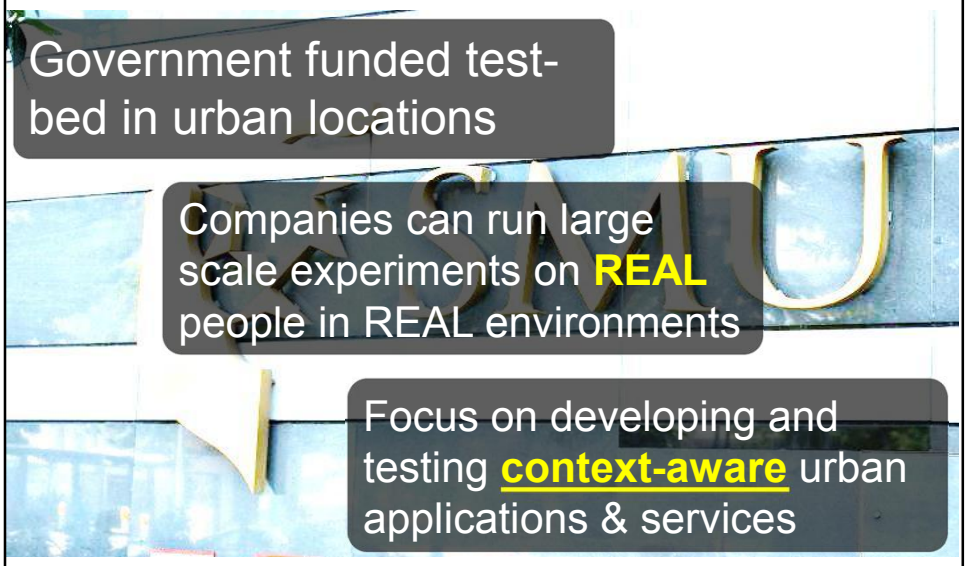
LIVELABS
SINGAPORE MANAGEMENT UNIVERSITY

The Challenge of Continuous Mobile Context Sensing

Talk at COMSNETS 2014
Bengalaru, Jan 9th 2014

WHAT IS LIVELABS?



LIVELABS IN ACTION

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LIVELABS: PARTICIPANTS & VENUES

30,000 opt-in consumers

Resource-efficient deep context collection

Real-time mobile analytics & insights

Real World experimentation

Multiple Urban Venues & Lifestyle Verticals

Telco & IDM

SMU

Mall@Singapore

Retail & Consumption

Changi Airport

Leisure & Tourism

Sentosa

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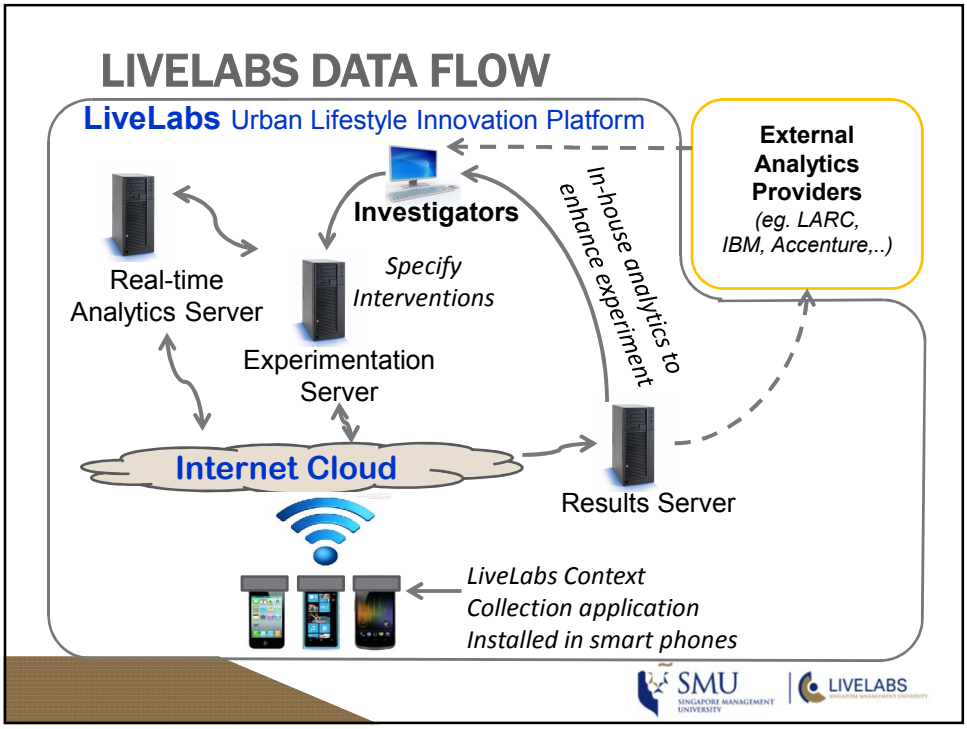
BENEFITS/FOCUS OF EACH LIVELABS TESTBED

