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Planning a WiMAX network
with ICS telecom nG

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ATDI is a member of the WiMAX Forum



Abstract

This document presents the WiMAX network planning capabilities of **ICS Telecom nG**.

The IEEE 802.16 standard is under continuous development within the WiMAX forum. Three different kinds of networks are outlined:

- WiMAX for backhauling solution
- Fixed Wireless Access type of WiMAX
- WiMAX for mobile purposes

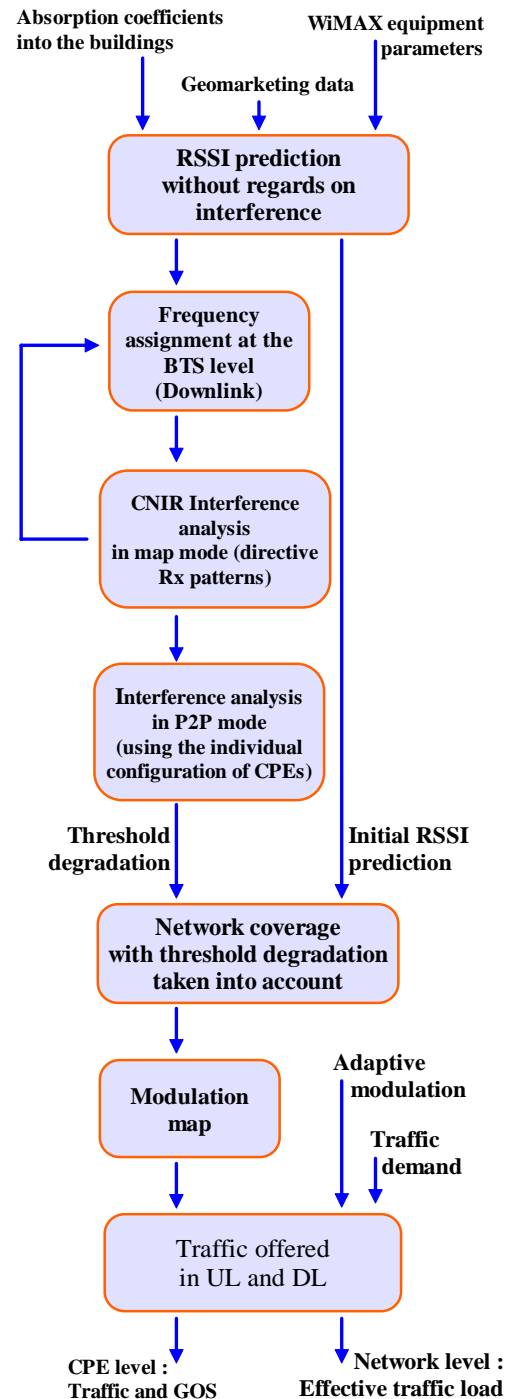


Dedicated propagation models, specially the new Outdoor/Indoor model, enable accurate coverage and traffic analysis. LOS, NLOS and nLOS situations can be simulated in wide and close range environment.

The technology behind WiMAX is optimized to provide excellent Non Line Of Sight coverage (NLOS). ICS telecom nG includes therefore dedicated WiMAX simulation capabilities, such as:

- OFDM compliancy
- Integration of the Uplink./Downlink asymmetry
- Integration of directive radiation patterns, at the BTS (sectorization) and at the CPE level. If needed, the behaviour of smart antennas can be taken into account
- Power control
- Adaptive modulation

WiMAX simulation in ICS telecom nG also includes interference analysis and frequency assignment for spectrum optimization.



References

- WiMAX Forum: "WiMAX's technology LOS and NLOS environments"
- Sam W. Ho (Intel®): "Adaptive modulation (QPSK, QAM)"
- MCI®: "WiMAX overview and MCI perspective"
- WiMAX Forum: "IEEE 802.16a Standard and WiMAX Igniting Broadband Wireless Access"



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1. WiMAX consideration in ICS telecom nG

1.1 What is WiMAX ?

The term WiMAX (Worldwide Interoperability for Microwave Access) has become synonymous with the IEEE 802.16 Wireless Metropolitan Area Network (MAN) air interface standard. Amendments to the original release have extended the 802.16 air interface standard to cover non-line of sight (NLOS) applications in licensed and unlicensed bands in the sub 11 GHz frequency range. This standard is designed as a wireless 'last-mile' technology to support fixed residential and business customers. It is especially valuable to those customers for whom cable-modem networks and DSL are not available.

Initial WiMAX profiles are a subset of the **802.16-REVd** standard, a modified version of the original 802.16a. A mobile extension to the low-frequency 802.16 standard is being developed by the IEEE **802.16e** working group. This extension will support delivery of broadband data to a moving wireless terminal, such as a laptop computer with an integrated WiMAX modem being used by a passenger on a commuter train. The WiMAX Forum expects to endorse a mobile profile following completion of the 802.16e standard.

	2004	2005	2006
Deployment Type / Usage Model	Outdoor install Fixed wireless broadband	Indoor install Fixed wireless broadband Portability for nomadic wireless broadband NO roaming across Service Providers	Higher speed support Roaming Higher level network support
Standards Mapping	(802.16a) / 802.16REVd	802.16REVd - 802.16e	802.16e
OEMs, TEMs & Carriers	BWA Equipment Carriers & WISPs emerging and developing low population markets	BWA Equipment Mfrs Larger Telecom Equipment Mfrs (infrastructure) Major carriers in all geos	

