Traffic behavior simulation of a DECT technology network

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ABSTRACT

In this paper we present the results of a simulation we performed in order to examine DECT's behavior as far as its traffic capabilities are concerned. Therefore, we consider a network that uses the DECT radio access technology and try to simulate a realistic traffic scenario. We are trying to involve DECT's characteristics as those were defined by the DECT ETSI specification. The results show a satisfactory capacity behavior for indoor applications.

I. INTRODUCTION

Towards the final implementation of 3rd generation telecommunication systems and the early planning of the 4th generation systems, DECT, a 2nd generation technology, seems to reflect certain characteristics that should be considered for indoor applications. Considered by many industry and wireless market specialists as a 2,5G system, DECT has been strongly involved in the process of 3G systems standardization. Therefore it poses as the ideal candidate for gaining insight into next generation's challenges [1].

It uses a radio access technology especially designed for indoor applications. Through the use of Dynamic Channel Allocation scheme, it allows a dynamic adaptation to many different harsh radio environments and assures the use of the best channel available [2-4]. Its Multi Carrier/TDMA/TDD structure permits the avoidance of frequency planning [5]. All base stations use the same channels. It allows an easy network installation, since it adapts to the unexpected needs of the various indoor environments.

In this paper we are especially concerned about the behavior of a network that uses the DECT radio access technology in matters of capacity and traffic. Before we moved on to the realization of this simulation we had performed several measurements in a "rough" indoor environment. The results kept us from our original ideas of performing a simple "probability"-based simulation. We were particularly interested in simulating in the best possible way the handover mechanism. In order, however, to do that, we found out that it would be necessary not only to simulate the fast fading indoor environment, but also the randomness of the people's movement.

We believe that the result of this effort has been a realistic approach to simulate the traffic behavior of a network; it produces reliable results and can easily be generalized to simulate the traffic behavior of other systems.

II. SIMULATION SCENARIO

We consider a square building, where 4 DECT base stations are positioned on the four acmes of another square inside the building, as shown in **Figure 1** (the numbers represent the points where the base stations are positioned).

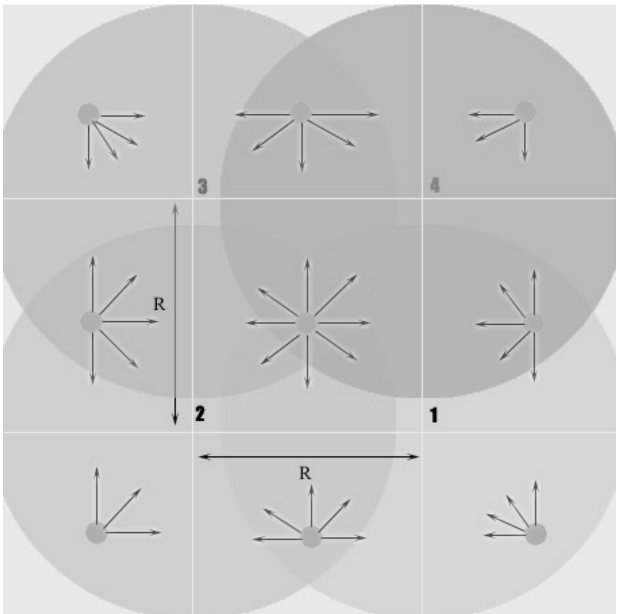

Figure 1. *Schematic representation of the simulation scenario.*

Any subscriber can appear in any one of the nine regions that exist in the building (**Figure 1**). Depending on the region where one appears, one can move towards any direction within the boundaries that are defined by the arrows in **Figure 1**. Those boundaries are placed in order to keep the subscribers moving towards the inner part of the building, thus provoking more handovers and a more complex traffic situation. 20% of the subscribers are standing still and 80% of them are moving maintaining the same velocity throughout their call. If anyone reaches the boundaries of the building he returns towards the opposite direction.

