Mobile crowdsensing of parking space using geofencing and activity recognition

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ITS in your pocket
Proven solutions driving user services

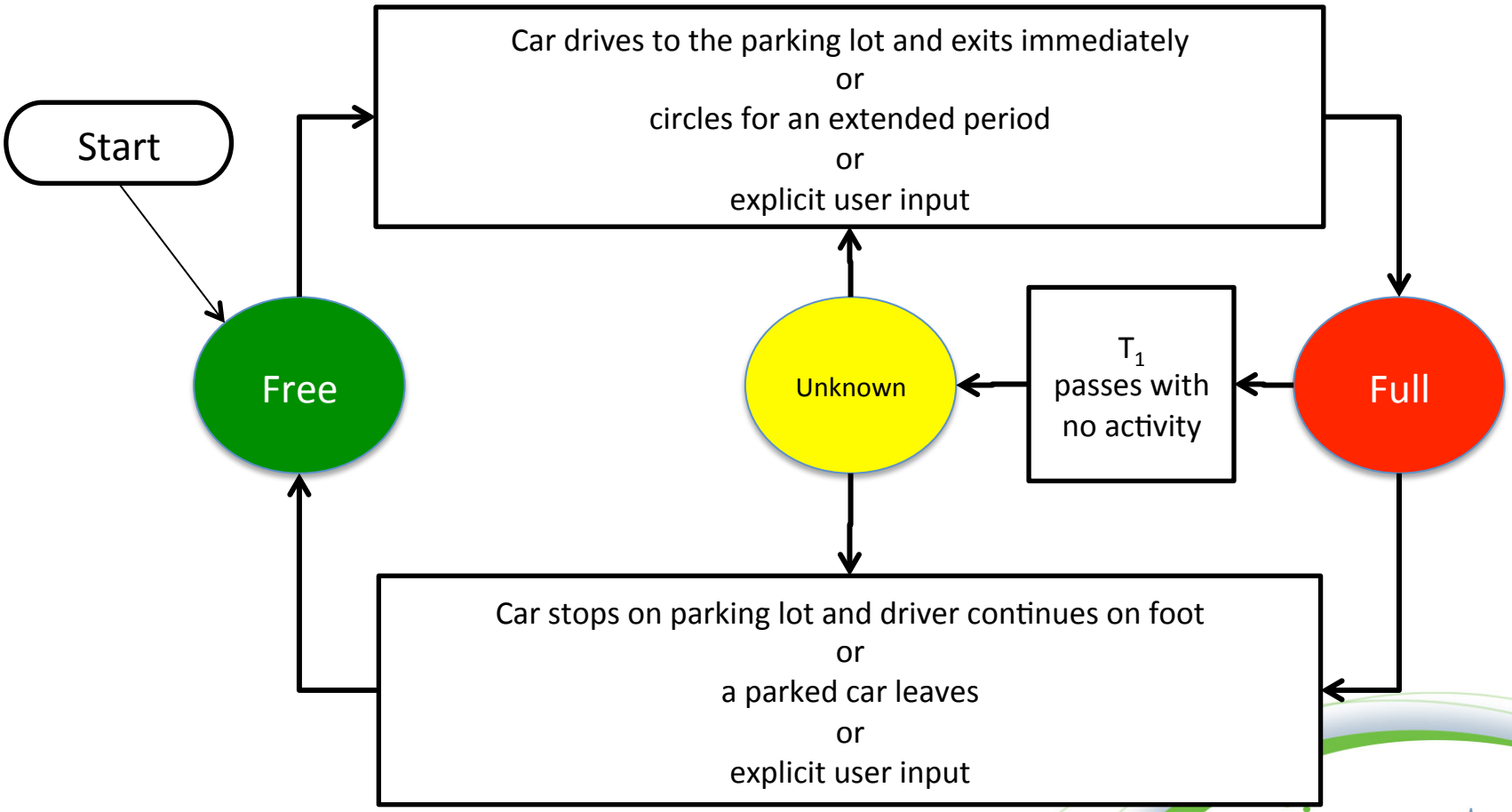
Three Methods of Gathering Parking Status Information

