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0. Summary

The purpose of this deliverable is to introduce some advanced automatic planning and optimisation tools, IFO (Intelligent Frequency Optimisation), ICO (Intelligent Cell Optimisation), ITO (Intelligent Topology Optimisation), and IMO (Intelligent Measurement-based Optimisation), which can provides automatic planning and optimisation of frequency assignment, heterogeneous network cell, and backhaul cost, especially for heterogeneous network, i.e. automatic HetNet P&O. The main idea behind the automatic planning and optimisation tool is to utilize the multiple objective optimisation algorithms to design the new network or optimize the existing network about the network elements, deployment parameters and routes by automatic antenna placement, automatic frequency allocation, intelligent system verification by measurement. These features are making a complete and flexible HRAN P&O framework together with site survey at a single platform. The validation of automatic planning and optimisation tools has been made in a heterogeneous scenarios, Chamber Business Centre, where macrocell covers the outdoor area, but because of the penetration loss, indoor has the poor coverage, thus some WLAN APs are deployed for complementary coverage and higher capacity. Finally, a comparison of system performance prediction, including coverage, downlink SIR and data rate, between the optimized and un-optimized system will be obtained as well.

1. Introduction

With more than 5.6 billion subscribers and the ever-increasing data driven traffic, global mobile broadband traffic has been predicted to grow eighteen fold from 2011 to 2016 [1]. Together with the explosion of mobile traffic, the data distribution shows a very uneven trend. Some 20% base stations serve 80% of the data traffic [2]. Also, indoor traffic has become dominating, contributing to more than 70% of the total mobile traffic – a trend that will continue to grow in the future. Because of this, the current mobile networks are facing great coverage and capacity challenges. To provide sufficient capacity for the increasing data demand, International Telecommunication Union (ITU) has defined the fourth generation (4G) networks to provide downlink data rate up to 1 Gbps and uplink data rate up to 100 Mbps [3]. Ever since the first release of the Third Generation Partnership Project (3GPP) Long Term Evolution (LTE), referred to as Release 8 [4], it has evolved as the primary technology for future radio access. Despite the fast deployment of LTE Release 8, the 4G requirement has not yet been met. In order to fulfil the 4G requirement, LTE-Advanced, referred to as Release 10 [5], has been standardized by 3GPP. However, with the 3GPP evolution, point-to-point transmission has been approaching its theoretical throughput limit defined by Shannon's law, which leaves less and less space for further improvement of spectral efficiency. Thus, Heterogeneous networks (HetNets), formed by Macrocell and densely distributed small cells, have thus attracted significant attention as a promising evolution path for mobile broadband.

1.1. Evolution of Mobile Network Architecture

HetNets are multi-tiered networks, which are formed by networks with different radio access technologies (RAT) [6]. A general architecture of HetNets is illustrated in Figure 1.

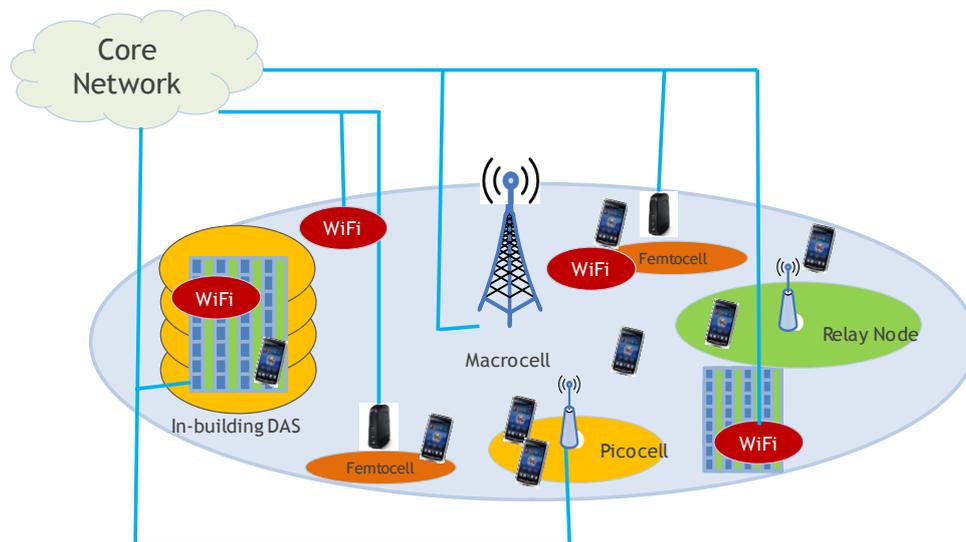


Figure 1. HetNet Architecture

Beside the conventional high powered Macrocells, HetNets introduce a range of low powered small cells. The small cells differ by their types, such as 3GPP cellular base stations, WiFi access points, and distributed antennas. 3GPP cellular base stations can be further divided into Microcell, Picocell, Femtocell as well as the newly introduced relay

nodes. HetNets potentially bring with many benefits, and are considered as a key enabler for future mobile broadband.

1.2. Challenges in Wireless Networks Planning and Optimization

The tremendous increase in HetNet deployment research has attracted the researchers' attention towards the planning and optimisation. The term "network planning and optimisation" refers to the process of constructing a network structure, selecting the network elements and tuning the parameters of network equipments to fulfil the operator's requirements. With the increasing size of radio networks and massive network elements, the tasks of network planning and optimisation are becoming more and more challenging. This is because, on the one hand, the radio resource is limited and precious due to the expanding number of subscribers and types of networks, such as HSPA, LTE and etc, are operating on the limited frequency band. On the other hand, deploying and operating a HetNet is highly expensive and therefore an efficient and cost effective design of the system has to be carried out to achieve high resource utilization. However, manual network planning and tuning for designing HetNet effectively and properly are impossible. Third, integrating different tiers of networks with varying RATs poses new challenges for the planning and optimization process. Finally, HetNet system should have the ability of self-organization, i.e. cell location choice, power, antenna parameters, frequency, and so on. So it should to a large extent self-optimized.

The main topic of this report is to explore the automatic HetNet planning and optimisation methods. The research can be divided into two parts. In the first part, the automatic HetNet planning and optimisation tool development principle has been studied in depth. The second part is mainly focused on performance issues since the goal is to investigate the applicability of optimisation algorithm. In particular, a HetNet scenario deploys multiple macrocells and small cells randomly, the automatic HetNet planning and optimisation tools are used to optimize the cell deployment to improve the performance.

2. Automatic Wireless Network Planning and Optimisation Tool

2.1. General Descriptions

Automatic HetNet planning and optimisation tools **Erreur! Source du renvoi introuvable.**, can assist mobile operators to design and optimize WLAN/WCDMA/HSPA/LTE in all kinds of indoor, outdoor-indoor, and indoor-outdoor scenarios. Hybrid indoor-outdoor scenarios and macrocell-small cell are main focuses, which captures environment aspects such as virtual building, clutters, streets etc., and RAN aspects, such as macro-, micro-, pico- and femtocell and RRH. Radio network design and performance improvements can be performed over the all-in-one tool.

