WiPPET SIGNAL

Signal Processing Simulation for a W-CDMA System

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WiPPET SIGNAL Modeling Domains

SSF 2000 - integration of Internet & Wireless models

Scale and Details matter!

wireless access + wired global net scalable design & analysis tools

Internet software radios, inter-protocol interactions, traffic, service design,...
WiPPET SIGNAL Modeling Domains contd..

- **System Design**
- **Shared Radio Channel**
  - Radio Propagation: Mobility, Fading, Multi-path
  - Interference
- **Distributed Protocols**
- **Data Protocols**
- **Physical Layer**
  - Framing structure, Transceiver design, Bits and Chips
  - BER and SIR based power control
  - Source & Channel Coding/Decoding, Spreading/De-spreading
WiPPET SIGNAL Highlights

Waveforms (spread sequences)

Mobility

Multi-Cell
WiPPET SIGNAL System Model Overview

- Asynchronous Bases
- DS-CDMA chip level precision
- Path Diversity
- Antenna Diversity
- Fading: Rayleigh & Shadow
- Distance Loss (4th power)
- Interference
- 12 Cell Manhattan grid.
- Wrap-around Streets and Avenues

In cell $I_{\text{int}}(t)$
Out of cell $I_{\text{ext}}(t)$
CDMA Receivers

External interference $I_{ext}(t)$

- Transmitter Powers
- Link Quality Measurements
- Receiver Structure
Radio Channel Design (Advanced)
CSSF (C++)

- Parallel discrete event simulation API
- Inheritance of base SSF objects - Entity, Event, Process, Channel to create higher entities - Mobile, Base, RadioChannel, TxAntenna, RxAntenna, Mobility.
- Events pass via channels between higher entities.
Entity : Mobility

- Geography provides LS Gain for every point on the grid
- Uniform loading.
- RCH gets updated LS Gains when Mobile moves
- NO bias for turns over streets & avenues
- Return on hitting the “border” (no handoff yet)
- Mobile speed and distance precision define freq of jumps
Entity: Radio Channel (RCH)

- Only Reverse Link in the original version.
- Both Forward & Reverse Link in the advanced version.
- LS Gain: Distance Loss
  E.g. Outdoor Pedestrian path loss model
  \[ L = 40 \log_{10} R + 30 \log_{10} f + 49 \]
  where \( R \): BS-MS separation distance (km)
  \( f \): carrier frequency for IMT-2000 application
- LS Gain: Shadow fading
  E.g. Gudmundson Model
  \[ R(\Delta x) = 0.5 \left| \frac{\Delta x}{d_{cor}} \right| \]
  where \( d_{cor} \) is the distance that has cross-correlation of 0.5
Entity : Radio Channel (RCH) contd..

- SS Gain : Multi-path Rayleigh Model
  - WSSUS Model
  - Number of Taps
  - Time delay relative to first tap
  - Average power relative to the strongest tap

- RCH Independent of framing/coding structure
- RxAntenna diversity
- Interference : Inter cell $I_{\text{ext}}(t)$ & Intra cell $I_{\text{int}}(t)$
- Each chip for each RxAntenna of each Base processed
- Power Control Error option
- Handles mobility event for each mobile
Entities : Mobile Station & TxAntenna

- Mobile Station
  - Same entity instantiated $n$ times with different mobileID
  - NTT DoCoMo Transmitter code instantiated
  - Data and Long Code generation based on mobileID
  - Multi-code support introduced
  - One-to-one mapping with TxAntenna entity
  - $TX\_DATA\_SYMBOL$ transmitted to TxAntenna after spreading

- TxAntenna
  - Forwards $TX\_DATA\_SYMBOL$ to RCH Entity where they are handled
Entities: RxAntenna & Base Station

- RxAntenna
  - Antenna Diversity
  - Stores \texttt{Rx\_DATA\_SYMBOL} and forwards slots and frames to Base

- Base Station
  - Same entity instantiated \textit{m} times with different baseID
  - NTT DoCoMo Receiver code instantiated
  - Data and Long Code generation based on mobileID
  - Many-to-One mapping with RxAntenna entity
  - SIR based Power Controller
  - BER, FER calculations
Event Flow

Transmitter → Ant → RADIO CHANNEL → Ant → DoCoMo Receiver

Mobile

Rayleigh
Dist Loss
Shadow

Mobility

Geography

Base
Propagation and Interference (Rev. Link)

$$S_k(t) = \sum_{i=2k}^{2k+1} \sum_{p=0}^{1} \sum_{j=0}^{n-1} A_j G_{jip} C_j(t - d_{jp})$$

