Project	**IEEE 802.16 Broadband Wireless Access Working Group** <http://ieee802.org/16>
Title	**New System Analysis Methodology**
Date Submitted	**2007-07-09**
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Re:	IEEE 802.16m-07/023: Call for Comments on Draft 802.16m Evaluation Methodology Document
Abstract	This document proposes a realistic evaluation method, which enables testing TGm proposals in an environment better suited for real deployments
Purpose	Adopt the proposed text into the Evaluation Methodology Document
Notice	
Release	
Patent Policy	

Using Realistic Scenarios for System Level Simulations

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1. Background

Contribution IEEE C802.16-07/083r1, [1], was submitted as a contribution towards the Evaluation Methodology document [2] to TGm meeting in session 49. As the contribution was not discussed during the meeting, it was referred to the ad-hoc drafting committee for further review. The drafting committee discussed the contribution and asked to clarify the text and to integrate the proposed changes better with the deployment scenarios and channel models as described in [3] and postpone the resolution to . This document provides the needed clarifications and adaptations.

2. Introduction

The motivation for the inclusion of system level simulations using real scenarios (as opposed to system level simulations using artificial 19-hexagonal cell scenario) was given in [1]. The system level simulations as described in [2] and [3] should rather be called (and so shall be referred to in this document) multi-cell level simulations, as they analyze system performance in a limited environment of similar cells. A true system simulation should take into account the non-uniform distribution of traffic, as well as true geographical constraints. As mentioned during the ad-hoc group discussions, the approach proposed in [1], of introducing system simulations as an option, is not clear enough, and indeed, a better approach is to make them an integral part of the simulation effort, especially when considering the fact that the computational requirements are similar, if not smaller than that those of the multi-cell level simulations. By using system level simulations, as described, the 802.16 group will put itself in a much better position towards IMT-2000, as they better demonstrate the proposal performance in real scenarios.

This document describes the process of using a real life simulation scenario, and adds a set of proposed changes to [3], needed for a full integration of this approach with the multi-cell simulations in [3].

3. Real Scenarios Description and Processing

System level simulations should test the TGm proposals in a realistic environment, taking into account the interaction of different cells size and types, different geographical conditions, and different user densities and requirement. By that the system level simulation will increase the confidence of operators and users with the system performance. Figure 1 below shows the evaluation process, at all its levels, and the relations between its components.

3.1 Scenario pre-requisites

Scenarios, to be used for system level simulations, should be representative of real deployment scenarios, according to the deployment and usage models of [4]. They should include:

1. Mixed geographical conditions, including flat and hilly terrains
2. Mixed land uses, including urban and suburban environments
3. Non-uniform user density
4. Realistic location of base stations

An area of approximately 5km x 5km, containing about 50 base stations is sufficient for reliable simulations.

One such scenario is given in section 4 of this document, with the proposed text changes to Appendix J.

