Experiences with Location Sensing Systems at the University of Michigan

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Introduction

Many location-aware projects are focused on novel ways of gathering and processing location information.

We want to provide this as infrastructure, to allow researchers to spend their time thinking about the "next step"—what can you *do* with location information.

Goals

- Developing a building-wide location sensing infrastructure using commercial, off-the-shelf technology.
- Keeping costs low enough for a large-scale installation, eventually spanning multiple buildings, and with many participants.
- Creating an interface to this system which is scalable, powerful, and respectful of users' privacy.

Technologies Tried

In our quest for the “perfect system,” we tried out quite a few different technologies:

- *Passive RFID, hallway*
- *Passive RFID, room*
- *Active RFID, hallway*
- *Active RFID, room*
- *UbiSense*
- *AeroScout*
- *Ekahau*
- *Many 802.11 APs*
- *Bluetooth*

I'll present a brief overview of these technologies, and what we found to be their strengths and weaknesses.

Tag-Based

Passive RFID, Hallway Thresholds

Summary

Use EPC sensors at hallway intersections to detect passersby. Maintain current location based on recent movements.

Key Facts

Status:	Small Prototype
Tag Lifetime:	Infinite
Granularity:	Hallway
Tag form:	Thin tag + foam on shirt

Estimated Cost

	0 Clients	1 Client	100 Cl	1000 Cl
0 Floors	$0	$2	$200	$2,000
1 Floor	$46,000	$46,002	$46,200	$48,000
5 Floors	$230,000	$230,002	$230,200	$232,000

- Cheap tags, moderately expensive infrastructure
- Tags are easily blocked, so must be worn on outside of clothing or near outside of bag
- Increasingly used in industry, so likely to get cheaper
- Sensing is sometimes subject to false positives, but we may be able to filter in software

Tag-Based

Passive RFID, Room Thresholds

Summary

Use EPC sensors at hallway intersections and room entrances to detect passersby. Maintain current location based on recent movements.

Key Facts

Status:	Small Prototype
Tag Lifetime:	Infinite
Granularity:	Room
Tag form:	Thin tag + foam on shirt

Estimated Cost

	0 Clients	1 Client	100 Cl	1000 Cl
0 Floors	$0	$2	$200	$2,000
1 Floor	$284,000	$284,002	$284,200	$286,000
5 Floors	$1,420,000	$1,420,002	$1,420,200	$1,422,000

- Cheap tags, very expensive infrastructure
- Tags are easily blocked, so must be worn on outside of clothing or near outside of bag
- Increasingly used in industry, so likely to get cheaper
- Sensing is sometimes subject to false positives, but we may be able to filter in software

Tag-Based

Active RFID, Hallway Thresholds

Summary

Use active RFID sensors at hallway intersections to detect passersby. Maintain current location based on recent movements.

Key Facts

Status:	Equipment testing
Tag Lifetime:	Unknown
Granularity:	Hallway
Tag form:	Keychain-size tag

Estimated Cost

	0 Clients	1 Client	100 Cl	1000 Cl
0 Floors	$0	$30	$3,000	$30,000
1 Floor	$46,000	$46,030	$49,000	$76,000
5 Floors	$230,000	$230,030	$233,000	$260,000

- Not yet thoroughly tested
- Moderately expensive tags and infrastructure
- Don't yet know where tags must be placed
- Sensing is likely to be subject to false positives, but we may be able to filter in software

Tag-Based

Active RFID, Room Thresholds

Summary

Use active RFID sensors at hallway intersections and room entrances to detect passersby. Maintain current location based on recent movements.

Key Facts

Status:	Equipment testing
Tag Lifetime:	Unknown
Granularity:	Hallway
Tag form:	Keychain-size tag

Estimated Cost

	0 Clients	1 Client	100 Cl	1000 Cl
0 Floors	$0	$30	$3,000	$30,000
1 Floor	$284,000	$284,030	$287,000	$314,000
5 Floors	$1,420,000	$1,420,030	$1,423,000	$1,450,000

- Not yet thoroughly tested
- Moderately expensive tags and very expensive infrastructure
- Don't yet know where tags must be placed
- Sensing is likely to be subject to false positives, but we may be able to filter in software

Tag-Based

Ubisense

Summary

Uses ultra wideband signaling to triangulate / trilateralate position.

