Mobile User Navigation Supported by WSAN: Full-fledge Demo of the SmartPark System

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The SmartPark System: \url{http://smartpark.epfl.ch}: 
- Driver arrives at unknown city
- System automatically identifies parking spots (empty or occupied)
- Wireless guidance device embedded in car (no GPS) provides driver with parking spot availability information
- System guides driver to a chosen empty parking spot

System Elements
- Each parking spot equipped with a wireless sensor
- Wireless guidance device embedded in the car
- Both mobile and fixed nodes form ad hoc Wireless Sensor and Actuator Network
- No central server, no navigation system like GPS
- Vehicle-to-vehicle and vehicle-to-sensor communication used mostly (inexpensive)
- Sensor-to-sensor communication allowed (expensive)

Research Challenges
- Connecting (possibly) partitioned networks
- Mobility
- Energy scarce in fixed nodes, plentiful in mobile nodes
- Scale of the network
- No full view of whole system (important for discovery and navigation)
- Radio channel uncertainty (fading, interference)
- Efficient conflict resolution methods (an ad hoc reservation system)
- In-network aggregation at different time and space scopes

Building Blocks

Information Dissemination: Provides users with the up-to-date information about parking spot availability.

Approach | Research Challenges:
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Epidemic-like dissemination (no need for end-to-end communication) | Efficient and robust dissemination algorithms
Connecting isolated city islands (mobile users as data mules) | Mobility forwarding

Current Implementation:
- Each node periodically broadcasts its own state (empty or occupied) sending the "BusyMsg".
- Nodes (fixed and mobile) can overhear nearby nodes and learn their state.
- Upon each new broadcast, the state of other nodes is piggybacked on the "BusyMsg".
- The information about nodes that are far away is broadcast more often than information about the one-hop neighbors. This is done by applying a selection policy:
  - Information about one-hop neighbors is selected from the node's cache with small probability $p$.
  - Information about other nodes is selected with high probability $1 - p$.
  - Only fresh information is selected.

Localization and Tracking: Provides users with location information when without navigation system like GPS.

Approach | Research Challenges:
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Path planning and following (dead reckoning) | Methods resistant to sensor outages and radio uncertainties
Local view of the system only | Epidemic-like messaging

Current Implementation:
- Uses both the location information stored at the fixed sensor and the RSS measurements
- Uses the center of mass approach (no constrained tracking implemented at the moment):
  - Exponentially-weighted: include past location estimates
  - RSS-weighted: for nodes that are closer, the RSS is higher

Distributed Navigation: Provides users with turn-by-turn instructions to the chosen empty parking spot.

Approach | Research Challenges:
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Computationally complex (no central server) | Local view of the system only
Multi mobile design (collaborative resource discovery) | Epidemic-like messaging

Current Implementation:
- Path to the chosen parking spot consists of fixed nodes that should be visited by mobile user sequentially.

Example

Testbed
Parking Sensor: TinyNode + Standard Extension Board \(\url{http://tinynode.com}\)

Hardware (Features):
- XE1205 Semtech radio transceiver
- Adjustable data rates up to 153kbit/s

Software (Service Division):
- TinyOS
- XEPoS

Wireless Guidance Device: Laptop/PDA + TinyNode

Software (Service Division):
- Information Dissemination
- Localization and Tracking
- Path Planning
- Path Following

Current Status
Deployment at WASAL \(\url{http://wasal.epfl.ch}\) - laboratory for prototyping applications of WSANs.
- Parking sensors: 25 TinyNodes at fixed locations deployed indoors
- Mobile users: 2 Laptop with TinyNodes on trolleys

Test scenarios:
- One mobile user at fixed location
  - Parking spot visible, How many parking spots were visible within a fixed time window?
- Two mobile users at fixed location, 2nd mobile approaching
  - Efficiency of information propagation, How fast does information about state change propagate?