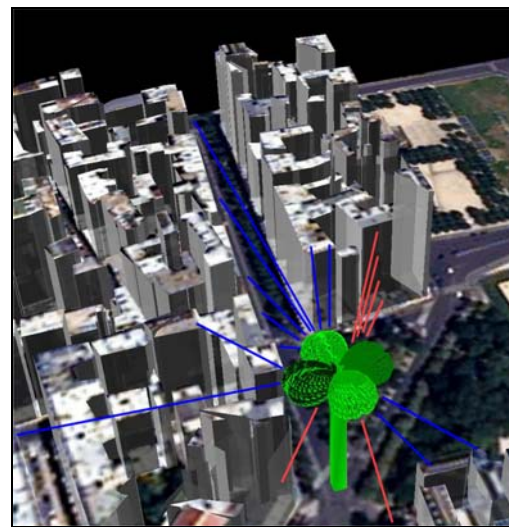
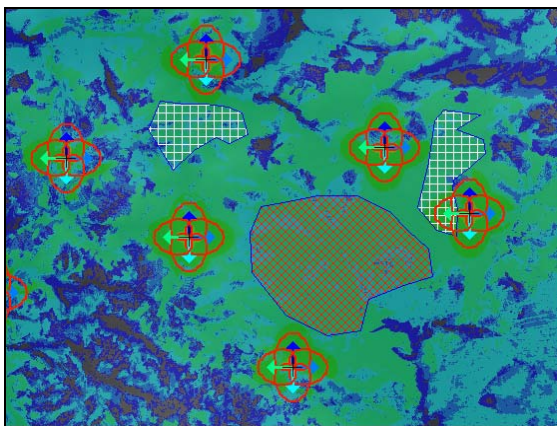
1.2 Selecting a planning process

The type of WiMAX network design in ICS telecom nG depends on several parameters. Among them can be outlined the phase of the WiMAX life cycle that needs to be simulated, the type of cartography available or that can be afforded, and the kind of outputs that are targeted at the end of the planning process. All these topics are linked one to each other, the planner needs to choose its engineering process according to:

- The time that needs to be spent on the project
- The quality of the result to be obtained



A wide range WiMAX network planning (e.g. over an entire province) gives a rough idea of the number of BTSs to deploy in order to achieve a coverage goal. Medium resolution cartography can be used here, mainly for a question of time processing. Close range analysis (detailed LOS/nLOS/NLOS propagation in high resolution urban environment) raises the simulation accuracy up to the analysis per CPE of its coverage, its achievable Grade of Service, and its uplink and downlink traffic.



**Wide range WiMAX planning (above)
Microcell WiMAX urban planning (right)
with ICS telecom nG**

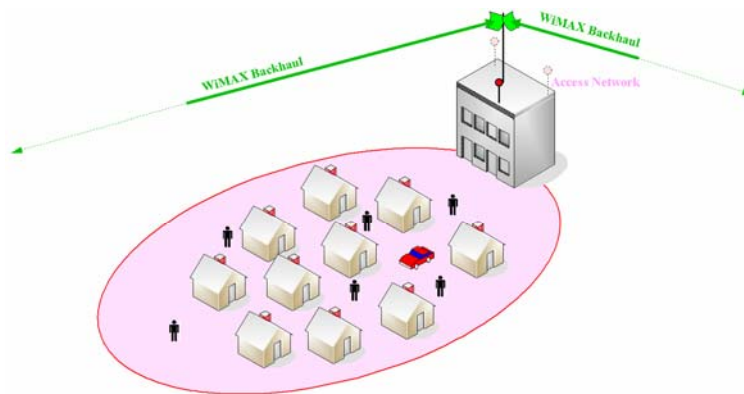
	PRE-DEPLOYMENT		DEPLOYMENT
Area Planned	Wide Range (Province...)	Close Range (City)	Close range (City)
Type of planning	ROUGH		DETAILED
Expected output	Estimating the number of BTSs needed to cover a wide area Estimating the required frequency range to avoid major interference cases Basic traffic analysis Regional CAPEX, global business model	Refining the rough analysis Improving the quality of the reporting CAPEX at the BTS level	Indoor/Outdoor analysis LOS/nLOS/NLOS analysis Diffusion effect into the buildings Detailed frequency assignment and analysis Traffic analysis at CPE level Investment return
Topographic and geomarketing data input	30/50m cartographic database Urban areas defined as clutter codes (approx 3 classes)	10/30m cartographic database Building block defined as clutter codes (approx 6 classes) Dimensioning according to basic geomarketing data	High Resolution data (<5m), incl. building heights Absorption coefficient per building type Fine tuning of the dimensioning based on high class geomarketing data and operating feedback



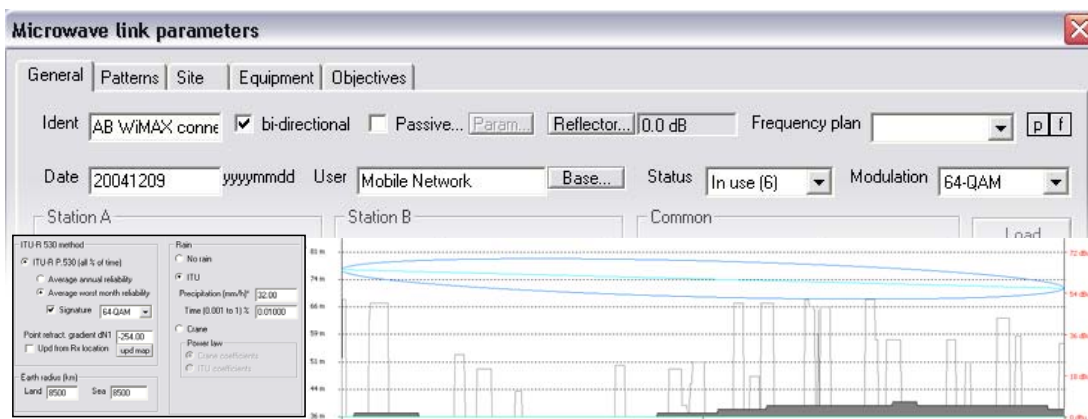
1.3 Different kinds of WiMAX

1.3.1 Backhauling solution

The use of point-to-point microwave is prevalent for mobile backhaul. However WiMAX can enable mobile operators to cost-effectively increase backhaul capacity using WiMAX as an overlay network. A typical example would be a mixed network between WiMAX, used for the backbone, and WiFi hotspots for the access.



In ICS telecom nG, the WiMAX equipment can be setup as a standard Point-to-Point network, enabling path budgets calculations and reliability margins evaluations.



