802.20 Evaluation Methodology

Ayman Naguib, Arak Sutivong, Jim Tomcik, and Ed Tiedemann
May 12-15
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Outline

• Goal and motivation.
• Channel Models.
• DL Traffic Models.
• Summary.
Goal and Motivation

• Develop an **evaluation methodology** that includes a set of definitions, assumptions, models, and a general framework for simulating technology proposals to 802.20.

• “**Evaluation Methodology**” along with **proposal details** would enable others to duplicate their results.

• An evaluation methodology would help us be sure that:
  – We've met the PAR
  – We have baselined against other technologies correctly
  – We have built consensus that we're developing the best technical solution.

• **Examples:**
  – 3GPP2 1xEV-DV Evaluation Methodology.
  – W-CDMA HSDPA technology simulation proposal R1-030115.
Evaluation Methods

- Link level methods are not adequate to capture the richness and dynamics of a system with multiple access points and terminals.

- Need a combination of link level and system level methods:
  - **System level**: model coverage area, propagation conditions for each link, captures the fading dynamics based on the shortest control process in the system (e.g. a power control period in WCDMA).
  - **Link level**: map the resulting $E_b/N_t$ on each link every update interval and evaluate the resulting error measures using link level curves.
Evaluation Methods (cont’d)

- System Simulation: **two phases**
  - Phase I: different mixture of services (**voice only**, voice + data, and data only). Would include physical layer HARQ and signaling errors.
  - Phase II: includes TCP and upper layers for data services
- Parameter set (different for each link).
  - Example: typical parameter set for DL:
    - # cells (sectors)
    - cell size
    - antenna pattern and orientation
    - propagation model
    - base station antenna correlation
    - Tx and Rx antenna gains
    - thermal noise model
    - carrier frequency
    - power control
    - etc.
Things to Consider

• Fading and propagation models

• DL Traffic models:
  – Web browsing, ftp, video, and voice
  – Different traffic models for UL and DL
  – Effects of TCP
Channel Models

• Three basic environments: path loss, shadowing, and delay profile model.
  – Indoor Environment
  – Pedestrian and Outdoor to Indoor Environment
  – Vehicular Environment.

• Each delay profile model has two variations:
  – “A” model: low delay spread case that happens frequently.
  – “B” model: median delay spread case that also happens frequently.
Fading and Propagation Models

• Different fading components:
  – Mean **path loss** model:
    • A deterministic model. Function of distance between Tx and Rx, antenna heights, carrier frequency, and the terrain.
    \[ L = \phi(f, R, h_a, h_b, \ldots) \]
  – **Shadowing** model: models the effect of blocking, diffraction, etc. A statistical model.
    Distribution Normal in dB \( \sigma_s \)
    Decorrelation Model (emp) \( R(\Delta x) = e^{\alpha|\Delta x|/x_d} \)
    \( x_d \)
  – **Fast fading and delay spread** models: number of paths, their delays and power profile, Doppler spectrum, and assignment probability.
Indoor Environment

- Small cell size and low transmit power
- Tx and Rx are located indoors.
- Very small Doppler values (walking speeds).
- Lots of scattering structures.
- Path loss Model

\[ L = 37 + 30 \log_{10}(R) + 18.3n^{((n+2)/(n+1)-0.46)} \]

- Shadowing: \( \sigma_s = 12 \, \text{dB} \).
- Worst case scenario from an interference point of view.
### Indoor Environment (cont’d)

#### Delay Power Profile for Indoor Environment

<table>
<thead>
<tr>
<th>Tap</th>
<th>Channel A</th>
<th></th>
<th>Channel B</th>
<th></th>
<th>Doppler Spectrum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Relative Delay (nsec)</td>
<td>Average Power (dB)</td>
<td>Relative Delay (nsec)</td>
<td>Average Power (dB)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Flat</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
<td>-3.0</td>
<td>100</td>
<td>-3.6</td>
<td>Flat</td>
</tr>
<tr>
<td>3</td>
<td>110</td>
<td>-10.0</td>
<td>200</td>
<td>-7.2</td>
<td>Flat</td>
</tr>
<tr>
<td>4</td>
<td>170</td>
<td>-18.0</td>
<td>300</td>
<td>-10.8</td>
<td>Flat</td>
</tr>
<tr>
<td>5</td>
<td>290</td>
<td>-26.0</td>
<td>400</td>
<td>-18.0</td>
<td>Flat</td>
</tr>
<tr>
<td>6</td>
<td>310</td>
<td>-32.0</td>
<td>700</td>
<td>-25.2</td>
<td>Flat</td>
</tr>
</tbody>
</table>
Pedestrian Environment

