电子科技大学
University of Electronic Science and Technology of China

TEMPLE UNIVERSITY

RTS Assisted Mobile Localization: Mitigating Jigsaw Puzzle Problem of Fingerprint Space with Extra Mile

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Outline

- ***Motivation***
- RTS Assisted Mobile Localization
- Building Map with Crowdsensing
- Implementation and Evaluation
- Conclusion

Outdoor mobile application

Waze

Pothole detection

Disadvantages of localization with GPS

High energy consumption

Urban canyons

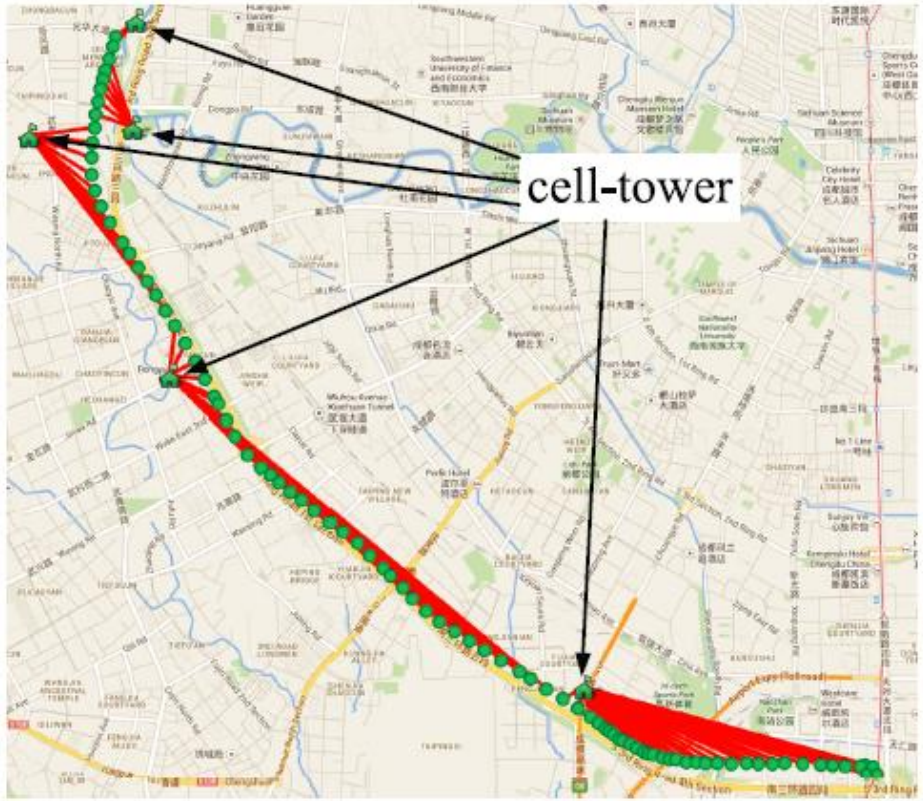
Phones without GPS

Signal-fingerprint

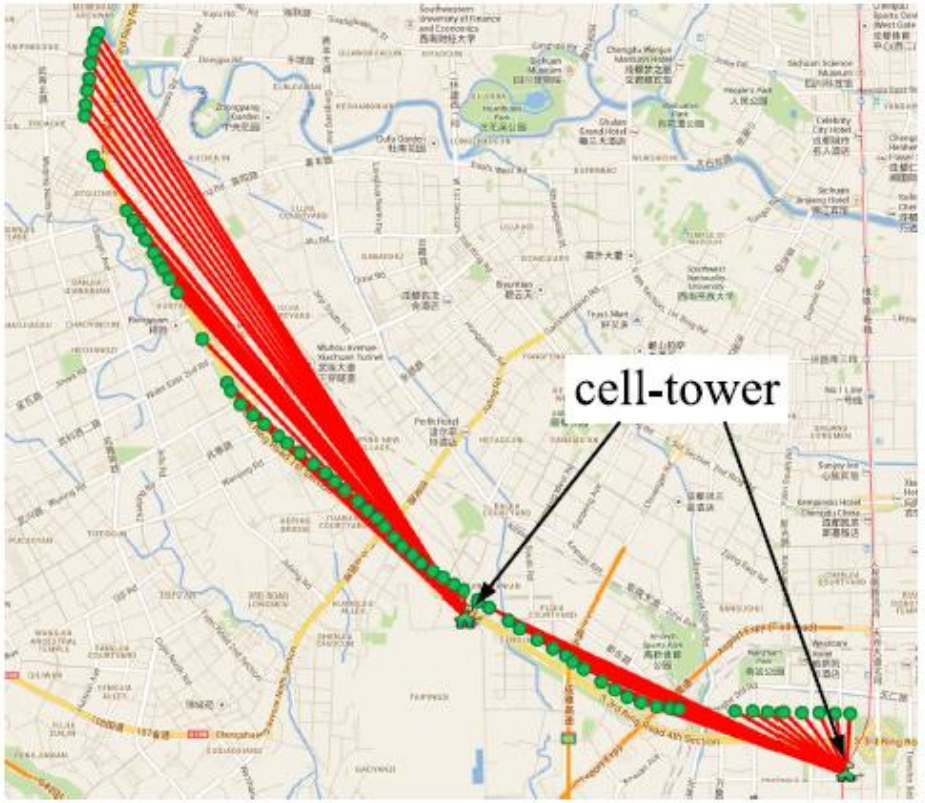
- RSS fingerprints: the WiFi signal strengths from multiple access points at every location of an interested area, and accordingly build a fingerprint database (a.k.a. radio map) in which fingerprints are associated with the locations where they are recorded.
- Trajectory-fingerprint-based approach: cell-ID sequence-based localization, which is recorded by changes of the IDs of the connected cell-towers by the mobile phone along the user's trajectory.

