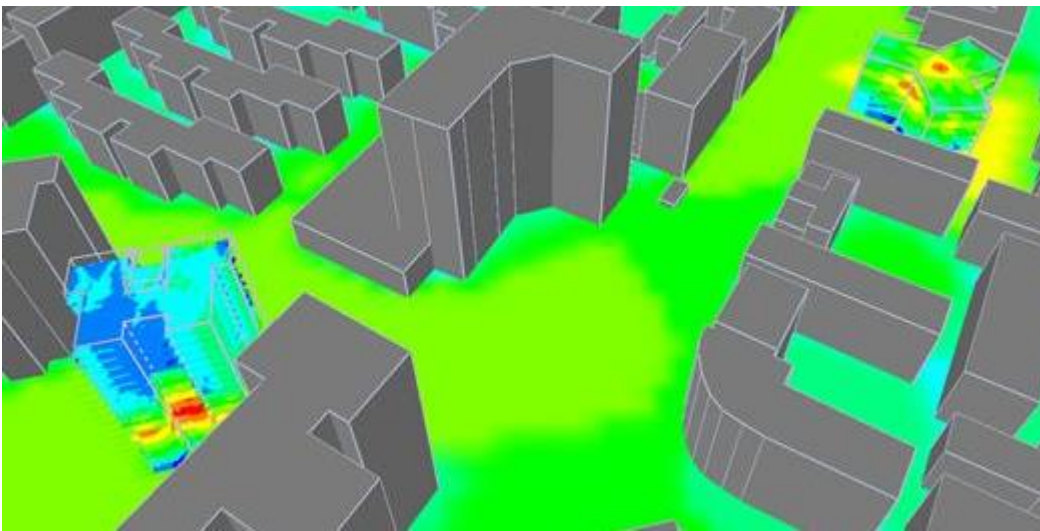


The Role and Benefits of RF and Performance Modelling Tools in the HetNet Era



February 2015

Summary

The growing and ever harder to reach demand from consumers for seamless mobile connectivity both indoors and outdoors is driving a proliferation in the types of Radio Access Network (RAN). Small cells, macrocells, Wi-Fi and DAS must all work together in the 'heterogeneous' network to deliver good experiences wherever consumers are – and for an ever-widening range of different service types and applications.

A holistic approach to network performance modelling is essential if we're to take the guesswork out of understanding how these different types of infrastructure will work together to create the desired customer experience. Independent models of indoor and outdoor, RAN and backhaul, RF performance and service performance factors cannot take account of their overall interaction and will therefore be implicitly inaccurate. This has the potential to greatly impact the profitability and success of network operators and their partners.

In the early days of the voice coverage rollout era, signal strength plots alone provided a good indicator of end user QoE. However, in today's capacity-limited data paradigm, interference, loading and types of service must all be taken into account in order to understand what the end user experience will actually be.

Although network density and complexity must scale to meet demand, revenues will not and so new and more cost effective processes must be introduced. There will also need to be an increased reuse of common tools and design data throughout the whole plan, deploy, maintain, and upgrade network lifecycle.

Once the preserve of bespoke tools within research groups, single platforms that combine indoor/outdoor, RAN/backhaul and traffic modelling functions are now commercially available for non-expert users, enabling them to design, deploy and operate the HetNets of today and tomorrow in the most efficient and cost effective ways possible.

In this paper we outline the functionality of the performance modelling tools needed to meet the challenges faced by the designers and deployers of today's HetNets. We look at the roles of such tools across different organisations and groups and the values that they bring. Finally, we look under the bonnet of the leading HetNet planning tool: iBuildNet® from Ranplan – the all-in-one platform for HetNet design, simulation and optimisation.

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1 Heterogeneous networks and their RF planning needs

The rise of mobile data is driving changes in the shape of radio access networks: Data services are more capacity hungry than voice and text, while the majority of consumption today tends to be indoors rather than outside. As a result, the historic ‘one size fits all’ outdoor macro network model is being supplemented with small cells, DAS and Wi-Fi to both increase capacity and improve indoor coverage depth. RF planning continues to be an essential part of wireless network design, but the increasing complexity and cost pressures of the move to HetNets has implications for the functionality of the tools involved. Figure 1 summarises a number of HetNet related trends and the implications for RF planning tools.

Aspect	Past	Present	Implications for RF planning
Cell types	outdoor macro	HetNet = macro +DAS + small cells	Holistic HetNet modelling includes interference co-ordination and small cell backhaul
Usage	mostly outdoor	mostly indoor	Outdoor and in-building modelling plus outdoor ↔ Indoor propagation
Technology	2G	2G+3G+4G +Wi-Fi	Multi RAT and multi vendor configurations
Services	voice & SMS	mixed data services	Traffic types, non uniform UE density and cell loading must all be factored into performance analysis of user QoE
Limited by	coverage limited	capacity limited	
Scale	smaller number of larger cells	larger number of smaller cells	Automated network planning, configuration and optimisation needed
Revenues	scaled with capacity	not scaling with capacity	Cost pressures require increased efficiency through reuse of modelling effort and data assets

Figure 1: Implications of the changing shape of mobile networks on performance modelling

1.1 HetNets and co-ordination

The ‘heterogeneous’ part of the term HetNets can mean different things to different people. Perhaps the most common interpretation involves a network that’s comprised of a range of different cell sizes: macro, micro and femto or ‘small’ cells¹. Capacity, or more specifically *spectral efficiency*, is maximised when the different sized cells all use the same carrier frequency, but this leads to a complex interference environment which demands co-ordination technologies such as eICIC² (enhanced Inter Cell Interference Co-ordination) and CoMP (Co-Ordinated Multi-Point). This managed interaction implies that RF planners should simultaneously analyse the different components of the HetNet as well as any supporting co-ordination technologies.

1.2 Small cells and their backhaul

Small cells deployed close to consumers indoors or at street level will increase capacity and coverage depth, but also introduce the new challenge of small cell backhaul. Identified by operators as one of the main barriers to deployment³, small cell backhaul is very much a part of the HetNet and will need to be jointly designed and optimised alongside the radio access networks⁴. Network planners will need tools to trade between siting the small

¹ “Small Cells, what’s the big idea?”, Small Cell Forum, Feb 2014, <http://scf.io/document/030>

² “Enhanced Inter-Cell Interference Coordination Challenges in Heterogeneous Networks.”, D. Lopez-Perez, I. Guvenc, G. de la Roche, M. Kountouris, T.Q.S. Quek, and J. Zhang. IEEE Wireless Communications, vol. 18, no 3, pp. 22 – 30, June 2011.

³ “Market Drivers for Urban Small Cells”, Small Cell Forum, Feb 2014, <http://scf.io/document/086>

⁴ “Backhaul for Urban Small Cells: A topic brief”, Small Cell Forum, Jun 2014, <http://scf.io/document/095>

cell at the ‘benefit maximising location’ versus the additional cost of extending backhaul connectivity, as described in [5].

1.3 Outdoor and Indoor

The original purpose of a mobile network was to provide voice coverage when users were away from their offices or homes. This was well served by outdoor macro networks which could largely be planned using straightforward outdoor RF coverage analysis. The shift to mobile data has driven usage indoors and today this represents an estimated 80% of total mobile data consumption⁶. The default planning position adopted here involves an outside-in approach, where outdoor macro coverage penetrates into buildings. Where subscriber densities justify it, indoor demand is better served by dedicated indoor systems such as DAS and small cells. Both approaches require RF planning tools to jointly model outdoor and indoor environments and their joint propagation patterns in order to understand how the different network components interact and interfere.

1.4 Loading

Data is greedy and will consume as much network capacity as it can take. The result is that networks today are ‘capacity limited’⁷, and the user experience therefore depends on loading – the number of other users they are sharing with and the types of data service in use. RF planning tools must therefore go beyond basic coverage analysis to also consider interference and loading if we’re to accurately predict the eventual end user experience.

1.5 Scalability

Scalability is becoming increasingly important for all aspects of the network lifecycle and this includes RF planning. Self-organising Network (SON) technologies are being incorporated into equipment and many processes require streamlining and automation⁸. RF planning tools will need automatic network planning features to automatically select an optimal set of sites and provide configuration parameters. Although automation will never give ‘perfect’ results, it will need to be ‘good enough’ to quickly identify the amount of infrastructure needed to meet expected consumer demands across an area that comprises both outdoor and indoor environments.

1.6 Cost pressures

The consumer’s willingness to pay for mobile connectivity is not keeping pace with their demands for richer services, increased data volumes and deeper coverage. Much has been said about mobile data creating a ‘scissor effect’ for the mobile industry, which assumes a scenario where the costs of meeting ‘exponentially’ increasing demand are rising faster than revenues, leading to a loss making situation⁹. However, equipment vendors and analysts have since pointed out the flaws in this simplistic analysis^{10,11}: demand growth is slowing, capacity will only be constrained by capital, and there is still plenty of room for innovation and increased operational efficiency. To the last point, RF planning tools will need to evolve to better fit with these new and leaner processes. There will need to be an increased reuse of a common platform and data assets, as well as closer integration with all the different teams involved throughout the design, deploy, maintain and optimise lifecycle.