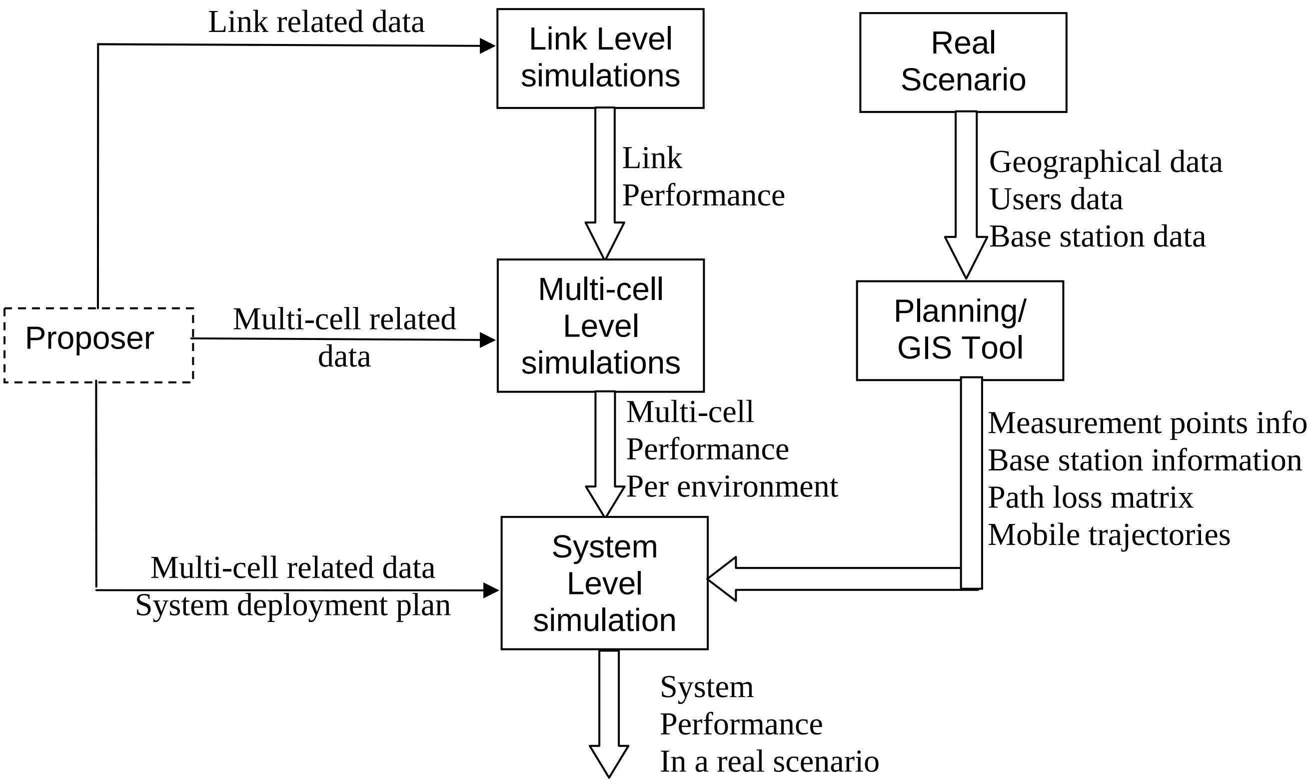

Figure 1: Evaluation Process

Additional scenarios can also be added later. A planning tool and a GIS tool should be used to prepare the data of such a scenario for the simulation tools written within the evaluation effort.

The following input should be provided to the planning/ GIS tool:

1. A digital terrain map describing the topography of the area to be analyzed
2. Building information, including building locations, heights and optionally shapes.
3. Optional streets and road information.
4. Data describing the nature of the different areas (urban, suburban, bad urban)
5. Data describing user density. These could be identical or different than the data of item 4.

This data will describe application usage mix for different areas and application profiles.

6. Possible location of base stations, including antenna heights and use (macro-cellular or micro cellular cells). The use can also be deduced from the antenna height relative to the surrounding buildings.

3.2 Input to the system simulation tool

The planning/ GIS tool will create the input needed for the simulation tool. For each scenario this input includes:

1. A list of all possible locations of base stations. For each location, the X,Y, Z coordinates of its antenna and an attribute describing if it is a macro cell or a microcell will be given.
2. A list of all possible measurement point locations. Each point will be given by its location coordinates (X,Y and Z) and a set of attributes describing the environment (urban, suburban, bad urban), the user density region it belongs to and an indoor/outdoor indication. The set of measurement points will be developed out of the building information (a point per building per floor, as a minimum), street and road information (a point for each 10m) and points in open areas (each 50m).
3. Data describing the user density. The density will be expressed as the number of active users, of each possible user type.
4. Optional streets and road information.
5. A matrix describing the pathloss between each possible base station and each measurement point. The pathloss will be calculated according to deterministic models, as described in the proposed changes to section 3.2.3.2 of [3], in section 4 of this document. No shadowing is needed to be added to the path loss. In addition, a matrix describing the line-of-sight clearance can also be provided to better select the channel model.
6. For all the links between an urban measurement point and an urban micro-cell base station, a list of rays will be given. For each ray the list will include:
   - Path loss
   - Delay
   - Angles of departure (azimuth and elevation) and angles of arrival (azimuth and elevation)

An example of such a scenario is given in the proposed additional Appendix J in section 4 (Proposed Text Changes) section of this document, as well as the proposed file formats.

