The NearMe Wireless Proximity Server
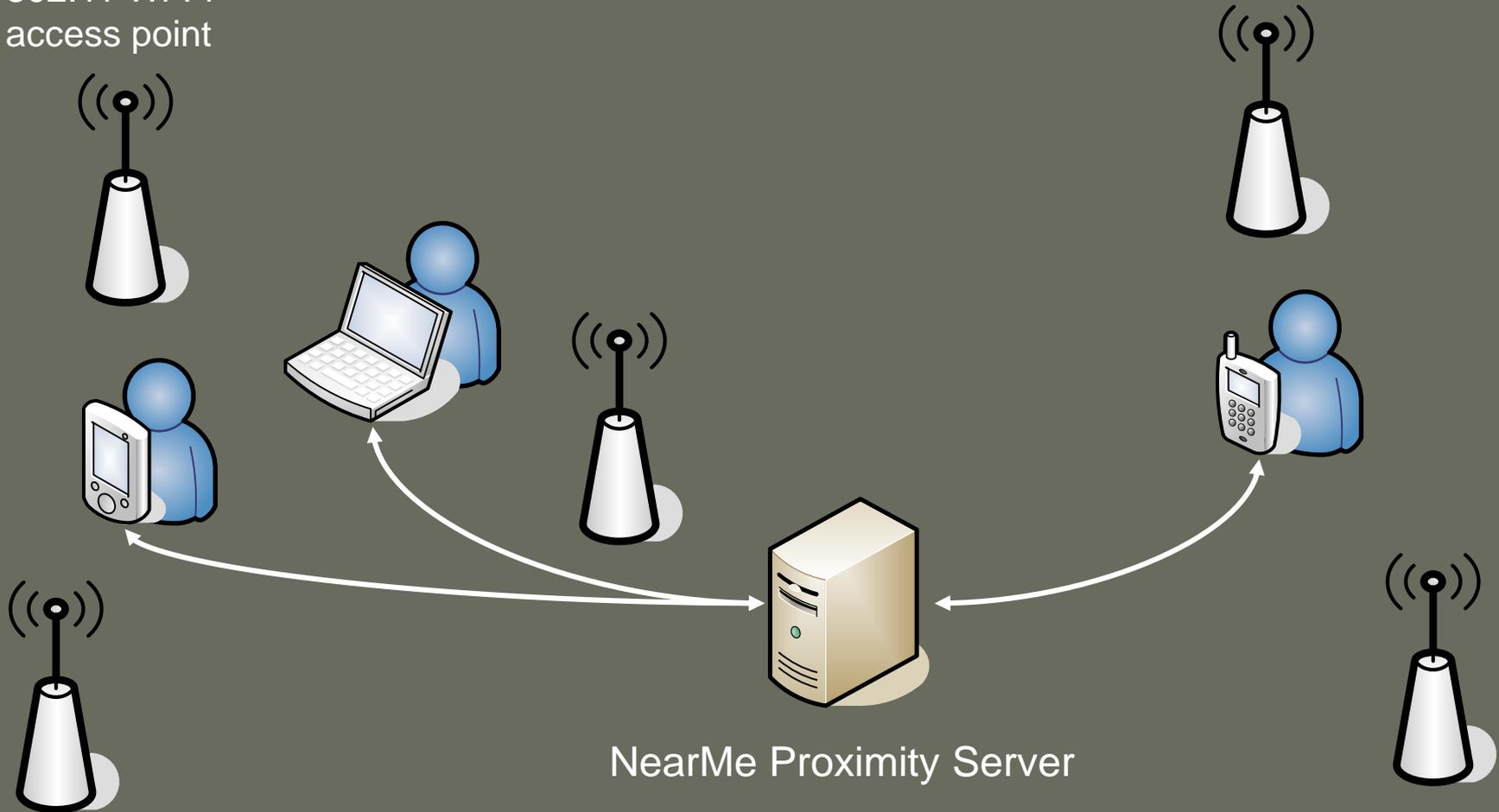
John Krumm and Ken Hinckley

