Embedded Networks Laboratory

USC Viterbi School of Engineering

Energy-Efficient Rate-Adaptive GPS-based Positioning for Smartphones

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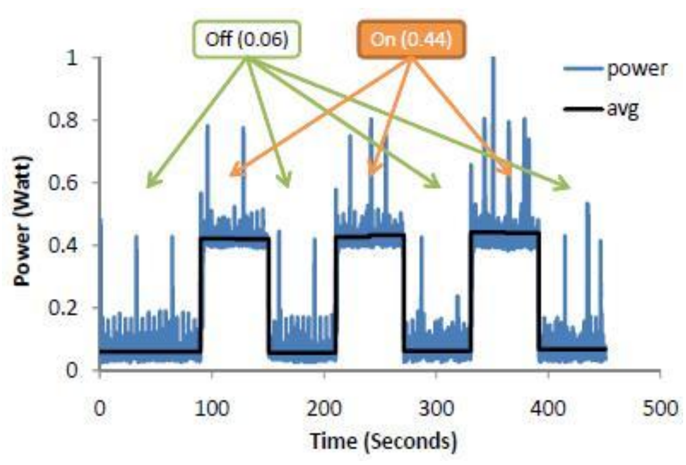
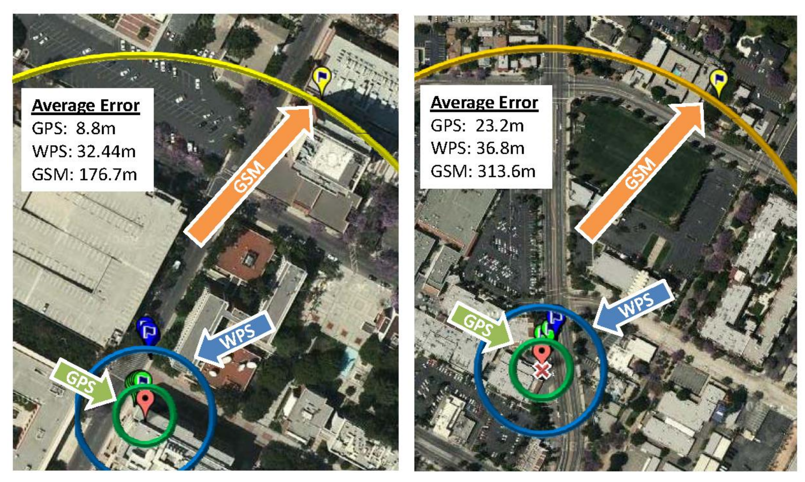
http://enl.usc.edu

Introduction – "Trade-off position accuracy for energy"

Problem

- Many emerging smartphone applications require position information to provide location-based or context aware services.
- GPS is preferred over GSM/WiFi based methods, but ***GPS is extremely power hungry***.
- Fixed interval periodic duty cycling will not solve the problem; it may have significant error without significant energy benefits.



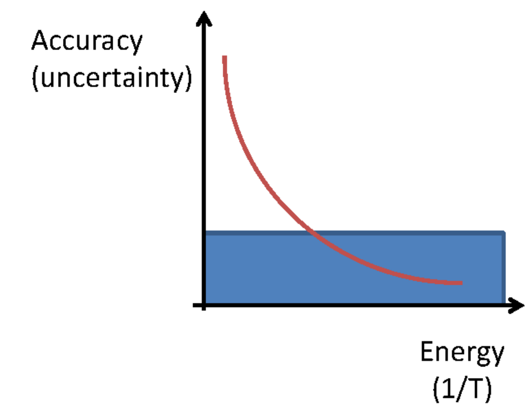


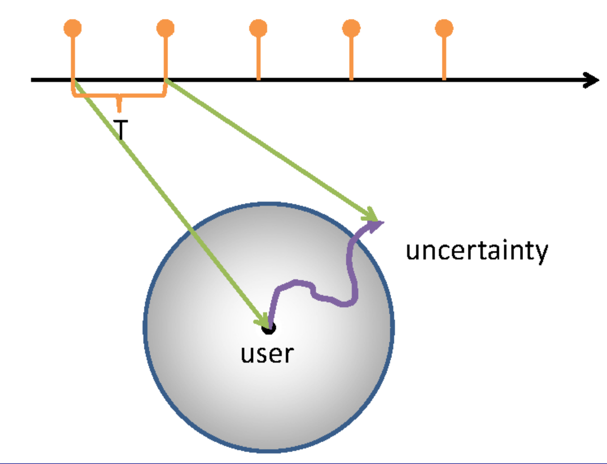
Goal

- Reduce the amount of energy spent by the positioning system while still providing sufficiently accurate position information.
- ***Trade-off position accuracy for reduced energy***.

