WHITE PAPER

Designing In-building Wireless Systems With Confidence

AN IN-DEPTH LOOK AT MEASUREMENT-BASED PREDICTION (MbP™) AND ITS ROLE IN CREATING THE MOST ACCURATE IN-BUILDING WIRELESS DESIGNS POSSIBLE

HIGH-QUALITY WIRELESS COVERAGE INDOORS IS AN ESSENTIAL COMPONENT OF IN-BUILDING IT AND INFRASTRUCTURE SYSTEMS. HOWEVER, TO CREATE EFFECTIVE, ECONOMICAL SYSTEMS REQUIRES DESIGNERS TO HAVE ACCESS TO TOOLS THAT CAN GIVE THEM A HIGH LEVEL OF CONFIDENCE IN THEIR DESIGNS BEFORE THEY EVEN LEAVE THE DRAWING BOARD. THIS WHITE PAPER EXPLAINS THE ISSUES AND DESCRIBES SOLUTIONS DEVELOPED BY RED-M, BASED ON ITS EXPERIENCE IN DESIGNING & IMPLEMENTING IN-BUILDING WIRELESS SYSTEMS.

IN-BUILDING SYSTEMS TODAY

Many of today's technologies require dedicated in-building systems if they are to work effectively, everywhere that there is demand for them.

- Wireless LANs alone (more commonly referred to as Wi-Fi) have been responsible for much of the recent growth in such systems
- 3G is now beginning to stimulate new growth in a bid to liberate its potential for higher data rates
- With TETRA systems, in-building deployments are helping provide safe policing and management of public and private buildings

This White Paper is for technically-orientated directors, managers and engineers interested in the network planning, design and optimisation of indoor wireless systems.

THE REASON FOR THIS WHITE PAPER

To explain how to attain the benefits of effective in-building wireless systems, such as:

- Improved coverage in the locations where more than 70% of all mobile phone calls originate and terminate
- Much needed capacity for large public spaces such as airports and shopping centres
- Flexible tariffs and reliable wireless services for corporate offices
- Excellent control of interference and wideband channel dispersion for high data rate systems

With its unique MbP technology, Red-M's Radio Frequency prediction tool, Red-Predict™, helps deliver such benefits by assuring excellent network performance from every design.

EXECUTIVE SUMMARY

With MbP technology, Red-Predict solves all of the issues currently associated with RF prediction tools:

- **Highly accurate predictions** - based on optimum combinations of actual in-building measurements and field-proven models
- **Accelerated design time** - with evaluation and optimisation from a factual baseline
- **Consistent design approach**
- **Coverage and capacity** - enables very precise planning of the exact performance required for the user population and applications in use
- **Quality** - ensuring that the wireless network design will deliver the required levels of service exactly where needed in the building

IN-BUILDING TECHNOLOGIES

There are many technology options available for in-building coverage. These include dedicated picocells, off-air repeaters, radiating cables, passive distribution systems and - increasingly - active systems which transport RF over optical fibres.

All of these solutions have one thing in common: they are all different flavours of Distributed Antenna System (DAS, see [1] for more details) and can provide excellent performance when compared with single indoor antennas or with penetration from macrocells outside. Each radiating element (antenna or radiating cable) in a DAS is located for optimum performance at the most important locations in a building for coverage or capacity. By distributing signal power among the various elements, coverage is impacted the least by signal losses through internal walls and floors. As a result radiated power can be reduced, helping the system stay within health and safety limits and minimising signal power leaking out of the building.

NO STANDARD IN-BUILDING DESIGN APPROACH

Despite the increasing maturity and sheer number of in-building systems, no standard design approach has yet emerged. Factors like antenna location, transmit power and overall structure usually depend entirely on the judgement of individual RF engineers working within the constraints of the location, and restricted to the particular antennas and distribution equipment specified by building owners and managers.

Experience will always be invaluable. But the absence of objective methods for evaluating and optimising system performance will always have a bearing on design, leading to increased cost and inevitably reduced take-up. Add a lack of consistency of approach between different designers, together with the conflicting demands of in-building coverage versus isolation from external networks, and it is not surprising that stated design criteria are rarely met in full.

It is perhaps surprising that this situation persists at all today. After all, outdoor systems are routinely designed using sophisticated planning tools and techniques, all of which are well standardised and which demonstrably give good results. Until now the inadequacies of in-building systems design have largely been hidden behind frequency planning, or by simply by avoiding in-building systems altogether. But this is no longer enough. The demands of contemporary 3G, Wi-Fi and high-performance private digital and 2G systems mean that a fresh approach is long overdue.