WiMAX Point to Point connection in ICS telecom nG

1.3.2 Access type

Nomadic or portable operation, synonymous with Metrozone, is an enhancement over basic fixed indoor/outdoor operation **enabling access from multiple network access points but without seamless mobility.**

ICS Telecom nG features calculation engines for:

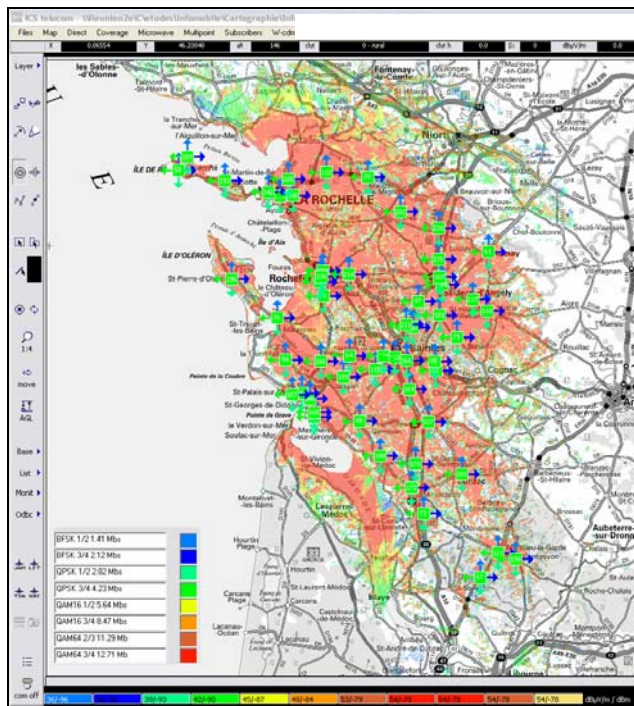
- Wide range analysis
- Close range analysis with outdoor receivers



- Close range analysis with indoor receivers

1.3.2.1 Wide range analysis

In that case, the network design is based upon large scale, medium resolution cartography.



Clutter code	Name	Attenuation (dB)	Clutter height ²	
0	rural	0.0	0	<input checked="" type="checkbox"/> rx ground
1	suburban	0.0	6	<input type="checkbox"/> rx ground
2	urban 8 m	0.0	8	<input type="checkbox"/> rx ground
3	urban 15 m	0.0	15	<input type="checkbox"/> rx ground
4	urban 30 m	0.0	30	<input type="checkbox"/> rx ground
5	forest	0.0	12	<input checked="" type="checkbox"/> rx ground
6	hydro	0.0	0	<input type="checkbox"/> rx ground
7	urban 50 m	0.0	50	<input type="checkbox"/> rx ground
8	wood	0.0	4	<input checked="" type="checkbox"/> rx ground
9	road	0.0	0	<input checked="" type="checkbox"/> rx ground

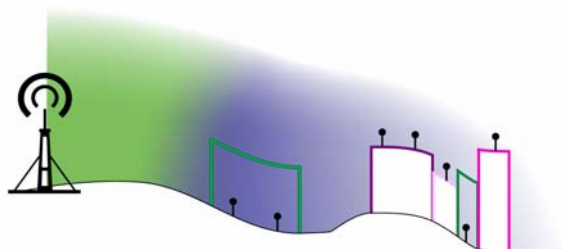
Rx over clutter Tx over clutter
 Rx over ground spot defined altitude
 Rx over ground relaxed

Clutter height factor: 1.0
Reference frequency (MHz): 3500.00000

Characterisation of the clutter code (e.g. receiver within or above the clutter)

Wide range WiMax network in ICS telecom nG

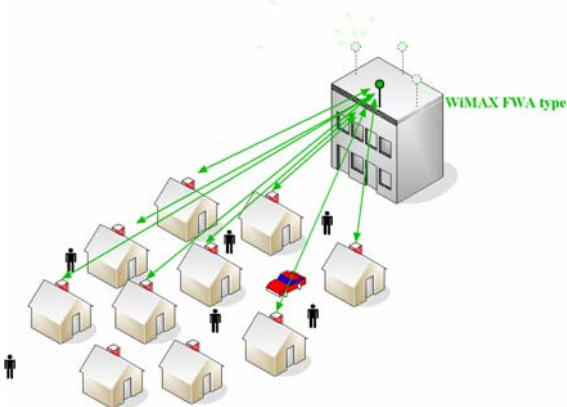
The ground occupancy is defined by a clutter layer, which characteristics (height, attenuation, etc) can be defined clutter class per clutter class. Each receiver is placed either above or within the clutter.



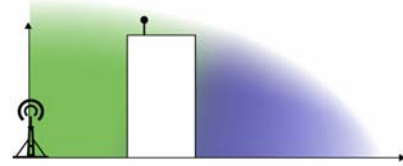
Macro cell WIMAX network design: placing the receiver above or within the clutter (green: vegetation, purple: urban clutter)

1.3.2.2 Close range analysis, with outdoor receiver antennas

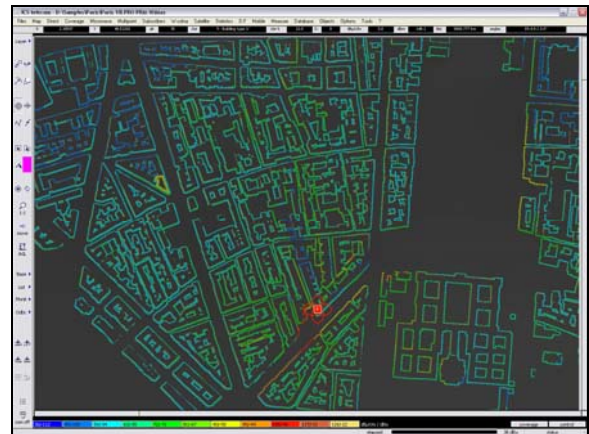
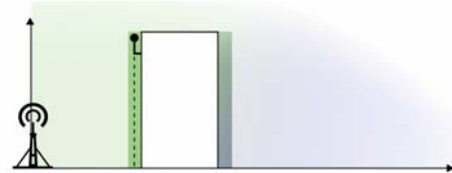
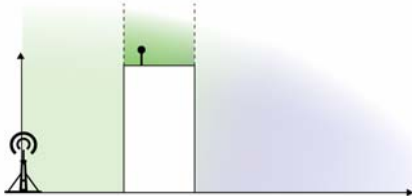
In that case, high resolution cartographic data (meaning including buildings heights) needs to be defined in the ICS telecom nG project. According to the location of the receiving antennas (above rooftops or on the building side), the field strength calculation will be filtered on the rooftops or on the outline of the buildings.