1. Infrastructure sensors
   - Loop detectors (or cameras) for entrances of parking areas
   - Detectors for individual parking squares
   - Requires supporting infrastructure investment
2. Crowdsourcing
   - User reporting of parking area status
     - Full, almost full, plenty of space
   - Active method – requires effort from a user
3. Crowdsensing
   - Parking status information gathered from sensors of a mobile device
   - Passive method - requires only minimal user interaction

Android Sensors

- Geofences
  - A circular geographical area can be defined
  - The service produces Enter and Exit events
- Activity recognition
  - In vehicle, On foot, and On bicycle (also Tilting, Still)
- Fused location provider
  - Combines information from GPS, cell location, Wi-Fi, and sensors (accelerometer, barometer, …)
  - Improved energy-efficiency and accuracy
  - Enables more accurate indoor location

Parking Area Status from Crowdsensing



Patterns of Parking-Related Events

Successful parking

1. enter geofence
2. in vehicle
3. on foot
4. exit geofence

Infer: free space in the parking area

Failed parking attempt

1. enter geofence
2. in vehicle
3. exit geofence (within a short duration)

Infer: the parking area is full

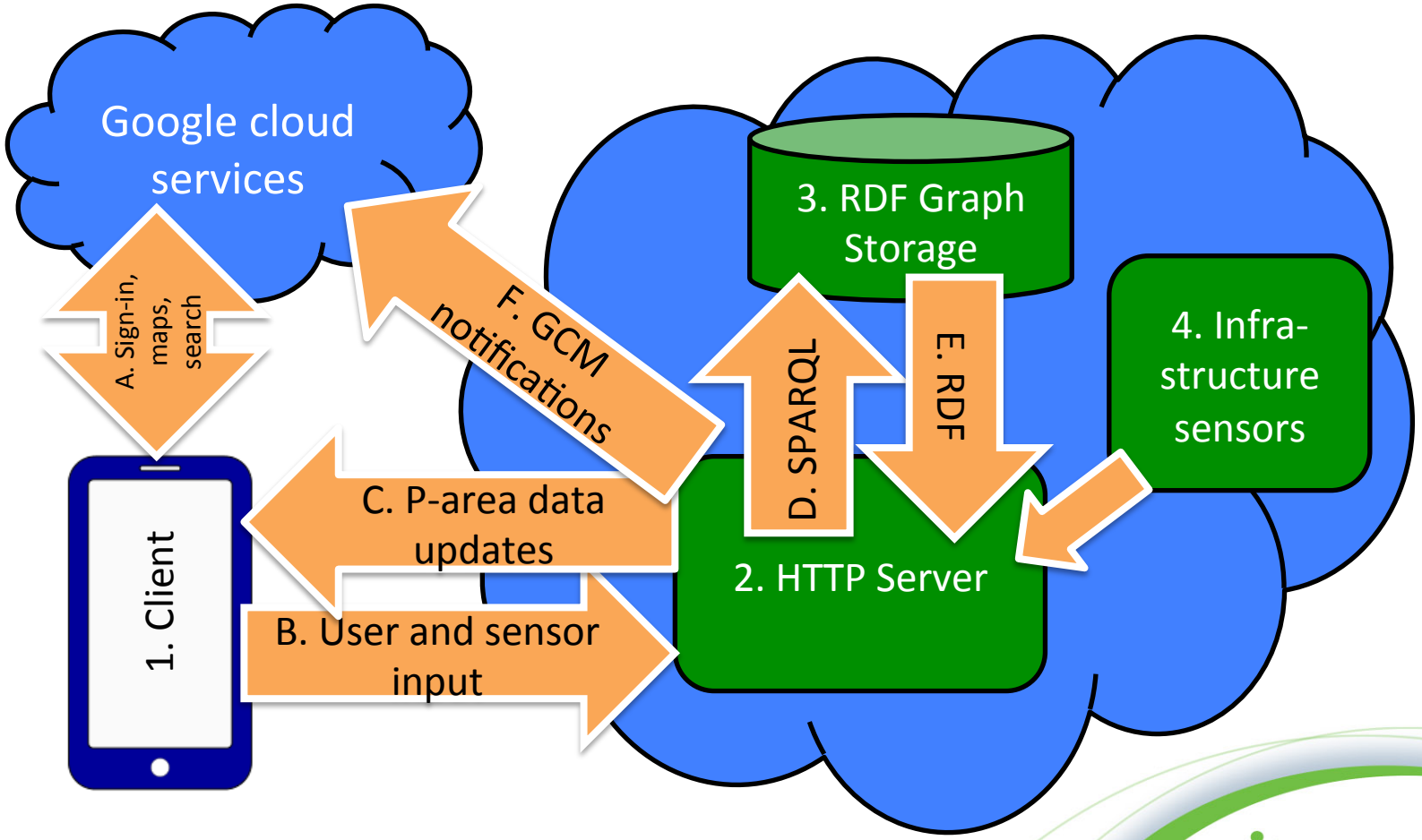
End of parking

1. enter geofence
2. on foot
3. in vehicle
4. exit geofence

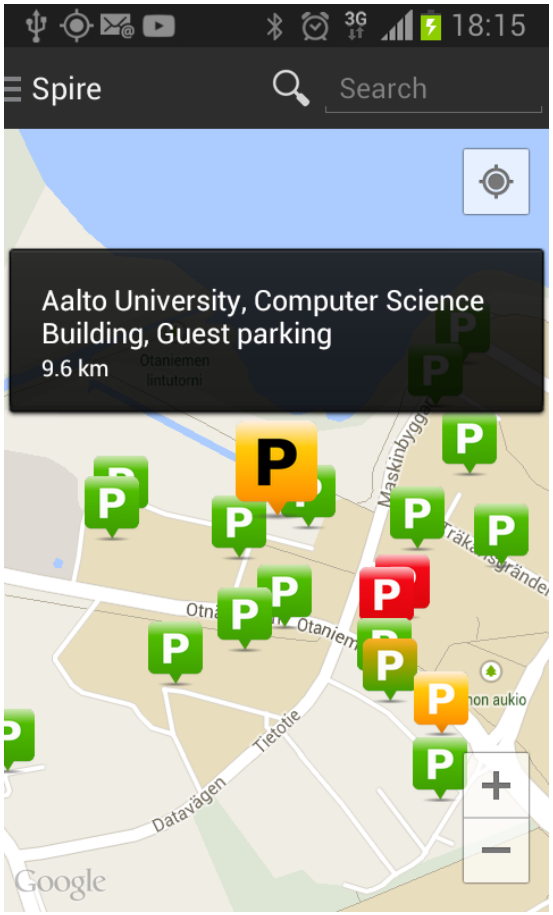
Infer: free space in the parking area

Visible and invisible drivers!

