passive DASs are the most commonly deployed and consist of coaxial feeder cables and components such as antennas, power tappers and power splitters. Radiating feeders work as a combined feeder cable and antenna. They are often used in tunnels and culverts.

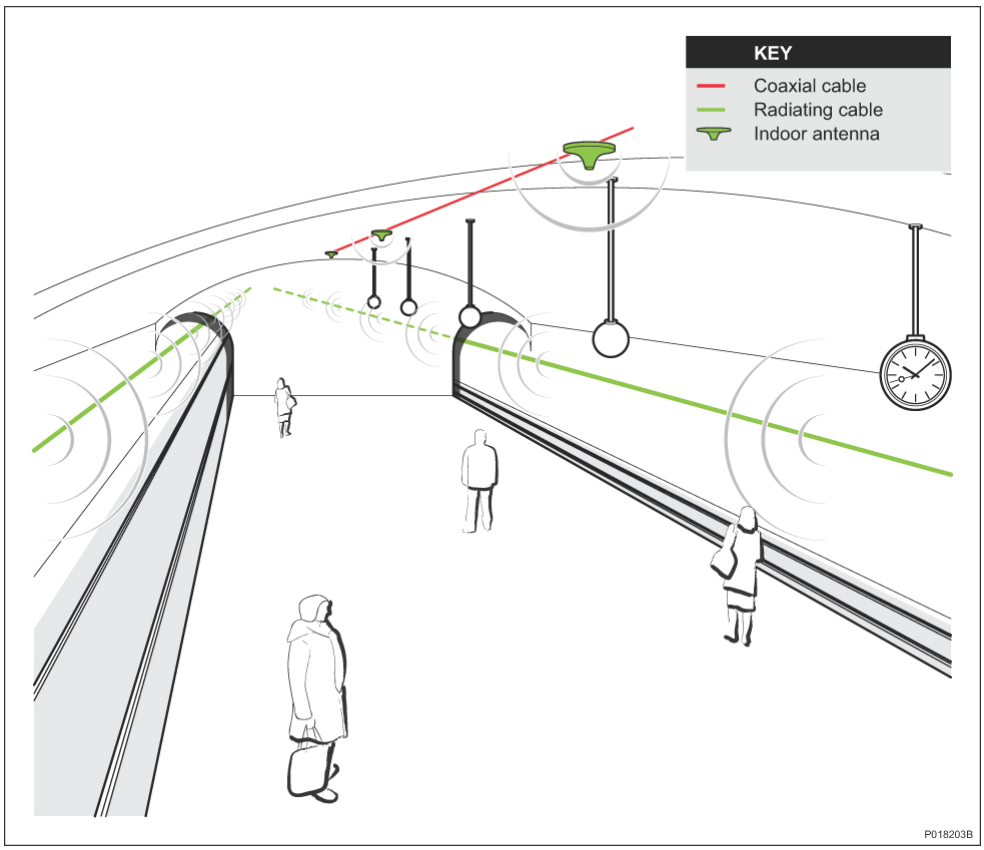

Figure 10 An example of a metro solution with radiating cables in the tunnels.

Distributed antenna systems, DASs, can be implemented in many different ways and some of the most frequently used designs are presented in this document.

The most commonly deployed DASs are the passive coaxial cable solutions that are shown in for example Figure 4, 5, 6 & 7. These consist typically of a micro or a macro base station that is connected to a number of distributed antennas via coaxial cables and combining equipment such as power splitters, power tappers, combiners, multi casting matrixes etc. The DASs can support one or several mobile operators and one or several mobile technologies (GSM, WCDMA, CDMA2000, TETRA etc).