Scheme of a WiMax Access Network

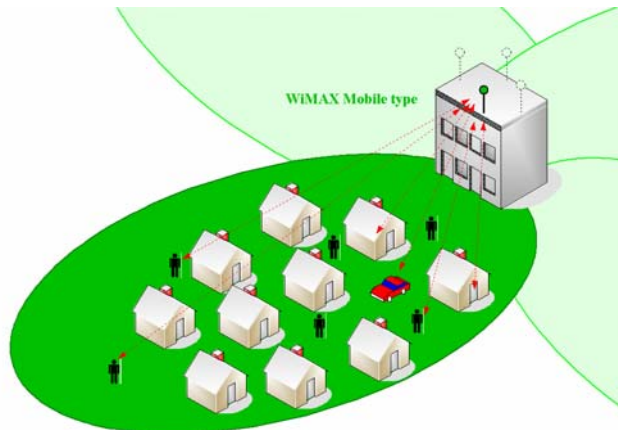


Field strength calculation principle in ICS Telecom nG



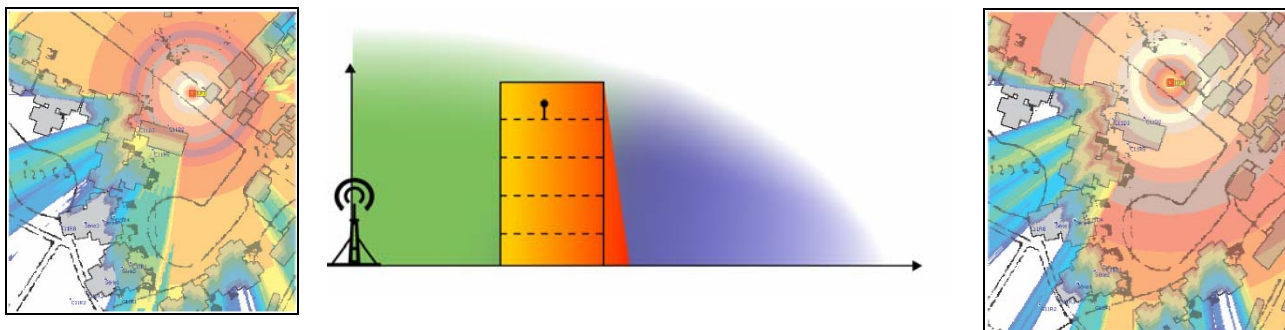
WiMAX access network in ICS telecom nG: receiving antennas above rooftops (left) or on façade(right)

1.3.2.3 Close range analysis, with outdoor/indoor Receivers





In that case, a mixed propagation model is applied, in order to calculate the field strength received by a CPE located either in outdoor or indoor environment. This will be explained in chapter 2.2.2.

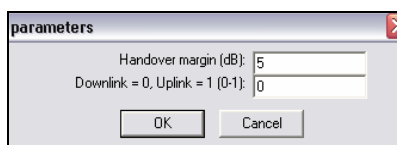
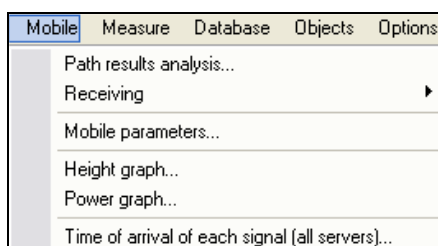


Simulations in ICS telecom nG using the mixed indoor/outdoor model
Left: simulation with a CPE height at 1.5m above ground level
Right: simulation with a CPE height at 20m above ground level

1.4 Mobility specificities

Support low packet loss handovers and handover latencies for applications such as near toll-quality VoIP. In that case the receiver can be located wherever on the map, in Outdoor or indoor.

In addition to all types of analysis listed above, ICS telecom nG features dedicated modules for mobile networks: Receiving signals along a mobile path, Handover analysis, in Uplink or downlink, Time of arrival, ...



Examples of dedicated analysis of mobile networks in ICS Telecom nG

To summarize, **802.16d**-type of equipment can be modelled thanks to the Point to Point and Point to Multi-point engines. Static and nomadic terminals can be considered as FWA-type terminals, simulated in ICS telecom nG using directional antennas, individual CPE parameters, adaptive modulation...

802.16e can be simulated using the coverage mode. Furthermore, through statistical functionalities, it is possible to take into account the nomadic and mobile behaviour of the users.



2 Propagation models

2.1 LOS, nLOS, NLOS: notions

Propagation aspects can be divided in three different topics:

- LOS propagation (Line Of Sight): The transmitter and the receiver are in visibility one with each other.
- NLOS propagation (NON Line Of Sight): The transmitter and the receiver are not in visibility one with each other. A typical example is a WiMAX BTS located in Outdoor environment, when the CPE is located inside a building. The signal between the BTS and the CPE is then diffracted, diffused, or both.
- nLOS propagation(near Line Of Sight): This case is a mix between the LOS and the NLOS case. The transmitter and the receiver can be for instance in visibility one with each other, but part of the Fresnel ellipsoid is obstructed. A transmitter and a receiver almost in visibility one with each other is all a possibility: the signal can then propagate using diffraction or multi-reflection on building sides.

2.2 Propagation aspects

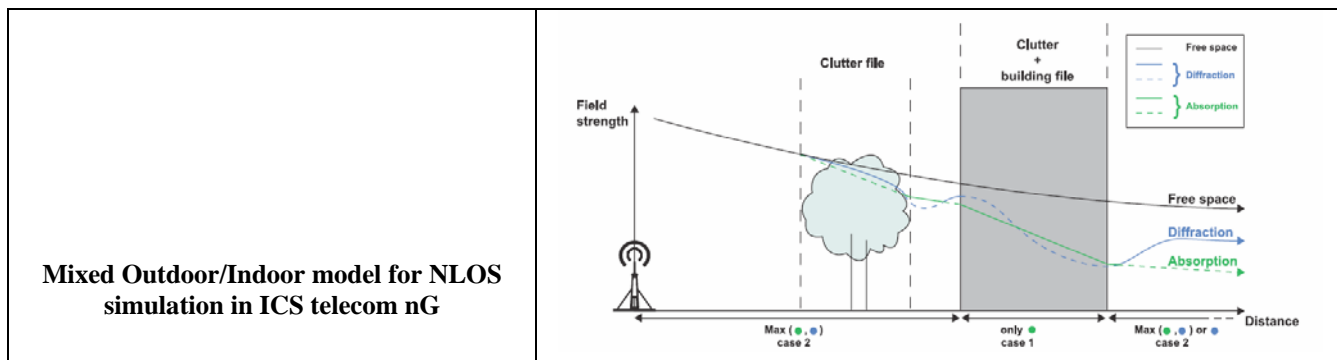
2.2.1 LOS (Line of Sight)

