Advanced Computer Graphics
CS 525M:
Mobile Social Networking

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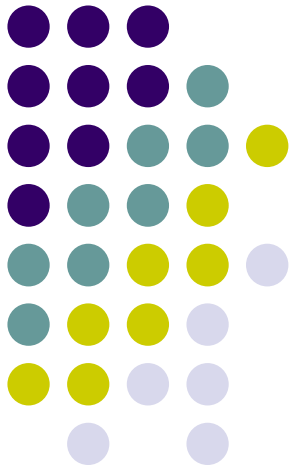
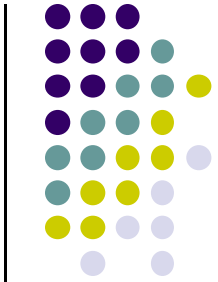


Bus arrival prediction system

How long to wait for buses ???

- For most city transport travelers, bus arrival time is primary information
- Schedule of a bus may be delayed due to many unpredictable factors (traffic jam, weather, etc)
- The accurate arrival time of next bus will mitigate travelers' anxiety and improve their experience on the road

Related work



- Phone-based transit tracking

  Automatic system for low cost, real-time transit tracking, mapping and arrival time prediction using GPS collected by personal smartphones.

- Celltower sequence matching

  Comprehensive set of APIs with low GPS usage, high efficiency, robustness new data structure is presented for mobile application development

- Participatory sensing

  Many recent works develop participatory platforms for people-centric mobile computing applications (Micro-blog, SoundSense, SurroundSence, etc).

A novel bus arrival time prediction system based on crowd-participatory sensing.

- **Sharing users**
  information collection to build database
- **Querying users**
  Request arrival time of interested route
- **Backend server**
  Data processing & Arrival time prediction

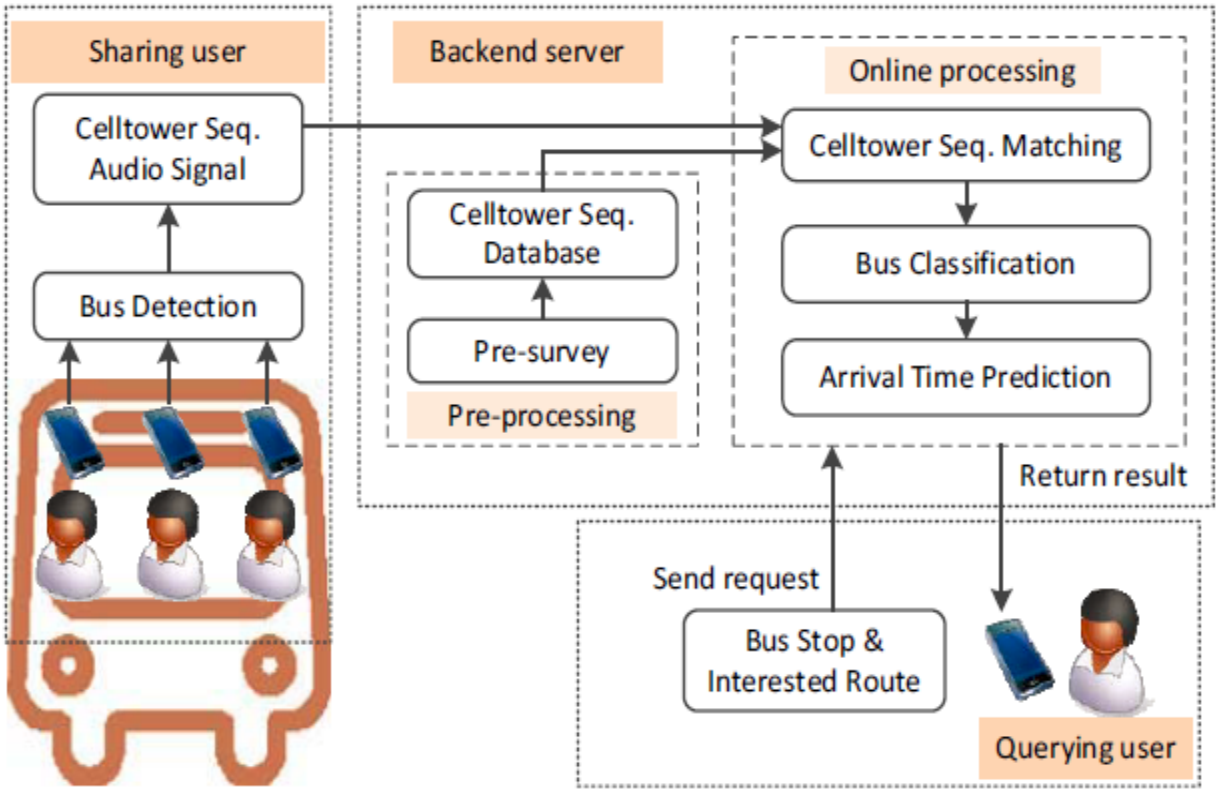
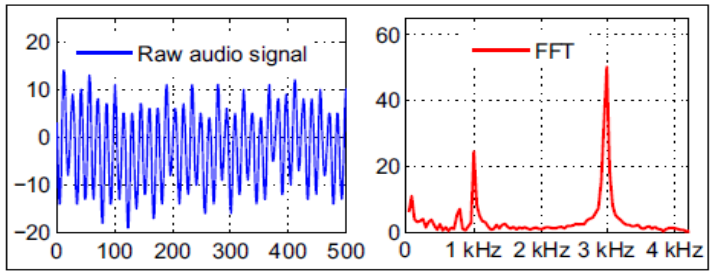


