Optimi

Analysis on the Effects of the AWS-3 to AWS-1 Mobile to Mobile Interference

Analysis Results
September 22, 2008

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1. Executive Summary

The Federal Communications Commission (FCC), through a Notice of Proposed Rule Making (NPRM) and a Further Notice of Proposed Rule Making (FNPRM), proposes service rules allowing time division duplex (TDD) broadband wireless service in the new AWS-3 band (2155 – 2180 MHz), which is adjacent to the downlink of the previously auctioned AWS-1 band (2110 – 2155 MHz). Comments filed by T-Mobile USA ("T-Mobile") and several other parties raised concerns about this TDD proposal because of the potential risk of mobile-to-mobile interference from the AWS-3 terminal devices into the reception band of AWS-1 mobiles. In those comments, T-Mobile and others stated that to avoid significant interference, stringent service rules on maximum allowed mobile transmit power and Out-of-Band Emissions (OOBE) would have to be enforced on the AWS-3 terminals, if TDD is allowed to operate immediately adjacent to the existing AWS-1 frequency division duplex (FDD) band.

T-Mobile has presented a "Laboratory Test Report" that measured the severity of the interference and suggested new service rules in line with the measurements gathered. M2Z Networks, Inc ("M2Z"), on its comments to these results, has suggested that T-Mobile and other parties have "overstated both the potential for and the severity of harmful interference between adjacent TDD and FDD operations".

Based on the aforementioned findings, this document presents a system level statistical analysis aimed at determining whether the generated interference is really harmful in a realistic scenario and, if this is the case, quantifying the capacity and service quality degradation that a UMTS network in the AWS-1 band will experience if TDD broadband wireless services are allowed to operate immediately adjacent to the existing AWS-1 band with the current requirements for OOBE. This statistical study is based on a version of Optimi Corporation's ("Optimi") state-of-the-art UMTS Monte-Carlo simulator that is capable to model and incorporate AWS-3 to AWS-1 mobile-to-mobile interference into the UMTS performance analysis.

More specifically, Optimi's simulator includes models for power control, admission control, soft/softer handover, overhead due to P-CPICH and other common control channels, multiple (asymmetrical) service profiles with different traffic maps, different UE and Node-B models and parameters (noise figure, antenna gain, link level performance mapping tables, etc.), indoor penetration losses and connection failures due to DCH power shortage (Eb/No problems in up and downlink), as well as lack of pilot coverage (based on CPICH RSCP and Ec/Io). In addition, further enhancements have been added in order to assess the scenario under consideration and the potential inter-system interference issues that may appear. These enhancements comprise: placement of AWS-3 transmitters according to a traffic map, distance-dependent models for the path-loss between AWS-3 and AWS-1 mobiles, models for penetration losses due to a distance-dependent number of walls through which the AWS-3 signal must propagate before interfering the UMTS downlink in the AWS-1 band, introduction of OOBE according to the current proposal, introduction of adjacent channel interference, models for determining the transmit power of the AWS-3 mobiles and models for receiver saturation mechanisms due to interference.

The different assumptions that have been made in order to parameterize these models are described throughout the document. In some cases (for example, when generating the hot spot scenario), these are based on public references, while in others (e.g. when modeling receiver saturation mechanisms, etc.) the selected parameter values are based on direct measurements that T-Mobile has carried out in the lab.

A range of reasonable scenarios with a carrier bandwidth of 20 MHz has been tested, and several user profiles are analyzed simultaneously (home, office and outdoor). Depending on the assumptions (all of them reasonable) the overall system capacity loss can range between 3.1% and 5.3%, although the capacity loss for home users can reach 10.6%.

A further drill down on the data shows that AWS-1 home users with an AWS-3 transmitter nearby (e.g. at home or at a neighbor's house and not necessarily being one meter away from the transmitter) will suffer significant losses:

- *Up to 66.40% of AWS-1 home users lost service with at least one AWS-3 user within 15 meters*
- *Up to 27.80% of AWS-1 home users lost service with at least one AWS-3 user within 45 meters*

WiMAX signals with bandwidths of 10 MHz and 5 MHz have also been studied and similar network degradation was found.

Therefore, it can be concluded that UMTS subscribers that have an AWS-3 in their surroundings (e.g. at home or at a neighbor's house and not necessarily being one meter away from the transmitter) may suffer from a severe degradation in their UMTS service.

2. Introduction

2.1 Problem formulation

The Federal Communications Commission (FCC), through a Notice of Proposed Rule Making (NPRM) and a Further Notice of Proposed Rule Making (FNPRM), proposes service rules allowing time division duplex (TDD) broadband wireless service in the new AWS-3 band (2155 – 2180 MHz), which is adjacent to the downlink of the previously auctioned AWS-1 band (2110 – 2155 MHz). Comments filed by T-Mobile USA ("T-Mobile") and several other parties raised concerns about this TDD proposal because of the potential risk of mobile-to-mobile interference from the AWS-3 terminal devices into the reception band of AWS-1 mobiles. In those comments, T-Mobile and others stated that to avoid significant interference, stringent service rules on maximum allowed mobile transmit power and Out-of-Band Emissions (OOBE) would have to be enforced on the AWS-3 terminals, if TDD is allowed to operate immediately adjacent to the existing AWS-1 frequency division duplex (FDD) band.

T-Mobile has presented a "Laboratory Test Report" that measured the severity of the interference and suggested new service rules in line with the measurements gathered. M2Z Networks, Inc ("M2Z"), on its comments to these results, has suggested that T-Mobile and other parties have "overstated both the potential for and the severity of harmful interference between adjacent TDD and FDD operations".

Based on the aforementioned findings, this document presents a system level statistical analysis aimed at determining whether the generated interference is really harmful in a realistic scenario and, if this is the case, quantifying the capacity and service quality degradation that a UMTS network in the AWS-1 band will experience if TDD broadband wireless services are allowed to operate immediately adjacent to the existing AWS-1 band with the current requirements for OOBE. This statistical study is based on a version of Optimi Corporation's ("Optimi") state-of-the-art UMTS Monte-Carlo simulator that is capable to model and incorporate AWS-3 to AWS-1 mobile-to-mobile interference into the UMTS performance analysis.

2.2 Methodology for UMTS statistical analysis

As stated before, the analysis described in this document is based on Optimi's UMTS Monte Carlo simulator, which is a widely used, proven and accurate solution that models the performance of real UTRA FDD networks. A more detailed description of the simulator is provided in Annex A. In summary, it is a semi-dynamic UMTS simulation platform that features state-of-the art simulation models for the following algorithms and mechanisms:

- *Power control*
- *Admission control*
- *Soft and softer handover*
- *Overhead due to P-CPICH and other common control channels*
- *Multiple (asymmetrical) service profiles with different traffic maps*
- *Different UE and Node-B models and parameters (Noise figure, antenna gain, link level performance mapping tables, etc.)*
- *Indoor penetration losses*
- *Connection failures due to DCH power shortage (Eb/No problems in up and downlink) and lack of pilot coverage (based on CPICH RSCP and Ec/Io)*

The simulations done for this study use a pixel resolution of 30 meters and additional measures have been taken into consideration in order to consider any distance between interferers with a resolution of one meter.

2.3 Assessing the influence of WiMAX transmitters in the AWS-3 band

In order to model the impact that WiMAX transmitters operating on the AWS-3 band will have on the UMTS mobiles operating on the AWS-1 band, a set of additional features must be used together with the standard set of functionalities available in Optimi's standard UMTS simulator. These features are listed below:

- *Placement of AWS-3 transmitters according to a traffic map*
- *Distance-dependent models for the path-loss between AWS-3 and AWS-1 mobiles*
- *Models for penetration losses due to a distance-dependent number of walls through which the AWS-3 signal must propagate before interfering the UMTS downlink in the AWS-1 band*
- *Introduction of OOBE according to the current proposal*
- *Introduction of Adjacent Channel Interference*
- *Models for determining the transmit power of the AWS-3 mobiles*
- *Models for receiver saturation mechanisms due to interference*

These features are described in the following subsections.

2.3.1. Placing AWS-3 users in the simulation scenario

During each statistical analysis, a number of Monte Carlo runs are executed. Each Monte Carlo run is a random realization of the system and therefore implies a different set of users generated in different random locations (even though they are generated according to the same statistical traffic map). When adding AWS-3 mobiles into the analysis, for each Monte Carlo run a number of AWS-3 users are randomly placed in the simulation scenario according to an AWS-3-specific traffic map.

Following the same policy that is applied in the UMTS case, the AWS-3 traffic map is considered in relative terms, i.e. the normalized value in every pixel indicates the probability of selecting that pixel when deciding the location of an AWS-3 mobile. In addition to the traffic map, the following pieces of information are provided as input data:

- *O = Offered AWS-3 load [Mbps]*
- *AF = Average activity factor of an AWS-3 user [real number, between 0 and 1]*
- *R = Average user data rate when active [Mbps]*

With this information, the number of users to be spread across the simulation area (and according to the statistical spatial distribution contained in the traffic map) is internally calculated as follows:

- *Number of users = O / (AF*R)*

2.3.2. Modeling the path-loss between AWS-3 and AWS-1 mobiles

It is assumed that an AWS-3 mobile can only be an interferer for those AWS-1 mobiles that are located in the same pixel or in the first tier of surrounding pixels. For those victim AWS-1 mobiles that are located further away, it is assumed that the AWS-3 will not generate any interference.

When calculating the amount of interference, the path-loss between AWS-3 and AWS-1 mobiles is assumed to equal the summation of two different components:

- *Free-space path-loss = PL_{fs}(dB) = 20log[d(km)]+20[f(MHz)]+32.44*
- *Penetration loss due to walls (PL_{walls}), calculated as follows for every pair of AWS-3 and AWS-1 mobiles in the same or adjacent pixels:*

  i. *A random distance d is calculated between 1 and 15 meters if the interferer falls within the same pixel as the victim AWS-1 mobile, and between 15 and 30 meters if it falls within an adjacent pixel (note that in this study the size of the pixels is 30 meters)*

  ii. *The maximum number of walls equals d/distanceBetweenWalls*

  iii. *A random number of walls (numWalls) is generated between 0 and the maximum number of walls*

  iv. *PL_{walls}(dB) = penetrationLossPerWall(dB)*numWalls,*

  where penetrationLossPerWall and distaceBetweenWalls are inputs for the inter-system interference model.

- *Adding the two aforementioned components, Path-loss(dB) = PL = PL_{fs} + PL_{walls}*

2.3.3. Modeling OOBE

This interference comes from the interfering (TDD) AWS-3 mobile and leaks into the AWS-1 band (as in-band noise, which therefore cannot be filtered out even with ideal reception filters in the UMTS receiver). It comes from the fact that the transmission mask of the interfering mobile is not perfect. FCC requirements are given as an isolation factor, which is denoted here by X_{OOBE}.

The interference that leaks into the AWS-1 band is modelled as:

$$P_{OOBE}(dBm) = P_{txAWS\text{-}3}(dBm) - PL(dB) - X_{OOBE}\ (dB),$$

where $P_{txAWS\text{-}3}$(dBm) is the transmit power for the interfering mobile and X_{OOBE}(dB) is an input parameter (the aforementioned isolation factor).

2.3.4. Modeling Adjacent Channel Interference

This interference is generated by the interfering (TDD) mobile in the AWS-3 band (not leaked into the AWS-1 band) and is captured by the UMTS mobile due to imperfect receiver filters (i.e. due to the fact that the AWS-1 UMTS receiver is capturing energy in the AWS-3 band). In this case the isolation factor is denoted here by X_{ADJ}.

This interference is modeled as:

$$P_{ADJ}(dBm) = P_{txAWS\text{-}3}(dBm) - PL(dB) - X_{ADJ}\ (dB),$$

where $P_{txAWS-3}$(dBm) is the transmit power for the interfering mobile and X_{ADJ}(dB) is given by the following user-configurable function:

X_{ADJ}(dB) = X_{ADJ1} for $P_{rxAWS-3}$(dBm) <= Thd1 dBm;
X_{ADJ}(dB) = X_{ADJ2} for $P_{rxAWS-3}$(dBm) >= Thd2 dBm;
Simple linear interpolation between X_{ADJ1} and X_{ADJ2} for Thd1 < $P_{rxAWS-3}$(dBm) < Thd2;

Note that $P_{rxAWS-3}$(dBm) = $P_{txAWS-3}$(dBm) - PL(dB).

2.3.5. Modeling the transmit power of the AWS-3 mobiles

It has been assumed that the value of the transmit power for the AWS-3 mobiles depends on the P-CPICH RSCP measured by the UMTS mobile. The simulation of this option will apply a look-up table provided by T-Mobile, and it implicitly models the correlation between low received signal level in the downlink and high transmission power in the uplink. Nonetheless, for it to be fully applicable, a 100% co-location between AWS-1 and AWS-3 base station has to be assumed.

2.3.6. Modeling receiver saturation mechanisms

Receiver saturation mechanisms are assumed to be independent from OOBE and Adjacent Channel Interference. For this study, these mechanisms will be defined as a function of $P_{rxAWS-3}$(dBm), which is assumed to equal

$P_{rxAWS-3}$(dBm) = $P_{txAWS-3}$(dBm) - PL(dB),

According to T-Mobile's measurements, the following levels of PrxAWS-3(dBm) (measured at AWS-1 antenna port) will cause a call setup failure:

- *$P_{rxAWS-3(}$dBm) > -33.2 dBm/20 MHz for UMTS RSCP <= -105 dBm*
- *$P_{rxAWS-3(}$dBm) > -28.2 dBm/20 MHz for UMTS RSCP <= -100 dBm*
- *$P_{rxAWS-3(}$dBm) > -24.2 dBm/20 MHz for UMTS RSCP <= -90 dBm*
- *$P_{rxAWS-3(}$dBm) > -22.2 dBm/20 MHz for UMTS RSCP <= -85 dBm*

Note that simple linear interpolation will be applied for values that fall in between the specified thresholds.

2.4 Key parameters and assumptions

2.4.1. Simulation area

The area under simulation is an urban US area that expands for 12 by 15 miles (see the screenshot below, showing the clutter map for the simulation area). The number of sectors in this area is 123, and their location is real, corresponding to a UMTS cellular network that has been deployed to serve the area under simulation. Traffic maps are

also real, and were created specifically for the area under analysis (traffic maps are covered in sub-section 2.4.3).