Z. Yang, C. Wu, and Y. Liu, "Locating in fingerprint space: wireless indoor localization with little human intervention," in Proc. of ACM MobiCom, 2012.
J. Paek, K.-H. Kim, J. P. Singh, and R. Govindan, "Energy-efficient positioning for smartphones using cell-id sequence matching," in Proc. of ACM MobiSys, 2011.

The connected cell-towers along the same route



(a)



(b)

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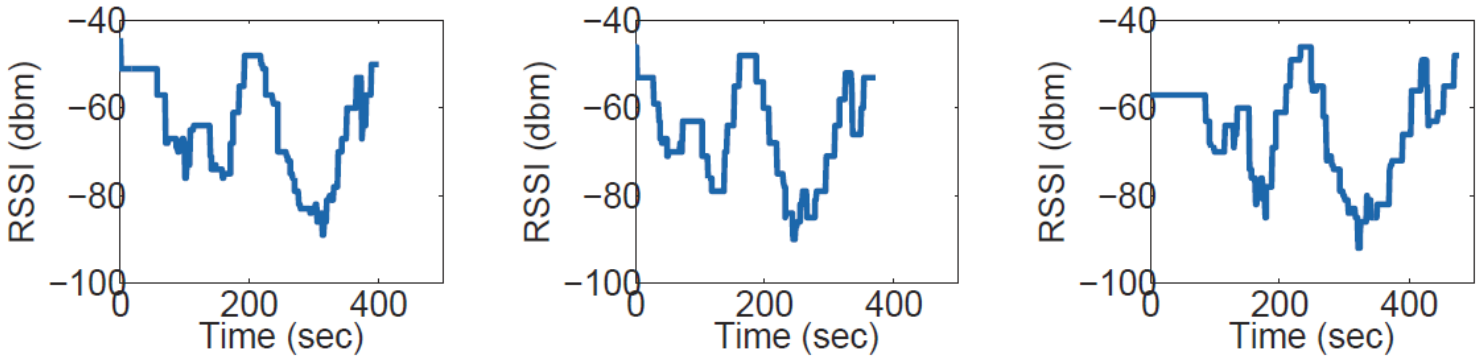
RTS-assisted mobile localization

- RSSI Time Series (RTS)

$$rts = \{(t_1, rssi_1), (t_2, rssi_2), \cdots, (t_n, rssi_w)\}$$

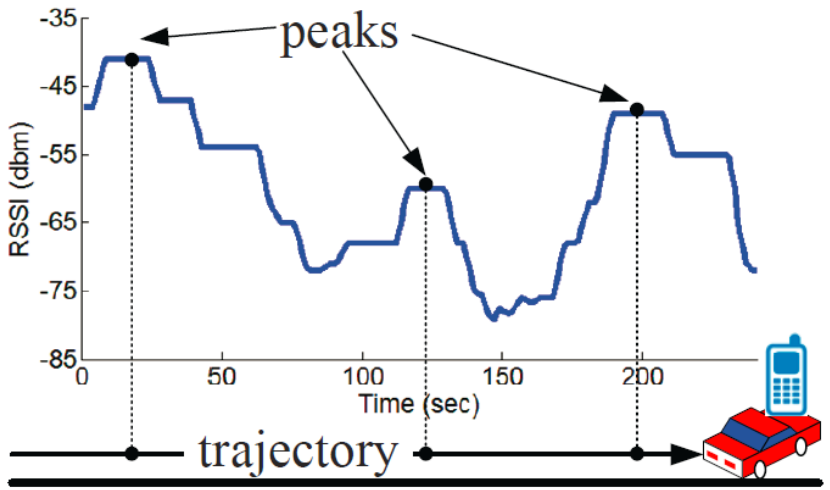
- Similar RTS on the same road with different average moving speeds



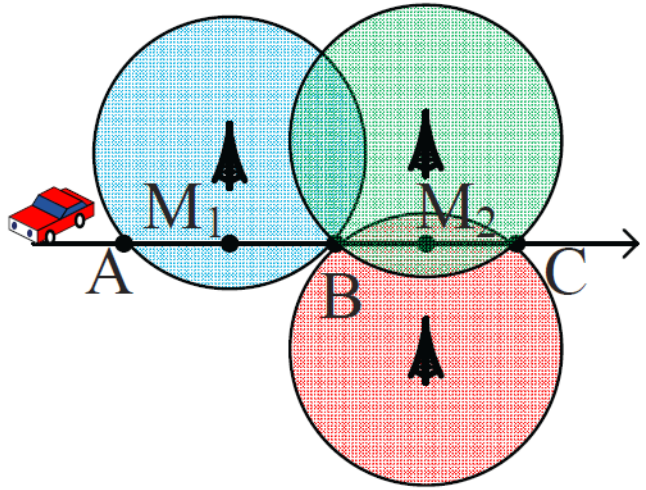
(a) 62 km/h (b) 67 km/h (c) 52 km/h

Peaks of RTS

- To mitigating the RSS fluctuation problem, we investigate the peaks along the RTS from connected cell-towers for outdoor localization.