3.3 Proposer input to the simulation tool

Given such a scenario, the proposers should:

1. Estimate the number of base stations needed for the required coverage, using their proposal parameters
2. Select, out of the list of base stations, those best fitted to provide the required coverage.
3. Set sector antenna directions and tilts
4. Correct the path loss matrix and ray list by the azimuth and elevation values of the antenna gains.
5. Set the frequency channels and other spectrum related information (e.g. for the reference system, the segments, zone switching times, TDD uplink and downlink switching time should be determined).

3.4 Running the simulation tool

The system level simulation tool should be identical to the multi-cell level simulation tool. The main differences are as follows:

1. MS drops are performed by selecting measurement points out of the measurement point list.
2. The number of MS's dropped is not determined per cell, but rather as a percentage of the number of users within each user density polygon.
3. The path loss is not calculated online but rather selected from a pre-calculated pathloss matrix, corrected

for antenna gains. No shadowing should be added to the pathloss.

4. Channel models are selected for each link individually according to the relevant environment and propagation conditions (e.g. clearance).
5. Ray tracing results can be used as a basis for the channel model in urban micro-cellular cases.
6. Mobile movement is simulated by selecting a track along actual streets and roads.
7. Parameters are evaluated over the entire area, and can be presented as an average per cell/ or per user.

4. Proposed Text Changes

Change globally

"System analysis" *to* "Multi-cell analysis"

"System level simulation" *to* "Multi-cell level simulation"

Note: Specific changes are also indicated in the proposed changes to the other sections.

p.14 l. 32 Add

[67] ITU-R Recommendation P.526-10 "Propagation by Diffraction" Feb. 2007

p.16 l. 22 Change

"The objective of this evaluation methodology is to define link-level and system-level simulation models"
into

"The objective of this evaluation methodology is to define link-level, multi-cell level and system-level simulation models"

p. 19, l.3 Insert

For system level analysis, proponents will define antenna orientation individually per cell, to best fit the local conditions.

p. 26 l.16 Change

Both system level and link level models are described in detail with a purpose of fulfilling the needs to conduct effective link and system level simulations that can generate trustworthy and verifiable results to assess performance related to the 802.16m system requirements.
Into
All system level, multi-cell level and link level models are described in detail with a purpose of fulfilling the needs to conduct effective link, multi-cell and system level simulations that can generate trustworthy and verifiable results to assess performance related to the 802.16m system requirements.

p. 27 l.32 Insert
Despite that, all the above mentioned models fail to capture the complexity and intricacy of a real network. It is necessary, at least for sanity check purposes, to add an additional level of simulation, system level simulation, which will use realistic environments, using deterministic models. Proponents will be required to perform deployment planning for their proposals thus providing a demonstration of its advantages in real scenarios. These plans will also serve the purpose of a demonstration and example of parameter tuning, which can serve system planners and operators in the future.
As it is envisioned that IMT-Advanced allocated spectrum be at the higher frequencies, the empirical models used for simulation of second and third generation cellular networks may not be valid, on the other hand geographical terrain databases, which used to be costly are now freely available, thus

making it possible to use deterministic models for system level simulation at least for path loss and shadow fading, while stochastic models will continue to be utilized for simulating the spatial impulse response.

p.29 l. 3 Replace
System Level *with* Multi-cell level

Add Section 3.1.5

3.1.5. System Level Channel Modeling Considerations

While multi-cell level simulation aims to provide a stochastic model that would provide the probability of occurrence of certain link conditions in a given deployment scenario, system level simulations aim to provide the probability of occurrence of each deployment scenario in realistic environments, as well as demonstrate the validity of multi-cell simulations in these environment, and to test the interactions in a mixed type of environment.