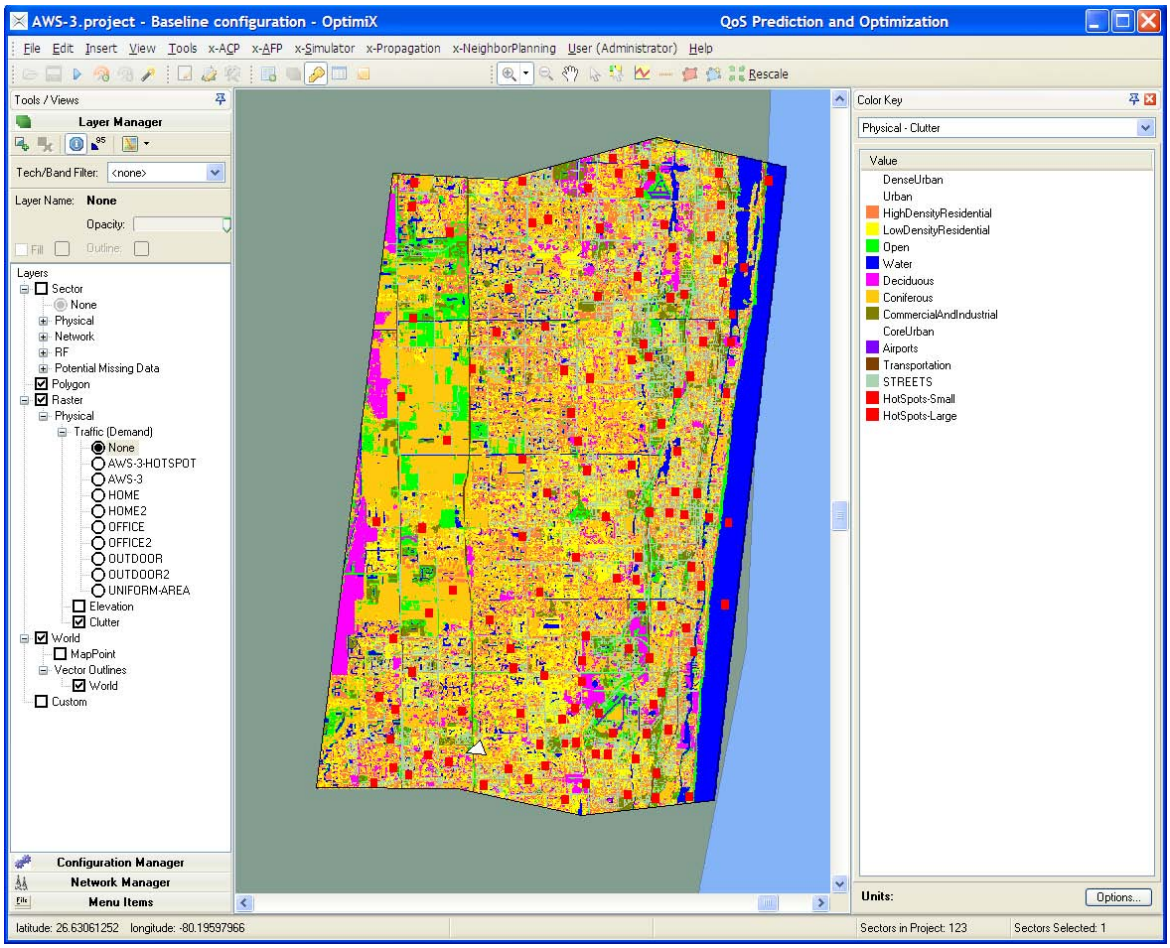

Figure 1. Simulation area and clutter types

2.4.2. UMTS Radio Resource Management

The following key UMTS parameter values have been used in order to configure the network under simulation.

- *PA power = 20 Watts*
- *CPICH power = 2 Watts (10% of the PA power)*
- *Power for other common control channels = 1.6 Watts (8% of the PA power)*
- *Soft handover window = 3 dB*

2.4.3. Traffic maps, version A

Several traffic maps have been used in order to run the different scenarios that will be assessed for this study. The exact traffic maps that correspond to each scenario will be detailed at a later stage. At this point, the different individual traffic maps are presented:

Uniform traffic map (not necessarily realistic, just created artificially for reference).

Home traffic map (created by spreading each sector's UMTS measured traffic across its dominance area according to a set clutter weights that are specific to this traffic map, which will be shown later):

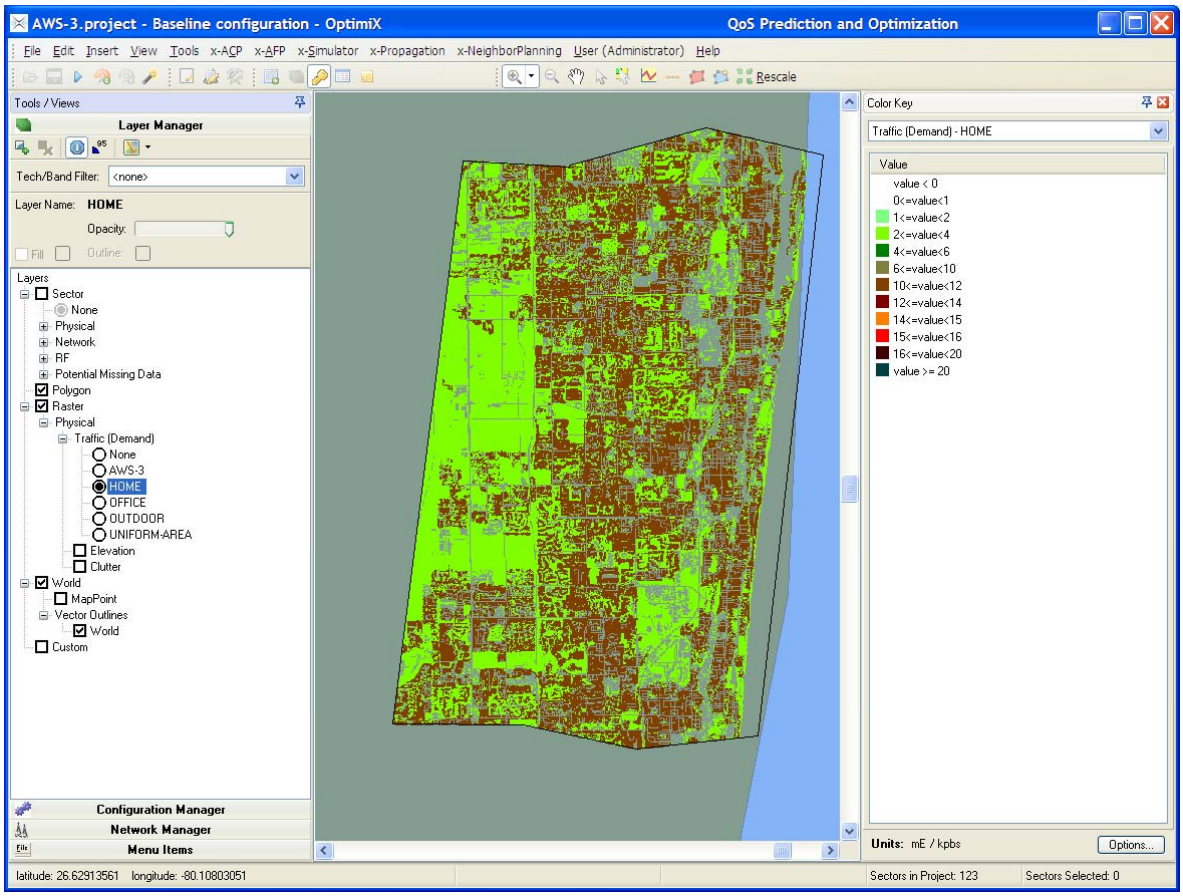

Figure 2. Home traffic map

Office traffic map (created by spreading each sector's UMTS measured traffic across its dominance area according to a set clutter weights that are specific to this traffic map, which will be shown later):

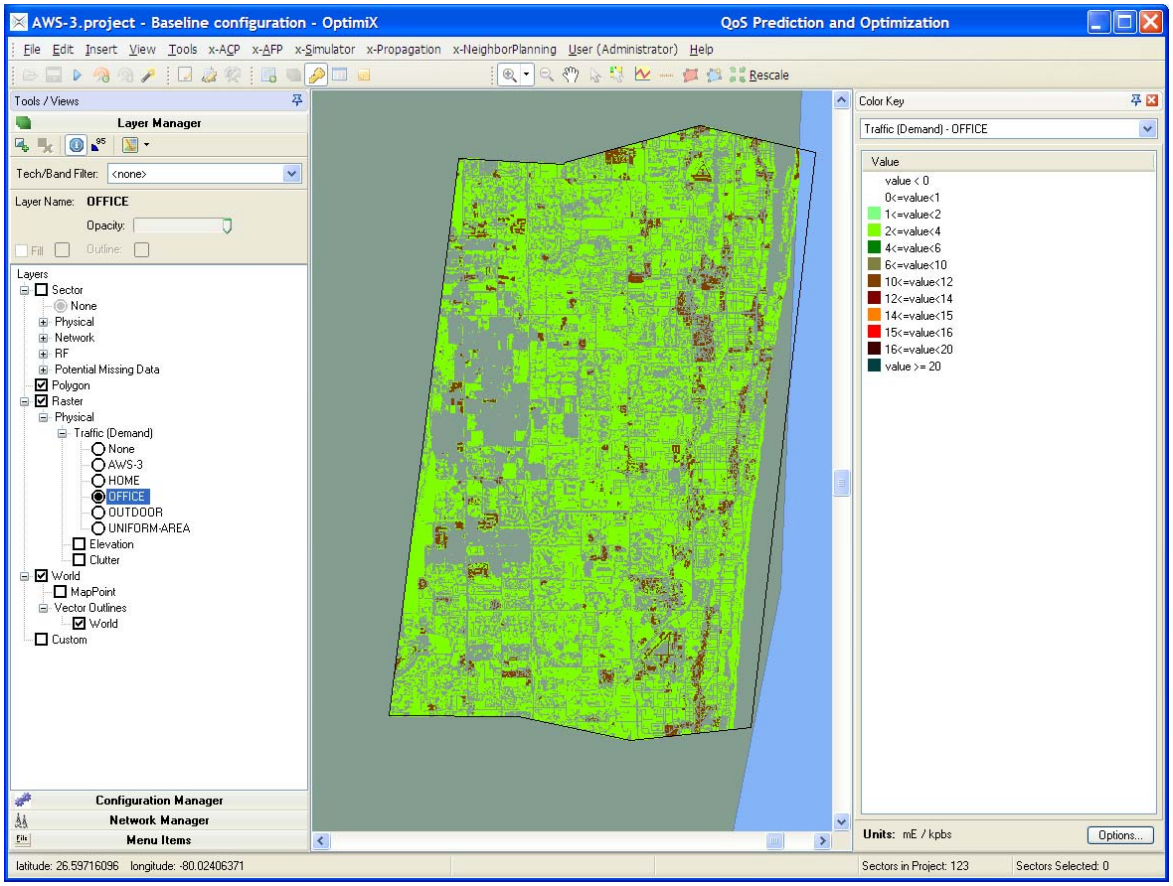

Figure 3. Office traffic map

Outdoor traffic map (created by spreading each sector's UMTS measured traffic across its dominance area according to a set clutter weights that are specific to this traffic map, which will be shown later):

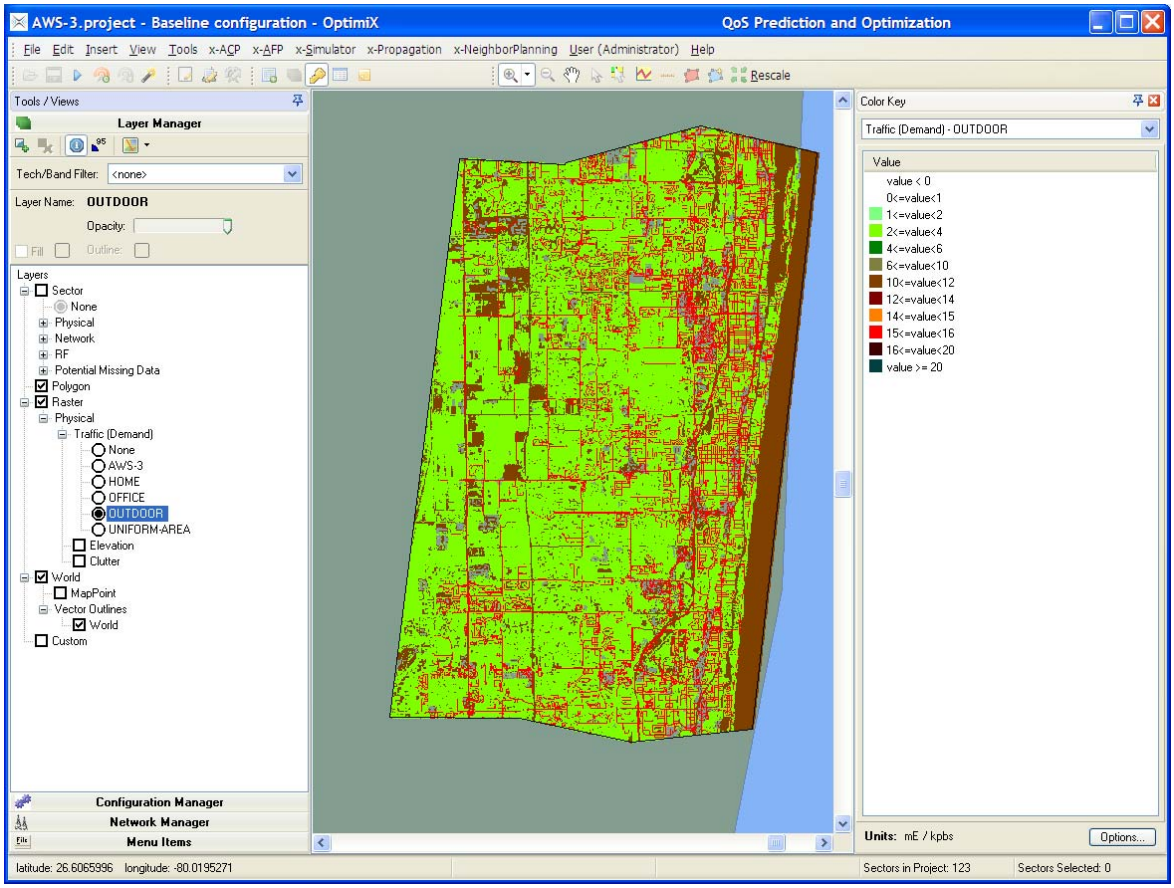

Figure 4. Outdoor traffic map

AWS-3 traffic map (created by adding the UMTS AWS-1 home and office traffic maps):