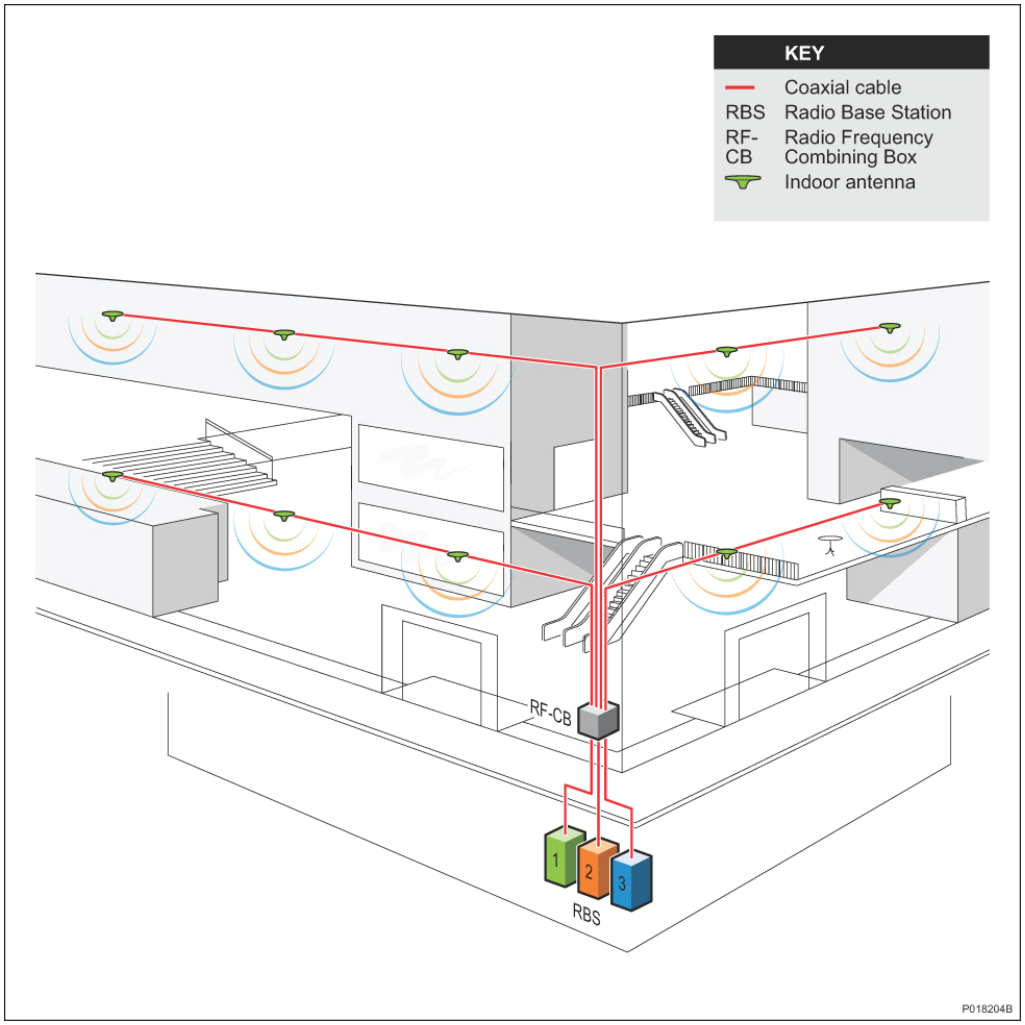

Figure 11 An example of a multi-operator coaxial cable solution with dedicated indoor RBSs that are connected to a common distributed antenna system, DAS.

Figure 11 illustrates an example of a passive distributed antenna system, DAS. The DAS can be designed to handle several bands or wireless standards and/or several operators. Sharing a single DAS between several operators / bands will reduce costs and minimize any disturbance to the building and tenants compared to the scenario where a multitude of DASs were deployed in the same building.

The DASs can be single or multi operator solutions and handle one or several bands (for example both GSM and WCDMA in a common antenna system). In e.g. multi-band and/or multi-operator solutions where more than one RBS shall be connected to the DAS (like in Figure 11) an interface between the DAS and the RBSs is needed. This interface can be built by RF filter components. There are also off-the shelf products such as combining boxes and multi casting

matrixes are available on the market. These units are tested and tuned on factories and minimises the verification tests on the sites.

Figure 12 An example of triple band combining box. This unit can be used as the interface between a distributed antenna system and up to twelve radio base stations (up to four RBSs per band).

