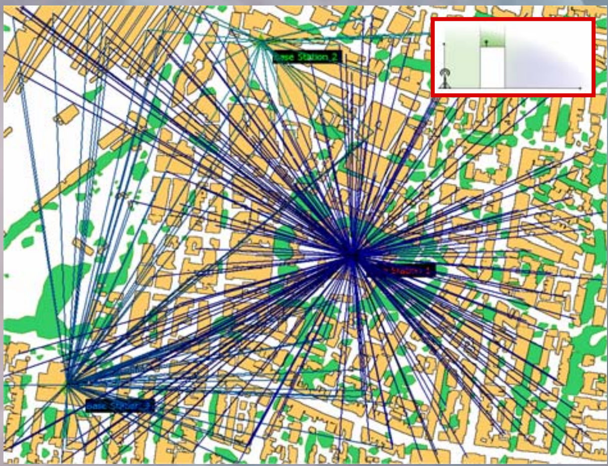
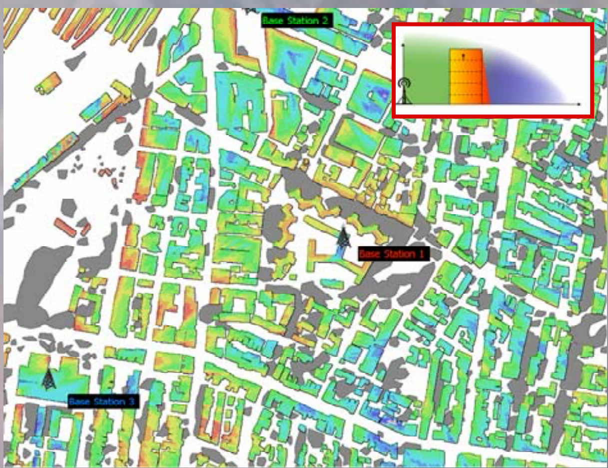
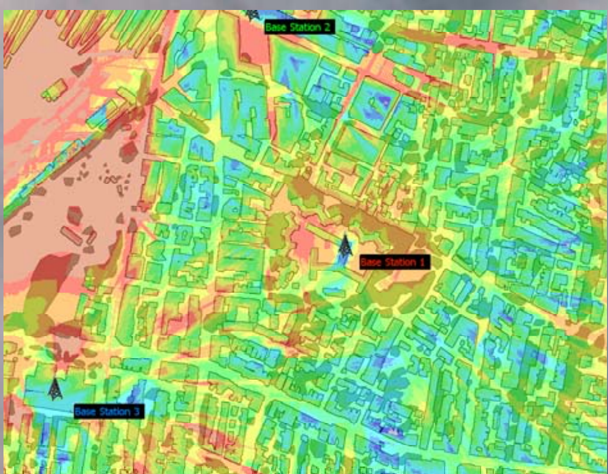


Fixed



Nomadic



Mobile

- White Paper
  March 2006

A quick-guide to 802.16e radio-planning with ICS telecom

Emmanuel Grenier

Software solutions in radiocommunications

Abstract

This white paper provides a radio-planning workflow for WiMax technologies with ICS telecom.

It focuses not only on **fixed and nomadic WiMax** that have heavily being tested and deployed all over the world, but also provides dedicated planning methodologies for **mobile WiMAX**. Since the early ratification of the 802.16e standard by IEEE, WiMAX becomes eventually mobile, enabling roaming between cells.

The provided workflow is divided in three parts:

- The **coverage model** allows the user to dimension its WiMax network.
- The **capacity model** will ensure that the WiMAX BS won't be overloaded due to the traffic requests of the CPEs or Mobile Units.
- The **spectrum model** will minimize the interference areas, and update the achievable traffic in the WiMAX network designed.

References

- WiMAX Forum: Mobile WiMAX -- Part I: A Technical Overview and Performance Evaluation
- ATDI (Daniel Humire-EG) : A brief overview of 802.16e specific features and current developments for simulating a WiMAX Network with ICS telecom
- WiMAX forum : WiMAX application usage profile (AWG Application Traffic Model and Usage Profile - Sub team)
- Intel Corporation : RF systems and circuit challenges for WiMAX
- J.H. Stott : How and why OFDM

Table of Content

A QUICK-GUIDE TO 802.16E RADIO-PLANNING WITH ICS TELECOM

Note : all provided values are FOR IN FORMATION ONLY

1 Required components

In order to perform an accurate WiMAX radio-planning of fixed, nomadic type or mobile type, ICS telecom requires several inputs such as **digital cartography**, **technical parameters of the equipment(s)** you want to simulate, having a good knowledge of the minimum **Quality of Service** you want to ensure, as well as being aware of the **spectrum** available.

Spectrum	Duplexing mode	Channel bandwidth (MHz)	FFT size	IEEE Standard
3400-3600	TDD	3.5	256	806.16-2004
3400-3600	FDD	3.5	256	806.16-2004
3400-3600	TDD	7	256	806.16-2004
3400-3600	FDD	7	256	806.16-2004
5725-5850	TDD	10	256	806.16-2004
2495-2690	TDD	1.25, 5, 10, 20	128, 512, 1024, 2048	802.16e
2495-2690	TDD	4.375	512	802.16e
2495-2690	TDD	8.75, 15	1024	802.16e
2300-2400	TDD	1.25, 5, 10, 20	128, 512, 1024, 2048	802.16e
3300-3600	TDD	3.5	512	802.16e
3300-3600	FDD	3.5	512	802.16e
3300-3600	HFDD	3.5	512	802.16e
3300-3800	TDD	4.375	512	802.16e
3300-3900	TDD	1.25, 5, 10, 20	128, 512, 1024, 2048	802.16e
3300-3900	TDD	7, 10	512, 1024	802.16e
3300-3900	FDD	7, 10	512, 1024	802.16e
3300-3900	HFDD	7, 10	512, 1024	802.16e

Different 802.16 profiles

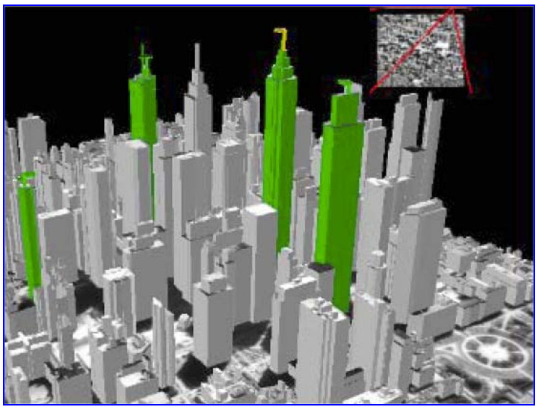
Definition	Devices	Locations	Speed	Handoffs	802.16-2004	802.16e 802.16-2005
Fixed access	Outdoor CPEs Indoor CPEs	Single	Stationary	No	Yes	Yes
Nomadic access	Indoor CPEs PCMCIA cards	Multiple	Stationary	No	Yes	Yes
Portability	Laptop PCMCIA mini cards	Multiple	Walking speed	Hard handoffs	No	Yes
Simple mobility	Laptop PCMCIA mini cards PDAs or smartphones	Multiple	Low vehicular speed	Hard handoffs	No	Yes
Full mobility	Laptop PCMCIA mini cards PDAs or smartphones	Multiple	High vehicular speed	Soft handoffs	No	Yes

Different types of WiMAX

1.1 Cartography

The choice of the cartography to use depends on the type of WiMAX radio-planning to perform:

- Large scale WiMAX networks would require Medium Resolution cartography
- Close range WiMAX network analysis would require High resolution cartography.



HR cartography

MR cartography

	Low resolution data	Medium resolution data	High resolution data
Typical content	DTM at 500m	. DTM at 30m . Clutter file giving different urban and vegetation heights as aggregates . Topographic map	. DTM at 2m . Building height file at 2m . Type of building map at 2m . True-orthophoto
Typical use	Not advised because of the lack of accuracy of the cartography	Network dimensioning Capacity and QoS analysis of an entire network Interchannel interference between the Base Stations Handover map of the network	High-end OFDM coverage of a few base stations Detailed throughput and interference analysis on a hot-spot

Different cartographic datasets for different planning methodologies

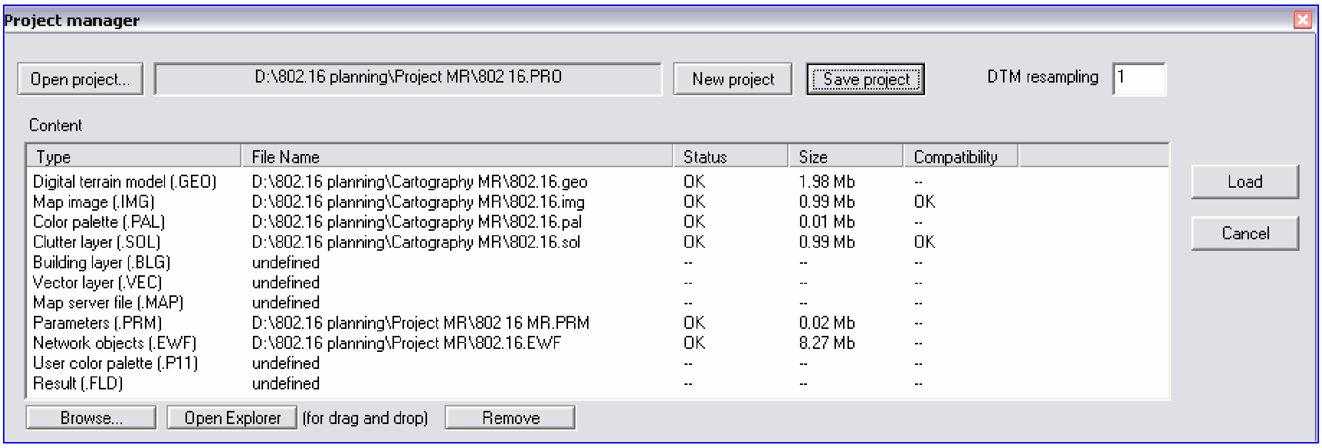
1.2 Network components

		Base Station	CPE	Goal
Connectivity Coverage	Common	Radiation pattern Antenna height	Radiation pattern Antenna height	Define the coverage model
	Downlink	Radiated power	Rx Gain Sensitivity Max tolerated latency	
	Uplink	Rx Gain Sensitivity	Radiated power	
Capacity	FDD	Downlink Throughput Uplink Throughput	UL and DL Traffic request Service flow repartition Activity factor Modulation table	Define the traffic/capacity model
	TDD	Throughput UL/DL duration ratio		
Interference	Coverage mode ISI	Max tolerated deltaToA between the direct and the reflected paths		Define the spectrum model
	Coverage mode ICI	Radiation pattern Protection ratios		
	PMP mode	Noise Floor Max threshold degradation tolerated Rejection mask Radiation pattern		
Mobility		Active set allocation FSBB handover value HHO handover value		Define the active sets of the network for an optimal managment of the handoffs

2 Project setup

WiMAX radio-planning in ICS telecom works on a project base. The project specifies:

- The area of interest;
- The cartographic layers to use for calculation and display purposes;
- The base stations location and their corresponding technical parameters and coverage;
- The CPE locations and their corresponding technical parameters (Fixed/Nomadic WiMAX);
- The calculation (propagation model, coverage threshold…) and display properties.



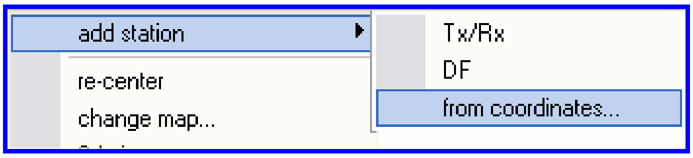
The project manager window in ICS telecom

3 The Base Stations network

3.1 Import

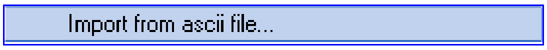
There are number of ways to add a base station on the map :

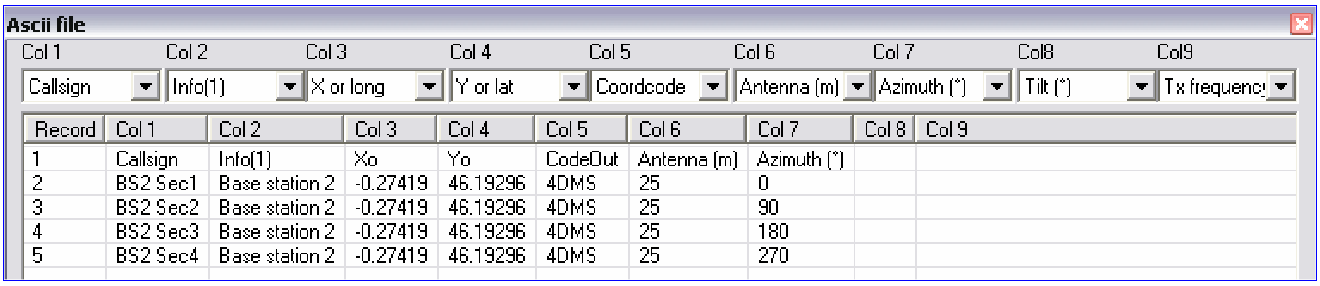
- Manually
- Using coordinates



Adding a site using its coordinates

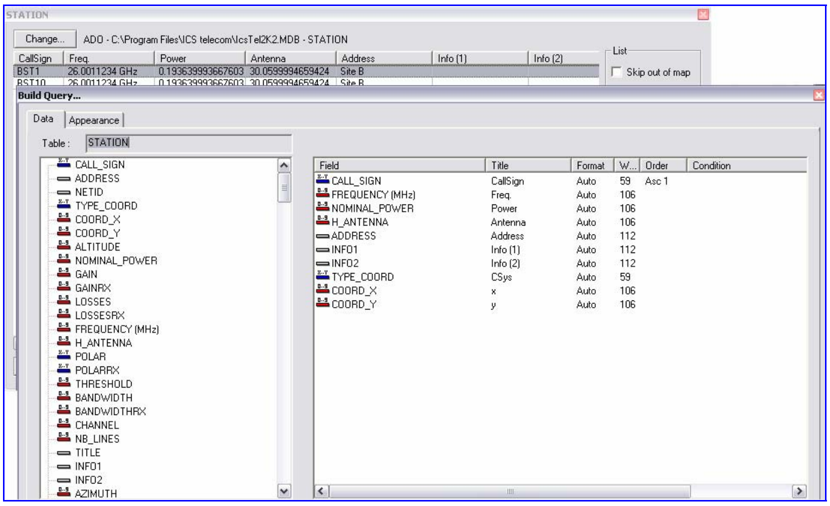
- Import from an Excel spreadsheet





Import of a site list from a spreadsheet

- Connection to an ODBC/ADO compliant exchange table (Access©, Oracle©, Foxpro©...)

