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DEMAND CAPACITY AND ANTENNA SYSTEM PLANNING FOR IN-BUILDING GSM NETWORKS

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***Abstract*—Due to growth of indoor mobile traffic, there is a growing focus on In-building solutions. This paper explains the requirement for quick development in IBS (In-Building Solutions) with a major focus on demand capacity planning and traffic planning which is carried out independently for general and business applications to differentiate common and intensive applications. It equally concentrates on accomplishing a more cost effective low grade of service (GoS) while having high quality of service (QoS). This paper additionally highlights the utilization of Distributed Antenna Systems (DAS) which is a novel solution for coverage improvement. The incorporated DAS implementation reduces the expenses that are required for enabling cellular coverage to the customers of wireless service providers in vast open locations. The paper additionally elucidates Radio Base Station (RBS) skeleton that aides in establishing connections for these DAS frameworks.**

***Index Terms*—IBS, DAS, Demand Planning, RBS, Antenna planning, Traffic planning, Donor cell.**

I. INTRODUCTION

In the world of networking, telecommunication sector is on the rise. There is a growing demand in economic, cultural and political spheres towards mobile and telecommunication technology. Due to rapid growth in technology, suppliers too are into improving the efficiency. Thus, growth is an amalgamation of “demand-pull” or “supply-push” activities [1]. Customers today are witnessing an extraordinary rush in data and voice traffic. This is largely due to the growing usage of smart devices and new bandwidth-hungry applications and services. Nevertheless, subscribers around the world demand better experiences from the network in terms of faster data speed, higher bandwidth & better coverage wherever they are moving or inside home or office [2].

Mobile connections rely on coverage from macro cells which are deployed on masts or high buildings to provide coverage to an area. When a mobile subscriber is inside a building, radio wave propagation involves wall penetration; there are radio wave energy absorption losses by furniture and presence of people in the surrounding area. In addition, indoor propagation is subjected to fast multipath fading and diffracted waves due to corners, presence of people, furniture and moving objects [3].

According to research, statistics show that 80 % of mobile use occurs inside buildings. 85% of data traffic and 70% of voice traffic is generated indoors being the revenue generation centre for communication service providers (CSPs). 81% of employees use personal smart phones at work. 87% of companies would switch providers for better indoor service. 72% of businesses are interested in enterprise cells boosting performance on their premises. 87% of businesses believe it is important for mobile network operators to offer enterprise cells. 5x growth of in-building wireless market is expected by 2018 [4]. But, it has been observed that it is very costly to increase the indoor location probability by outdoor sites which is greater than 90% [5].

The best way is to improve in-building coverage by using pico-cells in the interior of the building. This paper explains the need for rapid growth in In-Building Solutions with a key focus on demand capacity planning and traffic planning which is done separately for general and business applications to demarcate light and heavy users. It also focuses on achieving a low grade of service but at the same time having a high quality of service. This paper also highlights the use of Distributed Antenna Systems (DAS) which is an integrated solution for coverage enhancement. The integrated DAS solution reduces the cost of providing cellular coverage to the clients of wireless service providers in large public venues. It also explains Radio Base Station (RBS) framework that helps connect DAS systems.

II. IN-BUILDING SOLUTIONS PLANNING

The following are sequential steps involved in the planning of an In-Building network:

A. Need For Network Solutions Inside The Building

About 70% of voice traffic occurs inside buildings [6]. There is limited network coverage in areas such as basement and lifts of shopping malls, hospitals, commercial complexes and business houses. The drop call rate is high because the density is higher and there is a need for higher capacity in an indoor area. A concentrated number of users in such areas give rise to the need of deploying in-building solutions.

In areas that lack dedicated in-building coverage, path loss to different users within can vary depending on location of the user i.e. whether the user is located indoors or not. This variation in path loss means that capacity of the system fluctuates according to user distribution. Operators need to take this factor into account and allocate sufficient margins while planning their RF networks. But if indoor users are served via dedicated indoor cells, there will be less fluctuation in capacity, and operators can allocate smaller margins.