2.2. Main Advanced Features

Automatic HetNet planning and optimisation tool features intelligent frequency optimisation (IFO), intelligent cell optimisation (ICO), intelligent topology optimisation (ITO), and intelligent measurement-based optimisation (IMO).

2.2.1. Intelligent Frequency Optimisation(IFO)

In the HetNets, macrocells and small cells are co-existing, so which frequencies should be used by each cell? IFO can be used to automatically choose the optimal (or near-optimal) frequency assignment to maximize the system coverage and capacity, especially for WLAN system. The optimisation can be based on real measurement of received signal power, or signal prediction by radio propagation, or wireless network simulation results. The basic algorithm is described as following. Here, WLAN is as a example.

The contents of W_{intra}

W_{intra} is a $m \times m$ matrix (m is the number of tx from intra-network), with each element $w_{i,j}$ representing the total interference received from transmitter j to transmitter i .

Formulation of W_{intra}

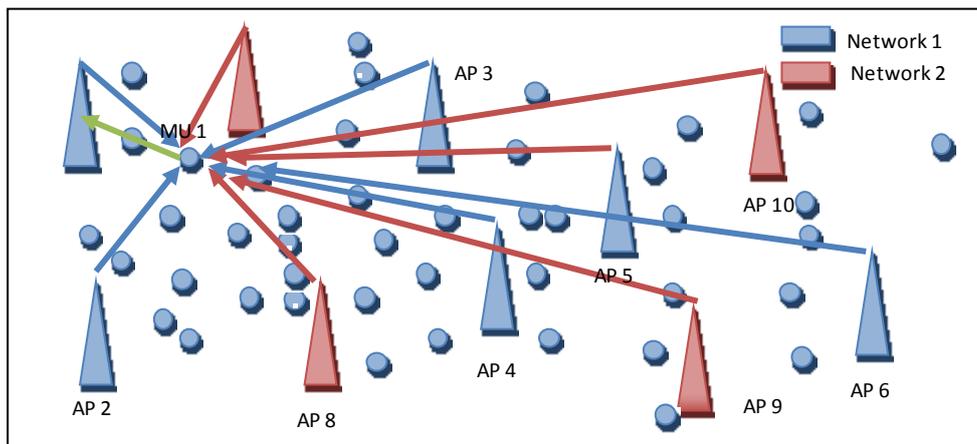


Figure 2 Intra-network deployment scenario

For example of MU 1, as shown in Figure 2, it will receive signals from 6 APs in total with signal vector $\{Rx_{1,1}, Rx_{2,1}, Rx_{3,1}, Rx_{4,1}, Rx_{5,1}, Rx_{6,1}\}$. MU 1 will then report all these information to AP1 (the server). The server will then add all these signals to the corresponding APs.

$$w_{i,j} = \sum_{k=1}^{MU(server==i)} \sum_{l=1}^{AP(AP \neq i)} Rx_{l,k}$$

The contents of W_{inter}

W_{inter} is a $m \times n$ matrix (n is the number of tx from inter-network), with each element $w_{i,j}$ representing the total interference received from transmitter j to transmitter i .

Formulation of W_{inter}

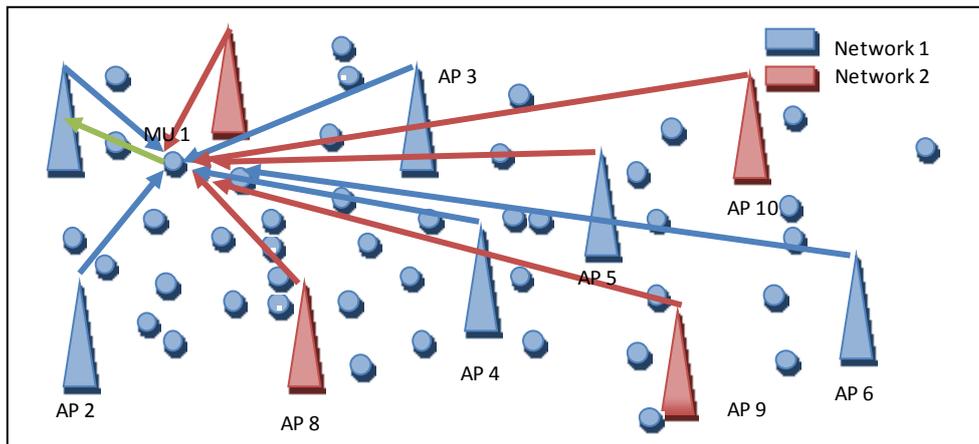


Figure 3 Inter-network deployment scenario

For example of MU 1, as shown in Figure 3, it will receive signals from 4 inter-network APs in total with signal vector $\{Rx_{7,1}, Rx_{8,1}, Rx_{9,1}, Rx_{10,1}\}$. MU 1 will then report all these information to AP1 (the server). The server will then add all these signals to the corresponding APs.

$$w_{i,j} = \sum_{k=1}^{MU(server==i)} \sum_{l=1}^{AP(SSID \neq Vodafone\ UK)} Rx_{l,k}$$

Where the MU report come from?

- **From measurement**

The measurement may contain the server together with the neighbouring AP information in each test point.

The network can be recognised by the SSID, here for example 'Vodafone UK', and the corresponding AP can be identified by MAC address. With these information ready, one can form the W_{intra} by the above formula.

The advantage of this method is the value shall quite accurate cause these data are collected from the real network. Disadvantage, however, the covered area is quite limited, thus the result may be quite biased and depends on the route of the measurement.

- **From prediction**

The SPE calculation, for example 'Signal Level' can predict the signal for each bin/pixel. These data can be used to calculate W_{intra} .

The advantage of this method is that it can consider the whole coverage of each AP without bias. However, the disadvantage is that the result is based on prediction which may not be as accurate as measurements. Furthermore, It does not take the load of each AP into consideration.

- **From Simulation**

The simulation will model the users' distribution and behaviour, which result can be also used to form W_{intra} .

The advantage of this method is that it can consider the whole coverage of each AP without bias. In addition, by modelling the number of users, it can consider the load difference of APs as well. However, the disadvantage is that the result is based on prediction which may not be as accurate as measurements.

How to use them together?

Since there is a clear advantageous of simulation than prediction, in a real optimisation algorithm, it may only take either of them and simulation is always preferred it is available. For the measurement, however, can also used alone as the optimization criteria or used with simulation or prediction. If this is the case, in order to differentiate the importance, one may need to decide the weight between them.

Problem Modelling

Object function:

$$\min_{x_{i,k}} \sum_{i=0}^{M(AP)} \sum_{j=0}^{M(AP)} \sum_{k=0}^{NF} \frac{W_{i,j}^{intra}}{D_i * D_j} y_{i,j,k} + \sum_{i=0}^{M(AP)} \sum_{j=0}^{N(AP)} \sum_{k=0}^{NF} \frac{W_{i,j}^{inter}}{D_i * D_j} y_{i,j,k}$$

Subject to:

$$\sum_{k=0}^{NF} x_{i,k} = D_i \quad \forall i$$

$x_{i,k} \in \{0,1\}$, D_i number of channel required by AP i .