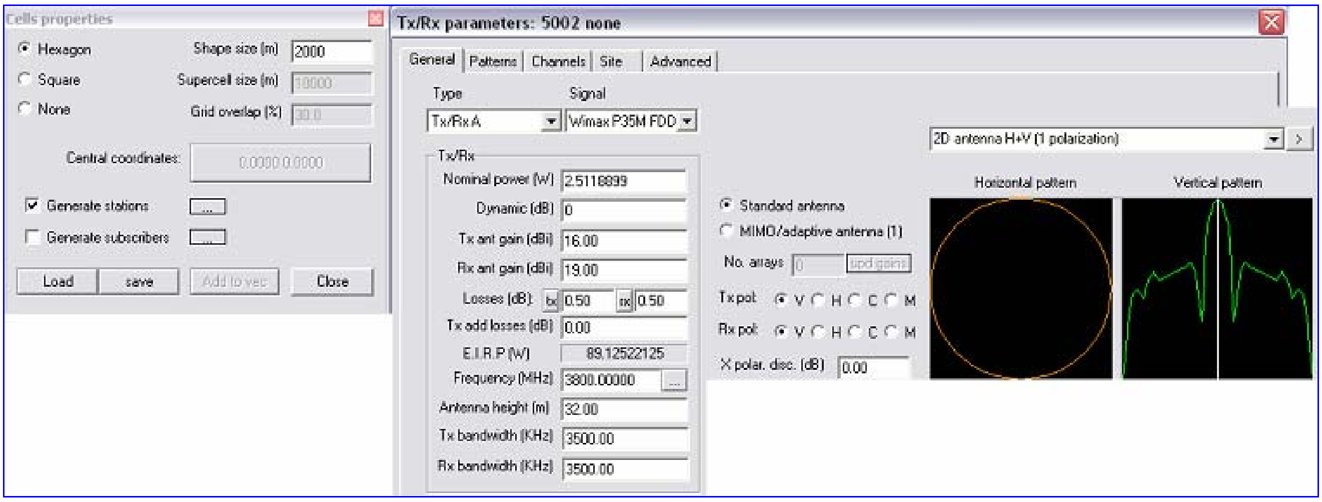


Integration of ICS telecom into an ODBC/DAO compliant database management software

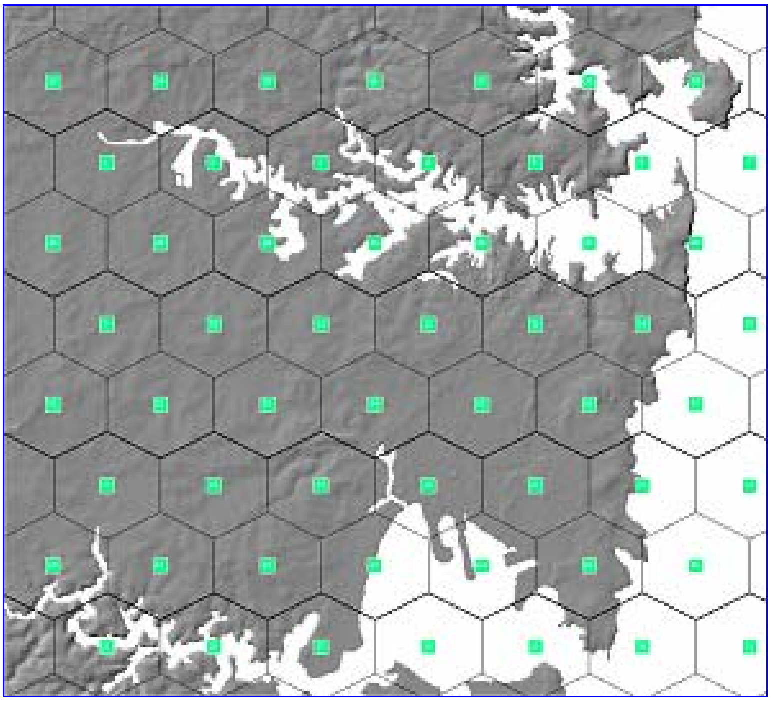
3.2 *Optimize the base station locations*

ICS telecom features different ways to find the best locations for a WiMAX BS (Identification of the highest point in a given area, site searching from the prospected CPE locations..).

One way to proceed would be to display on top of the Area of Interest a pattern of hexagonal shapes, and to place an omni-directionnal BS in the center of each cell.

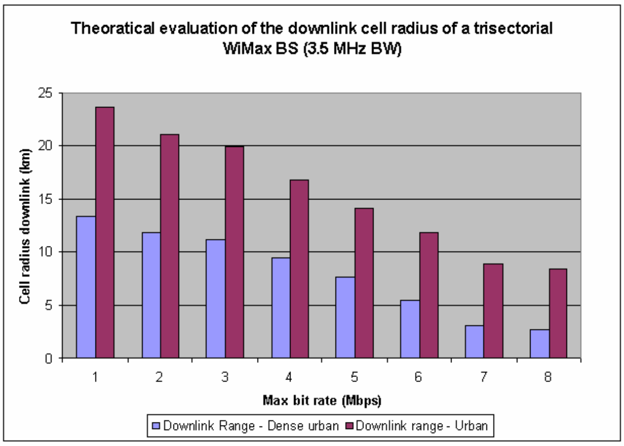


WiMAX Macrocell technical parameters

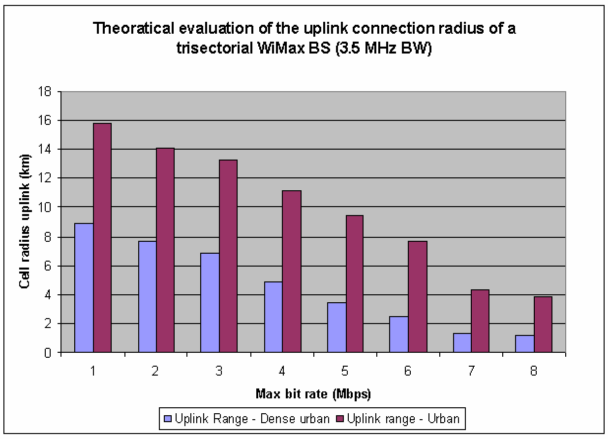


Raw distribution of the WiMAX macrocells in ICS telecom

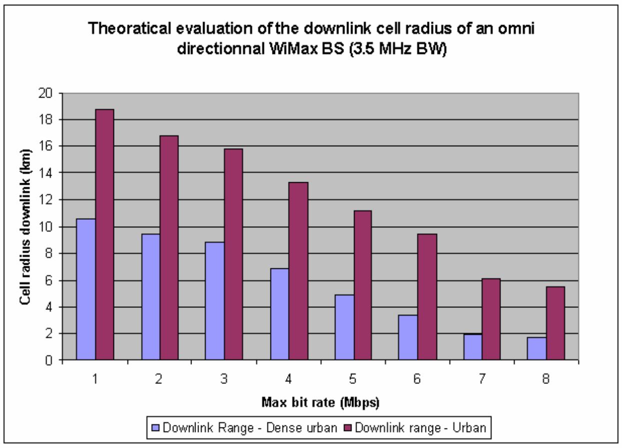
The **size of the cell** should be smaller than the expected coverage range.



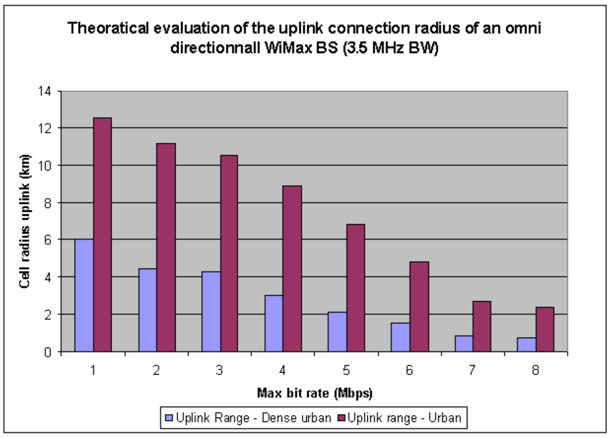
Downlink – 3 sectors



Uplink – 3 sectors



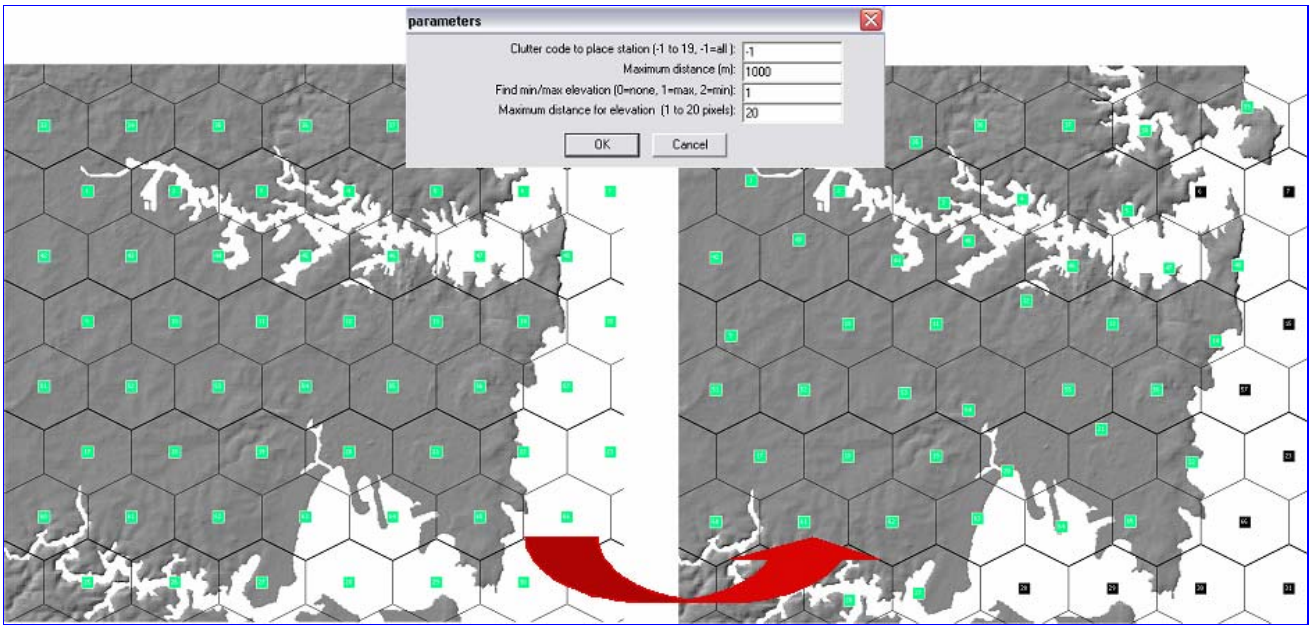
Downlink - Omni



Uplink - Omni

As a worst case scenario, defining a cell pattern of 2 km in a urban area guarantees on a good theoretical coverage, including the relevant fade margin.

The next stage is to replace the Base Stations on the **highest points** within the cell, and to remove the inadequate BS (in black here below).



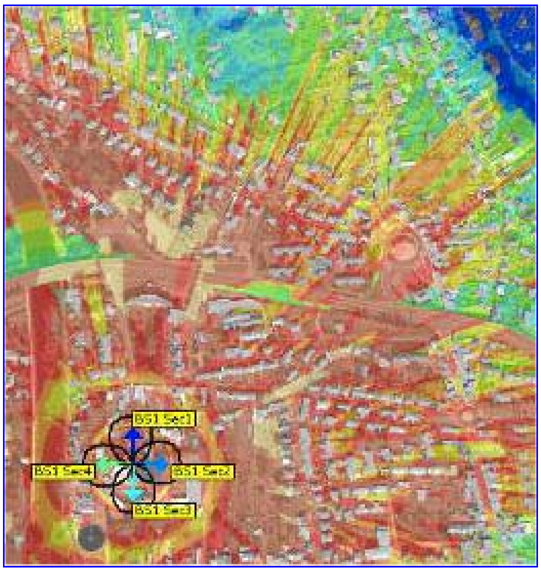
Filtering the relevant WiMAX macrocells

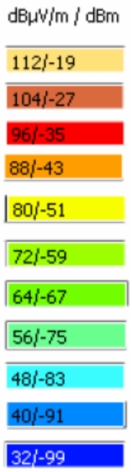
The next step is to calculate the corresponding coverage in order to decrease the density of the BS distribution while the coverage goal is still achieved.

4 The WiMAX coverage

4.1 802.16 Propagation

A previously published white paper entitled “3D Propagation Modeling in an Urban Environment” (June 2005) described the changes implemented in ICS telecom over two years ago in anticipation of demands to simulate propagation specific to Fixed Wireless Access technologies. These developments include the ability to simulate **outdoor to indoor propagation** (via absorption), the **InterSymbol Interference effects** of multipath reflection specific to OFDM equipment (ray-tracing) and the “urban canyoning” effect, LOS, NLOS and nLOS characteristics of a radio profile analysis, power delay spread and so forth.





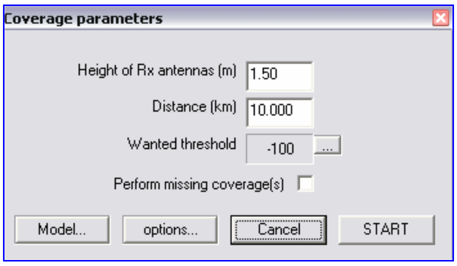
Deterministic simulation of the canyon effect in an urban setting without using ICS telecom’s ray-tracing engine. Each building along the direct path becomes a physical obstacle to the signal propagation. Cannot visualize the effects of reflection.

Deterministic simulation of the canyon effect in an urban setting with ICS telecom’s ray tracing engine. Each building along the possible paths (direct or not) become physical obstacles to the signal propagation. Some constructive field strength effects due to multipath reflection are highlighted with blue circles.

In addition to the features specific to deterministic planning in high resolution cartographic environments, several statistical algorithms (COST231, Okamura-Hata, ITM 122, ITU-R P.1225) have been integrated for propagation analysis over medium resolution environments (30m-90m), if the appropriate model tuning can be done. Given the prominence of the SUI Channel implementation of the Erceg model in the WiMAX Forum, an open configuration of this algorithm is integrated for use with ICS telecom. However, the use of these models for accurate propagation analysis for FWA/Mobile applications is still far from evident without a proper model tuning.

4.2 Coverage calculation

The coverage of the network can for instance be calculated according to:

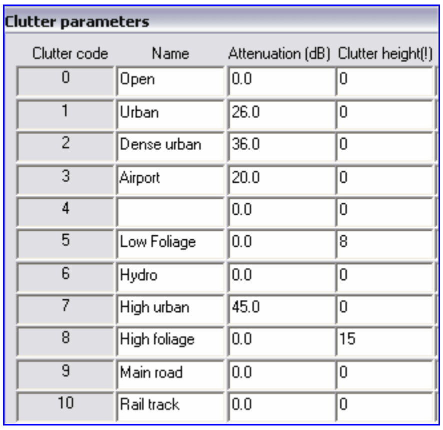


The sensitivity of the receiver in downlink.

The height of the receiver above ground level.