Microsoft Research

Redmond, WA, USA
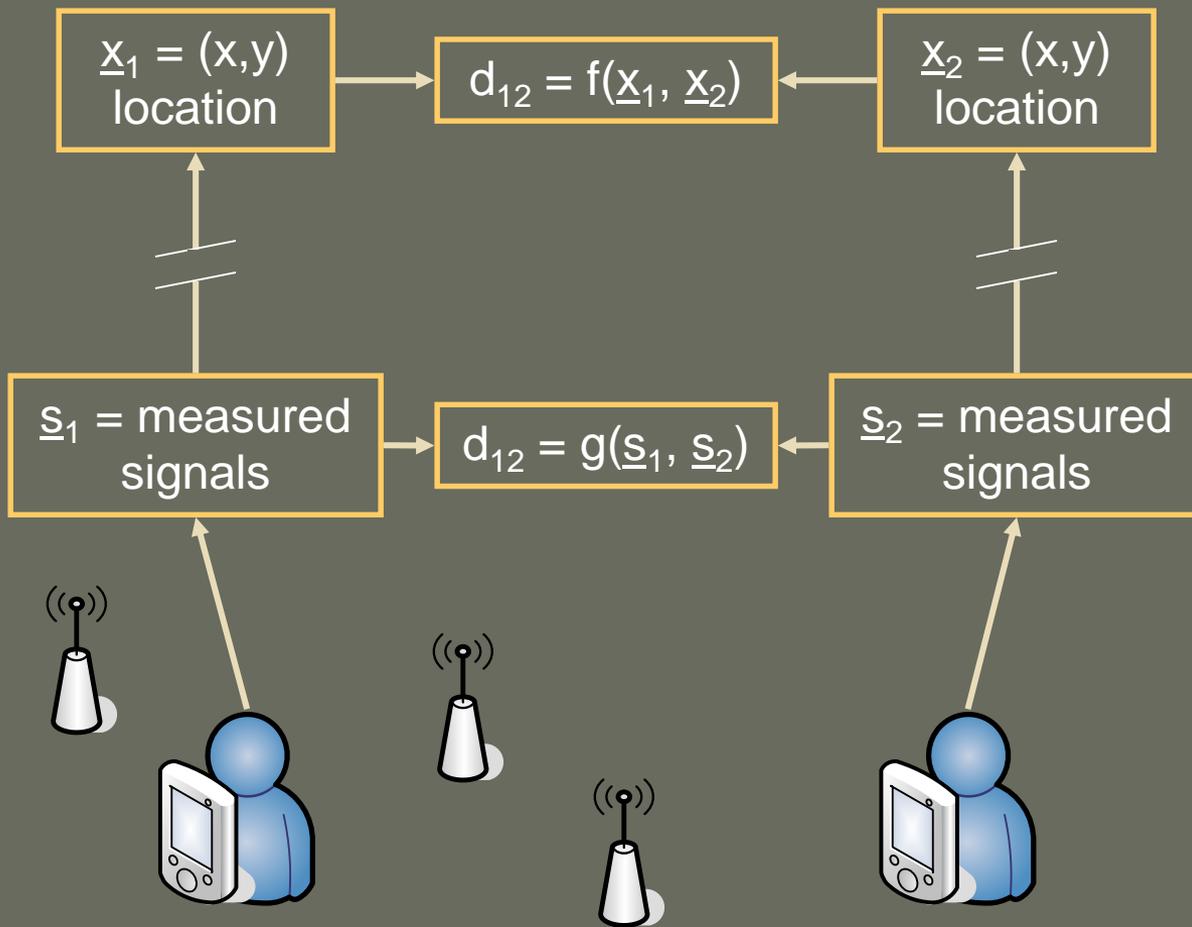
The Basic Idea

802.11 Wi-Fi
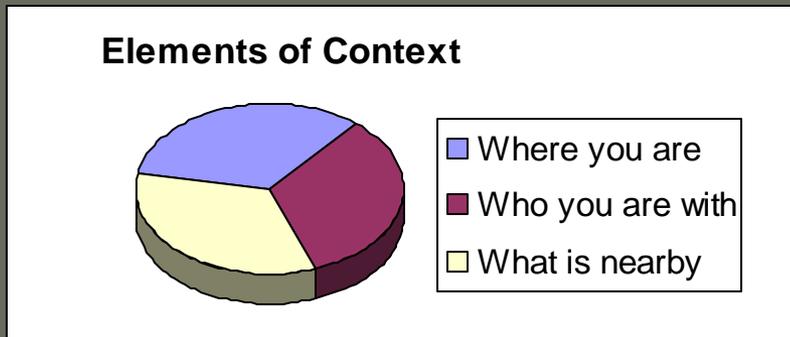access point

NearMe Proximity Server

Location *vs.* Proximity

$\underline{x}_1 = (x,y)$ location

$d_{12} = f(\underline{x}_1, \underline{x}_2)$

$\underline{x}_2 = (x,y)$ location

$\underline{s}_1 = $ measured signals

$d_{12} = g(\underline{s}_1, \underline{s}_2)$

$\underline{s}_2 = $ measured signals

"My sonar's got it at 12 feet away and closing ... 11 feet ... 10 feet ... God, it's enormous! ... Nine feet ..."

Who Cares?

Elements of Context

- Where you are
- Who you are with
- What is nearby

Schilit, Adams, & Want, "Context-Aware Computing Applications", 1994.

- Which of my friends, colleagues, relatives, or enemies are nearby?
- Who are these strangers with me?
- What are the names of nearby printers?
- What conference rooms are nearby?
- How far away is the nearest receptionist desk?

Other elements of context: velocity, mode of transportation, task, goal, mood …

Other Proximity Methods

- Location from
  - Active badges
  - Cameras
  - Wi-Fi
  - GPS
  - Cell Phones
  - …
- Conference Devices
  - SpotMe
  - nTAG™
  - IntelliBadge™ - NCSA
  - Conference Assistant – Georgia Tech
  - Proxy Lady – Viktoria Institute
  - Digital Assistant – ATR
- Synchronous Context
  - Synchronous Gestures – Microsoft
  - "Are You With Me?" – U. Washington
  - SyncTap – Sony
  - Stitching – Microsoft
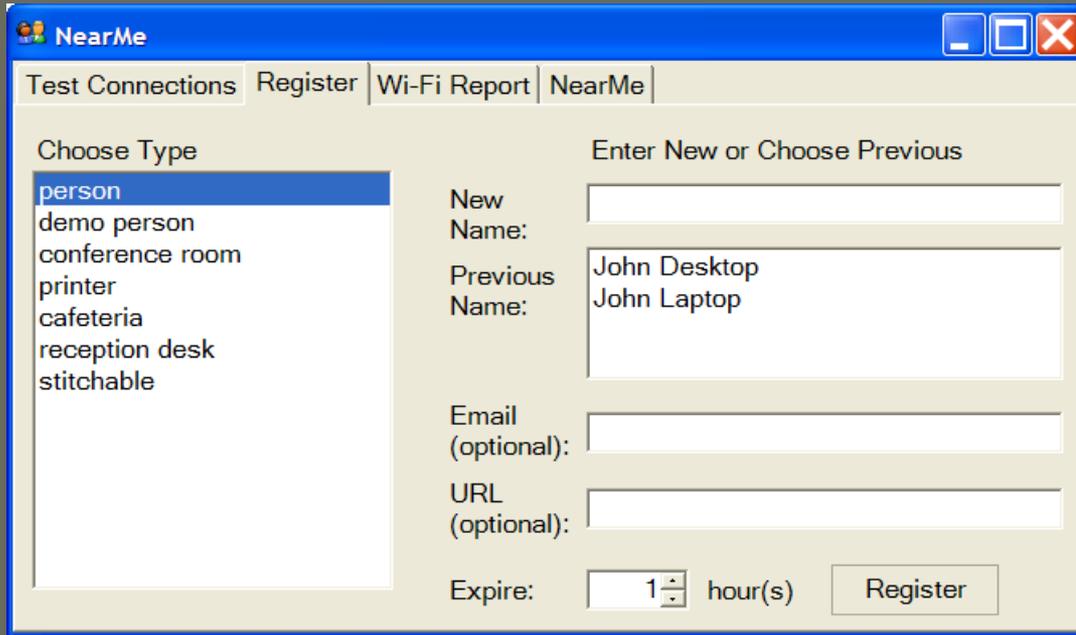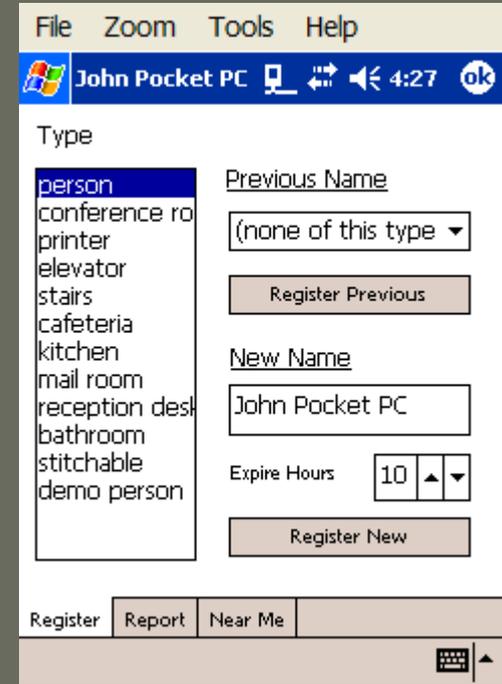 - Smart-Its Friends – Disappearing Computer Initiative

