MBUF APPLICATIONS FOR SMART PHONES AND OTHER DEVICES

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Overview

• Attributes to consider when selecting an MBUF Technology

• Functional Parameters used to evaluate MBUF Technologies

• The Minnesota Technology Solution
  – Platform Selection
  – Emerging Performance Metrics
A technology option is defined as a unique combination utilizing a choice/approach under each attribute.
23 MBUF Technology
Functional Parameters

9 User Parameters
- Privacy
- Equity
- Value Added Services
- Ability to Audit
- Transparency
- Ease of Use
- Voluntary Option
- Cost to User
- Charging Mechanism Complexity

14 System Parameters
- Ability to Reallocate Revenue
- Charging Accuracy
- Charging Precision / Repeatability
- Data Security
- Ease of Enforcement
- Operational Costs
- Maintenance Costs
- Capital Costs
- Evasion
- Support of Low Technology Opt. for RUF
- Cross Jurisdiction Interop.
- Flexibility to expand
- Flexibility to Adapt
- Reliability
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- Cross Jurisdiction Interop.
- Flexibility to expand
- Flexibility to Adapt
- Reliability
Battelle’s Role in the Minnesota Road Fee Test Project

• Develop software and hardware systems to conduct a demonstration of mileage-based user fees (MBUF)

• Demonstration is:
  – Using Commercial Off-The-Shelf (COTS) hardware
    - Deploying 500 in-vehicle devices & back office processing system
  – Capturing, invoicing, and handling payments associated with MBUFs
    - Permit a comparison of technology vs. odometer readings
  – Also deploy Value Added Services
    - Navigation, Safety Signage & Probe Data Collection
Core Principle

• Heavily reliance of Commercial Off The Shelf (COTs) hardware

• Three representative hardware platforms identified by the technology scan:
  – TomTom 630 (representing dedicated PND devices)
  – iPhone
  – Google Nexus One (representing Android-based smart phones)

Personal Navigation Device (e.g., TomTom)

Smart Phone (e.g.) iPhone or Android Based Phone
Platform Performance

• The quality of the GPS position given by the three devices was found to be very comparable.
  – All claim ±5 meter accuracy
  – Accuracies of ±10 meters are not uncommon
  – Accuracies greater than ±15 meters can occur for a significant percentage of a given route.

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**CPU Average Load**

<table>
<thead>
<tr>
<th>Platform</th>
<th>Average CPU Load</th>
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<tbody>
<tr>
<td>TomTom 630</td>
<td>400 MHz ARM</td>
</tr>
<tr>
<td>TomTom 740</td>
<td>800 MHz A4 + GPU</td>
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<tr>
<td>iPhone</td>
<td>800 MHz ARM + GPU</td>
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<tr>
<td>Android</td>
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Personal Navigation Device (e.g., TomTom)  

Smart Phone (e.g.) iPhone or Android Based Phone
Platform Selection Results

• Multi-use platforms (Smart phones) performed better than dedicated personal navigation devices at supporting 3rd party applications
  – Supplied the required processing power
  – Access to user interface elements

• Android-based phones provided more open interfaces for software development on the platform.

• We chose the Samsung Captivate™ Android Smartphone
What Does a Participant See?

- MBUF Rate
- Interstate Notification
- MBUF Geography

Current Fee: 3.5¢

Version 0.5.8099

Date mileage was last sent
Miles recorded
Estimated Fee

GPS Status
MBUF – How it works

• Designed as a “thick client”
• MBUF application accumulates mileage driven by fee category (roadway type, geography, etc.)
• Every 24 hours accumulated mileage by fee category transmitted via cellular to data warehouse
• Invoice generated monthly based upon aggregate miles in fee categories
Disputing the Fee Calculation

- Probe application captures vehicle location every second and sends this to infrastructure every 20 seconds.
- Probe does not contain ability to link a participant to a route, only a participant can do this.

<table>
<thead>
<tr>
<th>MBUF Application</th>
<th>Probe Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Stores accumulated miles by road rate category in OBU</td>
<td>• Latitude/Longitude on second-by-second basis</td>
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<tr>
<td>• Transmits cumulative miles by category and vehicle ID to Infrastructure no more than once per day</td>
<td>• Transmitted to Infrastructure every 20 seconds</td>
</tr>
<tr>
<td>• No information on individual trips</td>
<td>• Contains a TRIP identifier (ID) but no information on vehicle or person</td>
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</table>
Infrastructure Design Overview

- Infrastructure Components Built Upon open architecture and cloud-based storage/processing

- Communication to and from vehicle
  - RESTful Web service
  - Supports data payloads formatted in both JSON and XML
  - REST based web service
  - SSL Encryption

Cloud-Based Storage/Processing and Mileage Tax Accounting
## Participants Have Web-Access

### Invoices

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Technology Attributes for Minnesota Solution

In-Vehicle Fee Assessment Technology

- Odometer
- Engine Hour Meter
- OBD-II Plug-In
- CAN Bus Device
- GPS enabled Device
- Smartphone
- Passive RFID
- Active RFID
- License Plate Reader
- Cellular Triangulation
- DSRC

Communication Method

- Bluetooth
- Cellular
- DSRC
- Pull-Out / Plug-In
- RFID Transmission
- Visual Manual
- Wi-Fi
- Camera / Optical Recognition

Fee Assessment Location

- On-Board
- Off-Board

Communication Location

- Inspection / Reporting
- Wide Area
- Specific Roadway Location / Facility

Fee Assessment Calculation

- Dwell Time
- Miles Traveled
- Boundary Crossing
- Time within area
- Distance within area

Fee Assessment Metric

- Variable Rate
- Flat Rate

A technology option is defined as a unique combination utilizing a choice/approach under each attribute.
Functional Parameter Scoring for Minnesota Solution

User-Focused Parameters
- Privacy
- Equity
- Value Added Services
- Ability to Audit
- Ability to Reallocate Revenue
- Charging Accuracy
- Charging Precision / Repeatability
- Data Security
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System-Focused Parameters
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- Support of Low Technology Opt. for RUF
SYSTEM PERFORMANCE METRICS
MRFT Mileage Invoicing

- As of the end of March we have invoiced:
  - 1,418,166 miles across 2184 invoices worth $11,996.31
- 658,830 Baseline miles ($0.00 / mile)
- 759,336 Test miles ($0.00, $0.01 or $0.03 / mile)
Mileage Collection

Mileage per day

14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0

9/12/11 10/12/11 11/12/11 12/12/11 1/12/12 2/12/12 3/12/12 4/12/12

Miles
Odometer versus MBUF: Wave B

Participant had “corrupted” device, but still had a few trips (4) 
Suspect soft refusal. Now using device post 2
nd Odometer.
Probe Snapshot Collection

# of Probe Snapshots per day

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<td>3/12/2012</td>
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<td>4/12/2012</td>
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Total: 292,270,653
Avg / day: 1,259,787
Preliminary Operational Conclusions

- GPS technology via smart phone is a potentially viable technology mechanism for MBUF provided:
  - Mechanism to also capture odometer
  - Ability to handle cases when GPS not available

- Smart Phone platform is relatively stable and is able to meet the processing demands

- Monthly billing seems to be acceptable to participants
  - A few participants have expressed less frequent billing would be better

- Ability to see trip details in relation to fees assessed is of great interest by participants
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