Figure 2: System architecture

Bus detection : Am I on Bus?

As aforementioned, database is built by sharing users. Information to verify whether sharing users are on a public transit bus is needed.

- *Audio detection* :
  using audio frequency analysis (128pt FFT) for IC reader beep.



(b) IC card reader indication audio signal

- *Accelerometer detection* :
  measure acceleration to figure out whether users on the train or bus.

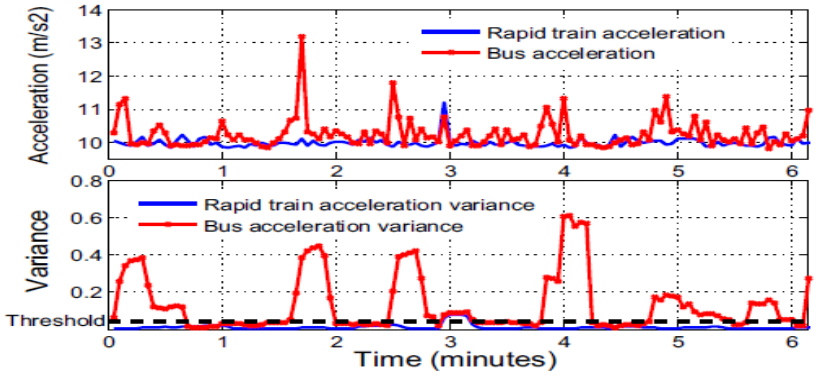


Figure 8: Accelerometer readings on rapid train and bus

Bus classification

Sharing users' mobile phone samples a sequence of celltower IDs and reports the information to the backend server

- *Celltower sequence matching*

  Received celltower sequences are used for matching with stored sequences

Database seq.	1 2 4	7 8 4 5	9 6
Uploaded seq.		7 8 4 5	
Matched seq.		7 8 4 5	

Table 1: Celltower sequence matching

- *Celltower sequence concatenation*

  For more accurate route classification, several sequences from different mobile phones on the same bus are concatenated