- Small cell size and low transmit power.
- BS with low antenna heights are located outdoor; with a mixture of indoor and outdoor users.
- Doppler rates are mainly small at walking speeds with occasional higher rates due to reflections from moving vehicles.
- Average building penetration loss of 12 dB with a standard deviation of 8 dB.
- Shadowing: $\sigma_s = 12$ dB for indoor and $\sigma_s = 10$ dB for outdoor.
Pedestrian Environment (cont’d)

• Path Loss Model I: describes worst case propagation. Used for coverage prediction.

\[ L = 40 \log_{10}(R) + 30 \log_{10}(f) + 49 \]

- \( R \) Distance between Tx and Rx
- \( f \) carrier frequency

• More accurate model, assumes urban environment (Manhattan distances)

\[ L = 20 \cdot \log_{10} \left( \frac{4\pi d_n}{\lambda} \right) \]

- \( d_n \) effective Manhattan distance
- \( \lambda \) wavelength
- \( n \) number of street segments

• Can be extended to cover dual slop behavior.
## Pedestrian Environment (cont’d)

### Delay Power Profile for Pedestrian and Outdoor to Indoor Environment

<table>
<thead>
<tr>
<th>Tap</th>
<th>Channel A</th>
<th>Channel B</th>
<th>Doppler Spectrum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Relative Delay (nsec)</td>
<td>Average Power (dB)</td>
<td>Relative Delay (nsec)</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>110</td>
<td>-9.7</td>
<td>200</td>
</tr>
<tr>
<td>3</td>
<td>190</td>
<td>-19.2</td>
<td>800</td>
</tr>
<tr>
<td>4</td>
<td>410</td>
<td>-22.8</td>
<td>1200</td>
</tr>
<tr>
<td>5</td>
<td>-</td>
<td>-</td>
<td>2300</td>
</tr>
<tr>
<td>6</td>
<td>-</td>
<td>-</td>
<td>3700</td>
</tr>
</tbody>
</table>
Vehicular Environment

- Large cell size and high transmit power
- BS with antennas at roof tops. Users are a mixture of pedestrian, stationary, and vehicular.
- Doppler rates are set by the vehicular speeds with occasional rates for stationary users.
- Path loss:

\[ L = 40 \left( 1 - 0.004 \times \Delta h_b \right) \log_{10}(R) - 18 \log_{10}(\Delta h_b) + 21 \log_{10}(f) + 80 \text{ dB} \]

- \( R \): distance between Tx and Rx
- \( f \): carrier frequency
- \( \Delta h_b \): BS antenna height above roof top (0-50 meters)

- Valid for NLOS and represents worst case.
- Shadowing: \( \sigma_s = 10 \text{ dB} \).
# Vehicular Environment (cont’d)

<table>
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<tr>
<th>Tap</th>
<th>Channel A</th>
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<th>Doppler Spectrum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Relative Delay (nsec)</td>
<td>Average Power (dB)</td>
<td>Relative Delay (nsec)</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>310</td>
<td>-1.0</td>
<td>300</td>
</tr>
<tr>
<td>3</td>
<td>710</td>
<td>-9.0</td>
<td>8900</td>
</tr>
<tr>
<td>4</td>
<td>1090</td>
<td>-10.0</td>
<td>12900</td>
</tr>
<tr>
<td>5</td>
<td>1730</td>
<td>-15.0</td>
<td>17100</td>
</tr>
<tr>
<td>6</td>
<td>2510</td>
<td>-20.0</td>
<td>20000</td>
</tr>
</tbody>
</table>

Delay Power Profile for Vehicular Environment
Shadow Fading Decorrelation

- Gudmundson: measurement based in urban and sub-urban (more accurate):

\[ \rho(\Delta x) = e^{-0.69315 \Delta x / x_d} \]

\[ x_d \quad \text{decorrelation distance} \]