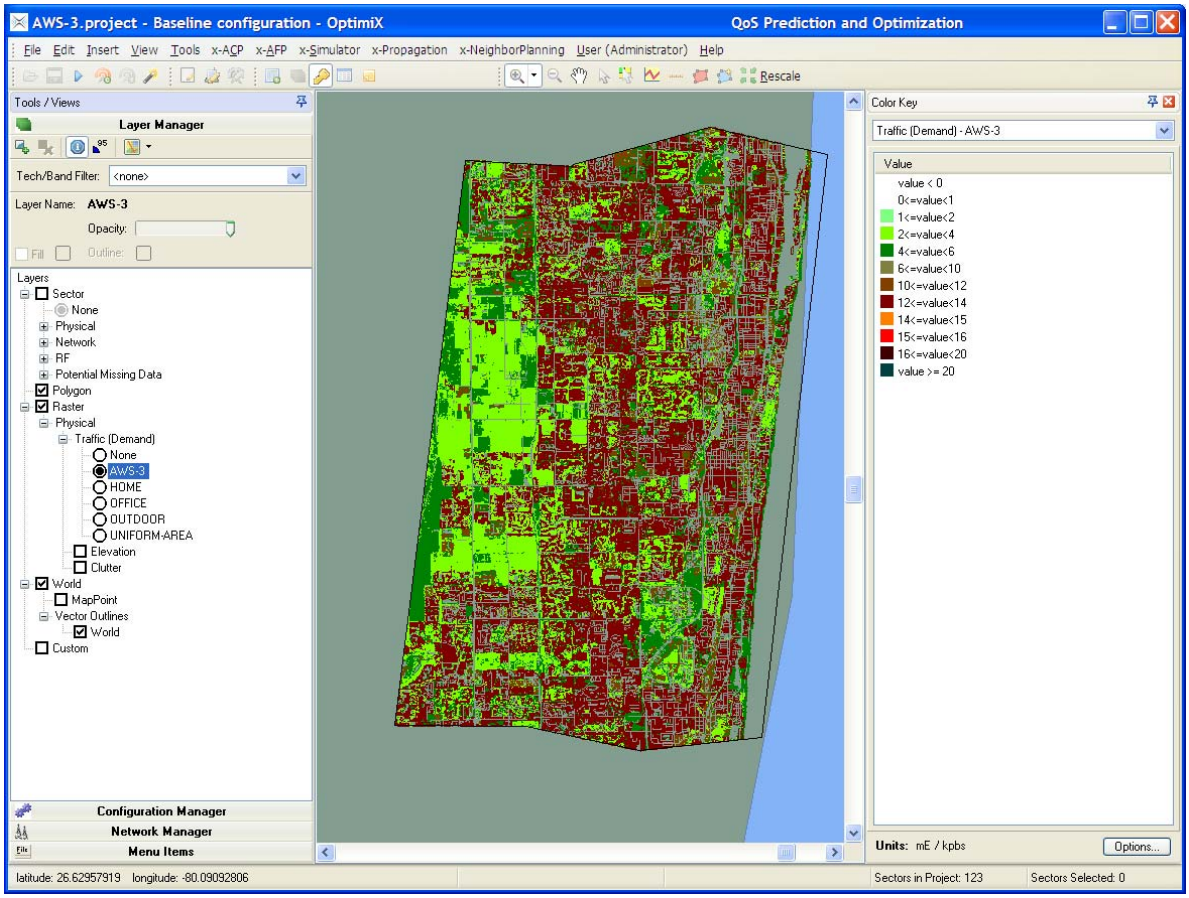

Figure 5. AWS-3 traffic map

At this point it is worth emphasizing the fact that traffic maps are used by the simulator in relative terms (i.e. to assign more probability to certain pixels as compared with others). Therefore, for each simulation, each traffic map must be accompanied with the absolute amount of traffic to be spread across the simulation area (according to the traffic map). Moreover, the sets of clutter weights that have been applied in order to generate each one of the aforementioned traffic maps are shown below:

			Traffic Map Clutter Weights				
Clutter Type	**No. Pixels**	**Area %**	**Outdoor**	**Home**	**Office**	**AWS3**	**Uniform**
Dense Urban	0	0.00%	0.00	0.00	0.00	0.00	0.00
Urban	0	0.00%	0.00	0.00	0.00	0.00	0.00
High Density Residential	89746	15.24%	2.00	10.00	2.00	12.00	1.00
Low Density Residential	119454	20.28%	2.00	10.00	2.00	12.00	1.00
Open	42273	7.18%	10.00	2.00	2.00	4.00	1.00
Water	62500	10.61%	10.00	0.00	0.00	0.00	1.00
Deciduous	45369	7.70%	2.00	2.00	2.00	4.00	1.00
Coniferous	119389	20.27%	2.00	2.00	0.00	2.00	1.00
Commercial and Industrial	22305	3.79%	0.00	0.00	10.00	10.00	1.00
Core Urban	0	0.00%	0.00	0.00	0.00	0.00	0.00
Airports	1084	0.18%	2.00	0.00	10.00	10.00	1.00
Transportation	3978	0.68%	10.00	0.00	0.00	0.00	1.00
Streets	82872	14.07%	15.00	0.00	0.00	0.00	1.00

Table 1. Clutter weights to generate the different traffic maps

2.4.4. Traffic maps, version B

Except for the uniform case, a second version of the different traffic maps has been created, in which some pixels are considered to be part of a hot spot. These pixels only carry traffic in the AWS-3 and Office traffic maps, not carrying any traffic with the other traffic maps. The hot spot pixels have been chosen according to the following rules:

- *Each sector has 3 small hot spots (1 pixel each), and the clutter type for these pixels is labelled as HotSpot-Small.*
- *Each sector has one large hot spot that is about 154 pixels (14*11) for most sectors and 12*10 for a few sectors. The shape of the hot spot is rectangular and it has been enforced that the hot spot associated with a sector is a contiguous area of 14x11 pixels that fits in the coverage area of that sector. The coordinates of the top left corner of each rectangle has been picked randomly (provided that the aforementioned condition is fulfilled). The clutter type for these pixels is labelled as HotSpot-Large.*

The weights that have been used to create these new traffic maps are depicted below. Note that if the numbers for the new AWS-3 traffic map are analysed, it can be noticed that 50% of the AWS-3 traffic will fall in the hot spots, as well as in airport, commercial and industrial areas. The other 50% of the load will fall in home areas. In this way, it is ensured that half of the AWS-3 load will be generated in the hot spots (and airport, commercial and industrial). Note that assigning the entire office traffic to the hotspots area would not have been realistic. In general, the hotspot modelling approach follows the one described in [1], written by Motorola.

			Traffic Map Clutter Weights				
Clutter Type	**No. Pixels**	**Area %**	**Outdoor2**	**Home2**	**Office2**	**AWS3**	**Uniform**
Dense Urban	0	0.00%	0.00	0.00	0.00	0.00	0.00
Urban	0	0.00%	0.00	0.00	0.00	0.00	0.00
High Density Residential	86248	14.64%	2.00	10.00	0.00	10.00	1.00
Low Density Residential	115106	19.54%	2.00	10.00	0.00	10.00	1.00
Open	40934	6.95%	10.00	2.00	0.00	2.00	1.00
Water	61087	10.37%	10.00	0.00	0.00	0.00	1.00
Deciduous	43830	7.44%	2.00	2.00	0.00	2.00	1.00
Coniferous	116086	19.71%	2.00	2.00	0.00	2.00	1.00
Commercial and Industrial	21171	3.59%	0.00	0.00	10.00	10.00	1.00
Core Urban	0	0.00%	0.00	0.00	0.00	0.00	0.00
Airports	1030	0.17%	2.00	0.00	10.00	10.00	1.00
Transportation	3836	0.65%	10.00	0.00	0.00	0.00	1.00
Streets	78728	13.37%	15.00	0.00	0.00	0.00	1.00
HotSpots-Small	346	0.06%	0.00	0.00	500.00	500.00	1.00
HotSpots-Large	20568	3.49%	0.00	0.00	100.00	100.00	1.00

Table 2. Clutter weights to generate the different traffic maps

The new versions of the traffic maps are depicted below:

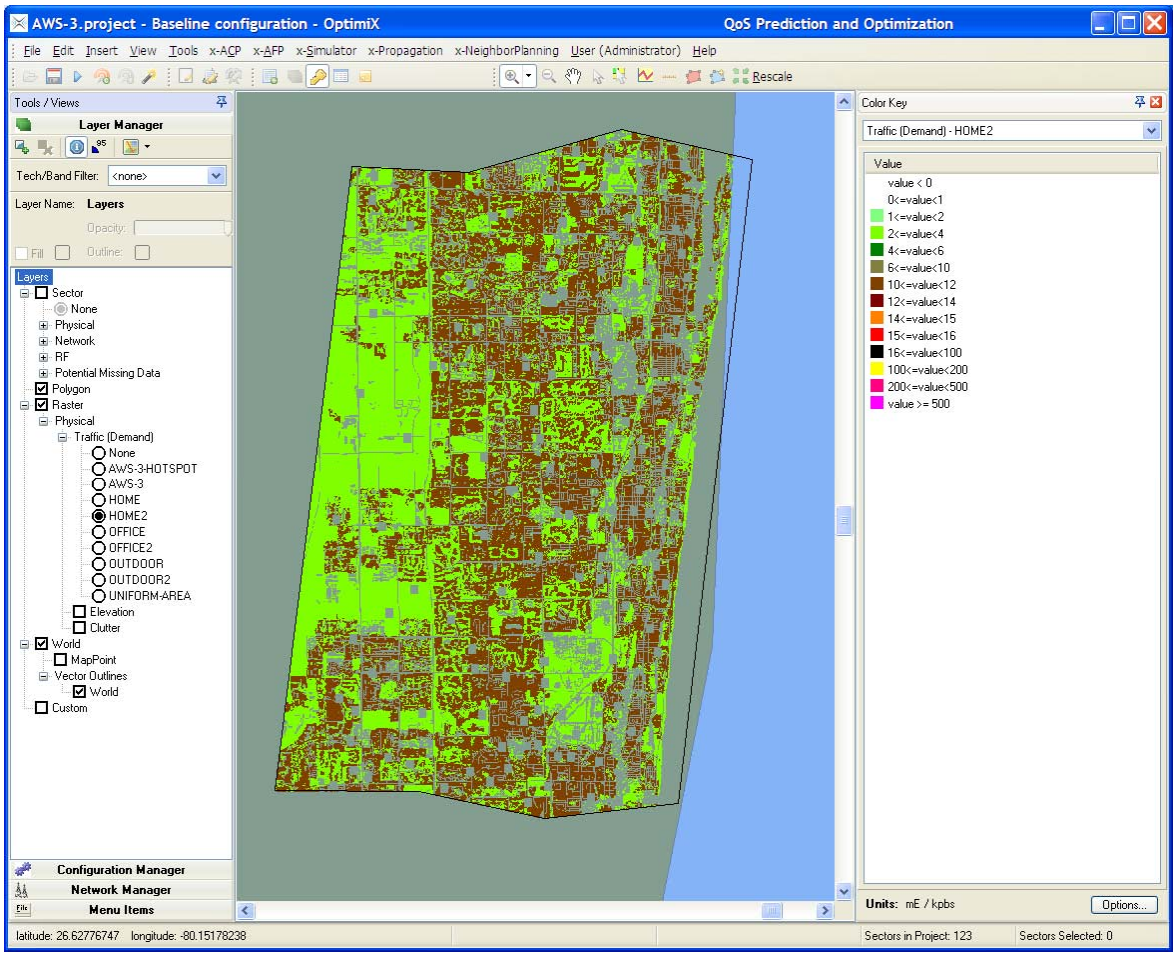

Figure 6. Home traffic map (version B)

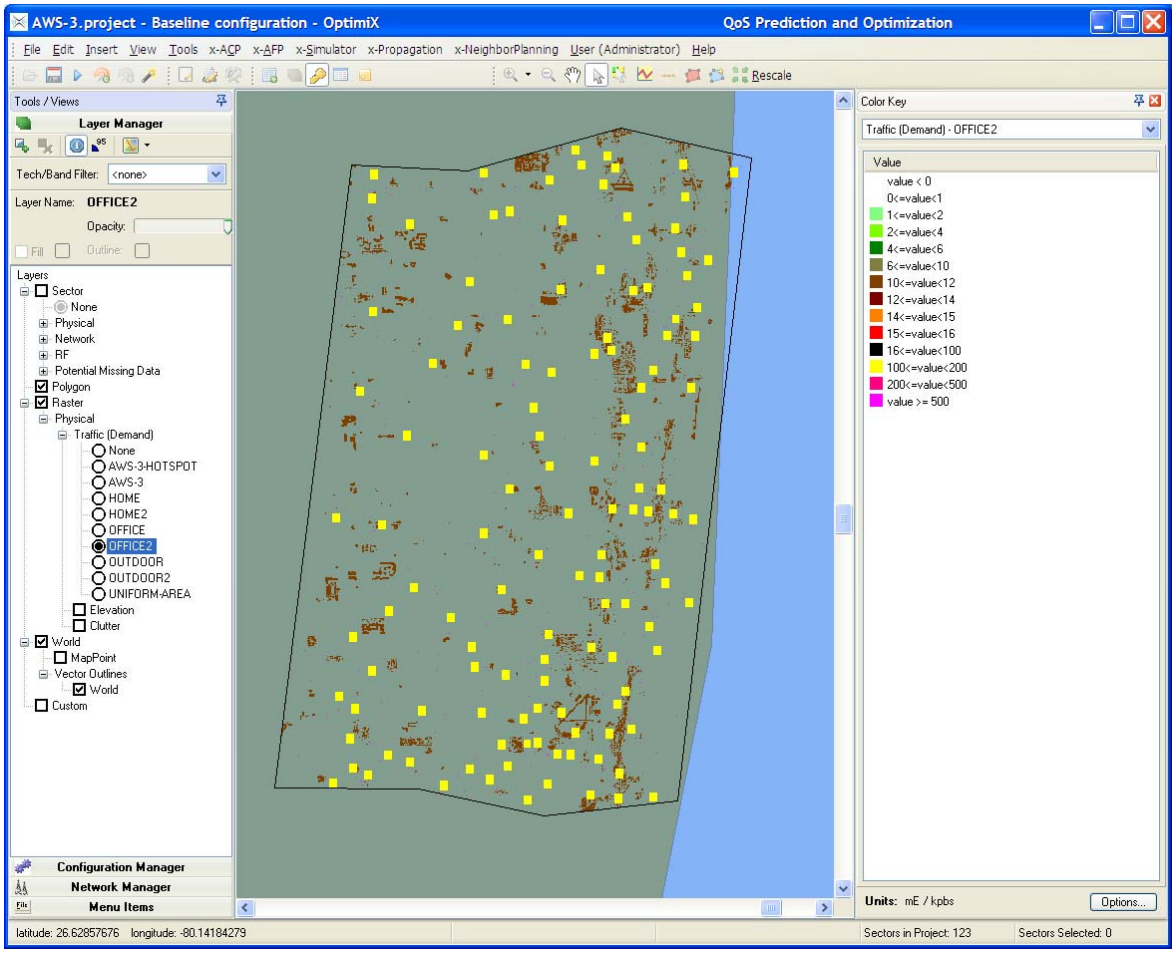

Figure 7. Office traffic map (version B)