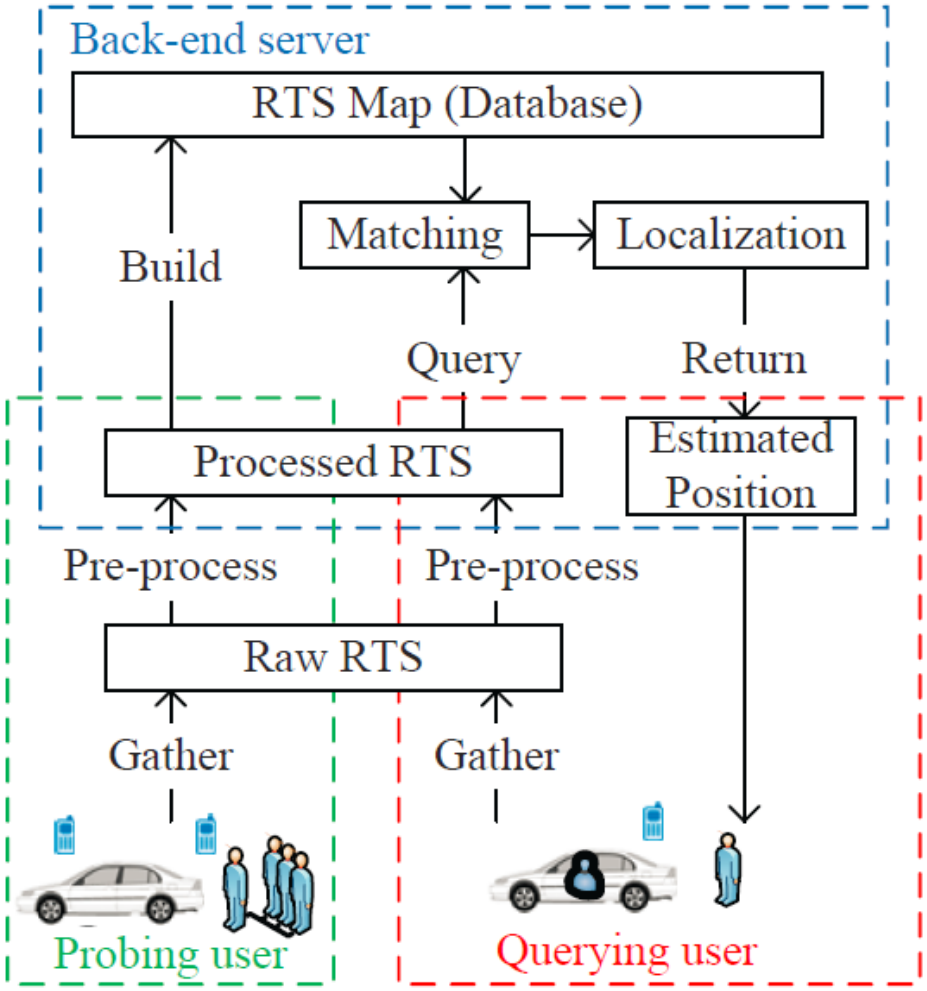
(a)



(b)

System Overview

- RTS Assisted Localization System (RALS)
  - Probing user, querying user, back-end server
  - Training phase, locating phase



Matching and Localization

- To track the current road where the querying user is moving, the back-end server matches the uploaded RTS from the querying user with the RTS map in the locating phase.
- After matching the road where the querying user moves, RALS utilizes the travel times among the peaks of an RTS for estimating the speed and the position of the querying user on the matchable road.