⁵ "Business case for Urban Small Cells", Small Cell Forum, Feb 2014, <http://scf.io/document/087>

⁶ "Wrestling with the data Tsunami", Commscope, March 2014, <http://www.commscope.com/Blog/Wrestling-with-the-Data-Tsunami-Indoors-Infographic/>

⁷ Coverage or noise limited refers to a young network during rollout where loading is light and user experience is limited by the reach of the signals. Capacity or interference limiting refers to a mature network state with a heavy load. User experience is limited by interference between cells and the degree of spectral resource sharing between users.

⁸ "Deployment Issues for Urban Small Cells", Small Cell Forum, Feb 2014, <http://scf.io/document/096>

⁹ "Cutting out the scissor effect", March 2010, <http://www.fiercewireless.com/europe/story/cutting-out-scissor-effect>

¹⁰ "Mobile broadband – busting the myth of the scissor effect", 2010, Ericsson, <http://goo.gl/HXM1Ek>

¹¹ "Crisis ahead for European mobile operators: Data growth dangerously slow, and network costs unhealthily low", September 2012, Analysis Mason

1.7 Purpose and structure of this paper

This paper looks the role of RF planning and performance prediction tools in future HetNets. Section 2 considers the needs of a range of user groups throughout the lifecycle of the network, and the value brought by the tools. Section 3 provides details on iBuildNet from Ranplan, an all-in-one solution that supports HetNet design, performance analysis and optimisation. Conclusions are made in section 4.

2 Roles of RF planning tools throughout the network lifecycle

RF network performance modelling is carried out by multiple different groups during the design, planning, deployment and operation lifecycle of a mobile network. Equipment vendors need to understand and demonstrate how their technology meets network operators' performance requirements and is within their cost constraints. Operators themselves need a vendor-agnostic comparison of the benefits of different technologies when applied to *their* network and subscriber base. They also need to perform detailed network planning to decide exactly where to site the equipment and how to backhaul it. Service groups and OTT players need to understand the Quality of Experience that will be achieved over a given network. Finally, the network must be maintained, monitored, optimised and upgraded – leading us back to the development of new equipment again in a hopefully virtuous cycle.

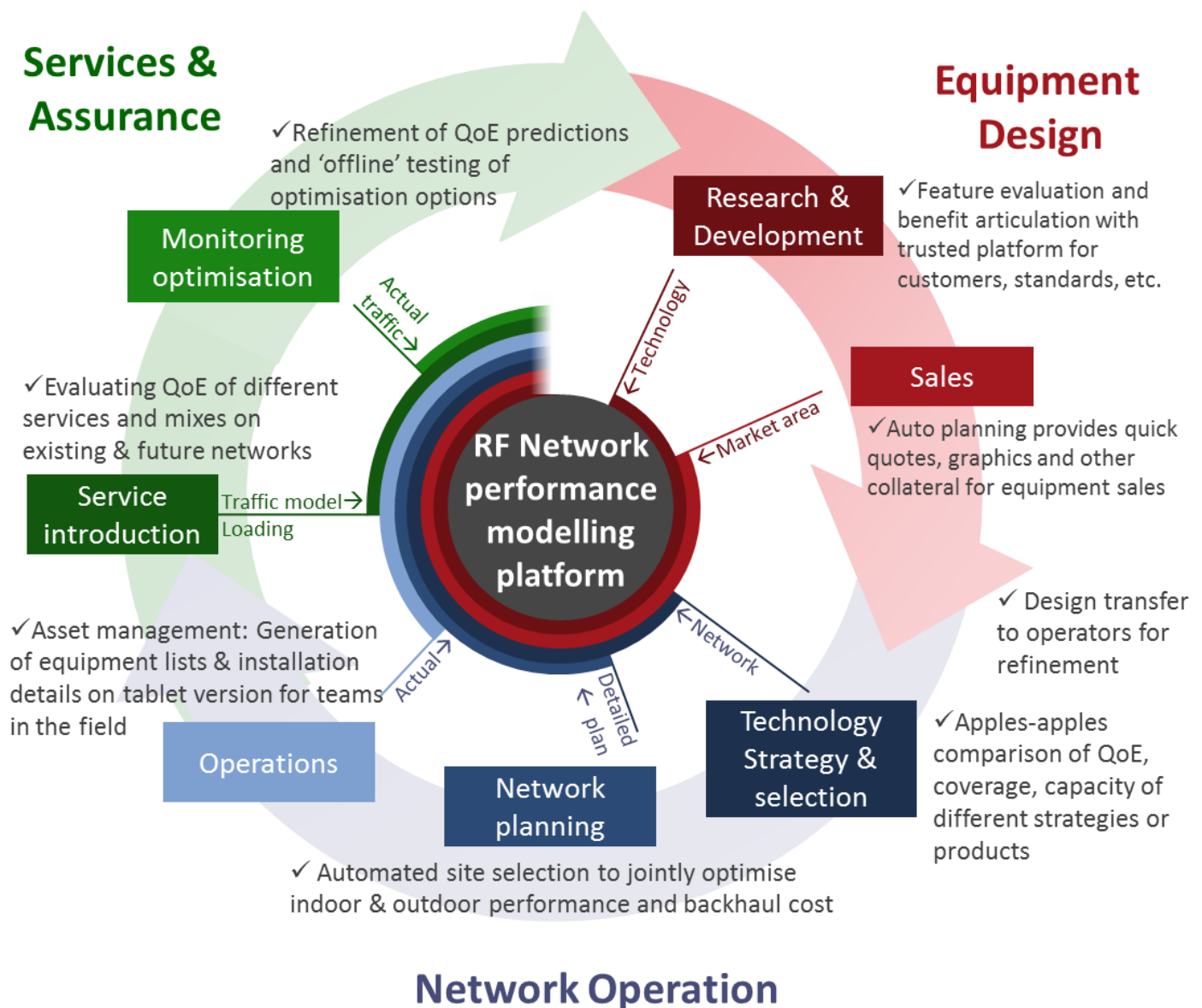


Figure 2: Network performance modelling brings value to many groups throughout the design, deploy, maintain and upgrade lifecycle

Figure 2 illustrates the organisations and functional groups involved in this lifecycle and the value brought to each of them by RF planning and performance prediction tools. At the centre of the lifecycle is a common performance modelling platform on which a detailed description of the HetNet technology, configuration and environment can be built. Each group has their area of specialist knowledge and associated data assets. For example, equipment designers wish to model the benefits of different technology features, while network planning teams have detailed data to describe the outdoor and indoor environments and existing network sites and configurations. Where a common platform is used, all groups can leverage the expertise and efforts of previous users, rather than starting from scratch at every stage. This conservation of effort reduces costs and brings value to all parts of the lifecycle. The following sections describe in more detail how each group uses and then benefits from an RF planning platform.

We note that Figure 2 associates groups with the organisational functions of equipment design, network operation and services and assurance, and these relate to the conventional roles of the equipment vendor, network operator and assurance solutions provider. It is however recognised that these organisations are also changing in their scope – for example major equipment vendors are increasingly managing infrastructure themselves, becoming providers of leased capacity¹² to operators. Network operators in turn are collaborating with OTT players to manage the resulting end user QoE¹³ and exploit brands and social networking and content partners. The functional groups shown in Figure 2 may therefore in real life fall under different organisational titles to used above.

¹² “*Network Managed Services*”, Ericsson, <http://goo.gl/LhwPRL>

¹³ “*Netflix pays AT&T to ensure streaming quality*”, 31 Jul 2014, <http://www.bbc.co.uk/news/technology-28560106>

2.1 Equipment Design

Equipment vendors need to develop and sell new equipment and technology to satisfy the needs of their customers, the network operators. RF planning tools have roles within both the development and sale of equipment as follows:

2.1.1 Research and development

Recent homogenous macro network technologies were developed and demonstrated using a standard 3GPP model of 19 equally spaced tri-sectorised base stations with a uniform user density, producing the classic hexagonal shaped cells with which many will be familiar¹⁴. HetNet co-ordination technologies however are designed to deal with different cell sizes and non-uniform user densities clustered around hotspots. They therefore need to be developed and proven on more realistic models of the environment, the network and the demand density. Creating bespoke tools to model the HetNet environment requires a significant investment and the use of a common tool not only reduces this cost, but enables the technology specifications to be reused in subsequent stages in the lifecycle.

Equipment designers need tools to represent the performance and behaviour of their technologies, requiring flexible APIs (Application Programming Interfaces) which can expose aspects such as UE measurement data or scheduling controls. Performance modelling tools then bring value in revealing the benefits of new equipment and features. Graphics and visualisations help articulate these to customers, both internal and external. The use of a common trusted platform rather than bespoke tools provides a ‘nothing up the sleeves’ approach to support this articulation.