CHALLENGES FOR IN-BUILDING PLANNING TOOLS

Planning tools for in-building systems are certainly available, but they are rarely used in practice since the results rarely justify the effort needed to use them.

The in-building environment is extremely complex, and is impacted by a variety of propagation mechanisms including reflection, rough surface scattering, diffraction and transmission. Although these mechanisms can be successfully simulated using techniques such as ray-tracing, in practice they are very time consuming and are extremely sensitive to internal building geometry. As a result, such tools have only been of use to academics and researchers.

Another approach is to ignore the more complex propagation mechanisms altogether and assume that signals always follow a direct path from transmitter to receiver, with only wall or floor attenuation to impede their passage. Examples of such approaches include the Keenan & Motley model[2], which includes both wall and floor loss factors, and the ITU-R 1238 model[3], which assumes average behaviour across all walls on the same floor. These models can give some useful indications of coverage for basic 'what-if' evaluations, but do not yield enough accuracy to deploy a low-cost system with any degree of confidence. However, both approaches share a common difficulty: that of obtaining accurate data on building characteristics. There are two parts to this - digitising the building layout and then assigning electrical properties to all its different elements.

Capturing a building layout means knowing the location and size of all floors and walls. This data may be available from CAD drawings and plans in digital form, but gaining access can be difficult as architect copyright may be involved. Even when digital files are available drawing conventions vary widely, requiring careful import filtering to separate walls and other features. More commonly only bitmap images or paper plots are available and these will require manual digitising. This is both time-consuming and prone to errors.

Once a building plan has been digitised, it is necessary to assign material types and other properties to all of the walls. The range of materials used in buildings varies widely. The electrical properties also vary significantly, even with superficially similar materials.

[1] S.R. Saunders, 'Antennas and Propagation for Wireless Communication Systems', John Wiley & Sons, ISBN 0471986097, July 1999.

[2] J.M. Keenan & A.J. Motley, Radio Coverage in Buildings, BT Technical Journal, vol. 8, no. 1, pp. 19-24, 1990.

[3] International Telecommunications Union, ITU-R Recommendation P.1238: Propagation data and prediction models for the planning of indoor radio communication systems and radio local area networks in the frequency range 900MHz to 100GHz, Geneva, 1997.

For example, the density of concrete varies over a wide range from the lightweight concrete composite floors found in steel framed structures to the dense concrete walls and floors used in concrete framed structures. These variations have a profound impact on losses at RF frequencies. Similarly, the presence and spacing of reinforcing bars within concrete can cause very rapidly varying, frequency dependant loss factors. The end result of these and other uncertainties is that current planning tools are hard to use, insufficiently accurate and have long design times, often beyond acceptable limits.

A ROLE FOR MEASUREMENT

During the design and deployment of most in-building systems, it is common practice to conduct RF site surveys to confirm the coverage from particular antenna locations, and to ensure it can meet user needs. A typical example - using the Red-M headquarters building, Graylands - is shown in Figure 1 below.

Such surveys, if conducted carefully and with properly calibrated equipment, provide an accurate guide to coverage. However, interpreting the results can be rather subjective. That said, good quality surveys will show the effect of construction materials on signal strength and reveal any complex propagation mechanisms present. If this information was to be extracted and processed in the right way, it could then be used to analyse and optimise system designs.

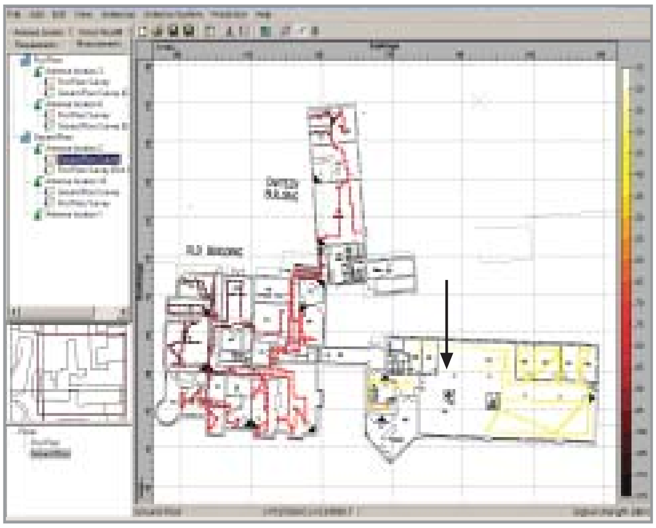

FIGURE 1: Typical indoor RF site survey: the colour indicates the signal strength in dBm recorded from the highlighted transmit antenna

MEASUREMENT-BASED PREDICTION

From the experience gained in carrying out more than 300 complex projects, Red-M has developed and refined its own process for optimising in-building systems design. This process, known as Measurement-based Prediction (MbP) and originally developed for macrocellular systems, creates an optimum combination of measurements and simple models in order to predict complete system coverage and performance.