The transmitting and the receiving antennas are considered as half-wave dipoles. In any simulation moment the receiving power for each subscriber from every base station is being calculated. The model we used to calculate the power has resulted from extensive measurements we performed into an indoor environment. Using numerical methods (curve fitting) we concluded to the following approximation for the receiving power (**Figure 2**):

$$P=a+bx+c\ln x+de^{-x} \qquad (1)$$

where P is the receiving power (in dB), x is the distance of the receiver from the transmitter (in m) and a, b, c, d are constants derived using numerical methods and are equal to: a=-20.051454, b=-1.3214449, c=-5.6241748 and d=-46.831869. By adding a Gaussian probability density function (pdf) to the previous model we simulate the Rayleigh channel [6-8].

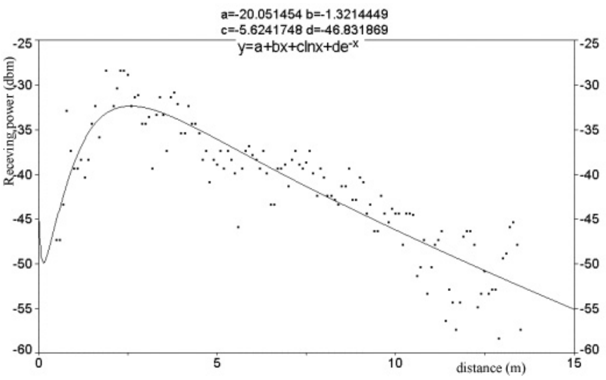

Figure 2. *Approximation of the receiving power from measurements in an indoor environment.*

The incoming calls are considered to follow a binomial probability density function. The duration of the calls follows an exponential pdf. The handover mechanism is defined by the DECT standard [9, 10]. Therefore if the power from a different base station than the one currently in use is 10dB stronger, then a handover attempt begins. No successive attempts can occur in less than 200msecs. A call could be interrupted if all successive handover attempts fail and the C/I ratio remains below a predefined threshold for 10secs.

III. PARAMETERS

The parameters that the user can change for the simulation are:

- The dimensions of the building.
- The distance between the base stations.
- The number of calls per subscriber per hour.
- The number of subscribers per base station.
- The mid duration of each call.
- The threshold for high quality communication.
- The duration of the simulation.
- The velocity of the subscribers.
- A 2nd threshold that is the limit for the desired dynamic range in order to maintain high quality communication.

Of course the user could choose to perform a variation of any of the above variables with a step that he desires, in order to see the performance of the network under varying conditions.

The possible outputs of the simulation are:

- ✓ The traffic per subscriber (Erlangs).
- ✓ The traffic per base station (E).
- ✓ The mid duration of each call (secs).
- ✓ The number of subscribers per base station.
- ✓ The mid number of calls per subscriber per hour.
- ✓ The distance between the base stations.
- ✓ The blocking probability.
- ✓ The percentage of time where communication was taking place while the dynamic range of the receiver was less than the one desired for high quality communication (11dB).
- ✓ The grade of service.
- ✓ A measure for the quality of service.
- ✓ The number of blocked calls.
- ✓ The successful handovers.
- ✓ The rate of incoming calls.

IV. SIMULATION-RESULTS

The level of background noise was considered at –96dBm. The desired dynamic range in order to assure bit-error-rate BER<10^{-3} for GFSK (used in DECT) is equal to 11dB. Additionally, we consider a diversity technique in the transmitter so the margin required for taking into account the Rayleigh fading channel is 10dB. Therefore the threshold for high quality communication was set to –75dBm. The total traffic per base station is given by:

$$E=\frac{N\times\lambda\times\mu}{T} \qquad (2)$$

where N is the number of the subscribers per base station, λ is the mid number of calls per subscriber in T secs and μ is the mid duration of each call. The grade of service was calculated as follows [9-11]:

$$GoS=\frac{Blocked\ Calls+10\times Interrupted\ Calls}{Total\ Calls} \qquad (3)$$

The number of interrupted calls is multiplied by ten because the interruption of communication is considered much more annoying for the user than being unable to establish communication at all. However this criterion was not considered sufficient since the user might suffer from severe interference while being below the threshold, thus resulting in loss of data. In order to include this possibility, we consider a 2nd threshold 10dB lower than the previous one where we assume the loss of data. So we consider the quantity L as:

$$L = \frac{lost \quad packets \quad of \quad data}{total \quad number \quad of \quad packets \quad transmitted} \qquad (4)$$