2.1.2 Infrastructure sales

Planning tools can help with equipment sales by informing quotations with the amount of equipment needed to cover an area, and by providing collateral that clearly show the benefits of the offered upgrades.

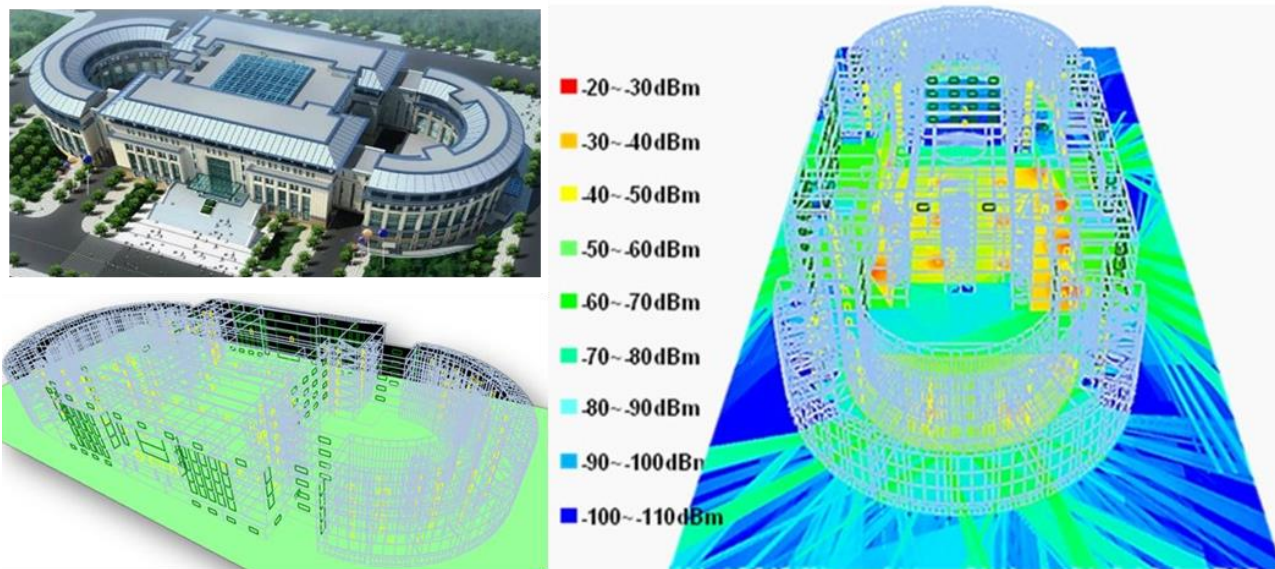


Figure 3: RF planning tools provide collateral to help sales teams communicate the benefits of the new technology

Automation de-skills the network planning process, while making it available to sales teams helps them quickly estimate the number and locations of the sites needed to provide the required capacity or coverage enhancement. Increased accuracy here adds value by reducing the costs associated with over- or under-provisioning and will help create ultimately profitable bids and contracts. Where a common tool is used throughout the lifecycle, investments in data assets to represent the improved technology and environmental modelling will be of value to other groups in subsequent stages.

¹⁴ “Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Frequency (RF) system scenarios; (Release 8)”, 3GPP document TR 36.942 8.3.0, 2010-10-01

2.2 Network Operation

2.2.1 Technology selection and strategy

The increasing and changing type of demand for mobile services means that operators must continually evolve their upgrade strategies and the technologies that they plan to use. RF planning tools have a role to play here by comparing different approaches and technologies. Strategy teams need to model the specifics of their markets, their existing network infrastructure and the anticipated growths in traffic and service demand. Technology comparisons must be made across a range of cost and performance metrics including coverage, capacity, user quality of experience, time to market and so on.

The benefits of particular technologies are often illustrated in bids using scenarios especially contrived to suggest maximised gains in a highly idealised world model. Operators therefore require a vendor-agnostic comparison of different approaches in real world scenarios that are properly representative of *their* actual networks. A common platform capable of comparing different vendor technologies deployed in the same environment is an essential tool for operator strategy teams.

2.2.2 Network planning

Network planners are a core user group for RF planning tools. They are used to determine the number and locations of cell sites needed to meet coverage, capacity and other performance requirements. To date, planners use different dedicated tools for outdoor, indoor, backhaul, cellular and Wi-Fi as these aspects were considered to be independent of each other. The relatively small scale of the networks involved meant that manually marrying up results from different tools was not overly onerous a task. However, as networks densify to meet capacity requirements, coverage from different cell sites increasingly overlaps and their mutual interference must be factored into the performance analysis. The scale and cost constraints of small cell networks means manual combination of results from different tools will no longer be viable. In future, both indoor and outdoor components of the HetNet must be jointly designed and optimised, and co-ordination technologies accurately represented.

“Planning tools will need to consider small cell backhaul as part of the HetNet, to be jointly optimised with the RAN”

Backhaul is recognised as a key challenge for small cells, involving the connection of many sites down at street level with high capacity, fibre-based Points of Presence (PoPs). Although there have been many different wired and wireless technologies proposed for this task, the industry recognises that no one solution fits all scenarios and that operators will need to work with a broad toolkit of options¹⁵. It is also recognised that there is a trade-off to be made between the increased benefit of locating a small cell in the centre of a hotspot, versus the additional cost of extending backhaul connectivity to that location¹⁶. Planning tools will need to consider backhaul as part of the HetNet and so needing to be jointly optimised with the RAN. Tools will need to be able to model the range of different wireless solutions with carrier frequencies that range from ‘Sub 6GHz’ Non-Line of Sight up to millimetre wave 80GHz¹⁷. They should help to automate the design of the network which optimises RAN performance versus backhaul cost. Figure 4 shows the Small Cell Forum’s view of the deployment planning process which combines both RAN and backhaul in the planning stage, and also takes into account the existing macro network. It shows that the planning process will be steered by a set of guidelines which define the backhaul toolkit and rules to determine which is used and when. Automated network planning features will need to be driven by these guidelines.

¹⁵ “Small Cell Backhaul Requirements”, NGMN Alliance, June 2012, <http://goo.gl/eHHtx>

¹⁶ “Business case for Urban Small Cells”, Small Cell Forum, Feb 2014, <http://scf.io/document/087>

¹⁷ “Backhaul Technologies for Small Cells: Use Cases, Requirements and Solutions”, Small Cell Forum, Feb 2013, <http://scf.io/document/049>

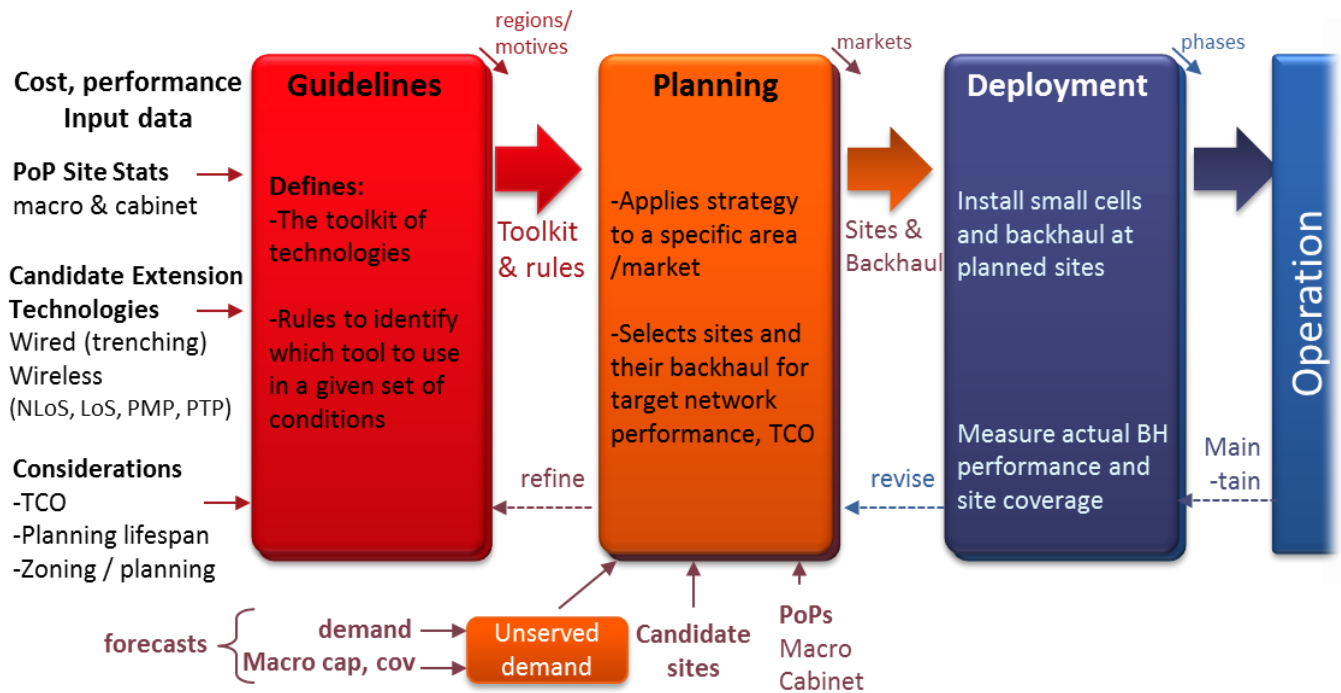


Figure 4: Planning and deployment process for Small Cells and their backhaul. Source: Small Cell Forum¹⁸

With the increasing numbers of cells in the network, automated site selection and configuration will be necessary. Planners would like to input their required performance metrics and a set of candidate sites and have a tool to rapidly produce the optimal selection. Manual overrides or locks will be needed for sites already deployed or for special cases. Fundamental to successful network planning are accurate models of indoor and outdoor environments, and sound propagation predictions. It is essential that the predicted performance is achieved when the network is deployed.