The passive DAS is suitable for many kinds of buildings and requires a minimum of operation and maintenance after it has been deployed. However, depending on e.g. the size of the feeders and the frequency band to be distributed, the maximum length of coaxial feeders is normally limited to a few hundred meters. In e.g. tunnels where it is possible to install very thick feeders, the feeder lengths can be several hundred meters.

If larger areas with longer distances are to be covered, fibre-optical solutions may be the desired and most preferred solution. These solutions are sometimes called active antenna systems or fibre-optical repeater systems.

Fibre-optical solutions are often combined with passive DASs, where the passive DAS distributes the RF-signals (via coaxial cables) in the areas closer ranges from the RBS, and the fibre system feeds the longer distribution distances. This concept is usually referred as a hybrid solution.

Several fibre optical solutions are available from different vendors and some of the basic concepts are described in this document. These solutions consist of a central unit that can be connected to several remote units via optical fibres. Depending on e.g. the output power from the remote units, one, two or many antennas can be connected. Many fibre-optical solutions can also be used to handle one or several operators and/or one or several bands.

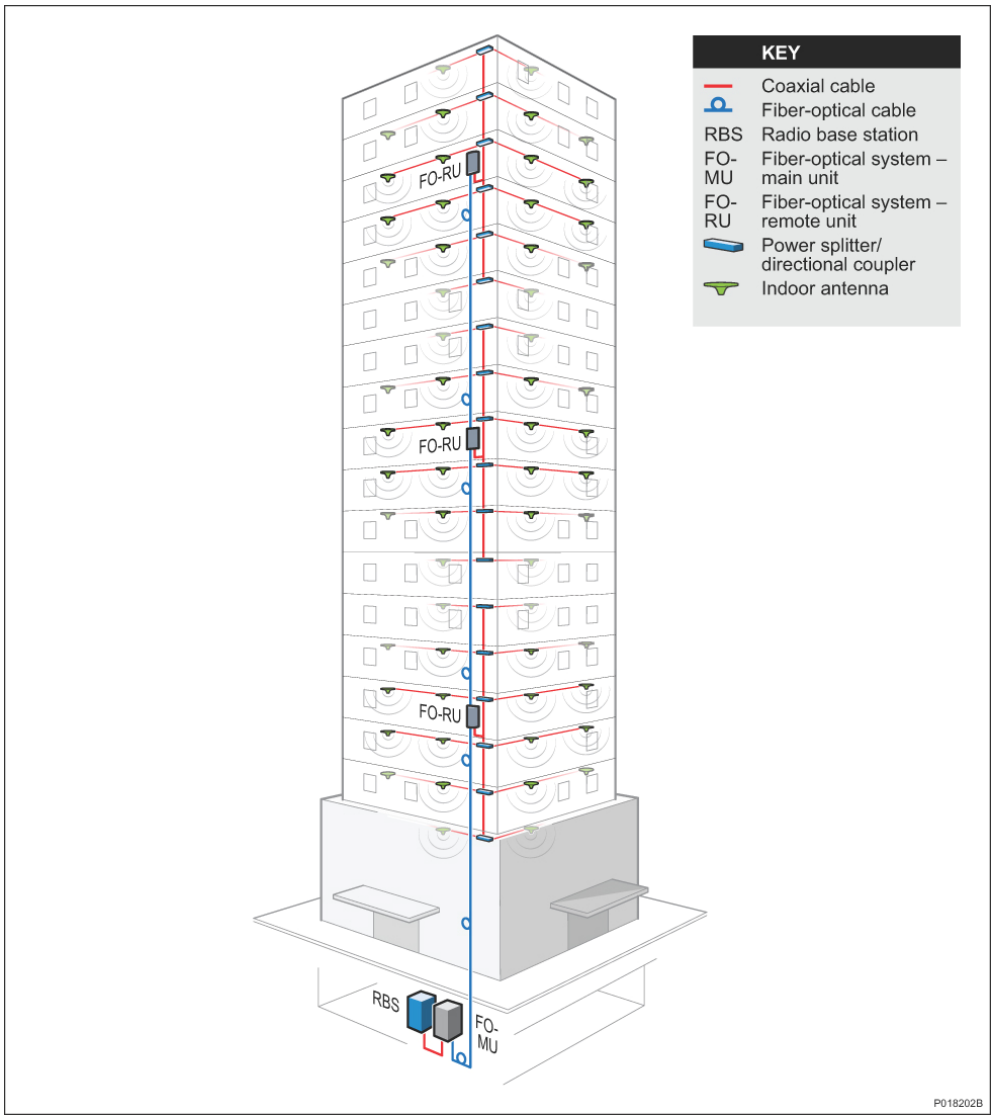

Figure 13 An example of a fibre-optical DAS covering a high-rise building.