- $A_j$ = Amplitude of $j_{th}$ mobile
- $C_j$ = Chip from $j_{th}$ mobile
- $G_{jip}$ = Channel Gain from $j_{th}$ mobile to $i_{th}$ rxAntenna for $p_{th}$ path
- $d_{jp}$ = Delay of $j_{th}$ mobile to $k_{th}$ base for $p_{th}$ path
- $S_k$ = Received composite chip at $k_{th}$ base
Chip Level Simulation

Mobile 0

Mobile 1

Mobile k

Base 0

Chips
# W-CDMA System Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bandwidth</td>
<td>5MHz</td>
</tr>
<tr>
<td>Chip Rate</td>
<td>4.096 Mcps</td>
</tr>
<tr>
<td>Spreading Factor</td>
<td>16,64</td>
</tr>
<tr>
<td>Symbol Rate</td>
<td>256 kps, 64 kps</td>
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<tr>
<td>Frame Length</td>
<td>10 ms</td>
</tr>
<tr>
<td>Data Modulation DL: QPSK/ UL: BPSK</td>
<td></td>
</tr>
<tr>
<td>Spreading Mod DL: QPSK/ UL: QPSK</td>
<td></td>
</tr>
<tr>
<td>Channel Coding DL: QPSK/ UL: QPSK</td>
<td></td>
</tr>
<tr>
<td>Turbo Coding (R=1/3, K=3) for high data rate</td>
<td></td>
</tr>
</tbody>
</table>
| Interleaving Length        | 10 ms for voice transmission  
                            80 ms for data transmission |
| Demodulation               | UL: Pilot Assisted Coherent detection 
I/Q-mux PL, (Time-mux PL for TDD mode)  
DL: Pilot Assisted Coherent Detection 
Time -mux PL }
Single Cell Result Verification

- No TPC Error, No distance loss, with 3-stage-IC and MF, SF=32

![Graph showing BER vs. Eb/N0 for various scenarios]
Multi Cell Results
Antenna Diversity, No TPC Error, 3-stage-IC, SF=64
Multi Cell Power Profiles

1 mobile per cell, Target SIR = 10 dB, 80 Hz Rayleigh
Single Cell vs. Multi Cell

10 mobiles per cell, No Channel Coding, 80 Hz Rayleigh
Simulation Time

Single Cell, 2 Antennas, 2 paths, SF=64, No Channel Coding, 80 Hz Rayleigh

Time from transmission to validation

- 1 Cell, 1 user per cell, MF
- 1 Cell, 2 users per cell, MF
- 1 Cell, 2 users per cell, IC
- 1 Cell, 12 users per cell, MF
- 1 Cell, 12 users per cell, IC

Time (secs)

Frames per user
Simulation Time contd..
Multi Cell, 2 Antennas, 2 paths, SF=64, No Channel Coding, 80 Hz Rayleigh
1 Frame = 186 raw bits = 16 slots of 40 symbols each

<table>
<thead>
<tr>
<th>Cells</th>
<th>Users/cell</th>
<th>Receiver</th>
<th>Secs/frame</th>
<th>Total bits/sec</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>MF</td>
<td>2</td>
<td>93</td>
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<tr>
<td>2</td>
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<td>3.16</td>
<td>117.7</td>
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<tr>
<td></td>
<td>IC</td>
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<td>4.5</td>
<td>82.6</td>
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<tr>
<td>12</td>
<td>MF</td>
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<td>19</td>
<td>117.4</td>
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<tr>
<td></td>
<td>IC</td>
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<td>67.63</td>
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<tr>
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<td>IC</td>
<td></td>
<td>474</td>
<td>9.4</td>
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</tbody>
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Evaluation Methodology

- **ARIB:**

- **ETSI:**
  - Selection Procedures For the Choice of Radio Transmission Technologies of the UMTS (UMTS 30.03, version 3.2.0), 1998
Project Status

- Integration of the DoCoMo transmitter and receiver complete.
  - Multistage Interference Cancelation, Convolutional Coding/Decoding, Channel Estimation
  - Frame by Frame processing + fake power control
- Design Verification complete
- Single Cell results verified against DoCoMo measurements
- Slot by slot power control implemented and verified
- Multi Cell W-CDMA System Evaluation in progress
- Forward Link implementation in progress
Project Future

- Mobility
  - Parameter controlled PDF for spatial loading
  - 2D Mobility controllable to define paths to support handoffs
- Soft Handoffs
- Better Transceiver
- Optimization of RCH
- DML : Configuration of a database via modular components
- Viewer : Integration with the generic WINLAB Java Viewer