Mesh Networked Sensors for Parking Inventory Management
Overview

• Business Background
• Our Deployment
• On-street Measurements
  – Parking and ‘Advice for the Gambling Parker’
  – Network
• A Short Wish List for Mesh Networks
The Importance of Inventory Management

Payment Systems

Enforcement & Workforce Mgmt

Demand Mgmt & Public Information

Actual Parking Demand & Usage

Actual Parking Capacity & Inventory
Inventory Managed Parking

More Violations Identified

Lower Cost of Ticketing

- More Violations Identified
- Lower Cost of Ticketing

- $0
- $5
- $10
- $15
- $20
- $25
## Consumer Convenience: Parking and Payment

### Space 33
- **Arrive:** 9:14am
- **Check In:** 9:19am
- **Depart:** 10:22am
- **Duration:** 1:08
- **Charge:** $2.25

### Space 42
- **Arrive:** 8:17am
- **Check In:** 9:12am
- **Depart:** 5:41pm
- **Duration:** 9:24
- **Charge:** $10.00
The Unpaid Dollars

- **$6.5B** Unpaid Use
- **$2.0B** Paid Use
- **$2.0B** Tickets
- **$40B** Unticketed Violations

Violation Capture Rate: ~5%
Meter Payment rate: 20-25%
Meter Occupancy rate: > 80%
Our Test Deployment

- Continuous monitoring of ~20 spaces via mesh networked raised pavement marker
- 300 instrumented spaces soon!
### Battery St  Total Spaces: 10

<table>
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<tr>
<th>SPACE NUMBER</th>
<th>CURRENT STATUS</th>
<th>ARRIVAL</th>
<th>LIMIT</th>
<th>DURATION</th>
<th>OVERSTAY?</th>
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**Notes:**

1. Occupancy: Percent of available time used for parking.
2. Turnover: Average number of parking sessions per hour.
3. Overstay: Number of parking sessions exceeding posted time limit.
Occupancy by Time of Day
Block: 1301 Battery
Period: February 2006

- **Off hours Use**
- **Metered Use**
- **Meter Receipts**
Advice for the Parking Gambler

- Average # of tickets per meter per month = 2
- Parking Ticket Cost ~ $40
- Monthly meter time cost ~ $400
- Optimistic monthly advantage of not paying for meter time ~ $320
- **Odds favor not paying for meter time**

**Disclaimers:**
- Parking control officers are known to periodically swarm areas
- Your results may vary - pls don’t call us 😊
Network Lifetime Results

- Parking sessions detected – 6100
  - 11 parked cars per space, per day
- Average Network Latency
  - 2.5 – 4.5 seconds
- Path Stability
  - 73%
- Network Reliability
  - 99.975%
Daily Network Statistics

Path stability = packets ‘ack’ed / packets sent

Network reliability = % of packets successfully delivered
Standardizing Network Management aka ‘Stuff I wish we didn’t have to build’

- For manageable deployment one needs:
  - Configuration Management
    - How often does mesh report?
    - Where are things located?
  - Security Management
  - Fault Management
  - Performance Management
    - Event correction/root cause
    - Alarming
- Proprietary/custom solution…. OR…
- Leverage conventional solutions!
Candidate Solution: SNMP

- ‘Conventional’ networking vendors use this
- The HTTP of network management
- Lots and lots of NMS tools
SNMP and Mesh Network Management: A Sample

Generics Traps

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<th>Gateway Relevance</th>
<th>Mote Relevance</th>
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Network Management: The Bottom Line

• Mesh and non-mesh networks have significant overlap of important performance metrics
• A standard network management interface allows the integrator to focus on the application, not the network
  – Obvious analogy: HTML, HTTP
• Is SNMP or ‘SNMP+Mesh’ the solution?
  – There is much to leverage from SNMP, but anything standardized and interoperable would be great.
Acknowledgements

• Dust Networks
• Streetline Team