 LiveLabs@SMU	• **Fine-grained** and **long-term** data monitoring ➔5,000 committed users with **3-4 year longitudinal experimentation study**	Cellular + Wi-Fi
 LiveLabs@Sentosa	• Unique **leisure demographic mix** (families, tourists, and students) of 10,000 users • Mix of popular outdoor (beaches, musical fountain, etc.) and indoor areas.	Medium-capacity cellular+ WiFi network.
 LiveLabs@Plaza Sing	• Large downtown mall testbed (~800K sq. ft., > 50,000 visitors per day) ➔ Diverse mix of retailers & mix of **youth & family demographics** (movie theatre etc.)	Medium-capacity WiFi network
 LiveLabs@Changi Airport	• Extremely busy airport – over 135,000 passengers per day • **Logistics & Retail** location • Two different groups of visitors --- transit and visitors	High-capacity Wi-Fi

LIVELABS DATA FLOW



LiveLabs: Key Component Technologies

Key Research Challenges	Current Innovations/Capabilities
1. Deep, energy-efficient, continuous, context collection	• Clients for Android, iOS, Phone8 . • Server-controlled capture of phone events (e.g., SMS, URLs) & sensor data
2. Continuous indoor location tracking in public spaces	• Client-side +-3m accuracy for Android. • Server-side tracking for all platforms (e.g., iOS, Phone 8)
3. Derive Deep Analytics from Context	• Real-time Queue Detection System. • Detection of Dynamic Groups from Spatiotemporal trajectories
4. Run automated social experiments on mobile devices	• Intervention Management Portal (v1) allows location & time-based delivery of ads/promotions.
5. Handle transient network traffic loads	• Use of TV Whitespace and real-time RF Mapping technologies *under investigation*

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ACHIEVEMENTS

- LiveLabs@SMU operational since Sep 2012.
  - Approx. 850 participants signed up; approx. 420 active participants
  - Data collection for Android and iOS platforms deployed
- Campus-wide Indoor Location Tracking
  - Longitudinal traces of over 3000+ individual devices using server-side location
  - Controlled activation of fine-grained client-side location (Android)
- Developed Analytics over Mobile Data
  - Queuing Detection: Research prototype tested
  - Group Detection: Under active R&D
- Interventions/Promotions
  - Merchant promotions provided to participants via SMUddy App
  - Dynamic context-based promotions ready for demos

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LIVELABS: LESSONS LEARNED UP TO NOW

- Indoor Location Tracking is Not a Solved Problem
  - Too many real-world anomalies with existing techniques
- The Tail Really Does Matter!
  - Venue operators prefer solutions with no fluctuation (even if base is worse)
- Attracting Participants is Easy, Retention is Hard!
  - Need to find what motivates participants to stay on (apps in our case)
- Production, Research, and Administration Do Not Mix!
  - Needed separate teams for each to ensure quality and prevent burnout
- Cannot do Continuous Mobile Sensing
  - Large amounts of low fidelity sensing with burst of high fidelity sensing

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THE CHALLENGE OF CONTINUOUS SENSING