So we define quality of service as:

$$QoS = GoS + L \qquad (5)$$

First of all, we wanted to determine the maximum possible distance between the base stations (and thus the maximum coverage) so that there would be no effect on the traffic. The distance between a base station and the side of the building was set to 25m. On this simulation we considered the total traffic load per base station equal to 5E (N=25, λ=7.2, μ=100, T=3600), which is a typical value of traffic in an office environment (0.2E/subscriber). So we concluded that the quality of communication remains unaffected for a distance of about 38m (**Figure 3**). Therefore, with the four base stations we can cover an area of $60 \times 60 = 3600m^2$. If however we suppose the existence of obstacles such as interior walls, we could calculate that each wall inserts losses of 10dB so the distance between the base stations should be reduced for about 15m, therefore covering a total area of $50\times50=2500m^2$.

Figure 4 shows the variation of the number of the successful handovers as the distance between the base stations increases. We can see that as the distance increases, for a fixed traffic load, the number of the successful handovers increases until it reaches a limit (45m) and then begins to decrease. The increase happens because the crucial zone grows larger, where the distance and of course the received signal power is such that the handover mechanism is more often initiated (one base station shows 10dB stronger signal power than the one currently in use). However from one point and on, the base stations are so apart that the unsuccessful handovers dominate, so the curve declines (the interrupted calls increase from just 3 at 42m to 3252 at 70m).

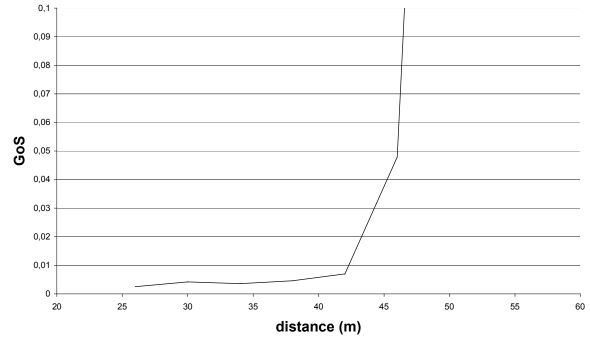

Figure 3. *Variation of the GoS while incrementing the distance between the base stations.*

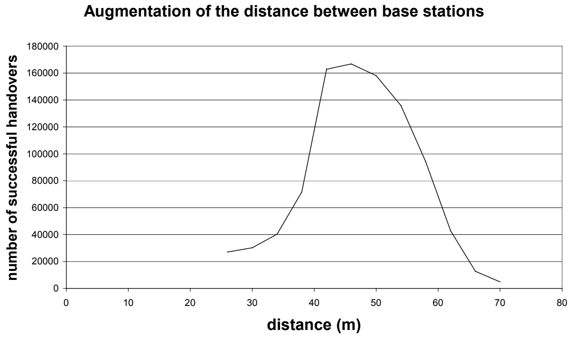

Figure 4. *Variation of the number of successful handovers while incrementing the distance between base stations.*

Since we have determined the distance between the base stations (35m) we can move on to the simulation of the traffic for our system. Each side of the building is considered 50m. The threshold was set to –75dBm. The velocity of each user was considered 0.5m/sec. The 2nd threshold was set to –85dBm. We performed several simulations altering either the number of calls per subscriber or the number of subscribers per base station or the mid duration of each call. Our two criteria were to sustain the $GoS \leq 0.01$ or the $QoS \leq 0.01$ (stronger criterion).

Based on the gos criterion the simulation results show that each base station can carry a total traffic load of approximately 5.6E. The 2nd criterion indicates that the total traffic load per base station varies between 5.4E to 5.6E. Those results are shown in **Figures 5, 6, 7** and on **Tables 1, 2 and 3**. So if we suppose, as a high traffic scenario, that each subscriber performs 10calls/hour with mid duration of each call 100secs, therefore keeping the system busy for 27% of time, then each base station can serve 19 subscribers (5.4E) or 20 subscribers (5.6E).

