DECT ARCHITECTURE PROPOSAL FOR A CONSTRUCTION SITE

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Abstract: *A construction site is an specific environment where important propagation related issues have to be considered. In particular an important problem concerns the coverage of buildings under construction and therefore continuously changing. The deployment of a DECT system in such scenarios can not be carried out as usually, by means of DECT base stations linked by cables. Another specific problem is that no measures can be done prior to decide the best place for the antennas since initially the building does not exist. In this paper a way to solve both problems is proposed through a specific system architecture, a propagation model and a combination of software with a CAD tool.*

Introduction:

Base Stations linked by cable and spread along the coverage area are used as a typical configuration for indoor mobile communication system to allow the communication with a number of portable radios inside the building. However, in buildings under construction the installation of fixed cables should be avoided as far as possible and therefore other ways to offer indoor coverage have to be employed. The solution proposed and studied in this paper is the use of the conventional base stations installed outdoors, but in the building vicinity. In particular a DECT system is retained because its suitability for such scenarios, so as the base stations and their controller can be co-located in a so named HUB Container. The increase in attenuation due to both, a higher distance between terminals and external wall penetration losses, can be overridden increasing the antenna gain by the use of directive antennas at the container. The number of required antennas depends on the building height and width and of the distance between the HUB and the building.

Taking into account that no prior measurements inside the building can be done because the building is not yet built and that once the construction process starts the environment is continuously changing, a software tool to predict received signal level in the indoor and outdoor environment as far as the building is in process is necessary to design the communications system. Recently reports of the application of analytical ray tracing techniques to indoor radio propagation modeling have appeared in the literature. This technique has been proposed to predict path loss and also the time invariant-impulse response. However instead of using ray tracing methods which are more accurate but very slow we use distance and partition dependent path loss model.

In section 1 the propagation model used to predict power level inside a building is defined. The system architecture proposed to offer coverage while the building is under construction is explained in section 2. Finally in section 3 a software tool designed to combine both, the prediction model and a CAD tool to represent signal level over building map, is described with detail. Also in this section several examples of the capabilities of the software designed are explained.

Section 1: Propagation model.

Models that allow a system designer to predict path loss for any type of buildings without measurements are extremely cost-effective and time-efficient. The model proposed in this work predicts the effects of external and internal walls, office partitions (light walls), floors and building layout on path loss between the transmitter and receiver. Then it provides simple prediction rules which relate signal strength to the log of distance allowing the representation of contour plots of locations of equal path loss for a fixed base transmitter.

Free space propagation with distance is assumed and we consider additional path loss to be caused by the physical obstacles that lie between the transmitter and receiver and the incident angle. Then the model requires system parameters as transmitted power, antenna radiation pattern and working frequency as well as building parameters, the building plan and information about different type of walls used. The information related to the building is usually contained in the building map files given by the constructor (different type of walls, staircases etc. are in different layers) [1,2].

When calculating the total path loss there are two different aspects that must be taken into account and therefore should be included in the model: the difference between the floor plan that is at the same height level than the base station antenna and the rest of floors, and the effects of the angle of illumination of the building, this is the angle between the outdoor antenna and the surface of the external wall of the building.

The model explained in this section accounts for all the different propagation conditions in one single expression, being the parameters described in the model represented in figure 1. The total path loss is determined with the following expression [3]:

$$L(dB) = 20\log\left(\frac{4\pi}{\lambda}\right) + 20\log(S+d) + Le + LGe\left(1-\frac{D}{S}\right)^2 + max(\Gamma_1, \Gamma_2)$$

with $\Gamma_1 = \sum_{i=1}^{I} k_i L_{wi}$ $\Gamma_2 = \alpha(d-2)\left(1-\frac{D}{S}\right)^2$

D and d are the perpendicular distances from external wall to Base Station and mobile respectively and S is the physical distance between the external antenna and the external wall at the actual floor. The grazing angle θ is calculated as sinθ = D/S and changes considerably with floor height at short distances D. Le is the attenuation due to external wall at perpendicular illumination (θ=90º) and LGe is the additional loss in dB when θ=0º (around 20 dB is considered). Γ1 accounts for the total losses due to internal walls in dB being Lwi the attenuation due to a wall of type i (light, medium or heavy wall) and ki the number of walls of type i to be in the line between transmitter and receiver. In the case that there are no internal walls, the existing additional loss is determined with the attenuation α in dB/m (around 0.6 dB/m is considered).

Usually three different types of walls are considered: light walls, this is a non-supporting wall like plasterboard, wood (L_{w1} between 1.5 and 3 dB), medium walls are thin concrete or brick walls (L_{w2} between 4 and 6 dB) and heavy wall this is a supporting wall like concrete wall. (L_{w3} from 7 to 10 dB)
The external walls present an attenuation that changes from 7 dB (concrete with windows) to 12 dB.