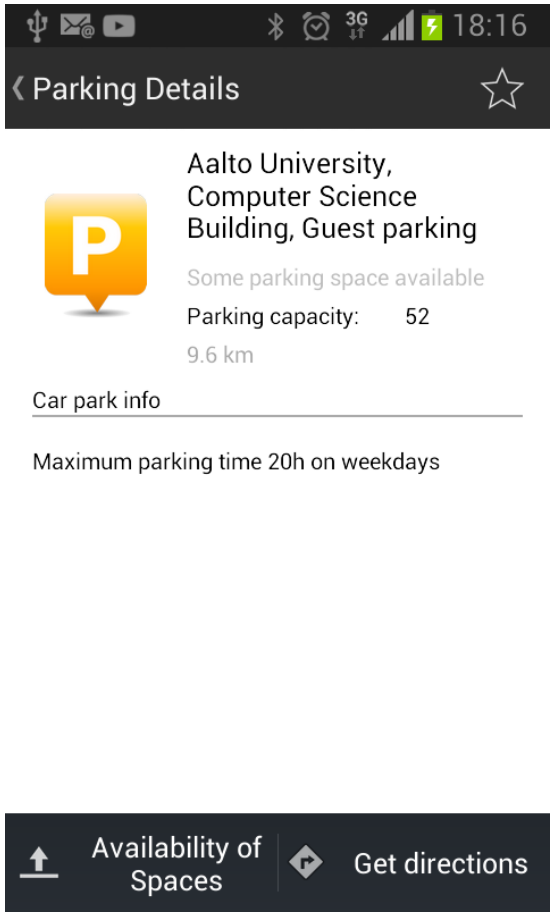
SPIRE Application Architecture



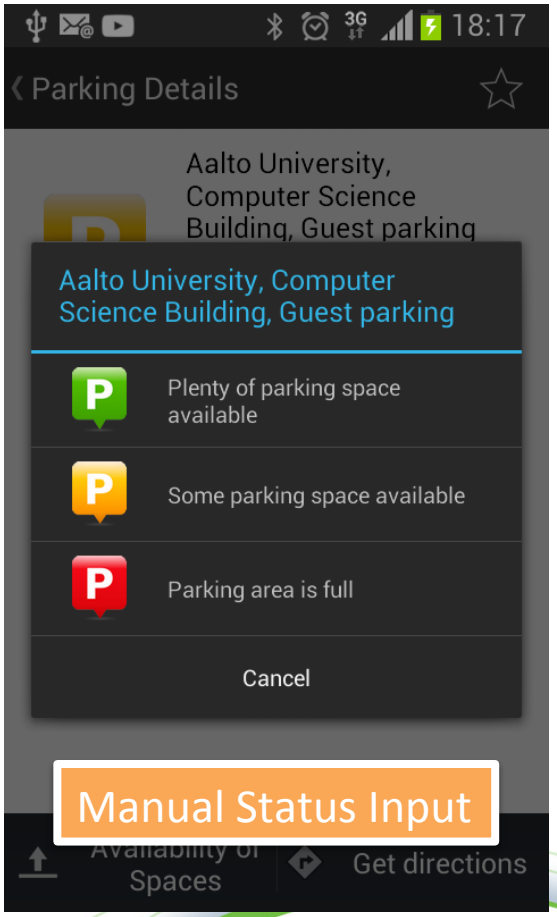
Mobile Client Screen Captures



Map View



Parking Lot Info



Event Trace Example

Table 1: Sample log of a successfully detected parking procedure

Time:	Type:	Event:
11:51:45	Geofence	<Computer Science Building, Guest parking> <Enter>
11:51:54	Activity	<IN_VEHICLE>
11:51:55	Location	60.187546 24.82136
	Location	...extra GPS coordinates removed...
11:52:40	Location	60.18752 24.821259
11:53:01	Activity	<ON_FOOT>
11:53:01	Geofence	<Computer Science Building, Guest parking> <Exit>

Challenges

- Algorithmic imperfections
  - Full parking area detection victim
  - Challenging geometries
    - Drive-thru
    - Small parking areas (Heterogeneous permissions)
  - Drivers invisible to the system
- Technical challenges
  - Power-consumption vs. geofence entry detection
  - Activity recognition uncertainty
- Human factors in crowdsourcing

Conclusions

- Benefits of crowdsensing
  - No infrastructure investment
  - No manual effort from the user
  - Good for large, homogeneous parking areas and high user penetration
- Crowdsensing is not a complete solution
  - Does not work well for all geometries
- Crowdsensing can be one source of information, but it needs to be complemented by infrastructure sensors and crowdsourcing, where appropriate