Total traffic load per base station	Number of the subscribers	GoS	QoS
5	25	0.003846	0.006213
5.2	26	0.005632	0.008343
5.4	27	0.006043	0.008606
5.6	***28***	***0.005658***	***0.007989***
5.8	29	0.009772	0.012299
6	30	0.013258	0.015694

Table 1. *Variation of the number of the subscribers per base station. The total traffic to maintain QoS≤0.01 is marked in bold.*

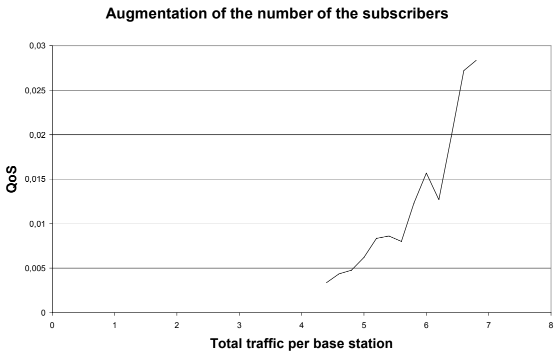

Figure 5. *Variation of QoS dependent on the total traffic per base station.*

Total traffic load per base station	Mid duration of each call	GoS	QoS
5	100	0.005124	0.007609
5.2	104	0.007285	0.00979
5.4	***108***	***0.006412***	***0.009107***
5.6	112	0.008442	0.010828
5.8	116	0.012858	0.015551
6	120	0.012743	0.015438

Table 2. *Variation of the mid duration of each call. The total traffic to maintain QoS≤0.01 is marked in bold.*

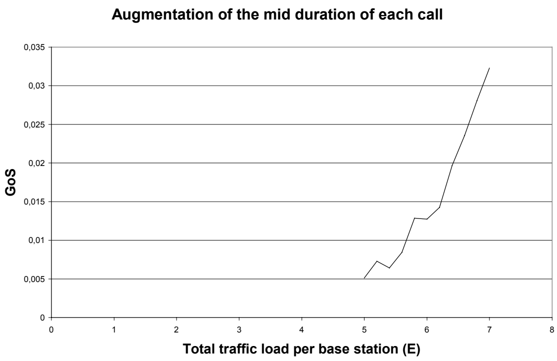

Figure 6. *Variation of GoS dependent on the total traffic per base station*

Total traffic load per base station	Number of calls per subscriber in 1 hour	GoS	QoS
5.138.889	7.4	0.003526	0.006057
5.277.777	7.599.999	0.004583	0.007009
5.416.666	7.799.999	0.006661	0.009073
5.555.555	***7.999.999***	***0.006491***	***0.00909***
5.694.444	8.199.999	0.010375	0.012882
5.833.332	8.399.999	0.010023	0.012315

Table 3. *Variation of the number of calls per subscriber in 1 hour. The total traffic to maintain QoS≤0.01 is marked in bold.*

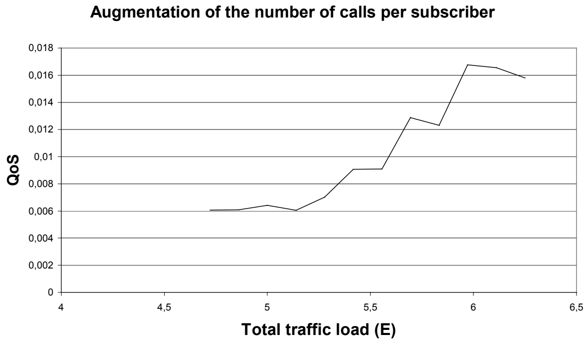

Figure 7. *Variation of QoS dependent on the total traffic per base station.*

V. CONCLUSIONS

In this simulation scenario we haven't taken into account certain parameters that could cause problems in the communication channel and lead to a further decrease of the total traffic per base station. Such parameters are intrachannel interference and intermodulation products. Therefore an even better estimation could have been to say that the system functions satisfactory for a total load of 5.2E per base station. Additionally DECT's characteristics allow for close positioning of different base stations, thus increasing the overall capacity of a network, depending on the special needs of any different indoor environment. We are now concentrating on further developing our software to be able to adapt to different systems' characteristics. We are trying to produce a more accurate software package that would be able to calculate the BER, by implementing a 3D ray tracing technique that we have developed [12] in another software package and use it in the above scenario.

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