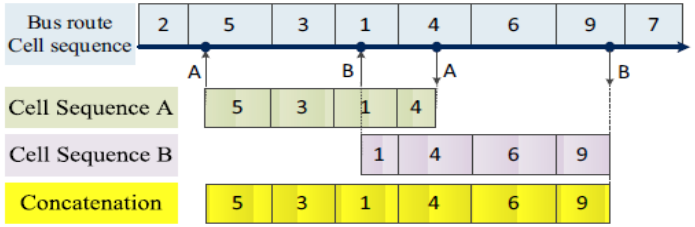


Figure 13: Celltower sequence concatenation

Arrival time prediction

Arrival time of the bus at queried stop is estimated as :

$$T = T_2 - t_2 + T_3 + t_{bs}$$

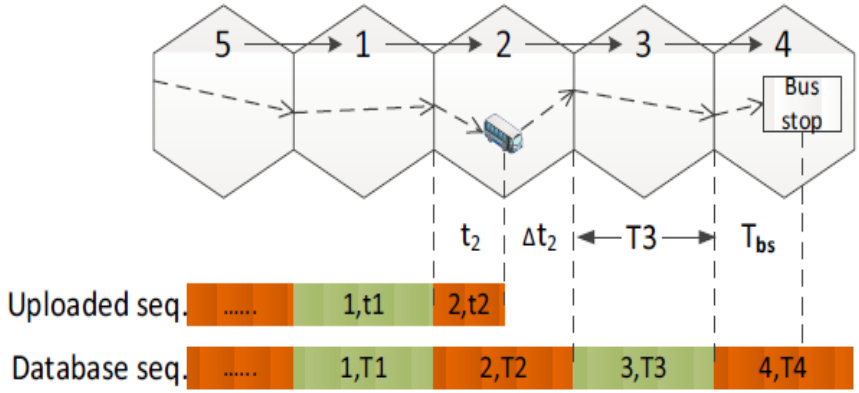


Figure 15: Bus arrival time prediction

In general,

$$T = \sum_{i=k}^{q-1} T_i - t_k + t_q$$

where T_i is the time for full block of cell tower; t_k is time spent in current block; t_q is time cost in last block

Performance of system

Bus detection accuracy:

Overall *95%* within 3m from IC reader.

Bus vs. MRT train classification:

Round *90%* at different time points

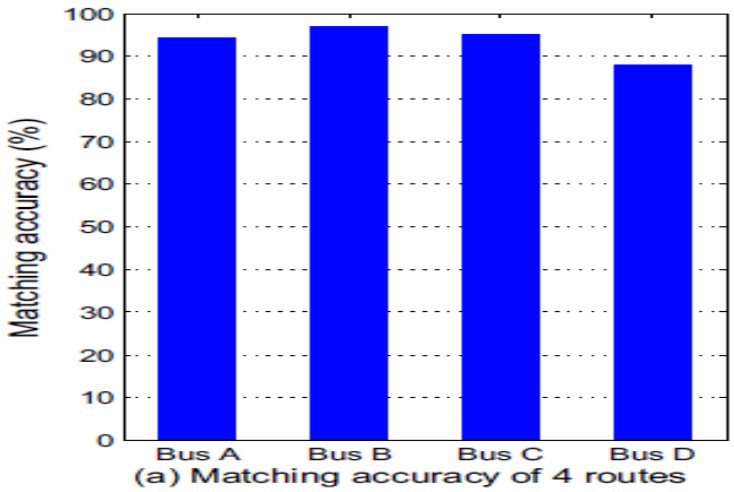
Bus classification accuracy

Round *90% (highest 96%, lowest 87%)*

accuracy for different 4 routes

Scenario	DR	FPR	Accuracy
Mobile phone in hand			
1m	100%	3%	98%
3m	97%		97%
5m	71%		84%
7m	15%		56%
Mobile phone in bag			
1m	98%	1%	98%
3m	95%		97%
5m	59%		79%
7m	5%		52%

Table 5: Bus detection accuracy. Detection rate (DR), false positive rate (FPR) and accuracy under various scenarios



