3G MOBILE NETWORK PLANNING BASED ON A TRAFFIC SIMULATION MODEL AND A COST-BENEFIT MODEL TO SERVICE LOS CABOS INTERNATIONAL AIRPORT

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ABSTRACT
We propose an application approach to planning a third-generation mobile network based on a traffic simulation model and a cost-benefit model to service the interior of an airport. This proposal represents an alternative to the mobile network planning traditional process. We developed a network traffic simulation model in terms of service transmission rates of applications such as voice over IP, video phone, FTP file transfer and high definition video-phone. The simulations are executed using ARENA software. From the results of the traffic simulation model, we obtained the network capacity in terms of the cell radius. Based on the cost-benefit model and on the network capacity, we got the cell radius that maximizes the net profit percentage of the network and satisfies the user´s requirements. Under this approach is not taken into consideration some of technical aspects, but rather it is to highlight the economic aspect of the network planning process.

Keywords: 3G mobile network, traffic simulation, network planning, economic model

1. INTRODUCTION

The telecommunications industry has been expanded substantially since the past decade. Technology advancement along with the liberation of once closed markets and privatization of government-held monopolies changed the nature of the industry in the 1990s and continues to shake up the industry every now and then. In early 2000, the industry scaled new highs with respect capitalization. Both business and technology disruptions have introduced significant expansion and innovation. The global mobile cellular subscription was closed to 5.3 billion by the end of 2010. That is equivalent to 77 percent of the world population. So 90 percent of the world now lives in a place with access to a mobile network. For people living in rural communities this is lower at 80 percent, according to the estimation of the International Telecommunication Union.

The mobile cellular technology, as happens in others technology fields, has had an innovation process in which has been defined and implemented successive generations. Each of these generations has responded to specific service demands from network users and operators. The first generation cellular mobile (1G) technology enabled the human communication via voice. While the second generation cellular mobile (2G) technology enabled the human communication via voice and text messages, and the third generation (3G) technology enabled the human communication via voice, text messages, data and video.

The same forces that fed the development of new services and the entrance of new players also saw margins grow slimmer for most services as well as significant customer churn as competitors offered alternative choices. So for network operators has been important to give mobile cellular service indoor and outdoor along cities and rural communities. To give the service, the network operators need, by first time, to plan the network. The network planning is a process on which operators take in consideration aspects such as demand of services and applications from users, service area based on the potential user locations, service rates, quality of service, environmental morphology and return of investment, for example.

By one hand, in today´s extremely challenging business environment, many telecommunications operators and carriers are measuring their success by the size and growth of their profit margins. As a result, operators are under intense pressure to reduce or eliminate the major threats to these slim margins including revenue leakages and frauds, churn, inefficient network usage, and least-cost routing plans. These competitive and market pressures are also making the telecommunications industry reassess its business model and redefining the path that will return it to competitiveness and profitability (Pareek 2007).

By another hand, under competitive conditions, the customer becomes the central focus of the carrier´s activities. Customer requirements not only determine service offerings, but also shape the network. In this sense, we propose a network design to service Los Cabos International Airport, which is located in Mexico country, based on user´s requirements and using 3G mobile cellular technology specifications. This proposal is based on a traffic simulation model and a cost-benefit model and the main objective is to get the cell radius that maximizes the net profit percentage of the network.

So we obtain the cell number and their corresponding configuration to cover the airport total physical area. The study is done considering the operator´s view and we hope it can help to support the decision making in the telecommunication industry, specifically in the network design area.

2. MOBILE CELLULAR TECHNOLOGY

In order to have access in the mobile cellular telecommunication networks, users must have a terminal device based on a specific technology and operators must implement a network based on a specific technology too. Mobile cellular technology has evolved over generations. Thus, we have the so-called first generation (1G) technology, characterized by analog devices, while the so-called second generation (2G) technology, characterized by digital devices and based on standards as GSM (Global System Mobile) and CDMA (Code Division Multiple Access). And the so-called third generation (3G) technology based on standards such as UMTS (Universal Mobile Telecommunications System) (see Fig. 1).

