Machine-to-Machine communications (m2m) on cdma2000
Why is m2m important?

- New market segment
- Radically different from phones, data cards, and Smartphones
- Market opportunity potential possibly comparable to that of Voice + Smartphones
- m2m is at the cusp of a major growth spurt...as wireless data in 1997 and Smartphones in 2006
- Organizations that prepare and execute on the m2m opportunity will be leaders in communications
Why develop m2m over cdma2000?
cdma2000 1x and m2m (1/2)

- 1x air-interface is the best solution for low-rate (voice, data) communications

- 1x deployments (at 800MHz) have excellent coverage and reliability

- Most m2m apps are characterized by low-rate data and require good link budget

- 1x offers a cost-effective solution (device, network) that meets the needs of a large % of m2m applications
Combination of lower network cost, higher network capacity, and improved module power consumption enables operators to aggressively promote use of m2m on their 1x network AND target new market segments.

Enables operators to maximize return-on-investment of their deployed 1x assets.
cdma2000 EV-DO and m2m

- m2m apps characterized by higher rates are better served by EV-DO
- EV-DO air-interface is optimized for higher rate communications and also benefits from excellent coverage with 800MHz deployments
- EV-DO air-interface continues to be optimized and evolved to handle explosive growth due to Smartphones
  - Enhanced Connection Management (from DO-Adv Phase I)
  - Smart Networks (from DO-Adv Phase I)
- Combination of Enhanced Connection Management and m2m-specific enhancements enables operators to target m2m apps better served by EV-DO
How can cdma2000 be optimized for m2m applications?
Most m2m is module initiated and very sensitive to power consumption

- What matters in m2m?
  - Module Power Consumption
    - Use of Access State vs Connected State for data transfer
    - Connection Setup Time
    - Connection Duration
    - Data Rate
    - Modem ON % (during a connection)

- Access Dimensions

- Reverse Link Capacity

- Network Signaling
- Reduce network signaling load
- Reduce airlink data transferred by m2m apps
- Increase modem (in module) battery life
- Increase network Connection Capacity
Example

- Simple app: 1x, m2m module uploads report (200 bytes) daily

![Diagram showing power up and down states, overhead read, call setup, PPP setup, data transfer, wait for network dormancy, and idle state.]

Using Traffic Channel (Baseline)

Figure not to scale
Optimize overhead read

Enhanced network control (of m2m modules)

Increase control dimensions (R-EACH) + DoS (with R-EACH)

Fast-Connection Setup

Optimize network resource usage

Optimize data transfer (speed, modem power consumption)

Enhanced Position Location
Minimize Overhead Read

- Allow m2m device to use stored overhead messages even if it has not read them recently

- Particularly valuable for stationary m2m devices
Network Control of m2m devices

- Enable network to treat m2m devices differently
  - For example, separate access control

- Most m2m is module-driven
- Higher Access Load is a possibility
- Enable Network to control access by m2m modules
Increase Access Channel Dimensions

Most m2m is module originated (requires access)

↑ module penetration → access dimension limit

↑ Access collisions

↑ RL RoT
↓ RL Capacity
↓ Module battery life
↑ Report + Control delay
Higher Data Rate Access Channel

- Faster Access
  - Faster data transfers
  - Eliminate connections
  - ↑ Network Capacity
- ↑ data rate (up to 38.4kbps) with R-EACH
- DoS for small data transfers
  - ↑ Network Connection Capacity
  - ↑ modem battery life
CDG 1x Voice Call Tx. Power Profile

- Total transmit power for a voice < 5dBm, 90% of the time
- Higher rate R-EACH (up to 38.4k) can be used most of the time
Optimized Connection Setup

- Reduce Network Signaling Load due to m2m
- Faster Connection Setup
- ↑ Network Connection Capacity
- ↑ modem battery life
Optimized Connection Setup

- Optimized channel assignment mechanisms
  - Module originated connections
    - One message for channel setup
  - Module terminated connections
    - Assign channel directly over paging channel and skip access procedure

- Speed-up connection setup
  - Parallelize FL acquisition (by MS) and RL acquisition (by BS)
Optimize Data Transfer

- Transmit at as high a data rate as possible (subject to network load and available module PA headroom) in order to complete data transfer quickly AND tear down connection as soon as data transfer is completed
  - Higher rate transmissions in connected state and immediately at connection setup

- Use modem (FL or RL) transmit chain only when needed
  - Shut off modem tx. (reverse link) when not transmitting data
  - Don’t allocate FL power (base station) to traffic frames when not transmitting actual data
Modem power consumption is typically flat until PA stages are used.