The system level simulations are based on real scenarios, as described in appendix J. Each real scenario contains a mix of deployment scenarios, together with real geographical data, and representative user locations in relations to existing base stations. Geography dictates the path loss and shadowing from each base station to each mobile station; it also determines the selection of a proper channel model for each link. Traffic models and user mixes are determined in this level also according to their geographical location.

The path loss, shadowing and propagation conditions (existence of line-of-sight) can be determined off line by a common planning tool. Based on these calculations, the simulation effort involved is equivalent computationally with that of the multi-cell level simulation.

A consideration for further study is the use of ray tracing techniques. While ray tracing provides good results for micro-cell and pico-cell scenarios, its usage in long range scenarios is computationally prohibitive, if an acceptable level of resolution is required (although techniques like ray splitting [2] can improve that). Ray tracing can also provide a good physical basis for the channel model as well as for the path loss model, but the ray list provided by ray tracing algorithms is limited in accuracy due to the incompleteness of existing databases, thus a stochastic modeling should be used as an augmentation to ray tracing for channel models.

While multi-cell level simulation may provide ambiguous results, as one system may prove better in one deployment scenario, while the other might be better in another, the results of the system level simulations in a given real scenario is more meaningful as it could be interpreted in terms of tangible terms for that particular scenario. Furthermore, it reduces the statistical variables of shadow fading and hence will probably converge faster than a similar multi-cell level simulation.

P.31 l.21 Change
This section focuses on the system-level simulation procedure
to
This section focuses on both the multi-cell level and system-level simulation procedure

p.34 l.38 Change the first sentence to read:
The path loss model depends on the propagation scenarios and the simulation level being used.

p.34 l.43 Add at the end of the paragraph
For system level simulations deterministic models can be used.

p.35 l.4 Add a sub section title

3.2.3.1 Multi-cell level simulation

And move all subsections (3.2.3.1- 3.2.3.5) down on level and renumber them 3.2.3.1.1-3.2.3.1.5

p. 37 l. 1 Add the following subsection

3.2.3.2 System level simulation

For system level simulations terrain and building information is available. Thus it is possible to use physical models. The models are not scenario dependent, as the various parameters of the different scenarios are built into the model, as well as frequency variations. The only consideration is whether ray tracing techniques should be used

3.2.3.2.1 Line-of-Sight and Diffraction model for outdoor scenarios

For the outdoor scenarios, Urban Macro-cell, Suburban Macro-Cell and Urban Microcell a LOS plus diffraction propagation model, based on ITU recommendation [67] shall be used. In this model, obstacles (buildings) are modeled as thin finite width screens. Calculation is performed by analyzing the profile from transmitter to receiver, identifying the most dominant obstacles. For each obstacle, the dimensionless parameter ν, describing the first Fresnel zone obstruction, is calculated. The parameter ν is given by:

$$\nu = h\sqrt{\frac{2}{\lambda}\left(\frac{1}{d_1}+\frac{1}{d_2}\right)}$$

Where d_1 is the distance between the transmitter and the obstacle, d_2 is the distance between the receiver and the obstacle, and h is the obstacle height above the line of sight. The diffraction loss of the obstacle is calculated by the Fresnel integral, to which the following approximation can be used:

$$J(\nu) = 6.9 + 20\log\left(\sqrt{(\nu-0.1)^2+1}+\nu-0.1\right)$$

Combination of the diffraction losses of several obstacles can be calculated using the methods described in [67].

Similar analysis should be performed in the horizontal plane to find the diffraction component around buildings and produce an equivalent diffraction loss component to be added to the loss predicted by a dual slope model.

Although the calculation is straightforward, it may be time consuming. It also requires a dedicated tool. To enable integrating it with a multi-cell simulation, a pre-calculated matrix will be supplied together with each scenario, describing the path loss between each potential base station and each potential terminal location (measurement point). In addition a visibility matrix, describing the line-of-sight clearance, in terms of the ν parameter, between each pair of base station- terminal station can be given. This matrix can assist in the selection of the channel model for this particular link.