2.2.3 Deployment and operations

Once a network design or upgrade has been planned, it needs to be transferred to the operations teams for deployment on the ground. Significant effort and costs can be saved if the tools used for planning can directly generate output in a format suitable for these teams. It is likely that some aspects of the design may not be implementable in practice and that operations teams will need to feed back revisions as shown in Figure 4. Such changes should be corrected in the model and the resulting performance re-checked to make sure targets are still achieved. Again, the use of a common platform for both teams helps streamline this workflow, reducing cost and time to market.

The transfer of network designs from the designers to the deployers requires the planning tool to be able to provide actionable instructions to teams on the ground. These outputs involve detailing installation and commissioning issues, such as the desired locations of infrastructure assets, the orientation and alignment of their antennas as well as power and backhaul details. The installer will also need to capture a report from the installation, including changes made on site if the desired position and orientation were not actually physically feasible. The results of installation and turn up tests can be recorded and checks against the predicted performance of any wireless backhaul and access point coverage can be made.

The cost pressures of massively scaled roll-outs are driving increasing automation, streamlining and de-skilling into the deployment process. Self-alignment, configuration and optimisation technologies are being introduced¹⁹ and RF planning tools need to keep pace with these changes, such as providing an easy-to-use interface on a tablet or portable device which can clearly communicate the desired installation to the engineers and capture the end results.

¹⁸ "Backhaul for Urban Small Cells: A topic brief", Small Cell Forum, Jun 2014, <http://scf.io/document/095>

¹⁹ "Recommended Practices for Multivendor SON Deployment", NGMN Alliance, Jan 2014, <http://goo.gl/kqGi02>

2.3 Services and Assurance

2.3.1 Service introduction and OTT players

Mobile data connectivity has enabled a diverse range of different service types to be delivered to consumers on the go. Volumes of data overtook those of voice late in 2009 ^[20] as consumers started to use their mobile devices for email, web browsing, streaming video and a wide array of connected apps. These different service types have widely varying requirements for the quality of the connection in terms of the data rates and latency needed to deliver a good Quality of Experience (QoE) for users. Much is being done by the cellular industry to categorise, prioritise and provision for these different service types, providing ‘intelligent pipes’²¹ that will be more valuable to consumers. On the other hand, OTT players are entering the fray and developing robust service offerings that can tolerate the ‘best effort’ or ‘dumb pipe’ connectivity characteristic of the internet and IP. Operators and OTT players are also negotiating to arrange prioritised connectivity for monetisable services²², although some see this as a breach of the principle of net neutrality²³.

Wireless networks are constrained by the finite spectral resources available, which must be shared between many consumers and then re-used across cell sites. Sharing limits the amount of spectrum each user can access, and re-use causes interference which in turn limits the amount of data which the spectrum can carry. The combination of these interference and loading factors determines the data rate that a user will actually get, and thus the quality of experience for a given service. In today’s capacity-limited networks, loading is the dominant factor in the user experience and must be incorporated into performance analysis. Latency (packet delay) also impacts QoE and increases during times of congestion due to packet queuing and buffering.

RF performance prediction tools can be used by service introduction and delivery groups to understand whether a service would be viably usable under given network and loading conditions. The tools must be able to model load in terms of varying user densities across both outdoor and indoor areas, as well as handle the types of services that users will be consuming. Performance metrics such as user throughput distribution can then be generated to indicate the proportion of users who will achieve a given data rate.

Performance and prediction tools will be used by network operators to understand and articulate to OTT players the quality of service available from premium connectivity options, which in turn reveal whether consumer QoE will meet agreed expectations.

2.3.2 Assurance, monitoring and optimisation

Once deployed, considerable effort is required to maintain the network and the quality of the mobile services it offers. Traffic and signalling flowing through the network is continually monitored to identify symptoms of poor health with the subsequent rapid drill down to identify causes of failure or poor performance. Some issues will be caused by faults or misconfigured equipment. In other cases, the network is simply overloaded and needs to be upgraded to be able to offer the services at the required QoE. In the latter case, RF planning tools can be used to predict the performance benefit of potential upgrades under extrapolated loading conditions. This way, operators can minimise costs with a ‘right first time’ approach to network upgrades. To enable this, planning tools should be able to accept data from assurance tools in order to capture the actual state of network load.

The assurance industry provides a range of tools to capture and analyse data to characterise actual network loading and performance.

²⁰ “Ericsson: Mobile data has overtaken voice”, Mar 2010, <http://www.mobileworldlive.com/ericsson-mobile-data-has-overtaken-voice>

²¹ “Integrated QoS Management”, NGMN, December 2012, <http://goo.gl/xlm0U>

²² “Netflix pays AT&T to ensure streaming quality”, 31 Jul 2014, <http://www.bbc.co.uk/news/technology-28560106>

²³ “U.S. Federal Communications Commission proposes new net neutrality rules”, May 2014, <http://inlinepolicy.com/2014/u-s-federal-communications-commission-proposes-new-net-neutrality-rules/>

3 iBuildNet® HetNet Design and Performance Planning

Tools enable people to perform tasks they could not otherwise do, or do them faster, more accurately or at lower cost. RF planning and performance prediction tools work by packaging up expertise from a range of disciplines and putting them into the hands of designers, planners and operations teams to give them the ability to understand, manage and monetise the mobile connectivity experience delivered by HetNets.

tool /tu:l/ (noun): A thing used to help perform a job

iBuildNet by Ranplan represents a new generation of holistic planning tools, fundamentally designed around the RF prediction needs throughout the design, deploy, operate and upgrade lifecycle of networks as illustrated in Figure 5. It is capable of modelling key components of the HetNet and their interactions: indoor/outdoor, macro, small cell, DAS and backhaul, 2G, 3G, 4G and Wi-Fi technologies. Interfaces have been designed and customised to integrate into different user groups' workflows, ensuring it can accurately model their technologies, environments and networks, and tailor the form of output to suit different customer needs. The use of a common platform throughout the lifecycle enables reuse of data assets from different groups, helping reduce overall effort and cost, and improving the accuracy of the later stages of network planning.

In this section we look at the different layers of modelling which go into iBuildNet and highlight the capabilities which meet the wide range of needs identified earlier in this paper.