Key Facts

Status:	Tested in small room, hallway
Tag Lifetime:	Up to 1 year
Granularity:	0.5 M Radius
Tag form:	Size of Deck of Cards

Estimated Cost

	0 Clients	1 Client	100 Cl	1000 Cl
0 Floors	$0	$140	$14,000	$140,000
1 Floor	$16,000	$16,140	$30,000	$156,000
5 Floors	$80,000	$80,140	$94,000	$220,000

- Works OK in small room
- In larger area, didn't work for us, perhaps because of metal-backed cement walls
- Very expensive tags but cheap infrastructure
- Haven't yet verified accuracy of battery claims
- Tags are a bit unwieldy, but can be carried in purse / briefcase / bookbag or kept in pocket

802.11- or Tag-Based

Aeroscout

Summary

Aeroscout uses time difference of arrival to custom hardware at known locations to estimate location of tags or any 802.11 device.

Key Facts

Status:	Small Prototype
Granularity:	4-5 Rooms (8M Radius)
	(maybe 1M w/ different walls)
Tag Lifetime:	3 months
Tag form:	3 x 1 x 3/4

Estimated Cost (with tags)

	0 Clients	1 Client	100 Cl	1000 Cl
0 Floors	$0	$85	$8,500	$85,000
1 Floor	$133,400	$133,485	$141,900	$218,400
5 Floors	$667,000	$667,085	$675,500	$752,000

- For us, accuracy was poor, perhaps because of metal-backed cement walls
- Integrates well into 802.11 infrastructure
- System requires a great deal of manual adjustment
- Requires no custom drivers, and works with any 802.11 device or with tags

802.11-Based

Ekahau

Summary

Ekahau uses 802.11 signal strength and a statistical model to estimate your location. A map of the area is first surveyed with their software, then clients supply RSSI readings to a server to get their location.

Key Facts

Status:	Building-wide installation
Granularity:	Room

Estimated Cost

	0 Clients	1 Client	100 Cl	1000 Cl
0 Floors	$0	$250	$25,000	$100,000
1 Floor	$0	$250	$25,000	$100,000
5 Floors	$0	$250	$25,000	$100,000

- Tests so far show good room-level accuracy
- Uses existing 802.11 APs, so no/low infrastructure costs
- Licensing is bulk of cost
- Can improve accuracy by adding more base stations
- Requires vendor-supplied drivers
- Requires IP network, which can be a problem for PDAs
- Tags too, but only last 2 days!

802.11-Based

Many Low-Power APs

Summary

Place low-power 802.11 access points in each room in the building. A client can then find its location by finding the AP with the strongest signal strength and consulting a database.

Key Facts

Status: Very Small Prototype

Granularity: Room

Estimated Cost

	0 Clients	1 Client	100 Cl	1000 Cl
0 Floors	$0	$0	$0	$0
1 Floor	$142,000	$142,000	$142,000	$142,000
5 Floors	$710,000	$710,000	$710,000	$710,000

- Usually works, but can be incorrect near doorways
- Copper screen can block signal to minimize bleed through walls
- Very expensive
- May be difficult to coordinate with IT staff and to plan channel allocation
- Clients can find their location anonymously, then tell server

Bluetooth-Based

Many Low-Power Bluetooth Sensors

Summary

Place low-power bluetooth devices in each room. A client can then find its location by finding the AP with the strongest signal strength and consulting a database, and the infrastructure can locate clients by scanning for active devices

Key Facts

Status:	Simple tests were succesful
Granularity:	Room

Estimated Cost

	0 Clients	1 Client	100 Cl	1000 Cl
0 Floors	$0	$30	$3,000	$30,000
1 Floor	$26,560	$26,590	$29,560	$56,560
5 Floors	$132,800	$132,830	$135,800	$162,800

- Likely to work comparably to 802.11 Many APs, but cheaper
- Signal should bleed out of rooms less
- Doesn't interfere with 802.11
- Equipment is cheap
- Designed for low-power, so cheap tags should be possible
- Clients can find their location anonymously, then tell server
- Or server can track registered clients

Lessons Learned

- System performance is very dependent on environment
- User factors are important
- Immature technology, no clear leader
- Decision driven by prioritizing trade-offs

Questions

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For more information:

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