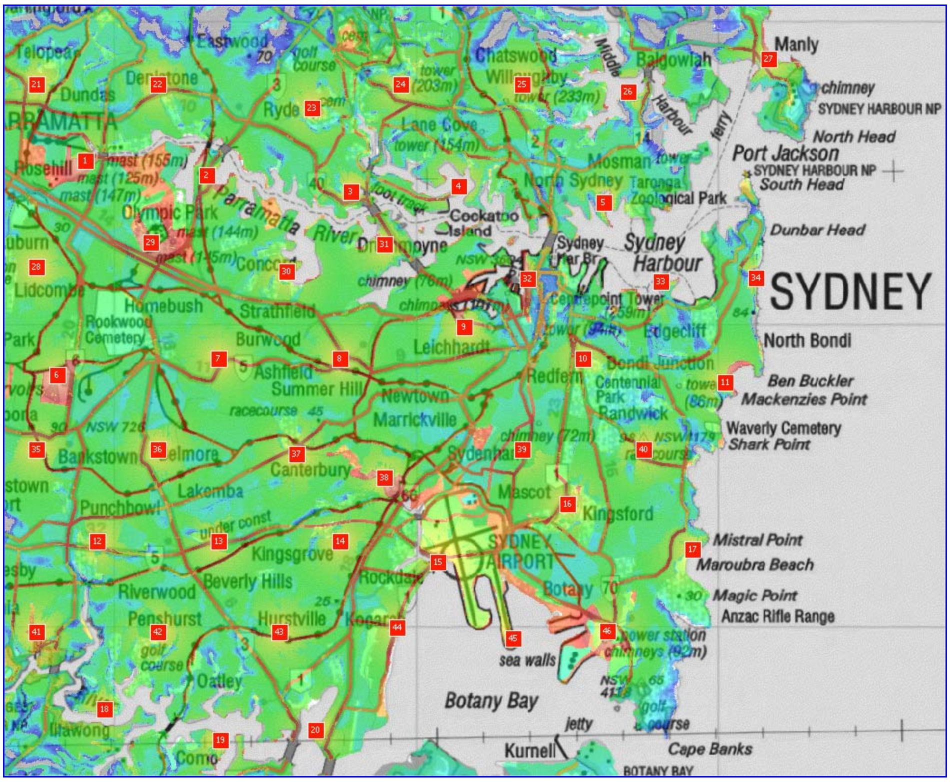
The maximum connection range in uplink.

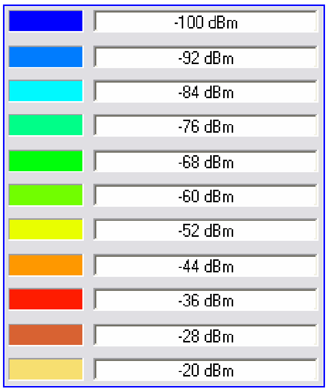
Typical fade margins for the urban ground occupancies (in that case, the corresponding clutter height is fixed at 0m) and typical heights for the vegetation (ICS telecom then calculate the signal loss by diffraction).



Clutter parameters

Clutter code	Name	Attenuation (dB)	Clutter height(!)
0	Open	0.0	0
1	Urban	26.0	0
2	Dense urban	36.0	0
3	Airport	20.0	0
4		0.0	0
5	Low Foliage	0.0	8
6	Hydro	0.0	0
7	High urban	45.0	0
8	High foliage	0.0	15
9	Main road	0.0	0
10	Rail track	0.0	0

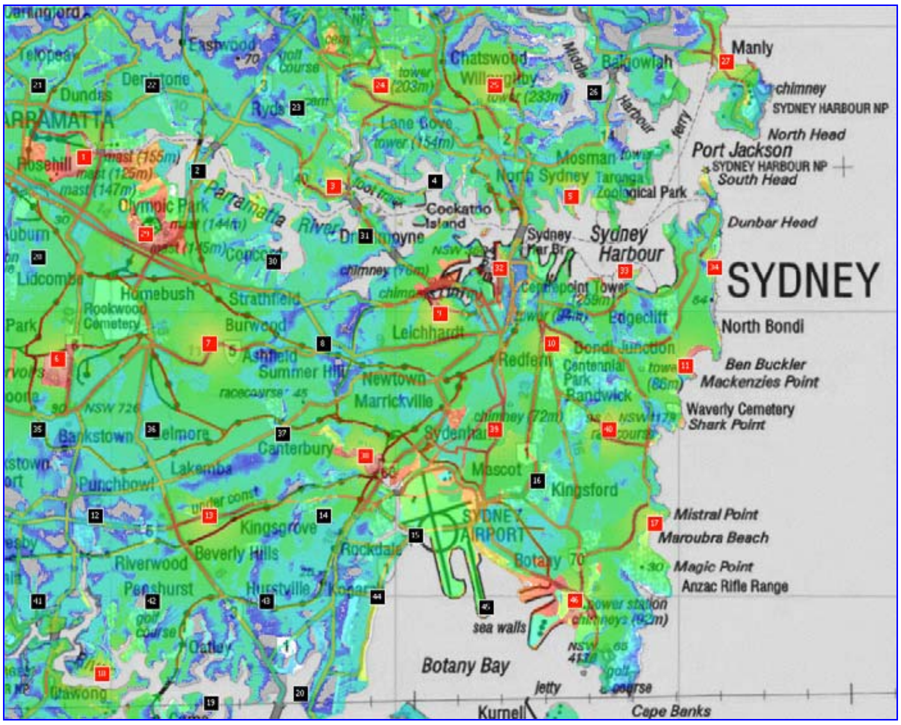


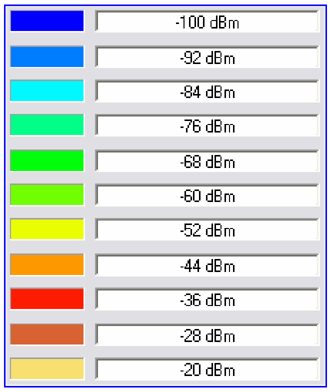


WiMAX coverage plot of the macrocells

4.3 Filtering the best BS locations

ICS telecom can then select among this site list the BS covering the largest area and the most interesting ground occupancies.





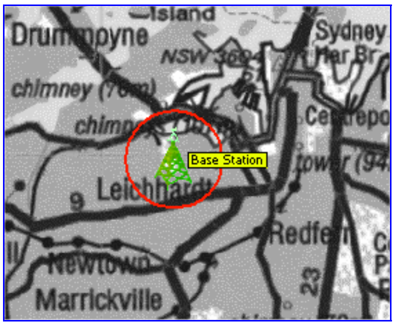
Selected sites

Removed sites

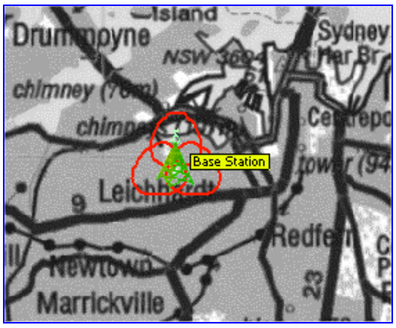
WiMAX coverage plot of the most relevant macrocells

4.4 Sectorizing the Base Stations and analyze the coverage

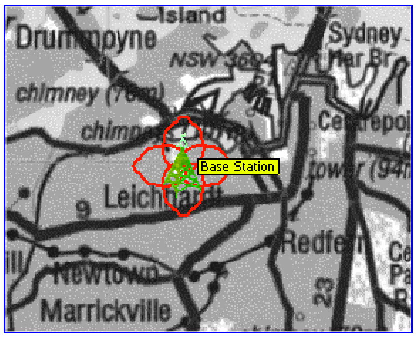
Once the best site locations have been found, the BS can be sectorized (for fixed/nomadic WiMax).



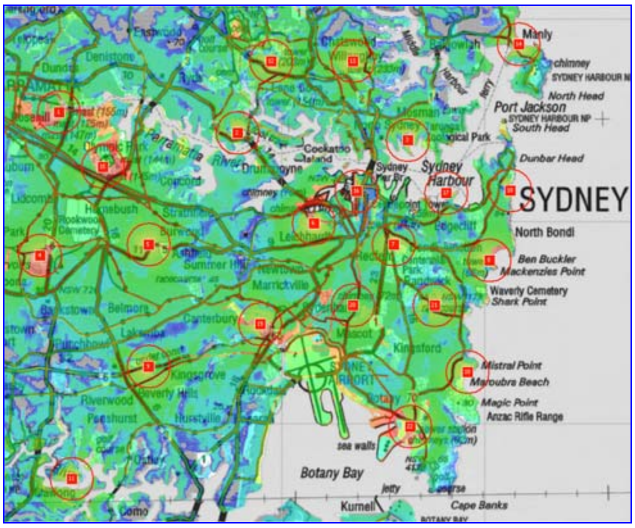
Omni-directional



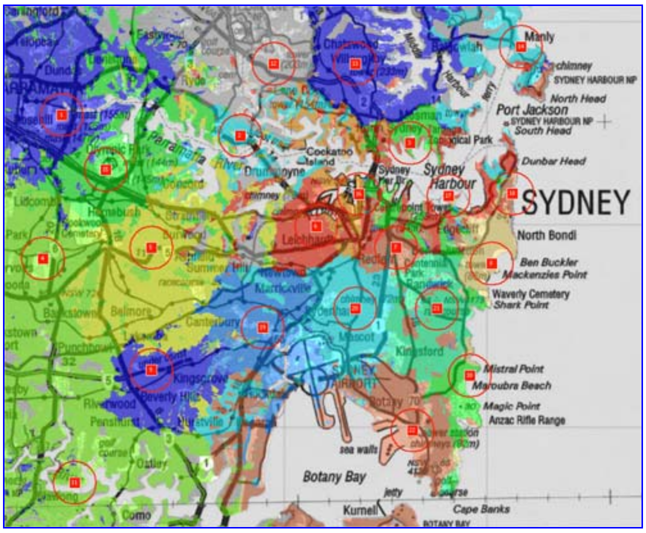
3 Sectors



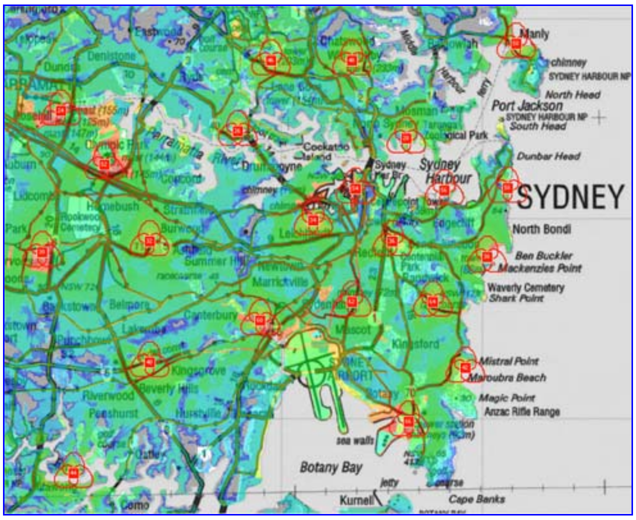
4 Sectors



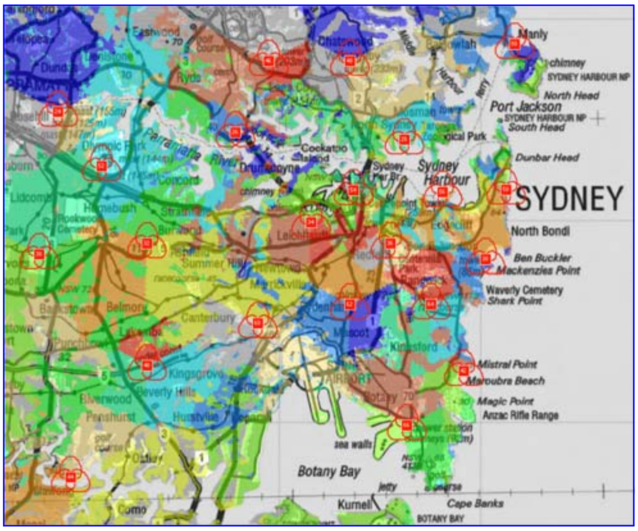
Coverage map (Omni-directional)



Best Server map (Omni-directional)



Coverage map (Tri-sectorial)



Best Server map (Tri-sectorial)

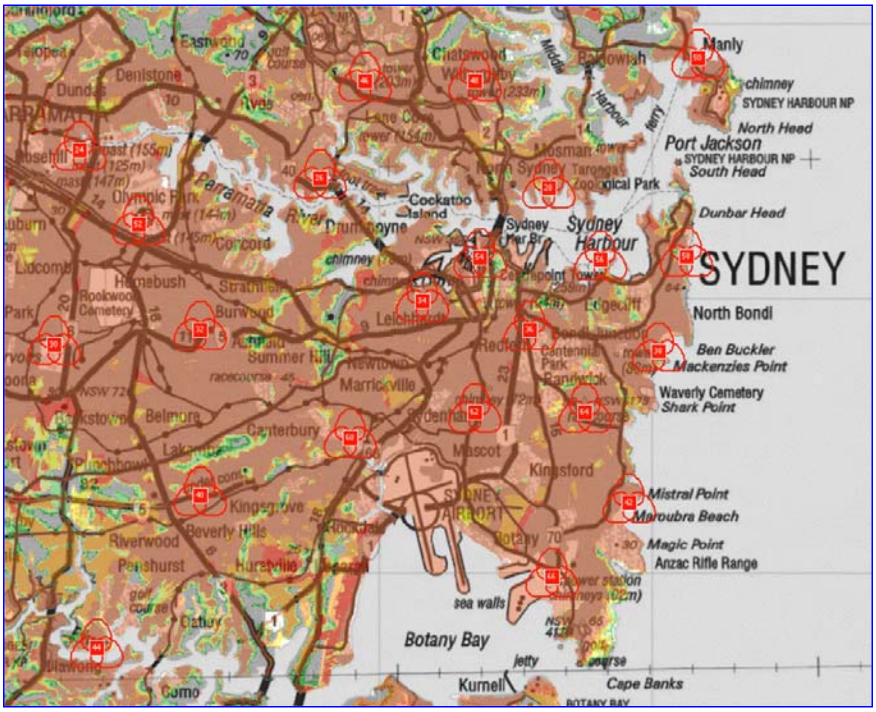
5 WiMAX Capacity analysis

5.1 Bit rate / modulation map

A first stage is to display a map of the **achievable bit rates according to the power received.** Typical values are given here below:

Typical sensitivities in fixed mode:

Modulation	Code rate	Sensitivity dBm	Raw Bit Rate DL fixed (Mbps) 3.5 MHz BW	Net throughput DL fixed (Mbps) 3.5 MHz BW
BFSK	1/2	-100	1.41	1.128
	3/4	-98	2.12	1.696
QPSK	1/2	-97	2.82	2.256
	3/4	-94	4.23	3.384
16QAM	1/2	-91	5.64	4.512
	3/4	-88	8.87	7.096
64QAM	2/3	-83	11.29	9.032
	3/4	-82	12.71	10.168