Some of the biggest advantages of an active DAS, compared with passive coaxial DASs, are the much longer distribution distances as well as the smoothness and ease with which one may install the optical fibres. The initial cost of the system as well as the operation and maintenance costs are commonly higher than for a passive solution.

Single-operator DASs are typically owned by the mobile operator, while multi-operator DASs tend to be owned by other players in the market, such as neutral host providers, building owners, government authorities and enterprises.

3 Benefits of In-Building Solutions

For mobile operators, in-building solutions off-load the macro network, and thus permit increased mobile traffic. The IBS may attract new subscribers due to the enhanced mobile network quality and accessibility to mobile Internet applications and other offered services.

In-building solutions may be considered a necessity in a highly competitive market where outdoor coverage is no longer the major differentiating factor. In-building solutions offer much more than just coverage. Some drivers for in-building solutions are noted in below subchapters.

3.1 Benefits for the Mobile Operators

New traffic resulting in increased revenue streams

In-building solutions is a well-proven method for an operator to capture new traffic and revenue streams. Having in-building coverage means more calls and longer duration of calls from the building and to the building. This means also that an in-building solution enables a new revenue stream in addition to the macro network.

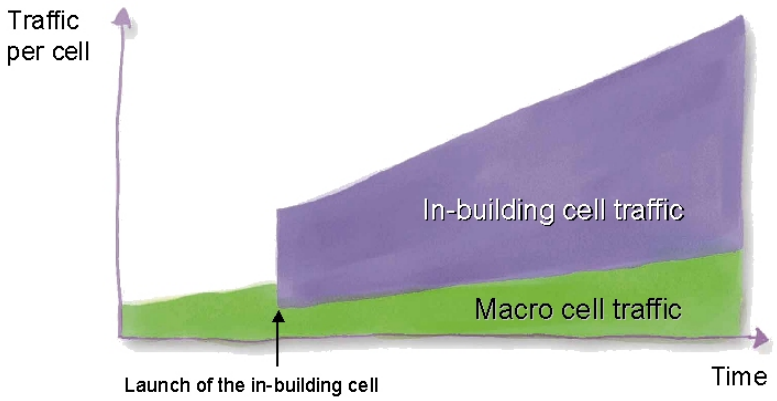

Figure 14 Increased traffic from in-building site over time

Measurements show that up to 80% of the traffic generated from an in-building site is new traffic. This is traffic and revenue that would otherwise have been lost without the in-building solution.

Competitive edge and image

Having good coverage “everywhere” helps the operator on any competitive market to keep their competitive edge and build the image of a high quality mobile network. This is a business advantage that helps to retain existing subscribers as well as attracting new ones. Good in-building coverage and quality will therefore reduce the churn.

Network off-load which frees capacity

The traffic generated from the building, with an in-building solution, off-loads the macro network. The freed capacity in the macro network can therefore be utilized for the increase of traffic in the macro cell instead of having to provide coverage of the building as well. This means that the operators may postpone investments in the macro network.

Prepared for future needs with excellent network quality

The deployment of 3G networks with new high-speed data services (e.g. mobile broadband and TV in the mobiles) as well as an expected increased demand from end-users for fixed to mobile substitution, everywhere coverage etc, highlights the need for dedicated in-building solutions. In-building solutions are required for providing good quality wireless data (e.g. EGDE, WCDMA and CDMA2000) where a higher carrier to interference (C/I) ratio and a higher capacity (data throughput) are needed.

A dual GSM/WCDMA network, with good in-building coverage, will function better with fewer handovers to GSM and less undesired load of the GSM network. Without a good WCDMA coverage there is a risk that a 3G user (with a WCDMA/GSM phone) will connect to the GSM network that may penetrate better into the building.