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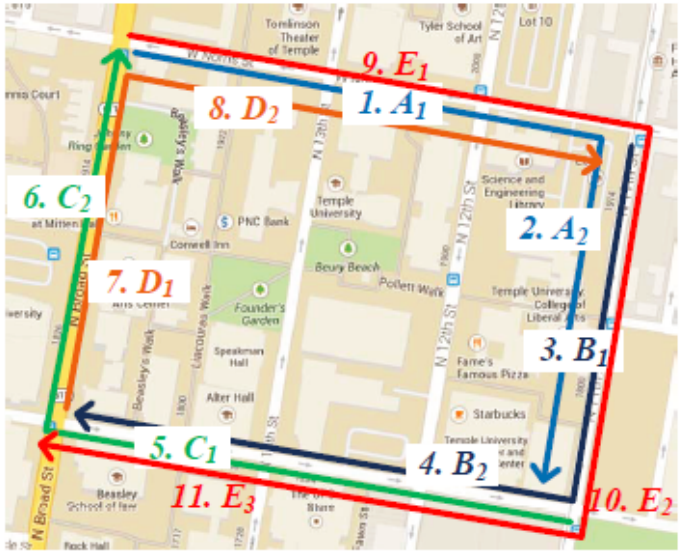
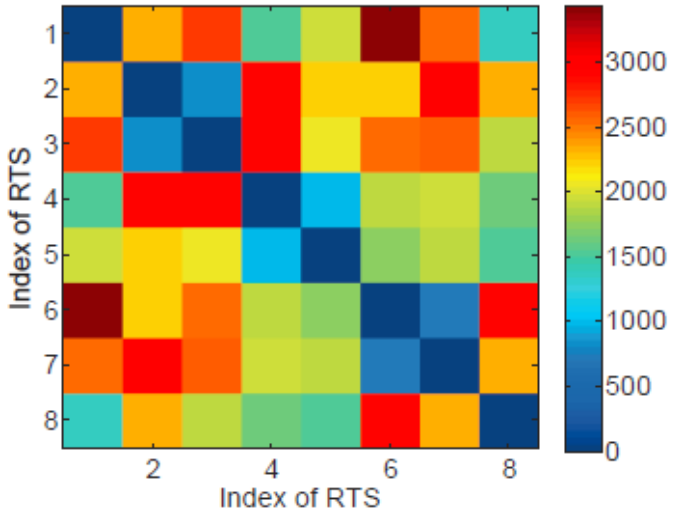
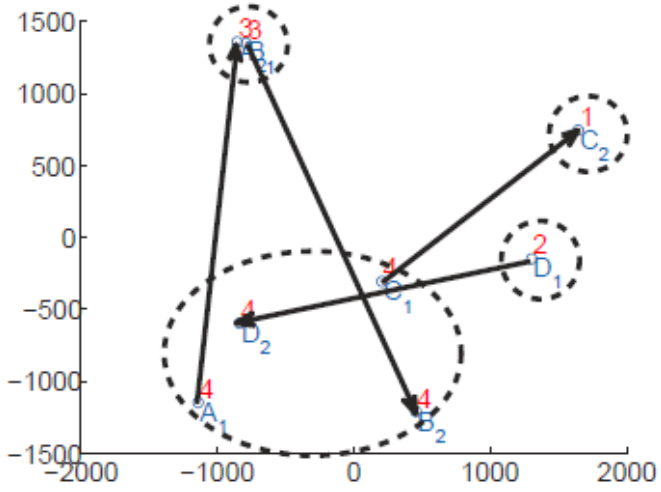
Building RTS Map without Site Survey



(a) Trajectories on road map



(b) Distance matrix $\mathcal{D}$



(c) Clustering mapped in 2D graph

- We term the problem of the uncertain fingerprints as the ***jigsaw puzzle problem***, which need more RTS from the unintentional users, and slows down the map construction.

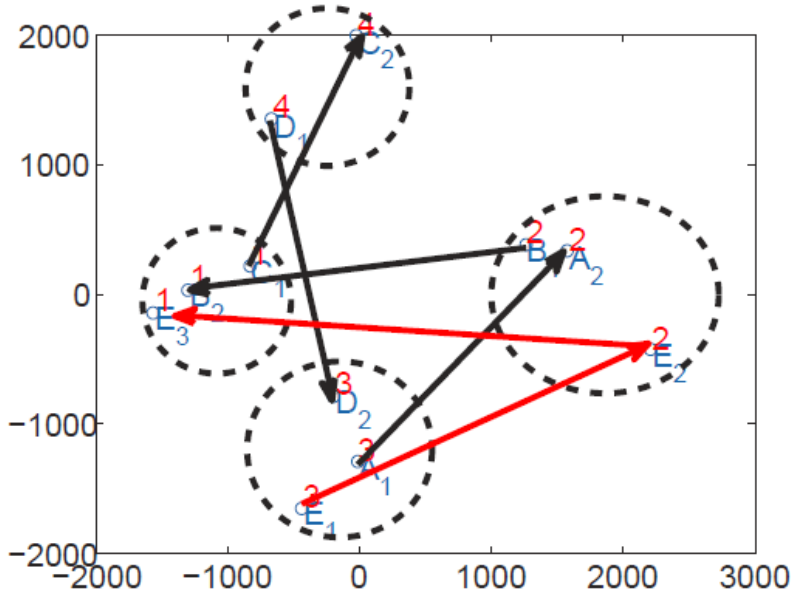
Jigsaw Puzzle Problem with Uncertain Fingerprints