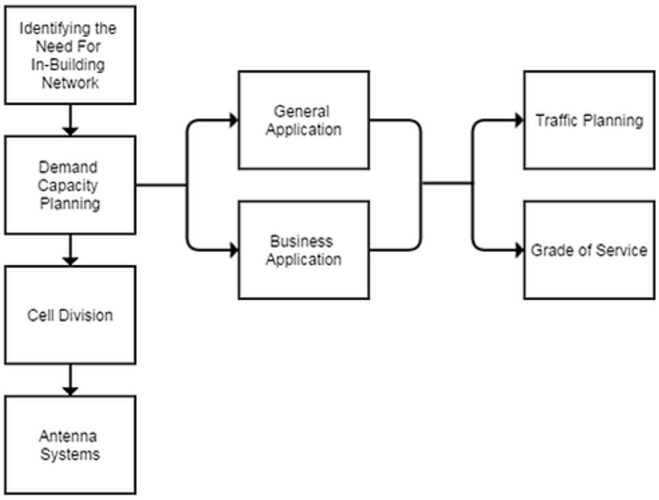

Fig. 1. IBS Framework

B. *Demand capacity planning*

Capacity planning is typically done for the first time during the dimensioning phase and a second time in parallel with the coverage planning. When dimensioning the capacity of an indoor cell, one must consider its application. Two different categories of indoor cells can be identified:

1) *General Application:* The indoor cells which cover public buildings such as shopping centers, airport terminals and hospitals are referred to as public indoor cells. The user distribution varies depending on the time of the day and hence requires planning of these areas with bigger capacity margins.

2) *Business Application*: The indoor cells covering areas such as business houses and commercial complexes are termed as business indoor cells. They require higher capacity and quality demands than in public indoor cells. The number of users generally remains constant and thus operators can plan with smaller margins with higher Quality of service to users. They are installed in order to improve the performance of the existing radio network, or as an alternative for the fixed telephone network.

The precise need for capacity can be determined based on the real information about traffic in the radio network depending on the performance management reports and outage reports. Costs incurred due to the proposed capacity plan are also made to check the feasibility.

a) Traffic Planning: Traffic planning of business indoor cells is particularly important since the number of users is more and requires higher quality of service. Thus, determining the number of subscribers in a concentrated area is the first step of this procedure.

The second step involves identifying their usage behavior. Subscribers may be broadly classified as heavy users and light users depending on the number of calls per hour or the amount of cellular data usage and network occupancy. So, if the network usage and user density is higher, the antennas must be planned in such a way that they get full coverage and do not encounter the problem of call drops.

Finally, the most critical step is determining the busy hour traffic as a percentage of the total traffic. Busy hour, as the name suggests is a 60 minute window in a day that experiences maximum traffic load [7]. From a business application perspective, the busy hour accounts for 15-20% of the traffic of that day. Whereas, the busy hour report for a public indoor cell will be around 10-12% of a particular day.

b) Grade of service: The ability to make a call during the busiest time or is typically defined as the probability that a call is blocked or the likelihood of a call experiencing a delay for more than a specified interval [8]. This is always with respect to the busy hour when the traffic intensity is the greatest. Grade of service can be represented from the point of view of incoming versus outgoing calls. The demand on network accessibility is likely to be higher in business indoor cells than in public indoor cells. Since the business indoor cell is to be used as a substitute to the fixed telephone network, the performance must be similar to it and thus grade of service must be very low, not more than 0.5% for a business application and 1% for public indoor cells.