If not consider interference from adjacent channels then,

$$y_{i,j,k} = \begin{cases} 1, & \text{the } i\text{th and } j\text{th tx has the same frequency } k \\ 0, & \text{otherwise} \end{cases}$$

otherwise,

$$y_{i,j,k} = \frac{1}{ACLR(f(i), f(j))} \quad f(i) = k$$

2.2.2. Intelligent Cell Optimisation (ICO)

In the HetNets, where small cells should be located? ICO is used to automatically plan and optimise small cell and heterogeneous networks, e.g., the optimal number & location, antenna type, transmit power, tilt and azimuth. Which can be used to plan a new or optimise an existing network. The basic algorithm is described as following. Here, WLAN is also as a example.

The contents of PL_{intra} , H_{intra} , V_{intra}

PL_{intra} is a $m \times n$ matrix (m is the number of MU within the coverage zones), with each element $pl_{i,j}$ representing the path loss from transmitter j to receiver i .

H_{intra} is a $m \times n$ matrix (m is the number of MU within the coverage zones), with each element $h_{i,j}$ representing the horizontal angle from transmitter j to receiver i .

V_{intra} is a $m \times n$ matrix (m is the number of MU within the coverage zones), with each element $v_{i,j}$ representing the vertical angle from transmitter j to receiver i .

Note: PL_{intra} is the pure path loss in which the antenna pattern is not considered.

Formulation of PL_{intra}

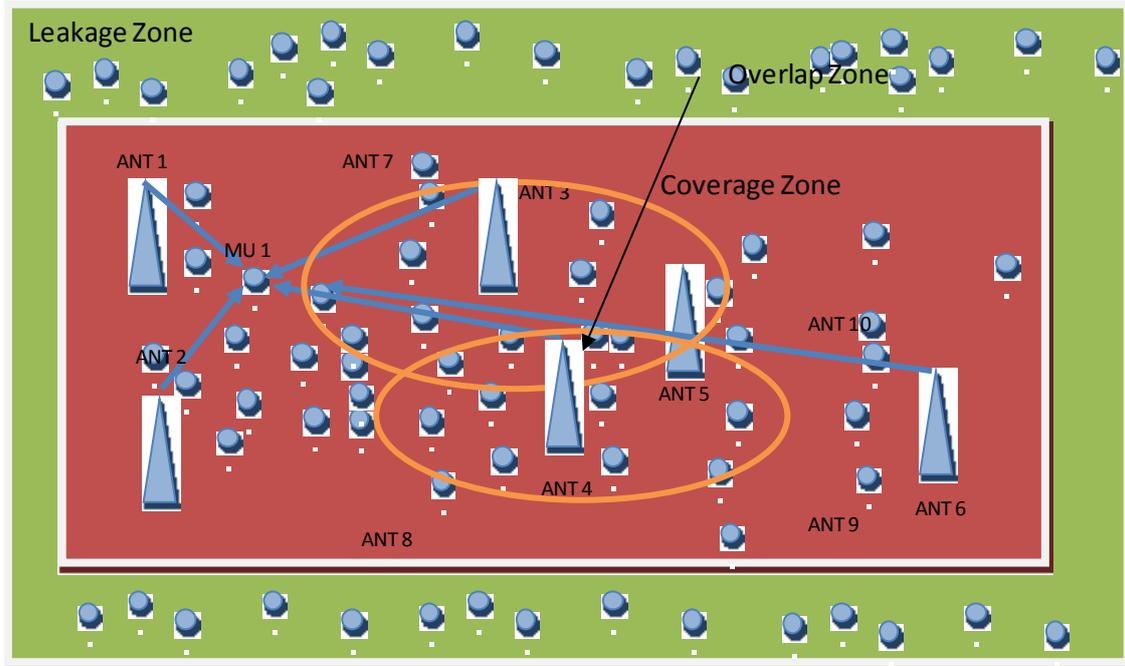


Figure 4 Intra-cell deployment scenario

For example of MU 1, as shown in Figure 4, signals from 6 ANTs in total with path loss vector $\{pl_{1,1}, pl_{2,1}, pl_{3,1}, pl_{4,1}, pl_{5,1}, pl_{6,1}\}$. All the $pl_{i,j}$ will then form the following matrix as PL_{intra}

Formulation of H_{intra} and V_{intra}

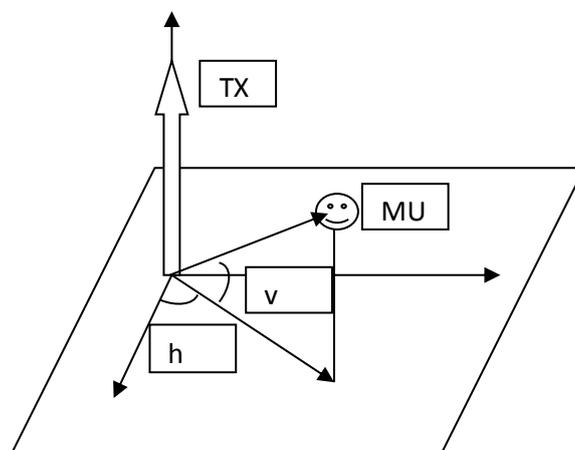


Figure 5 Propagation model

Note: These value can be calculate by the propagation model efficiently, as shown in Figure 5.

The contents of PL_{inter} , H_{inter} , V_{inter}

These values are very similar to the intra-networks ones. The only difference is the MUs here come from the leakage area.

How to set the candidate transmitters?

The first step for the ICO input would be the candidate locations of the transmitters. There are basically two kind of method to decide the locations.

- **By individual**

User will manually add the transmitters to the points with interests in FLD module (like adding normal antennas). He will then select the ones need to be optimized in the ICO module.

- **By area**

User will define the zone that transmitters will be possibly located. In order to generate a reasonable number of transmitters before the ICO module. User need to set the antenna radius to the area. The available transmitters will then be generated by cellular algorithm.

How to set the MUs ?

MUs are the final measurements for the performance of the solution. The number and location of the MUs can be generated by this simple method.

- **By area**

User can specify the location area of the MUs. In order to generate a certain number of MUs, a MU density can be set for the area, otherwise ICO can simply use the default density as the resolution of the SPE.

2.2.3.Intelligent Topology Optimisation(ITO)

ITO is used to automatically select the device type, connectivity, and routing to optimize the wireless network structure. The basic algorithm is described as following.

Optimized objective

- **Power**

The difference between output power at antenna port and required power

$$|Tx_i - Tx_{reqi}| \leq Tx_{\Delta}$$

In order to match the antenna coverage and requirement in the topology, the power difference is less than 1dB

- **Cable length**

Minimize the length of cable to reduce the cost

$$\min \sum(L_{ij})$$

- **Device number**

Minimize the cost of networks

$$\min \sum(N_i)$$

- **Required power**

Let the required transmit power is less than the threshold, which is based on the maximum transmit power of device

Variables

- **No of active device**

Based on the location and number of device customers selected, the optimisation algorithm can determine the optimisation aim

- **Device type**

Based on the candidate location, select the device type

- **Connection**

Determine the connection relation between antenna and source

- **Device port**

Determine the connection relation based on the assigned port

Algorithm

Based on the problem, model, objective, and variables, select the optimisation algorithm, and solve the mathematic model.