SpotMe
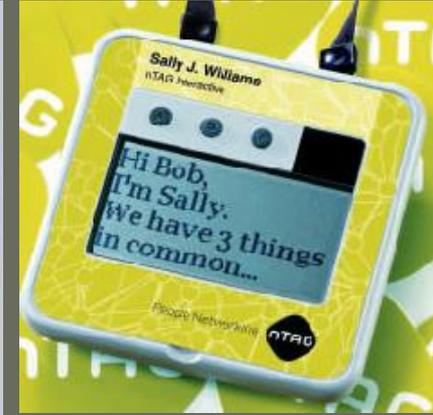
nTAG™

- Services
  - Trepia
  - iChat – Apple
- Short Range Networking
  - Infrared
  - Bluetooth
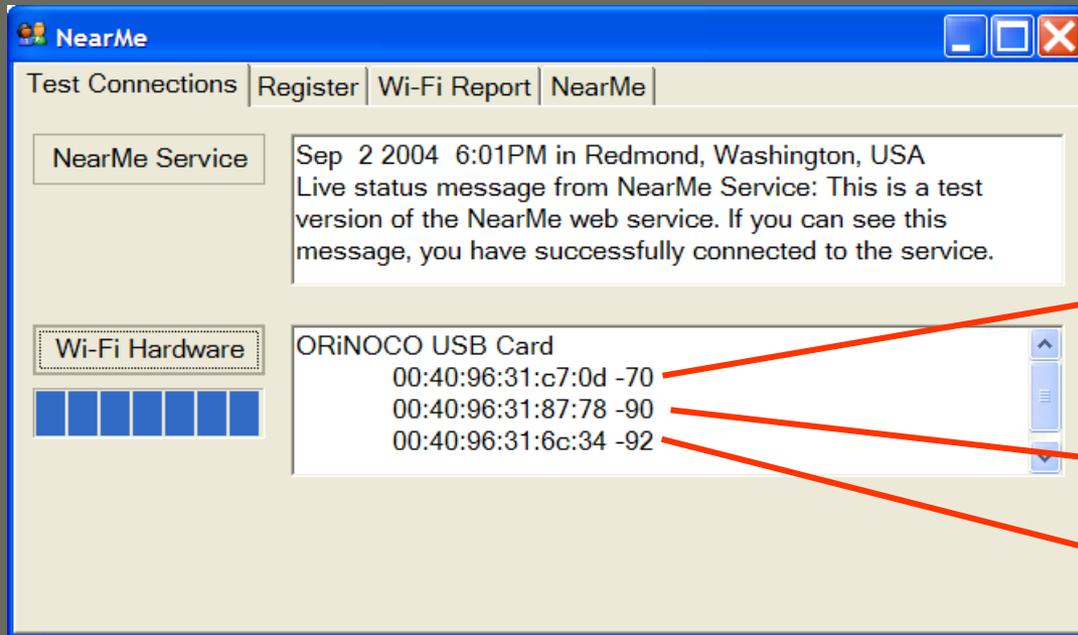
NearMe Client

Windows XP

PocketPC 2003

Requirements:
• Windows XP
• WWW access
• Microsoft .NET Framework

NearMe Client – Test Connections

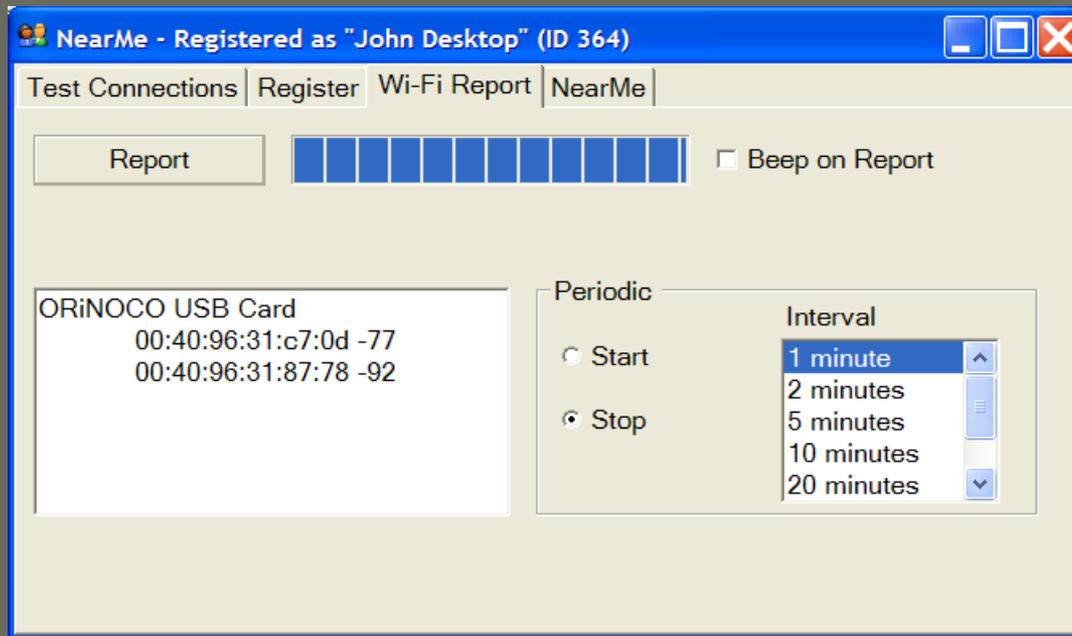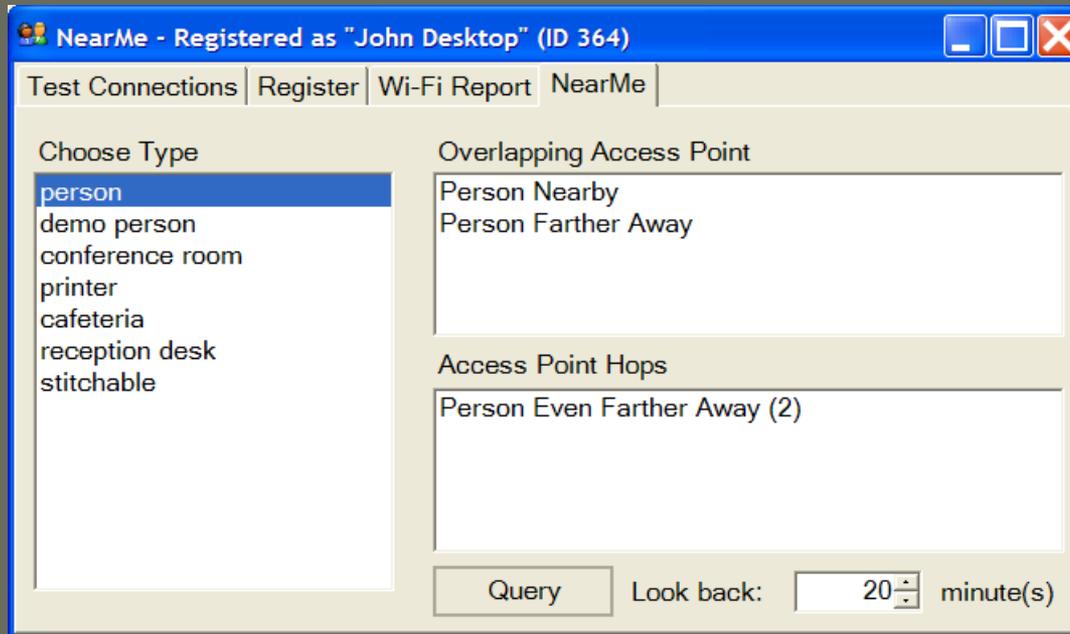# NearMe Client – Register

Register with:
- Name
- Email (optional)
- URL (optional)
- Expiration interval

NearMe Client – Report Wi-Fi

- List of detectable Wi-Fi access points
    - Access points used only as beacons
- Periodic reports for mobility

