ZeroSquare: A Privacy-Friendly Location Hub for Geosocial Applications

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Geosocial Applications

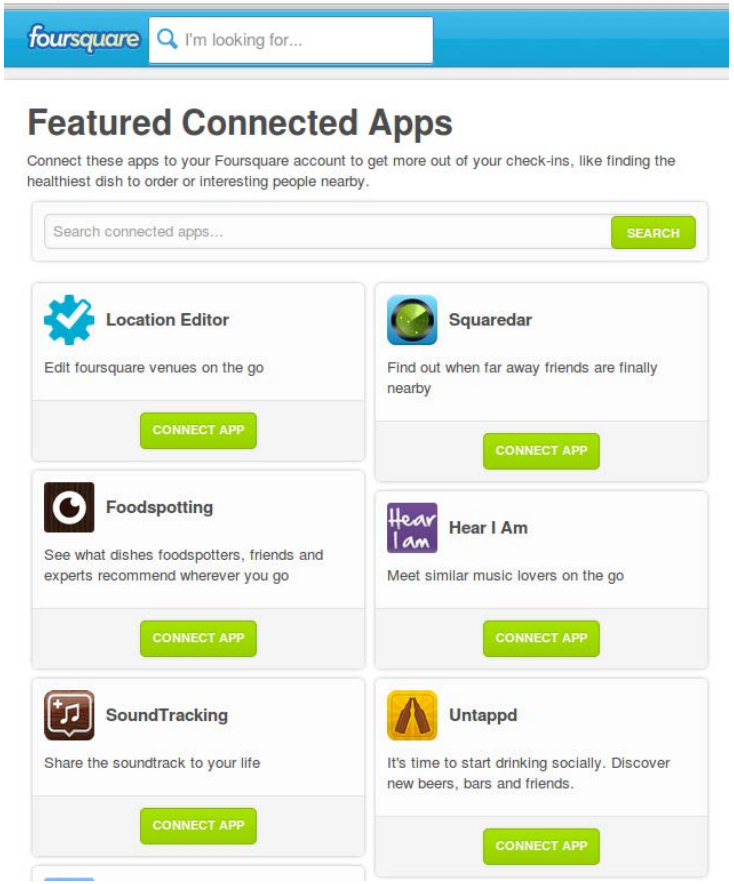
Geosocial Apps Raise Privacy Concerns

Many geosocial apps that want to know our location and maybe other personal information

Each of them needs to be trusted to properly secure this information

This will become worse if existing services become location hubs and allow access to third-party apps

Foursquare Connect



Research Challenge

Design of a privacy-friendly location hub that supports many types of geosocial applications

What does privacy-friendly mean?

Less privacy than application-specific privacy-enhancing protocols for geosocial applications

More privacy than today's widely deployed geosocial applications

Design Goals

Privacy based on separation of information

Support of various application use cases

Decoupling of data storage and social networking functionality

No significant client-side computation

Separation of Information

Each component of the location hub can learn either a user's identity or her location, but not both

Each component is run by a different organization (or kept in a different data silo if all run by the same organization)