(a) Matching accuracy of 4 routes

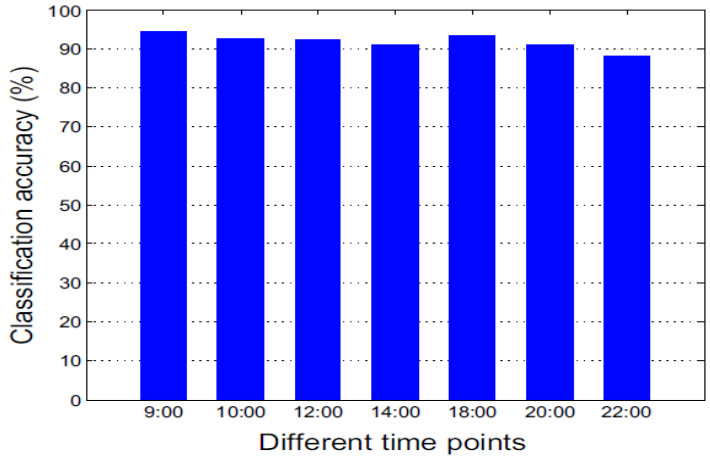
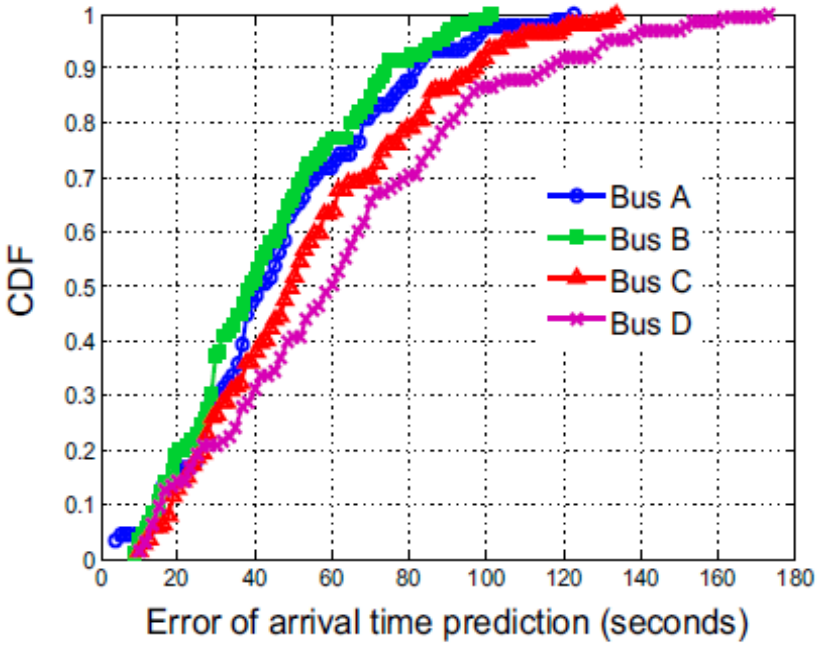
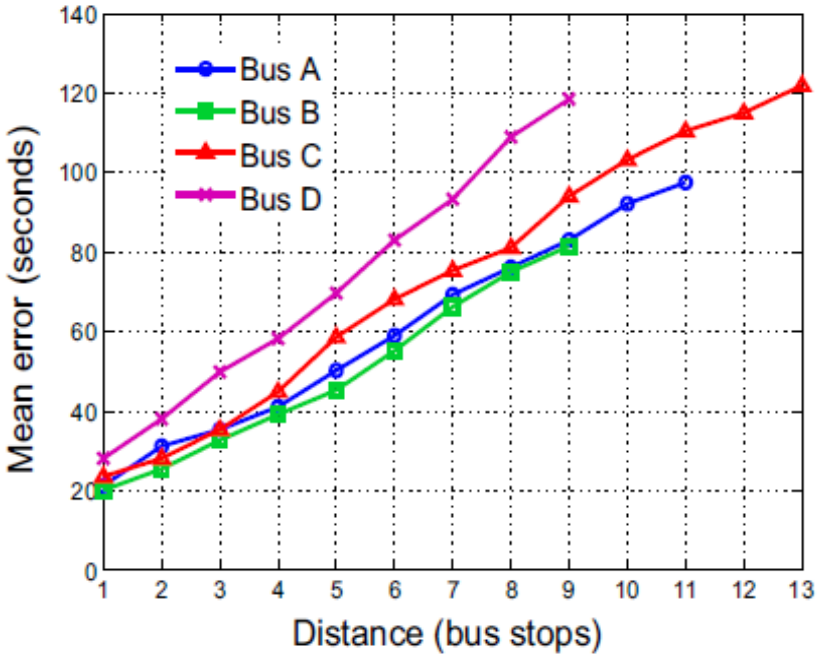