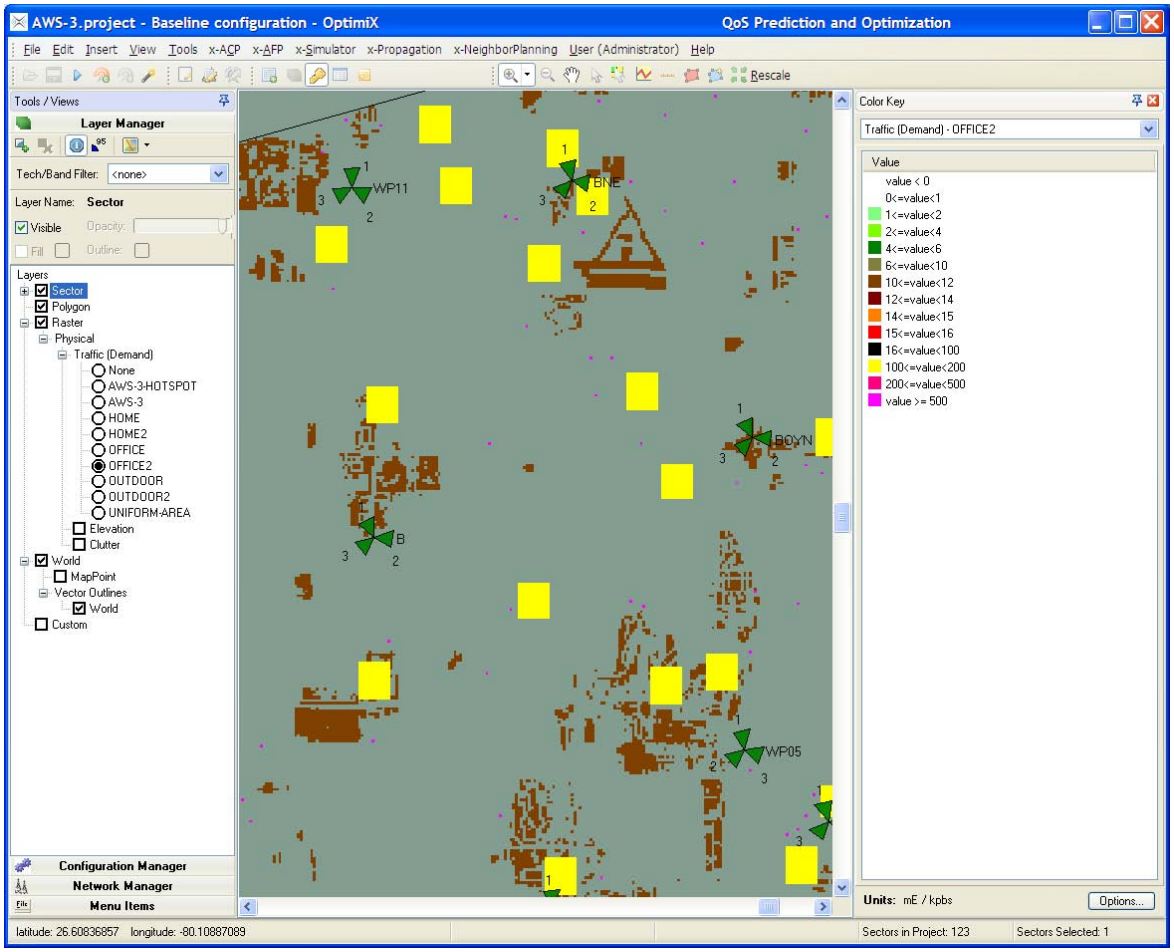

Figure 8. Office traffic map (zoomed in, version B)

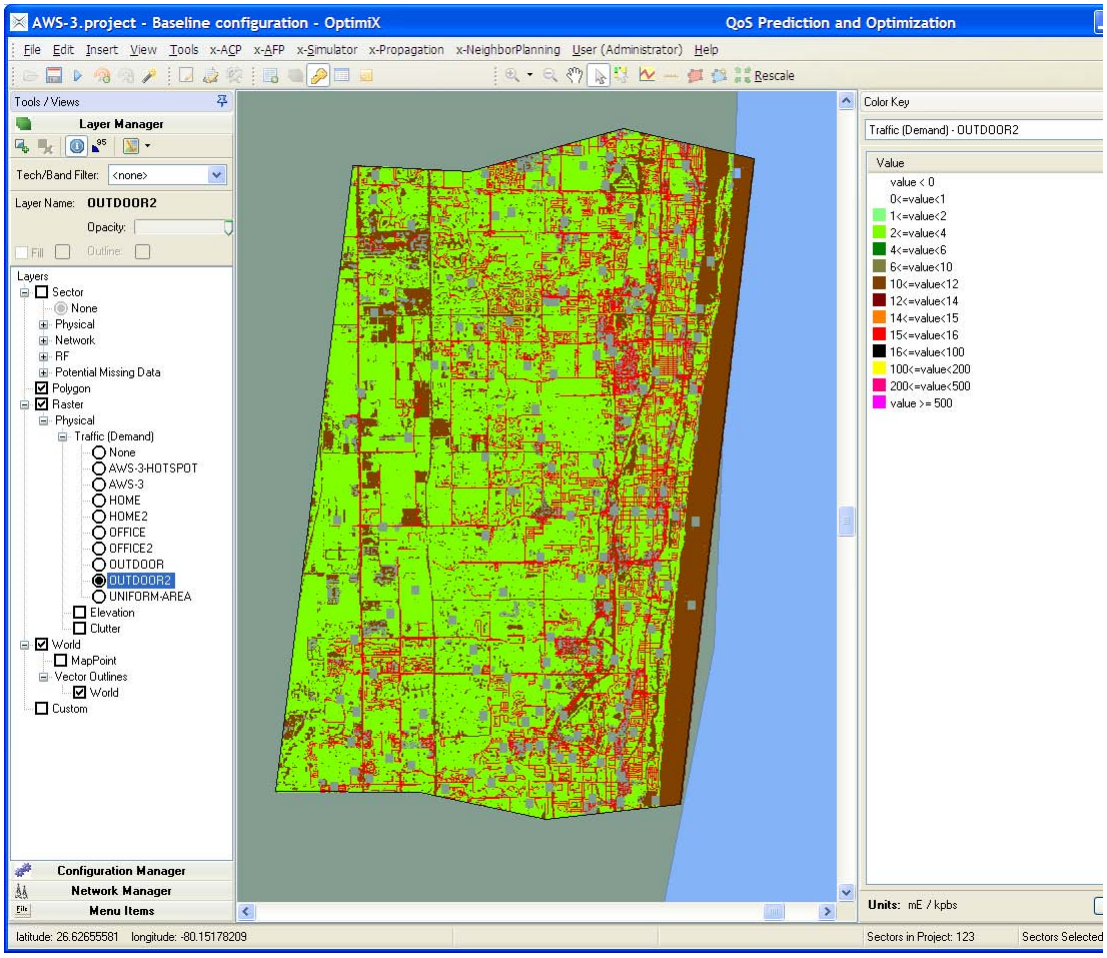

Figure 9. Outdoor traffic map (version B)

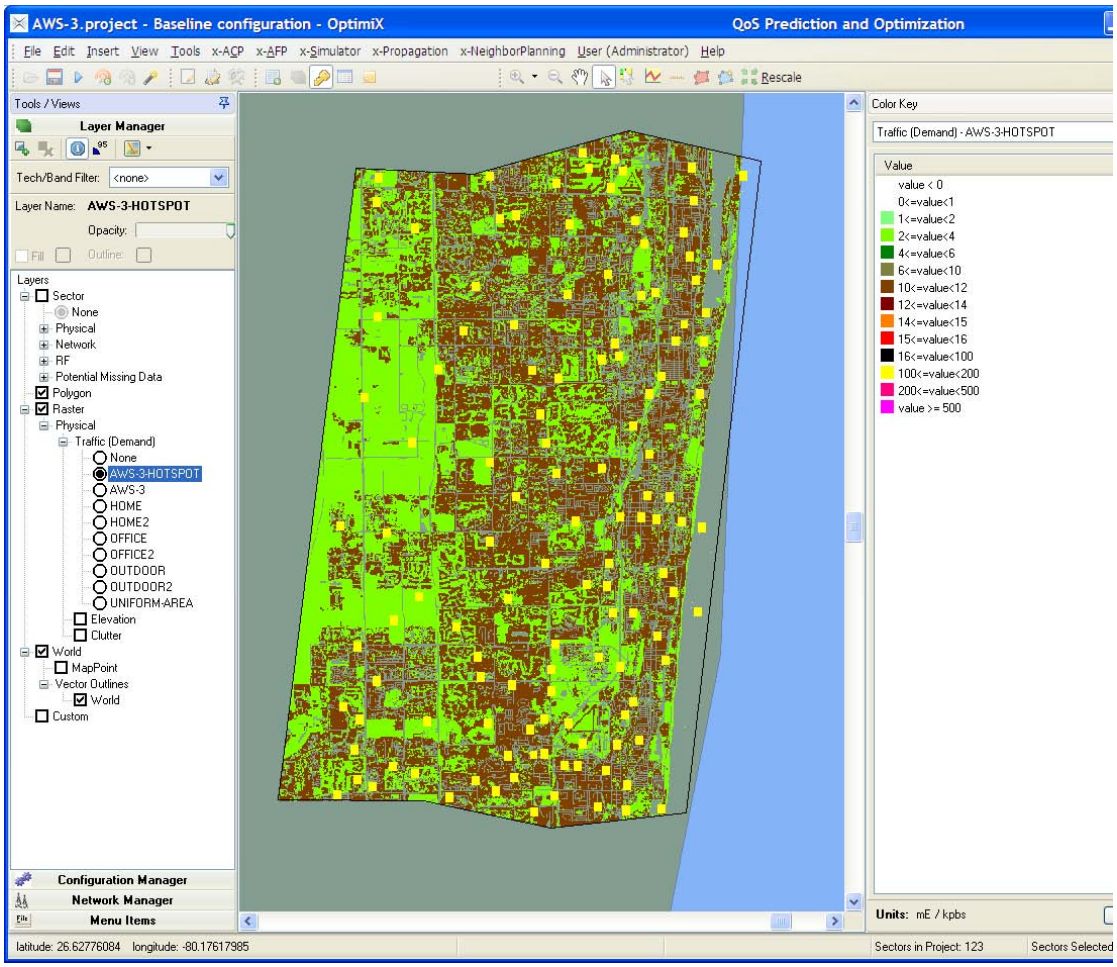

Figure 10. AWS-3 traffic map (version B)

2.4.5. Penetration losses

The model for penetration losses that was described in section 2.3.2 has been parameterised in the following way for this study:

- *distanceBetweenWalls = 4 meters*
- *penetrationLossPerWall = 5 dB*

2.4.6. Out of Band Emissions (OOBE)

The model described in section 2.3.3 has been applied and, according to T-Mobile's indications, the value of X_{OOBE} has been assumed to equal 53 dB.

2.4.7. Adjacent Channel Interference

The model described in section 2.3.4 has been applied and, according to T-Mobile's indications, the following parameter values have been selected for the simulations:

- *Thd1 = -44 dBm*
- *Thd2 = -27 dBm*
- *X_{ADJ1} = 68 dB*
- *X_{ADJ2} = 46 dB*

2.4.8. Modeling the transmit power from the AWS-3 mobiles

Following the selection presented in section 2.3.5, the transmit power for the AWS-3 transmitters has been assumed to be dependent on the UMTS RSCP, according to the provided look-up table, with a maximum value of 36 dBm.

2.4.9. AWS-3 interference attenuation due to activity factor

Based on the results from the lab measurements carried out by T-Mobile, no additional attenuation will be included in the AWS-3 interfering signal that is received by the AWS-1 UMTS mobiles due to activity factor.

2.5 Simulation scenarios

Three different simulation scenarios have been considered. They are described in the following subsections:

2.5.1. Scenario 1

Scenario 1 depicts a theoretical situation with a uniform distribution of traffic in both the AWS-1 and the AWS-3 networks.

AWS-1 UMTS traffic:

- *Traffic type: Voice traffic, 60% activity factor, 12.2 kbps.*
- *Traffic maps and offered load: Uniform traffic map, 5000 Erlangs across the entire simulation area.*

AWS-3 traffic:

- *Traffic type: WiMAX traffic, modelled as a source of transmit power.*
- *Traffic map and offered load: Uniform traffic map, with an offered load in the entire simulation area (O) of 600 Mbps, an activity factor (AF) of 20% and a user data rate when active (R) of 125 kbps. These 600 Mbps are justified by the fact that a WiMAX sector can handle around 5.4 MHz in the uplink. If the WiMAX network is assumed to be collocated with the UMTS network, there will be 123 WiMAX sectors in the simulation area, which yields 664 Mbps.*

2.5.2. Scenario 2

Scenario 2 depicts a realistic situation with some of the traffic of both the AWS-1 and AWS-3 networks concentrating in hot spots. This scenario represents the typical busy hour within regular business hours.

AWS-1 UMTS traffic:

- *Traffic type: Voice traffic, 60% activity factor, 12.2 kbps.*
- *Traffic maps and offered load: Home traffic map (version B, with 1500 Erlangs across the entire simulation area), Office traffic map (version B, with 1500 Erlangs across the entire simulation area) and Outdoor traffic map (version B, with 2000 Erlangs across the entire simulation area), all of them simulated simultaneously. Note that version B is the one handling hot spots.*

AWS-3 traffic:

- *Traffic type: WiMAX traffic, modelled as a source of transmit power.*
- *Traffic map and offered load: AWS-3 traffic map (version B), with an offered load in the entire simulation area (O) of 600 Mbps, an activity factor (AF) of 20% and a user data rate when active (R) of 125 kbps. Note that version B is the one handling hot spots. These 600 Mbps are justified by the fact that a WiMAX sector can handle around 5.4 MHz in the uplink. If the WiMAX network is assumed to be collocated with the UMTS network, there will be 123 WiMAX sectors in the simulation area, which yields 664 Mbps.*

2.5.3. Scenario 3

Scenario 3 depicts a realistic situation with neither of the two networks carrying office traffic. This scenario represents the typical evening busy hour when users have left their workplace and concentrate around home and outdoor areas.

AWS-1 UMTS traffic:

- *Traffic type: Voice traffic, 60% activity factor, 12.2 kbps.*
- *Traffic maps and offered load: Home traffic map (version A, with 3000 Erlangs across the entire simulation area) and Outdoor traffic map (version A, with 2000 Erlangs across the entire simulation area), both of them simulated simultaneously.*

AWS-3 traffic:

- *Traffic type: WiMAX traffic, modelled as a source of transmit power.*
- *Traffic map and offered load: AWS-3 traffic map (version A), with an offered load in the entire simulation area (O) of 600 Mbps, an activity factor (AF) of 20% and a user data rate when active (R) of 125 kbps. These 600 Mbps are justified by*

the fact that a WiMAX sector can handle around 5.4 MHz in the uplink. If the WiMAX network is assumed to be collocated with the UMTS network, there will be 123 WiMAX sectors in the simulation area, which yields 664 Mbps.

3. Simulation results

For each one of the proposed scenarios, two simulations have been carried out: one with AWS-3 interference and another one without interference. For each pair of simulations, the potential degradation in the percentage of offered traffic that the network is capable of serving has been computed in order to assess whether the interference that is introduced by AWS-3 mobiles is truly harmful when looking at the performance from a system level perspective. Such evaluation has been conducted in three ways:

- *Performance metric #1: looking at the overall capacity and service performance degradation on a global level and on a per-clutter type basis measured as the relative difference in carried traffic between both scenarios. I.e., 5.3% of the traffic initially carried by the AWS-1 network is lost due to the interference created by the AWS-3 terminals."*
- *Performance metric #2: looking at the absolute difference in the percentage of home users that, having at least one AWS-3 transmitter in their same pixel on in the first tier of surrounding pixels, have lost their UMTS connection when introducing the AWS-3 service. This information is presented in the following way:*
    - *Home users with at least one interferer within 15 meters*
    - *Home users with at least one interferer within 45 meters*
- *Performance metric #3: looking at the capacity and service performance degradation on a per-sector basis (presented as a per-sector bar chart, as well as in the form of a cumulative probability function that allows to assess the percentage of sectors that face a degradation that is lower or equal than the degradation values presented at the X axis) measured as the relative difference in the percentage of users who could not be serviced by the AWS-1 network*

3.1.1. Performance metric #1

Overall capacity and service performance degradation on a global level and on a per-clutter type basis. Note that, in this context, a positive number means degradation (i.e. worse performance).