ZeroSquare: Architecture

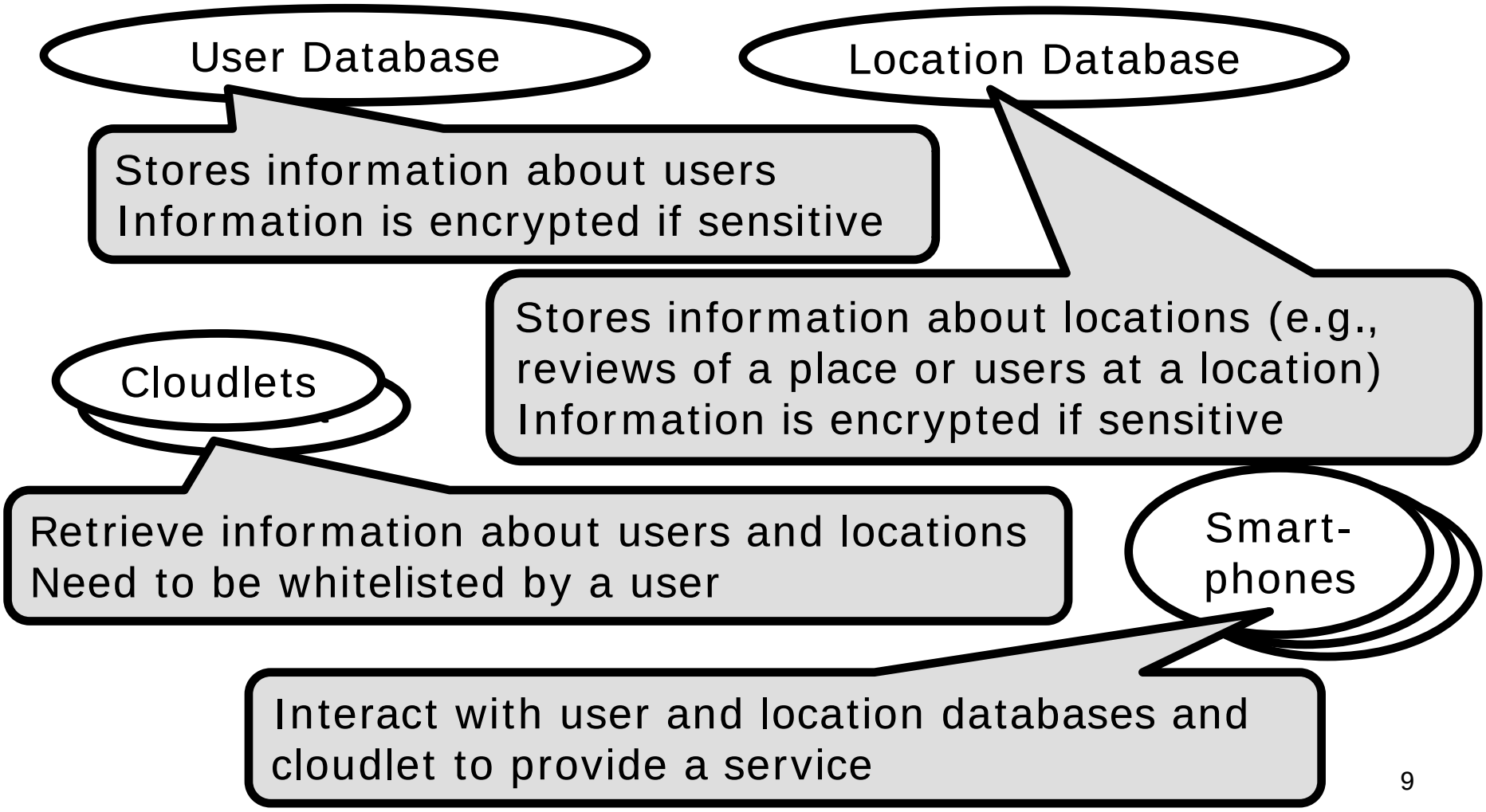
Geosocial apps require information about users and about locations

Therefore, we have two databases:
User Database with information about users
Location Database with information about locations

Optionally, for scalability or privacy reasons, a geosocial app comes with an additional component running in the cloud ("cloudlet")

User Database, Location Database and cloudlets are honest-but-curious and do not collude

ZeroSquare: Architecture



Encryption of Sensitive Information

Anyone can retrieve information stored in User Database or Location Database

A user storing sensitive information in either database should encrypt it with a key specific to the user and the type of information

The user hands out decryption keys to friends (and cloudlets of apps that he/she uses)

Details of key management are out of scope

Decryption of Information stored in Location Database

Assume a ciphertext associated with a location (e.g., an encrypted review of a restaurant) stored in Location Database needs to be decrypted

How do we find the right decryption key?