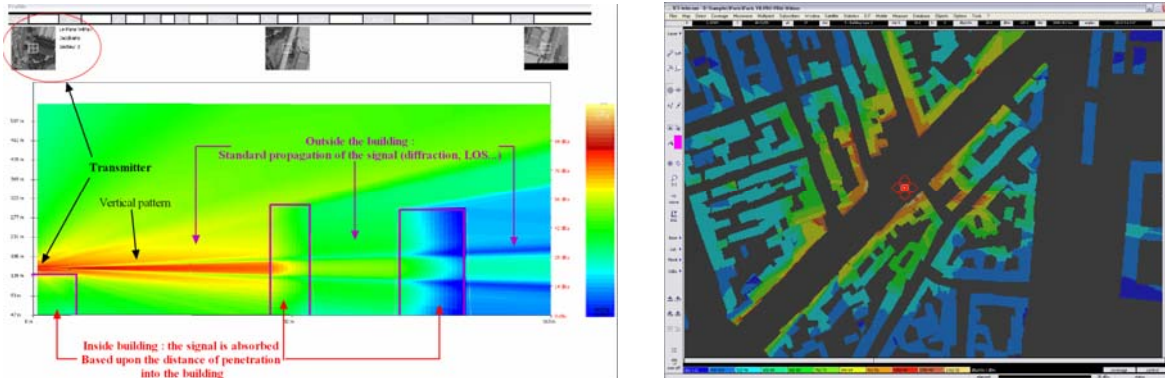
The propagation in LOS is based upon clearly defined propagation methods, such as the ITU-R P 525 model. Note that in ICS Telecom nG, taking full advantage of the quality of the cartography loaded, **deterministic** propagation models, have proved to give the best correlation when correlated with on-field measurements. Of course, additional effects, such as attenuations due to the rain or gas are also considered.

2.2.2 NLOS (Non Line Of Sight)

ICS telecom nG features a new cartographic layer, called the building file that describes the building height above ground level. In ICS telecom nG, the Digital Terrain Model is now separated from the above-the-ground features (buildings, trees...). Specific attenuation coefficients can be applied to the buildings in order to simulate the diffusion effect when the Outdoor signal penetrates an Indoor environment.

For a thorough description of this model, please refer to ATDI's White-paper called "**Mixed absorption-diffraction propagation models for wireless proximity networks**".



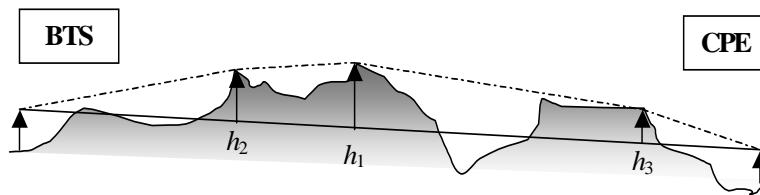


Losses due to the indoor absorption of the outdoor signal in ICS telecom nG

2.2.3 NLOS (near Line Of Sight)

2.2.3.1 Diffraction effect

The diffraction models in ICS telecom nG do quantify the losses due to obstacles between the BTS and the CPE, avoiding the two entities to be in Line of Sight one with each other.



Diffraction geometry

- Bullington method
- Deygout 94 method
- ITU-R 526, round mask
- ITU-R 526, cylinders
- ITU-R 526, deygout
- Visibility / Indoor
- No diffraction loss

ITU-R 452 * (0=rand)

Time (0 to 50%)

2.2.3.2 Subpath attenuation effect

The subpath model in ICS telecom nG quantifies the losses due partial obstructions of the Fresnel zone. Such an attenuation term can be defined for partial obstruction in the Z axis only, or in full 3D.

Subpath attenuations

- Standard (1)
- Coarse integration (2)
- Fine integration (3)
- Area (4)
- ITU-R 526
- Free ellipsoid (5)
- No subpath loss (6)

other subpath methods...

FZ fraction

Spherical wave

Profile View

3D View

Profile View

Considered obstruction

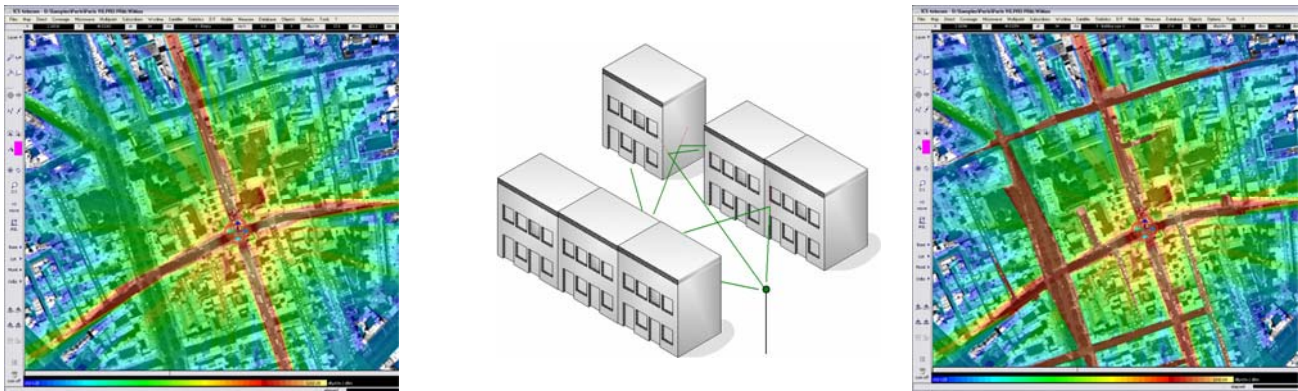
Fresnel ellipsoid

Subpath attenuation due to a partial obstruction of the Fresnel ellipsoid
Left: subpath attenuation due to an obstruction in the Z plane only
Right: subpath attenuation due to an obstruction anywhere in Fresnel zone



2.2.3.3 Multi-reflection effect

This model calculates the field strength at all point of the simulation area according to reflected signals contribution, taking into account a reflection coefficient defined by the user.