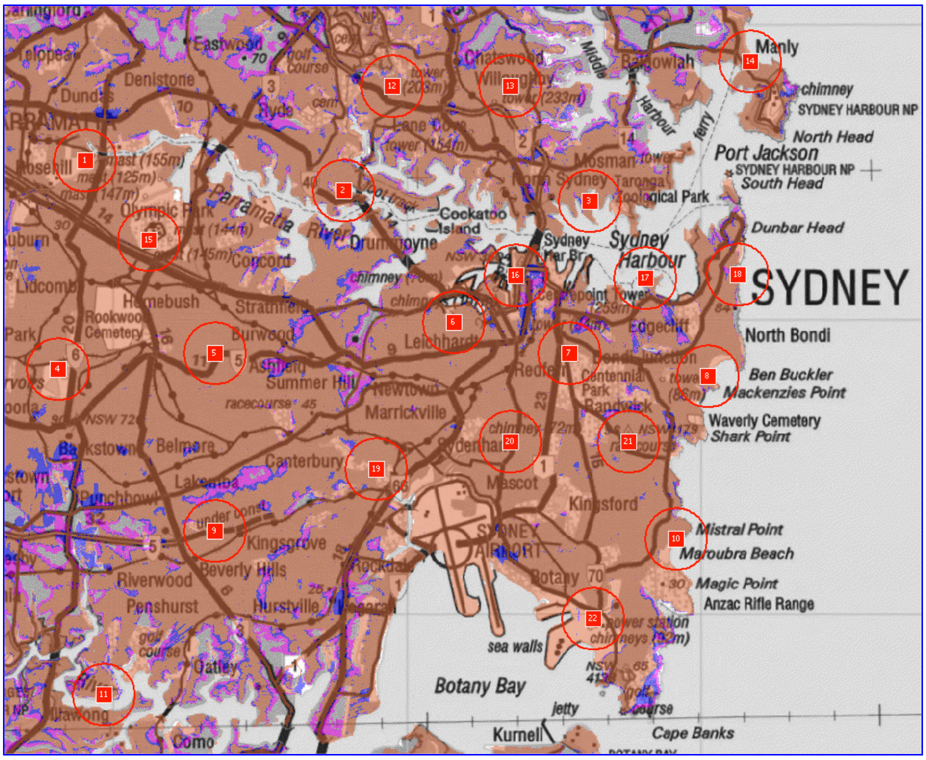


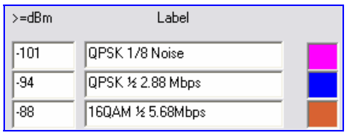
>=dBm	Label
-100	BFSK ½ 1.41Mbps
-98	BFSK ¾ 2.12Mbps
-97	QPSK ½ 2.82Mbps
-94	QPSK ¾ 4.23Mbps
-91	QAM16 ½ 5.64Mbps
-88	QAM16 ¾ 8.47Mbps
-83	QAM642/3 11.29Mbp
-82	QAM64 ¾ 12.71Mbps

Traffic map (raw bit rates) of a fixed/nomadic WiMAX network in ICS telecom

Typical sensitivities in mobile mode:

Modulation	Code rate	Sensitivity dBm	Bit rate DL Mobile (Mbps) 5 MHz BW
QPSK	1/8	-101	Below the noise floor
QPSK	1/2	-94	2.88
16QAM	1/2	-88	5.68

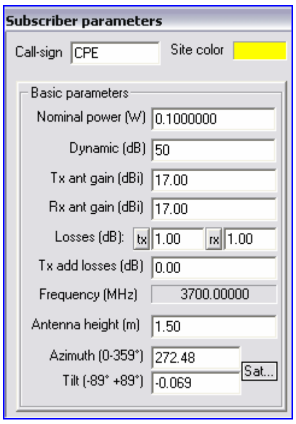




Traffic map of a mobile WiMAX network in ICS telecom

5.2 The WiMAX CPE

In order to refine the capacity analysis in fixed/nomadic WiMax, each CPE can be placed and defined **individually**.



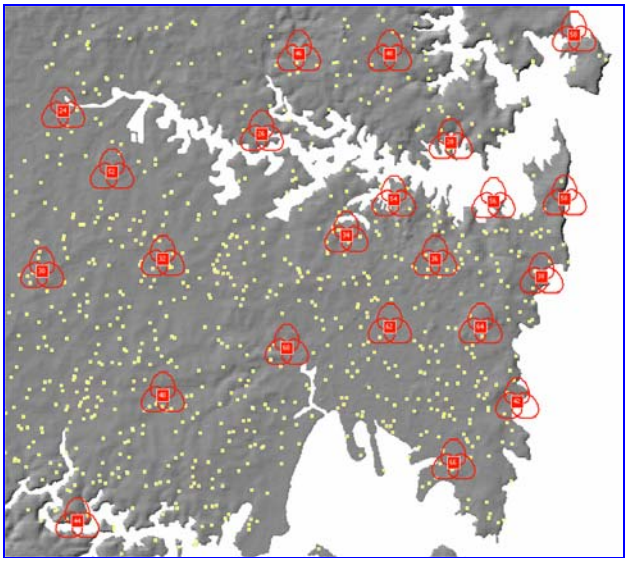
Subscriber parameters

Call-sign: CPE — Site color

Basic parameters

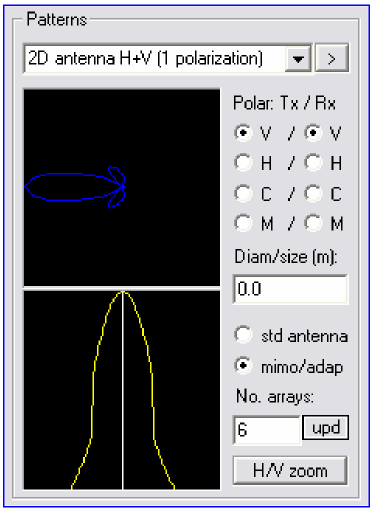
Nominal power (W)	0.1000000
Dynamic (dB)	50
Tx ant gain (dBi)	17.00
Rx ant gain (dBi)	17.00
Losses (dB): tx	1.00
Losses (dB): rx	1.00
Tx add losses (dB)	0.00
Frequency (MHz)	3700.00000
Antenna height (m)	1.50
Azimuth (0-359°)	272.48
Tilt (-89° +89°)	-0.069

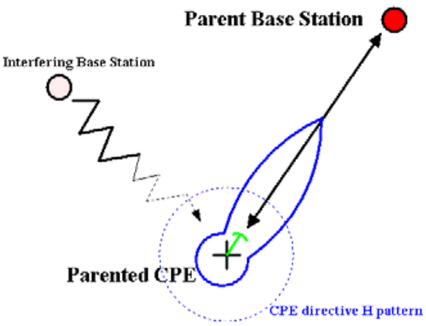
Sat...

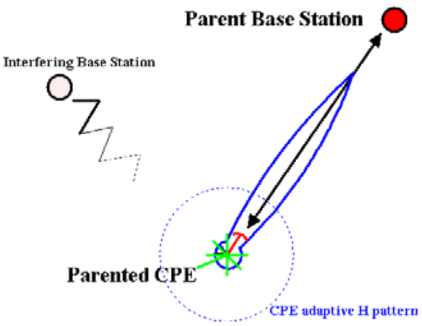


5.2.1 Radiation pattern

Each WiMAX CPE is configured using its corresponding radiation pattern. It can be a standard antenna, or being adaptive (better connectivity, with more resistance with regards to the interference).





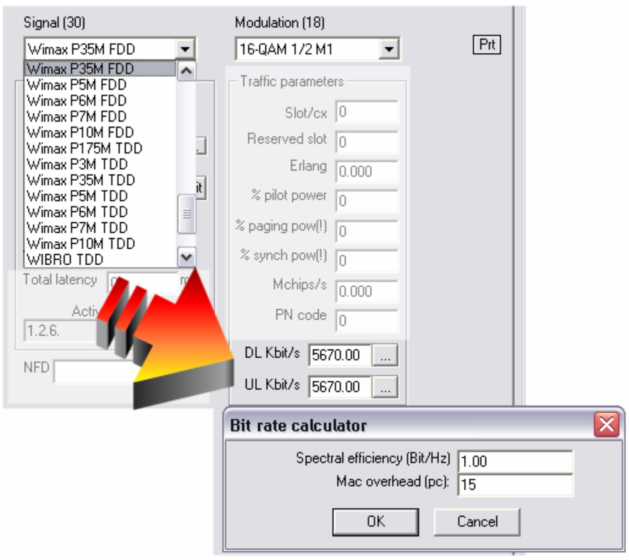


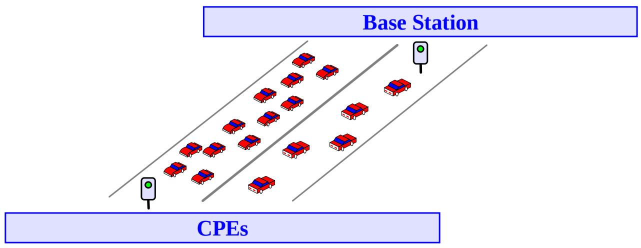
5.2.2 The 802.16 parenting according to the Service Flows

5.2.2.1 Throughput at the BS level

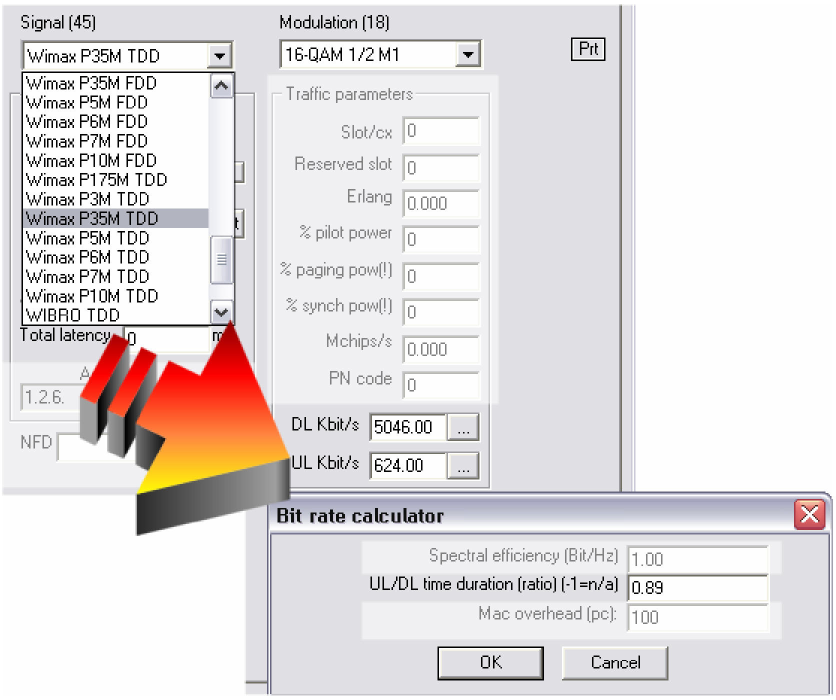
The user can make the choice between TDD or FDD type of equipment. The way the BS throughput is managed is different.

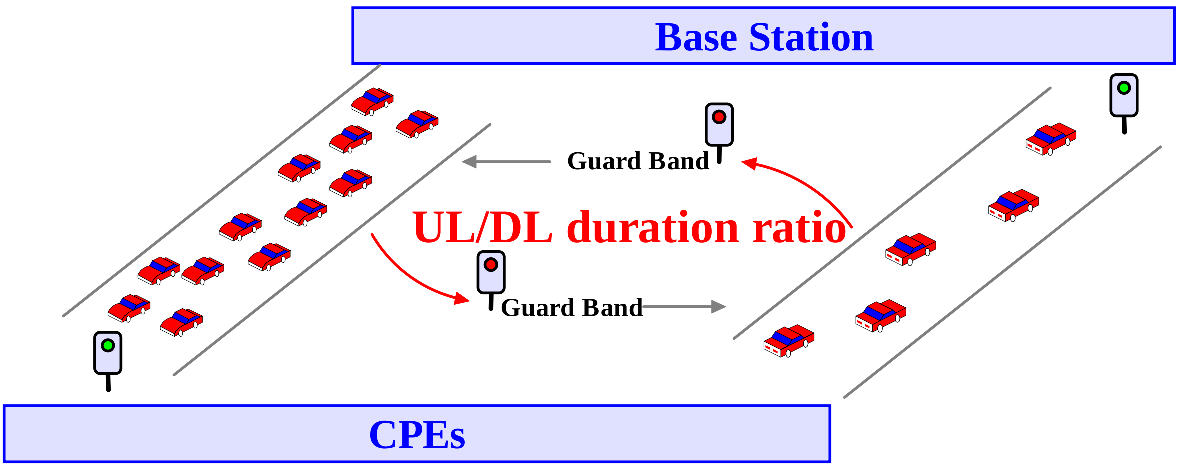
For **FDD systems**, the user can specify one throughput value for the downlink, and one for the uplink.





For **TDD systems**, the throughput is shared between the downlink and the uplink. This sharing is defined an UL/DL duration ratio.



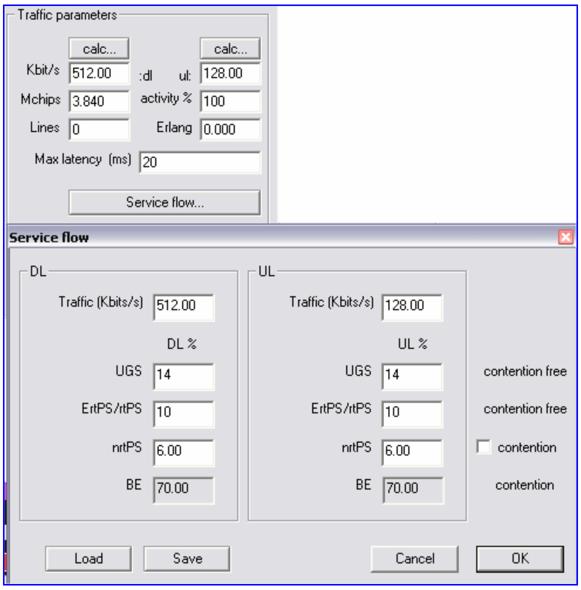


5.2.2.2 Service Flow at the CPE level

Each CPE has its own traffic request, in downlink and in uplink. But the way the traffic request is managed by the BS depends on the type of connection that is used. These types are called **Service Flows** by the NWG of the WiMax Forum©.

