The Application of Femtocells as a Technical Solution for a Telecomunication Provider

- Analysis of Benefit and Utility-

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Abstract - **The technology of femtocell application will most likely enable reduction of costs for telecommunications provider. This paper presents the installation and use of femtocells, as well as the problems one may encounter during this process. It also offers a technical solution, with its basic characteristics and the possibility of realization at a particular location, illustrated by the example of a telecomunications provider. The possibilities of implementation of new equipment to existing mobile networks are also discussed, followed by the comparative analysis which aims at emphasizing the significant reduction of electrical energy consumption between GSM macro base stations and femtocell application.**

Keywords - **femtocell, UMTS, indoor coverage, electrical energy consumption**

1. Introduction: Femtocells in the next generation of mobile networks

By atempting to service a growing number of users and by increasing bit rate, mobile network providers are aiming at improving their performance. The demands for better service are also constantly increasing, especially in densely populated areas where standard coverage is insufficient. Therefore, the need for the new solution which would accommodate clients' needs and simultaneoulsy provide high-quality wireless mobile network, is always present. Since this new solution should also contribute to saving electrical energy consumption of macro base stations, the realization and application of femtocells, also known as home mobile base stations, seems to be a viable proposition.

3G technology mobile operators presented femtocell technology towards the end of 2007. in order to enable more enhanced services for their clients, mainly for data transfer. These activities prompted the international organization in charge of 3G procedures 3GPP (Third Generation Partnership Project) to define the whole set of standards regarding femtocells [1].

The quality enhancement of GSM coverage (Global System Mobile Communications) and 3G mobile networks, especially at indoor locations, represents one of the main functions of femtocells. Besides improving signal quality, femtocells enable the increase of bit rate to the final user, regardless of the type: standard, residential or advanced bussines clients. Since numerous studies have shown that the majority of calls from mobile phones are made from within the inside premisses, better coverage at indoor locations (i.e. offices, flats, buildings, etc.), could offer better service options. Such services, for instance the answering service for mobile operators, would enable them to compete with fixed telephony operators or VOIP (Voice over IP) providers. Moreover, the application of this technology would contribute to avoiding macro base stations overload, and reduced electric energy expenditure.

Since the income from common type services (voice transfer in particular) is decreasing, mobile providers should turn to new technical solutions which could improve their bussiness and increase their profit. The application of femtocells, which have commercially been in use since 2008, seems to be one of the most popular solutions.

Femtocells are gaining an important position in m obile telecommunications industry, mostly because they seem to have overcome the existing problems that are common to macro cells, as well as because of the fact that these cells provide high quality coverage of inner premisses (small amount of transmitting power – up to 20mV in the range of up to 50m).

The installation of femtocells is very simple. Femtocells, or femto access points, are miniature base stations connected to mobile network by broadband line ADSL (Asymmetric Digital Subscriber Line). This is particulary useful for small and medium companies, as well as for private clients with demands for high bit rate.

The client's acceptance of the new technology and its success on the market depends solely on the quality and value of the service itself, as well as on the willingness of clients to pay the estimated price for using this new technology. Some of the applications that might be of interest for broad population would most likely be online game playing, downloading files, etc.

2. Technical solution for femtocells

Figure 1 illustrates the block-scheme of femtocell solution which comprises the following elements:

- femto access point FAP (Femto Access Point);
- femto gateway FGW (Femto Gateway) whose main purpose is to manage and control FAP element, and to enable its authentication on mobile provider's network;
- AAA server AAA (Authentication, Autorization, Accounting). The server is in function of checking, authorization and price rate accounting;
- number of switches and routers that are connected to femto cell and further to femto platform defined by mobile provider;
- NMS- (Network Management System);

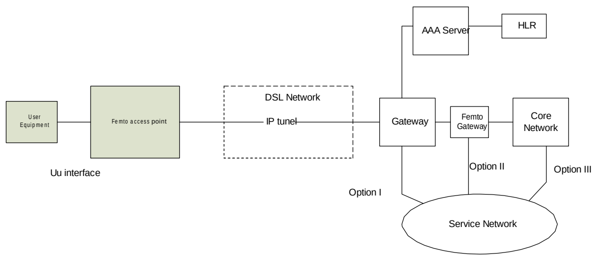


Figure 1: The block-scheme of femto cell solution

In order to apply femto solution regardless of conditions required for this specific platform, mobile oparators must enable integration of femtocells to the core of their network, obtain neccessary permits and licences from regulatory bodies and overcome interference problems so that femtocells could function simultaneously with outer mobile telephony cells.