For example is Ericsson's "combining box" portfolio enables multi-operator and multi-system solutions. Both single operator multi-systems and a multitude of multi-operator solutions can be handled by combining existing 2G and future 3G technologies for a single operator or multiple operators, with the consistent reduction of hardware-, installation -and maintenance cost.

Booster of Mobile Internet and Applications

General trends and forecasts all indicate an impressive growth of mobile data traffic. Several 3G operators have already started to offer flat rate subscriptions or subscriptions with a large amount of data for a fixed monthly fee. This enables PC users to access the Internet via a mobile broadband connection. This and the evolution of both networks and terminals to support higher data rates and more useful and easy-to-use data applications are believed to increase the need for in-building solutions.

It can also be assumed that in most cases mobile Internet users will be sitting comfortably inside buildings, rather than walking around outdoors.

This will especially be the case for mobile broadband, where the majority of traffic will be from users that are indoors. For sites where there are likely to be a large number of mobile broadband users, such as airports, train stations and office buildings, a dedicated in-building solution will offload the macro network and free up capacity for users elsewhere.

3.2 Benefits for Neutral Host Providers, Building Owners, Enterprises and End-Users

Benefits and Opportunities for Neutral Host Providers

Tower companies speciality is to own towers and rent space to mobile operators. Likewise there is a similar possibility to deploy in-building antenna systems and let the mobile operators connect their RBSs to these.

Since it is possible to deploy solutions that support several operators and bands (e.g. GSM 900, GSM 1800 & WCDMA) in one and the same distributed antenna system, it is fully possible for a Neutral Host Provider to own it and allow operators to connect their RBS to the DAS.

Especially for multi-operator solutions there is a big opportunity for all parties to benefit from such a solution, compared with a scenario where all operators deploy separate DASs.

Benefits and opportunities for Building Owners

The demand for good indoor access to mobile networks is increasing in buildings such as offices, hotels and conference centres. With poor coverage/quality there is a risk that both tenants and other customers will choose another location.

It is fully possible for building owners to build and own DASs themselves, after agreements with mobile operators, or together with a neutral host provider, for instance. A passive DAS will be considered as a permanent part of the building's infrastructure and can therefore also be owned by the building owner (like e.g. data and electric cables).

Benefits and opportunities for Enterprises

A good in-building solution enables the enterprise both to save costs, become more efficient and improve the image by e.g. answering more calls. With today's high quality mobile networks, applications that provide PBX-like functionality to the mobile phones and the user-friendly terminals it is fully possible to replace wireline and DECT phones with mobile phones.