- *Theoretical uniform traffic distribution: 3.8%*
- *Realistic business hour traffic distribution: 3.1%*
    - *Home users: 7.4%*
    - *Office and hot spot users: 4.3%*
    - *Outdoor users: -0.8%*
- *Realistic evening hour traffic distribution: 5.3%*
    - *Home users: 10.6%*
    - *Outdoor users: -2.4%*

3.1.2. Performance metric #2

Absolute difference in the percentage of home users that, having an AWS-3 transmitter in their same pixel on in the first tier of surrounding pixels, have lost their UMTS connection when introducing the AWS-3 service:

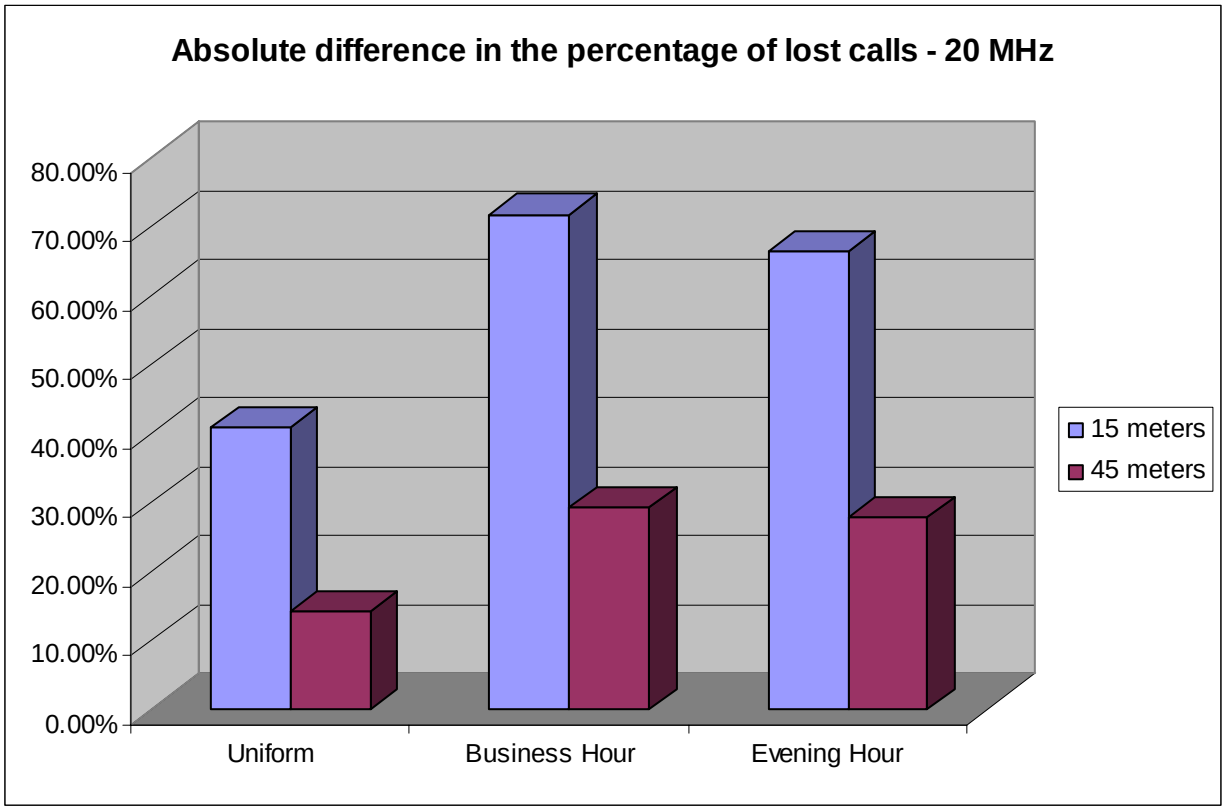

Figure 11. Capacity degradation for home users close to an AWS-3 transmitter

3.1.3. Performance metric #3

This metric describes capacity and service performance degradation on a per-sector basis. Note that, in this context, a positive number means degradation (i.e. worse performance).

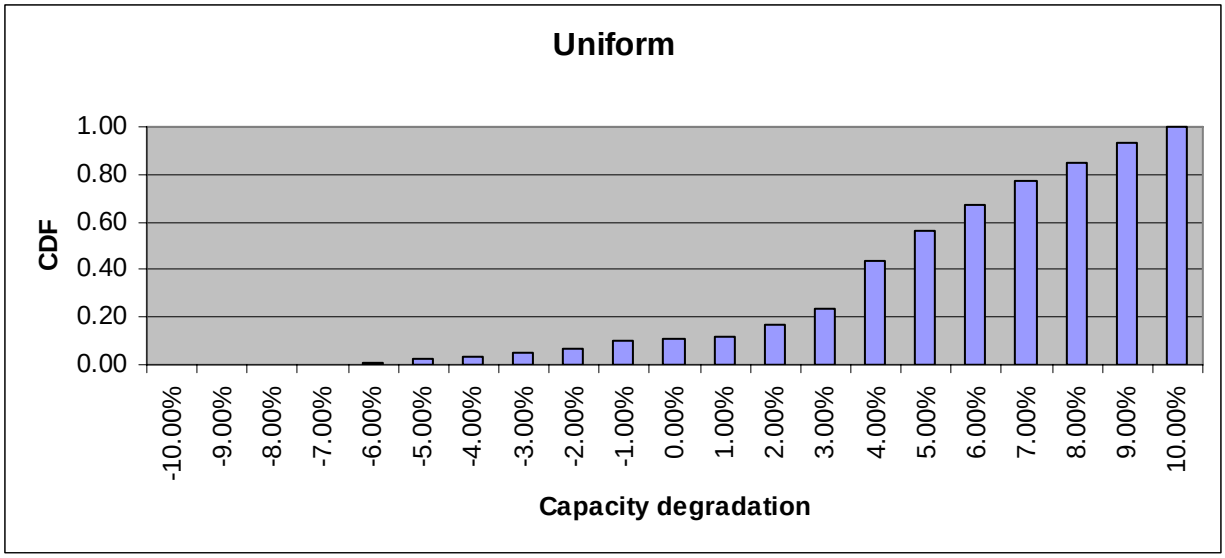

Figure 12. CDF of the capacity degradation on a per-sector basis for scenario 1

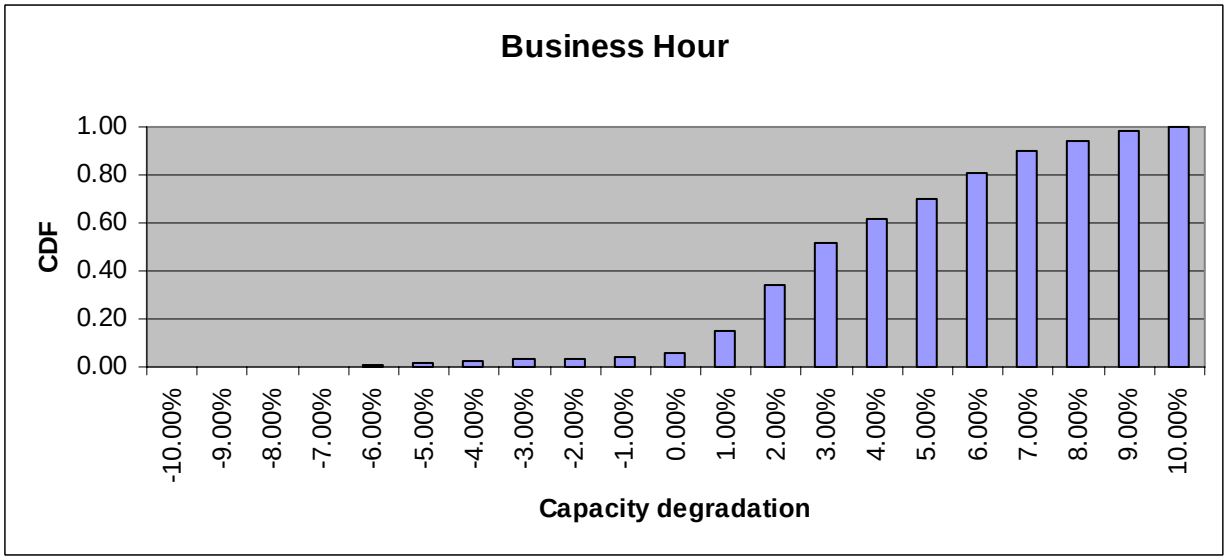

Figure 13. CDF of the capacity degradation on a per-sector basis for scenario 2

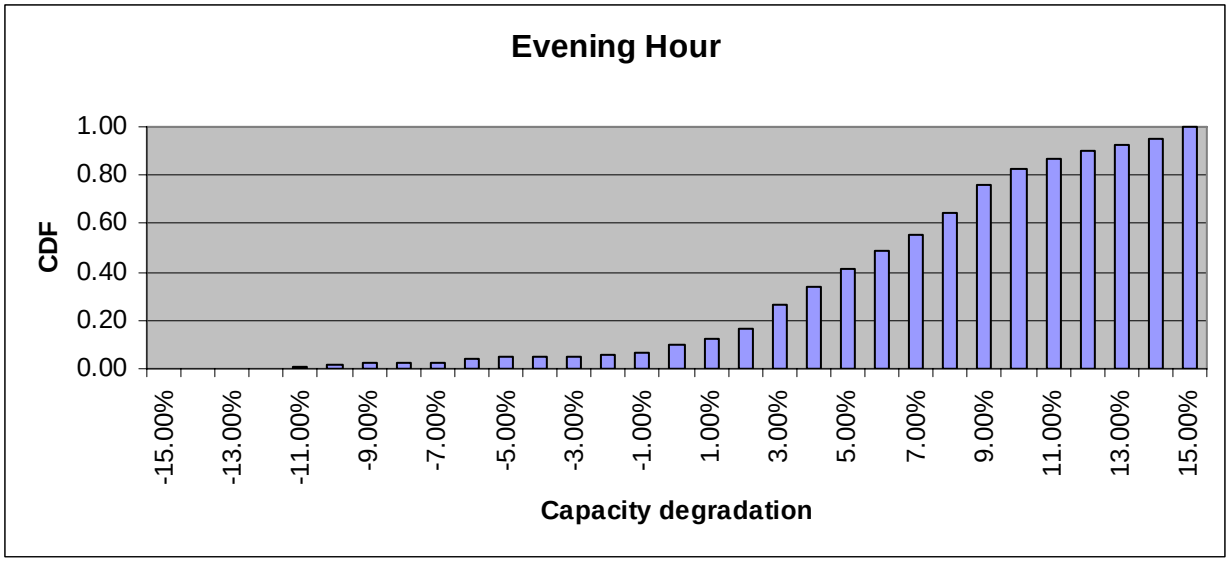

Figure 14. CDF of the capacity degradation on a per-sector basis for scenario 3

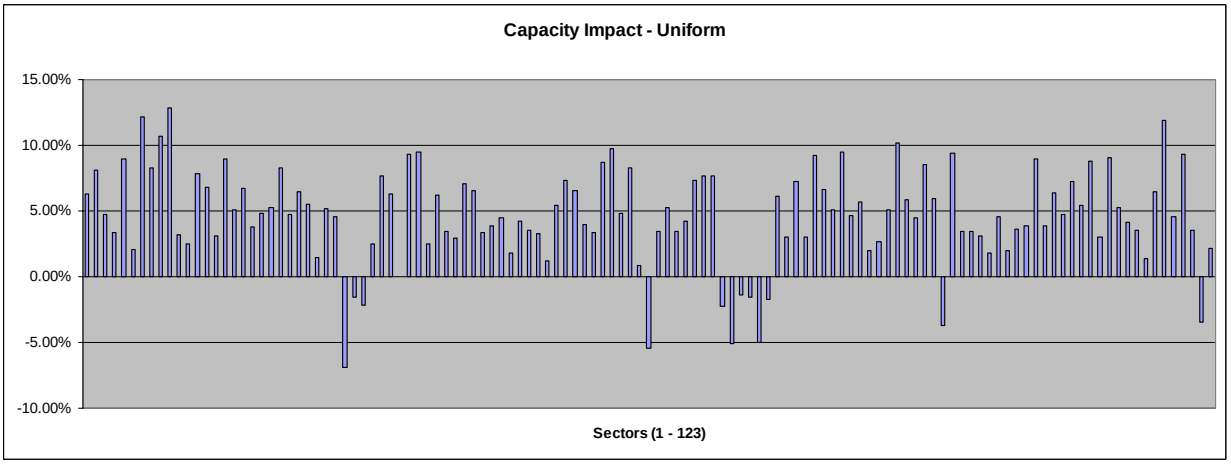

Figure 15. Per-sector capacity degradation for scenario 1

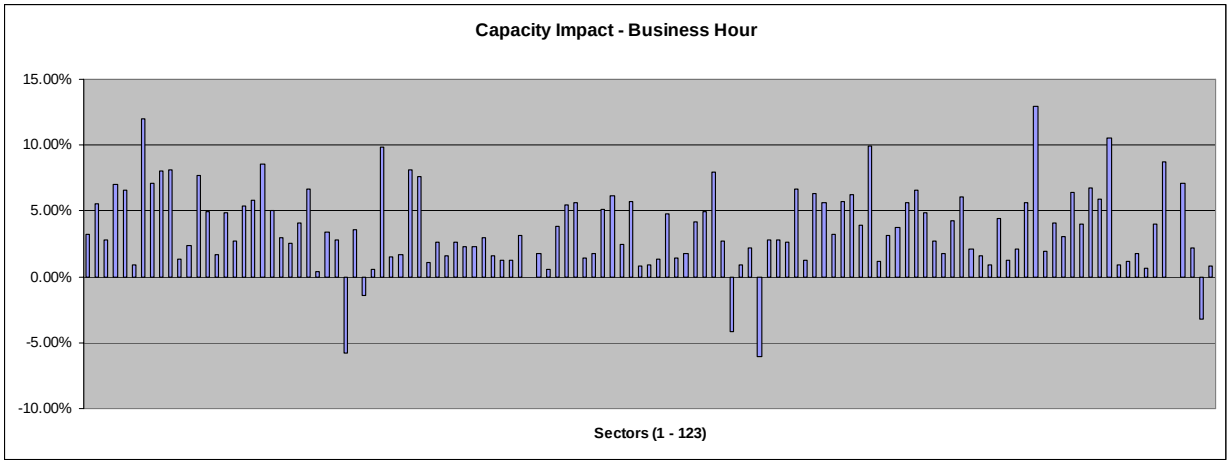

Figure 16. Per-sector capacity degradation for scenario 2

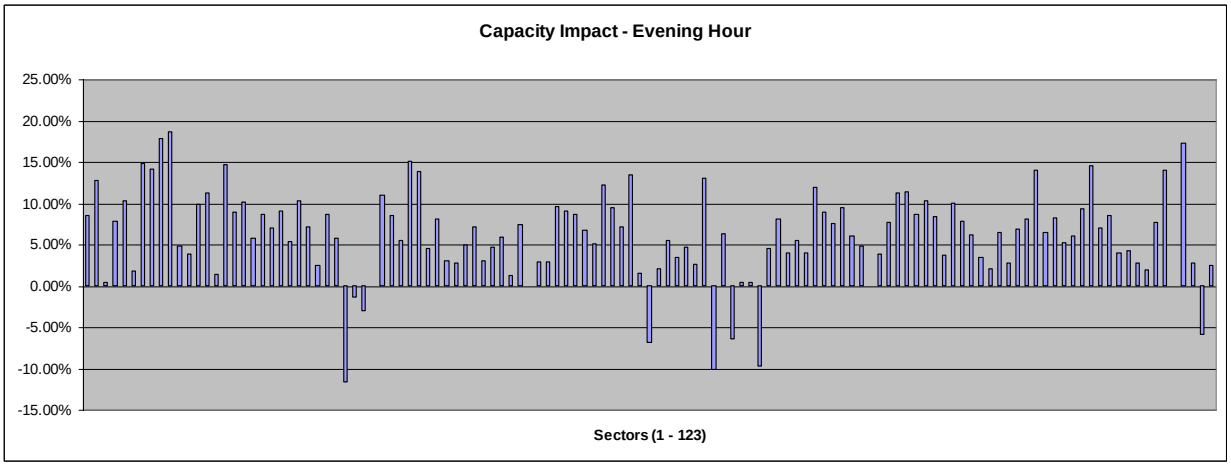

Figure 17. Per-sector capacity degradation for scenario 3

4. Concluding remarks

A range of reasonable scenarios has been tested, and several user profiles are analyzed simultaneously (home, office and outdoor). Depending on the assumptions (all of them reasonable) the overall system capacity loss can range between 3.1% and 5.3%, although the capacity loss for home users can reach 10.6%.