QoS category	Applications	QoS specifications
UGS Unsolicited Grand Service	VoIP	Maximum Sustained Rate Maximum latency Tolerance Jitter tolerance
rtPS Real-Time Packet Service	Streaming Audio or Video	Minimum reserved rate Maximum sustained rate Maximum latency tolerance Traffic priority
ErtPS Extended Real-Time Packet Service	Voice with Acitity Detection (VoIP)	Minimum reserved rate Maximum sustained rate Maximum latency tolerance Jitter tolerance Traffic priority
nrtPS Non Real-Time Packet Service	File Transfer Protocol (FTP)	Minimum reserved rate Maximum sustained rate Traffic priority
BE Best-Effort Service	Data transfer, Web Browsing, etc…	Maximum sustained rate Traffic priority

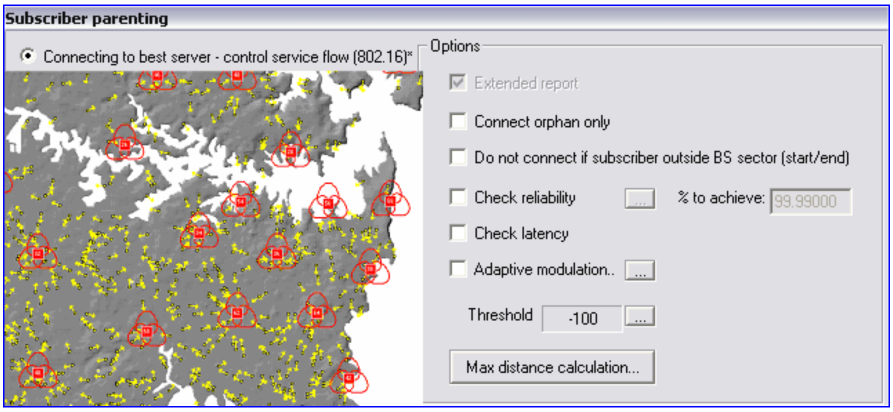
Depending on the customer profile, the user can specify per CPE what is its Service Flow repartition:



Traffic request and Service Flows at the CPE level in ICS telecom

5.2.2.3 The service Flow parenting

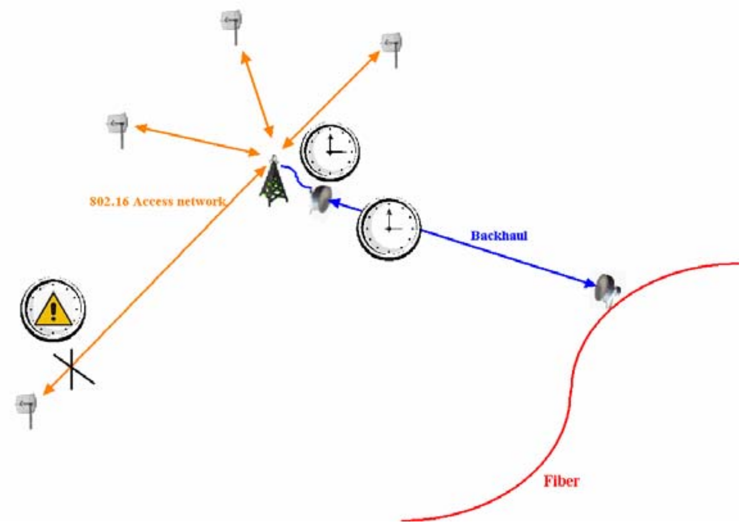
Once the user has defined the available throughput available at the BS level, and the traffic/service flow requests at the CPEs level, a very detailed QoS analysis can be performed.

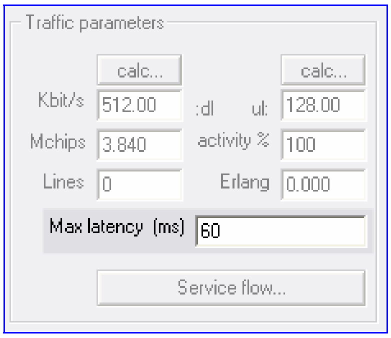


Parenting 802.16 CPEs in ICS telecom

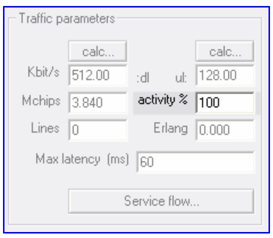
The 802.16 parenting checks:

- The **priorities** between the service flows
- The fact that the service flows might be **contention free** (UGS, rtPS...) or **contention based** (BE)
- The parenting in **DL**, then in **UL**
- The maximum **tolerable latency** between the end user and the source of the signal



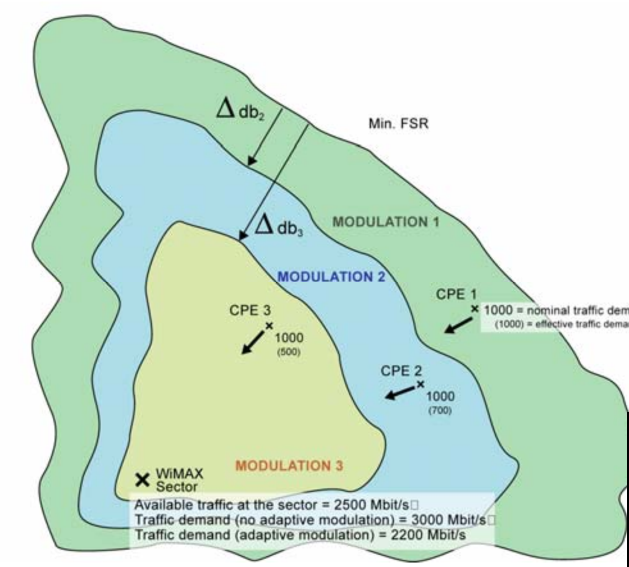


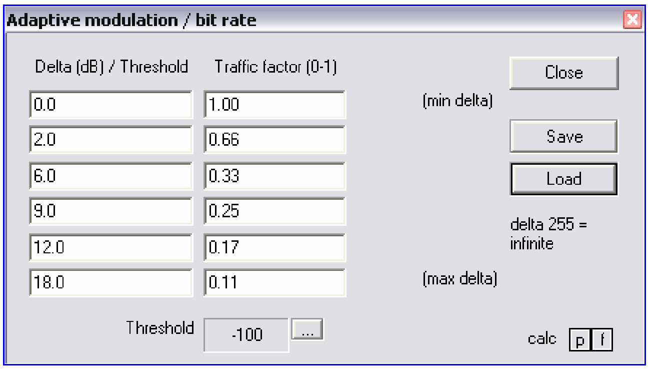
- The **contention ratio** of each CPE



- The **adaptive modulation**

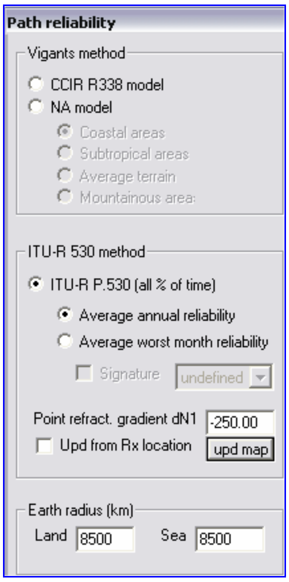
The key parameter for traffic modeling (using adaptive antenna arrays or not) from a planning tool point of view is the bit rate that can be offered for a given received signal level. This characteristic itself depends on the modulation used, hardware algorithms, transmitting and receiving antenna specifications... The user can specify its own traffic parameters according to the power received, it is then straightforward to deal with a large set of scenarios. In addition, ICS telecom also includes features dedicated to adaptive modulation, to offer the maximum bit rate according to the best modulation and the signal level received.





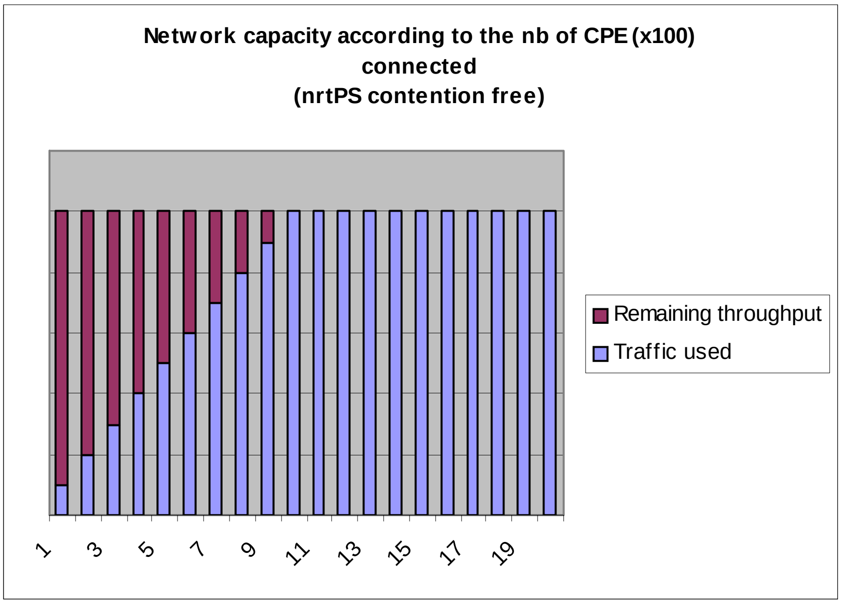
Modulation	Bit rate	Sensitivity [dBm]	dBs above the threshold	Bit rate ratio
BFSK ½	1.41Mbps	-100	0	1
BFSK ¾	2.12Mbps	-98	2	0.66
QPSK ½	2.82Mbps	-97	3	0.5
QPSK ¾	4.23Mbps	-94	6	0.33
QAM16 ½	5.64Mbps	-91	9	0.25
QAM16 ¾	8.47Mbps	-88	12	0.17
QAM64 $^{2}/_{3}$	11.29Mbps	-83	17	0.12
QAM64 ¾	12.71Mbps	-82	18	0.11

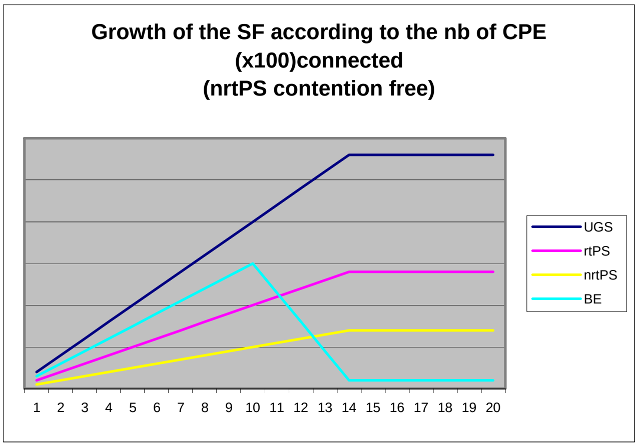
- The **reliability** of each CPE-BS link

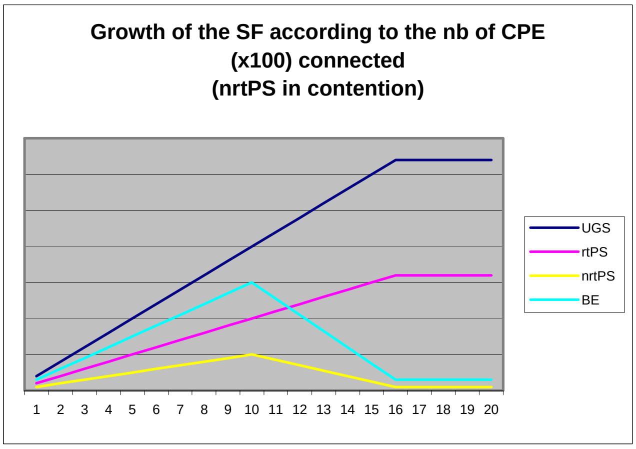


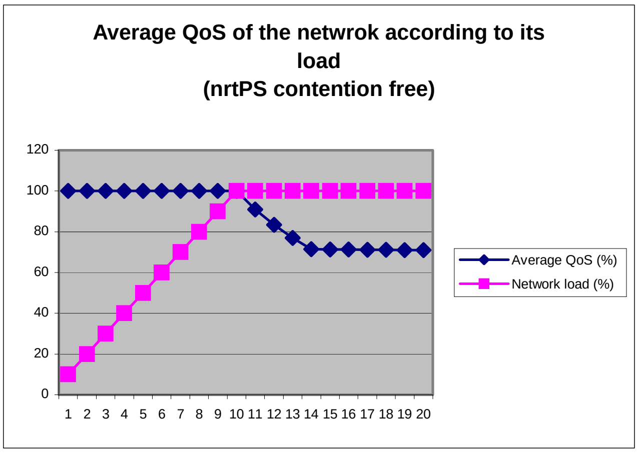
Margin: 10-3: 50.1 dB, 10-6: 45.1 dB (no rain) - PR: -37.87 dBm (rain), -37.87 dBm (no rain) - TD: 0 dB - S(uV): 2862.05
Path reliability multi-path: (10-6) 99.99999 % (0.0526 min/y) - (10-3) 99.99999 % (0.0526 min/y)
Path reliability rain: (10-6) 99.99999 % (0.0703 min/y) - (10-3) 99.99999 % (0.0703 min/y)
Path reliability: (10-6) 99.99998 % - (10-3) 99.99998 % (-41.9 dB needed to expect 99.99000%, EIRP = -21.90 dBW 10-6)
Frequency: 2.20 GHz - Power: 34.0 dBm - Free space loss: 94.7 dB - Diffraction: 0.0 dB - EndToEnd: -63.7 dB
Earth (Km): 8500 (land) 8500 (sea) - Rain (ITU): 0.00 dB (30.00 mm/h) - Gaz/Fog: 0.0000 dB (7.50 g/m3)

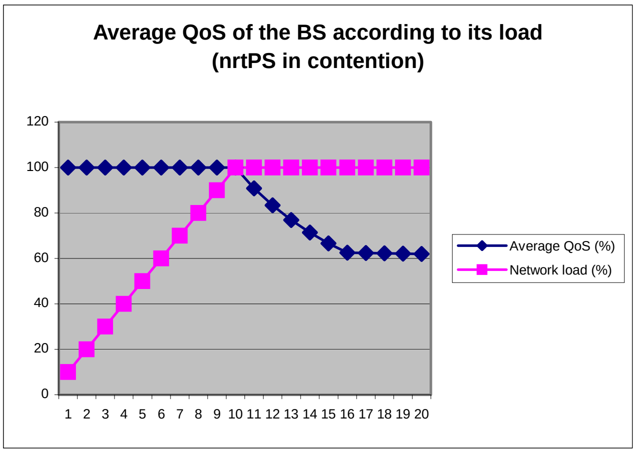
The user can then check the load of the network with regards to the **capacity**:











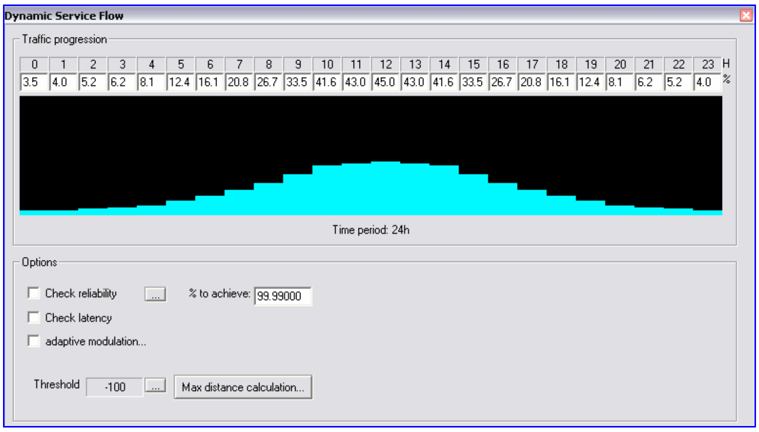
Load of the network with business or game oriented CPEs **Load of the network with web browsing or P2P CPEs**