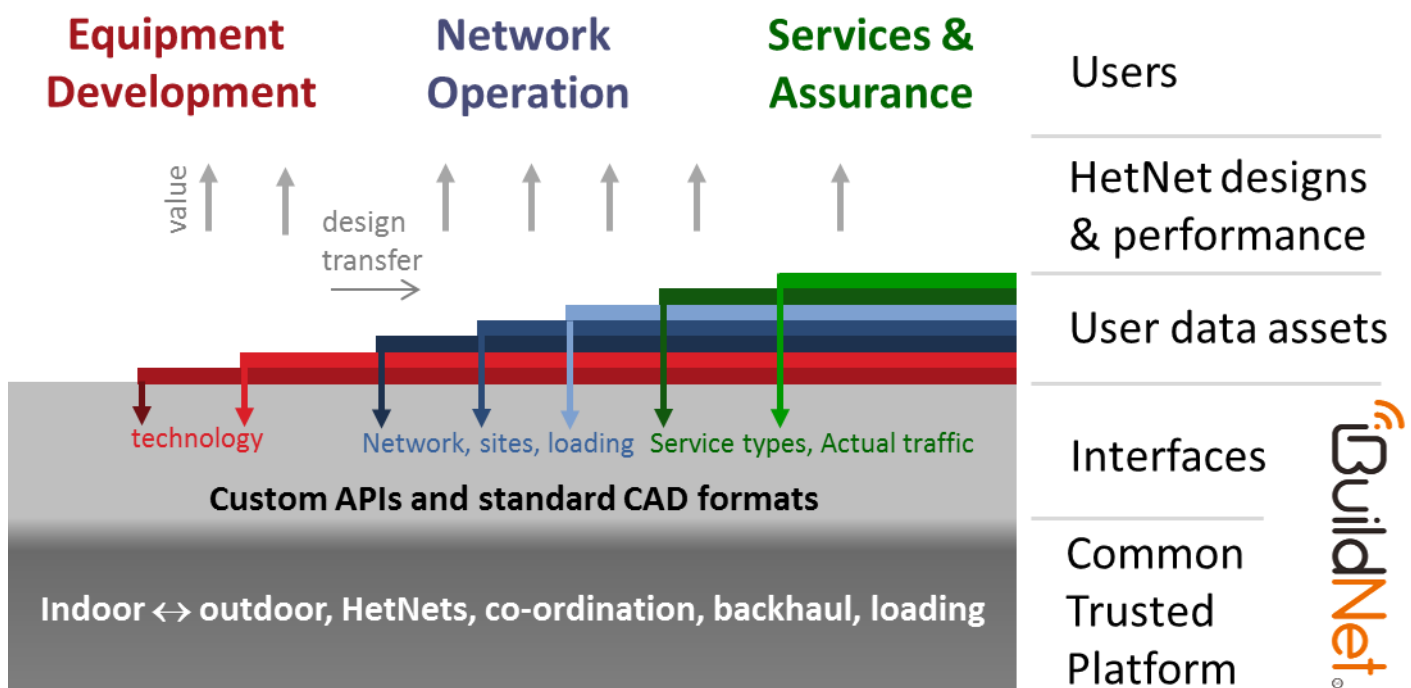


Figure 5: iBuildNet is a common trusted platform to enable HetNet design, performance analysis and optimisation

3.1 Overview of Functional Layers

RF performance modelling can be represented as a number of layers, each building on those below it to model higher level functionalities as shown in Figure 6. For the high level analyses to be sound, they must be built on solid foundations: an accurate model of the physical environment and network as well as a proven propagation prediction engine to evaluate the reach of RF signals from each transmitter. The following sections describe each layer in detail, giving examples of the input data sets and the output results.

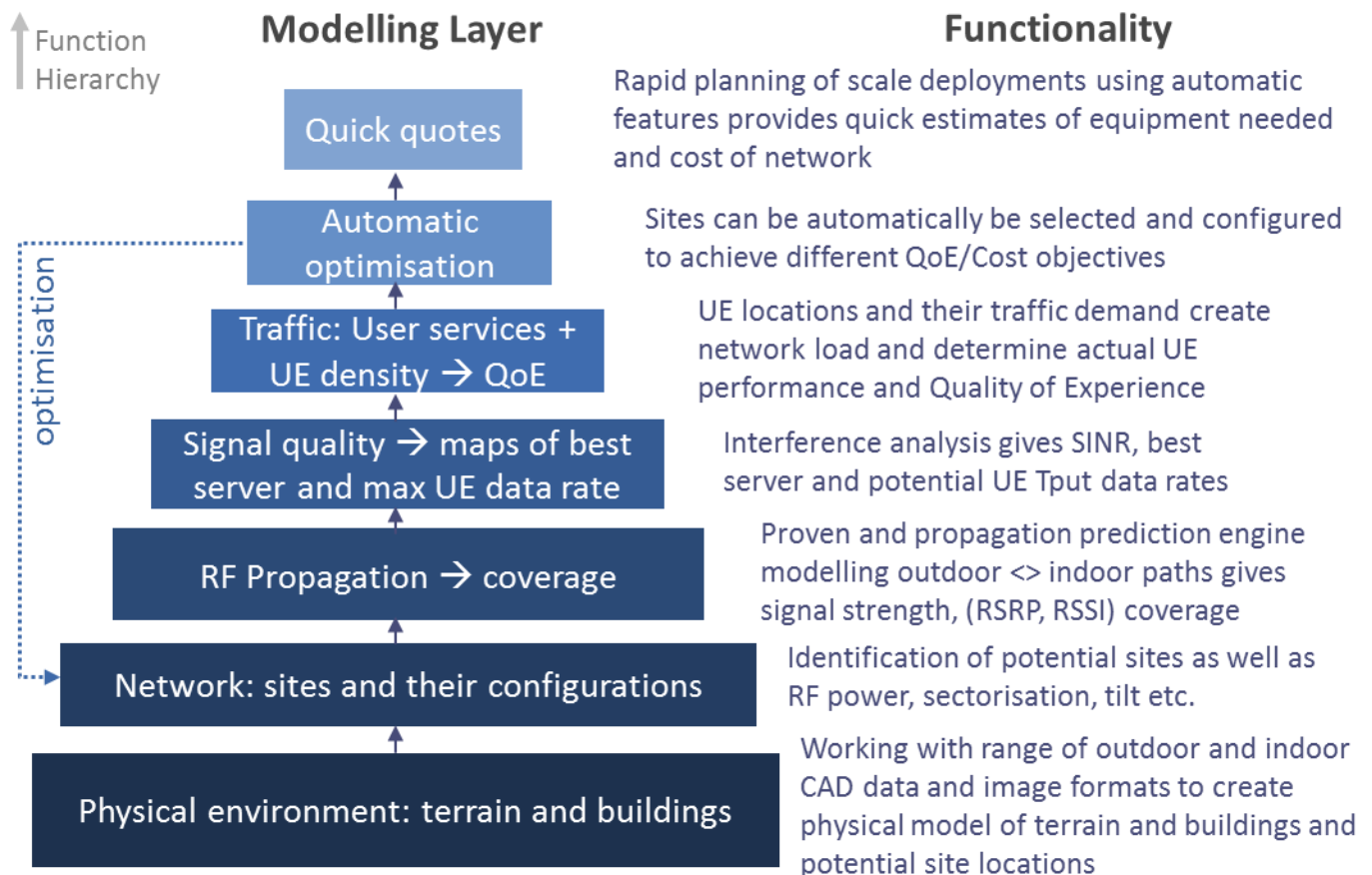


Figure 6: Network performance prediction and optimisation must be built on solid foundations of good quality data and accurate propagation predictions

3.2 Physical Environment

The foundation of RF planning is a model of the physical environment: the shape of the terrain and what was once considered ‘clutter’ for outdoor macro coverage - i.e. the buildings where the vast majority of traffic is now consumed. iBuildNet simultaneously models both indoor and outdoor environments and propagation interactions between them. In constructing models of large areas, in-building details can be added where needed to provide accurate indoor performance analysis. It can also be left out where just a quick initial view of only the outdoor area is needed.

3.2.1 Outdoor Wide Area

Large metropolitan areas are modelled starting with the outdoor environment. Wide area characteristics of terrain, buildings and other ‘clutter’ can be automatically captured from a range of formats and iBuildNet’s 3D capability is used to visualise and refine the model.

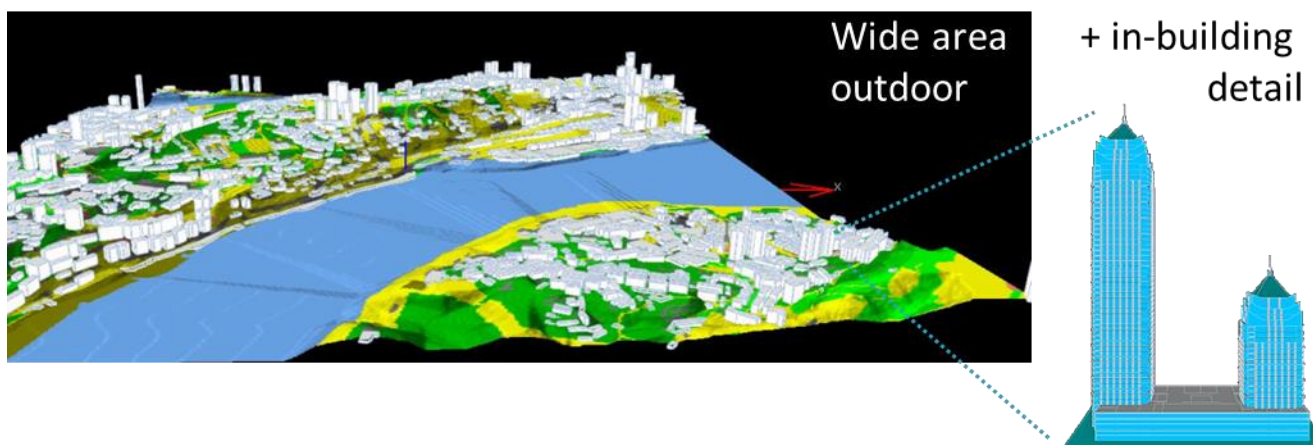


Figure 7: 3D modelling of outdoor terrain, building vectors and clutter in iBuildNet

Key features of iBuildNet’s wide area modelling capability include:

- 3D and 2D visualisation of terrain, building vectors and clutter.
- Compatibility with a range of GIS formats, including planet, mid, mif, etc.
- A database of propagation characteristics for different clutter types including building materials, forest, green spaces, rivers etc. Default transmission, reflection and diffraction losses can later be calibrated against measurements.
- Integration with Google Earth, assisting verification of relative locations of buildings .
- Wide area modelling of up to 40km², sufficient for most HetNet deployments.
- Seamless integration of outdoor and indoor environments. Where analysis of in building systems and performance is needed, external building vectors can be replaced with detailed 3D in-building models, such as those shown in Figure 7.