RAPS: Rate-Adaptive Positioning System

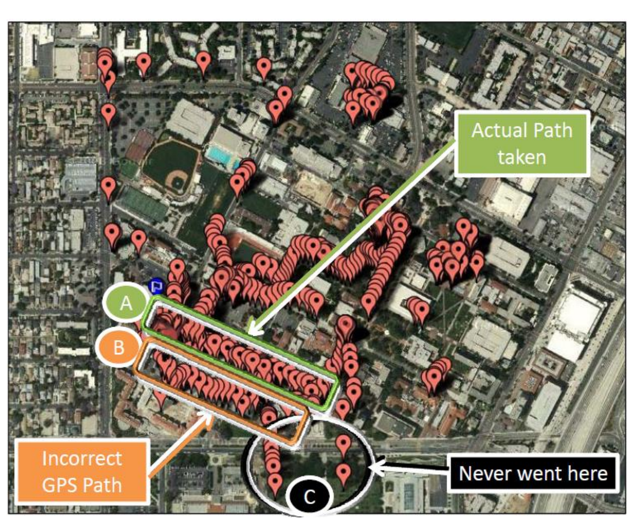
- An energy-efficient positioning system that ***adaptively duty-cycle GPS*** only as often as necessary to achieve required accuracy based on user mobility and environment.

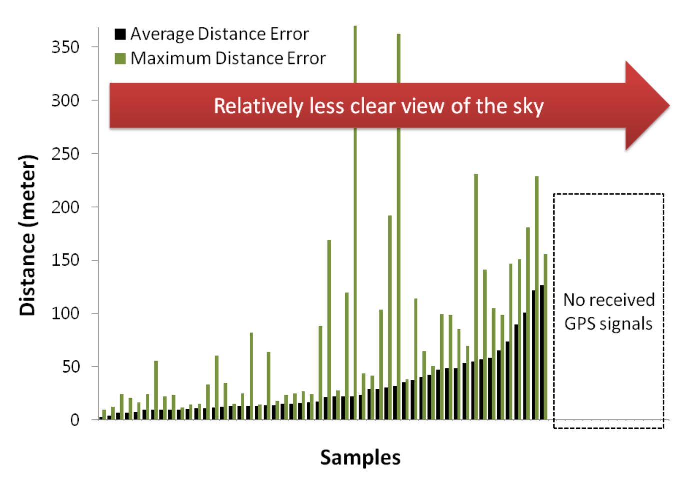




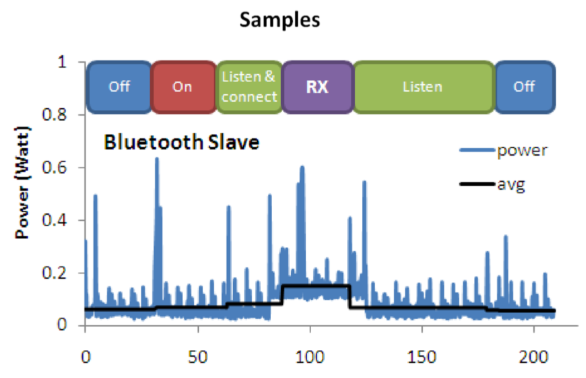
Observations and Challenges – "GPS is less accurate in urban areas"