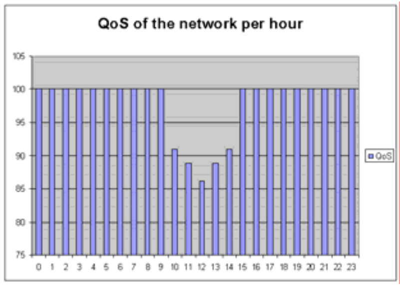
Identification of the saturation in capacity of the WiMAX network, according to different usage profiles

5.2.3 QoS curve according to the contention ratio

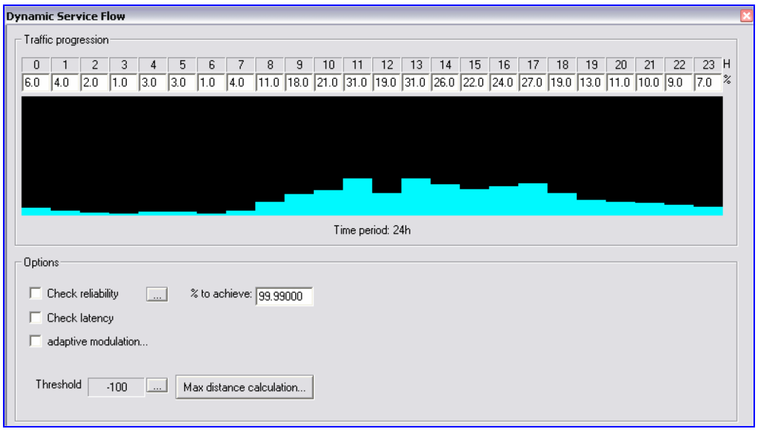
The QoS of the network also varies according to the time of the journey. Each customer does not use its connection in the same time of the day. **The contention ratio of the WiMAX connection can be setup individually, or on a 24 hours basis.**

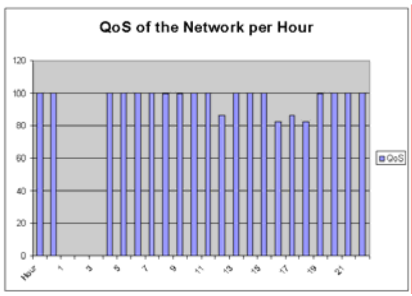
Business profile





Consumer profile





QoS of the WiMAX network according to the time of the journey and the variation of the contention ratio

6 WiMAX Spectrum analysis

6.1 FWA-type analysis

6.1.1 Coverage mode

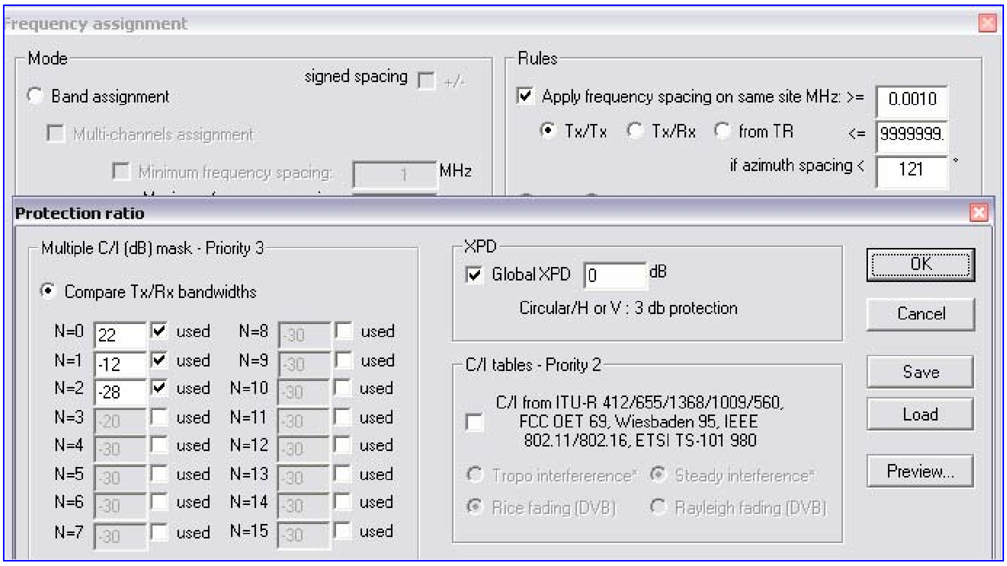
Fixed Wireless Access type of networks must be configured in order to lower as much as possible the interference cases between the sectors of the network. In order to so, the **protection ratios** according to co-channel or adjacent channel unwanted signals must be known. The interference generated might decrease the C/N ratio.

6.1.1.1 Frequency allocation

Based upon the allocated spectrum, the user can ask ICS telecom to automatically find the best frequency plan that would be used by the BS.

When the connection is made with the highest modulation, the receiver is the most sensible; it therefore advised to use the worst case scenario when the frequencies are assigned by ICS telecom.

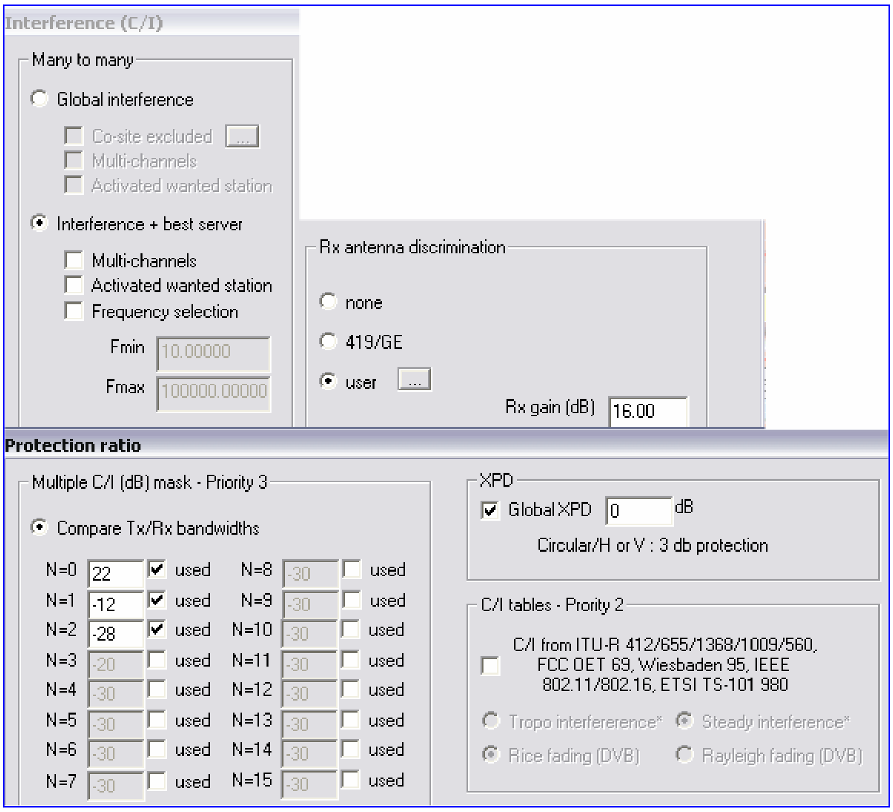
Modulation	Code rate	Cochannel Interfrence Sensitivity BW 3.5 MHz	Adjacent channel Interfrence Sensitivity BW 3.5 MHz	N+2 channel interfrence sensitivity 3.5 MHz BW
BFSK	1/2	4	-30	-46
	3/4	6	-28	-44
QPSK	1/2	7	-27	-43
	3/4	10	-24	-40
16QAM	1/2	12	-22	-38
	3/4	16	-18	-34
64QAM	2/3	21	-13	-29
	3/4	22	-12	-28

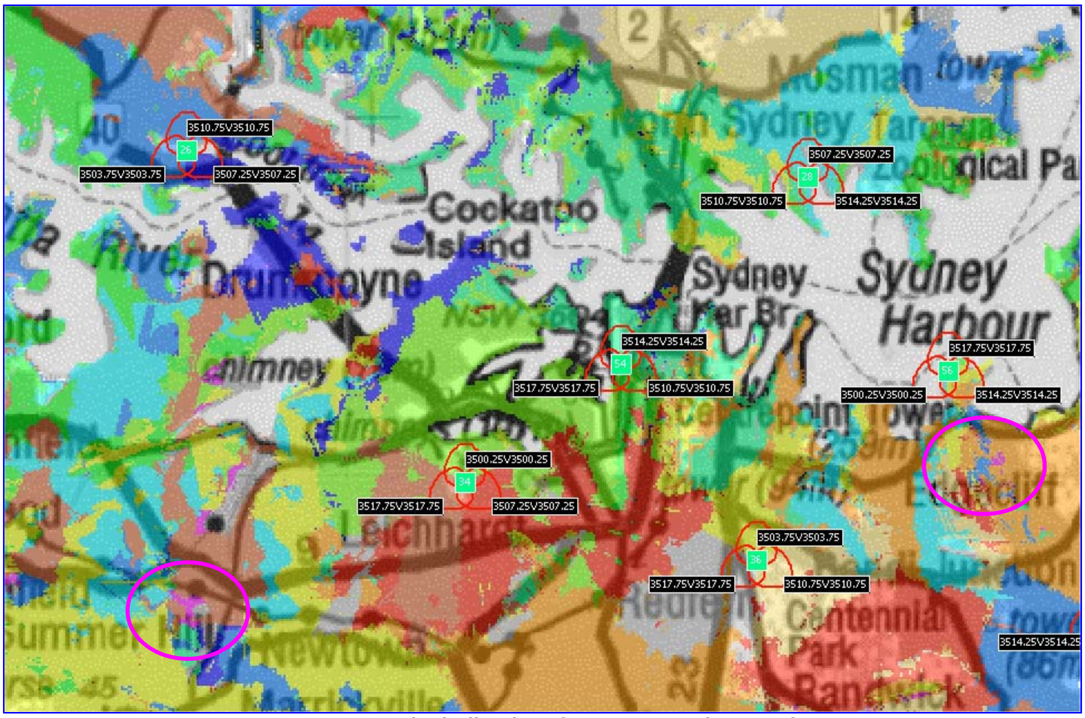


Frequency assignment engine in ICS telecom

6.1.1.2 Interference calculation and resulting traffic map

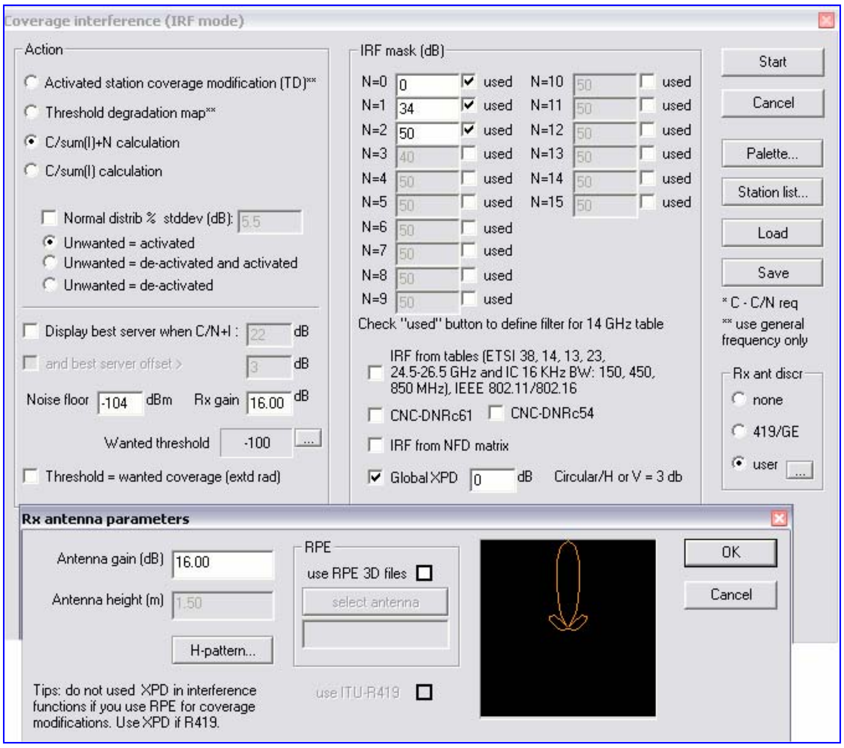
The calculation can be launched on a best RSSI basis, highlighting for each covered location the best non-interfered sector, or the pink color, meaning that all potential servers interfere one with each other.

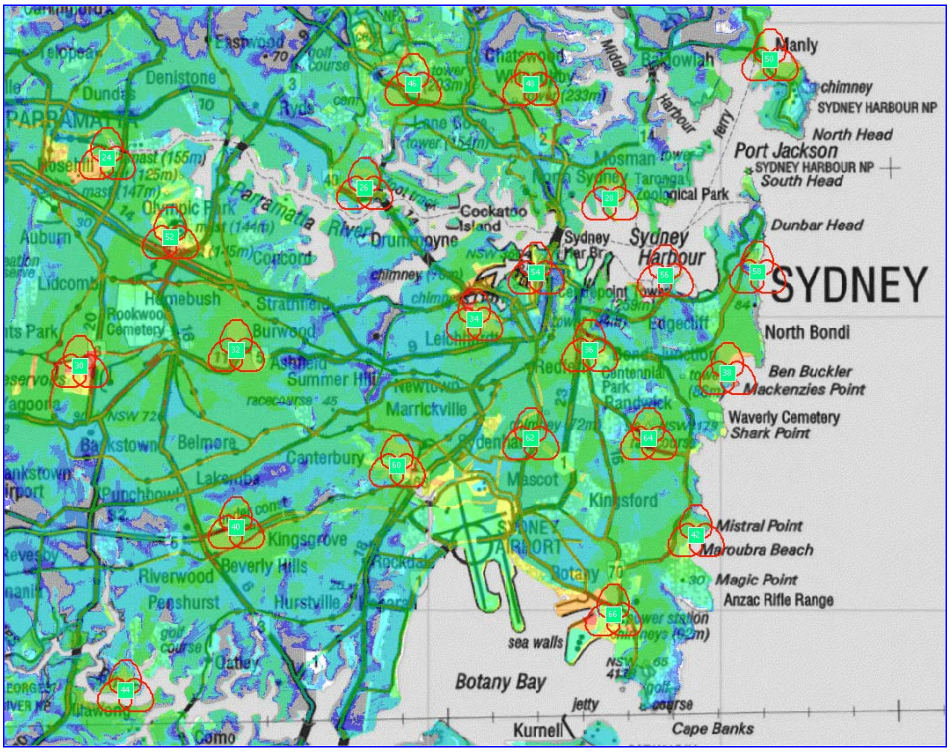




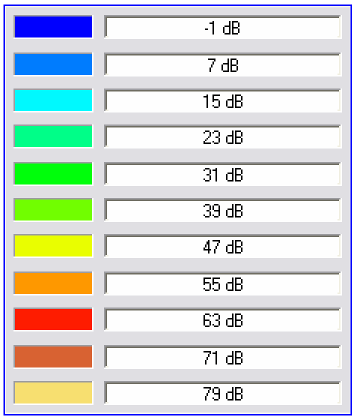
Best server map, including interference cases in ICS telecom

ICS telecom can also display a SNR map, based upon the rejection filter. Here below an example of a SNR map in C/sum(I) + N mode, using a Noise Floor of –104 dBm, a 1st channel attenuation of 34 dB, and a second channel attenuation of 50 dB, and an directive Rx pattern with 16 dBi gain.