NearMe Client -- Query

Adjustable "Look back" time to filter outdated reports

NearMe Client – Nearby Things
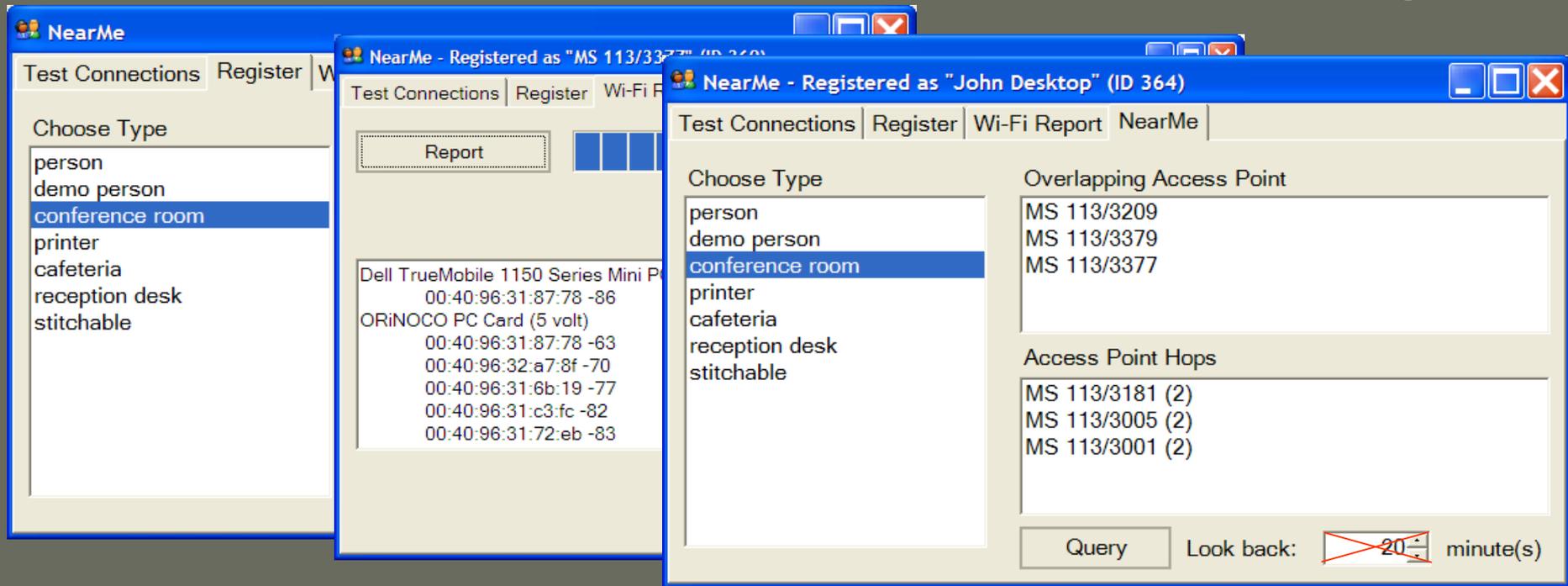
Register as thing   Report signal strengths   Query for things

person	elevator	kitchen	bathroom
conference room	stairs	mail room	stitchable device
printer	cafeteria	reception desk	demo person

NearMe Server

Clients **.NET Web Service** **SQL Server**
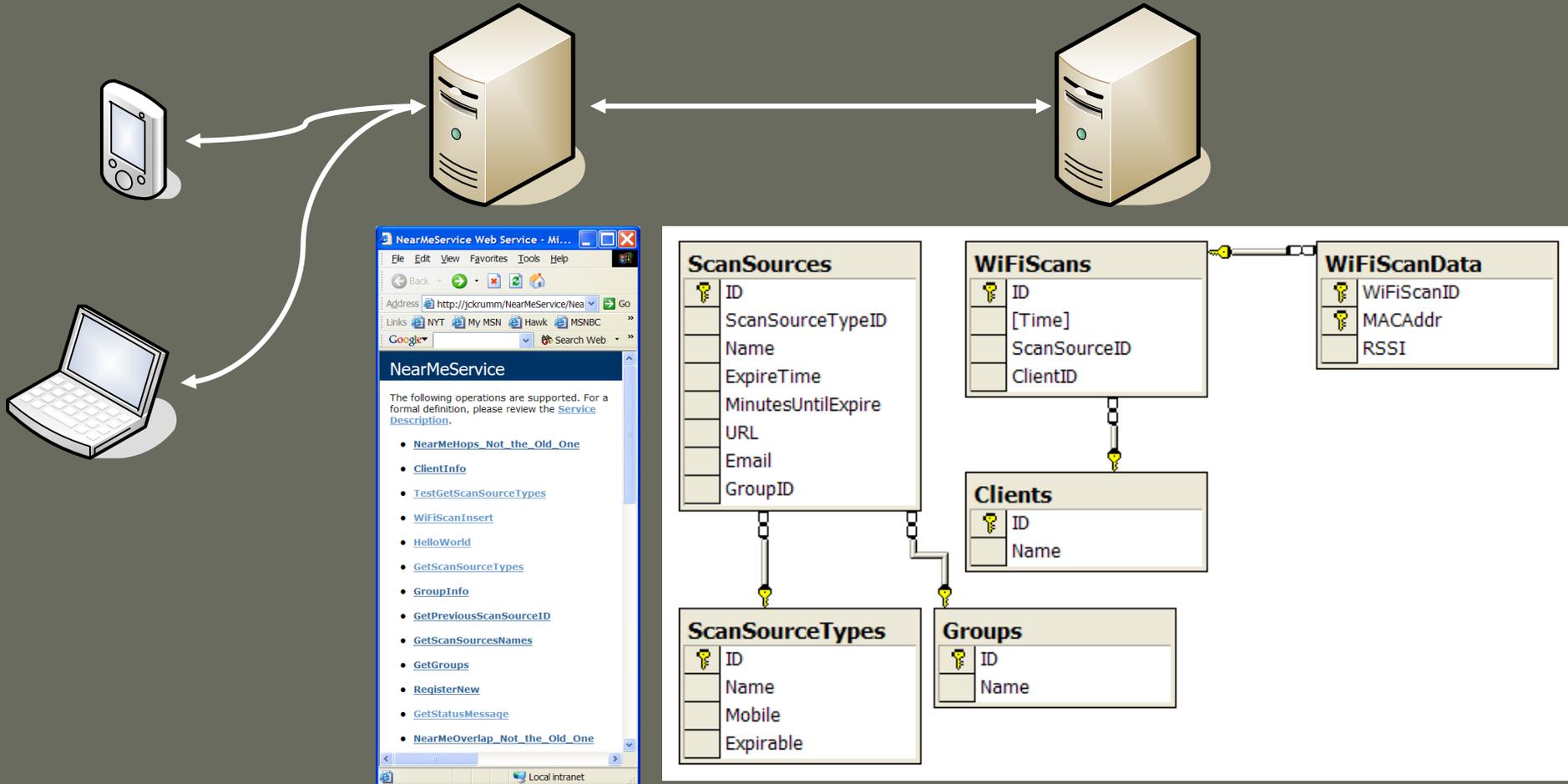

NearMeService Web Service — Mi...

File   Edit   View   Favorites   Tools   Help

Back

Address http://jckrumm/NearMeService/Nea...   Go

Links   NYT   My MSN   Hawk   MSNBC

Google   Search Web

NearMeService

The following operations are supported. For a formal definition, please review the Service Description.