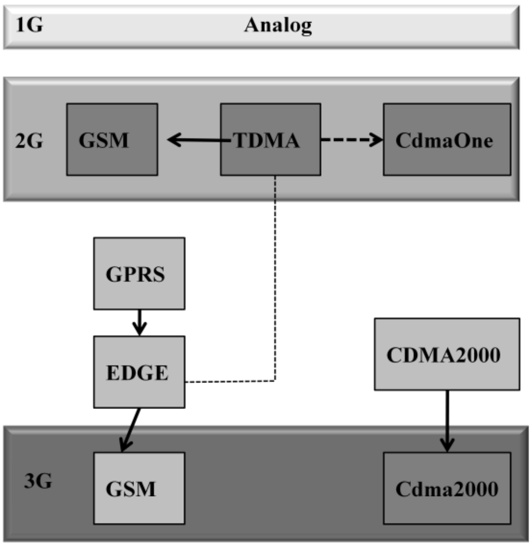

Figure 1: Mobile cellular technology evolution

In accordance with the UMTS specifications (3GPP 2002), using this technology makes possible to increase network bandwidth in order to get a major and better data transmission. In fact, this situation has encouraged to operators to offer a wider range of mobile services and applications, through introducing a new technology platform over their actual network (located physically between the user terminal device and the network controllers). So, using UMTS technology, the network must be planned in accordance with criteria evaluated by operators in order to satisfy customer requirements but customer requirements depend of customer communications needs, in certain places and in certain time. The operators must know the customer communications needs in order to be a very good option in a competitive market as is nowadays the mobile cellular telecommunication market.

3. MOBILE CELLULAR NETWORK PLANNING

3.1. The process

The network planning process consists of ten specific activities (Mishra 2007) which are carried out by different technical teams (see Fig. 2).

It starts with the network design, which may or not be based on field measurements of an existing network. The next activity is the locations acquisition. The locations acquisition means that networks operators rent a physical space where sites will be built. After the acquisitions and building, the equipment is implemented through installation and commissioning. The commissioning is the activity on which the engineer field sets the correct value of the equipment parameters. This activity includes the integration of the new site to the total network according to the operator criteria. Once the commissioning is without technical and operational problems, the site is put into service. It means that phone calls can be processed by the site through the network. The activity which closed the process is the optimization.

In order to optimize a new site and its integration to the telecommunication network, we need to collect measurements about the level and the quality of the signal and then to eliminate signal interferences in order to improve indicators such as the dropped call rate for example.

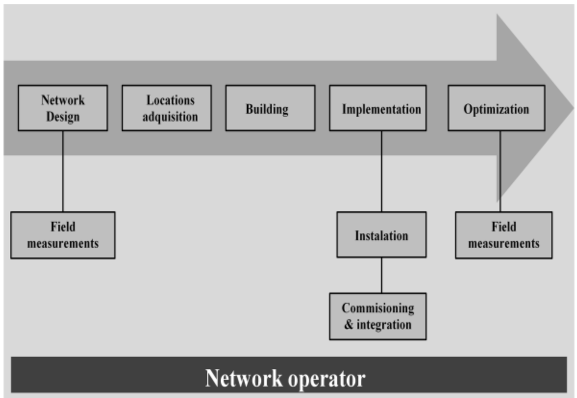

Figure 2: The network planning process

3.2. Different type of cells

The network design, the first activity in the network planning process, is carried out based on certain criteria which must be specified by the network operator in accordance with specific customer requirements. Normally, the network operator must adapt these requirements to his business model. As noted, the network design is an activity which may or may not be based on field measurements. To get field measurements is not always possible because for that, it is necessary that exists a mobile telecommunication network, does not matter if the existing mobile telecommunication network works with a different technology, the most important thing is to get the field measurements. If does not exist a network, the design is made using simulation models based on theoretical assumptions. At the end of the network design, we can get the different types of cells, which will be implemented, as well as their capacity, both in terms of the number of transmission channels. The different types of cells depend on the physical area to which the cell needs to give the communication service.