Outdoor/Indoor simulation of a WiMAX BTS, considering the reflections on buildings sides (right), or not (left)

Note that the multipath calculation engine of ICS telecom nG also allows dedicated analysis of **power delay spread** effect.

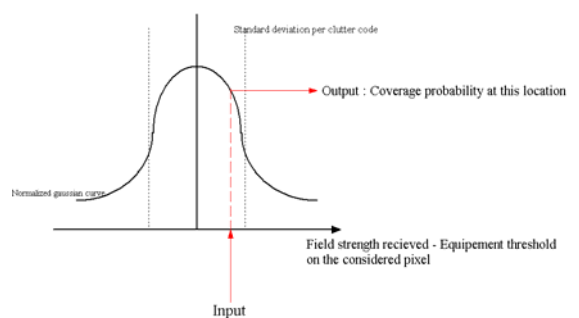
This refers to the maximum difference in arrival times at the receiver when there is more than one signal received via different transmission paths. Studies show that for delays limited to a fraction of the symbol time, the amount of signal degradation depends not in the actual delay profile, but on the rms value of the delay, weighted by their respective power levels.

FS dBμV/m	ToA μs
60	23
38	24
37	25
35	26
33	27
33	28
34	29
39	30
39	31
38	32
37	33
35	34
34	35
31	36
28	37

2.2.4 Coverage probability

ICS telecom nG can display a map of probability of coverage. Such map is based on:

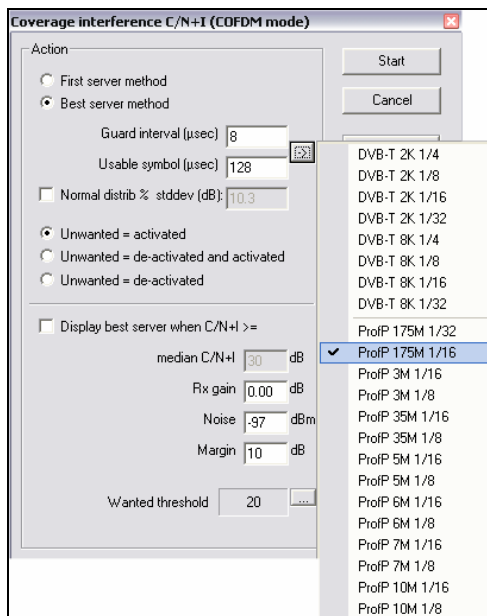
- The power received at each pixel of the map
- The equipment receiving threshold
- The standard deviation that can be setup per clutter code on the entire map





2.3 NLOS solutions in ICS telecom nG

2.3.1 OFDM



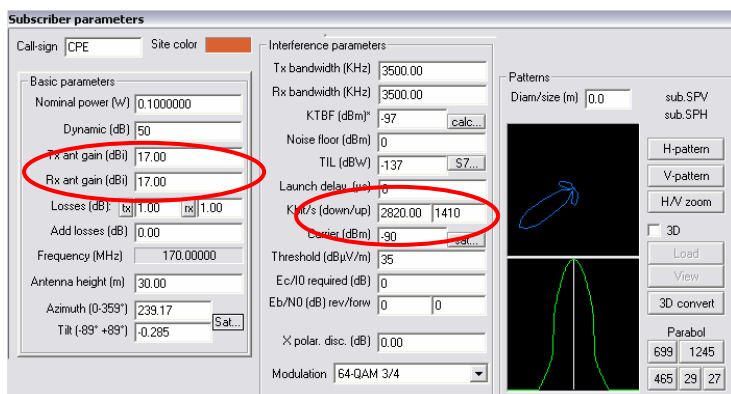
Interference analysis in COFDM mode

Orthogonal frequency division multiplexing (OFDM) technology provides operators with an efficient means to overcome the challenges of NLOS propagation. The WiMAX OFDM waveform offers the advantage of being able to operate with the larger delay spread of the NLOS environment. By virtue of the OFDM symbol time and use of a cyclic prefix, the OFDM waveform eliminates the inter-symbol interference (ISI) problems and the complexities of adaptive equalization.

ICS telecom nG features a dedicated OFDM interference calculation engine and the ability to create orthogonal frequency groups as well.

2.3.2 Uplink/Downlink asymmetry, subchannelization

The subchannelization option concentrates the transmitted power into fewer OFDM carriers. Hence, the uplink and downlink budgets are balanced and the global system gain increased (not anymore uplink limited). It can be used to extend the reach of the system, overcome the building penetration losses, and/or reduce the power consumption of the CPE. In ICS telecom nG this is accounted for by the configuration of each CPE **individual parameters** (gain, UL DL required bit/rate, ...)



STATION TRAFFIC

Station	BST	Subscribers	Mbits ul	Mbits dl
BTS2 Sec3	7	38	9.73	9.73
BTS2 Sec4	8	86	22.02	22.02
BTS3 Sec1	9	40	10.24	10.24
BTS3 Sec2	10	38	9.73	9.73

Point to Multipoint network planning, uplink and downlink, using individual requirement per CPE



2.3.3 Antenna consideration

2.3.3.1 Directionality, sectorisation

Each sector of a WiMax BTS can be setup independently in ICS Telecom nG. The **directivity of the CPE** is also described and taken into account at each stage of the simulation process

Directivity of the CPE

Technical parameters of a WiMAX sector in ICS telecom nG

2.3.3.2 Smart antenna systems

Various technologies are used for smart antenna systems: Switched Beams, Adaptive Array (AA), Dynamically Phased Array (PA), MIMO, SDMA. The strategies used rely on optimising the gain or the directionality of the radiation patterns, spatial multiplexing, combining multipath signals. These adaptive systems take advantage of their ability to effectively locate and track various types of signals to dynamically minimize interferences and maximize intended signal reception.