- **NearMeHops_Not_the_Old_One**
- **ClientInfo**
- **TestGetScanSourceTypes**
- **WiFiScanInsert**
- **HelloWorld**
- **GetScanSourceTypes**
- **GroupInfo**
- **GetPreviousScanSourceID**
- **GetScanSourcesNames**
- **GetGroups**
- **RegisterNew**
- **GetStatusMessage**
- **NearMeOverlap_Not_the_Old_One**

Local intranet

ScanSources
- ID
- ScanSourceTypeID
- Name
- ExpireTime
- MinutesUntilExpire
- URL
- Email
- GroupID

WiFiScans
- ID
- [Time]
- ScanSourceID
- ClientID

WiFiScanData
- WiFiScanID
- MACAddr
- RSSI

Clients
- ID
- Name

ScanSourceTypes
- ID
- Name
- Mobile
- Expirable

Groups
- ID
- Name

NearMe Server Data

Name	Type	Minutes Until Expire	Time Stamp		Access Point 1		Access Point 2		…	
			Date	Time	MAC	RSSI	MAC	RSSI		
~~Bob480~~	~~person~~	~~128~~	1-Sep-2004	16:13:04	00:40:96:31:c7:0d	-78	00:45:cf:1e:7a:d0	-67		
			1-Sep-2004	16:14:04	00:40:96:31:c7:0d	-81	00:45:cf:1e:7a:d0	-65		
			1-Sep-2004	16:15:04	00:40:96:31:c7:0d	-75	00:45:cf:1e:7a:d0	-70		
~~Mary221~~	~~person~~	~~35~~	1-Sep-2004	16:18:25	00:45:cf:1e:7a:d0	-79				
			1-Sep-2004	16:21:25	00:40:96:31:c7:0d	-65				
B113-3-N	printer	N/A	5-Mar-2004	12:04:32	00:0f:34:ab:0c:a0	-82	00:02:dd:34:44:e5	-63		
B42/231	conference	N/A	12-May-2004	20:12:31	00:0f:34:ab:0c:a0	-60				

Expiration deletes source of Wi-Fi data, but not Wi-Fi data itself

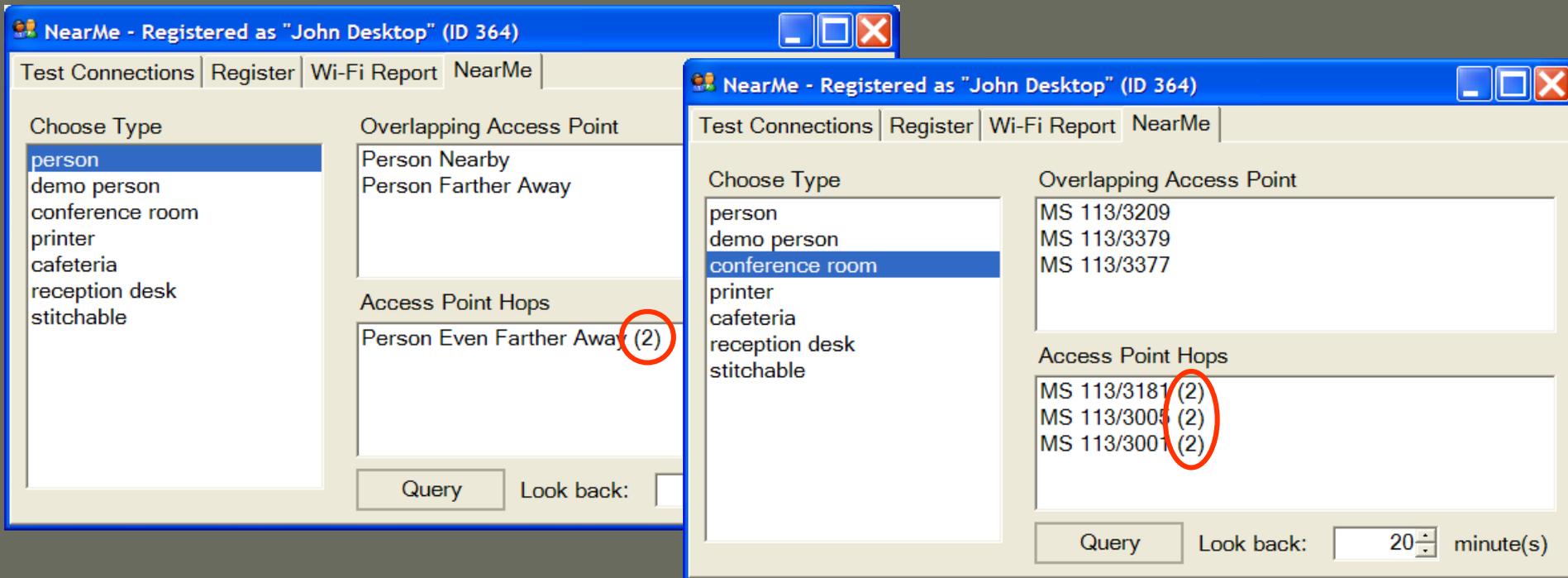# Access Point Layout
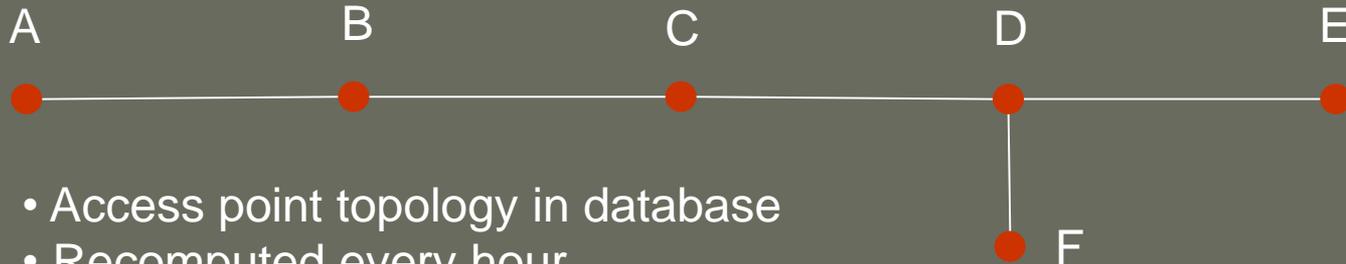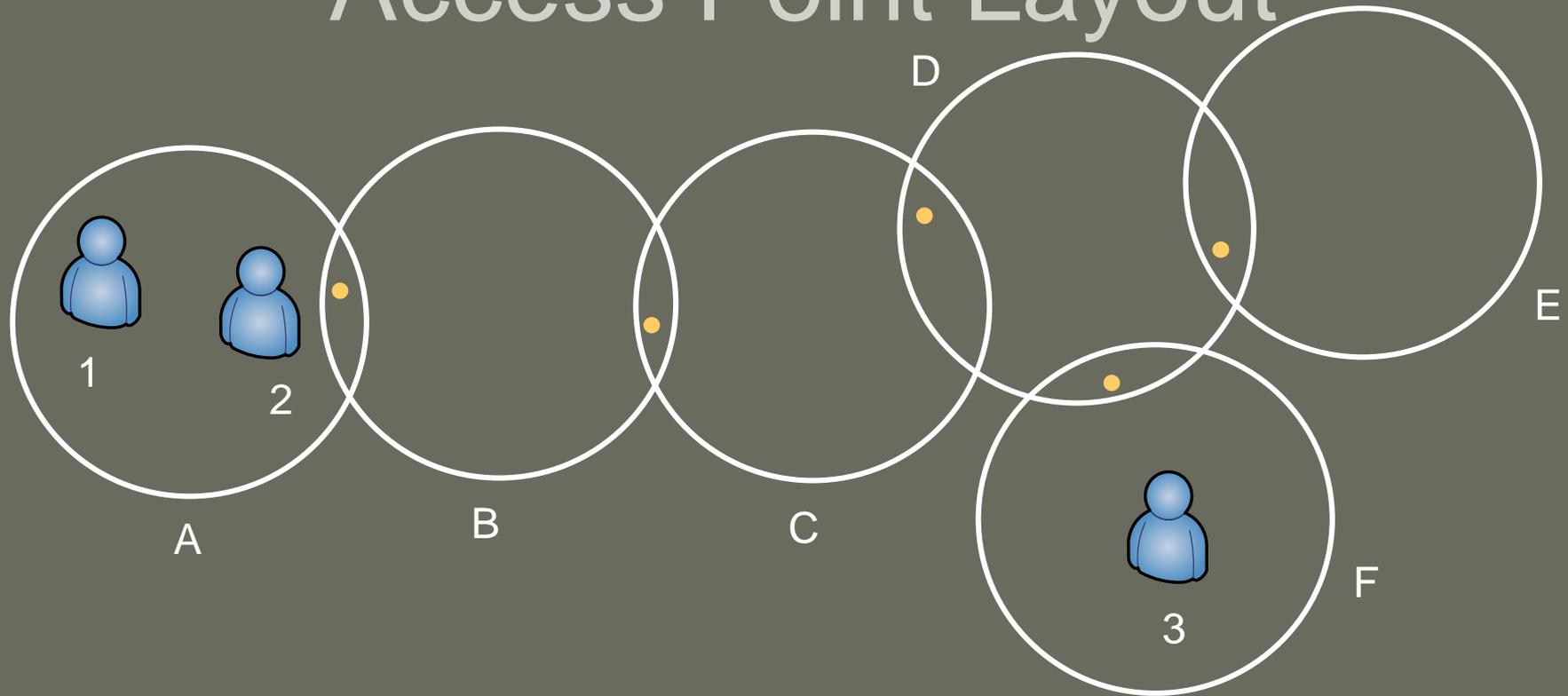
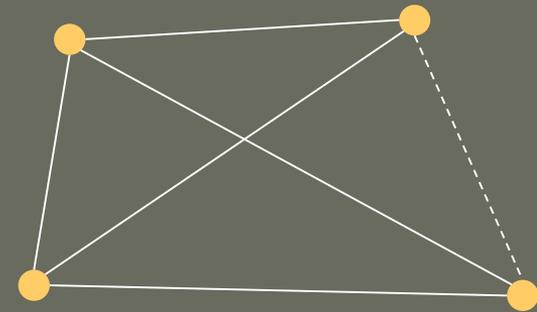- Access point topology in database
- Recomputed every hour

