

RFID Data Management for Pervasive Computing Applications

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What is RFID?

Outline

- Pervasive applications and challenges
- The Cascadia system: RFID Data Manager
 Handling holes in RFID data streams
 - □ Extracting high-level events from low-level RFID data
 - □ Supporting privacy
 - Facilitating application development

What is **RFID**?

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- Wireless ID and tracking
- Captures information on:
 Identity
 - Location
 - Time
- Unique identification
- Passive (no batteries)

Reader



Passive RFID Markets

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Today: \$5 B industry, 2 billion tags



In 2018: \$25 B industry, 600+ billion tags

(source: IDTechEx)

The RFID Ecosystem

- 100s of passive EPC Gen 2 tags
- 100s of RFID antennas
- 85,000 sq ft (8,000 sq m) building
- Simulating an RFID-saturated future

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Personal asset tracking

"Is my advisor in her office?"



"Where are my keys?"



Done

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- Personal asset tracking
- Personal diary of physical events

"How did I spend my time?"

	Today Oct	29, 2007	· <u>∰ Print</u> Day Week Month
Expand All	Collapse All		
Monday	Oct 29	10:45am	Detected Came-to-Work
		11:30am	Detected Meeting: Carol, CSE324 🛱
		12:31pm	Detected Lunch
		1:06pm	Detected Meeting: Bob, CSE435 - 🕸
		2:13pm	Detected Got-Coffee: 2nd floor coffee room
		3pm	Detected DB-Group-Meeting: CSE605 🕸
		3:56pm	Detected Left-Behind: Umbrella, CSE605
		4:01pm	Detected Got-Coffee: 2nd floor coffee room
		4:55pm	Detected Got-Coffee: 2nd floor coffee room
		5:35pm	Detected Left-Work



Showing events until 10/29/2007. Look for more

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- Personal asset tracking
- Personal diary of physical events
- Event-based search

"What emails did I send during the meeting a few weeks ago?"



- Personal asset tracking
 - Personal diary of physical events
- Event-based search
- Focus on mobile and web 2.0 applications

- Current trend: RFID in Hospitals
 - Tracking equipment, patients, personnel
 - Improved utilization of assets
 - > We extend with more sophisticated inference



Application Challenges

- Must cope with holes in RFID data stream
- Must ensure a reasonable level or privacy
- Application development is extremely difficult
- The Cascadia system answers these challenges:



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Holes and Uncertainty in Data

- Holes or gaps appear for two reasons:
- Missed tag reads



Holes and Uncertainty in Data

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Holes or gaps appear for two reasons:

- Missed tag reads
- Limited reader topology



Coping With Uncertainty

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- Smooth the data using a particle filter
- Directly represent uncertainty with probabilistic data



(tag_1, 'lab',2,.33), (tag_1,'office 406',2,.33), (tag_1,'office 408',2,.33),

Coping With Uncertainty

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Note on Data Rates / Volume

Average rates for 9am-5pm for 50 people, 300 tags:

Raw RFID data rate: With on-the-fly compression: 50 tag reads / sec 2 tag reads / sec

ID, loc, time, prob

Raw data per week: Raw data per week, compressed:

Particle filter data rate:

Smoothed data per week:

7,200,000 tag reads 300,000 tag reads 500 particles / tag / sec

21B particles (20GB)



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Location Data

ID	location	time



Example Application: Track / verify patient treatments
 Nurse is tagged
 Equipment is tagged

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Location DataIDlocationtimeNurseA4IVA4IVA4



Example Application: Track / verify patient treatments
 Nurse is tagged
 Equipment is tagged

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Location Data ID location time Nurse Α 4 IV Α 4 В 5 Nurse IV В 5



Example Application: Track / verify patient treatments
 Nurse is tagged
 Equipment is tagged

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Location Data location ID time Nurse Α 4 IV Α 4 В 5 Nurse IV В 5 . . .



Example Application: Track / verify patient treatments
 Nurse is tagged
 Equipment is tagged

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Nurse treats patient in 407



Example Application: Track / verify patient treatments
 Nurse is tagged
 Equipment is tagged

Extracting Events: Step 1

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Translate to Event Specification Language

- PeexL "Probabilistic Event Extraction Language"
- SQL-like language
- SEQ sequencing construct

Extracting Events: Step 2

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Extract Specified Events

- PEEX "Probabilistic Event Extractor"
- Accepts specifications in PeexL
- Periodically queries for new events
- Assigns probabilities to extracted events
- Events are stored or streamed to apps

Performance: Precision & Recall

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Extracting a common event: ENTERED-MEETING-ROOM
 10 people, 30 tags, 30 minutes



- Precision: Fraction of extracted events that match ground truth.
- Recall: Fraction of ground truth events captured by extracted events.

Performance: Precision & Recall

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Extracting a common event: ENTERED-MEETING-ROOM
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- Precision: Fraction of extracted events that match ground truth.
- Recall: Fraction of ground truth events captured by extracted events.



1) Precision/Recall trade-off: developer chooses best threshold

- 2) Performance highly varied between tags
 - For best tags at probability \geq 0.3, Precision = .92, Recall = .85
- 3) These results are for a very uncertain dataset:
 - There are no readers *inside* rooms, only in hallways



Precision/Recall tra**Bottom Line**

Application only specifies event and probability threshold

-- Cascadia does the rest

Ongoing improvement of event detection techniques!



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Default Policy: Physical Access Control

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Problem: Asymmetric visibility among peers

"How do I know who can see my data?"

Concept:

□ Each user has a personal store of data / events

Stores only events that occurred when and where user was physically present





sightings	timestamp
A	0



sightings	timestamp
в	0



sightings	timestamp
C	0





sightings	timestamp
	0
ABC	1



sightings	timestamp
В	0
AB	1



sightings	timestamp
С	0
AC	1





sightings	timestamp
A	0
ABC	1
A	2



sightings	timestamp
В	0
AB	1
В	2



sightings	timestamp
C	0
AC	1
AC	2

Default Policy: Physical Access Control

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Key Points:

- □ Each user must carry a personal RFID badge
- □ Enables applications that augment a user's memory
- □ Implemented as materialized authorization views in DB
- Other "context-aware" policies are possible:
 - "Only reveal my location during business hours"
 - □ "Only reveal my activity when I am in a meeting"
 - Interesting adaptations for probabilistic data

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Supporting Applications

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Web 2.0 Personal Data Management Tool Suite:



Create/Manage Objects, Associate Tags Specify Significant Places, Share with Others Specify Events, Share with Others

- Applications can integrate with tool suite
- Declarative event language removes burden from developer
- Event-based programming API simplifies development

Conclusions

- RFID is an increasingly ubiquitous technology
- More sophisticated applications face serious challenges:
 - Uncertain data streams (gaps or holes in the data)
 - Low-level data, high-level information needs
 - □ Privacy risks
 - Complex application development
- The Cascadia system addresses these challenges with:
 - □ A probabilistic model of uncertainty
 - Declarative event specifications
 - □ A probabilistic event extractor
 - □ Context-aware access control policies
 - □ Suite of web-based personal data management tools

Thank You & Questions

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Thank you!

- Misc notes:
 - See publications for details: <u>http://rfid.cs.washington.edu/publications.html</u>
 - Online demos available soon, see: <u>http://rfid.cs.washington.edu/</u>

□ Lots of ongoing and future work with Cascadia!