Example

- Power consumption @ -60dBm and 0dBm tx. power could be roughly the same.
Optimize Network Resource Usage

Enable m2m modules to register far less frequently than voice and data-centric devices
Persistent PPP

- Increase inactivity timer for PPP
  - For power-sensitive devices with a long data reporting period

- More resource used at PDSN
  - Memory for PPP state

- Most direct approach to reducing PPP airlink overhead
  - As load increases, can add resource (e.g. memory) to PDSN

- PPP-free methods may be considered as m2m devices proliferate
Enhanced Position Location

- Improve 1x-AFLT solution
- Higher position accuracy
  - Enables m2m modules without GPS (for some apps)
  - Improve 1x-AFLT with GPS
  - Lower-cost 1x-m2m modules
    - Improve position location where GPS is not accessible or degraded (e.g., Urban Canyons)
Reuse for Highly Detectable Pilot

- Color code the sectors
- $K=9$ reuse in time domain is illustrated below
Enhanced Position Location

- Extend the Highly Detectable Pilot concept to 1x
  - Specification developed for EV-DO Similar principle as EV-DO HDP

- Application to 1x
  - Network allocates dedicated PCG’s to transmit HD Pilots only
    - Overhead = 1%
  - Legacy pilot, overhead, and traffic are not transmitted during the HDP PCG’s
**Initial cdma2000 1x Rev F Proposal**

<table>
<thead>
<tr>
<th>#</th>
<th>Feature</th>
<th>Spec</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Skip overhead channel read if SEQ # in GPM is unchanged</td>
<td>C.S0005-F</td>
</tr>
<tr>
<td>2</td>
<td>R-EACH (coupled with F-PCH)</td>
<td>C.S0004-F, C.S0005-F</td>
</tr>
<tr>
<td></td>
<td>RL Data-over-Signaling (using R-EACH) in Access State</td>
<td>No change</td>
</tr>
<tr>
<td>3</td>
<td>One-message Connection Setup (ECAM+SCM) from BS using GEM</td>
<td>C.S0005-F</td>
</tr>
<tr>
<td>4</td>
<td>Direct Channel Assignment (over F-PCH)</td>
<td>C.S0005-F</td>
</tr>
<tr>
<td>5</td>
<td>Parallelize RL (at BS) and FL (at MS) acquisition</td>
<td>C.S0005-F</td>
</tr>
<tr>
<td>6</td>
<td>Joint R-FCH and R-SCH request and assignment at connection setup</td>
<td>C.S0005-F</td>
</tr>
<tr>
<td>7</td>
<td>Smart Blanking (same as 1x-RevE) for SO33</td>
<td>C.S0017-0 v3.0</td>
</tr>
<tr>
<td>8</td>
<td>Longer timer-based registration values for m2m (capability) devices</td>
<td>C.S0005-F</td>
</tr>
<tr>
<td>9</td>
<td>m2m capability indicator</td>
<td>C.S0005-F</td>
</tr>
<tr>
<td>10</td>
<td>Unique Access Overload Class for m2m devices</td>
<td>C.S0005-F, TSB-16-C</td>
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<tr>
<td>11</td>
<td>1x-AFLT w/ Highly Detectable Pilot</td>
<td>C.S0002-F, C.S0004-F, C.S0005-F</td>
</tr>
</tbody>
</table>
Example (↓Signaling Load, ↓Data Transfer, ↑Battery Life ↑Connection Capacity)

- Simple app: 1x, m2m module uploads report (200 bytes) daily

![Diagram showing device power states and time analysis]

Using Traffic Channel (Baseline)

Using Traffic Channel (Proposed)

Figure not to scale
Example (↓Signaling Load, ↓Data Transfer, ↑Battery Life ↑Connection Capacity)

- Simple app: 1x, m2m module uploads report (200 bytes) daily

Figure not to scale
How much gain is achievable?