Thus, pico cell can be designed to provide service within buildings and are characterized because theirs dimensions are small and their transmission power is low. Technically, a one location correspond one kind of this cell. While micro cells are designed to provide service to shopping centers, open parks and business centers, for example, and are characterized as well as the pico cell by a low transmission power.

We can also implement macro cells, which reach 2000 meters as radio service area with a transmission rate of 144 kb/s. If the applications require a better transmission rate, the network can be adapted to a major one, but the radio service area must decrease until to reach almost 500 meters (ETSI 1997). This type of cells is characterized by a big transmission power (see Fig. 3).

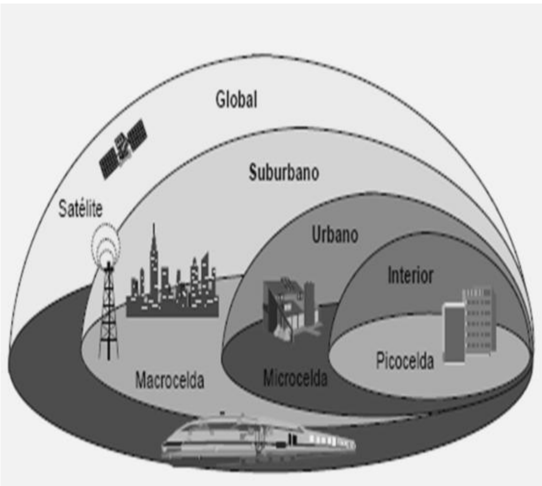

Figure 3: Different types of cells

In order to be most competitive, in some cases the operators design a telecommunications network based on the service area criteria. This criteria works well in the cases of macro cells, it means, to cover a big area such as a community, because it helps operators to attract new customers. But in the case of a network designed to service inside of a building with pico cells, is very important to consider the cost-benefit approach and the specific user requirements because the customer will move around all the building and need to get the service in any point inside the building and the service operator need to be provided in all point inside the building in order to get customer satisfaction which will be converted in revenue for operators. So network operators must implement a network that first satisfies customer service needs and then, guarantees revenue for him.

We do not say that the cost-benefit criteria is not taken in account when a network operator design his own network based on macro cells, instead, we say that in many cases is more convenient for operators, in terms of trade, to base the network design on the service area criteria for macro cells and for the network design based on pico cells is more convenient for operators to be ensure the availability of the network in terms of services, applications and transmission channels.

4. ANOTHER APPROACHES

There are many approaches to design a mobile telecommunications networks and it depends on the priorities of the network operator. Once operators have defined their design criteria, it is necessary to select the technical design tools to be used. One of the most used tools in these cases is the simulation. At the present time, there are many kinds of simulators for UMTS telecommunications networks design which are configured in accordance with the parameters that we need to modeling and analyzing (Alonso y Lopez 2005).

Simulators permit to analyze the network at different levels. The advantages for working with network simulators are the increased productivity in the network development, less time to market so total cost is decreased. Some examples of simulators used in the network planning are the follows:

- Network simulator (System level), is possible to analyze the traffic, QoS, handover, admission control,
- Link simulator (Link level), controls the transmission errors,
- Physical layer simulator, is used to evaluate coverage area, power transmission, cells and interferences,
- Protocols simulator, verifies, analyzes and optimizes protocols,
- Integrated simulators, this kind of simulators has many functions integrated as the name indicates.

Many studies are development each year in accordance with the specific criteria of the network operators. The criteria could be technical, economic or both of them.