Adding the identity of the creator to the ciphertext would violate separation of information goal

Trying every obtained decryption key would violate efficiency goal

Tags

The creator of a ciphertext stored in the Location Database attaches a tag to the ciphertext

A tag must not reveal any information about the creator to the Location Database

A tag must never be reused

Tags are generated by the User Database

The User Database allows entities that were whitelisted by the creator to map the tag back to the creator's identity

Example – Friend Proximity Detection (Option 1)

1. Alice is Bob's friend and has the decryption key for his location information
2. Bob stores his current location in the User Database in encrypted form
3. Alice retrieves Bob's encrypted location from the User Database, decrypts it, and checks whether Bob is nearby

Inefficient for many friends and Alice learns more information than necessary

Example – Friend Proximity Detection (Option 2)

1. Bob retrieves a tag from the User Database and stores it at his current location in the Location Database
2. Alice retrieves all tags currently at her location from the Location Database
3. If whitelisted by Bob, the User Database will allow Alice to map Bob's tag back to his identity

Inefficient

Example – Friend Proximity Detection (Option 3)

1. Same as option 2, except that list of tags at Alice's location (but not the location!) is given to clouldlet associated with the friend proximity detection app
2. If Bob has whitelisted this app, the cloudlet can map his tag back to his identity
3. Cloudlet checks whether Bob is a friend of Alice
4. If so, cloudlet notifies Alice of Bob's proximity

ZeroSquare: API

Defined an API for both the User Database and the Location Database

Used this API to build various geosocial applications

Friend locator, friend proximity detection, social recommendations, advertising service

API provided by User Database

Accessing information:

setAttribute(identity, attribute, value, ttl)

// value can be encrypted

value(s) ← **getAttribute**(identity, attribute)

Managing tags:

tag ← **createTag**(identity)

whitelist(identity, application)

identity ← **getIdentity**(tag, application)

API provided by Location Database

setAttribute(location, attribute, value, tag, ttl)

// e.g., attribute = “review”/value = <encrypted review> or attribute = “present”/value = true

value(s)/tag(s) ← **getAttribute**(location, attribute)

token ← **registerCallback**(location, attribute, ttl, handler)

// call handler whenever setAttribute() is invoked for given location and attribute

Example – Interest matching

Alice signs up with Match, an interest matching app, to get notified when she is at the same location as somebody else with matching interests (e.g., Bob)

Signup:

1) Alice and Bob give Match the decryption keys for their interests, as stored in the User Database
2) Alice @ User Database: **whitelist**(Alice, Match)
   Bob @ User Database: **whitelist**(Bob, Match)

Example – Interest matching (cont.)

Alice and Bob are checking in at a location:

1) Alice @ User Database: Tag_A ← **createTag**(Alice)
2) Alice @ Location Database: **setAttribute** (<Alice's location>, "present", Tag_A)
3) Alice sends her encrypted location to Match
4) Match @ Location Database: **registerCallback**(<Alice's encrypted location>, "present", handler @ Match)

Bob performs the same steps

Example – Interest matching (cont.)

Bob checks in at Alice's location, and her callback gets invoked

1) Location Database invokes Match's handler and passes over set of tags at the location
2) For each received tag Tag_k, Match @ User Database:
   1) $Id_k \leftarrow$ **getIdentity**(Tag_k, Match)
   2) interests $\leftarrow$ **getAttribute**(Id_k, "interests")
   3) Notify Alice of Id_k (Bob) if interests match

Match does not learn Alice and Bob's location

Implementation and Evaluation

ZeroSquare has been implemented with Android and a Python client as end-user platforms

Evaluated the performance of an interest-matching application

End-to-end performance of combined sign-up, check-in, and notification is 500 ms for Python client and 1.4 s for Android client (see paper for details)

Related Work

Lots of related work on retrieving PoIs in a privacy-friendly manner, where location of PoI is static and non-sensitive

Does not apply to geosocial apps

Storing encrypted user and location information in two different databases: Puttaswamy et al. (HotMobile 2010)

Targets friends only, not efficient

Double indirection between objects and their plaintext attributes: Trust No One (MobiHeld 2010), Koi (NSDI 2012)

Susceptible to traffic analysis and trace analysis attacks

Future Work

Ensure that location updates seen by Location Database remain unlinkable

Avoid information leak where by polling User Database, attacker can observe that a user has moved (but not to where)

Conclusions

Privacy-friendly architecture for geosocial apps based on separating information between two non-colluding databases, one for user-specific information, the other one for location-specific information

Databases provide simple API that is sufficient for building many of today's geosocial apps

Application-specific cloudlets for improved scalability and privacy