EXTENSIBLE SYSTEMS: CPS

- Ultra large scale ubiquitous software integrated distributed systems that interact with physical environment.
- A networked (wireless) platform that can be used by many, possibly concurrent applications.
- Physical configuration/topology affects the available computational resources.
- Physics imposes timing constraints on activities.
- The available computational resources.

EXTENSIBLE SYSTEMS: EVOLUTION

- Ultra-wideband (UWB) active tags
- Bluetooth Low Energy (BLE) RSSI
- Requires specialized hardware (beacons and tags)
- High accuracy (from JPL) fingerprinting
- Positioning accuracy is ~3m
- Requires training to create a mapping from RSSI statistics to positions (fingerprinting)
- Training algorithm is running continuously
- Two indoor positioning technologies
- Bluetooth Low Energy (BLE) RSSI
- Ultra-wideband (UWB) active tags
- Tags are COTS devices, such as current generation smartphones and tablets
- Requires specialized hardware (beacons and tags)
- Positioning accuracy is ~10cm

CHALLENGES IN EXTENSIBLE CPS

<table>
<thead>
<tr>
<th>Property</th>
<th>Description</th>
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<tbody>
<tr>
<td>Multi-tenant</td>
<td>Extensible CPS are open platforms that can host multiple applications belonging to different organizations/clients</td>
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<tr>
<td>Dynamic</td>
<td>Functionality and resource extensibility results in a dynamic system that can expand or contract at any time</td>
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<td>Remotely deployed</td>
<td>Some resources may be remotely deployed resulting in very limited or no opportunity for human interaction, e.g.: UAVs, satellites, etc.</td>
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<td>Heterogeneous</td>
<td>Each subsystem of an extensible CPS platform can belong to different domain. Also, distributed ownership of entities in same domain</td>
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<tr>
<td>Resilient</td>
<td>Susceptible to failures and anomalies during which functionalities provided by different systems should be maintained in order to be continuously operational as long as possible</td>
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CITY EXAMPLE

AN EXTENSIBLE ARCHITECTURE FOR CITY SERVICES

USE CASE

1. A car is looking for a place to park.
2. Hub prompts that the car go to the parking lot on Edge Street.
3. Hub interacts and reserves a parking spot.
4. Parking Management guides the car to the parking spot.
5. The car successfully parks in the reserved spot.

TECHNICAL APPROACH

UNIFIED APPLICATION MODEL AND RUNTIME MANAGEMENT

APPLICATION TO SMART PARKING

- The smart parking application relies on two indoor positioning technologies
  - Ultra-wideband (UWB) active tags
  - Bluetooth Low Energy (BLE) RSSI
  - Requires specialized hardware (beacons and tags)
- Parking space manager
- Allocates parking spot
- Uses the positioning subsystem to track vehicle (BLE equipped tablet/smartphone with optional UWB tag)
- Computes and dispatches driving directions.

SUMMARY

- Supports integration of legacy and external applications
- Supports three consensus and voter redundancy patterns
- Support for multiple middleware transports
- Support for active monitoring of application (future)
- Support for Application Diagnosis (future)
- Support for other languages (future)
- Support for iOS (future)