- D. Cox: for urban environment with large number of high rises, shadowing process is better modeled as an independent increment process with increment durations approx. 1 city block.
Antenna Pattern for Sectorization

\[ A(\theta) = -\min \left\{ 12 \left( \frac{\theta}{\theta_{3dB}} \right)^2, A_m \right\} \quad -180 \leq \theta \leq 180 \]

\( \theta_{3dB} \) is the 3 dB beamwidth

\( A_m \) is the maximum attenuation
Traffic Models

• Different mixtures of users: voice only, voice+data, and data only

• Voice traffic models:
  – Voice codec
  – Circuit-switched or VoIP
  – In general, a Markov source with different rates (full rate, half rate, etc) with a corresponding set of transition probabilities between different rates
  – Voice capacity is obtained based on satisfying a certain outage criteria (or a group of); e.g, short term FER, per user outage, and/or system outage.
Traffic Models (cont’d)

- Data Traffic: FTP, web browsing (HTTP), WAP, near real time video.
- Different traffic models for FL and RL, e.g. web browsing
  - RL traffic: http requests
  - FL traffic: web page downloads.
- Must pay attention to interactions with TCP.
- Different assignment probability for each traffic type

<table>
<thead>
<tr>
<th></th>
<th>HTTP</th>
<th>FTP</th>
<th>WAP</th>
<th>Real Time Video</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24.43%</td>
<td>9.29%</td>
<td>56.43%</td>
<td>9.85%</td>
</tr>
</tbody>
</table>
FTP Traffic Model

• Uses TCP as the transport protocol.
• An FTP session consists of a sequence of file transfers separated by *reading times*. Two main parameters:
  – $S$: size of file to be transferred
  – $D_{pc}$: reading time
• For each file transfer a new TCP connection is used whose initial congestion window size is MTU (segment). An MTU could be 576 bytes or 1500 bytes.
• Packet arrival process described by the TCP traffic model.
FTP Traffic Model (cont’d)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Distribution</th>
<th>Parameters</th>
<th>PDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>File size (S)</td>
<td>Truncated Lognormal</td>
<td>Mean = 2Mbytes&lt;br&gt;Std. Dev. = 0.722 Mbytes&lt;br&gt;Maximum = 5 Mbytes</td>
<td>( f_x = \frac{1}{\sqrt{2\pi\sigma}} \exp \left[ -\frac{(\ln x - \mu)^2}{2\sigma^2} \right], x \geq 0 )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \sigma = 0.35, \mu = 14.45 )</td>
<td>( f_x = \frac{1}{\sqrt{2\pi\sigma}} \exp \left[ -\frac{(\ln x - \mu)^2}{2\sigma^2} \right], x \geq 0 )</td>
</tr>
<tr>
<td>Reading time (Dpc)</td>
<td>Exponential</td>
<td>Mean = 180 sec.</td>
<td>( f_x = \lambda e^{-\lambda x}, x \geq 0 )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \lambda = 0.006 )</td>
<td>( f_x = \lambda e^{-\lambda x}, x \geq 0 )</td>
</tr>
</tbody>
</table>
HTTP Traffic Model

- Uses TCP as its transport protocols.
- A session is made of ON/OFF periods representing web downloads and intermediate reading times.
- The traffic is self similar (the traffic exhibits similar statistics on different time scales)
- Each web download is made of a main object and a number of embedded objects
- Two versions of HTTP
  - HTTP/1.0: a distinct TCP connection is used for each object. May have up to 4 parallel connections (burst mode).
  - HTTP/1.1: 1 TCP connection is used to transmit each object (persistent mode).
HTTP Traffic Model (cont’d)
## HTTP Traffic Model (cont’d)