Hops = Distance Estimate

Extends proximity range beyond radio range

Access Point Travel Times

	00:0f:34:ab:0c:a0	00:02:dd:34:44:e5	00:40:96:31:c7:0d	00:45:cf:1e:7a:d0	...
00:0f:34:ab:0c:a0	0	21	5	132	
00:02:dd:34:44:e5		0	45	11	
00:40:96:31:c7:0d			0	N/A	
00:45:cf:1e:7a:d0				0	
...					

Minimum observed client travel time between access points

- Recomputed every hour
- Could be computed from other "wardriving" data, *e.g.*
    - Intel Research Place Lab
    - NetStumbler
- To Do
    - Path plan, *e.g.* A→C = A→B + B→C
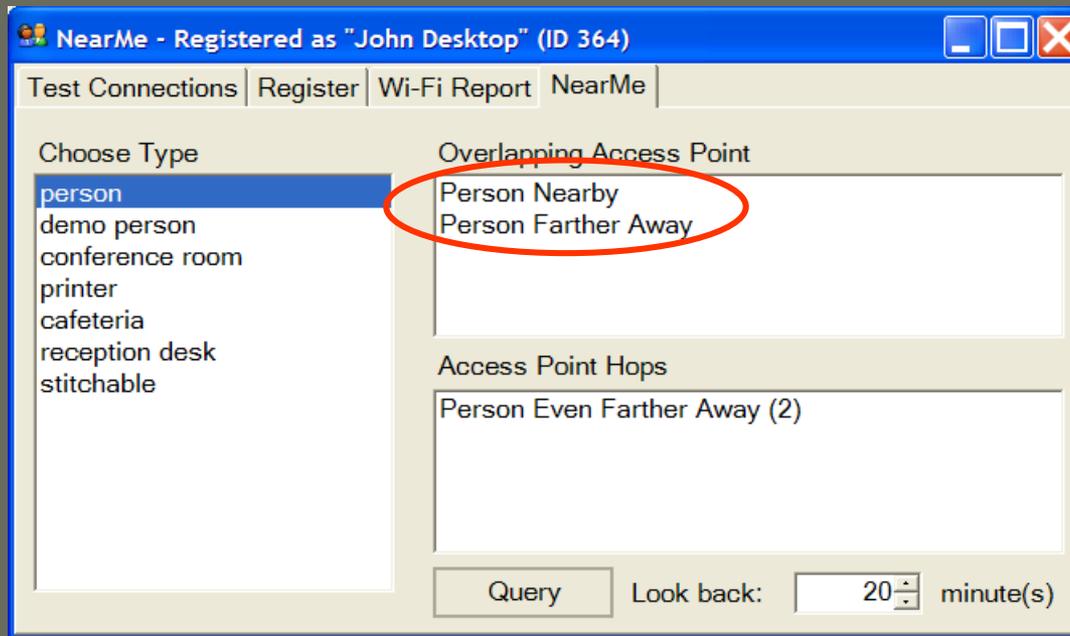   - Cluster times, *e.g.* times for walk, bike, drive

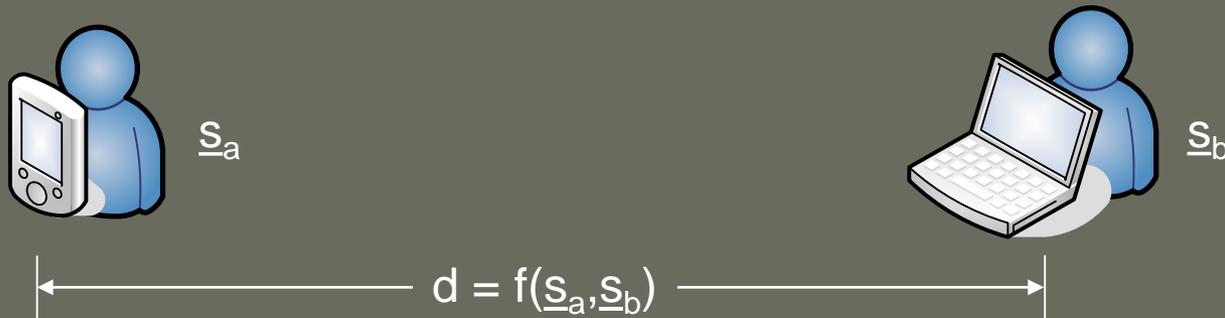# Travel Times = Distance Estimate
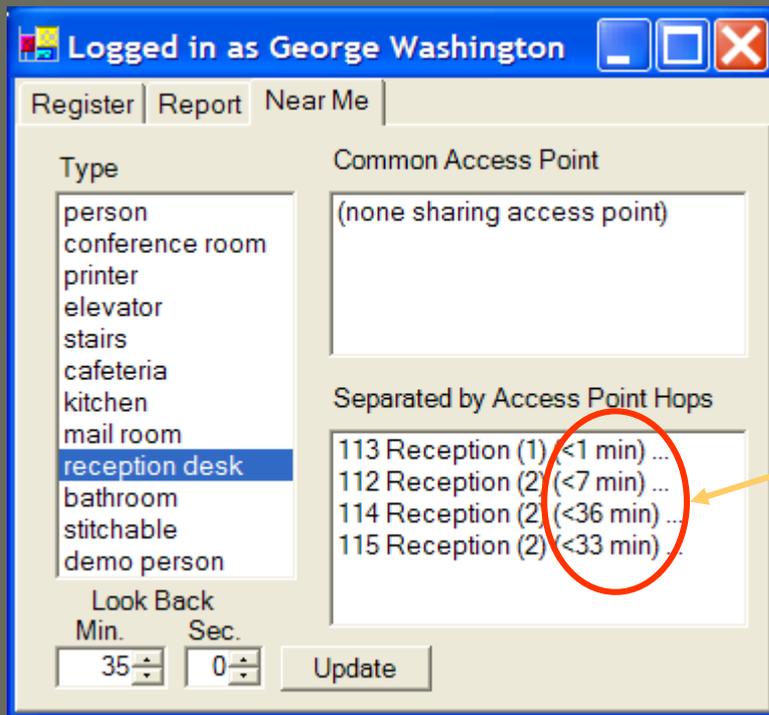
Observed lower bound on travel time

Distance Estimation

How to estimate distance between things?