A further drill down on the data shows that AWS-1 home users with an AWS-3 transmitter nearby (e.g. at home or at a neighbor's house and not necessarily being one meter away from the transmitter) will suffer significant losses:

- *Up to 66.40% of AWS-1 home users lost service with at least one AWS-3 user within 15 meters*

- *Up to 27.80% of AWS-1 home users lost service with at least one AWS-3 user within 45 meters*

Therefore, it can be concluded UMTS subscribers that have an AWS-3 in their surroundings (e.g. at home or at a neighbor's house and not necessarily being one meter away from the transmitter) may suffer from a severe degradation in their UMTS service.

5. Annex A: Scenarios for 10 MHz and 5 MHz AWS-3 deployments

5.1 Description

The study done by Optimi has focused on the most likely scenario for the deployment of a TDD based broadband wireless network on the AWS-3 band which assumes the usage of 20 MHz for one single carrier.

The wireless industry is moving towards using 20 MHz for one single carrier whenever possible for multiple reasons, including the increased service performance offered by the higher peak data rates and the reduction of CAPEX associated with the network deployment.

Economically, it is significantly more expensive to operate with multiple smaller carriers with a bandwidth of 5 MHz or 10 MHz since it requires the installation of 4 or 2 carriers respectively in each base station compared with the installation of one single carrier per base station when operating with one single carrier on a bandwidth of 20 MHz.

Nevertheless, T-Mobile USA has requested Optimi to include also scenarios for operations with a carrier bandwidth of 10 MHz and 5 MHz. The results for these scenarios are presented in this Annex using the same performance metrics described in section 3.

Optimi has focused on the scenario 3 described in section 2.5.3 that depicts a realistic situation with neither of the two networks carrying office traffic. This scenario represents the typical evening busy hour when users have left their workplace and concentrate around home and outdoor areas.

The key parameters and assumptions considered for the simulations done for these scenarios are similar to the ones presented in section 2.4 with the exception of the modeling of the receiver saturation mechanism that has been adjusted to the new carrier bandwidth.

For a carried bandwidth of 5 MHz (as measured in the lab by T-Mobile USA):

- $P_{rxAWS\text{-}3(}$dBm) > -43.2 dBm/5 MHz for UMTS RSCP <= -105 dBm
- $P_{rxAWS\text{-}3(}$dBm) > -34.2 dBm/5 MHz for UMTS RSCP <= -100 dBm
- $P_{rxAWS\text{-}3(}$dBm) > -23.2 dBm/5 MHz for UMTS RSCP <= -90 dBm
- $P_{rxAWS\text{-}3(}$dBm) > -20.2 dBm/5 MHz for UMTS RSCP <= -85 dBm

For a carrier bandwidth of 10 MHz (inferred from measurements in the lab for 5 MHz and 20 MHz):

- $P_{rxAWS\text{-}3(}$dBm) > -36.0 dBm/10 MHz for UMTS RSCP <= -105 dBm
- $P_{rxAWS\text{-}3(}$dBm) > -31.0 dBm/10 MHz for UMTS RSCP <= -100 dBm
- $P_{rxAWS\text{-}3(}$dBm) > -23.2 dBm/10 MHz for UMTS RSCP <= -90 dBm
- $P_{rxAWS\text{-}3(}$dBm) > -20.2 dBm/10 MHz for UMTS RSCP <= -85 dBm

Note that simple linear interpolation will be applied for values that fall in between the specified thresholds.

5.2 Performance metric #1

Overall capacity and service performance degradation on a global level and on a per-clutter type basis. Note that, in this context, a positive number means degradation (i.e. worse performance):

- *Carrier with 10 MHz: 3.8%*
  - *Home users: 7.8%*
  - *Outdoor users: -1.8%*
- *Carrier with 5 MHz: 2.7%*
  - *Home users: 5.7%*
  - *Outdoor users: -1.3%*

5.3 Performance metric #2

Absolute difference in the percentage of home users that, having an AWS-3 transmitter in their same pixel on in the first tier of surrounding pixels, have lost their UMTS connection when introducing the AWS-3 service:

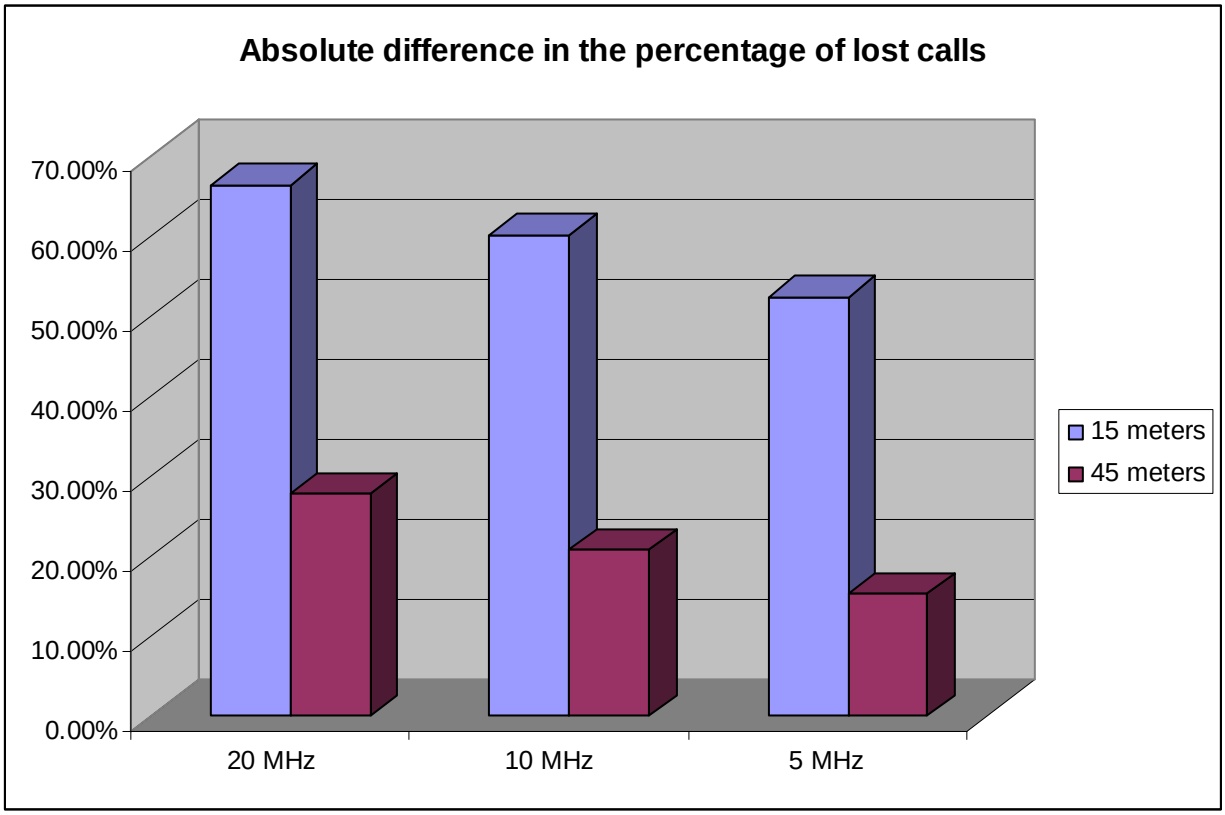

Figure 18. Capacity degradation for home users close to an AWS-3 transmitter

5.4 Performance metric #3

This metric describes capacity and service performance degradation on a per-sector basis. Note that, in this context, a positive number means degradation (i.e. worse performance).