3.2.2 Detailed Indoor Environments

iBuildNet includes sophisticated tools for the rapid modelling of indoor environments and systems. In-building models can be standalone for analysis of single buildings, or integrated into the wide area model for joint indoor-outdoor analyses as described above. Key features include:

- Compatibility with a range of CAD formats such as dwg and dxf, or the ability to work from scans of maps and diagrams.
- Built-in advanced pattern recognition automates the creation of walls, doors, windows, etc.
- Fast 3D building modelling for different types of buildings such as offices, stations and stadiums, as shown in Figure 8.
- A database of propagation characteristics for different building materials. Default settings can later be calibrated against measurements.

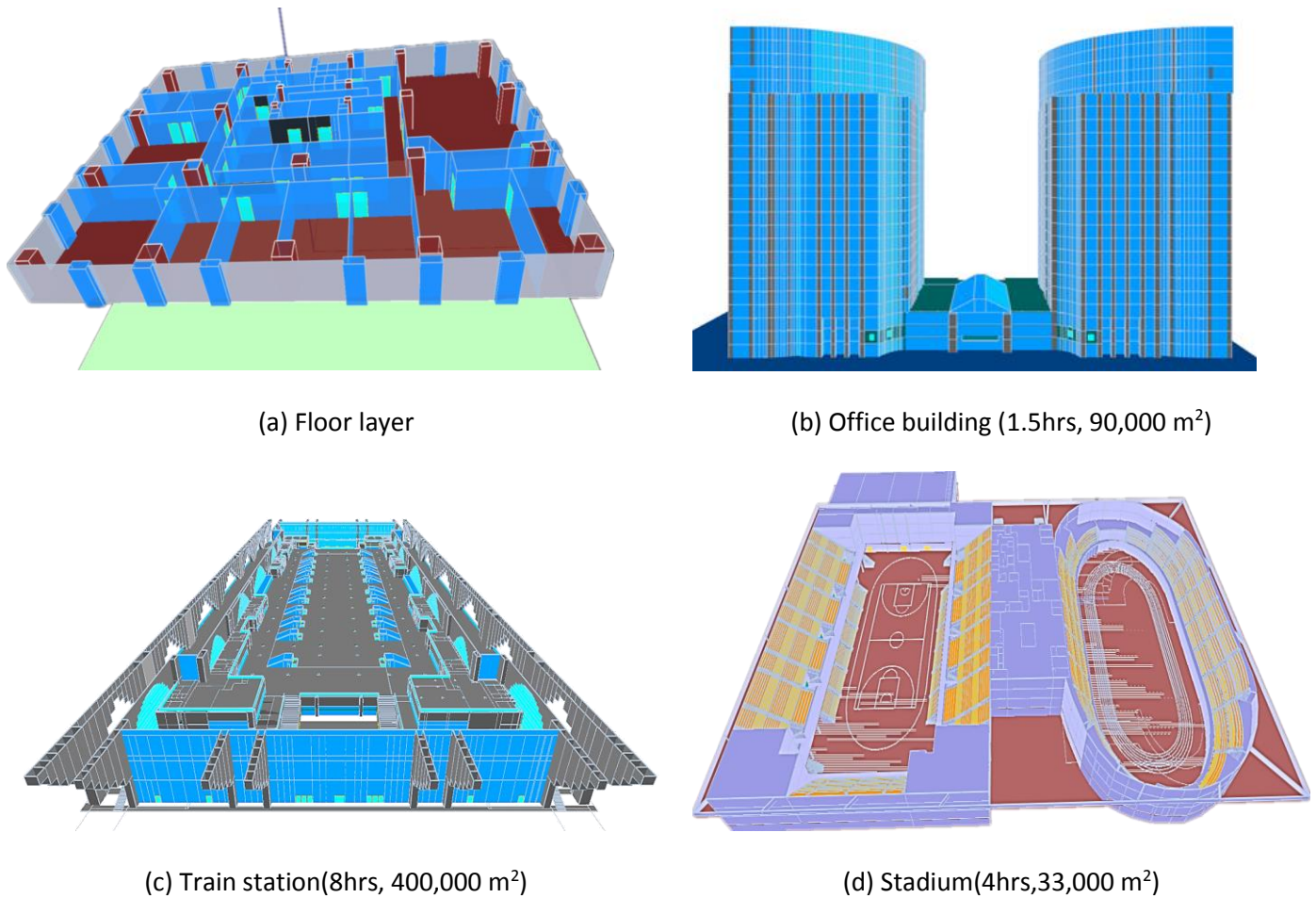


Figure 8: Assisted 3D building modelling of indoor environment (modelling time, floor area)

3.3 Radio Access Network (RAN) Layout and Configuration

The network model represents the locations and configurations of the cell sites, antennas and DAS nodes which comprise the heterogeneous network. Modelling of the HetNet configuration in iBuildNet is facilitated by the following features:

- Joint modelling of different HetNet layers including Macro, Small cell/femto, DAS, Cloud/Centralised RAN (BBU+RRU) and backhaul.
- Indoor, outdoor, joint indoor/outdoor heterogeneous RAN design and configuration.
- FDD-LTE, TD-LTE, HSPA, WCDMA, CDMA2000, TD-SCDMA, GSM, Wi-Fi, WiMAX, Tetra and more.
- Integrated radio access and backhaul network design, planning and optimisation.
- 3D and 2D visualisations of RAN layout in Google Earth, building floor layout, terrain map.
- Customisable network components database containing associated specifications for elements including base stations, antennas, amplifiers, cables, splitters, couplers, etc.

3.4 RF Propagation Engine

iBuildNet uses Ranplan's proprietary radio propagation engine for fast and accurate system performance evaluations including path loss, signal level, SINR, cell overlap area and best server maps. The Intelligent Ray Launching Algorithm (IRLA) is based on ray launching and tracing techniques, which in addition to accurate prediction of path loss and coverage, enables the evaluation of more advanced channel characteristics such as the Angle of Arrival (AoA), Angle of Departure (AoD) and Power Delay Profiles (PDP) shown in Figure 9. These angle and delay spread analyses are useful in the optimisation of MIMO antenna configuration and alignment²⁴.

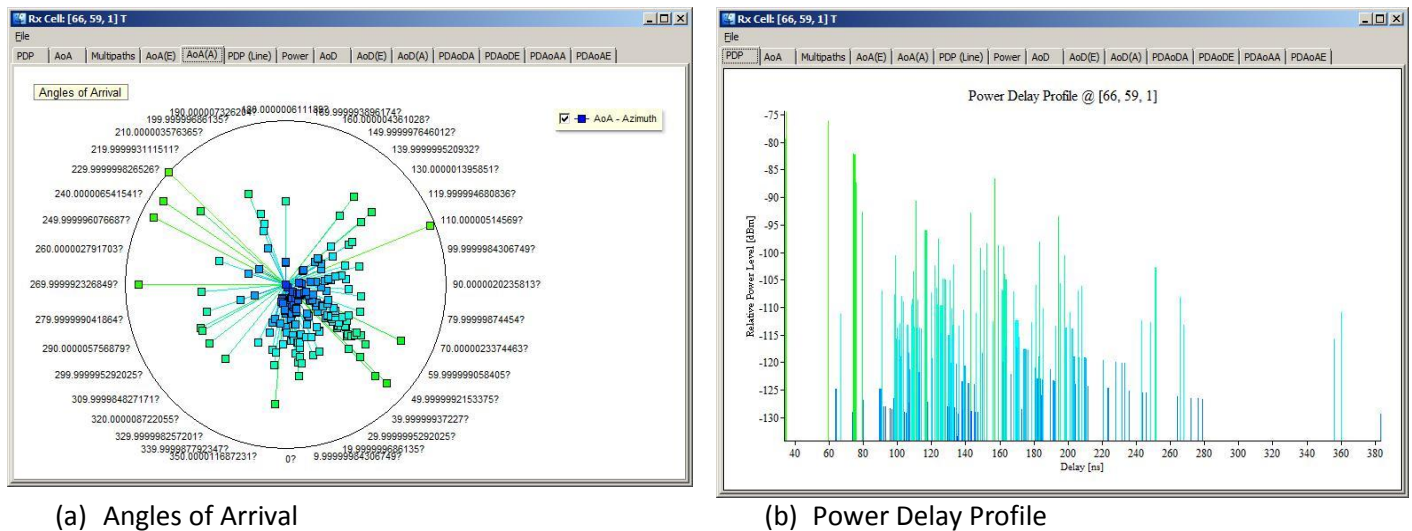


Figure 9: AoA, AoD and PDP in Propagation engine

Key features of the iBuildNet propagation engine include:

- Fast and accurate propagation prediction:
 - Computation of 2 million receiving points' signal strengths and multipath information in 2 minutes on a standard PC
 - Signal strength prediction within 6dB RMSE for indoor and 8dB RMSE for outdoor scenarios.
 - Accuracy has been verified by numerous measurement campaigns with some of the world's largest network vendors and operators and through academic research^{25 26}.
- 300MHz to 65GHz carrier frequencies covered
- Indoor, outdoor, indoor to outdoor and outdoor to indoor scenarios.
- APIs to enable further processing of propagation and channel data.
- Supports all multipath parameters specified in 3GPP TR25.996²⁷ for MIMO simulations.
- Supports massive MIMO and FD-MIMO modelling.
- Comprehensive materials database of RF properties for frequencies up to 65GHz.
- Runs on PCs or distributed/parallel computing environments.

iBuildNet also supports empirical/semi-empirical models such as COST-231-HATA, COST-231-Walsh-Ikegami, SPM, multi-wall and WINNER. These may be used for comparison and alignment with other analysis.