C. *Cell Division*

A way to increase the overall capacity is to make cells small. This is achieved by splitting the building which is considered as “one cell” into at least three cells. This should be done when the building is huge and the demand is high. It enables power distribution from the antennas which can be adjusted depending upon the obstacles, distance to be covered and capacity demand in that respective cell. It must be split into three cells to allow frequency reuse between the floors of the building. Cell division technique is widely deployed to:

- Cater uneven and peaky demands on capacity using indoor small cells. But, the traffic demand on every small cell must be taken into consideration when dimensioning the system
- Extend coverage at cell edges [9]
- Target on high value business users
- Provide High quality and secured service

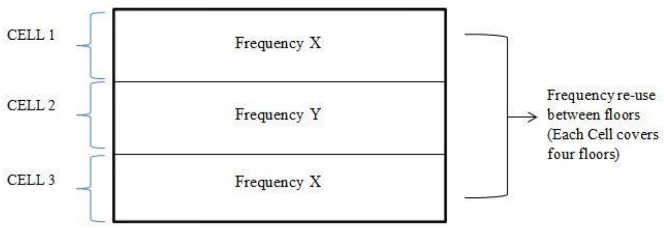

Fig. 2. Cell Splitting

D. Distributed Antenna System

A distributed antenna system (DAS) is made of a network of antennas connected to a common source using a transport medium that provides wireless service within a geographic area. DAS components are designed to deal with spots of poor coverage inside a large building and improve the coverage with highest performance. The antennas used in DAS are small discrete antenna elements designed specifically for indoor use. In DAS implementation, signal is transferred from base station by network of feeder cables, connected by splitters and couplers. The idea is to split the transmitted power among several antennas, separated in space to provide coverage over the same area as a single antenna but with reduced total power, i.e., a single antenna radiating at high power is replaced by a group of low-power antennas to cover the same area [10]. The antenna elevations in this kind of antenna system are generally at or below the clutter level. Typically, the two most commonly used antenna types are omnidirectional and directional antennas. The two types of omnidirectional antennas are the Mexican hat antenna and the tubular mast antenna. But, the Mexican hat is preferred because of its stable construction.

A DAS is used in large tall buildings, underground parking, train stations, hotels, resorts, conference centers, airports, stadiums, government offices etc.

a) Passive In-Building cellular enhancement system

Passive systems are the systems that use coaxial cable (1/2" to 7/8" in diameter) to distribute the wireless signal from a repeater or base station to a set of distributed antennas. These systems use coaxial couplers and splitters for distribution of cabling. The coaxial cable used to distribute radio signals is intrinsically capable of supporting multiple carrier frequencies. These systems are referred as "broadband" systems because the DAS itself supports any wireless frequency delivered to the coax system [11].

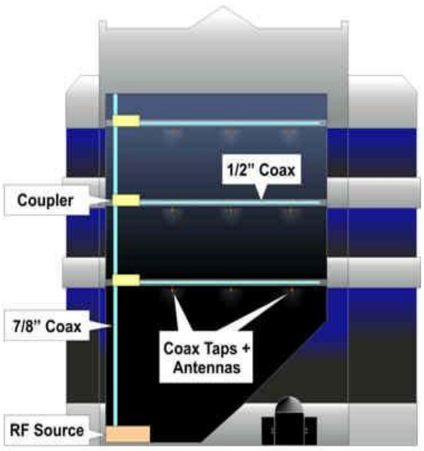

Fig. 3. Passive DAS

A passive system is less expensive to install and is best suited for smaller buildings where one or possibly two mobile network operators need to be enhanced within the building and are not usually installed in spaces over 100,000 square feet area. These require the RF power to be balanced among all the coverage antennas so there is uniform signal strength throughout the building. Developing a passive system after the initial establishment could require a re-engineering of the entire system to ensure proper operation throughout the building. The number of antennas and coverage area of such a system is dependent on the output power of the signal source.

TABLE I. COAXIAL CABLE ATTENUATION PER 100M (DB) [12]

Cable Type	900 MHz	1800 MHz	2100 MHz
1/4 inch	13	19	20
1/2 inch	7	10	11
7/8 inch	4	6	6.5

b) Active In-Building cellular enhancement system

The fundamental difference between active and passive system is the digital distribution of signals as well as low feeder losses. These systems have a LAN like topology [6]. Rather than relying on transport cabling from the RF source to the antennas, these systems use optical fiber and Cat-5 cabling. To distribute the signal from the RF source through the DAS, these systems use managed hubs and Remote Access Units (RAUs) that amplify the signal.