5. THE PROPOSAL

In this paper, we propose an application approach to design a third-generation mobile network based on a traffic simulation model and a cost-benefit model, to provide 3G mobile telecommunication service at the interior of an airport. This approach consists of five general steps (see Fig. 4).

1. First, we develop a network traffic simulation model in terms of transmission services and third-generation applications,
2. Then, we perform the simulation experiments using the software ARENA™,

3. From the results of the experiments simulation, we obtain the network capacity measured in Mbits/s depending on the cell radius,
4. Based on the cost-benefit model and the network capacity, both as functions of the radio cell, we get the cell radius that maximizes the net profit percentage of the network,
5. So we obtain the network configuration, number of cells and radius cells, which satisfy the operator and users requirements.

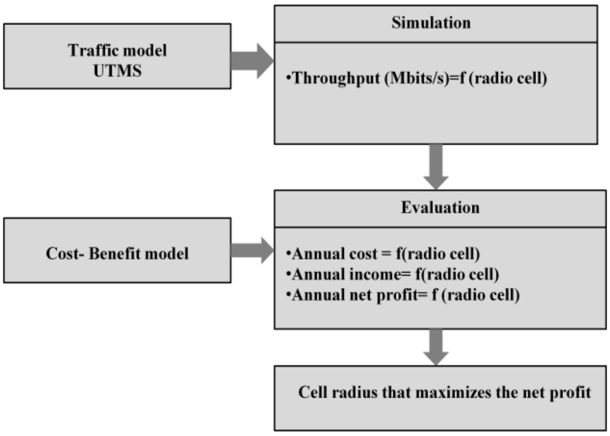

Figure 4: An approach for design a 3G mobile network based on cost-benefit

This approach represents an alternative to the mobile network design traditional process and we propose it to be used by network operators because this approach take account the users requirements and the operator cost-benefit, which are operation basic criteria in a competitive industry as actually is the telecommunication industry.

5.1. The scenario

The scenario considered is the international airport of Los Cabos, Baja California Sur, Mexico. Currently, this airport is ranked as the seventh most important in Mexico. In 2005, the airport received a total of 2,466,733 passengers, of whom 431,724 were domestic and 2.035,009 were international, in accordance with GAP (Grupo Aeropuertuario del Pacifico). The physical dimension of the terminal is 8440 meters square and it receives, on average, 730 passengers per hour every day (see Fig. 5).

5.2. The 3G mobile services and applications

According to the ITU (International Telecommunications Union), the network services and applications based on technology 3G are grouped as follows:

- Interactive (Conversation, messages and information download).
- Distribution (emission and cyclic).

Figure 5: The international airport of Los Cabos, BCS

By one hand, in accordance with Ferreira and Velez (2005), an application is defined as a work which requires the communication between one or more information flow, between two or more parts geographically distributed. The applications are characterized by the service attributes, the communication and the traffic characteristics. One essential data to the analyses purposes is the utilization rate for each application. By another hand, the services and applications distribution requirements can be over real time and over no real time as follows:

- Real time, in this case, the applications need the information distributed for immediate use,
- No real time, in this case, the information is stored in specific reception points to be used later.

5.3. The network traffic model

The most important traffic parameters included in a network design are transmission rate and average duration. The transmission rate is an average number of bits which are transferred between two devices, in each unit time. A possible measurement unit is kb/s. While the average duration represents the duration which each user uses a specific application, for own purposes.

In accordance with Ferreira, Gomez and Velez (2003), a traffic generation model can be used to measure and to describe the traffic over the network only if it is based on the population density and on the service insight, so we can be able to know the call rate for each service. The potential services are grouped as follows:

- Sound,
- Multimedia,
- Narrow band,
- Wide band.

For each service, we select one application in order to get a traffic model (see Table 1). The utilization figures are approximations proposed in this study and that can be tailored for particular cases.