The realization of femtocells in already commercially existing 2G and 3G networks should be considered as well.

A femto solution could encompass about 100, 000 femto access points, with a potentially equal number of users. This solution is applicable in the defined area. The number of cabinets varies from 2 to 12, with beforehand optimized electric power consumption. The diversity of such a system requres the so called "tree" model, in order for diferent architecture of equipement to be realized.

Femtocells should be installed in such a way so as to enable the client to access it in different ways. [3, 4]

Three basic ways of access are defined:

- open access to femtocells;

All users that are located in one femto zone could have unlimited access to network as long as the cell resources are available.

- closed access to femtocells;

Only one user, or a relatively small number of defined registered users could have access the network.

- hybrid access;

Users that ordinarily do not have access to network, could use limited services and have limited level of quality.

It is possible to realize and adjust all of these types of accesses according to clients needs and quality level.

3. The possibility of implementation of femtocell technology in the network of Mobile Telephony of Serbia

The possibility of realization of this new technology in the company Telekom Serbia, could be presented in one particular object. For this example, a big shoping mall in Belgrade was chosen (Figure 2. Delta City shopping mall). It has all the standards required for femto cell application: large area, several floors, long working hours both on week days and weekends, large number of potential users, of different age, interests and demands for different services.

Figure 2: Delta City shopping mall

A particularly important aspect of the potential application of femtocells is the fact that Telekom Serbia is a provider for both mobile and fixed telephony, so there could be no dilemma as to the ways and types of charging for services. However, what types of services could be offered to clients are an important thing.

For the standard, quality mobile signal coverage (GSM and 3G) for such an object, the size of which is 80 000 m^2 in total, special equipment for indoor coverage is provided. It is a technology which combines base stations and added equipment for enabling high signal inside the object itself. In this

object, two Ericsson macro base stations were used for indoor and outdoor coverage, with working frequencies of 900 MHz and 1800 MHz.
Figures 3, 4 and 5 illustrate the level of radio field coverage inside the object where the position of antennas which enable an even distribution of mobile network signal is marked as well. The number of antennas varies from floor to floor. The practice of measuring the level of signal inside the object could serve as a starting point for the successful implementation of femtocell technology.

Figure 3: The level of radio field coverage inside the object (ground)

Figure 4: The level of radio field coverage inside the object (I flor)

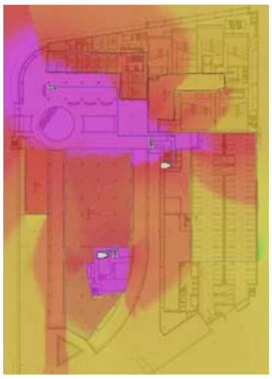
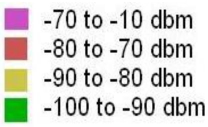


Figure 5: The level of radio field coverage inside the object (II flor)



Legend

Besides the two base stations already installed in the mall, coverage is also provided by means of three GSM (two of 900 MHz and one of 1800 MHz) and three UMTS (Universal Mobile Telecommunications System) macro base stations.

The data about signal quality and the already installed equipment are used as starting points for the implementation of new femtocell technology. If successfuly installed, femtocells would contribute to enhancing the mobile network quality inside the object, and reduce electric power consumption at locations outside the object.

4. Introduction of new equipment

Besides providing mobile network signal around and within the shopping mall, most mobile network providers have recently been focussing on reducing the electric power consumption. In this case, most power consumption is used for supplying base stations. The importance of equipment quality and correct installation leads to the reduction of power consumption, therefore reducing the expenses for the providers as well. The ecological aspect should be taken into account as well. Monthly expenses for common macro base stations amounts to 1,000 dollars approximately, regardless of the power supply charges and potential renting fees for transport links [5].
The main goal of this project is to obtain the best technical solution which would enable good and consistent mobile network signal while saving electrical energy at the same time.
In short, it is necessary to reconsider two aspects. The first one is optimization and rationalization when purchasing and installing new telecomunications equipment for the purpose of obtaining better coverage and increased capacity, and the other is constant rationalization of electrical power consumption.
The area around the shopping mall has highquality signal reception of Mobile Telephony of Serbia which is provided from several base stations installed within and around the mall. The total of 5 GSM and 3 UMTS Ericsson base stations were installed. Data was retrieved for the total traffic within 24 hours, on a typical working day in January 2010, both for voice transfer and UL (UpLink) and DL (DownLink) data transfer.
Figures 6 and 7 illustrate the retrieved data. Most of the traffic was realized in the period between 9,00 and 22,00 hours.

