Radio Network Planning Tool for WiMAX Networks

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- Focus of WiMAX Module in WinProp
- WiMAX Network Planning Module
  - Propagation
  - Interference
  - Specification of air interface
  - Properties of BS and SS
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  - Traffic
  - Predicted Results
- Evolution of WiMAX Module
Motivation

- The performance of wireless communication networks depends on an efficient architecture of the network.
- Point-to-multipoint and cellular WiMAX networks require network planning due to frequency reuse and high requirements for signal-to-noise-and-interference-ratio at each receiver location.

➢ Network planning is required to analyze the performance of the wireless network.
Focus of WinProp WiMAX Module

- **Version 7.4** (Oct. 2007)
  - Propagation Models for WiMAX
    - Multiple prediction heights
    - Seamless transition rural ⇔ urban ⇔ indoor
  - Interference computation for OFDM transmission (guard interval → multipath interference and inter-cell interference)
  - Air Interfaces
    - Fixed WiMAX (IEEE 802.16-2004)
    - Mobile WiMAX (IEEE 802.16e)
  - Frequency bands
    - Definition of arbitrary carriers and bandwidths
  - Individual simulation for each transmission mode
    - received power & SNIR
    - required Tx powers (DL / UL)
    - cell areas, best server
    - max data rates

The planning of these LOS and NLOS radio links is the focus of the WiMAX module in WinProp.
Next WinProp Release

➢ Version 8.0 (Feb. 2008)

- Enhanced Propagation Models
  - multiple prediction heights relative to individual roof top levels

- Consideration of traffic (services)
  - multiple traffic maps
  - selection of supported transmission mode(s) for each traffic map
  - ranking of traffic maps (high and low priority)
  - threshold for max. data throughput in BTS (→ reduction of cell size due to overload)

- Automatic adjustment of subscriber antennas (Fixed WiMAX)
  - selection of best location (from a set of optional locations)
  - selection of best antenna height
  - auto-adjustment of antenna orientation (azimuth and tilt)
WiMAX Network Planning with WinProp

Wave Propagation
- path loss
- impulse response

Spec of Air Interface
- RF parameters
- Transmission modes (e.g. MCS)

WinProp WiMAX Module

Max. Data Rates
Received Signal Level
SNIR
Cell Area / Best Server
Tx power (DL / UL)
Coverage Probability
Handover Options
Antenna Adjustment
Base Station Load

Module Inputs

Module Outputs

Gray colored items are currently under construction and will be available in WinProp V8.0 (Jan. 2008)
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- Evolution of WiMAX Module
Wave Propagation (1/2)

- Highly accurate wave propagation models for rural, suburban, urban and indoor environments
- Hybrid scenarios: Smooth transition between indoor, urban, and rural in one simulation
- Consideration of 3D vector building databases (urban & indoor), topography (pixel), and clutter (pixel) data
Wave Propagation (2/2)

- Propagation on multiple height levels
  - Absolute (V7.4) / Relative (V8.0) to building roof tops and along building claddings for fixed WiMAX
  - On different building floors for mobile WiMAX
- Propagation paths
- Calculation of spatial channel impulse response, delay spread, angular spread & angular profile at BTS and SS
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Interference (1/3): Two Types of Interference

- Type 1: multipath interference (only if delays between paths > guard interval)
  - Signal contributions arriving after the guard interval are interference

- Propagation model must be able to predict multiple paths and path delays (i.e. channel impulse response)
Interference (2/3): Effect of guard interval

- Guard interval influences multi path interference
- Figures: Effect of guard interval on SNIR (frequency reuse = 1)

Useful: 224 µs
Guard: 1 µs

Useful: 224 µs
Guard: 10 µs

Useful: 224 µs
Guard: 28 µs

Useful: 224 µs
Guard: 5 µs
Interference (3/3): Two Types of Interference

- Type 2: Inter-cell interference (if other cells are using the same carriers)
  - BTS Tx power of interfering BTS can be specified relative to max. Tx power of the BTS (e.g. 80% of max power)
    - for all BTS in the network homogenously
    - for selected (or each) BTS individually
    - especially important if frequency reuse factor is equal to 1 (or 3)
    - due to relative power value also sub-channelization can be modeled (if adjacent cells in OFDMA mode are using the same sub-carriers, the interference is higher)
  - Relative Tx power is suitable to define typical and/or worst case scenario (sufficient for network planning)
  - Actual traffic (load) of BTS depending on the number of users in the cell is not considered to determine Tx power because
    - Actual Tx power depends on transmission modes
    - Resource management must be included in simulator to decide which user/traffic is transmitted in which transmission mode…. → this resource management is operator dependent and cannot be handled in an external planning tool
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  - **Evolution of WiMAX Module**
Air Interface (1/5): Overview

- Multiple Access (OFDM)
- UL / DL separation mode (FDD / TDD)
- Channel Bandwidth
- Carriers available in network
- Transmission Modes
  - MCS
  - FFT-Size, Subcarriers
  - Sampling Rate
  - Data Rate
- Cell assignment
  - Highest received power (pilot subcarriers) in DL
  - Min. required SNIR and min. Required Rx power in DL

Definition of air interface
Orthogonal Frequency Division Multiple Access

- FFT Size
  (128, 256, 512, 1024, 2048)

- Sampling Frequency
  (8/7, 28/25, ...)