Table 1: Services and applications

Service	Application	Utilization
Sound	Voice over IP	50%
Multimedia	Video-telephone	22%
Narrow band	File Transfer Protocol	16%
Wide band	High Definition Video-Telephone	12%

The transmission rate and the duration statistic distribution, which characterize the applications selected, are included in Table 2 (Antoniou, Vassiliou and Jacovides 2003).

Table 2: Technical specifications for applications

Application	Duration statistic distribution	Transmission rate
Voice over IP	EXP/3 min	12 kb/s
Video-telephone	EXP/3 min	128 kb/s
File Transfer Protocol	EXP/0.1 min	384 kb/s
High Definition Video-Telephone	EXP/30 min	1920 kb/s

5.4. The simulation study

Now, we need to simulate the traffic model proposed in order to be able to analyze the traffic as function of the network capacity and the applications. Since the early days of simulation, people have constantly looked for new and better ways to model a system, as well as novel ways to use existing computer hardware and software in simulation (Law and Kelton 2000). For the purposes of this work, we use discrete-event simulation to model and analyze the network traffic. The steps that will compose a simulation study are showed in Figure 6.

On the next sub-sections, we conduct the simulation study according to the steps in Figure 6.

5.4.1. Data collected

The data which characterized the scenario were described in section 5.1 and the data which characterized the traffic were described in section 5.3.We propose the call arrival based on the statistics from the user arrival peak times at the airport. We considered that the periods on which more call are processed are when the users arrive to the airport in peak times, turn on the cellular phone and make a call.

The periods considered in one day are:

- 8:00 hrs. – 12:00 hrs.,
- 14:00 hrs. – 16:00 hrs.,
- 17:00 hrs-18:00 hrs.