1) Energy cost of individual sensors is large

2) Energy cost of multiple sensors may not be linear

3) Energy cost of multiple tasks is dominated by the most expensive taks

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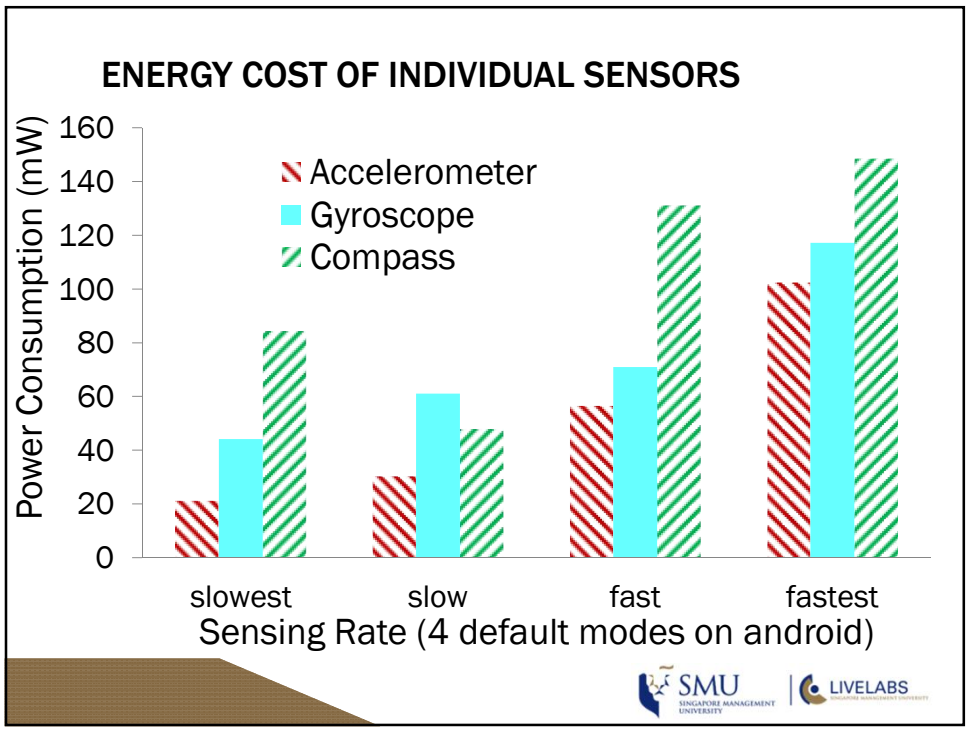
ENERGY COST OF INDIVIDUAL SENSORS
Power Consumption (mW)
160
140
120
100
80
60
40
20
0
Accelerometer
Gyroscope
Compass
slowest
slow
fast
fastest
Sensing Rate (4 default modes on android)
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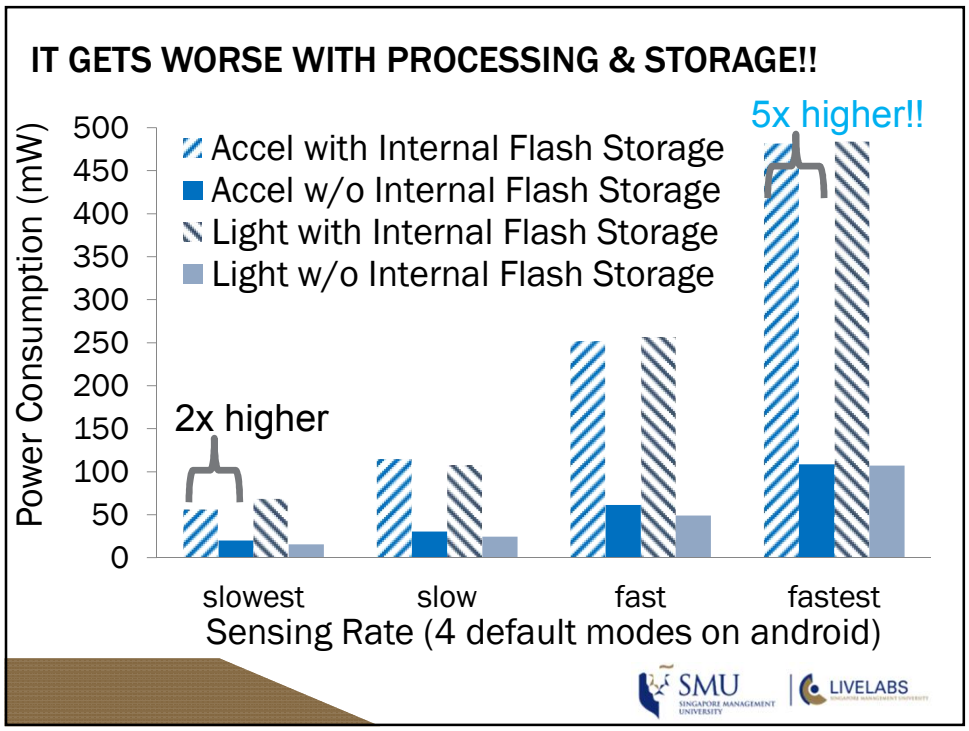
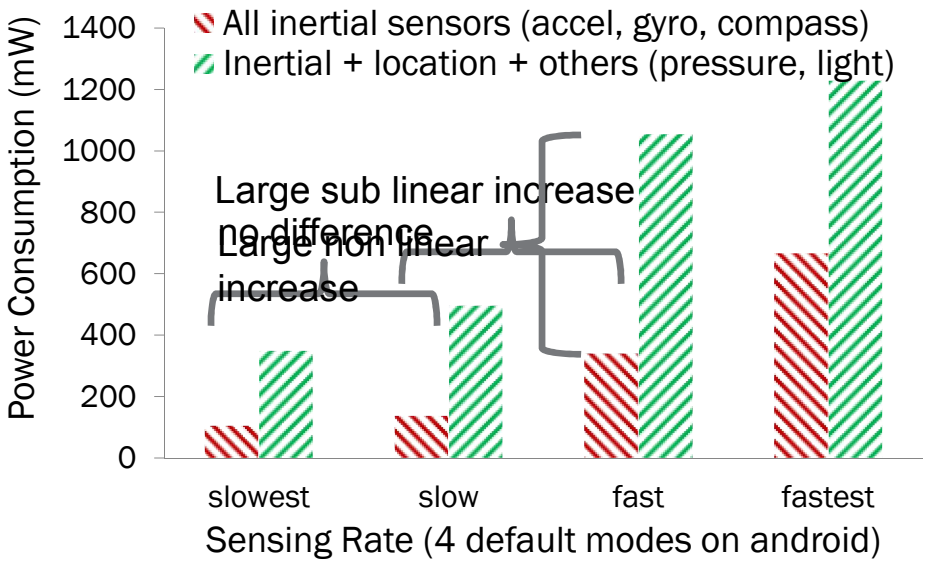

