Herecast: An Open Infrastructure for Location-Based Services using WiFi

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Introduction

• User’s **context** includes location, time, date, temperature, schedule, etc
• Context-aware Location takes advantage of user context for computing
• Location is most widely used piece of context
• Example location-aware applications:
  – Pull up web pages relevant to user location (e.g. google search that returns nearest restaurants)
  – Users publish their presence so friends can find them
• Also, location-based service:
  – E.g find print to closest printer
GPS

- GPS finds location of users worldwide
- GPS uses satellite constellations
- Signals cannot penetrate walls
- **Result:** GPS works great outdoors, not so well indoors
- Even tall buildings cause GPS problems
- EU planning new GPS standard that can blast through walls…. Not here now!!!
Indoor location sensing

• Some authors have proposed indoor location sensing
• Example: Location finger printing method.
• Used in RADAR (Microsoft), LOCUS (WPI)
• Location fingerprinting has two stages:
  – Calibration (offline)
  – Look-up (real-time)
• Calibration:
  – Walk around, record signal strength at known location, build database called radio map
• Look-up:
  – As user moves, use current unknown signal strength to infer location (matching)
Location Fingerprinting

• Parameters affecting accuracy/performance
  – Number and location of access points
  – Number of training points
  – Pattern matching algorithm
Obtaining Signal Strength

- Signal strength varies with
  - Location: hence location fingerprinting
  - Orientation: user direction, antenna omni-directional Vs. directional
  - Building: construction, walls, attenuation
  - Time: people moving, doors opening
  - Sampling: number of SS samples used
- Important: SS variation due to location >> all other factors combined
- SS better measure than SNR
- Associate SS tuple with location
- Note: directional antennas improve results
### Signal Strength Matching

#### MEASURED TUPLES

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<tr>
<th>LOCATION</th>
<th>SIGNAL STRENGTH</th>
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<td>380</td>
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#### OBSERVED SIGNAL STRENGTH

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- Find closest match in database
Signal Strength Matching

- **Simple**: Return closest match
- **Deterministic**:  
  - Smallest Euclidean distance (RADAR, Infocom 2000)  
    - $\sqrt{(ss_1' - ss_1)^2 + (ss_2' - ss_2)^2 + (ss_3' - ss_3)^2}$  
    - Elimination via Thresholding
- **Probabilistic**:  
  - Joint PDF and clustering (Horus, Percom 2003)  
  - Bayesian inference, sensor fusion (LADD, Mobicom 2002)  
  - Markov modeling and Kalman filters (Liu, JSAC 1998)
LOCUS MQP

- Ali Taheri, Arvinder Singh, Best CS MQP WPI
- Determine physical location of clients on an 802.11b real wireless network at WPI
- Software-only, platform independent solution:
  - Uses existing access points and wireless cards
  - Does not use GPS or proprietary tags
  - Commercial products already from Ekahau, Newbury
- Performance in WPI Network
Issues with Location Fingerprinting

- Location fingerprinting is very accurate
- Main issue is that callibration is manual, takes a lot of time
- About 12 hours required to calibrate a floor of a building
- New directions: community-based systems
- Main idea: users upload radio map (list of access points, locations, observed signal strength)
- Projects: Herecast, PlaceLab (Intel)
Herecast Architecture

- Herecast implemented with examples on Univ. of Western Ontario campus
- Wireless access points broadcast MAC address (unique identifier) that distinguishes it from other Aps
- Computing device can use it to map location, find location-based services
Data modeling and management

- Location information is associated with AP
- UML diagram of data model is shown below
- Example: UWO -> London -> province of Ontario
- UWO has many buildings (Middlesex, Taylor lib, etc)
Access Points

• Access points constantly being added/deleted
• Do not want Sys admin to be burdened with city-wide or campus wide database maintenance
• **Solution:** community-based AP information maintenance
• Users assigned role, some can add new APs found, delete AP info, etc
• Users initially assigned few privileges
• Add more privileges as users observed to give accurate information
Access Point Information

- Changes stored in change log, can be rolled back
- Deletions placed in queue to be vetted by high-ranking user
- Future: users may vote to accept/reject changes
- When user finds new AP, fills form to upload info
- Details filled include city, province, country, area, street address, floor, etc
Uploading AP information

• Entered information is symbolic
• GPS uses coordinates (longitude, latitude)
Symbolic Information

- Coordinates make it easier to calculate distances
- Users more comfortable with symbolic representation
- E.g. The name of a building.
- Client Device software consists of:
  - Finding AP Information Component
  - Maintaining AP Information Component
  - Communication with server
Client Device Software

• Finding AP Information Component:
  – Reads AP MAC address, Signal Strength

• Maintaining AP Information Component:
  – Stores gathered AP info in AccessPoint object
  – List of AccessPoint objects stored in AccessPointList
  – Includes method to query highest RSSI
  – **Herecast approach:** Location is associated with AP with strongest Signal Strength…. Hmmm!

• Communication with server
  – Information transfer using standard HTTP
  – HTTP GET to download database info
  – HTTP POST used by client to upload info to database
Client Device Software

• Data Cache Component:
  – Server returns entire `AccessPointList` to client, not just requested AP info
  – Thus, the additional information can be cached
  – Stored using text file to keep it compact for mobile device
  – On next request, cache is first searched
Possible Services

• Initial screen includes services available at user’s location
• Services may
  – retrieve location once
  – Constantly updated
• Example service:
  – Map of UWO, user location
• Users may subscribe to services
Implementation

- Written in C++
- Pocket PC version uses embedded visual C++
- WiFi Scanner is open source to interface to network card and discover APs.
- Can show all available APs at user location
Implementation

• Library code is open-source
• Consists of WiFi scanner, software to maintain AccessPointList, software to ask for service subscription
• Testing work: surveyed approx. 140 APs in 12 buildings at UWO
• Building with most APs (20) had all APs found in 1 hr
Applications

- Area Maps
- Friend finder
  - Automatically publish user locations to his/her friends
Applications

- Heresay: location-based message board
Bandwidth Advisor

- Users with no connectivity, pull up list of APs in area and load associated with each AP
- Device detects congestion, advises user to move to better location
- BA also helps balance network
- User can click on location to find out load
Related work

- Active badge (infrared)
- Active bat (radio signals + ultrasound)
- Cricket, MIT (ultrasound)
- RADAR, Microsoft (Radio signals)
- Placelab, Intel (Radio signals, community-based)
Discussion

- **Wide-area Vs Local**: Herecast can support wide-area location application
- **Fine Vs Coarse resolution**: Herecast is not as fine-grained as triangulation using multiple access point
- **Privacy**: Use opt-in approach
- **Resource consumption**: was minimal
- **Ease of development location-aware app**: easy… area map service created in an hour
- **Data management issues**: one server okay now, more needed in future
Future Work

- Future applications
- GPS integration
- Warn user when AP signal leakage (signal received in different building)
- Autonomous map generation: use symbolic info to generate map and compare distances