The key parameters for field strength predictions are the antenna gain in the transmitting and receiving ways and the sensitivity of the receiver.

- the radio planner can use ICS telecom nG to define manually its own parameters to set the antenna gain and receiving threshold;
- For adaptive antenna arrays, the user defines the composite pattern corresponding to all radiating elements and the number of available elements. The "burst" gain" is calculated and the nominal gain updated, based on the assumption that an antenna array containing M elements can provide a power gain of M over white noise level.
- For switched beams, ICS telecom nG automatically detects the best predefined beam



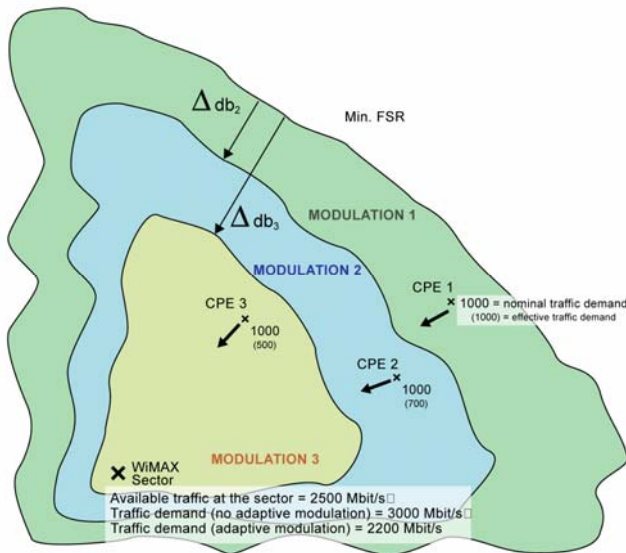
to offer/receive the best signal in a given direction and then applies interference rejection from pattern discrimination and location of the interferers.

In addition to the features available to model adaptive antenna arrays, ICS telecom also includes specific functions related to dynamic beam forming according to angle or arrival (off-axis angle) of the signals.

2.3.4 Adaptive modulation

The key parameter for traffic modelling (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... As in ICS Telecom nG 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 nG also includes features dedicated to adaptive modulation, to offer the maximum bit rate according to the best modulation and the signal level received:

- Traffic analysis between two BTS (backbone for instance): a connection between two WiMax stations is created and the bit rate is set according to the margin above minimum received threshold.
- CPE connection at a parent WiMAX sector: The available bit rate at the BTS will be controlled and the CPE (subscriber) connected according the power received (threshold versus modulation scheme). This process can be done in both Uplink and Downlink.



Delta (dB) / Threshold	Traffic factor (0-1)	
0.0	1.00	(min delta)
3.0	0.50	
6.0	0.33	
9.0	0.25	
12.0	0.17	
18.0	0.11	(max delta)

Threshold: -96

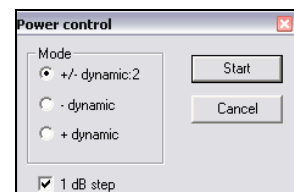
delta 255 = infinite

calc [p] [f]

**Adaptive modulation in ICS telecom nG:
Backhauling solution
CPE connection (left)**

2.3.5 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 pre-determined level. ICS telecom nG adjusts the uplink radiated power at the CPE side, limiting therefore potential interference cases.





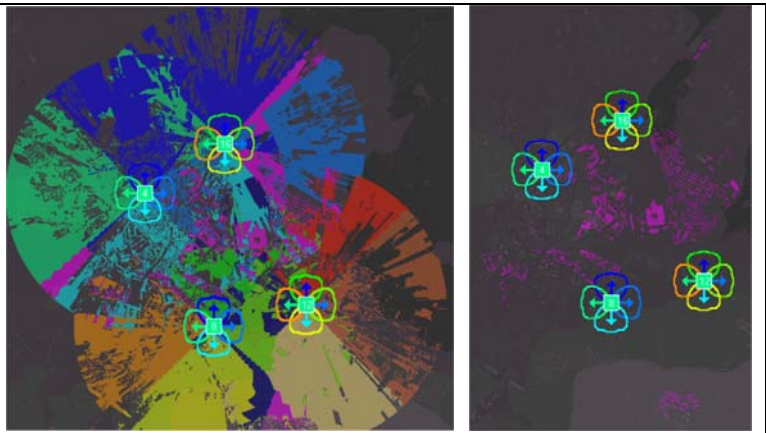
3 Interference consideration

3.1 Evaluating the SNR

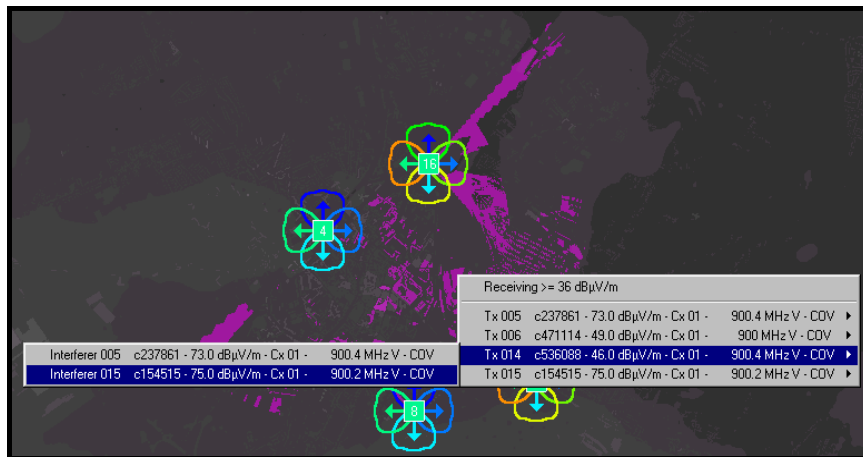
3.1.1 At the BTS level

Interference calculations can be performed according to C/I or IRF rules. Results are displayed on map, and various reports (export, printing, filtering...) can be extracted.

**Result of interference calculation.
Interfered areas are displayed in pink
Interfered areas filtered on rooftops (right)**



The interference results can also be analyzed in point mode, in order to check what are the field strength received, what are the interfering channels (pilot or not...) at a particular location.