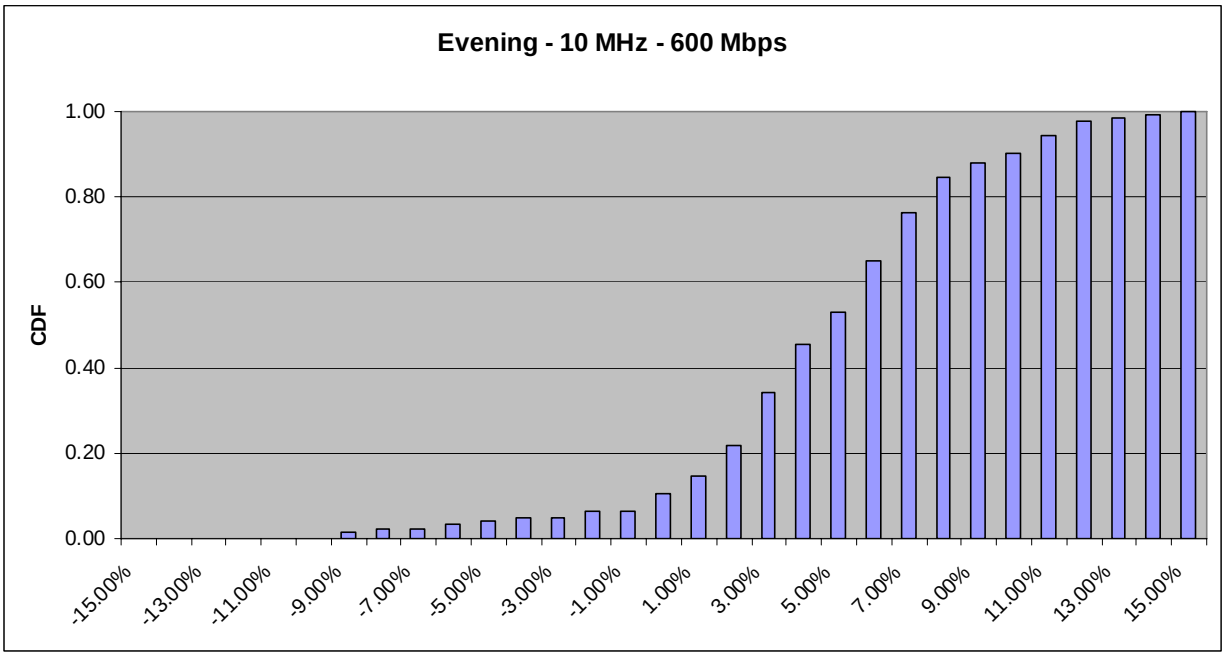

Figure 19. CDF of the capacity degradation on a per-sector basis with 10 MHz

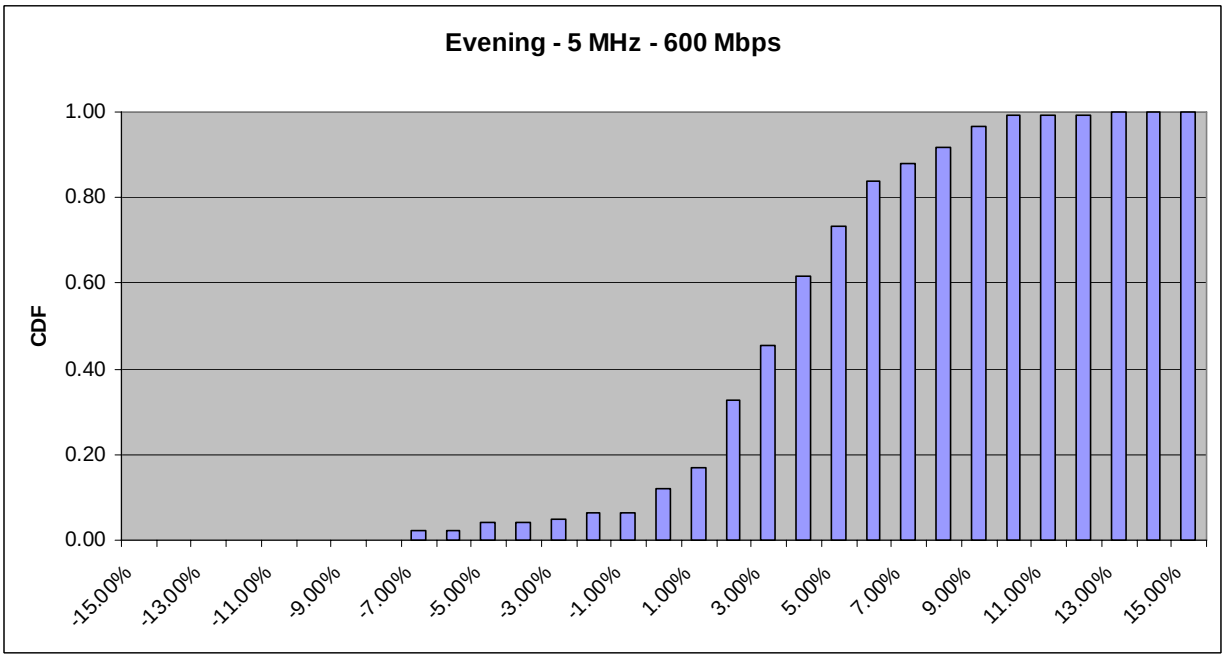

Figure 20. CDF of the capacity degradation on a per-sector basis with 5 MHz

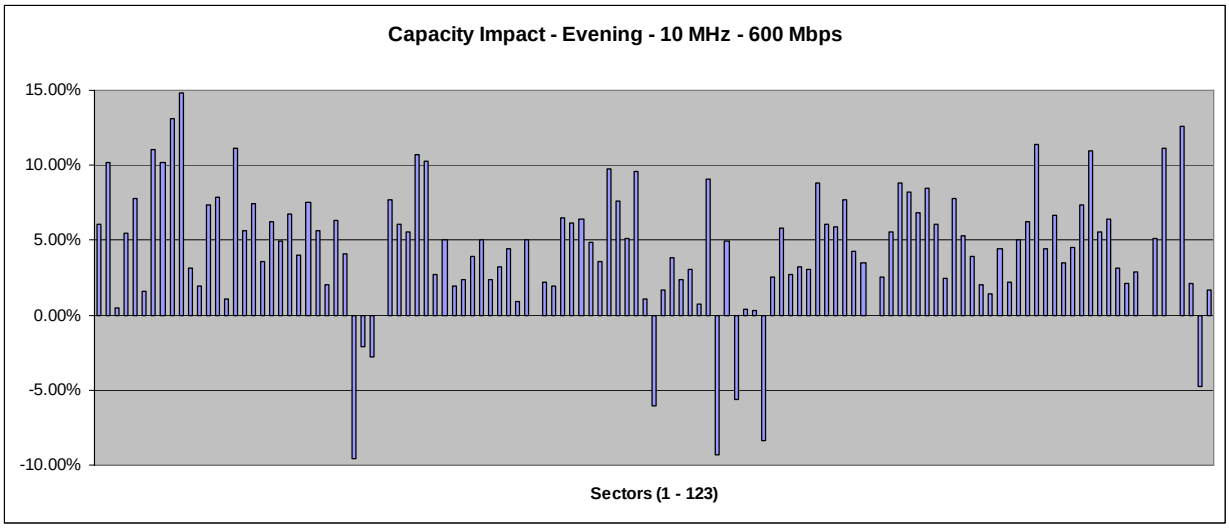

Figure 21. Per-sector capacity degradation with 10 MHz

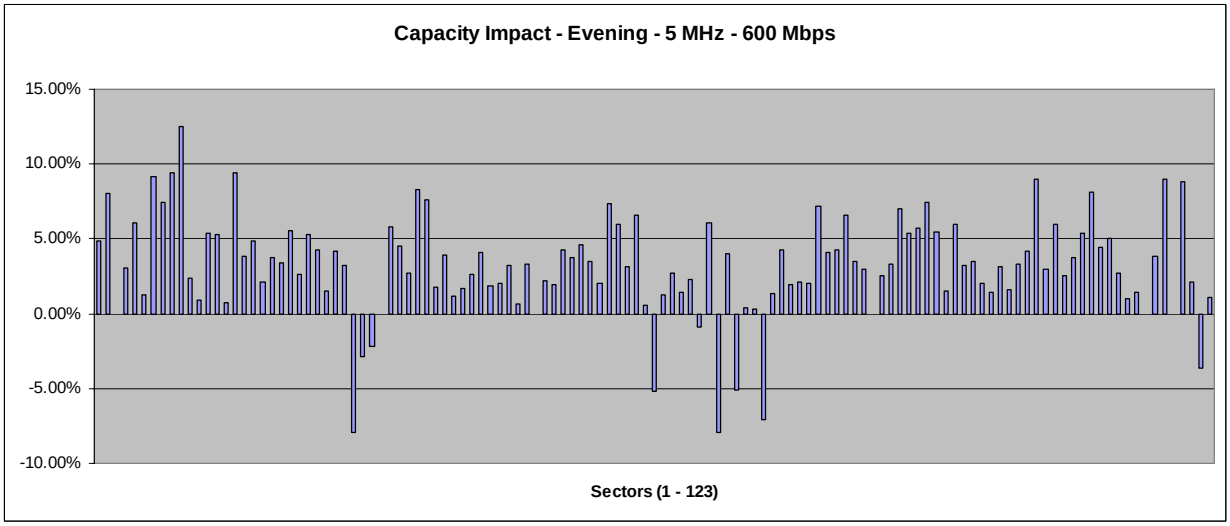

Figure 22. Per-sector capacity degradation with 5 MHz

6. Annex B: Optimi's UMTS Monte Carlo simulation solution

6.1 Main features

As compared with dynamic simulators, a semi-dynamic simulation solution does not include the time dimension in an explicit manner, and evaluates the radio performance of the network by assessing a set of standstill snapshots of the radio interface when it has reached a state of equilibrium. As input, the semi-dynamic simulator takes the following information from the RF planning solution:

- *Propagation data (path-loss predictions)*
- *Traffic map*
- *Network topology and configuration*
- *Services model: service mix, bit rates, Eb/No targets, etc…*
- *Resources dedicated to HSDPA (downlink transmission power, channelization codes)*
- *Characterization of the HSDPA receivers (Es/No req.'s for the different TFRC, etc.)*

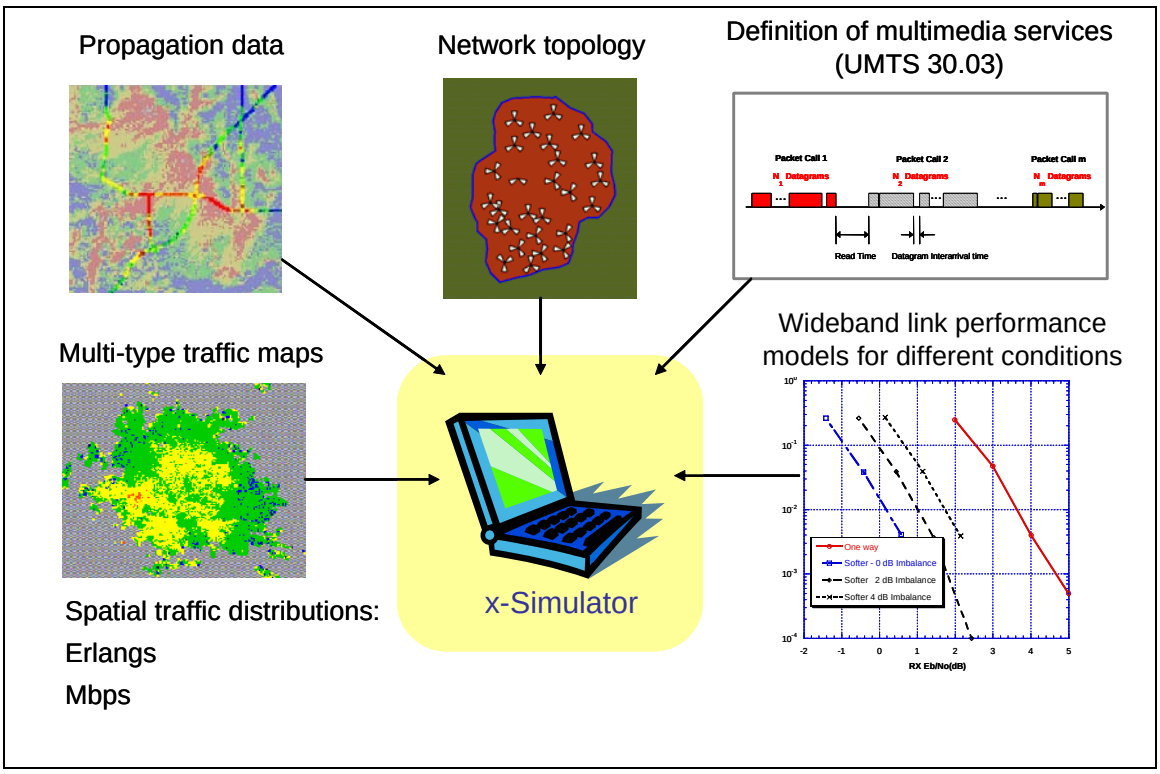

Figure 23. Inputs to the UMTS static simulator

Based on these inputs, the static simulator evaluates a configurable number of independent user distributions and provides output statistics that characterize the system radio performance at different levels. The performance assessment is done by

means of full-blown static simulations, which are composed of a complete set of accurate calculations that do not involve any approximation, over-assumption or shortcut. As a consequence, the calculation process remains accurate even for high system loads, for which the application of some commercial analytical models becomes less accurate. The simulation engine that conducts the aforementioned calculations has the following characteristics:

- *Static Monte Carlo simulation engine*
- *Explicit and accurate HSDPA modeling, apart from the interaction between HSDPA and R99*
- *Support for a configurable mix of simulation profiles:*
    - *Multiple traffic maps and multiple User Equipment (UE) types*
    - *Configurable mix of services (Radio Access Bearers)*
    - *Possibility to simulate asymmetrical RABs*
    - *Each simulation profile can be associated with a different set of design parameters: Spatial distribution, temporal distribution, UE parameters (noise figure, power of the amplifier, etc.), RF penetration loss…*
- *Built-in Eb/No vs. BLER curves*
- *Built-in set of Es/No vs. BLER lookup tables (for HSDPA support)*
- *Power Control embedded in the executed calculations (For the UMTS R99 territory)*
- *Sector by sector Admission Control and Load Control policy*
- *Soft and softer handover accurately modeled and computed*
    - *Maximal Ratio Combining in downlink for soft handover*
    - *Maximal Ratio Combining for uplink softer handover*
    - *Selection Combining for uplink soft handover*

After the execution of the simulation, a comprehensive set of output reports are available.

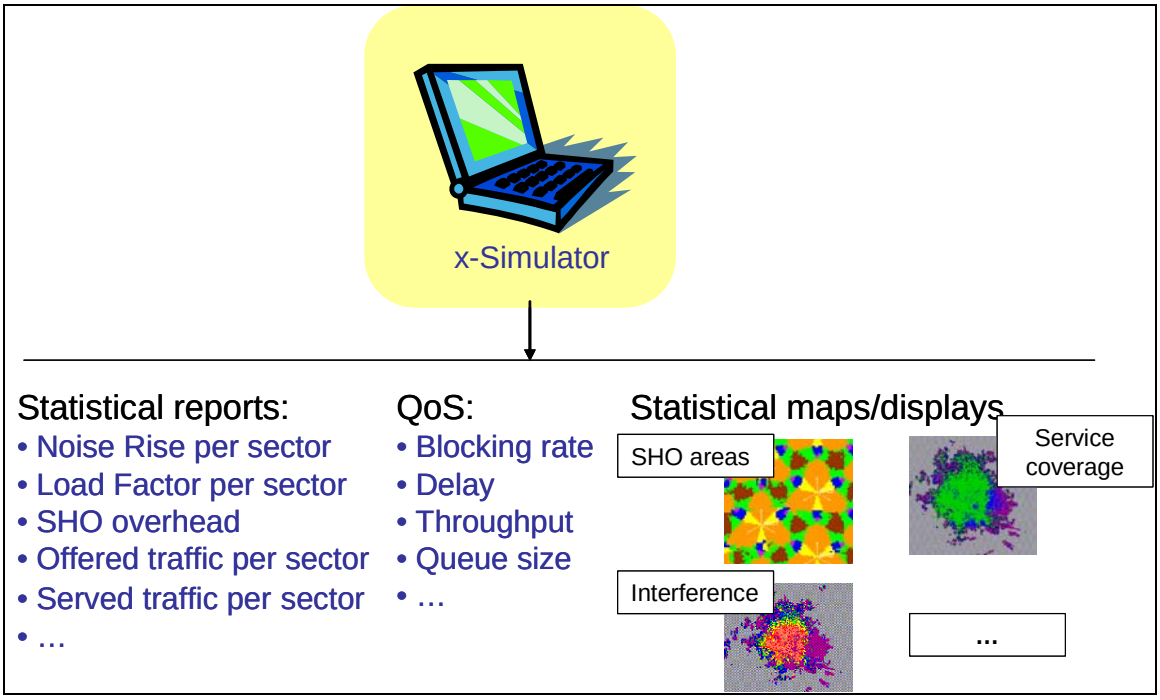

Figure 24. Outputs of the UMTS static simulator

6.2 Simulation profiles

A simulation profile can be looked as a service type offered in the UMTS network. Each simulation profile includes a traffic demand grid, a user equipment type, radio access bearer(s) on each link, and penetration margin. A simulation profile can be created with the menu that is shown in the following Figure.

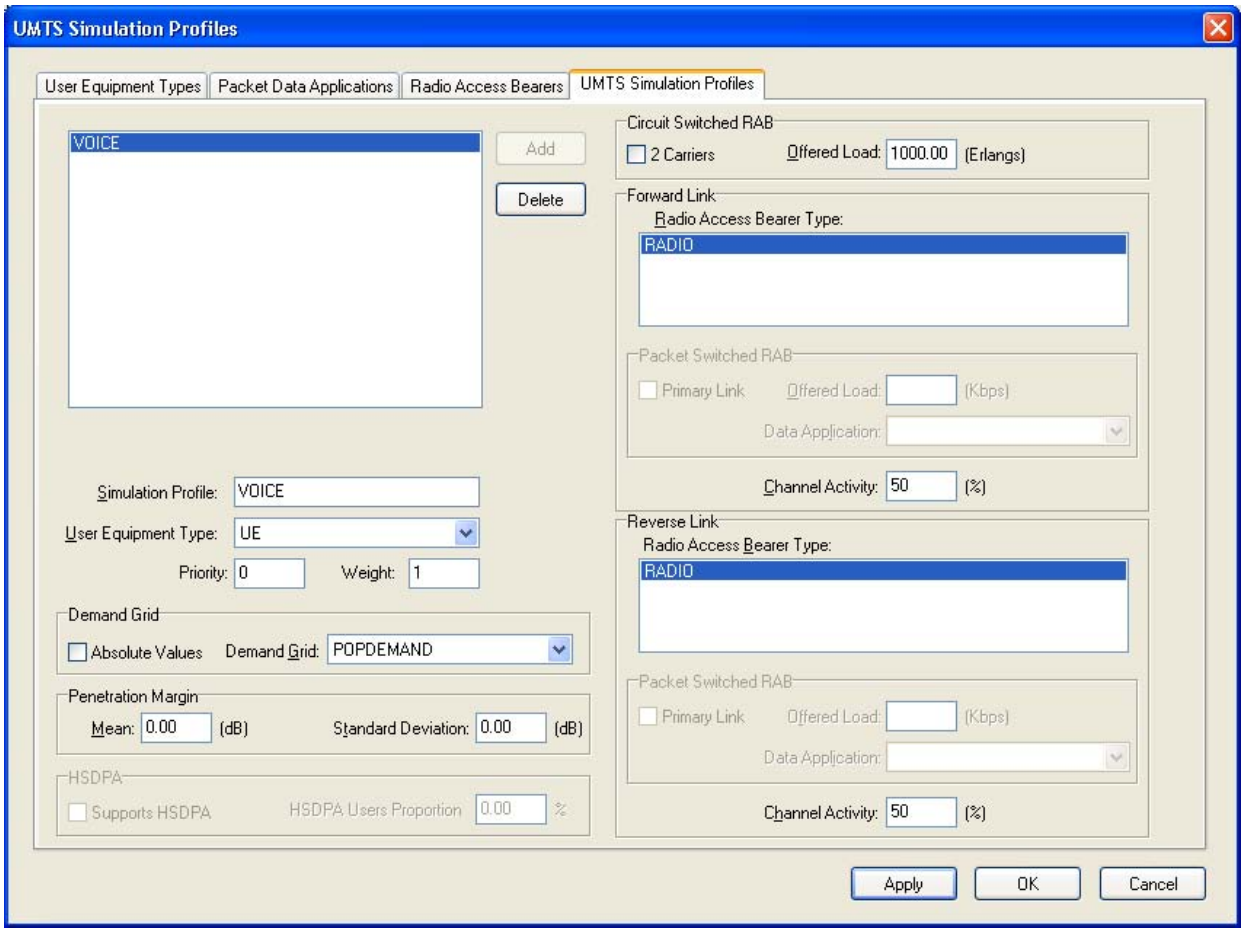

Figure 25. Editing simulation profiles

The following summarizes the simulation profile parameters:

- *User Equipment Type: Select one of the previously defined user equipment types.*
- *DL & UL RABs: Select the RAB for the forward link and reverse link and the percentage of channel activity on each link. For example, for voice the channel activity for both links is typically 50%.*
- *Offered Load: This setting represents the total offered traffic to the network (Erlang or Data throughput in Kbps) that will be spread according to the Demand Grid that is used only as a relative demand. This allows for extra flexibility to scale traffic given a certain traffic distribution pattern.*
- *Demand Grid: Select one of the traffic demand distributions previously imported or created.*

- *Penetration Margin: (Mean and Standard Deviation) This parameter represents the additional loss due to, for example, in-building penetration in the case of an indoor service, or in-car penetration in an in vehicle environment. If this additional loss is already part of the PLOSS imported then the Mean penetration margin can be set to zero and only the penetration Standard Deviation would need to be defined.*

- *HSDPA: If the Simulation Profile being edited or added supports HSDPA check the "Supports HSDPA" checkbox and specify the proportion of HSDPA users that will be using the Simulation Profile (or Radio Access Bearer).*

6.2.1. User equipments

Different services offered in a UMTS network may require the use of different user equipment types, such as voice users, video telephony users, web browsing user, etc. A User Equipment Type can be created by means of the menu depicted below.