It is important to notice that the loss factors considered are not physical wall losses but model coefficients which are optimized by using multiple linear regression to the measured path loss. For this reason the values include the effect of furniture, diffraction and scattering as well as signal path guided through corridors [4].

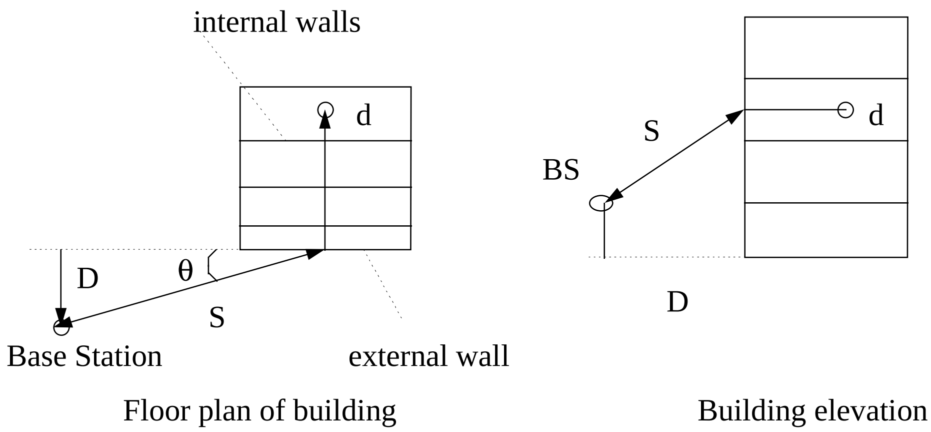

Figure 1: Definition of parameters used in the propagation model

As an example, when the base station is perpendicular to the external wall, and calculating the attenuation loss for the floor plan that is at the same height than the base station antenna (D=S), the well known equation is obtained :

$$L = 20\log\left(\frac{4\pi}{\lambda}\right) + 20\log(S+d) + \sum_{i=1}^{I} k_{wi} L_{wi} + L_e$$

Section 2: System Architecture

The indoor coverage of a building in a construction site could rise serious problems if a number of DECT Base Stations (BS) must be linked by cables. These BS belonging to the same floor or different floors. So in order to circumvent, at least partially, this problem an architecture is proposed consisting of the placement of all the required BS in the outdoor as illustrates the Figure 2. These BS`s could be connected to the Base Station Controller via cable inside the so named HUB container. Moreover, this network layout allows the HUB container to be moved from one to another construction site as needed, avoiding costly network deployment with indoor BS layout.

Due to the low transmitted power specified in the DECT system and to cope with building penetration losses, directive antennas will be used. Moreover this allows us to illuminate only the building to be covered. The antenna gain, the radiation beamwidth and the distance between the antenna and the building determine the number of floors to be covered by one single antenna and then if more antennas should be required to cover higher floors. For rather tall buildings a broadside illumination of the building could be obtained by the use of several antennas appointing to different floors. This situation is illustrated in figure 2 in relation to the antenna of H1 height (perpendicular illumination) and H2 height (broadside illumination). For rather wide buildings like commercial centers or airports, and in order to ensure the coverage of the whole building this can be simply obtained repeating the above architecture but in the horizontal plane.

As an example of system design an antenna of 60 cm of diameter presents an approximate radiation beam of 20º. That means an aperture of about 12 m. height or 4 floors at a 50 meters distance (D=50 m). Then in this case H1 should be about 6 meters.

The received power in the portable is given by:

$$P_r(dBm) = P_t(dBm) + G_r(dB) + G_t(dB) - L(dB) - \alpha(dB) - MF(dB)$$

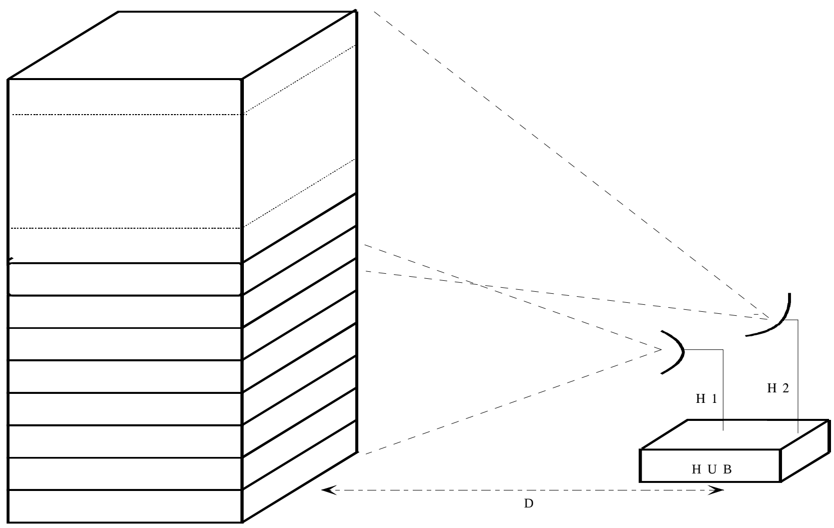

Figure 2: proposed system architecture

and typical values for the link budget could be the presented in the following table:

System Parameters:

Transmitted Power (P_t)	24 dBm
BS Antenna Gain	17 dB
Portable Antenna Gain	2.14 dB
Connector losses (α)	1.5 dB
Fading margin (MF)	18 dB
Receiver Sensitivity (P_r)	-86 dBm

The fading margin (MF) accounts for the presence of fading and the value of 18 dB represents the worst case situation when a lot of people is moving within the vicinity of the portable receiver (Rayleigh fading). Otherwise this figure could be lowered below 10 dB (Rice fading*)*.

In the cases where no complete coverage is possible from the outdoor antenna it is always possible to locate a repeater, this is a directive antenna pointing towards the BS and ommnidirectional antenna for the coverage of the floor (or floors) to get a global coverage of the building.

Section 3: Software Tool.

Computer models can represent a valid alternative for the analysis and the design of efficient indoor communication systems. The Base Station has to be placed strategically to achieve optimum communication coverage at the lowest cost. Unfortunately the coverage region depends heavily on the type of building and on the placement of walls within the building.

Traditionally BS locations have been selected by experts but in this paper an interactive software system that can be used to assist in base station placement is described. It is intended to be easy to use by individuals who are not experts at wireless communications system design. After the user has selected base station location within a graphical building plan, the system interprets the building plan and uses simple path loss models as described in previous sections to estimate coverage regions for this position of base station. The software tool allows to consider an arbitrary antenna radiation pattern and orientation, so different types of antenna can be tested to optimize coverage. It can also deal with arbitrary building topology and construction materials. The model takes into account building penetration losses and wall and floor losses depending on building materials (concrete, metal, plasterboard, brick, glass, etc) and represents predicted signal level in different colors and in a three dimensional structure as far as the building is in progress.

This software tool is combined with a CAD tool to represent the building in a three dimensional structure. Different floor plans are introduced in separated files, and for each file the information about building construction progress is stored in different layers. Different colors are assigned to different materials so that the attenuation introduced by the wall is directly associated to the color used for its representation. To introduce all this data two different approaches can be used, starting with a scanner and a software (AutoCad or Designer) to prepare the format of the files, or starting directly with the .dxf files given by the architect and modifying them to adapt to the software program.

A database is generated with information about different construction materials at the frequency band of DECT system . This database includes the attenuation expected from COST 231 model and also the permitivity and conductivity for different materials, in prevision of a future incorporation of a ray tracing model which accounts for reflections, diffraction and scattering to the software. After this it is possible to simulate the building construction process from its beginning and therefore design the DECT network in an active way, choosing the best configuration at each construction stage. Also a database is generated containing information about different antenna that could be used in the design (with different radiation diagram, gain, etc.).

Then a software tool easy to use to give graphical information about the building coverage is designed. This software is structured by menus and submenus, offers a graphical representation in 3D of building map (global, one floor, several floors, front view, rear view, etc), represents the coverage (received power level in layers of different colors, the limits of the coverage area for a given sensitivity, etc). Interactivity is also possible as system parameters can be changed from program (another antenna, change of building materials, change of antenna position, transmitted power level, sensitivity, etc).

The software also accounts for the possibility of having more than one antenna to cover the building. In this case the software tool represents the coverage with an indication of which antenna is the best server at each floor plan. The possibility that at the final stage perhaps it will be difficult to reach some locations of the building due to obstacle shadowing (the internal and external walls and all the ceilings already constructed can introduce a considerable attenuation) has been also considered. In this case there is the possibility to locate a repeater (directive antenna pointing towards the Base Station and omnidirectional antenna for the coverage of the floor or floors to get a global coverage of the building). Repeater coverage could also be represented allowing a quick analysis of the advantages obtained by the use of the repeater.