²⁴ "What base station antenna configuration is best for LTE-Advanced?", J. Robson, K. Linehan, Commscope, Jan 2013, <http://goo.gl/Taq8U6>

²⁵ Z Lai, G Villemaud, M Luo, J Zhang, "Radio Propagation Modelling", in Heterogeneous Cellular Networks: Theory, Simulation and Deployment, Cambridge Press, 2013.

²⁶ A. Alayon Glazunov, Z. Lai and J. Zhang. "Outdoor-Indoor Channel," in LTE Advanced and Next Generation Wireless Networks - Channel Modelling and Propagation, John Wiley & Sons, October 2012.

²⁷ "Spatial channel model for Multiple Input Multiple Output (MIMO) simulations", <http://www.3gpp.org/DynaReport/25996.htm>

3.5 Coverage prediction and not-spot identification

The combination of physical model, RAN site locations and configurations with propagation prediction yields the *coverage* of the HetNet– the downlink signal strengths available to user terminals in any given location. Although high signal strength does not necessarily mean a good user experience, a lack of any signal certainly indicates a service outage, or ‘not spot’, which planners must avoid. iBuildNet overlays coverage onto the 3D outdoor and indoor areas as shown in Figure 10. Where detailed indoor areas have been modelled, the indoor coverage on each floor is included.

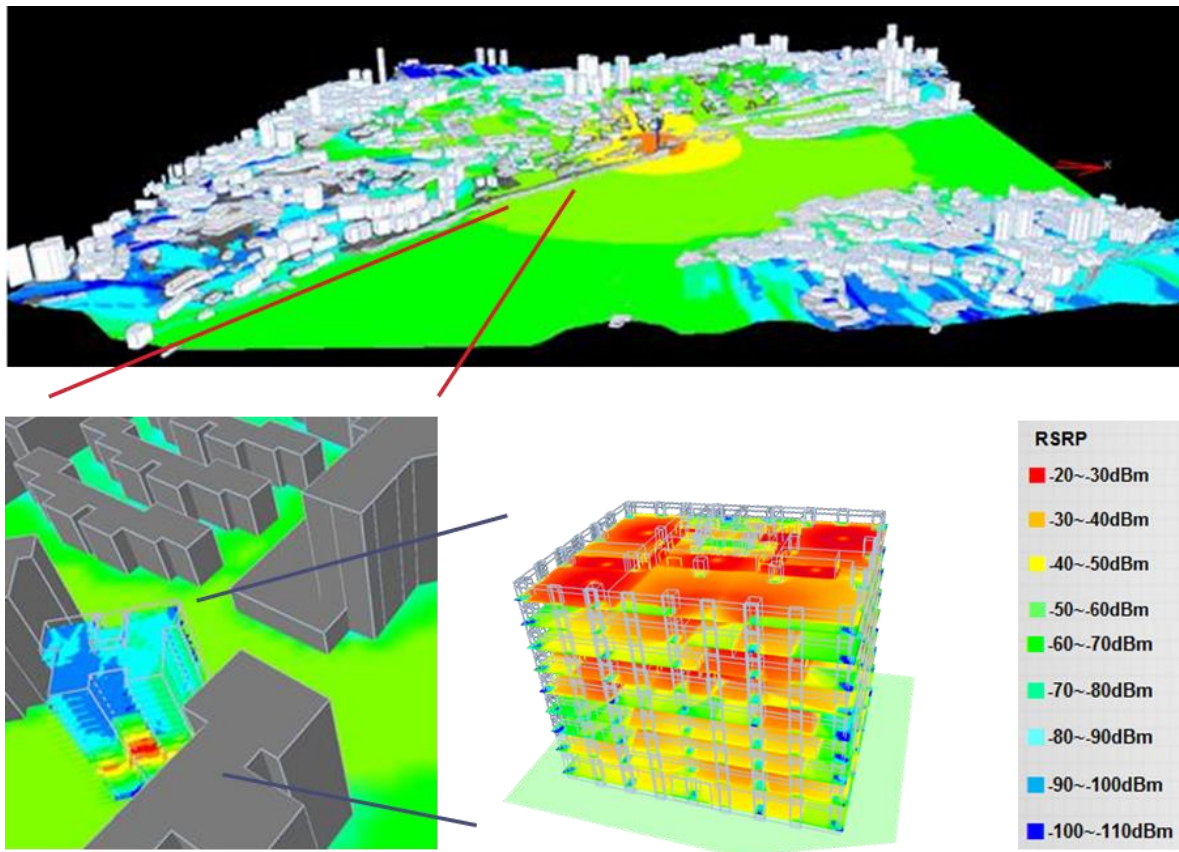


Figure 10: Integrated outdoor/indoor coverage prediction

Prediction accuracy has been verified by numerous measurement campaigns with some of the world’s largest mobile operators and network vendors. Figure 11 shows results of one such campaign for an indoor area. Overall, we find accuracy to be RMSE of 6dB for indoor prediction and 8dB for outdoor prediction.

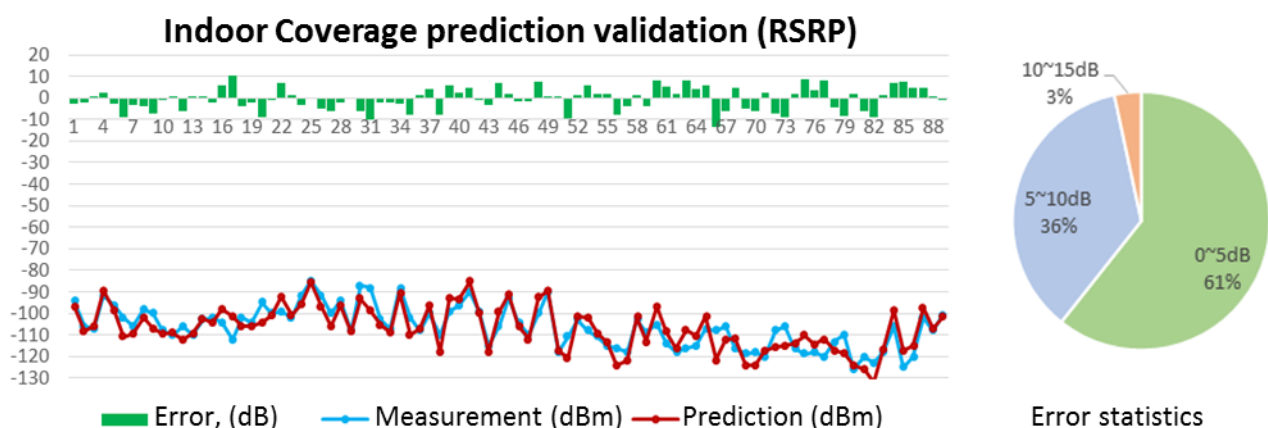


Figure 11: Accuracy of coverage prediction and the error statistics

3.6 Signal Quality and Best Server Map

Whilst coverage is essential for mobile services, signal strength analysis alone does not reveal whether consumers will experience good network performance. For this, interference and loading must also be taken into account. In today's capacity limited networks, there are significant coverage overlaps between different elements of the HetNet. Best server mapping reveals the catchment area of any one cell site or sector antenna. Interference analysis then calculates the signal quality in terms of the wanted signal to noise ratios plus interference from all other sites (SINR). In evaluating SINR, iBuildNet's Wireless Network Simulator module (WNS) also takes into account the interference co-ordination mechanisms such as eICIC or CoMP. Key features of WNS include:

- Uplink and downlink simulation of LTE, HSPA, UMTS, and Wi-Fi systems.
- DAS and independent Femto/Wi-Fi system simulation.
- SINR and best server prediction, as shown in Figure 12(a).
- Co-channel interference reduction in HetNets through eICIC, dynamic power and channel allocation.
- Semi-dynamic simulation: for each Monte Carlo snapshot of user locations, multiple TTIs are simulated to ensure RRM and mobility management algorithms are correctly represented.