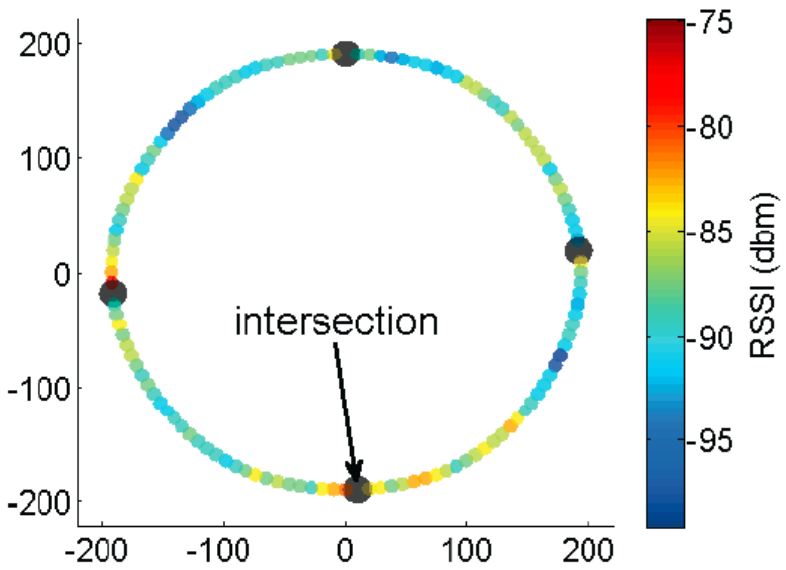
- We define the *size* of an area (*k*) as the number of the road segments in this area, and define the *length* of a trajectory (*m*) as the number of non-overlapped road segments covered by this trajectory.
- We define the ***certainty*** as the probability of distinguishing a pair for a trajectory in the area, which can be calculated as follows:

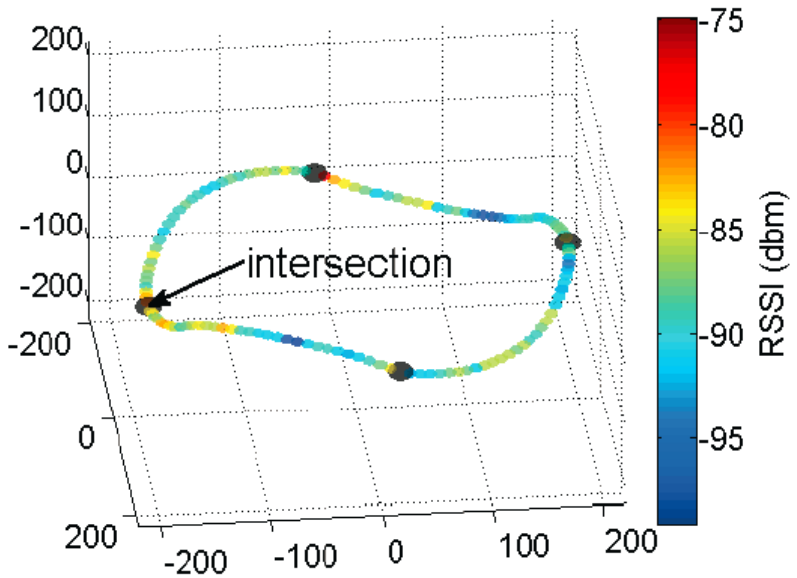
$$Certainty(m,k) = \frac{\binom{m}{2}}{\binom{k}{2}} = \frac{m(m-1)}{k(k-1)}$$

Speeding up the Map Construction

- To speed up the map construction, RALS employs a small number of the intentional users with an additionally longer non-overlapped trajectory, termed as ***extra mile***.







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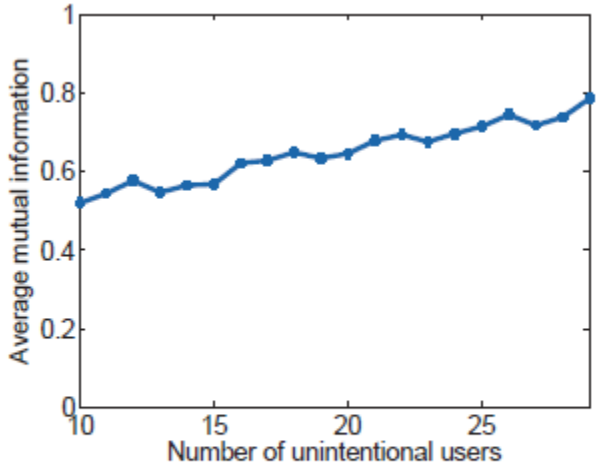
Experimental Methodology

- Experimental Scenario
- Mobile Phone
- Back-end Server

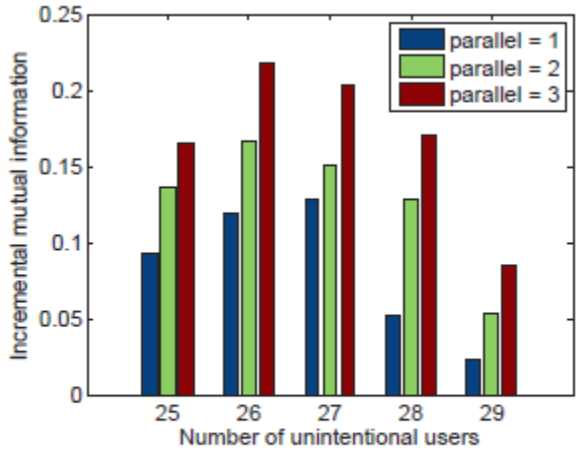
TABLE I. EXPERIMENT SCENARIO

Route	Description	Distance	Speed
HCW	Highway from Chengdu to Wengjiang, China	5 km	63 km/h
HCC	Highway from Chengdu to Chongzhou, China	25 km	80 km/h
SJU	Campus shuttle bus of SJU, China	3 km	22 km/h
CDC	Roads at the downtown of Chengdu city, China	5 km	28 km/h
Temple	Main campus of Temple University, USA	5 km	5 km/h