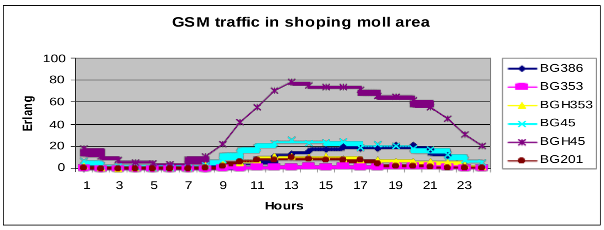


Figure 6: Total 24 hours traffic on GSM base stations

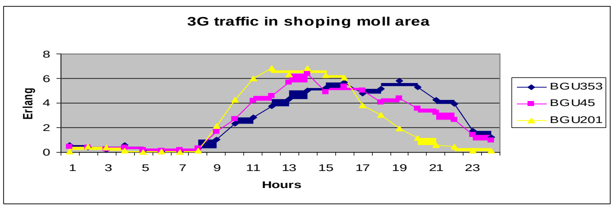


Figure 7: Total 24 hours traffic on 3G base stations

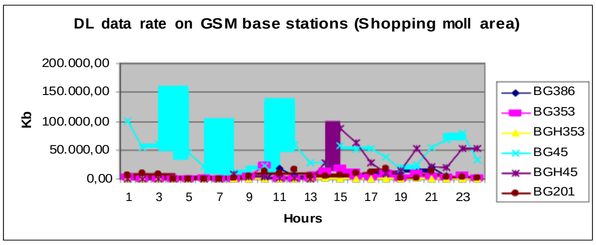


Figure 8: DL data rate on GSM base stations

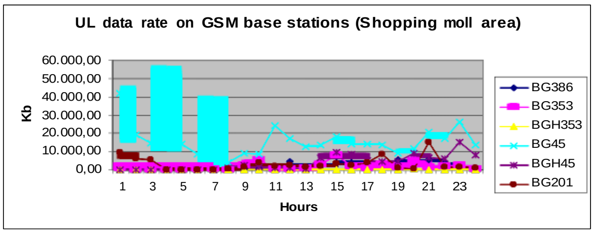


Figure 9: UL data rate on GSM base stations

Data on power consumption in KWh was retrieved from technical documentation [6]. Data presented here are related only to 3G and GSM base stations which were taken into consideration for the purpose of this paper, namely the ones installed within and around the shopping mall. Table 1 represents power consumption within one hour during normal regime and in maximum load regime. The amount of maxiumum electrical energy expenditure is particularly important when planning, projecting and constructing new location, in order for the predicted power consumption of the equipment to be defined.

Code of location	BTS	Power consumption Average (W)	Max. Power consumption (W)
BG353	2116	1500	7900
BGH353	2116	1500	7900
BG45	2116	1500	7900
BGH45	2116	1500	7900
BG201	2116	1500	7900
BGU353	3518	200	500
BGU45	3106 (3x1 on 20w)	1400	1900
BGU201	3106 (3x1 on 20w)	1400	1900

Table 1. Power consumption within one hour during normal regime

With all relevant infomation at disposal, the current status could be overviewed and the need for implementing new technology could be analyzed.
In our analysis, the proposed femtocell technology leads to better performance in signal quality and lower power consumption. The device, whose technical characteristics are used for this example, is UAP2105, manufactured by HUAWEI. The device is conneted to network core using classical DSL fixed telephone line.

Basic characteristics of the device are the following:

Working frequency	1920-1980 Mhz DL i 2110-2170 UL
Output power	20mW (13dB)
Power consumption.	8 W
Weight	0.4 kg

This device is constructed in such a way that in real traffic it can replace one mobile telephony cell. Bit rate is defined by DSL line capacity. Since Telekom Serbia is both fixed and mobile telephony provider, DSL line capacity depends only on technical limitations of that equipment [7].

5. Comparative analysis and conclusions

Since we now have relevant information, the analysis of the profitability of introducing such new equipment in existing and planned objects, often populated with people frequently using mobile telephone technology, can be carried out.