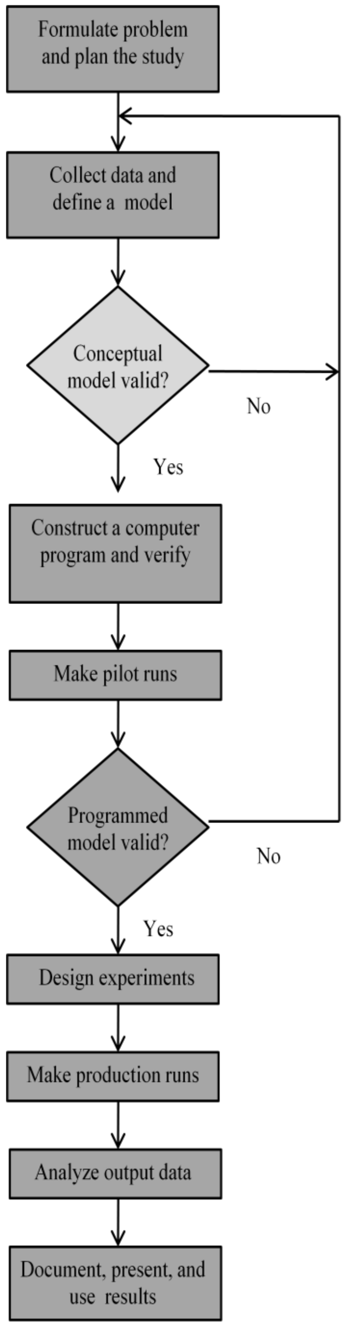

Figure 6: The steps for a simulation study

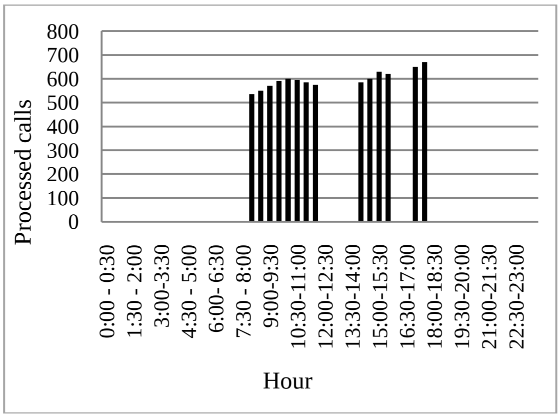

Figure 7: Peak processed calls

In this study, we consider six configurations which take into account a different network capacity. The network capacity is based on the theoretical cell radius, we considered omnidirectional cells. Also, we considered that each cell is composed by seven traffic channels. For a radius cell of 30 meters corresponds a total capacity of 21 traffic channels. While for a radius cell of 21 meters corresponds a total capacity of 42 traffic channels, and so on until reaching a cell whose radius is less than 14 meters, which account for a total capacity exceeding the 98 traffic channels.

5.4.2. The conceptual model defined

The conceptual model about the traffic generated in a network is described in Figure 8.

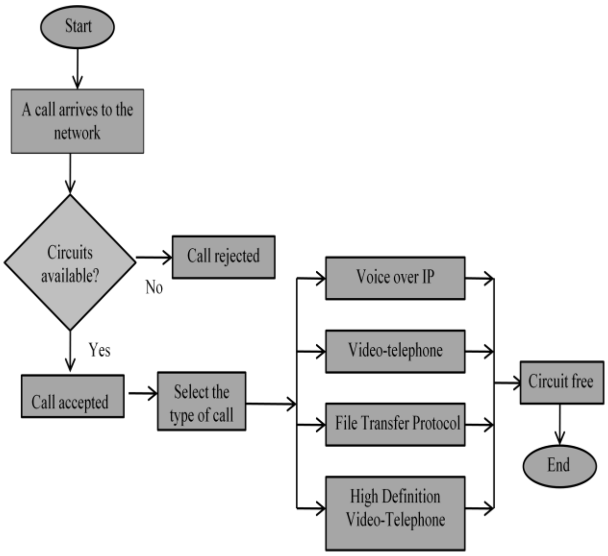

Figure 8: Conceptual model

Once a call starts, the network verifies if a circuit is available. For case negative, the call is rejected and the counter for this kind of calls is incremented. For case positive, the call is accepted and then is classified according to the type of call. There are four types of calls, each type corresponds a one application considered in the traffic model:

1. Voice over IP,
2. Video-telephone,
3. File Transfer Protocol,
4. High Definition Video-Telephone.

Once a call is classified, it is processed in accordance with their duration statistic distribution specified in Table 2. Then the counter is incremented and when the call is finished, the circuit is free to be used by another call.

5.4.3. Software selection

Elizondo and Flores de la Mota (2006) suggest a process which is based on some questions, in order to select a software simulation. The process is divided in two phases. By one side, the first phase is related with references, documentation and compatibility software and, by another side the second phase considers the problem characteristics as follows. We select ARENA software to this simulation study, so some of the questions are answered about this software.

Phase one

- There is a user manual? Yes,
- The language code is compatible with actual computers? Yes,
- The software has enough documentation and error diagnosis? Yes,
- The language is known and easy to be learned? Yes,
- The software is compatible with another kind of software? Yes.

Phase two

- What kind of real problems can be analyzed by the software? Process simulation, business simulation, supply chain simulation, logistic simulation.
- Is easy to store and modify the system data? Is easy through modules.
- Is easy to include user subroutines? Yes, users can create theirs owns modules and add to the software in order to create new systems.

5.4.4. Computer program

Based on the conceptual model and on the ARENA software modules, we develop the computer program (see Figure 9).