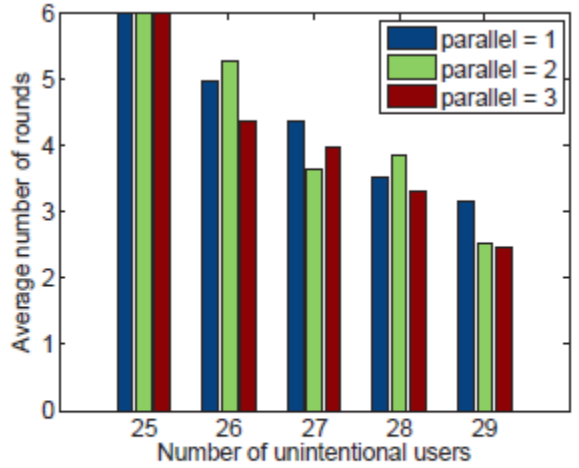
Performance of map construction with crowdsensing



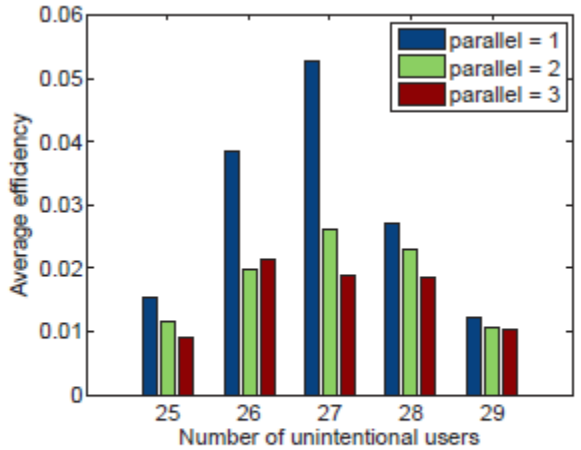
(a) Quality of unintentional users



(b) Incremental quality of intentional users per round

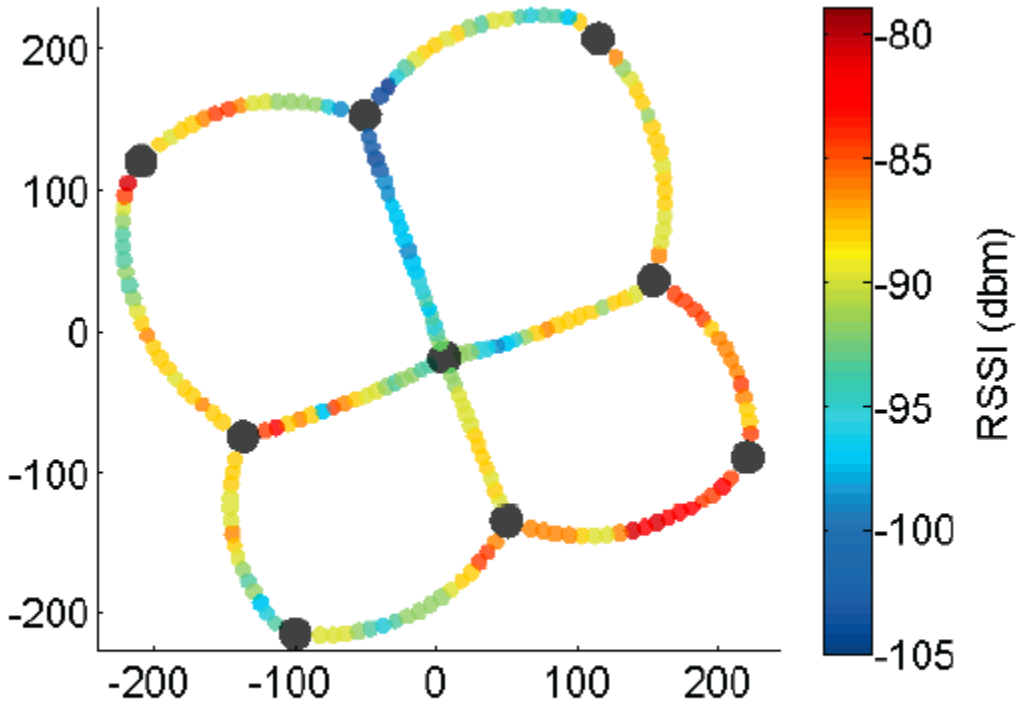


(c) Number of rounds with intentional users

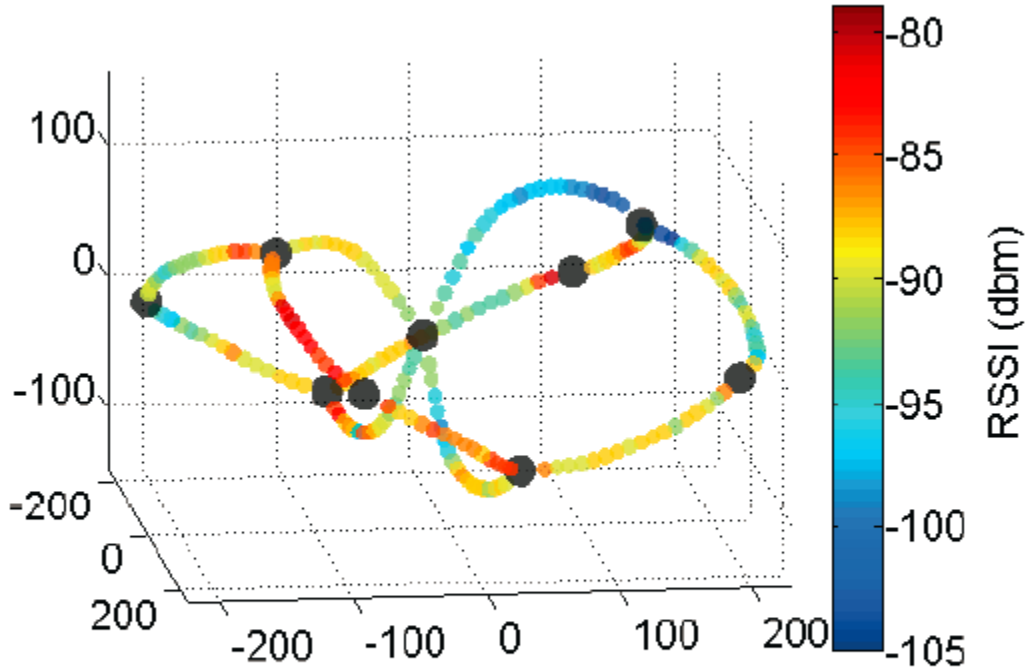


(d) Average efficiency of intentional users

Virtual Temporal Map with Twelve Road Segments



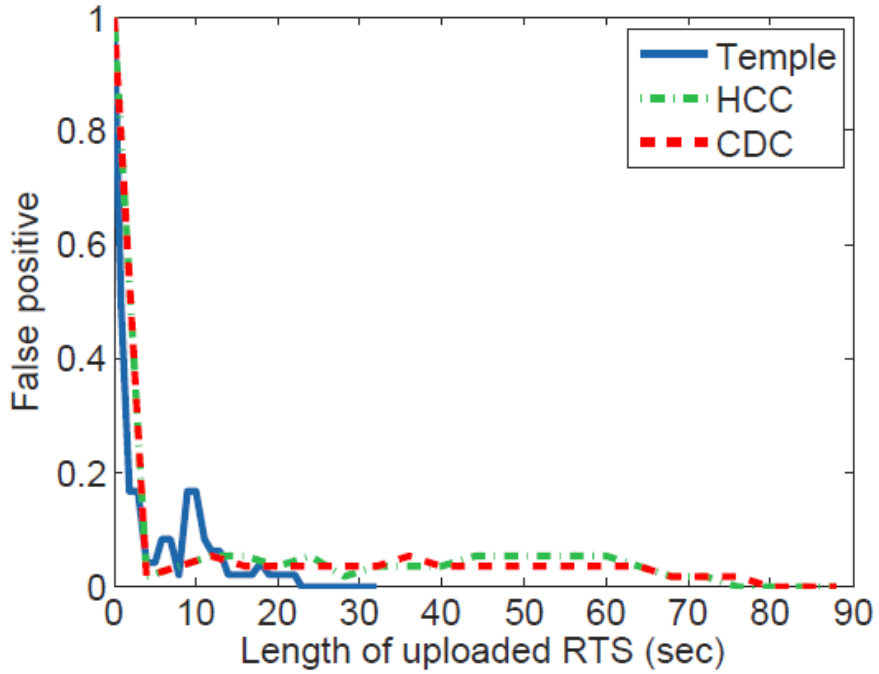