2.2.4. Intelligent Measurement-based optimisation (IMO)

IMO is used to optimise a radio access network via importing measurement data from third party measurement tools, especially indoor data to optimize the designed network. At the same time, IMO can also support automatic real-time measurement data collection from a live network and record collection positions, e.g. in an indoor WiFi network. In particular, this function is important for an indoor network where GPS signal is too weak or not available

2.3. Automatic P&O Procedure

According to the main features of automatic HetNet planning and optimisation tools, the basic procedure of the automatic planning and optimisation is presented in Figure 6 [8].

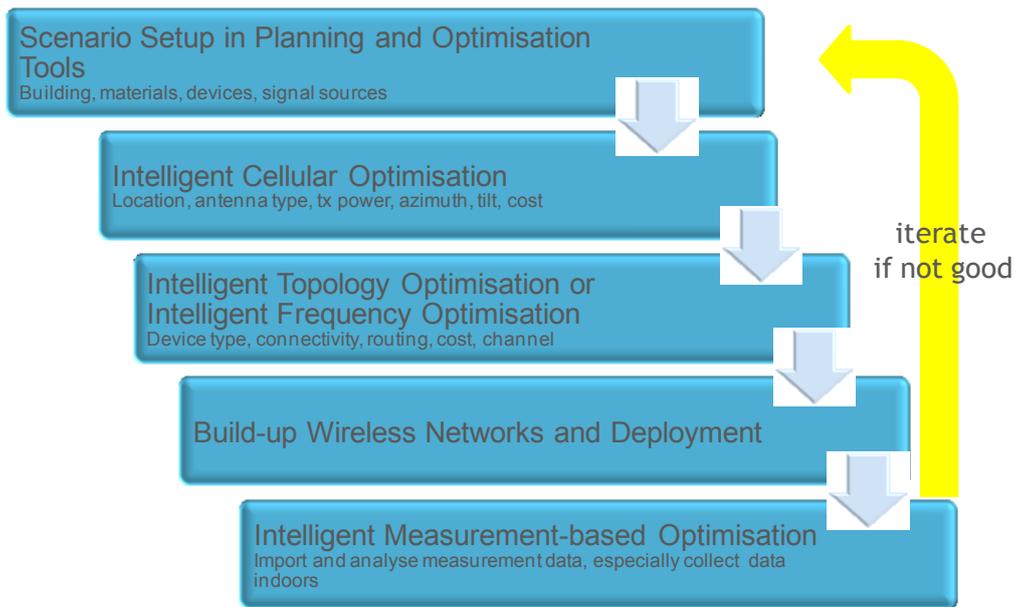


Figure 6 Intelligent network P&O procedure

The complete process depicted in *Figure 7*. Obviously, intelligent optimisation tools are one of the keys for network design. If ICO and IFO/ITO can accurately configure the network, then the results from WNS and IMO can match the system requirement.

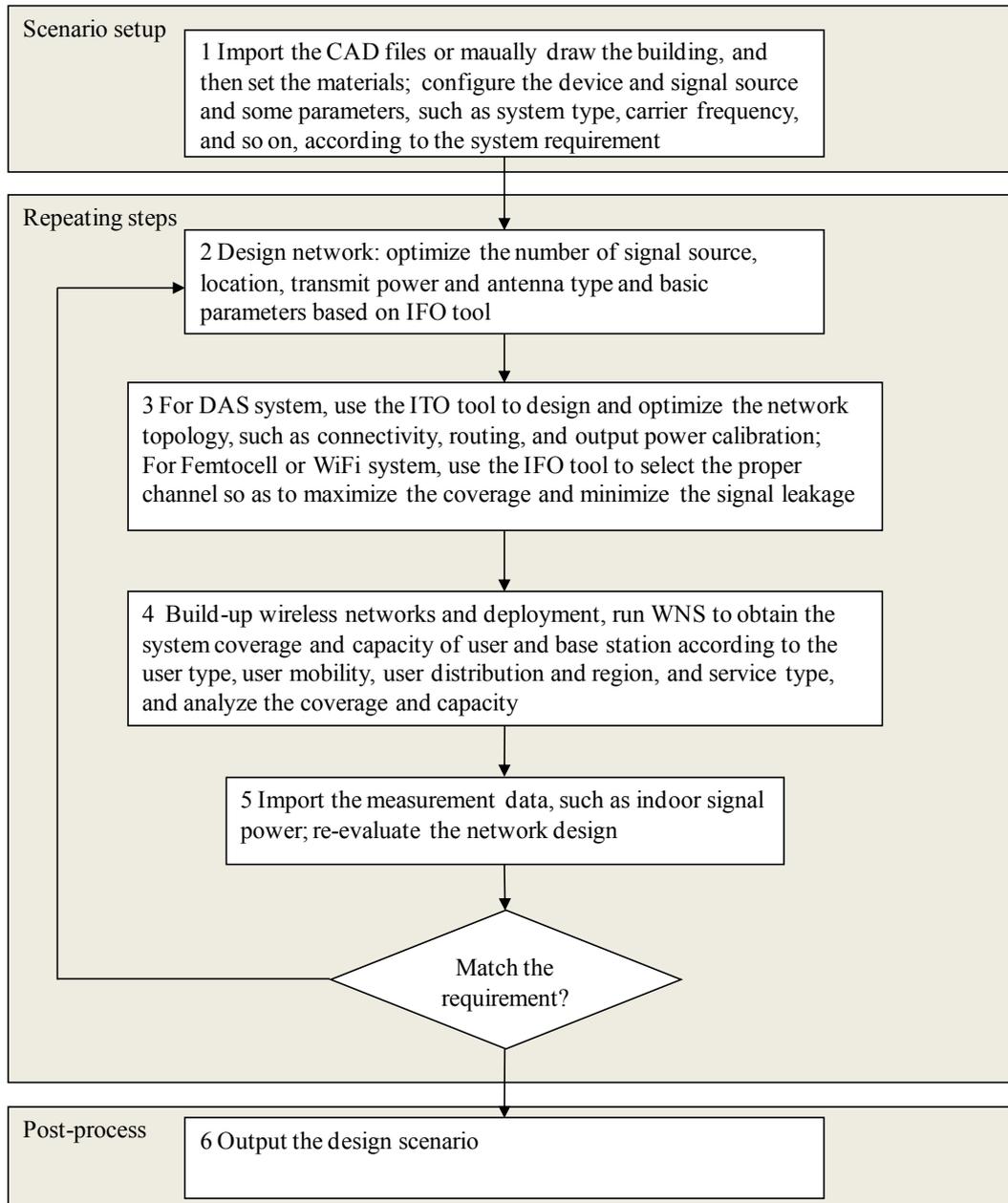


Figure 7 Automatic P&O Flowchart

3. Performance of Optimisation for HetNet Scenario

3.1. Scenario Description

HetNet scenario considers The Chamber Business Centre, which is situated at Kimpton Road in Luton, UK. It has two storeys and built by brick stacks with stone cornicing. A photo of the building is shown in *Figure 8*.



Figure 8 Photo of the Chamber Business Centre

A three-dimensional building is modelled according to the building plan in iBuildNet®[7]. Figure 9 illustrates the building with texture surface displayed in iBuildNet®.