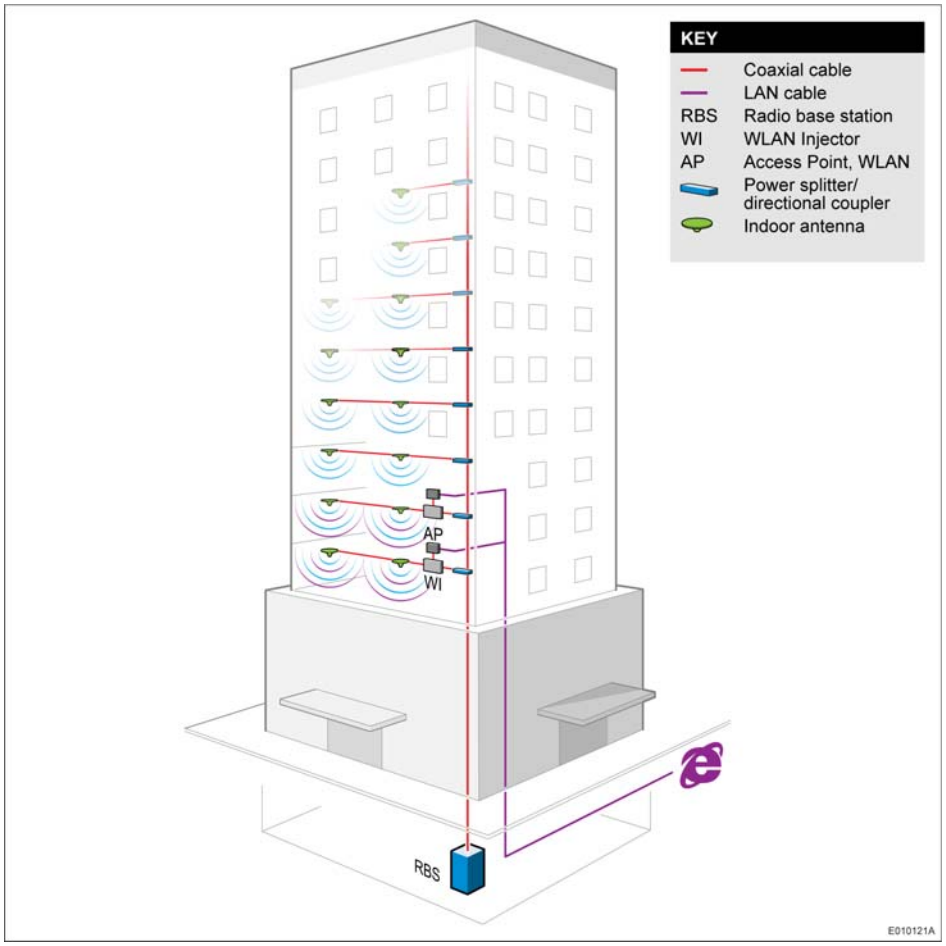

Figure 15 Distributed antenna systems can be used to distribute Wireless LAN (or Bluetooth) together with for example GSM and/or 3G if using a so called WLAN Injector.

The DAS may also be used for distributing e.g. WLAN (802.11.b/g) by installing the WLAN access points together with the DAS. The WLAN signal is injected in to the DAS and thus the costs associated with a separate WLAN deployment are reduced.

Figure 16 A photo of a Wireless LAN Injector.

Benefits for the End-users

The benefits for the mobile users are obviously improved coverage and quality. Everyone benefits from a good in-building solution, since they can get high quality access to both mobile voice and data services.

The introduction of Femto cells will enable the users to deploy an own low power radio base station in their homes and achieve high quality mobile coverage. This is especially useful in houses and apartments where the macro network coverage is not sufficient.

Figure 17 An example of a Femto home access point for GSM.

4 Conclusion

In-building Solutions, IBS, as defined in this document is a way to enable efficient usage of wireless mobile applications inside different kinds of buildings. This requires that sufficient coverage and capacity with good radio quality is available inside the buildings. Although the mobile operators will cover most buildings from outdoor sites in their macro network, there is a need to provide many buildings with an extended radio coverage and capacity.

In-building solutions are well-proven methods for an operator to capture new traffic and new revenue streams. One can provide enhanced in-building solutions to off-load the macro network, thus increasing mobile traffic, and attract additional subscribers due to the enhanced mobile network quality and accessibility to mobile Internet applications and other services that require high data-rates and capacity.

There are several different ways to implement in-building solutions. Dedicated Radio Base Stations, RBSs, that are connected to Distributed Antenna Systems, DASs, are commonly implemented solutions. These solutions provide additional capacity as well as covers “black holes” inside different kinds of buildings. A number of different types of both RBSs and DASs are available and the solutions can be customized for different buildings and needs.

Repeaters are often used for buildings with a limited need for capacity, but where additional coverage is needed, like road tunnels and smaller buildings or parts of buildings.

5 Glossary

3G (third generation): Radio technology for wireless networks, telephones and other devices. Narrowband digital radio is the second generation of technology.

ADSL: Asymmetric Digital Subscriber Line

CDMA: Code Division Multiple Access

DAS: Distributed Antenna System

EDGE: Enhanced Data rates for Global Evolution

GSM: Global System for Mobile communications

GPRS: General Packet Radio Services

HSPA: High-Speed Packet Access

IBS: In-Building Solutions

RBS: Radio Base Station

RF: Radio Frequency

TETRA: Terrestrial Trunked Radio

WCDMA: Wideband Code Division Multiple Access

WLAN: Wireless Local Area Network