Distance Functions

Wi-Fi Signature = $\underline{s}$ = { $(mac_1, rssi_1)$, $(mac_2, rssi_2)$, … , $\{(mac_n, rssi_n)$ }

$\underline{s}_a$

$\underline{s}_b$

$d = f(\underline{s}_a, \underline{s}_b)$

Candidate Distance Features:

1. $n_\cap$ = number of access points in common
2. $ssd_\cap$ = sum of squared differences of rssi in common
3. n_u = number of access points *not* in common
4. ρ_s = Spearman rank coefficient of access points in common
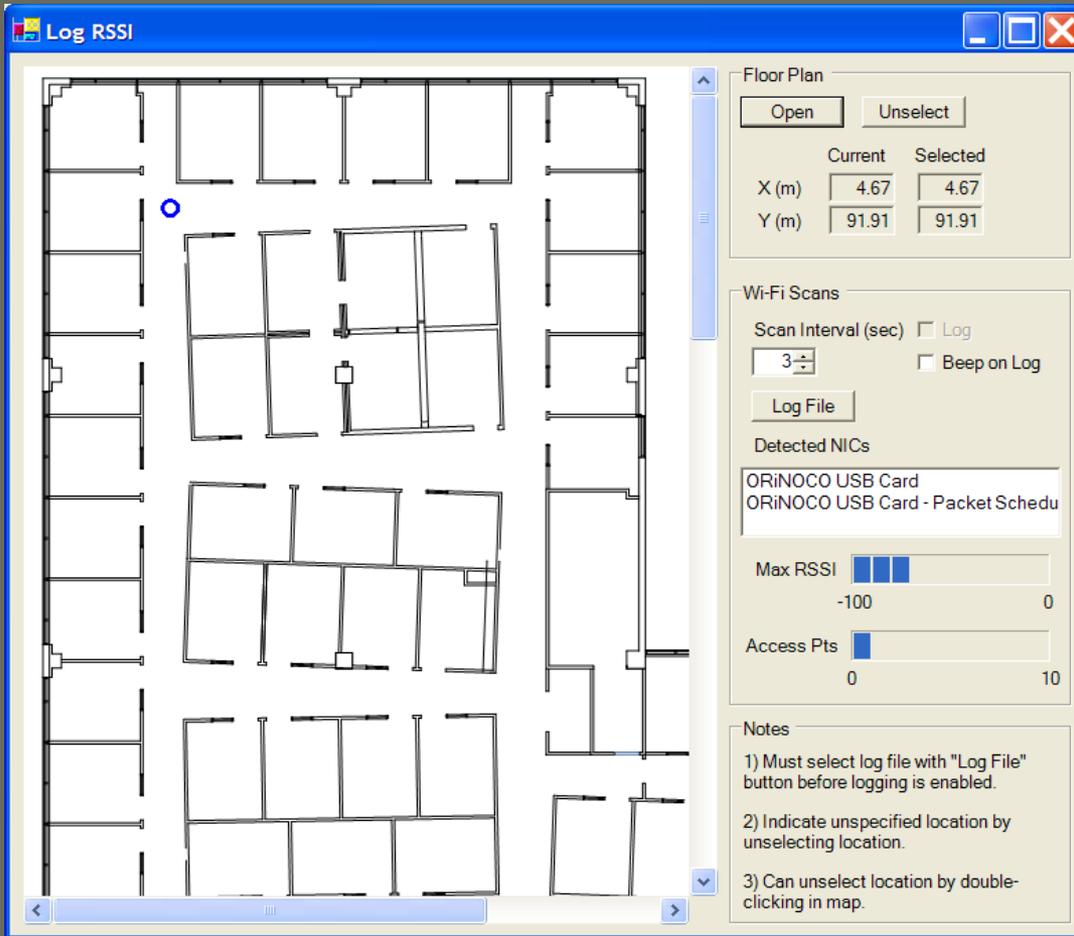
Compare Ranked Signal Strengths