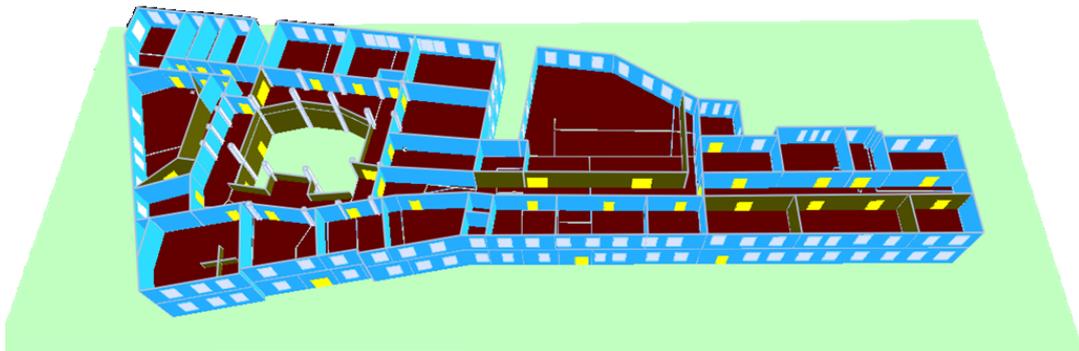


Figure 9 3D building models

3.2. Optimisation Considerations

How to efficiently deploy the low power base stations, such as number of low power base stations and their location, and how to deploy the system parameters of these low power base stations, such as antenna, power, and so on, are the main challenges in the HetNet design. So the automatic HetNet P&O tools can be used to improve the system network performance. A series of optimization objectives, such as leakage, coverage, capacity and CAPEX are considered in the wireless network design and optimization procedures.

At the same time, due to the isolation of wall and floor, so WLAN APs can use the same channel, and obtain more frequency reuse gain. Moreover, the network design can utilize the building structure, for example, pillars can be actually used to form directional transmission.

3.3. P&O procedures

Figure 10 indicates the procedure of automatic HetNet planning and optimisation system design.

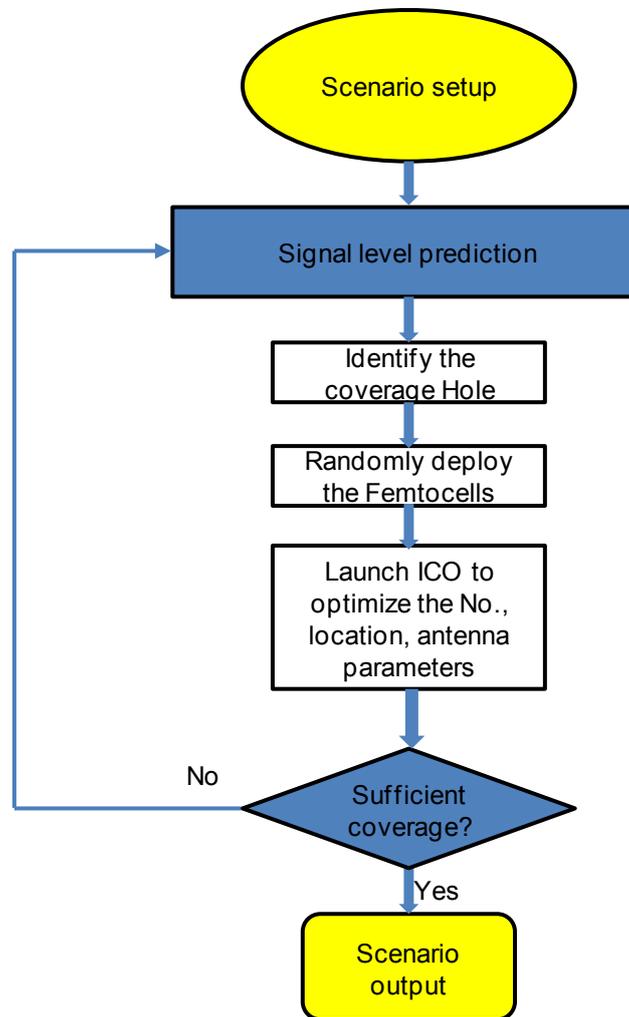


Figure 10 P&O procedure

Firstly, system design is finished, and a macro base station is deployed to cover the outdoor area. The signal prediction can judge the macro base station’s coverage, as shown in Figure 11. From the figure, some coverage holes or low data rate areas are identified to deploy the WLAN APs so as to the user experience can be improved.

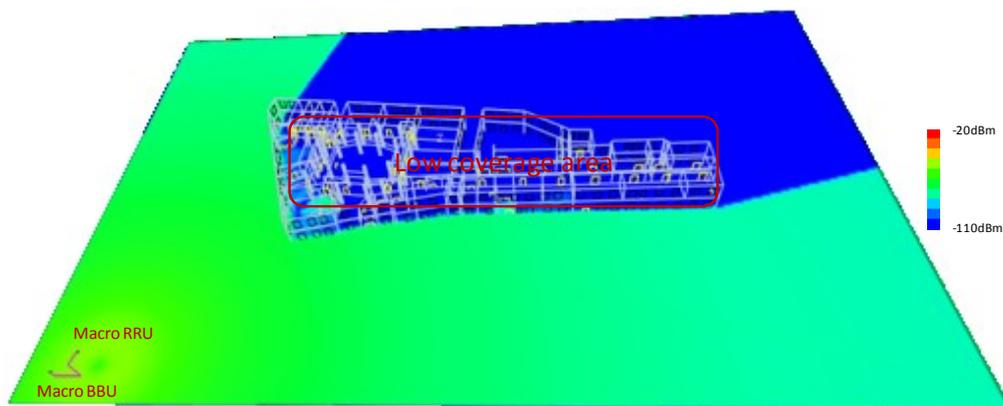


Figure 11 Signal level coverage of macro base station with coverage hole in the buildings