3.2.3.2.2 Ray tracing model for the urban micro-cell scenario

As described above, further study is still needed whether to adopt Ray tracing for Urban Micro-cell scenarios. Those scenarios are characterized by short ranges and a large number of reflections. In this case ray tracing can be used for path losses calculation as well as for identification of the delay, angle of departure and angle of arrival of each ray, thus providing a good physical basis for the channel model to be created.

In each real scenario described in Appendix J, a subset of the potential base stations will be marked as micro-cell base stations, a sub-set of the measurement points will be associated to those base stations. For the relevant links, a list of rays will be provided. For each ray, the power, relative delay, angle of departure and angle of arrival will be given.

3.2.3.2.3 Outdoor to indoor

The model described in section 3.2.3.1.5 will be applied with the following differences:

a. If the external wall is not illuminated by a LOS illumination, the second term in the PL_{tw} expression will be replaced by a constant, which represents an averaging over all incidence angles, as described in [17]. Hence the term would be: PL_{tw} = 20dB
b. If the external wall is partially shadowed, the total path loss will be taken as the minimum loss estimated between the closest shadowed point and closest illuminated point, even if the later is not the closest point to the indoor receiver.

3.2.3.2.4 Indoor small office scenarios

This scenario will not be analyzed at a system level.

p.40 l.4 Add at the end of section 3.2.4

No shadowing factor will be added in the system level simulations using the deterministic path loss models described in section 3.2.3.2 above.

p.42 l.7 Add at the end of section 3.2.5.1

These values apply to both multi-cell and system level simulations. A K factor (TBD, >>1) can be selected if clear line of sight is available.

p.43 l.2 Add at the end of section 3.2.5.2

These values apply to both multi-cell and system level simulations. A K factor (TBD, >>1) can be selected if clear line of sight is available.

p.44 l.7 Add at the end of section 3.2.5.3

These values apply to both multi-cell and system level simulations, if ray tracing is not used. If ray tracing is used in system level simulations, the tap power, delay and mean AOA and AOD will be replaced by the ray tracing result, while the ray spread will remain as specified in Tables 12 and 13.

p.46 l.27 Add, at the end of the sentence:

For system simulations, the user drop is performed by a random selection of the user location. The propagation scenario is determined by the selected location.

p.47 l.5 Change

Step 2: *Calculate the bulk path loss associated with the BS to MS distance.*

to:

Step 2: *Determine the bulk path loss associated with the BS to MS relative location.*

p.47 l.11 Add at the end of the sentence:

", if needed."

p.52 l.8 Change the sentence to read

Therefore, current system level evaluation methodologies are based on explicitly modeling the system behavior by including fast fading models within both the multi-cell level and system level simulations.

p.71 l.31 Add a subsection title

8.2.1. Multi-cell level simulations

Demote subsections 8.2.1 and 8.2.2 and all their subsections by one level.

p.74 l.17 Add

8.2.2. System level simulations

All system levels simulations will include mobility. The number of mobile stations to be dropped is determined by the simulations scenario. A mobile speed will be randomly selected according to table 16. The movement of high speed mobiles will be along roads and streets defined in the scenario.

p.101 l.3 Change

The nineteen-cell network topology with wrap-around (as shown in the Appendix G) shall be used as the baseline network topology for all system-level simulations. The system simulation flow required in this evaluation methodology is illustrated in Figure 28.

to

The nineteen-cell network topology with wrap-around (as shown in the Appendix G) shall be used as the baseline network topology for all multi cell -level simulations and the real scenarios described in Appendix J shall be used for system level simulations. The simulation flow required in this evaluation methodology is illustrated in Figure 28.

p.101 l.55 Add Section title:

11.1 Procedures for Multi-cell Level Simulations

p.102 l.35 Add

11.2 Procedures for System Level Simulations

1. The system is modeled as described in Appendix J. Proponents may select a set of base station sites, set antenna orientations and frequency allocations in different sectors in the network.
2. User density is part of the scenario definition, and is given by regions each with a given number of users. Each user is attributed with a type (traffic mix). MSs are selected uniformly within each area for the same clutter type. Each mobile corresponds to an active user session that runs for the duration of the drop. MSs drops are implemented by selection of measurement points out of the measurement point list provided with each scenario.
3. Each BS-MS link is assigned a channel model according to the location of the MS and the BS.
5. For all sectors, sector assignment to an MS is based on the received power at an MS from all potential serving sectors.
6. Mobile stations are randomly dropped within each region such that each region has the required numbers of users. Although users may be in regions supporting handover each user is assigned to only one sector for counting purposes. All sectors of the system shall continue accepting users until the desired number of users per region is achieved everywhere or radio resource management constraints are met.
7. Fading signal and fading interference are computed from each mobile station into each sector and from each sector to each mobile for each simulation interval.
8. Users with a required traffic class shall be modeled according to the traffic models defined in this document. Start times for each traffic type for each user should be randomized as specified in the traffic model being simulated.

9. Packets are scheduled with a packet scheduler using the required fairness metric. Channel quality feedback delay, PDU errors and ARQ are modeled and packets are retransmitted as necessary. The ARQ process is modeled by explicitly rescheduling a packet as part of the current packet call after a specified ARQ feedback delay period.
10. Simulation time is chosen to ensure convergence in user performance metrics. For a given drop the simulation is run for this duration, and then the process is repeated again, with the MSs dropped at new random locations. A sufficient number of drops are simulated to ensure convergence in the system performance metrics.
11. Performance statistics are collected for MSs in all cells according to the output matrix requirements.
12. All the sectors in the system shall be simulated

p.103 l.23 Change
Multi-cell scheduling shall be modeled to capture dynamics of interference in the 19-cell network as described in Appendix G.
to
System and multi-cell scheduling shall be modeled to capture interference in the network as described in Appendices G and J.

p.104 l.14 Add
For system level simulations, only the percentage area coverage (X%), computed over the entire analysis area will be assessed.

p.104 l.20 Add
For system level simulations, only the percentage area of the entire analysis area will be computed.

p.105 l.13 Change
It is assumed that simulation statistics are collected from sectors belonging to the test cell(s) of the 19-cell deployment scenario.
to
For multi-cell simulations, it is assumed that simulation statistics are collected from sectors belonging to the test cell(s) of the 19-cell deployment scenario. For the system level simulations, the statistics will be collected from all cells.

p.110 l.13 Change
The first case consists of all 57 sectors transmitting the same MBS service. In the second case, which is used to evaluate the performance at the MBS zone edge,…
to
The first case consists of all sectors transmitting the same MBS service. In the second case, which is used to evaluate the performance at the MBS zone edge only in the multi-cell level simulation,…

p.135 l.11 Add

Appendix-J: Scenarios for System Simulation

J.1 Scenarios

J.1.1 Urban- Suburban Scenario

Figure J.1, below, shows an example of an urban-suburban region. This is a 5 by 7km area, which mixes a hilly terrain, with two urban regions, and a sub-urban one. The map shows the main roads as well as streets, and buildings in the area are depicted by polygons. For that area a building database, which includes each building height is also available. Prediction points can be defined within the buildings for pedestrian and home users, while for vehicular users a set of points can be defined along the streets.

