AutoMedia: Linking the Vehicle with Consumer Electronics and Services

Jason Flinn

University of Michigan
Problem: Vehicle is an island

Each vehicle is an island unto itself

data crosses the border generally with carried device
device (and its data) must be consciously managed
limited extra-vehicle networks are separate stovepipes

Several lost opportunities

passengers don’t have what they want
context which could help organize is ignored
few existing applications don’t coordinate
many vehicular applications hard to create
Vision: Bridge the islands

Bridges to the “mainland” of home and office
unified view of all of a passenger’s media
automatic exchange of context and meta-data
allow individual consumer devices to come and go
no effort on the part of the passengers

Bridges to the “other islands”—vehicles on the road
exchange traffic, road conditions
communicate for immediate safety concerns
form communities among co-located travelers

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What’s needed?

Advances in **distributed storage**:
- Share data among home, vehicle, and web services
- Cache data and propagate updates asynchronously
- Support non-traditional clients

Advances in **networking**:
- Leverage multiple networks: WiFi, WiMax, GPRS, DSRC
- Predict where you are going
- Provide connectivity forecasts

Advances in **middleware**:
- Allow applications to declare intentions
- Hide vagaries of intermittent and uneven connectivity
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Managing Data: Today
Managing Data: BlueFS

BlueFS helps manage personal data and devices

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BlueFS Goals

Pervasive data access (anytime, anywhere, any device)
- Support consumer electronics devices (iPod, phone, etc.)
- Support web services (Flickr, Facebook, Amazon S3, etc.)

Simplified data management
- Automation (indexing, organizing, transcoding, etc.)
- Policies (reliability, privacy, etc.)
- Context (location, time, nearby people, etc.)
BlueFS Overview

Server stores primary replica of all data
Clients cache data to improve performance
Clients register affinity for specific types of data
Cached data available when disconnected

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Connecting Consumer Electronics

Device-Specific Protocol

DFS Protocol

Distributed File System

Attach: computer speaks for CEDWorks with disconnected clients

DFS Protocol

Device-Specific Protocol

Additional information:

- Device-Specific Protocol
- DFS Protocol
- Distributed File System
- Attach: computer speaks for CEDWorks with disconnected clients

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Device-Specific Namespaces

User prefers one organization

Consumer electronics device requires another organization

Solution: Store translations on the consumer device
Adding Automation

- Updating indexes
- Transcoding
- Type-specific caching
- Organizers
Adding Automation

Cannot execute on CED

Leverage general-purpose computers
Take action when files change

Problem: Need notification of file changes
Notification Via Persistent Queries

Don’t need new mechanism

Leverage cache consistency mechanism
Structure notifications as file system object
Robust to crash
Handles disconnected operation

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Persistent Queries

Example: video recording and playback
Leveraging intra-vehicle context

Vehicle has a wealth of contextual data

Can we provide a “context bus” that enriches data?

Enrich data by sharing context among local devices:
  vehicle location used to tag site where photos taken
  Allows searching by location
  Can automatically organize digital photo albums
    Wireless proximity of cell phones reveals user presence
  Match music on stereo to tastes of passengers
  Start playing audio-book where left off last time
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The Big Picture

State of the art: systems are *reactive* not *proactive*

There are opportunities to plan
people are *creatures of habit*
infrastructure is *slow to change*

If the system knew
where you were likely to be, and
what connectivity was available there…

…then applications could schedule their usage appropriately

Our goal: expose this *connectivity derivative* to applications
**Pieces of the puzzle**

Where are you likely to be?
- figure out where you are now
- use the past to predict where you’ll be next

What are conditions likely to be when you get there?
- map access points at newly-visited locations
- refresh infrequently to catch stale state

Expose this information to applications
- simple API: expected bandwidth in 10 (20, 30, ...) seconds
- applications use this however they like
Where are you?

Existing solutions
- GPS when you can
- WiFi localization
- GSM fingerprinting

Our implementation: PlaceLab/WiFi
- 20-30 meter avg accuracy
  acceptable for our needs

Convert to a discrete grid
- limit precision of lat/lon
- grid square ~110x80 meters
  compact, useful representation

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Where are you going?

We need a *personal* mobility model
    people are creatures of habit, but...
    ...different people have different habits

Song et. al. (Dartmouth) conducted a bake-off
    winner: second-order Markov model

Model consists of discrete states and transitions
    states: your current and former location
    transitions: possible next states, with probabilities assigned
    probabilities computed by past behavior
    discrete transition steps: we use 10 seconds (arbitrary)
What will conditions be like?

Overlapping public coverage

Heterogeneous quality
  Bandwidth, latency, ports

Decentralized ownership

Multiple “usable” options

Which AP is the best AP?

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Virgil AP selection daemon

Current mechanism: loudest must be best
  okay in a homogenous deployment
  no better than random selection in the wild

Instead, we perform active testing and discovery
  Scan for APs and associate to each in turn
  Run bandwidth, latency, port tests to reference server
  Choose AP with the “best” connection

**Cache test results for future prediction**
History is useful

Repeated traversals of the same area benefit (a lot!)

History: % scans finding usable AP

History: scanning overhead (s)

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The Commute

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Connectivity Forecasts

Close is often good enough, thanks to range issues

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Declarative Networking

Allow applications to declare their intent in using network.

Main goal: simplicity of the interface.

Applications specify:
- Foreground (latency-sensitive) vs. background
- Bulk vs. small messages
- Important vs. unimportant
- etc.

May specify on a per-message, per-socket, or per-thread basis.
Connectivity middleware

Manage vagaries in network connectivity:
- Transient networks (WiFi hotspots)
- Intermittent networks (cell coverage)
- Changes in latency
- Varying bandwidth

Challenge: map application sends/receives to networks
- Choose best network for each request
- Defer traffic when necessary, continue when available
- Allow applications to tear-down, re-establish connections
Declarative networking example

Download mail (background)

Read mail (foreground)

Intermittent High bandwidth

High availability Low bandwidth

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Building Bridges

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