Example 1: Metering application (cdma2000 1x)
Example 2: SmartGrid with modem as aggregator (cdma2000 1x)
Example 3: SmartGrid with modem as node(cdma2000 EV-DO)
Example 1: Metering Application (1x) module power consumption improvement

- Implementation only uses shorter preamble with RACH
- Implementation + Stds
  - DoS w/ 38.4k R-EACH @ 0dBm
  - Connection w/ R-FCH @ 20dBm
Example 2: SmartGrid - cdma2000 1x modem as an aggregator with 40-nodes per aggregator

- Traffic Source based on model developed by 3GPP2 in collaboration with NIST

<table>
<thead>
<tr>
<th>Message type</th>
<th>Frequency (msgs/meter/day)</th>
<th>Payload size (bytes/msg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commercial gas</td>
<td>3.5</td>
<td>1167</td>
</tr>
<tr>
<td>Residential gas</td>
<td>3.5</td>
<td>1167</td>
</tr>
<tr>
<td>Commercial electricity</td>
<td>18</td>
<td>900</td>
</tr>
<tr>
<td>Residential electricity</td>
<td>5</td>
<td>1667</td>
</tr>
<tr>
<td>Misc.</td>
<td>2.5</td>
<td>365</td>
</tr>
<tr>
<td>FL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pricing</td>
<td>4</td>
<td>297</td>
</tr>
<tr>
<td>Other Misc.</td>
<td>1</td>
<td>187</td>
</tr>
</tbody>
</table>
## Simulation Scenarios

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Baseline</th>
<th>+Proposed</th>
<th>+ CSM8700</th>
<th>+ CSM8700 + Proposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dormancy Timer (sec)</td>
<td>10</td>
<td>1</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Access Slot Duration (Frames)</td>
<td>9 (3+6)</td>
<td>1 PCG</td>
<td>9 (3+6)</td>
<td>1 PCG</td>
</tr>
<tr>
<td># RACH</td>
<td>4</td>
<td>N/A</td>
<td>4</td>
<td>N/A</td>
</tr>
<tr>
<td>RL IC (CSM8700)</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Smart Blanking</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>R-EACH</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Connection Capacity
(# of nodes/sector/1.25MHz)

Partially Loaded Network

<table>
<thead>
<tr>
<th>Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
</tr>
<tr>
<td>+ Proposed</td>
</tr>
<tr>
<td>+ CSM8700</td>
</tr>
<tr>
<td>+ CSM8700 + Proposed</td>
</tr>
<tr>
<td># of nodes/sector/1.25MHz</td>
</tr>
<tr>
<td>12500</td>
</tr>
<tr>
<td>57000</td>
</tr>
<tr>
<td>25000</td>
</tr>
<tr>
<td>65000</td>
</tr>
</tbody>
</table>

Fully Loaded Network

<table>
<thead>
<tr>
<th>Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
</tr>
<tr>
<td>+ Proposed</td>
</tr>
<tr>
<td>+ CSM8700</td>
</tr>
<tr>
<td>+ CSM8700 + Proposed</td>
</tr>
<tr>
<td># of nodes/sector/1.25MHz</td>
</tr>
<tr>
<td>7000</td>
</tr>
<tr>
<td>37000</td>
</tr>
<tr>
<td>13000</td>
</tr>
<tr>
<td>50000</td>
</tr>
</tbody>
</table>

- 40 nodes per aggregator
- RL Capacity defined at RoT > 10dB, 1% of the time
  - Similar relative gains are observed at RoT > 7dB, 1% of the time
Example 3: SmartGrid with Direct Cellular (EV-DO modem as a node)

• Model provided by Consert – a SmartGrid solution provider –

“report”

“control”

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## CSM6850 (Gains to m2m from Enhanced Connection Mgmt – developed for Smartphones –)

<table>
<thead>
<tr>
<th></th>
<th>Baseline (7sec dormancy)</th>
<th>+1sec dormancy</th>
<th>+DTX</th>
<th>+Short Pkt Async CC + ACAck and TCA Bundling (same/different users)</th>
<th>+Typical Frequency of Control Messages</th>
</tr>
</thead>
<tbody>
<tr>
<td># of nodes per sector per 1.25MHz</td>
<td>3500</td>
<td>10,350</td>
<td>10,700</td>
<td>16,100</td>
<td>18,350</td>
</tr>
<tr>
<td>Gain wrt baseline</td>
<td>1.3x</td>
<td>3.9x</td>
<td>4.1x</td>
<td>6.1x</td>
<td>7.0x</td>
</tr>
<tr>
<td>FL delay*</td>
<td>4.7s</td>
<td>5.2s</td>
<td>15.0s</td>
<td>15.0s</td>
<td>15.0s</td>
</tr>
</tbody>
</table>

Further gains can be achieved with airlink friendly m2m app design

* 90-percentile tail in the CDF of each AT’s 90% tail point in its delay CDF <=15sec