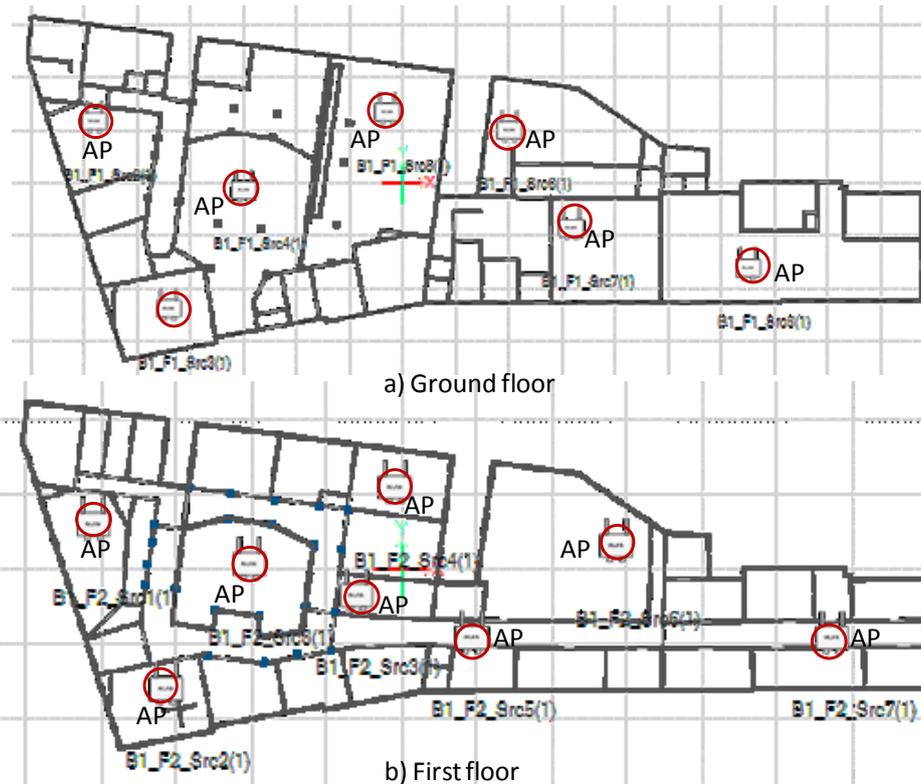


Figure 12 WLAN AP deployment randomly

Secondly, WLAN AP are deployed on each floor to fill in the coverage holes randomly, as shown in Figure 12. Candidate locations, initial transmit power, and candidate antenna types are configured in ICO to be part of the optimization objectives, as show in Figure 13. From the figure, the location and transmit power are adjusted based on the coverage and leakage targets. After finishing the ICO optimization, the AP deployment is shown in Figure 14, and the signal coverage can meet the requirement, as shown in Figure 15. From the figure, it can be seen that there only need more less no. of AP, more lower transmit power to cover the in-building region. Therefore, by using ICO, the CAPEX and OPEX can be reduced, and system design is improved. But due to the interference between AP, some areas have low SIR, so there need IFO to do the frequency optimisation.

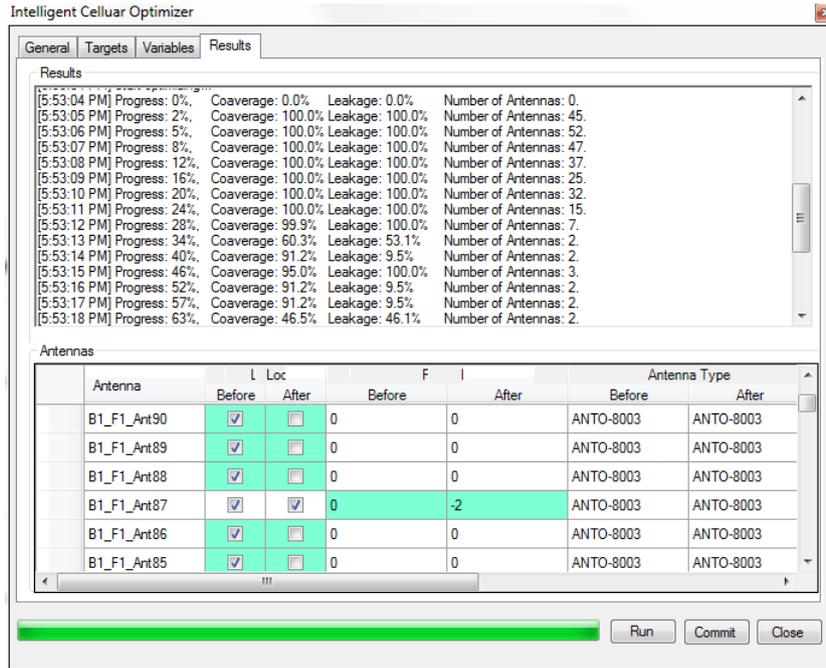


Figure 13 ICO optimisation user interface



Figure 14 ICO optimisation results

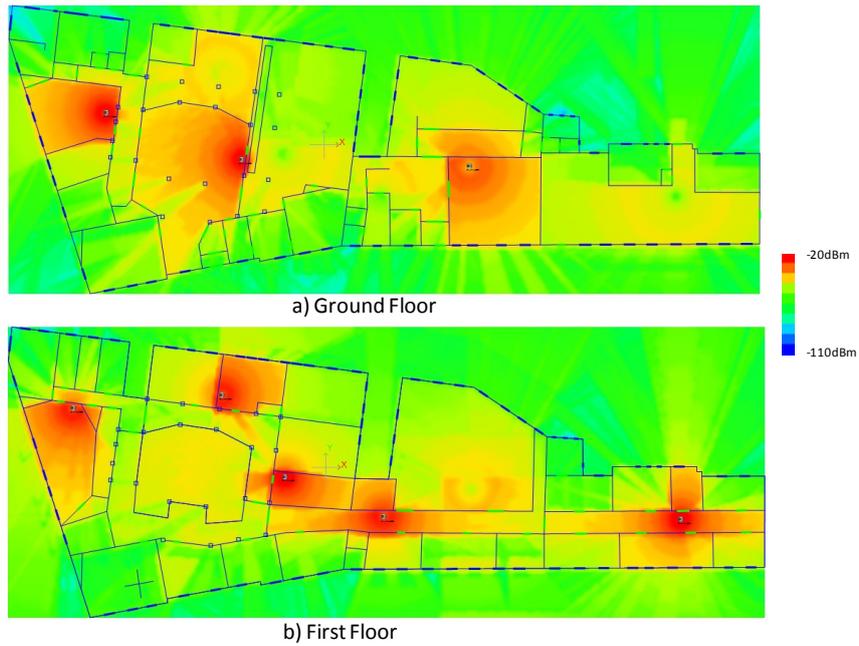


Figure 15 RSSI signal prediction

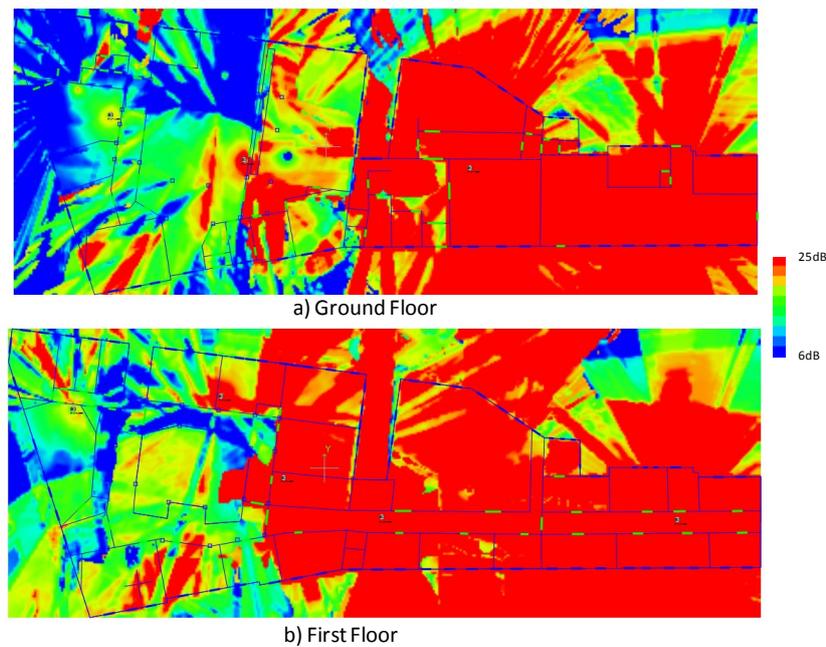


Figure 16 SIR map before optimisation

iBuildNet[®] integrates with an intelligent Frequency Optimisation module. Users will only need one click to carry out the Frequency Optimisation. A screenshot of the optimisation user interface is shown in Figure 17. A comparison between the channel selections of each AP is shown in Table 1.