<= 1
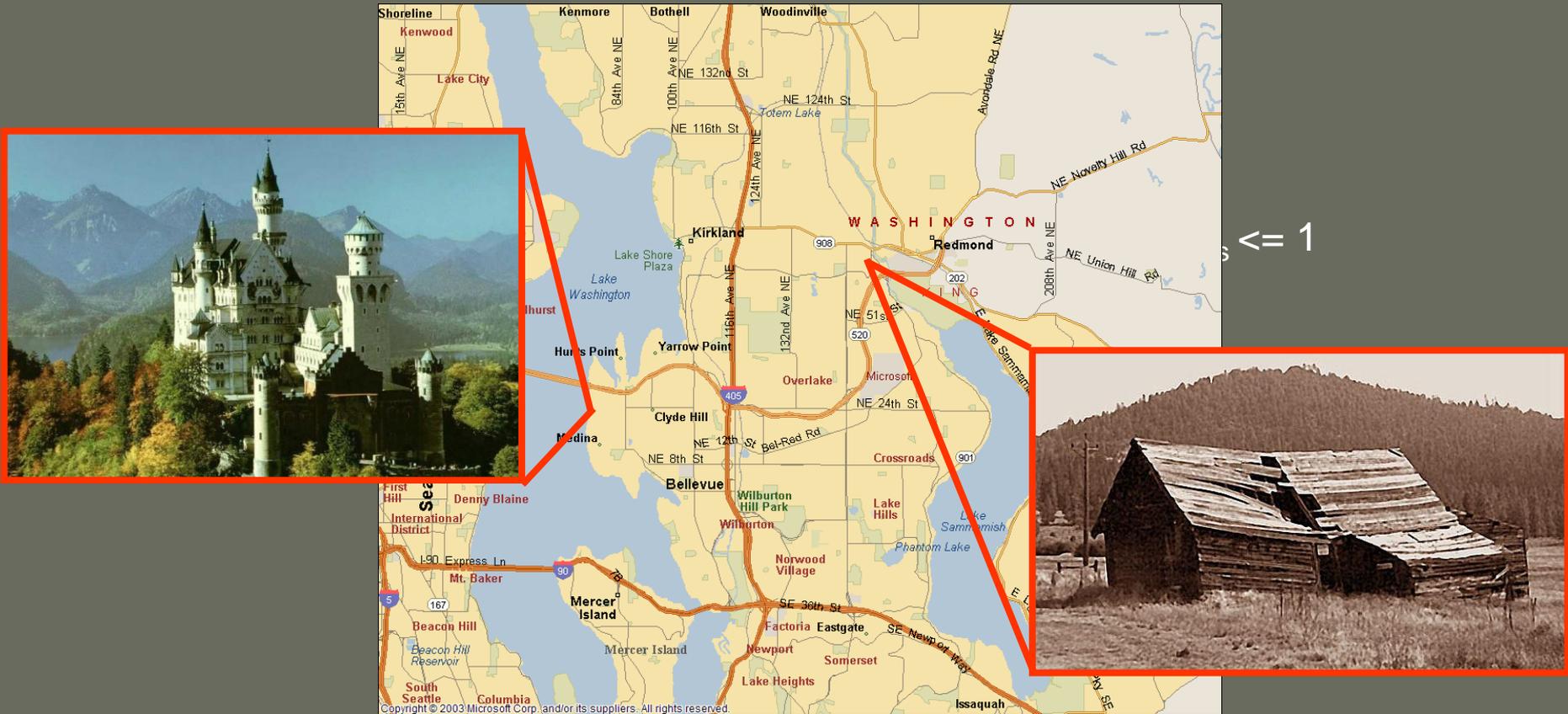
Distance Functions

$d = f(\underline{s}_a, \underline{s}_b)$

$d = f(n_\cap, ssd_\cap, n_u, \rho_s)$

Example: $d = a \cdot n_\cap{}^2 + b \cdot ssd_\cap + c \cdot n_u{}^3 + d \cdot \rho_s$

4 features + polynomials to 3rd degree = 45 different test functions
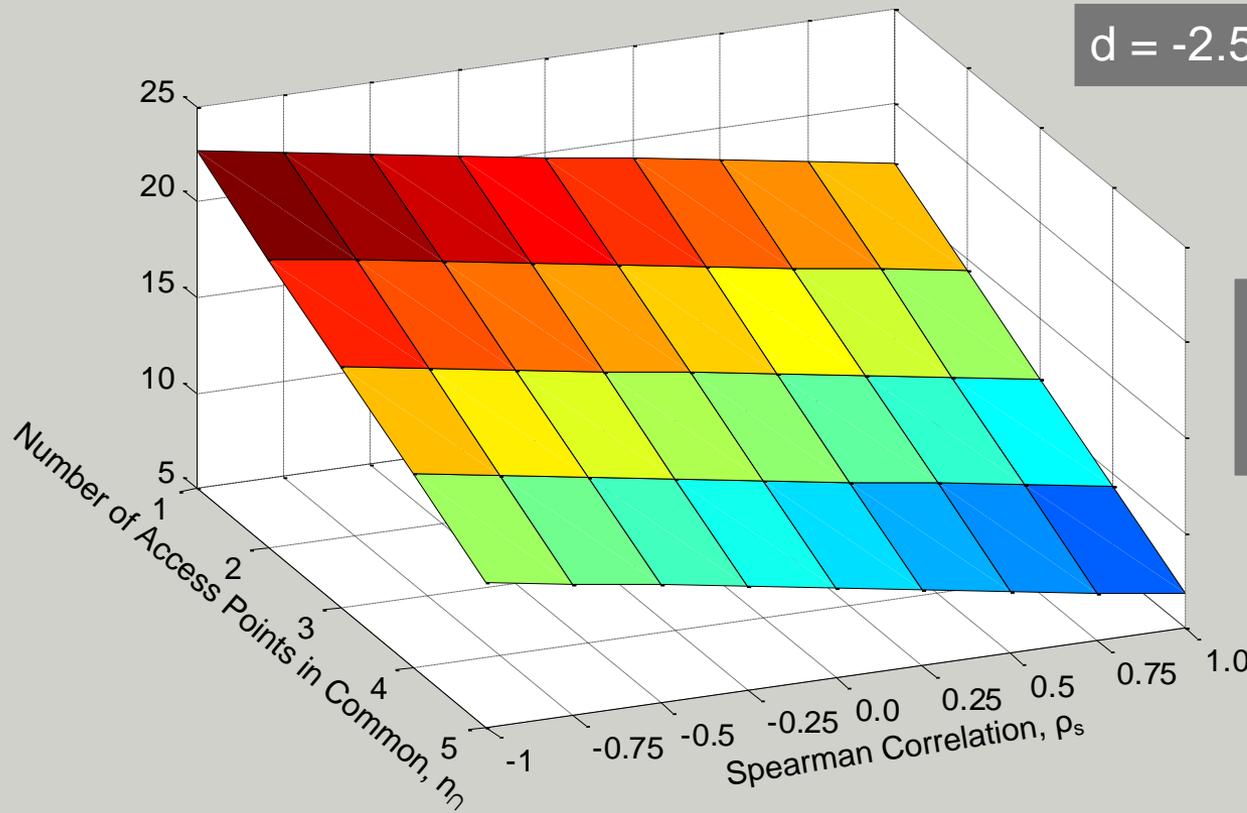
Test Data

Wi-Fi Cards

1. Dell built-in laptop
2. Microsoft Wireless USB
3. ORiNOCO PC Card
4. Actiontec USB
5. Cisco Aironet PC Card
6. Linksys USB

Office Building: 1,441,739 pairs
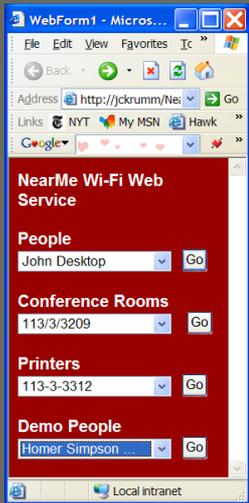Cafeteria: 572,027 pairs

Simple Distance Function

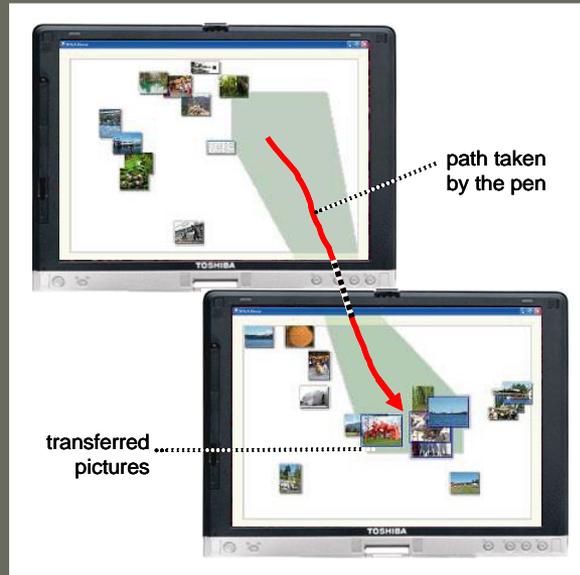$$d = -2.53 \cdot n_{\cap} - 2.90 \cdot \rho_s - 22.31$$

rms error = 14.04 meters

$\rho_s = 0.39$

Applications

Stitching

path taken by the pen

transferred pictures

Look up URLs of nearby people

Send email to people nearby

What Makes NearMe Different?

- Works on existing Wi-Fi devices
- Minimal setup
  - "Out of the box" for nearby people
  - Capability grows with use
- Short range proximity
  - Accounts for different Wi-Fi hardware
  - Sorted by distance
- Long range proximity
  - Hop distances via adjacency analysis
  - Travel times via timestamp analysis

Demo