- Subcarrier Settings
  (Pilot, Guard, DC & Data)

- Individual Tx power for pilot subcarriers
  (important in case of interference computation in downlink)

- Useful symbol duration and Guard interval

- Sub-Channelization
  (1, 2, 4, 8, 16 → leading to relaxed SNIR targets)
Air Interface (3/5): Carriers

- Carriers available in the network
  - Bandwidth of carrier (thermal noise)
  - Spectral mask for carriers can be defined for adjacent channel interference
  - Multiple carriers in different frequency bands can be used in one project (same bandwidth for all carriers required).
  - Arbitrary carriers can be assigned to a BTS
  - TDD or FDD mode can be selected (identical for all BTS in whole network)
  - TDD mode: Ratio between UL and DL (e.g.: 1:1 or 3:1) can be defined for whole network or for each BTS individually
  - FDD mode: UL-DL carrier separation can be defined (identical for all carriers)
Air Interface (4/5): Transmission Modes

- Specification of an arbitrary number of transmission modes for DL and UL individually by definition of:
  - FFT size
    (128, 256, 512, 1024, 2048)
  - Sampling frequency ratio
    (8/7, 28/25,…)
  - Modulation
    (BPSK, QPSK, 16-QAM, 64-QAM)
  - Coding Rate
    (1/2 ,3/4, 5/6,… → only total coding rate is considered)
  - Max. available Tx power at BTS and SS
  - Tx power for data and pilot subcarriers individually
  - Min. required SNIR target at BTS and SS
  - Min. required received signal level at BTS and SS
  - Fast Fading Margins
  - Special SS properties (losses, antenna gains, etc.)
Air Interface (5/5): Duplex Mode

- Duplex Mode:
  - FDD
    - Specification of carrier separation of UL and DL
  - TDD
    - Specification of guard time to switch between UL and DL
    - Ratio between DL and UL (e.g. 1:1, 3:1, ...)

- Options for settings of duplex mode
  - Default: whole network (i.e. all carriers and cells (BS)) operating in same duplex mode
  - Optional: Duplex mode of selected cells can be defined individually

- Specific simulation of TDD mode
  - TDD simulated similar to FDD. But results (max. data rate, etc.) are scaled with DL:UL ratio
  - SS ↔ SS interference can be ignored (default) or can be computed (optional) with simple one slope model (depending on frequency, distance and path loss exponent (exponent can be defined by user depending on heights or clutter class of SS))
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- Evolution of WiMAX Module
Sites and Base Stations (1/2)

- **Location**
  - Longitude, Latitude, Height

- **Transmission mode**
  - Duplex: FDD or TDD

- **RF parameters**
  - Carrier assignment
    (multiple carriers possible)
  - Tx power
    (for data and pilot individually)
  - Noise figure, cables losses,…

- **Antenna**
  - Azimuth, downtilt
  - Antenna pattern
  - …
Sites and Base Stations (2/2)

- Selection of carriers assigned to BTS
- List of all carriers available in network
- Properties of TRX
  - Location
  - Antenna Pattern
  - TRX properties:
    - Noise Figure
    - Cable losses
    - ...
- Power ratio for interference
- Tx Power (Downlink)

(Multiple) carriers assigned to BTS
WiMAX Network Planning Module – BS and SS

**Subscriber Stations (1/2)**

- **Name**
- **Type**
  - stationary for fixed WiMAX (rooftop antenna, …)
  - handheld/portable equipment
- **Services**
  - multiple services for each SS possible (selected from list in air interface settings)
  - definition of min. required link quality for each service individually
- **Mobility**
  - either stationary, nomadic or mobile (individual margins)
  - in case of Mobile WiMAX (mobile/nomadic stations):
    - max. allowed Doppler shift
    - active set size (for handover)
    - thresholds and criteria for handover
WiMAX Network Planning Module – Air Interface

Subscriber Stations (2/2)

- WiMAX specific parameters
  - Duplex mode (FDD/TDD)
  - Supported transmission modes for UL and DL individually
  - Max. UL Tx power (pilot / data subcarriers)
  - DL Receiver sensitivity (incl. fast fading margin)
  - Noise figure
  - Antenna gain (Mobile WiMAX)
    Antenna pattern (Fixed WiMAX)
    Azimuth & downtilt (Fixed WiMAX)
  - Fast Fading Margin (especially for Mobile WiMAX)
  - General losses (body and equipment losses)
Focus of WiMAX Module in WinProp

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- Evolution of WiMAX Module
WiMAX allows multiple services on one carrier
- Mobile TV applications
- Fixed and mobile access to the internet
- High speed data links between buildings
- WiFi backhaul
- …