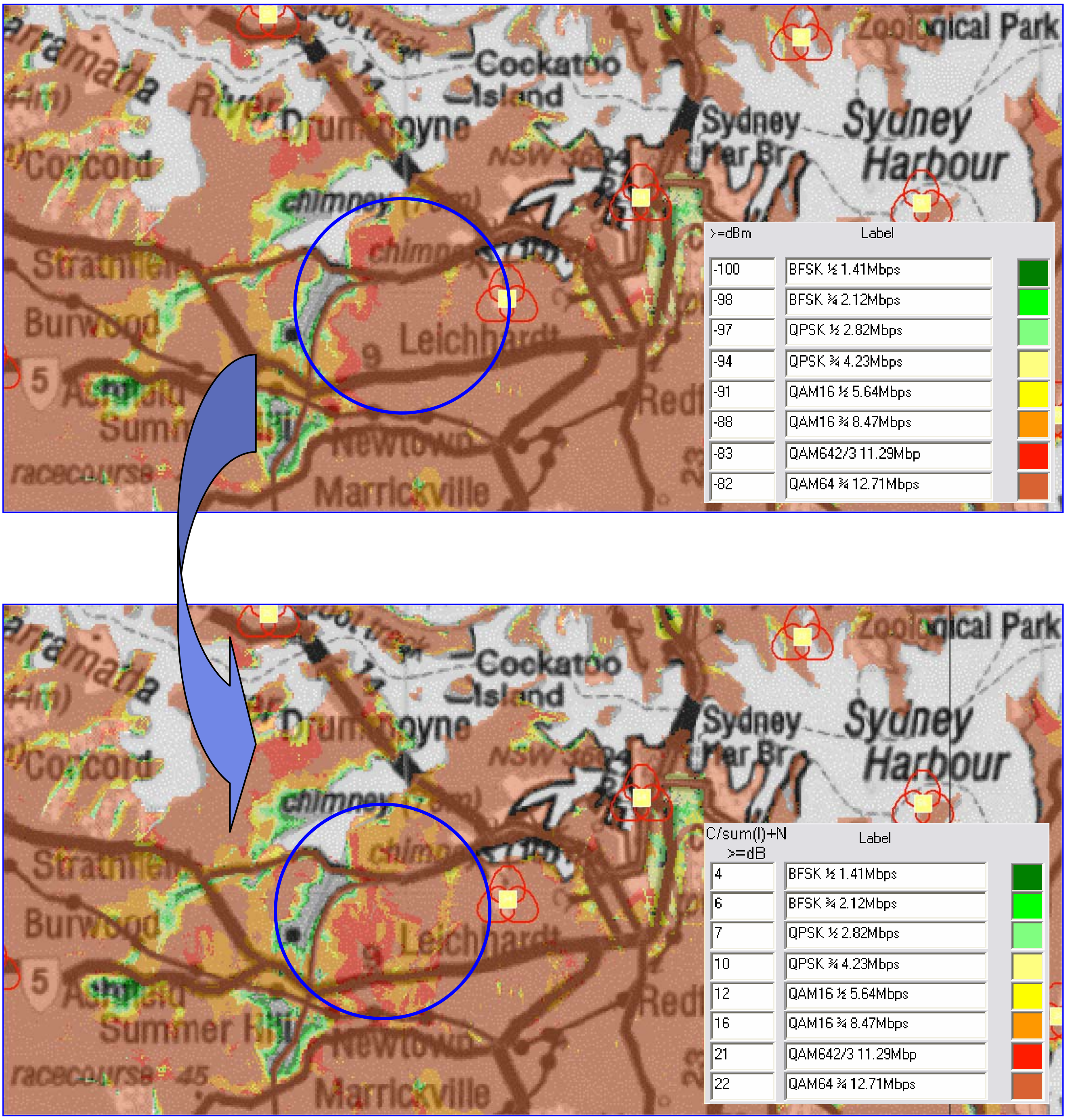




Signal to Noise ratio map (in C/sum(I)+n mode) of a WiMAX network in ICS telecom



This map can be used in order to update the original traffic map with a new traffic map, taking not only the power received into account, but also the C/N ratio.

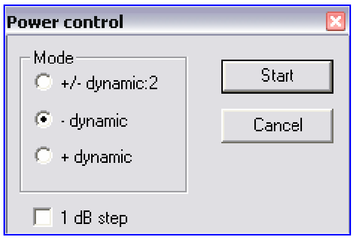


Traffic map according to the SNR in ICS telecom

6.1.2 PMP interference

6.1.2.1 Power control

To improve the overall performance of the system. The transmitted power of the CPEs is regulated so that the power received at the base station is at a predetermined level. ICS telecom adjusts the uplink radiated power at the CPE side, thereby limiting cases of interference.

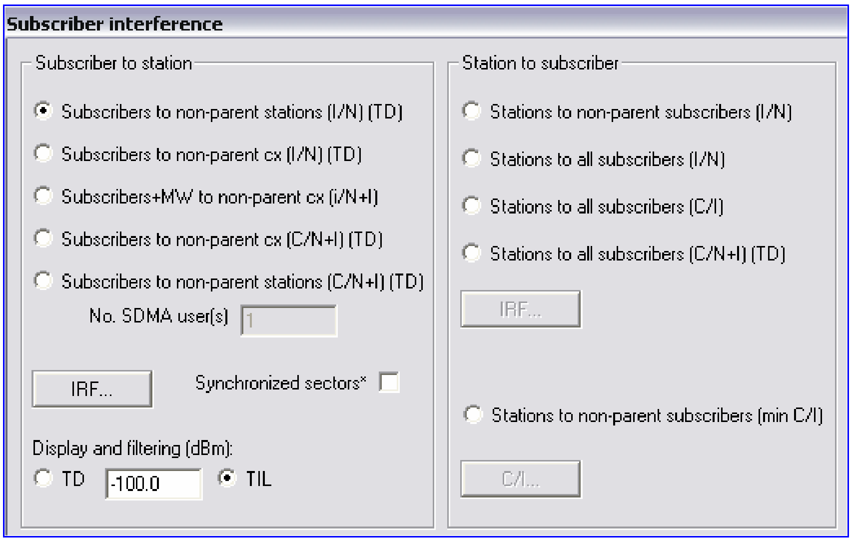


6.1.2.2 UL/DL interference

ICS telecom features an interference calculation engine specially dedicated to the Point to Point connections that allow an easy analysis for uplink and downlink interference cases.

This could be useful for non-synchronized TDD systems, or FDD systems, where the CPEs can raise the noise floor of the BS they are non-parented to (or the other way).

SDMA systems uplink interference can be managed by specifying the maximum number of terminals that can be simultaneously connected to a given BS.

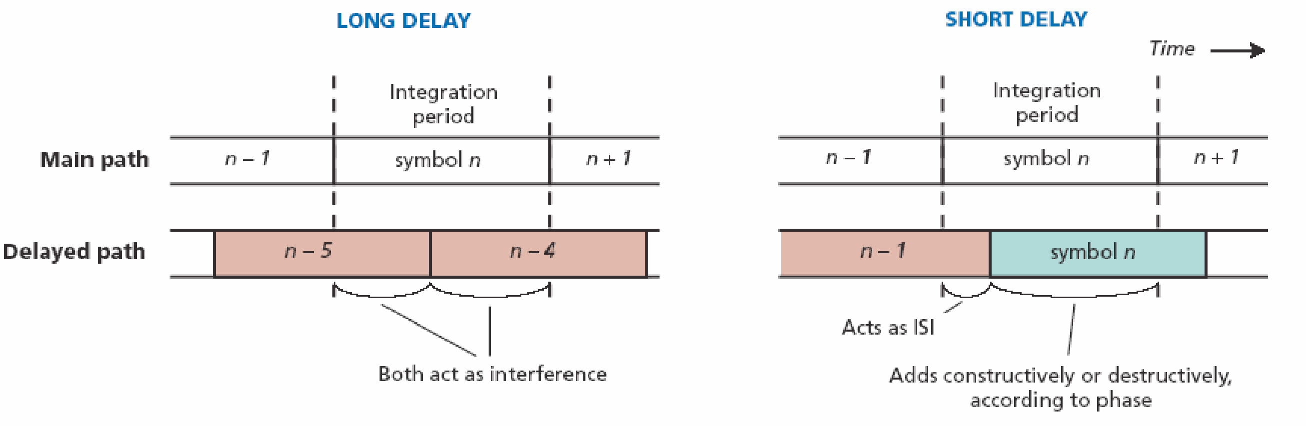


7 Mobility analysis

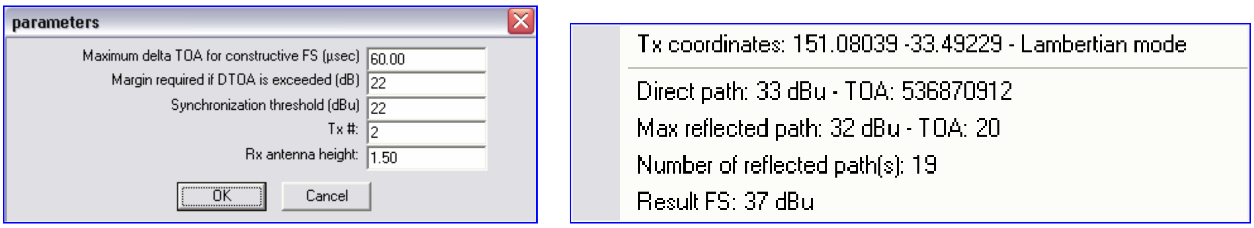
ICS telecom features various functions in order to manage the upcoming WiMax mobility.

7.1 Delay spread

Orthogonal Frequency Division Multiplexing (OFDM) is a multiplexing technique that subdivides the bandwidth into multiple frequency sub-carriers. In an OFDM system, the input data stream is divided into several parallel sub-streams of reduced data rate (thus increased symbol duration) and each sub-stream is modulated and transmitted on a separate orthogonal sub-carrier. The increased symbol duration improves the robustness of OFDM to delay spread. Furthermore, the introduction of the cyclic prefix (CP) can completely eliminate Inter-Symbol Interference (ISI) as long as the CP duration is longer than the channel delay spread (source: WiMAX Forum©).



ICS telecom’s OFDM parameters box for simulating multipath reflection can also highlight the cases where the signal is damaged due to the reflected signal being greater (by a user-defined margin in dB) than the direct path threshold and with a ToA outside of the OFDM receiver Guard interval:



Constructive and Destructive OFDM signals in ICS telecom

7.2 Hand-over maps

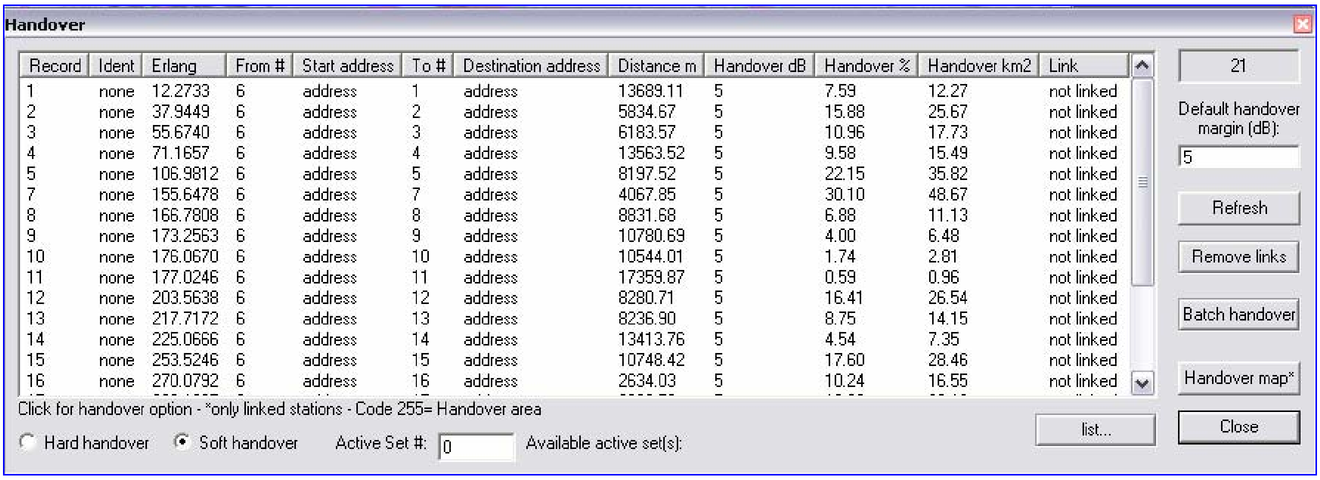
ICS telecom manages the display of handover maps.

7.2.1 Fast Base Station Switching

When the Fast Base Station Switching (FBSS) is supported, the MS and BS maintain a list of BSs that are involved in FBSS with the MS. This set is called an Active Set. In FBSS, the MS continuously monitors the base stations in the Active Set. Among the BSs in the Active Set, an Anchor BS is defined. When operating in FBSS, the MS only communicates with the Anchor BS for uplink and downlink messages including management and traffic connections. Transition from one Anchor BS to another (i.e. BS switching) is performed without invocation of explicit HO signaling messages.

7.2.1.1 List of neighbors

If it is not already known by the mobile operator, the use can locate BS per BS with what other BS it could be a neighbor.