3.7 Traffic loading, User density and QoE

End user data rates are determined by the combination of signal quality and network loading. iBuildNet simulates different traffic loading conditions by populating the network with a set of UEs consuming a mix of services. This reveals how user experience and network performance vary under load and helps identify areas for network upgrades. Key features of iBuildNet's traffic modelling capability include:

- Voice, video, web browsing, FTP, full buffer traffic types supported.
- Uniform and non-uniform or 'hot spot' UE density distributions.
- User-definable traffic maps representing variable service mixes and UE density across coverage area.
- Monte-Carlo style population of network with UEs for building up statistics.
- Key performance indicators include: user data rate distribution (e.g. cell edge 5%ile, mean, peak etc.), user QoE, cell load, cell throughput distribution, etc.

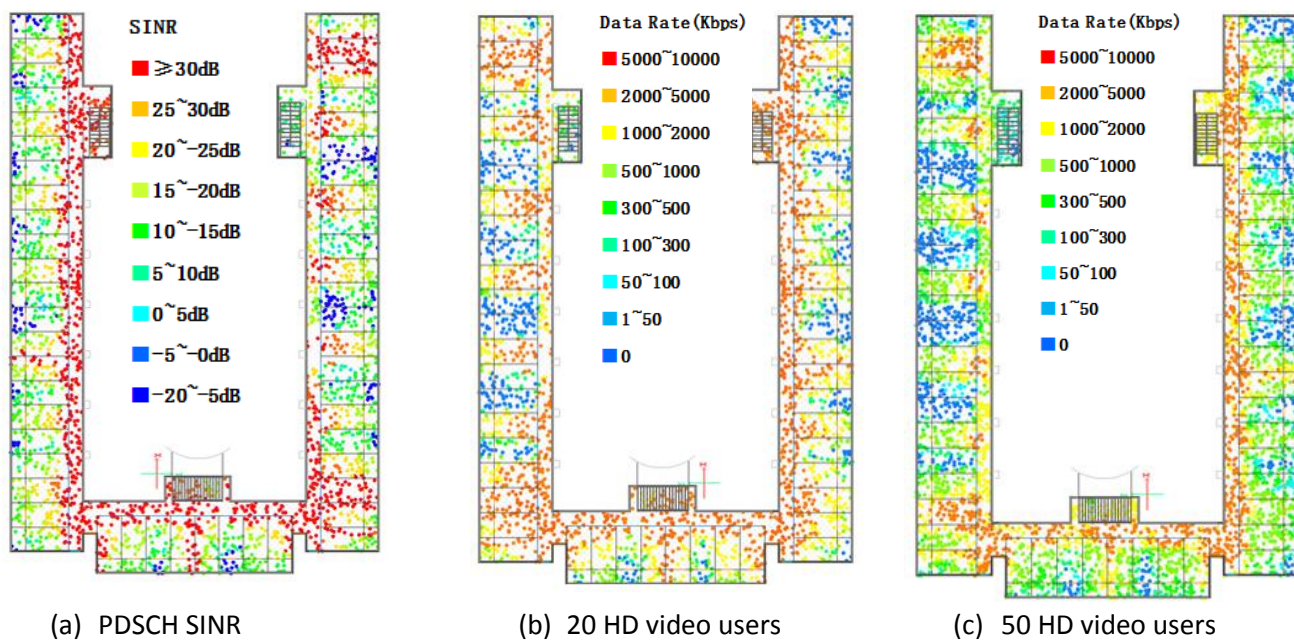


Figure 12: Modelling of signal quality and user data rates.

3.8 Automatic Optimisation

Automatic network optimisation can dramatically reduce the amount of time taken for network planning, optimisation and maintenance. It also helps reduce the skill levels required for network design, optimisation and troubleshooting tasks. iBuildNet includes intelligent optimisation modules which work jointly across indoor/outdoor and different HetNet layers. Modules include Intelligent Cell Optimisation (ICO), Intelligent Frequency Optimisation (IFO), Intelligent Topology Optimisation (ITO), Intelligent Network Profiler (INP) and Intelligent Test Point locator (ITP). These cover the whole lifecycle of small cell/HetNet planning, optimisation and maintenance and help engineers achieve an optimised network topology, assign channels and diagnose faulty elements.

The key features of iBuildNet's automatic optimisation functions include:

- ICO: Automatically fine tunes cellsite locations, numbers, transmit powers and antenna types to optimise key performance indicators such as signal strength and leakage.
- IFO: Optimises the channel allocation and transmitted powers to reduce inter and intra-network interference and signal leakage.
- ITO: Optimises both the route of the cables between devices in a DAS and the optimal components between antennas and signal sources. It helps the user obtain the optimal network layout not only in terms of cable route but also the components used.
- INP: Provides statistics of the network performance in terms of signal strength, not-spots and leakage from indoor to outdoor, facilitating network design and performance analysis.
- ITP: Identifies an optimal set of test points and locations in a passive DAS system for diagnostic purposes. By comparing the predicted and measured signal strengths at these optimized test point locations, faulty antennas can be quickly and accurately identified.

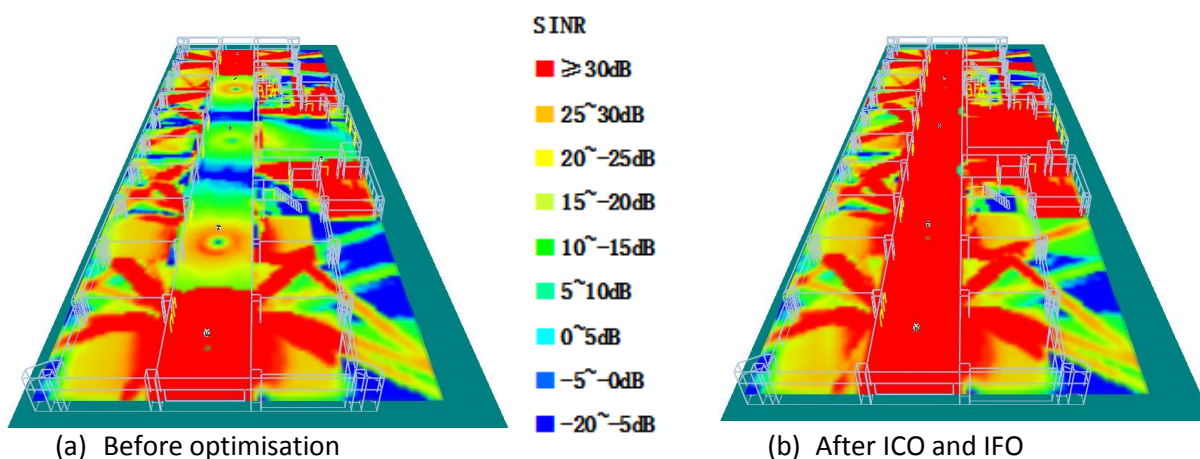


Figure 13: Automatic optimisation of sites and frequency assignments can significantly improve signal quality - which has knock-on benefits for QoE

3.9 Reports and Quick Quotes

iBuildNet automated network planning can help pre-sales engineers to quickly design a network and provide quotes immediately. The key features of iBuildNet's quick quotes facility include:

- Provides customisable report generation to meet the need of various users.
- Generates a range of report types: Antenna EIRP, cable routing, equipment budget, equipment list, layout plan, and project budget.
- Auto generation of devices needed, cost of devices, installation cost and other costs.
- Auto generation of network plan with QoE and associated BoM.
- Tablet version provides rapid on-site network design.

Quick quotes, accurate prediction of network KPIs and eye catching visualisation will help network equipment vendors win bids from operators. They also help operators estimate the cost of a network with the required QoE.

4 Conclusions

The rise of mobile data is changing the shape of mobile networks. The need for more capacity is driving densification while the move to indoor consumption requires in-building systems including DAS, Wi-Fi and small cells technologies. All of these interfere with each other and the existing macrocell network coverage and so need to be co-ordinated using HetNet technologies such as eICIC. RF planning tools will continue to play an essential role in the design of cellular networks, but will increasingly need to offer greatly enhanced functionality and flexibility if they're to meet the emergent needs of the HetNet era. They will need to:

- Simultaneously model both indoor and outdoor environments and their radio access networks.
- Represent HetNet interference co-ordination technologies such as eICIC.
- Automate network design and configuration to enable quick estimates of infrastructure upgrade costs.
- Model small cell backhaul and take its cost into consideration in automatic site selection.
- Ease the integration of these activities into existing processes and workflows by working with standard data formats, having customisable APIs, and offering a range of output formats that can be tailored to the user group.
- Be suitable for a range of user groups throughout the design, deploy and maintain upgrade lifecycle of the network.

iBuildNet by Ranplan is an all-in-one solution for HetNet design and performance analysis. It is being continually improved to better serve needs of equipment designers, network operators, services and assurance groups. Please contact us if you would like to find out more or see a demonstration.

5 For further information

Interested to find out more about Ranplan and the software capabilities?

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