Figure 18: Bus vs. MRT using accelerometer

Performance of arrival time prediction



(a) Bus arrival time prediction error



(b) Bus arrival time prediction

(a) shows CDF of 4 routes, it indicates mean error round 80 seconds

(b) shows mean errors of 4 routes along with distance, it indicates mean error increase when distance increases.

Conclusion

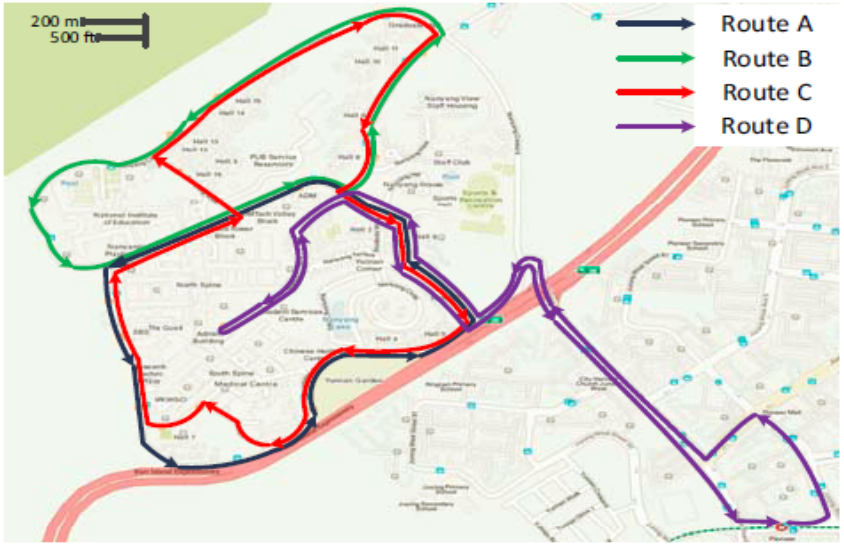


Figure 16: Campus shuttle bus routes

- The crowd-participated based system efficiently utilizes lightweight onboard sensors of cell phones, to predict the bus arrival time for users

- Over a 7-week experiment in Singapore, the evaluation demonstrate that the system can accurately predict the bus arrival time.(98% detection accuracy, arrival time error around 80 seconds)

Discussion and future work

- Number of celltowers a user could capture on a bus influences the bus classification accuracy

  WiFi points along the route might complement celltower ID

- First few bus stops

  Only using history data to generate a prediction arrival time

- Overlapped routes at downtown or major transit centers

  Challenging…

References

[1] Bus transport in Singapore. http:// en.wikipedia.org/wiki/Bus_transport _in_Singapore.

[2] EZ-Link. http://www.ezlink.com.sg.

[3] Octupus. http://www.octopus.com.hk/home/en.

[4] Oyster. https://oyster.tfl.gov.uk/oyster.

[5] PublicTransport@SG. http://www.publictransport.sg/.

[6] T. Abdelzaher, Y. Anokwa, P. Boda, J. Burke,D. Estrin, L. Guibas, A. Kansal, S. Madden, and J. Reich. Mobiscopes for Human Spaces. *IEEE Pervasive Computing, vol. 6(issue 2): pages 20–29,* Apr. 2007.

[7] G. Ananthanarayanan, M. Haridasan, I. Mohomed, D. Terry, and C. A. Thekkath. Startrack: a framework for enabling track-based applications. In Proceedings of ACM MobiSys, pages 207–220, 2009.