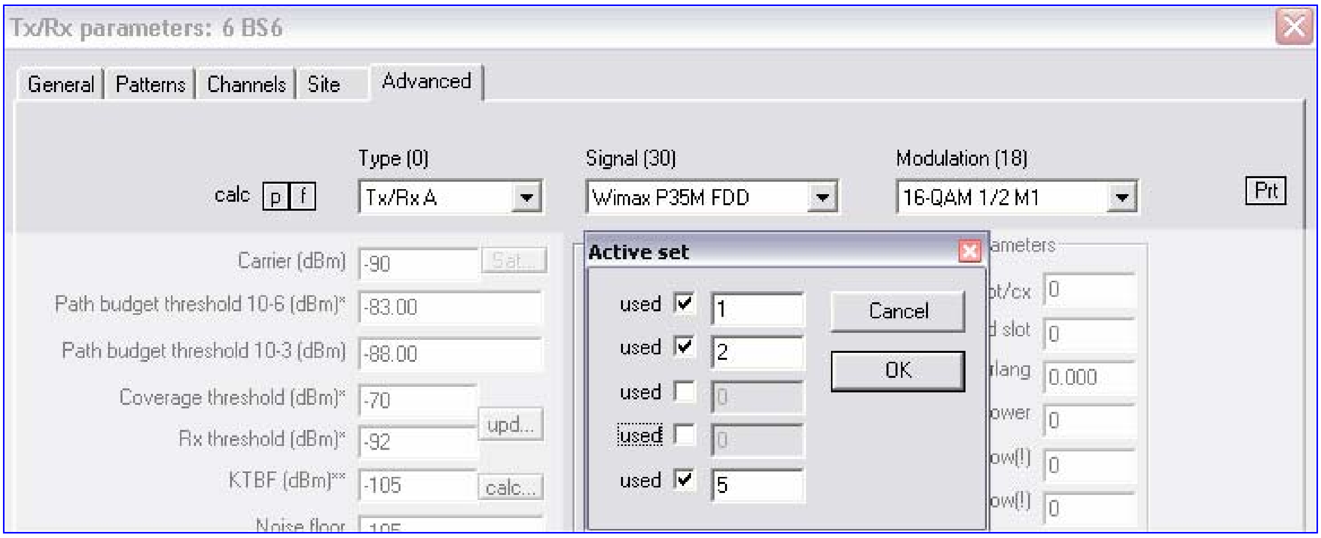


Record	Ident	Erlang	From #	Start address	To #	Destination address	Distance m	Handover dB	Handover %	Handover km2	Link
1	none	12.2733	6	address	1	address	13689.11	5	7.59	12.27	not linked
2	none	37.9449	6	address	2	address	5834.67	5	15.88	25.67	not linked
3	none	55.6740	6	address	3	address	6183.57	5	10.96	17.73	not linked
4	none	71.1657	6	address	4	address	13563.52	5	9.58	15.49	not linked
5	none	106.9812	6	address	5	address	8197.52	5	22.15	35.82	not linked
7	none	155.6478	6	address	7	address	4067.85	5	30.10	48.67	not linked
8	none	166.7808	6	address	8	address	8831.68	5	6.88	11.13	not linked
9	none	173.2563	6	address	9	address	10780.69	5	4.00	6.48	not linked
10	none	176.0670	6	address	10	address	10544.01	5	1.74	2.81	not linked
11	none	177.0246	6	address	11	address	17359.87	5	0.59	0.96	not linked
12	none	203.5638	6	address	12	address	8280.71	5	16.41	26.54	not linked
13	none	217.7172	6	address	13	address	8236.90	5	8.75	14.15	not linked
14	none	225.0666	6	address	14	address	13413.76	5	4.54	7.35	not linked
15	none	253.5246	6	address	15	address	10748.42	5	17.60	28.46	not linked
16	none	270.0792	6	address	16	address	2634.03	5	10.24	16.55	not linked

Highlighting the neighbours of the Base Station in order to define the Active Sets

7.2.1.2 Active set allocation

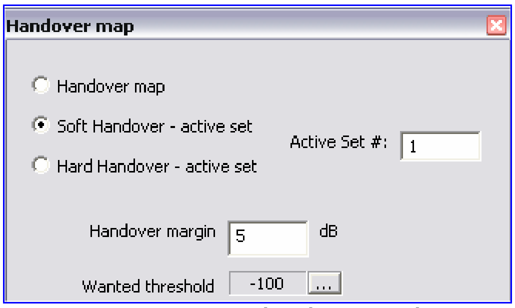
The radio-planner can specify for each BS the active set(s) it is belonging to:

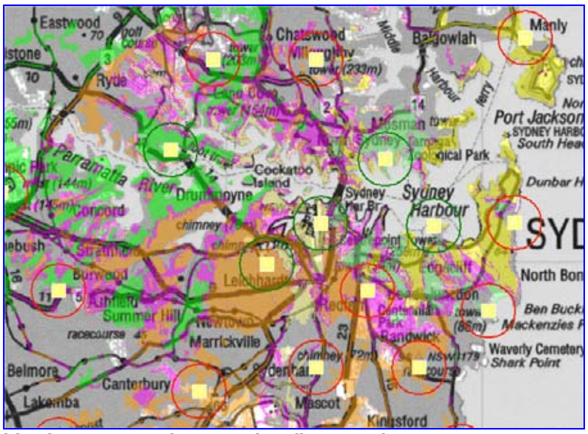


Definition of the active sets each BS belongs to in ICS telecom

7.2.1.3 FSBB handover map within the same active set

The user can specify the active set to be analyzed. By specifying the soft handover mode, ICS telecom will highlight the areas where an FSBB handover can occur. These areas are highlighted in pink in the picture below, otherwise ICS telecom will give the best server site color.

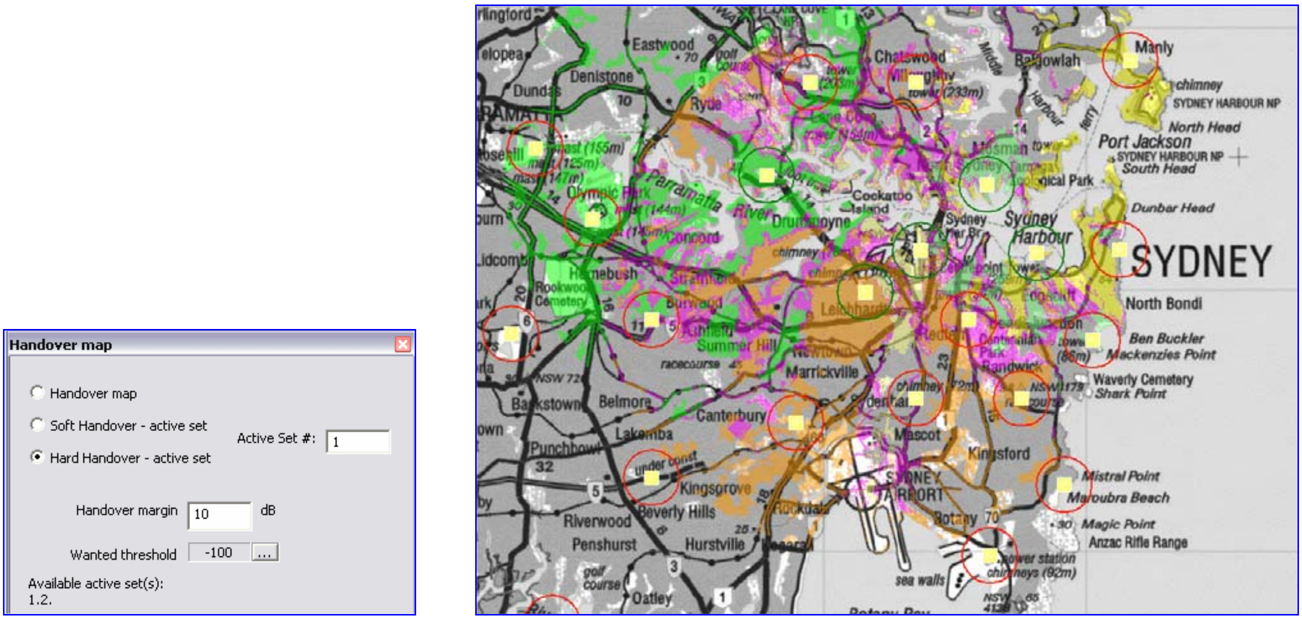




FSBB handover map between stations defined in the same active set nb 1 (in green)

7.2.2 Hard handover

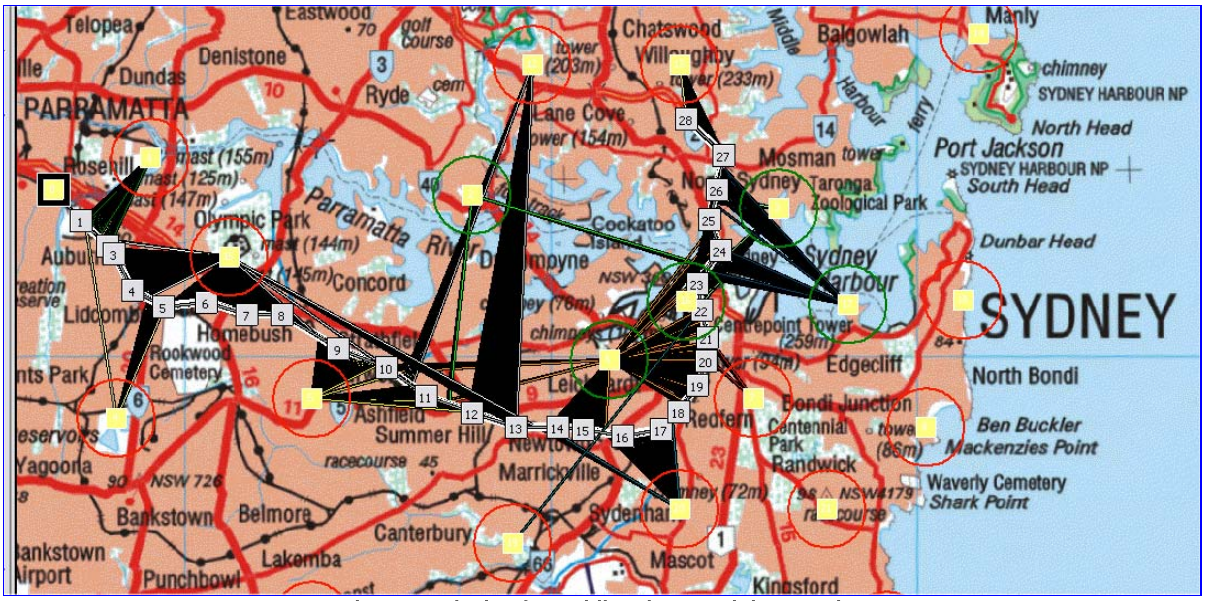
When the Mobile WiMAX unit will switch from one active set area to another, it performs what is called a hard handover. ICS telecom can display where the mobile anchored to a specific active set will have to hard hand off to another one.



HHO map of a mobile anchored to Active set 1 to any other active set

7.3 Hand-over along a mobile path

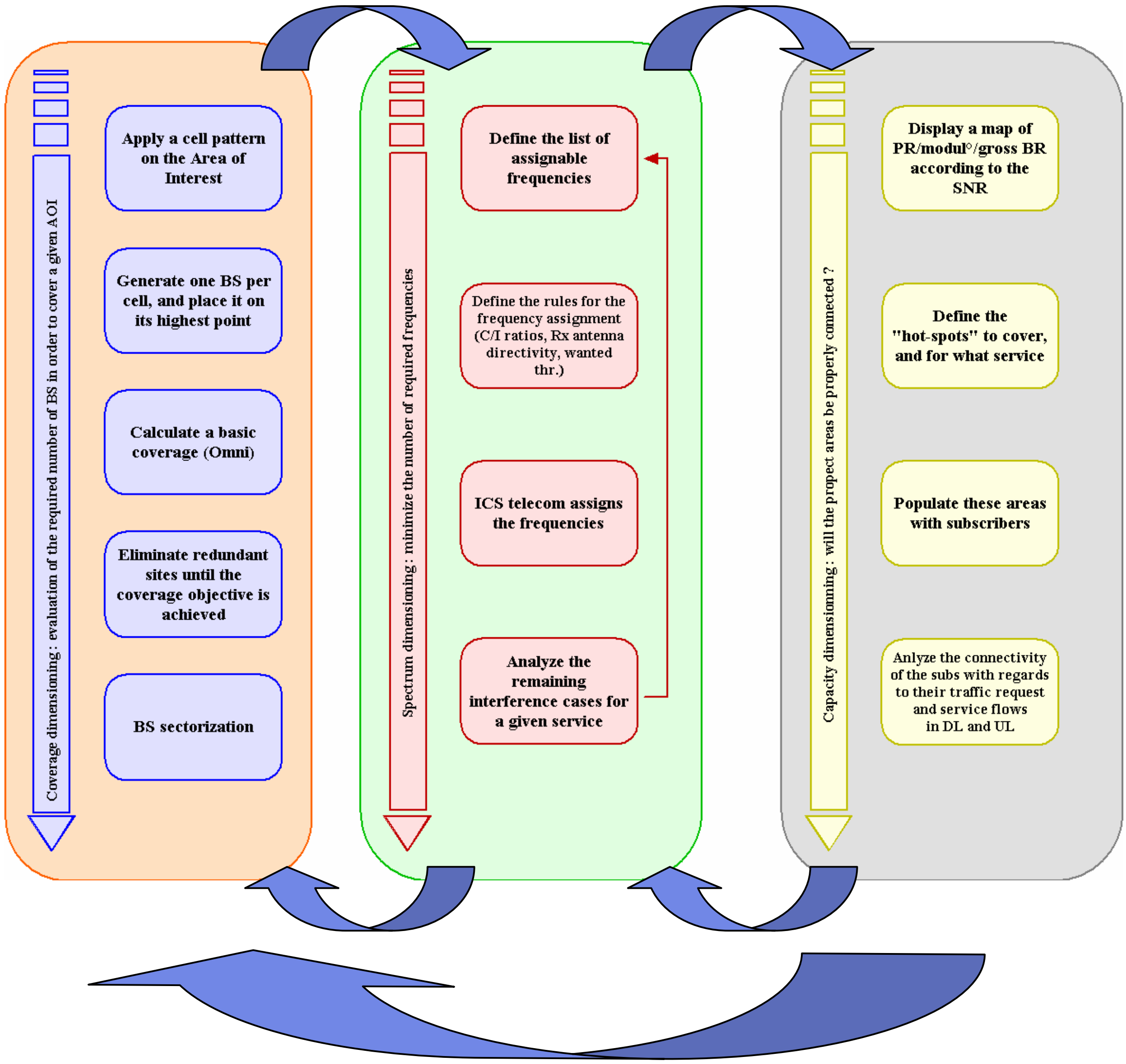
If the radio planner is more particularly interested into a mobile path, a dedicated hand over analysis can be performed, in UL or in DL.



Hand over analysis of a mobile WiMAX unit in ICS telecom

8 WiMAX radio-planning: a workflow with ICS telecom

WiMAX radio-planning is an iterative process. A first start would be to select the **best location**s for the Base stations (Phase 1), in order to minimize the **spectrum required** (Phase 2). If the interference areas are too large, or if the SNR map highlights a high decrease of bandwidth, the network itself might have to be optimized from Phase 1 again. What's more, guaranteeing coverage without interference does not close the planning process: the capacity of the designed network needs indeed to be checked, in order to foresee a **potential saturation of the network** (Phase 3). If so, the network might have to be densified, generating therefore additional potential interference (Phase 2). Radio-planning is mean of iteration between these 3 phases, in order to achieve a good balance between them.



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