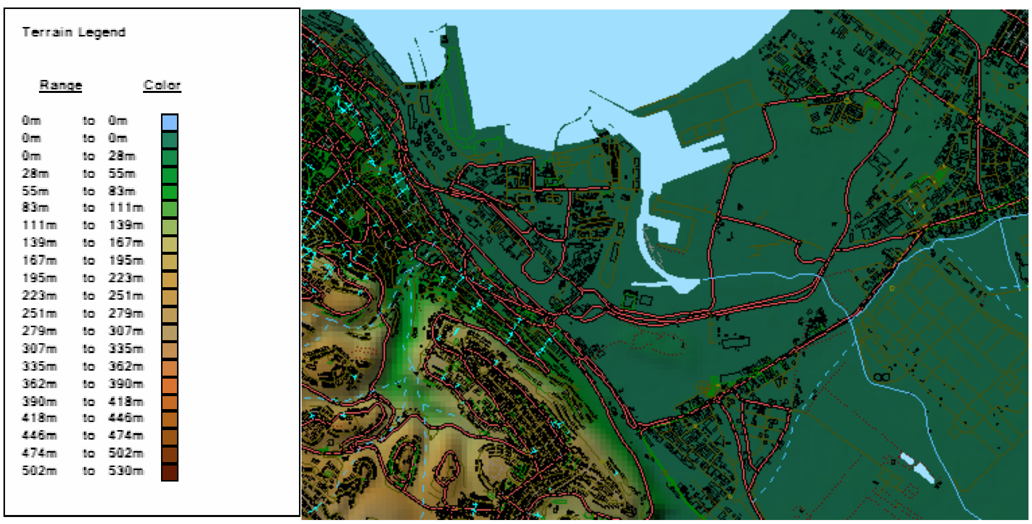

Figure J.1: A real mixed environment Area

The base stations of an existing GSM-1800/UMTS cellular network are shown in Figure J.2. There are 62 of them.

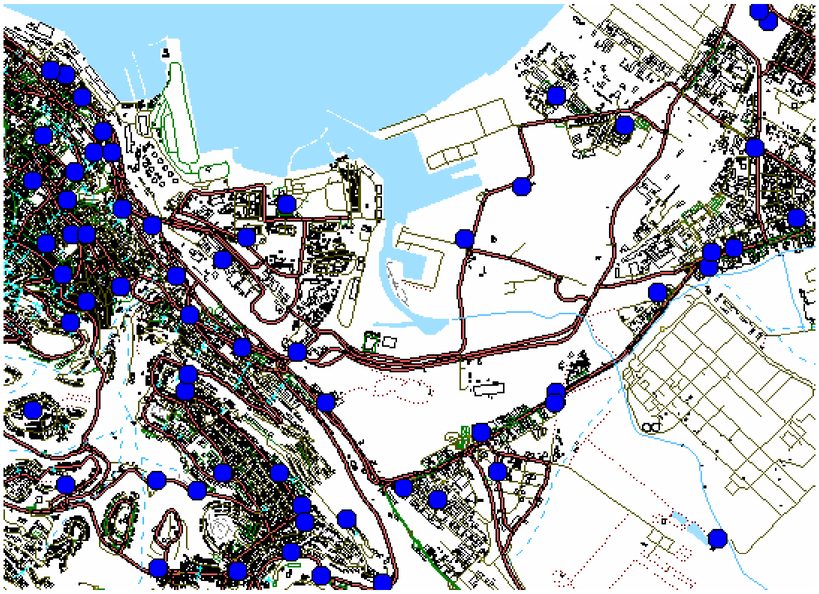

Figure J.2: Base station Location

Figure J.3 shows the land-use of the different parts of the map. This information can be used for user type/ user mix selection, as well as for channel model selection in each area.