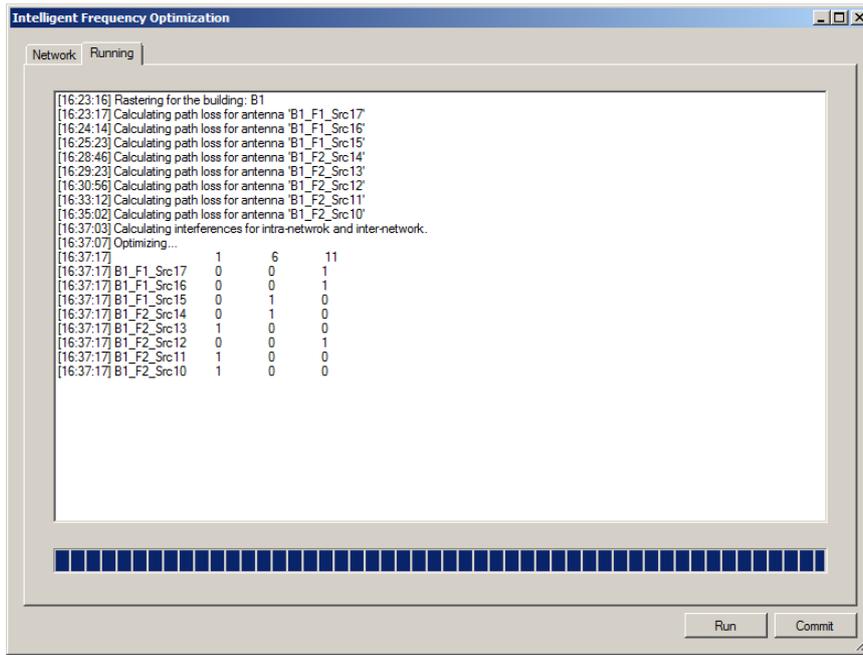


Figure 17 IFO optimisation user interface

Table 1 Comparison of Channel Selection Before/After Optimisation

Name in iBuildNet®	Channel Before Optimisation	Channel After Optimisation
B1_F2_Src10	1	1
B1_F2_Src11	6	1
B1_F2_Src12	11	11
B1_F2_Src13	1	1
B1_F2_Src14	6	6
B1_F1_Src15	6	6
B1_F1_Src16	1	11
B1_F1_Src17	11	11

The optimized Downlink SIR of the two floors are shown in Figure 18 SIR map after optimisation. The figures demonstrate the effectiveness of the optimization module, and SIR has significantly improvement, comparing with Figure 16 SIR map.

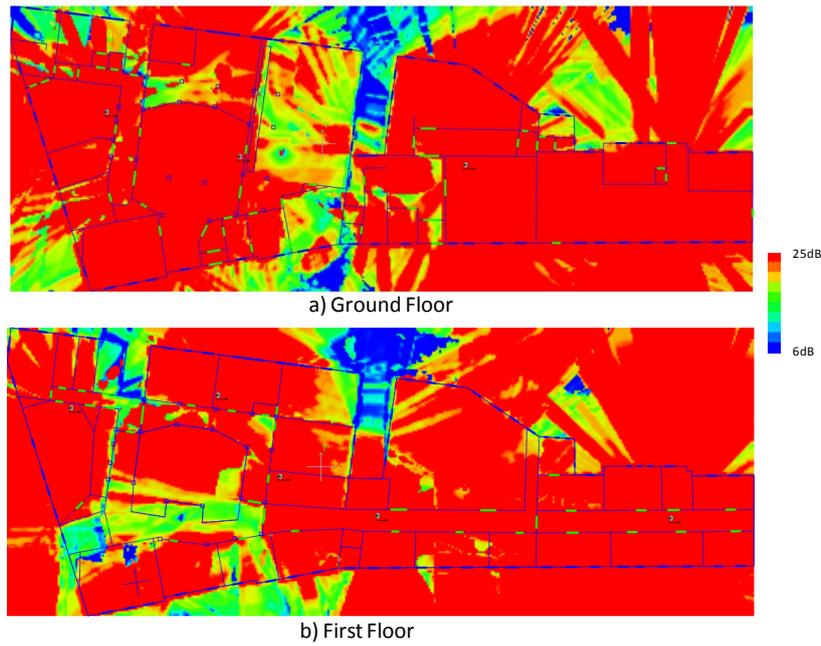


Figure 18 SIR map after optimisation

3.4. Performance Evaluation and Verification

Based on the P&O tool, system performance and user experience are expected to be greatly improved. Figure 19 and Figure 20 show the SIR comparison before/after optimization. From these figure, it can be seen that SIR is greatly improved from 23% to 37.6% in [20 24] region. Figure 21 and Figure 22 show the data rate statistic before/after optimization. From these figure, it can be seen that the low data rate users are decreased, up to 10%, and high data rate users are increased greatly, which shows IFO can effectively improve the coverage and capacity for wireless network design.