<table>
<thead>
<tr>
<th>Component</th>
<th>Distribution</th>
<th>Parameters</th>
<th>PDF</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Main object size ($S_M$)</strong></td>
<td>Truncated Lognormal</td>
<td>Mean = 10710 bytes&lt;br&gt;Std. dev. = 25032 bytes&lt;br&gt;Minimum = 100 bytes&lt;br&gt;Maximum = 2 Mbytes</td>
<td>$f_X = \frac{1}{\sqrt{2\pi\sigma}} \exp \left[ \frac{- (\ln x - \mu)^2}{2\sigma^2} \right], x \geq 0$&lt;br&gt;$\sigma = 1.37, \mu = 8.35$</td>
</tr>
<tr>
<td><strong>Embedded object size ($S_E$)</strong></td>
<td>Truncated Lognormal</td>
<td>Mean = 7758 bytes&lt;br&gt;Std. dev. = 126168 bytes&lt;br&gt;Minimum = 50 bytes&lt;br&gt;Maximum = 2 Mbytes</td>
<td>$f_X = \frac{1}{\sqrt{2\pi\sigma}} \exp \left[ \frac{- (\ln x - \mu)^2}{2\sigma^2} \right], x \geq 0$&lt;br&gt;$\sigma = 2.36, \mu = 6.17$</td>
</tr>
<tr>
<td><strong>Number of embedded objects per page ($N_d$)</strong></td>
<td>Truncated Pareto</td>
<td>Mean = 5.64&lt;br&gt;Max. = 53</td>
<td>Note: Subtract k from the generated r.v. to get $N_d$&lt;br&gt;$f_X(x) = \frac{\alpha k^{\alpha}}{x^{\alpha+1}}, k \leq x &lt; m$&lt;br&gt;$\alpha = 1.1, k = 2, m = 55$</td>
</tr>
<tr>
<td><strong>Reading time ($D_{pe}$)</strong></td>
<td>Exponential</td>
<td>Mean = 30 sec</td>
<td>$f_X = \lambda e^{-\lambda x}, x \geq 0$&lt;br&gt;$\lambda = 0.033$</td>
</tr>
<tr>
<td><strong>Parsing time ($T_p$)</strong></td>
<td>Exponential</td>
<td>Mean = 0.13 sec</td>
<td>$f_X = \lambda e^{-\lambda x}, x \geq 0$&lt;br&gt;$\lambda = 7.69$</td>
</tr>
</tbody>
</table>
### WAP Traffic Model

<table>
<thead>
<tr>
<th>Packet based information types</th>
<th>Size of WAP request</th>
<th>Object size</th>
<th># of objects per response</th>
<th>Inter-arrival time between objects</th>
<th>WAP gateway response time</th>
<th>Reading time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distribution</td>
<td>Deterministic</td>
<td>Deterministic</td>
<td>Deterministic</td>
<td>Deterministic</td>
<td>Deterministic</td>
<td>Deterministic</td>
</tr>
<tr>
<td>Distribution Parameters</td>
<td>76 octets</td>
<td>K = 71.7 bytes, ( \alpha = 1.1 )</td>
<td>Mean = 2 plus offset of 1</td>
<td>Mean = 1.6 s</td>
<td>Mean = 2.5 s</td>
<td>Mean = 5.5 s</td>
</tr>
</tbody>
</table>

- Each WAP request will have a fixed size.
- Each WAP User is assumed to be continuously active:

  Make a WAP request → Wait for a response → Wait for reading time → Make the next WAP request
A video streaming session is divided into a number of frames arriving at a regular interval of \( T \) sec (depends on the fps)

Each frame is divided into a fixed number of packets or slices, each is transmitted as a single packet.

Parameters:
- Inter-arrival time between frames
- Number of packets in a frame
- Packet size
- Inter-arrival time between packets within a frame
### Real Time Video Traffic Model (cont’d)

<table>
<thead>
<tr>
<th>Information Type</th>
<th>Inter-arrival time between frames</th>
<th>Number of packets (slices) in a frame</th>
<th>Packet (slice) size</th>
<th>Inter-arrival time between packets (slices) in a frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distribution</td>
<td>Deterministic (based on 10 fps)</td>
<td>Deterministic</td>
<td>Truncated Pareto</td>
<td>Truncated Pareto</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean=50 bytes</td>
<td>Mean=6 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Max=125 bytes</td>
<td>Max=12.5 ms</td>
</tr>
<tr>
<td>Parameters</td>
<td>100 ms</td>
<td>8</td>
<td>K=20 bytes, $\alpha=1.2$</td>
<td>K=2.5ms, $\alpha=1.2$</td>
</tr>
</tbody>
</table>

Traffic Model for a 32kps, 10fps video streaming session
Summary

• **Things that we covered:**
  – Channel and fading models.
  – Data Traffic Models for FL.

• **Things that need to be covered:**
  – C/I calculations (models?).
  – Fairness and delay criteria.
  – Performance metrics for data services.
  – Reverse Link.