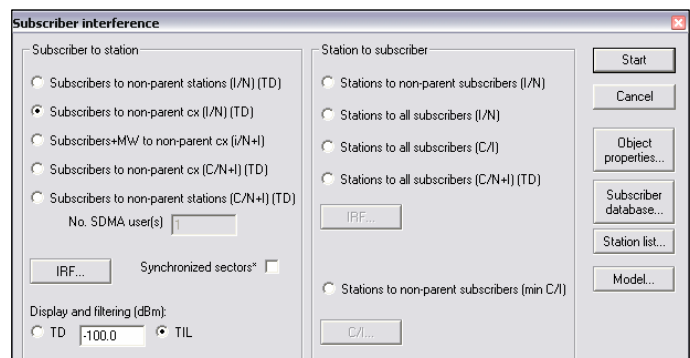


List of received transmitters at a particular location, and for each one, the interferer

3.1.2 At the CPE level

ICS telecom nG features an interference calculation engine specially dedicated to the Point to Point connections. Uplink and downlink interference cases can be closely analyzed.

Uplink.Downlink interference analysis between the CPEs and the BTSs





In addition to the previous features, for SDMA systems, the radio planner can specify the maximum number of terminals that can be simultaneously connected to a given base station for uplink interference calculations (from terminals to base stations).

Subscribers to non-parent cx (C/N+I) (TD)
 Subscribers to non-parent stations (C/N+I) (TD)
 No. SDMA user(s)
 Synchronized sectors

Point to Point interference analysis for SDMA systems

3.2 Frequency Assignment

The assignable frequencies can be defined by band, a list, from a frequency plan, etc. In the same way, the frequency assignment engine follows customizable rules and parameters, which can be WIMAX dedicated (sectorisation...) or describe external constraints or given engineering rules.

Rules

Interference wanted/unwanted (slower)

Apply frequency spacing on same site (MHz):
 if azimuth spacing <

Forbid same polarization on site if az. spacing <

Forbid same frequency on same site
 Site: Distance between stations <= m

Organize Tx list - frequency isolation constraint: m

Organize Tx list - sector constraint (delta=0°)

Organize Tx list - coverage size constraint

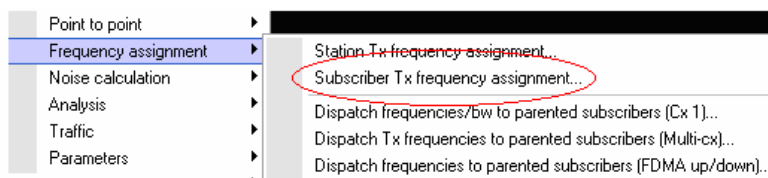
Assign polarization (H/V)

Number of pass

Exhaustive method Assign all channels
 Monte-Carlo method Assign pilot channel
 Iterative method Assign traffic channels
 Sequential method

Frequency assignment rules: here at least one channel difference must be applied between sectors of the same BTS. (Note that the assignment engine distinguishes the assignment of signalling ("Pilots") and data channels)

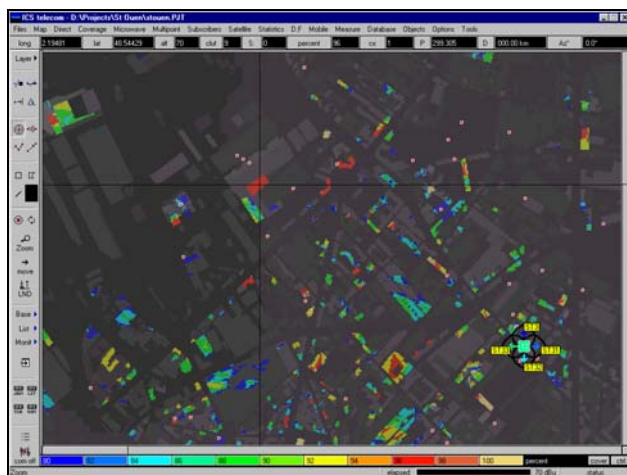
An equivalent process can be used for the **Uplink frequency assignment** of the CPE. Generally, a threshold degradation or a CNIR method is used.





4 Computer aided network planning with ICS telecom nG

4.1 Auto planning



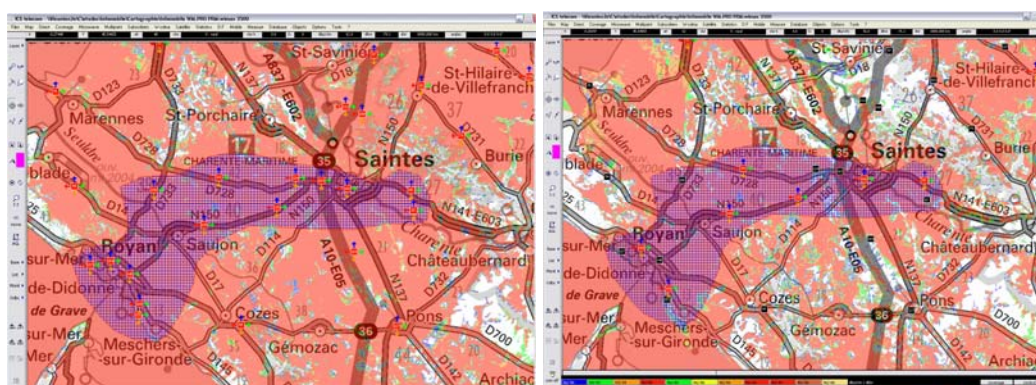
Given a number of subscribers (fixed or random) ICS telecom nG can search for suitable locations for BTSs according to a number of criteria. This search can take into account existing BTSs.

This example shows the buildings where a BTS is likely to cover the prospects. For example, the location where the mouse is pointing has a coverage probability of 96%.

4.2 Selecting the best stations from a list

The user can have a list of locations among which he has to select the best ones in order to achieve a coverage objective. E.g.: among the 300 potential locations of my sites, what are the ones that should be selected in order to cover the best way an area of interest?

ICS telecom nG calculates the selection of the minimum of sites that do satisfy the coverage objective.



Optimizing the number of sites to match the coverage objective (in blue): all not needed sites are de-activated

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