In our opinion, the analysis of the GSM macro base stations which provide indoor and outdoor coverage of the object would be sufficient. The proposed technical solution envisages the use of omnidirectional antennas as well as distributed antenna system. On the floors of the object, the provider has installed antennas conected to base stations with optical fibres. The number of antennas is different for each floor, as illustrated by Figures 3, 4 and 5. The position of these antennas could be taken as the recommended position for femtocell location. Since each femtocell represents only one real mobile telephony cell, 3 femtocells are recommended for installation at the each location of the antenna.
In this way, there would be 18 cells (6x3) on the ground floor, 15 cells on the first floor(5x3), and 9 cells on the second floor (3x3).

Based on the analysis of the the existing data on measuring zone coverage of the signal, it is estimated that sufficient signal quality could be obtained. However, the expected field level would be lower because of the lower transfer power of the equipment

The final result would be that there is no need for installing macro base stations for indoor coverage, which take up much space. The achieved saving of electrical energy is also an important aspect to be taken into consideration.

The estimated rate of electrical power consumption is based on the comparison between the energy spent by the already installed equipment (macro base stations) and the avaliable femtocells. It is estimated that the total of 42 units of femtocells should be installed. Each of these cells has the maxiumum consumption of 8 W in maximum workload regime, which represents consumption of 336 W within an hour, 8,064 KW daily and 2,94 MW annually. Two GSM macro base stations spend 72 KW daily and 26,28 MW per year. This means that two macro base stations, in comparison to all installed femtocells, spend 9 times more electrical power. The summary of data is given in Table 2.

	BTS GSM (900 i 1800 MHz)	**femtocell**
Number of units	2	42
Power consumption per unit	1.5 KW	8 W
Power consumption per hour (for all units)	2x1.5=3 KW	42x8=336 W
Power consumption per day (for all units)	3x24=72 KW	336x24=8,064 KW
Power consumption per year (for all units)	26 280 KW	2 943 KW

Table 2: The summary of data (macro base stations and avaliable femtocells)

If we take into consideration the number of business and shopping centres in urban areas, as well as other objects where it is important to have high quality mobile network signal coverage at an indoor location, the application of femtocells from the aspect of saving the energy becomes a predominant one. Another important aspect represetns the reduction of the load within the existing mobile network infrastructure.

Furthermore, signal quality and the number of users which could be served in the zone of coverage also has to be taken into consideration. With macro base stations, the number of users is limited by the coverage zone and maximal bit rate.

Installation of femtocells would not have the influence of interference on macro base stations. There is a possibility of realizing both the same and different frequency range of the femtocells. A recent study [8] has shown that both femtocells and macro base stations are able to operate in the same frequency and with minimal interference in the network.

The average bit rate (from 4 to more than 5 Mb/s) for macro base stations is realized when signal/noise ratio SNR- (Signal Noise Ratio) is between 0 and 30 dB. By increasing SNR to 20dB or higher, or by increasing transfer power, the median bit rate on the base station is not significantly increased whereby the femtocell signal becomes dominant and offers proof that femtocells could provide increased bit rate [8].

Femtocells represent an ideal solution for small and medium companies as well as for large companies in urban and densely populated areas. As regards to femtocell application, Vodafon company in Great Britain may serve an example which should be followed This provider started with commercial use of femtocells in July 2009. According to their statistical data, it is expected that the number of femtocells used by private clients would be more than 20 million units in the near future. It is also expected that the number of the so-called *business* clients, who use femtocell technology with closed access, would also be on the increase [9].

6. Conclusion

The advancement in new technology and increasing demands of users for enchanced bit rate are highly likely to result in the need for commercial use of femtocells. In the past years, the telecommunications networks for voice transfer were dominant and had broad tolerance for signal quality. Data transfer networks demand much higher signal quality, the one that would enable bit rate of hundreds of megabites for the user. Therefore, a logical question arises: why wouldn't the telecommunications providers initiate the installation of femtocells themselves, in order to service demanding business and private clients? It would result in higer QoS, with significant savings in power consumption.

Since Telecom Serbia is the provider for both fixed and mobile network, the high level of QoS by means of using femtocells could be guaranteed, primarily by fixed bandwidth of the femtocell in DSL transport network. This predefined bit rate maximum to client should be sufficient to provide voice transfer, multimedia traffic and data transfer. It is also possible to define a changable bit rate which would suit clients' needs and demands for special services, as is the case of mobile multimedia applications.

The application of femtocells is the efficient and profitable solution for every mobile operator, especially for the one with optical transport network on disposal. The challenge for the operator, from the technical point of view, would be high QoS, transport network capacity, sufficient number of DSL ports, minimalization of outer interference and high quality technical support. Economy wise, attracting new clients with this new service would lead to significant rise in profit and at the same time to a decrease in expenses related to electrical energy consumption.

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