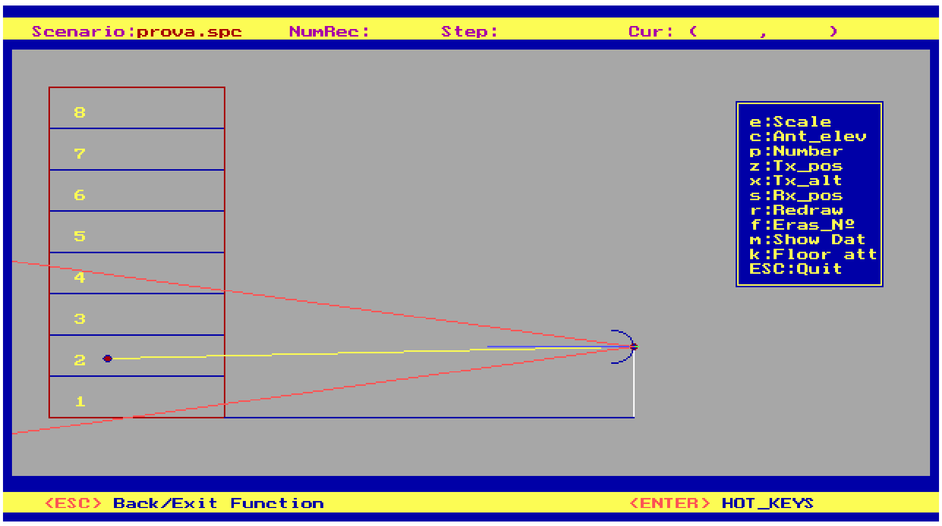

Figure 3: buiding representation and designed software

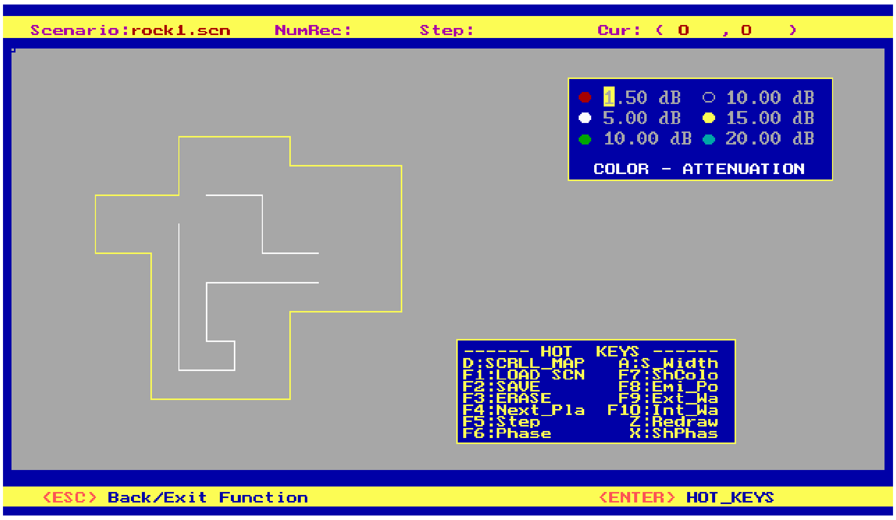

Figura 4: Example of floor plan with building construction phases and materials

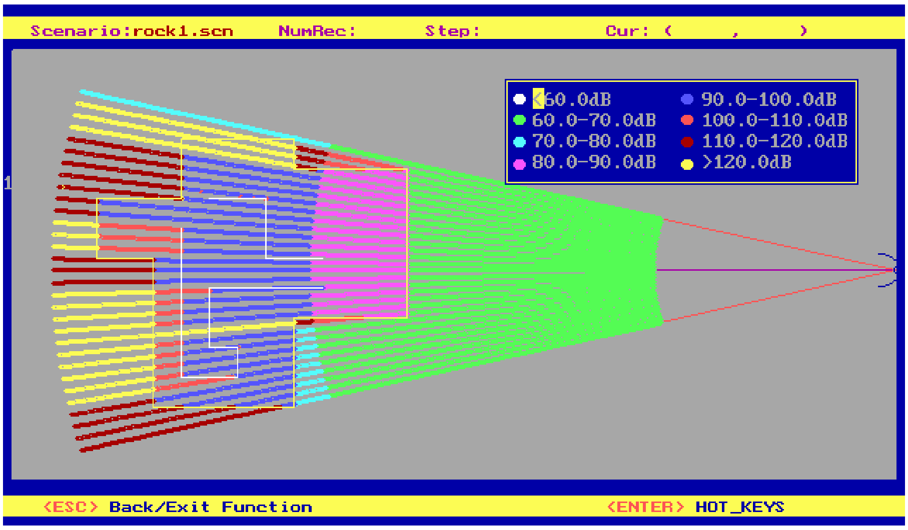

Figure 5: Example of floor coverage

Section 4: Conclusions

A system architecture and an easy to use interactive software tool have been designed to help the installation of proper mobile communication systems in buildings under construction using DECT standard. The system supports both, single-floor and multifloor buildings. In order to simplify the design all the parameters have been set to default values (in tables) but in order to offer versatility all the parameters can be modified by the user. The floor plan can be generated by using AutoCAD or any other CAD but the input files should be .dxf files. The system calculates the coverage of the building once the Base Station Antenna is selected. To test the software next step should be a measurement campaign in several construction sites. The resulting system is expected to be useful to constructors.

References

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