Predictions are made over the whole area of interest, even though actual measurements may be limited, with each measurement point influencing every prediction point to varying extents. MbP is described in more detail elsewhere but, by applying a modified version of the MbP process to in-building environments, it is entirely possible to make very accurate predictions of coverage.

RED-PREDICT: A TOOL FOR IN-BUILDING DESIGN

To fully exploit the advances made possible by MbP, Red-M created a software tool, known as Red-Predict, which implements a version of the MbP algorithm optimised for in-building application. Additionally, by incorporating certain factors specific to in-building environments, the tool allows accurate predictions to be made for antennas and locations not part of the original site survey.

This latter feature is especially important when changes to initial plans have to be made in response to requests from building owners, or to accommodate constraints on equipment location or cable runs. It also allows system designers to optimise their DAS design by adjusting the number, location and types of antennas together with associated distribution technologies and transmit powers. Experience with Red-Predict shows that the number of antennas to meet a given coverage requirement can be reduced by some 25% when compared to a purely experience-based approach. Figure 2 overleaf shows an example of the composite DAS coverage for Graylands using the data presented earlier.

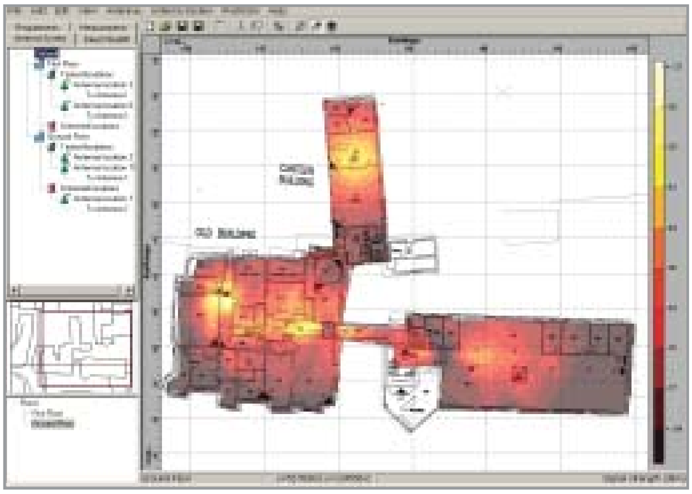

FIGURE 2: Predicted system coverage from Red-Predict using a combination of tested and untested antenna locations

Red-Predict also enables all of the disparate data required for an in-building project to be managed in a single file. This structured management of in-building systems data is invaluable in ensuring that subsequent system upgrades - following technology or building changes - can be carried out in an efficient and consistent manner.

CRITICAL FACTORS FOR SUCCESSFUL IN-BUILDING DESIGN

In summary, a number of factors are essential for the successful creation of cost-effective in-building systems:

- Clear capture of requirements: As well as client requirements for coverage, capacity and isolation, this also means consulting building owners and/or managers to establish ground rules for access during design and deployment together with any aesthetic constraints.
- Use of site surveys: Collecting clear information on the structure of a building using both RF site surveys and physical surveys to assess constraints like space, electrical supplies and mechanical considerations.
- Access to a wide range of distribution system options: The most cost-effective distribution system depends on both the building and the requirements for the system. Passive and active options from a variety of manufacturers should be considered.
- Use of appropriate planning tools: To generate confidence in both designs and finished systems a measurement-based approach is required. New buildings potentially benefit most, as experience from previous projects in similar environments can be incorporated.
- Clear communication: In-building system design and deployment is a multi-disciplinary activity. Effective project management and communication involving all parties throughout design and deployment is essential for a successful end result.

By considering and putting into practice all of these elements, Red-Predict, with MbP technology, can help in-building systems reach their full potential.

Independent of equipment vendors and technologies, Red-M enables organisations to fully realise the benefits of wireless systems by delivering high quality solutions through an integrated, five-step cycle of best practice:

1. CONSULTING
Defining exactly how, when and where wireless will be used.

2. AUDIT
Understanding what is happening and developing a design baseline.

3. DESIGN
Optimum wireless performance from a design that works right, first time.

4. IMPLEMENT
A non-disruptive installation using best-of-breed technologies.

5. MANAGE
Maintaining a healthy network that continues to meet your needs.

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