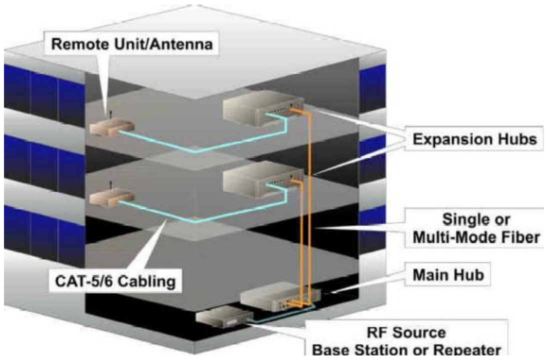

Fig. 4. Active DAS

An active system can be deployed in large buildings and within a campus of buildings by converting and transporting the radio frequency over optical fiber. Many active systems have been deployed covering areas of 1,000,000 square feet and larger. These systems are best suited when there is a need to support multiple mobile network operators or large single buildings or campuses with multiple buildings. Improvement of an active system is usually in the form of adding more active equipment to increase the number of coverage antennas within the building, to increase the number of mobile network operators, or to increase the service offerings of a mobile network operator such as adding 3G or 4G services. In a properly designed system, no reengineering of the original system is required when the system is expanded. Optical fiber systems can provide coverage in areas up to 2 km from the signal source making them ideal for campus environments. These will always be more expensive than a passive system. For a more cost effective and performance oriented utilization of distributed antenna systems, a combination of passive and active, i.e., hybrid system is used. Radio Base Stations prove a backbone for validating connections between DAS systems.

III. Radio Base Station Systems

Radio Base Station (RBS) is a name given to a significant part of the radio access network. It is synonymous to the base transceiver station and has varied hardware configurations. The radio wire framework could be joined with a base station in one of the accompanying ways:

A. *RF-repeater*

An RF-repeater offers an easy and simple to-introduce option to give coverage in a building. The macro cell encompassing the building, defined as donor cell, should however have the save limit. At the point when the demand request in the building expands and gets to be higher than what the donor cell can offer, the RF-repeater may be supplanted by a customary RBS (in addition to transmission). The indoor reception apparatus framework, initially intended for the RF-repeater, ought to in substantial parts be conceivable to keep. The RF-repeater can therefore halfway be seen as a brief answer case in point when there is uncertainty if the potential activity in a building will motivate a conventional indoor framework.

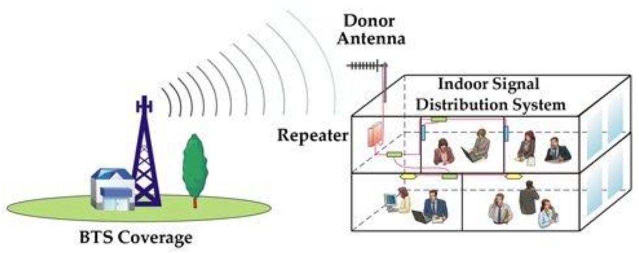

Fig. 5. Radio Base Station

B. *Single and Multiple RBS configurations*

A solitary RBS is the most direct approach to design the RBS framework in an indoor application. It is more trunking efficient than utilizing numerous RBSs [13]. In any case, in substantial structures where extensive regions are to be secured, high feeder losses confine the pertinence of a solitary RBS. For this situation, various RBSs, adopted over the building is a better decision. The evident reason for this is that in a various RBS framework the RBSs may be set closer to the receiving antennas as contrasted with a solitary RBS framework, and subsequently the feeder losses are decreased [14].

IV. Conclusion

We have discussed the various factors which should be focused on while considering utilization and expansion of In Building Solutions to improve network coverage at indoor locations. Distributed Antenna Systems (DAS) are an encompassing solution to facilitate different degrees of demand and traffic requirements that are faced by wireless subscribers. IBS have become a crucial requirement in all phases of everyday life. This paper presented a range of options that may be utilized to plan the implementation of these solutions to achieve the most logical demand based results. These possibilities should be further complemented with power budget parameters, cost parameters and hardware options for successful execution of any such systems.

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