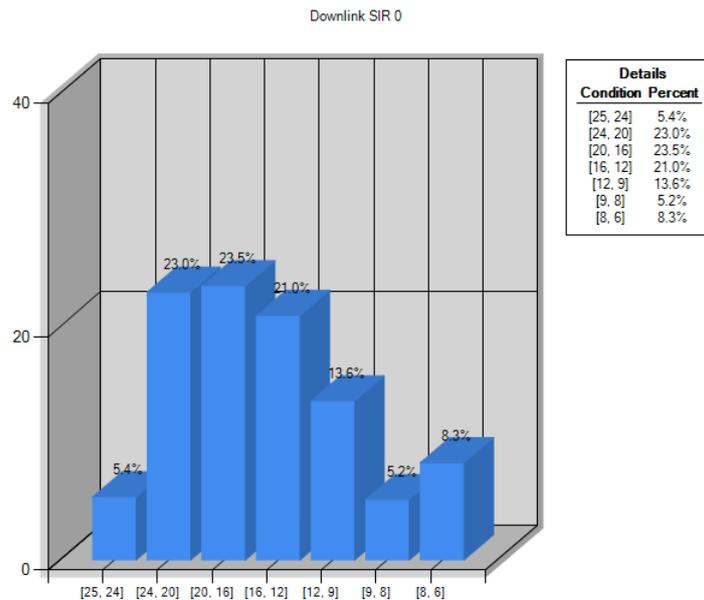


Figure 19 SIR Statistical Data before Optimisation

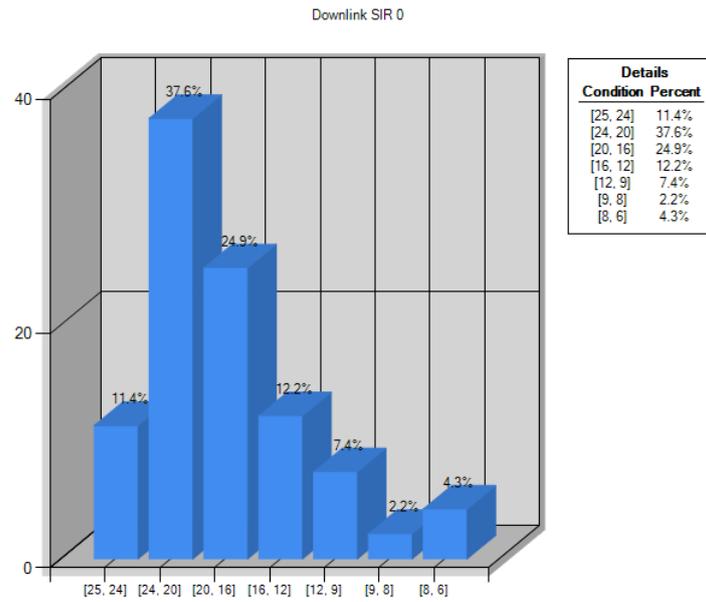


Figure 20 SIR Statistical Data after optimisation

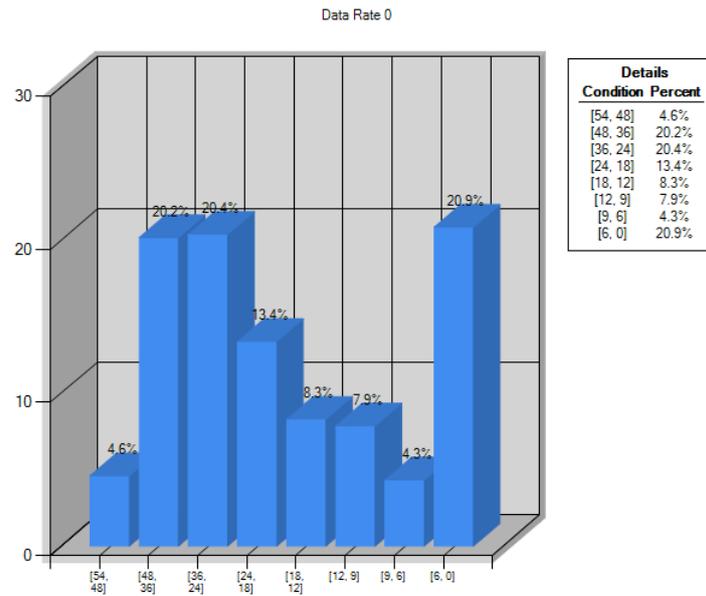


Figure 21 Data Rate Statistical Data before Optimisation

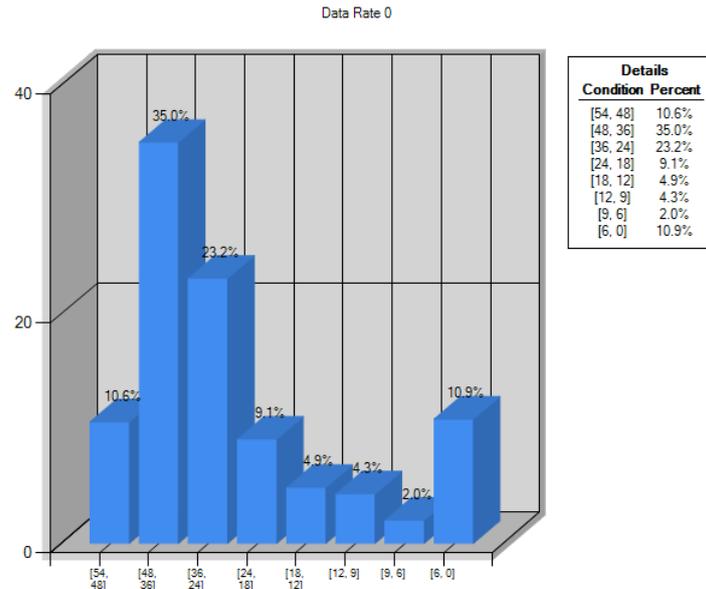


Figure 22 Data Rate Statistical Data after Optimisation

4. Conclusions

Automatic Network Planning and Optimisation are becoming critical to save operators' CAPEX and OPEX with considerable performance targets. The automatic HetNet P&O tool set is a promising candidate to gently perform this task to minimize the number of low power base stations, greatly reduce the leakage to outside from in-building small cells, reduce the transmit power of base stations with optimized configuration parameters. One typical scenarios are investigated in the deliverable for HetNet deployment scenario. The optimisation results presents a great improvements on user SIR and data rate.

5. Publications

- [1] Jiming Chen, Jie Zhang, "WiFi Deployment in LTE Cellular Networks: Achieving Always-on High Data Rate," Small Cell and HetNet panel, IEEE ICC'12, Aug. 2012
- [2] Hui Song, Jie Zhang, "Towards Small Cell Solutions for HetNets," Industry Forums on Heterogeneous Network (HetNet) Deployment: Challenges and Strategies, IEEE ICC 2012, June 2012

Reference

- [1] Cisco, "Cisco Visual networking Index: Global Mobile Data Traffic Forecast Update, 2011-2016," February 14, 2012.
- [2] P. Cerwall and S. Bergqvist, "Ericsson traffic and market data report," in Nov. 2011.
- [3] ITU-R, "ITU global standard for international mobile telecommunications 'IMT-Advanced'," Circular letter, March 2008.
- [4] 3GPP, "Requirements for further advancements for Evolved Universal Terrestrial Radio Access (E-UTRA) (Release 8)," 3GPP Technical Specification (TS 36.913) v8.0.1, March 2009.
- [5] 3GPP, "Requirements for further advancements for Evolved Universal Terrestrial Radio Access (E-UTRA) (Release 10)," 3GPP Technical Specification (TS 36.913) v10.0.0, March 2011.
- [6] A.Hamnjanonic, J. Montojo, Y. Wei, et al., "A Survey on 3GPP Heterogeneous Networks," IEEE Wireless Communications magazine, vol. 18, no. 3, June 2011, pp. 10-21.
- [7] iBuildNet®, [Online]. Available: <http://www.ranplan.co.uk>
- [8] J. Chen, and J. Zhang, "WiFi Deployment in LTE Cellular Networks: Achieving Always-on High Data Rate," Small Cell and HetNet panel, IEEE ICC'12, Aug. 2012

Glossary of Terms

ITU	International Telecommunication Union
4G	Fourth Generation
3GPP	the Third Generation Partnership Project
LTE	Long Term Evolution
HetNet	Heterogeneous Networks
RAT	Radio Access Technologies
P&O	Planning and Optimisation
IFO	Intelligent Frequency Optimisation
ICO	Intelligent Cell Optimisation
ITO	Intelligent Topology Optimisation
IMO	Intelligent Measurement-based Optimisation
WLAN	Wireless Location Access Network
AP	Access Point
SPE	Signal Prediction Engine
WNS	iBuildNet [®] Wireless Network Simulator
RSSI	Received Signal Strength Indicator
SIR	Signal Interference Ratio

End of Document