Service concept in WinProp
- Multiple services (arbitrary number)
- Supported transmission modes for DL and UL for each service (min required / preferred) selected from list of transmission modes (⇒ air interface specification)
- Rules for selection of transmission modes (e.g. SNIR thresholds, etc.)
- Max. allowed delays / QoS for each service
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▪ Evolution of WiMAX Module
Traffic

- Definition of location depending traffic (for each service individually)

- Location depending traffic is defined via clutter maps for each service
  - Clutter maps from database vendors (e.g. rural, suburban or urban scenarios)
  - Clutter maps automatically generated with WinProp based on urban or indoor vector databases (e.g. maps with classes for outdoor/indoor/number of floors of buildings/…)
  - Modification of clutter maps with CAD tools possible (drawing polygons, lines, rectangles,…)

- Two options for definition of traffic for the pixels of clutter classes
  - Erlang /km² (arrival processes… based on users…. if each user requests same amount of data )
  - MByte /km² /s (general definition of requested throughput, independent of number of users)
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▪ Evolution of WiMAX Module
Selection of Prediction Results

- Results computed for all transmission modes
  - Max data rate (achievable)
  - Max received power (DL)

- Results computed individually for each transmission mode (depending on selected air interface)
  - SNIR
  - Best Server, Cell layout
  - Min. required Tx power (UL and DL)
  - Nr of carriers received above threshold
  - handover regions

- In WinProp V7.4 "only" prediction of achievable network performance. Actual performance can be reduced due to higher traffic and load (i.e. interference) in network
Max. achievable Data Rates

- Max. achievable data rates on different (and multiple) heights for mobile and fixed WiMAX applications

Urban mobile WiMAX network
Prediction height: 1.5m above ground

Urban fixed WiMAX network
Prediction height: 25m above ground
Max. Received Signal Level

- Reception level on different (and multiple) heights for fixed WiMAX (e.g. multiple layers above roof top levels)

- Reception level on street level and in different building floors for mobile WiMAX
Signal/ Noise & Interference Ratio (SNIR)

- Essential for mobile and fixed WiMAX networks
- Computed for each transmission mode individually

Fixed WiMAX network
Prediction height: 25m above ground

Mobile WiMAX network
Prediction height: 1.5m above ground
Cell Areas

- Knowledge of best server especially important for mobile WiMAX networks
- Also useful for fixed WiMAX to avoid cell overloads
- Computed for each transmission mode individually
Required Tx Power for BTS and SS (i.e. DL & UL)

- Required Tx power for a connection between subscriber and BTS for each transmission mode (MCS, etc.)
- Actual Tx power can be higher depending on traffic load (and interference situation)
Reception Probability (Coverage)

- Essential for fixed and mobile WiMAX networks
- Individually computed for each transmission mode
Handover options

- Especially important for Mobile WiMAX networks
- For the determination of alternatives also useful for fixed WiMAX
- Computed for each transmission mode individually
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Optimum Antenna Adjustment (1/2)

- Relevant for fixed receiving antennas of WiMAX terminals
- Adjustment of antennas at the user terminal in order to optimize reception and transmit conditions for a fixed location
  - Optimum azimuth angle
  - Tilt optimization
  - Best suited installation height
Optimum Antenna Adjustment (2/2)

- Antenna adjustment can be done for every possible receiving position of the simulation scenario.
- Optimization in order to achieve maximum possible reception power and minimum interference.
- Weight of influence (reception power ↔ interference) can be chosen arbitrarily.
- Prioritization of receiving positions via clutter and priority maps.
Base Station Load

- Determine load of base stations depending on traffic situation
  - Maximum load can be chosen arbitrarily for each sector individually
  - Actual load of sectors is given in ASCII tables
  - Overloaded sectors can be highlighted in output maps
Next WinProp Release

Version 13.0

- Enhanced Propagation Models
  - multiple prediction heights relative to individual roof top levels

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  - multiple traffic maps
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  - ranking of traffic maps (high and low priority)
  - threshold for max. data throughput in BTS (\(\rightarrow\) reduction of cell size due to overload)

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Further Information

AWE Communications GmbH

WinProp Software Package

WinProp

Product News
- Components for Indoor Networks incl. new Editor Command
- Scattering for Indoor Ray-Optical Models
- Bridges in urban scenarios supported
- New Traffic Simulators: Monte-Carlo and Fractional-user
- Read more...

Traffic Modeling
- Monte Carlo Simulator and Fractional User Simulator for sophisticated consideration of inhomogeneous traffic defined by the user (based on vector or clutter databases).
- Prediction of Blocking, Capacity, Throughput, and Call Load.

Company related News and Events
- GHJT purchases new indoor components module
- AWE purchases WinProp licenses for all scenarios
- New customers: ASO, ETSI, PFS, ...
- ELT Project: Validation with measurements started
- Read more...

New WinProp Release

V13

Download the free WinProp trial version

WTP2014

Virtually Together 2014

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Wave Propagation and Radio Network Planning

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