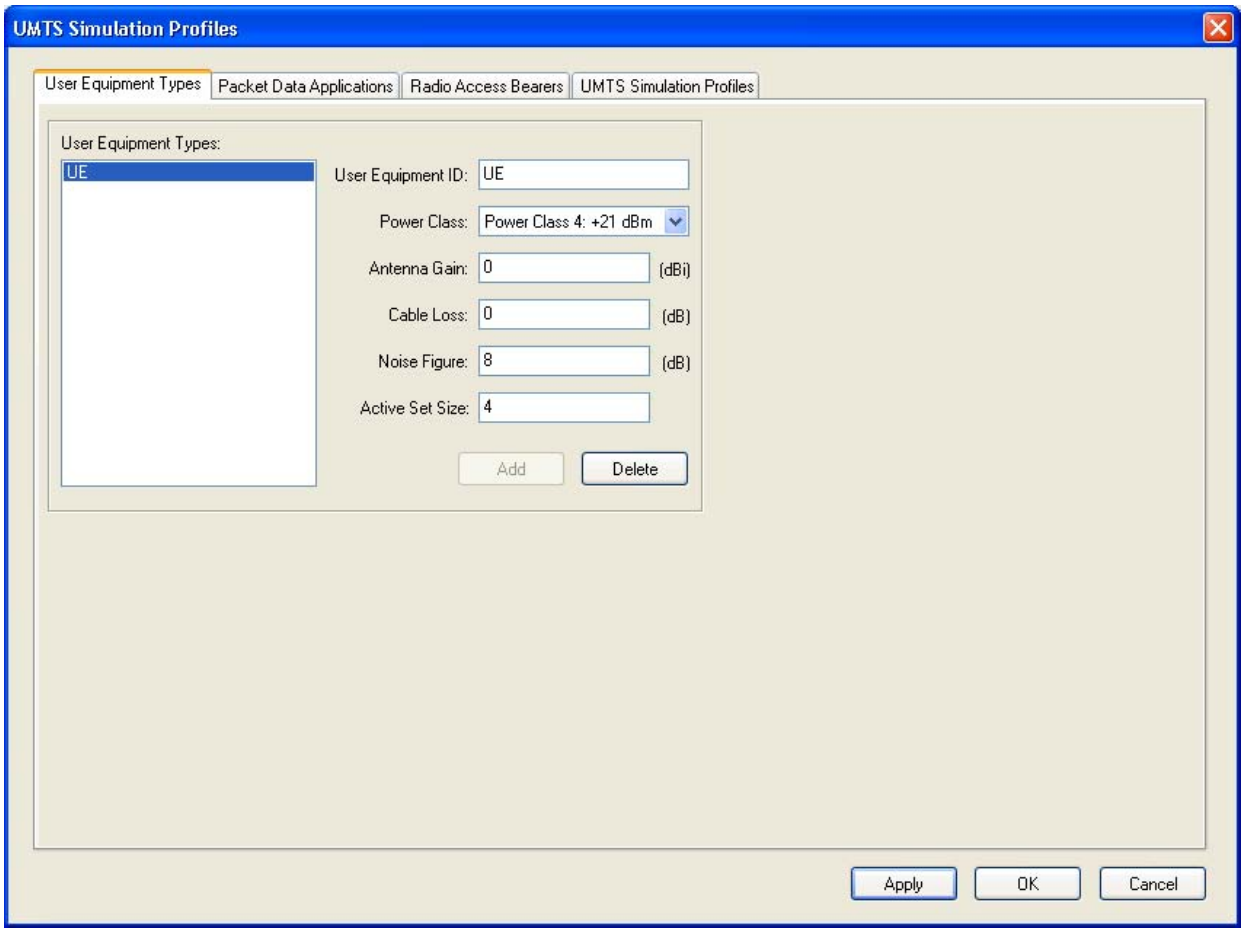

Figure 26. User Equipment types

In that menu, the following attributes can be specified:

- *Power Class (dBm): Choose from available options.*
- *Antenna Gain (dB): Specify the antenna gain for the selected equipment.*
- *Cable Loss (dB): Specify the cable loss for the selected equipment, including body/head losses.*
- *Noise Figure (dB): Specify the noise figure for the selected equipment.*

The users can define as many user equipment types as necessary.

6.2.2. Environment related considerations

Optimi's simulator allows the specification of the orthogonality factor on a per-sector basis in order to facilitate accurate modeling of the partial loss of orthogonality between signals under the same scrambling code, which is due to the inherent wideband nature of the wideband channel through which UMTS communication is carried out.

6.3 UMTS specific radio resource management algorithms

The following RRM parameters affect the behavior of the UMTS static simulator:

Maximum Allowed Noise Rise: Indicates the Noise Rise (total wideband received interference / thermal noise) that is tolerable in each cell. Users that make the cell exceed this target will not be admitted during simulations and therefore RF configurations that involve blocking due to this mechanism will not be selected.

- *Addition Window for Soft Handover: Maximum tolerable ratio between the strongest pilot Ec/Io in the active set and a candidate pilot that is intended to be added.*

Maximum Allowed Downlink Loading: Similar to the maximum allowed noise rise in the uplink, but taking the downlink loading as a driving metric and governing downlink capacity and congestion issues.

Maximum Traffic Power Allocation per RAB: Defined relative to the CPICH power for every RAB. It is the maximum allowed power for a RAB of that type. In the simulator, a user that requires more power will be dropped due to quality reasons.

Maximum Active Set Size: defined on a per-UE type basis. It specifies the maximum number of soft handover branches that a UE can have.

CPICH, SCH, PCCPCH and SCCPCH power allocations.

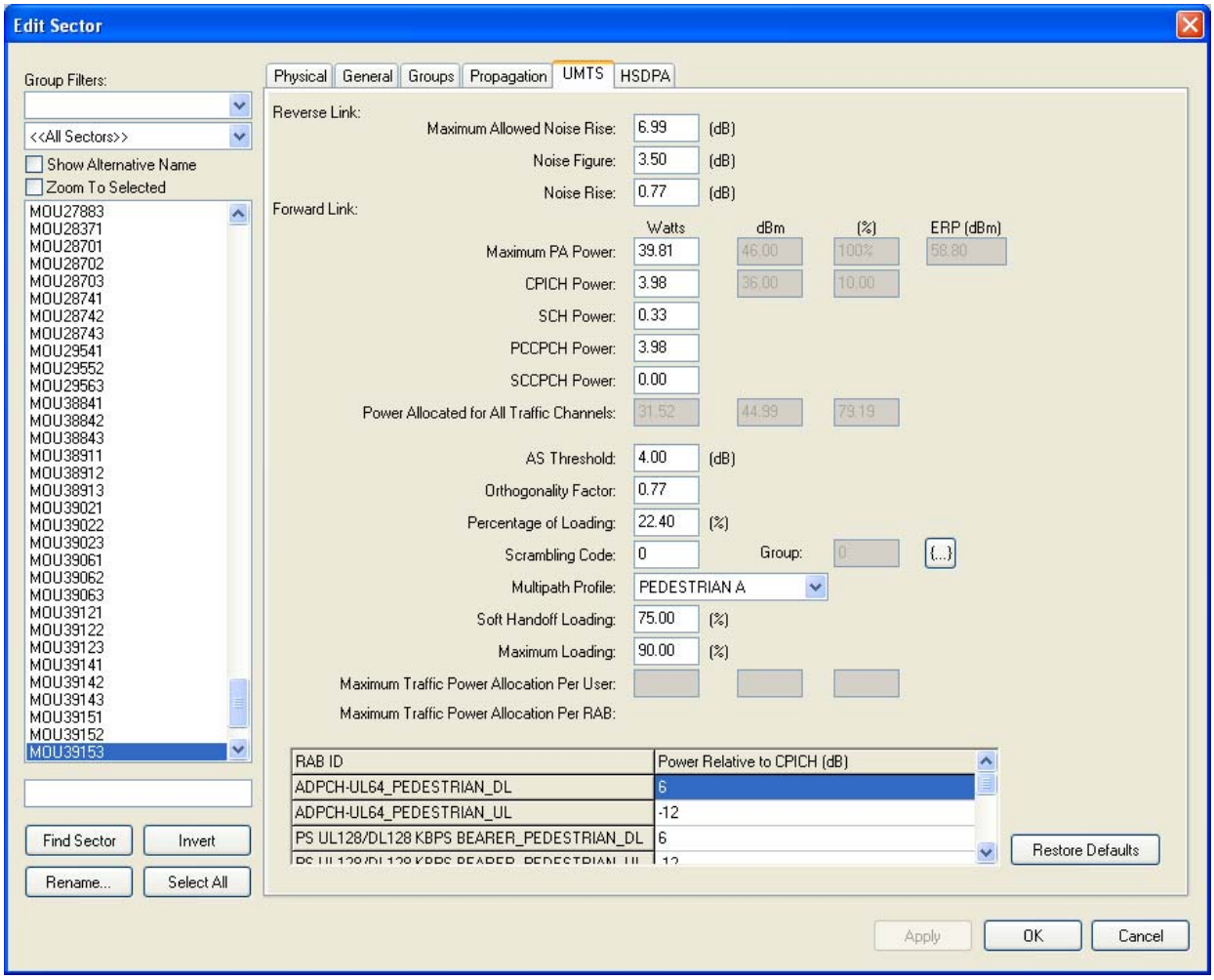

Figure 27. RRM parameters in the UMTS simulator

HS-DSCH power: Power reserved for HSDPA

HS-SCCH power: Power for the HS-SCCH channel

Maximum number of codes for HSDPA

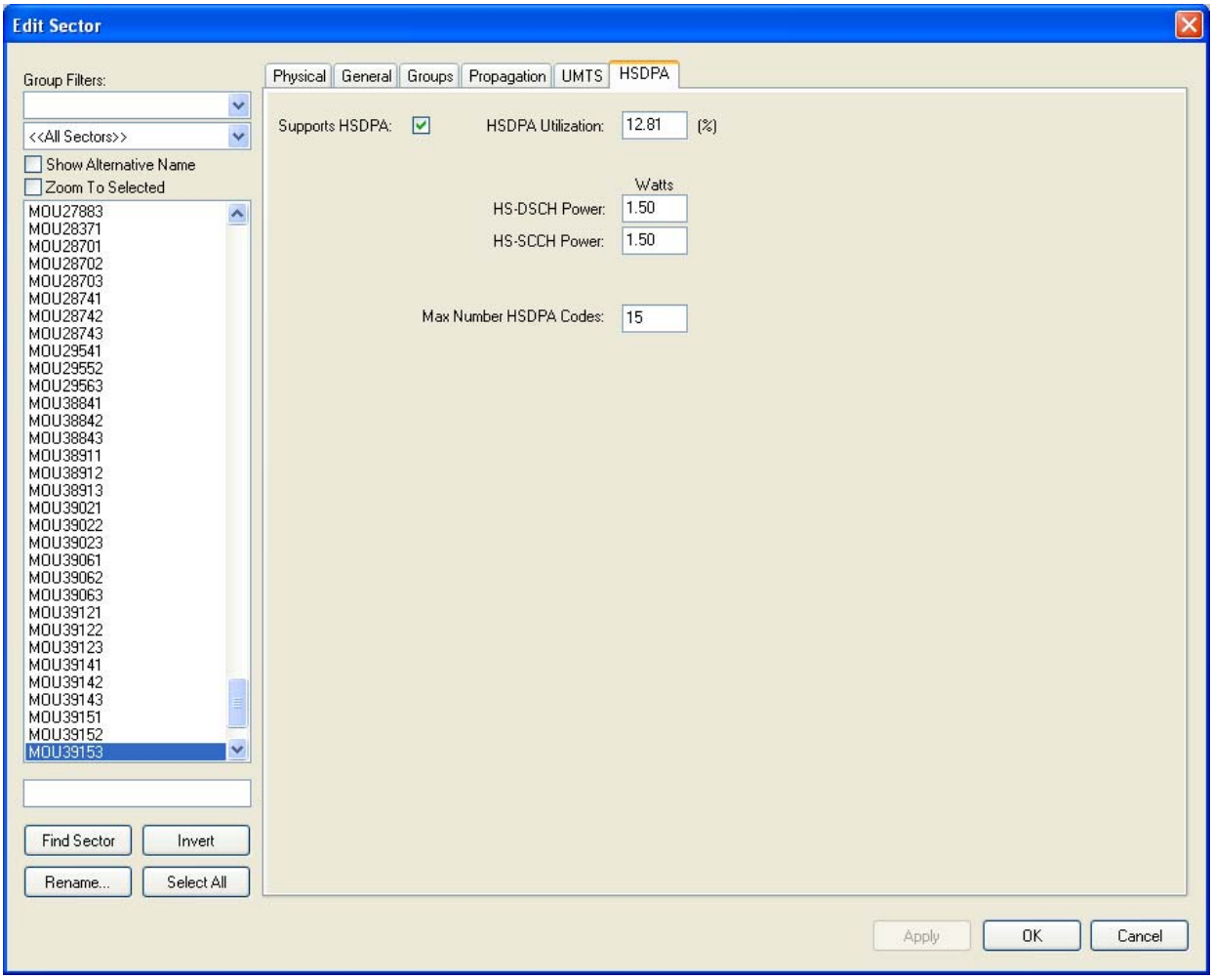

Figure 28. Configuring the HSDPA parameters

7. References

[1] P. Ding, P. Liu, X. Jin and P. Moorut. “A framework for evaluating mobile-to-mobile inter-system interference with hotspot considerations for WiMAX TDD coexistence”. IEEE VTC, Spring 2008.