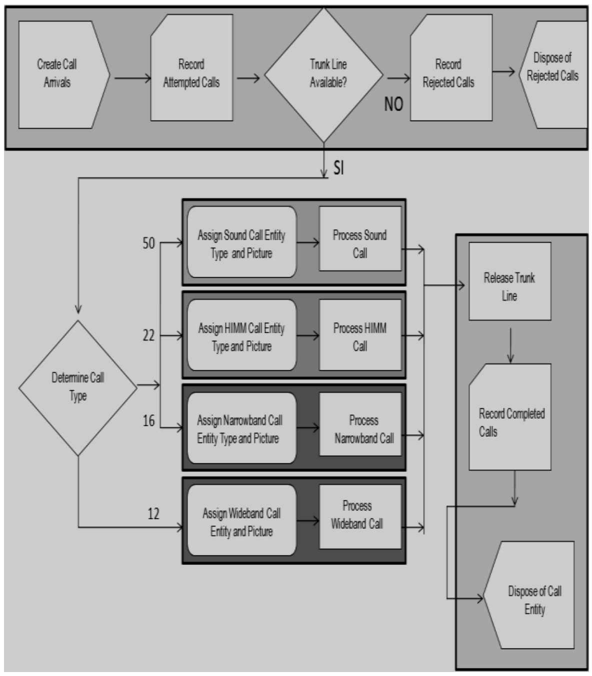

Figure 9: The computer program using ARENA software

5.4.5. Verification & validation

Once the model has been implemented, it is necessary to verify its performance. Based on the technique number 4 suggested by Elizondo and Flores de la Mota (2006), we verified the computer program. This technique consisted in the simulation execution considering many different scenarios so it was necessary to make many changes in the program parameters. After the executions, we checked the consistency of the results in accordance with the expert´s opinion.

As results, we found that when the network capacity was increased, the number of rejected calls decreased and the number of call processed increased. This result corresponded with a real situation over a telecommunications network because a major network capacity correspond a major number of call processed and a minor number of calls rejected.

5.4.6. Design of simulation experiments

We carried out 17 simulation experiments, in each experiment we increased the number of traffic days. So, in the first experiment we simulated 5 traffic days, in the second experiment we simulated 10 traffic days, and so on, until in the experiment 17 we simulated 80 traffic days.

5.4.7. Analysis of output data

1652 total calls were processed for the network configuration with capacity of 21 traffic channels, 3155 total calls were processed for the network configuration of 42 traffic channels, 3505 total calls were processed for the network configuration with capacity of 48 traffic channels, 4146 total calls were processed for setting network of 70 traffic channels, 4173 total calls were processed for the network configuration with capacity of 84 traffic channels, and finally, 4171 total calls were processed for the network configuration with a capacity greater than 98 traffic channels (see fig. 10).

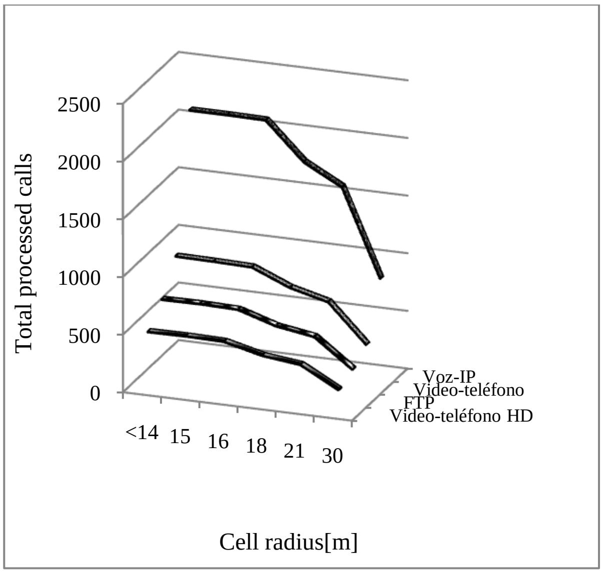

Figure 10: Total calls processed

5.4.8. Use of the results

At this point, we use the total number of calls processed in the cost-benefit model, in order to obtain the annual net profit as a function of cell radius for the different network configurations considered.

5.5. The cost-benefit model

As stated in Gavish and Sridhar (1995), the economic aspect for a telecommunication network can be analyzed by four different approaches: user´s approach, service provider´s approach, regulator´s approach and manufacturer´s approach.