(a) 2D graph



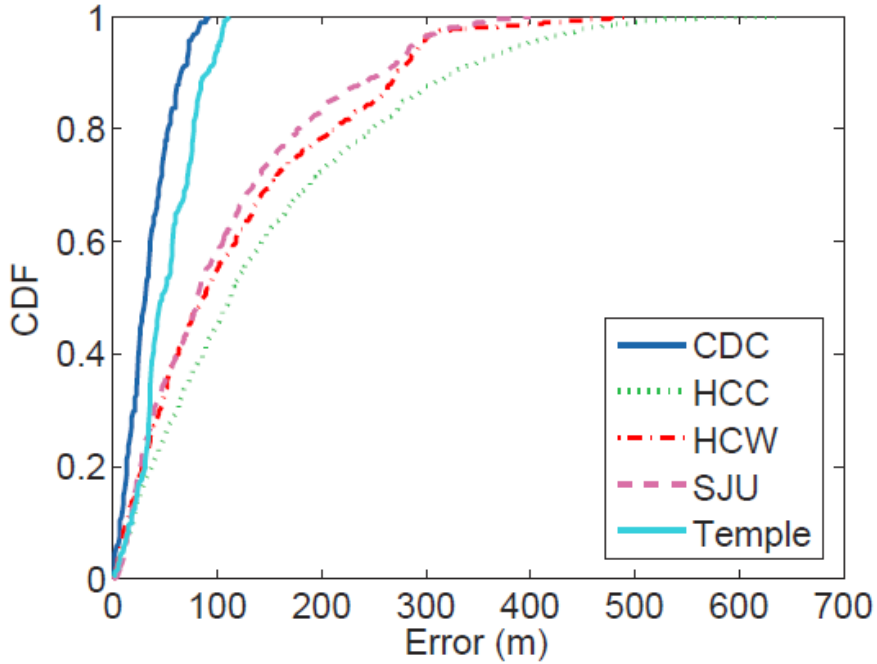
(b) 3D graph

Evaluation results

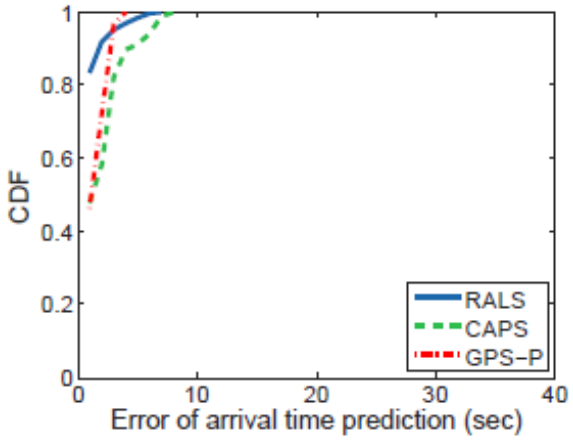
- Matching the roads



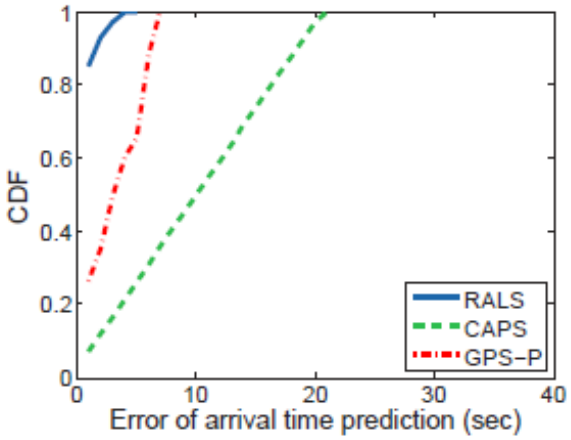
- Error of physical distance



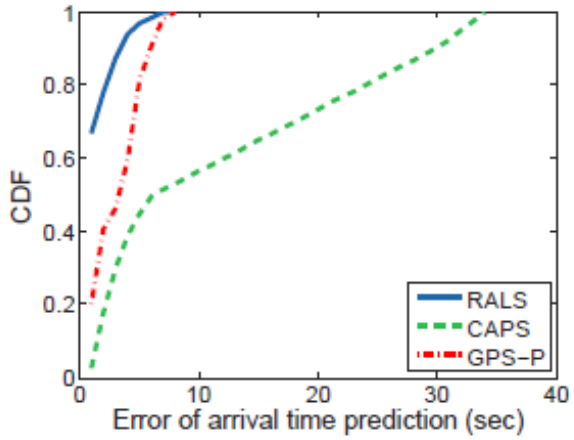
Error of Arrival Time Prediction



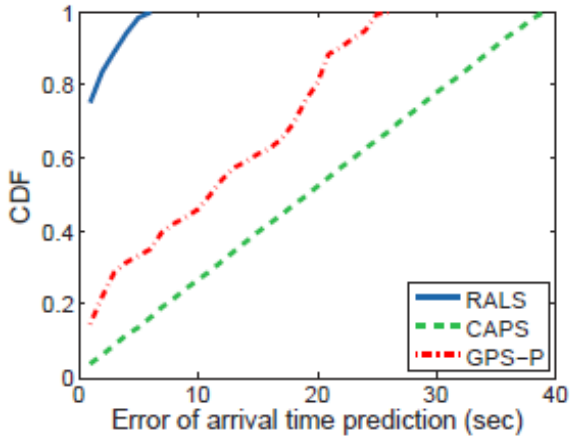
(a) HCC



(b) HCW



(c) SJU



(d) Tunnel

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Conclusion

- For an energy-efficient and accurate mobile localization, we design RALS, an RTS assisted localization system.
- However, the trajectories of the regular unintentional users are often limited to being short, and the map construction with short trajectories can cause the jigsaw puzzle problem. The jigsaw puzzle problem slows down the map construction, and affects its efficiency.
- RALS hires a small number of the advanced intentional users, who can move a longer distance for collecting the RTS, in order to speed up the map construction.

Thank you!