IT GETS WORSE WITH PROCESSING & STORAGE!!
Power Consumption (mW)
500
450
400
350
300
250
200
150
100
50
0
Accel with Internal Flash Storage
Accel w/o Internal Flash Storage
Light with Internal Flash Storage
Light w/o Internal Flash Storage
5x higher!!
2x higher
slowest
slow
fast
fastest
Sensing Rate (4 default modes on android)
SMU
LIVELABS

ENERGY COSTS MAY NOT BE LINEAR



OTHER CHALLENGES

1) Heterogeneity of devices
   - Different devices have different sensors
   - Energy costs, latencies, accuracies all differ

2) Accuracy is not the only important metric. Latency matters too!!
   - No point collecting accurate data 1 hr ago for a real-time application
   - Hence, transmission and computation costs must be factored in

SUMMARY

- LiveLabs aims to change 3 real-world venues into living testbeds
  - Using the cell phones of opted in participants as the main sensors
- Collecting sensor data from these phones in an energy-efficient yet accurate manner is challenging
- Current Solution
  - Low fidelity sensing by default with high fidelity sensing enabled for short periods (duing expts)

FOR MORE DETAILS

Contact me at rajesh@smu.edu.sg and/or visit

http://www.livelabs.smu.edu.sg

We are looking to hire

Post-docs, research engineers, and Ph.D. students (in all areas of systems development and research)

Please contact me if you are interested.