By one side, for users, the most important aspects about the network are the service quality and cost. By another side, for service providers represented by networks operators the most important aspect is to find the network configuration which maximizes the expected revenues. While for the regulator, the most important aspect is the social welfare, to promote competition between network operators and to manage the frequency spectrum. Then, for manufacturers, the most important aspect about a telecommunication network is the equipment cost. So, each approach has their necessities to satisfy.

The approach used in this contribution is the service provider. Because of the service provider business model, in this study we will take in account the impact of the other tree approaches. Cabral *et al.* (2005) suggest that the total annual cost of a radio network is determined by a fixed cost and a cost proportional to the number of cells required to service the area required by the operator. For this particular case, the fixed cost includes the cost of an operating license that the operator must ask the Mexican government.While the cost of each cell (node) is determined by the cost of equipment, the cost of installation and cost of operation and the maintenance as in (1).

$$\text{Annual cost[\$]} = \text{Fixed cost} + (\text{Cell annual cost}) * (\text{Cell}) \quad (1)$$

On another side, the net income diary is obtained as a function of traffic carried across the network as in (2), i.e. the total number of calls processed by all cells in the network. It means taking into account the traffic flow at peak hours the network, as in the rest of the hours of operation of the network, calls are processed very few reaching sometimes be invalided.

$$\text{Annual net income[\$]} = \text{Net income diary} * \text{Traffic Days} \quad (2)$$

The total annual net profit is obtained for different network configurations as in (3).

$$\text{Total annual net profit [\$]} = \text{Annual net income} - \text{annual cost} \quad (3)$$

For the purposes of this study, the trade data was taken from the dominant mobile phone operator in Mexico. So, the annual net profit (%) obtained for different network configurations, according to the traffic simulation model and the cost-benefit model is showed in Figure 11.

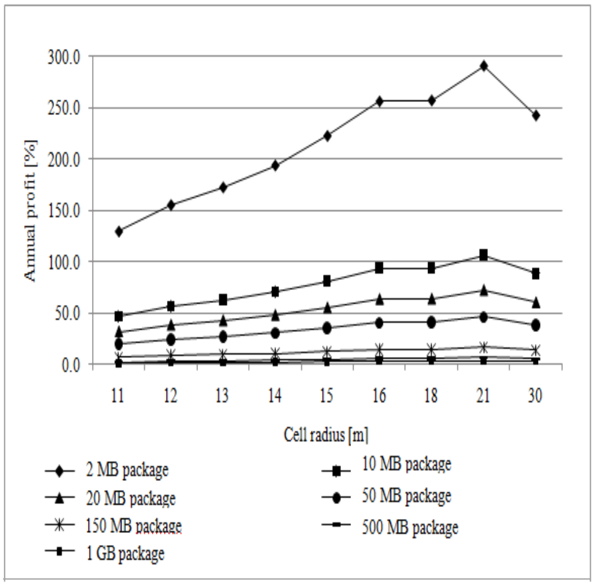

Figure 11: Annual net profit as a function of cell radius of different network configurations

5.6. Results and conclusions

Thus, to attend the use demand of voice over IP (50%) video phone (22%), FTP file transfer (16%), high definition video-phone (12%) at the international airport of Los Cabos in Baja California Sur Mexico, it requires a UMTS network with a total capacity of 42 channels, consisting of 6 cells, each one with a radius of 21 meters, so that the network operator maximizes the percentage of annual net profit network up to 300%.

This proposal represents an alternative to the traditional process of mobile communications network planning. To conceptualize a network as a discrete event model, we can get an approximation of the network configuration that meets the demands of users and supports the decision of the operator, using the simulation. It is clear that under this approach is not taken into consideration technical aspects of a communications network as the propagation loss for example, but rather it is to highlight the importance of the economics of network planning.

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