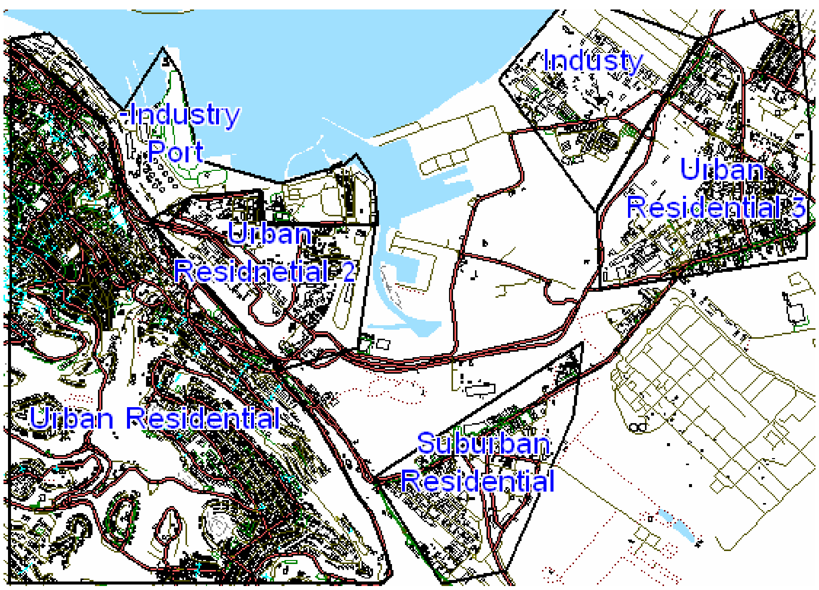

Figure 3: Land-use

Measurement points are located within each building, in every floor (every 3m). Additionally, points are located along the streets and randomly in open areas. About 30,000 points are needed to cover the entire area, with "building" resolution.

Number of users (active) per region per type yet TBD.

J.2 Data Formats

Editor Note: This is a proposed data format, yet to be completed.

All the system simulation input files will be tab delimited text files including the following information.

J.2.1. Potential Base Station Locations

The file will have N_{BS} rows, with N_{BS} the number of base stations. Each row will contain:

- Base station ID
- X, Y, Z coordinates for the antenna location (of all sectors in the site)
- A 0 or 1 flag, indicating if the base station is a microcellular base station.
- Antenna direction (tilt, azimuth)
- Antenna type

J.2.2. Used Density Regions

The file will have N_{ud} rows, each describing a user density regions. N_{ud} is the number of user density regions.

Each row will have 2*N_{ut}+1 columns, where N_{ut} is the number of user types/ traffic mixes as defined in section 10.7. The columns will be:

- Region ID
- N_{ut} columns with the number of users per type in that region
- N_{ut} columns with the number of users per type in that region, which are to be simulated as vehicular/ moving.

The structure is repeated for each region.

J.2.3. Measurement Points Information

The file will have N_{MP} rows, with N_{MP} the number of measurement points. Each row will contain:

- An index number of this point
- X, Y, Z coordinates for the antenna location (m)
- A numerical value indicating the environment, as defined in section 2.3. - A numerical value (between 1 to N_{ud}) indicating the user density region the measurement point belongs to.
- A flag (0 or 1) indicating whether the point is an indoor point.

J.2.5. Path loss matrix

The file will have N_{MP} rows and N_{BS} columns. Each row will contain the path gain (in dB) between each base station and each measurement point.

J.2.6. Path loss clearance

The file will have N_{MP} rows and N_{BS} columns. Each row will contain the Fresnel zone clearance of the link between each base station and each measurement point. The Fresnel zone clearance will be given in terms of the clearance factor ν, as described in section 3.2.3.2.1.

J.2.7.Ray List

The file will contain the information of rays produced by a ray tracing algorithm, between each microcellular base station to all the urban or bad urban measurement points located within 1000m from it. Each ray's information will be given in a row in this file and it will contain:

- Base station index
- Measurement point index
- Ray Index
- Azimuth angle of departure (from BS), in degrees
- Elevation angle of departure (from BS), in degrees
- Ray's path gain (dB)
- Azimuth angle of arrival (at the MS), in degrees
- Elevation angle of arrival (at the MS), in degrees

---*END OF PRPOSED TEXT CHANGES*----------------------------------

5. References

[1] IEEE C802.16m-07/083r1- *Realistic Scenarios for System Evaluation*
[2] IEEE C802.16m-07/080r1- *Draft IEEE 802.16m Evaluation Methodology Document*. Rev.1
[3] IEEE C802.16m-07/080r2- *Draft IEEE 802.16m Evaluation Methodology Document*. Rev. 2
[4] IEEE 802.16m-07/02r2 – *Draft IEEE 802.16m Requirements*