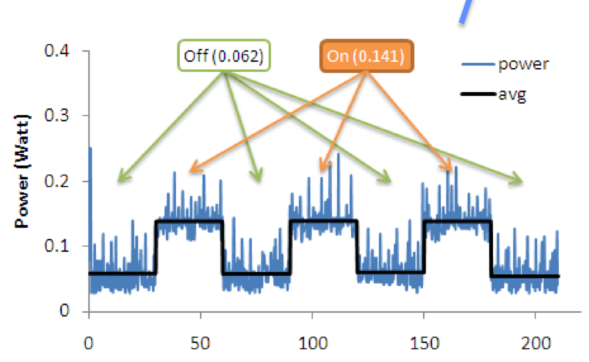
GPS is less accurate in urban areas

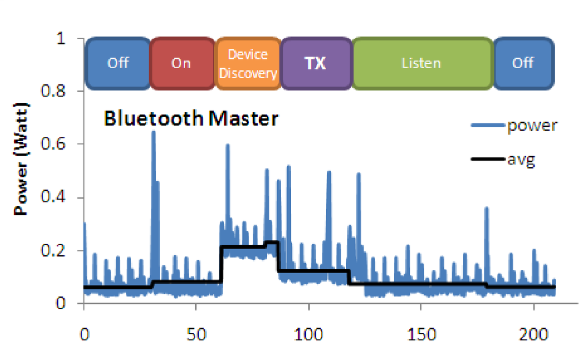




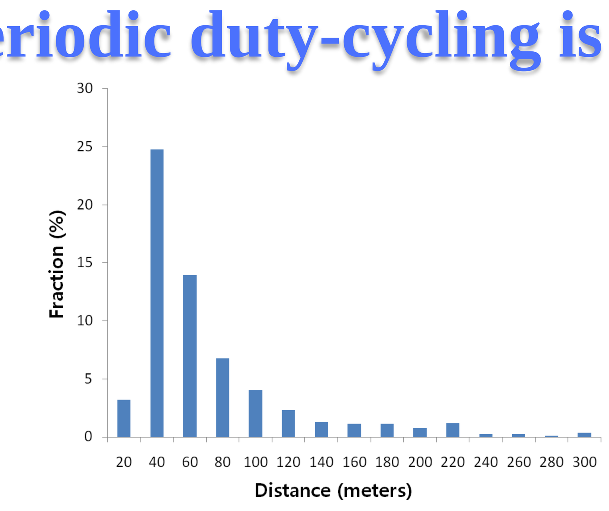
Accelerometer and Bluetooth consume less energy than GPS, if used cleverly

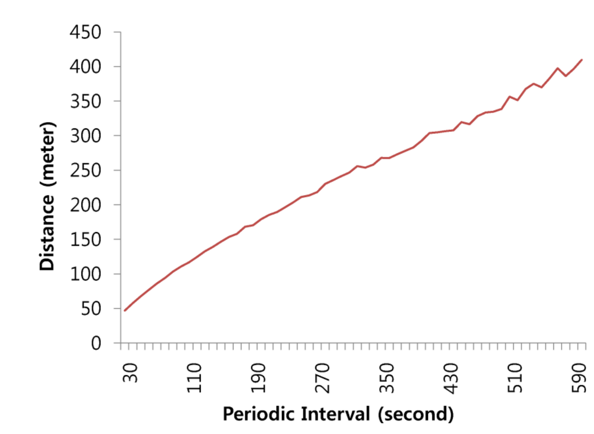


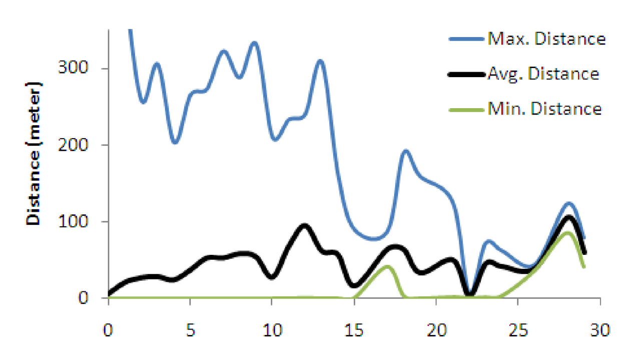




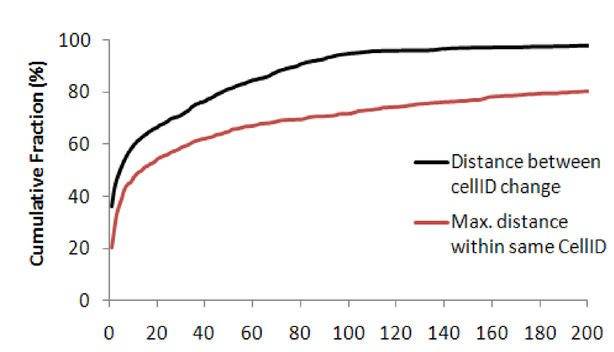
Periodic duty-cycling is not good enough

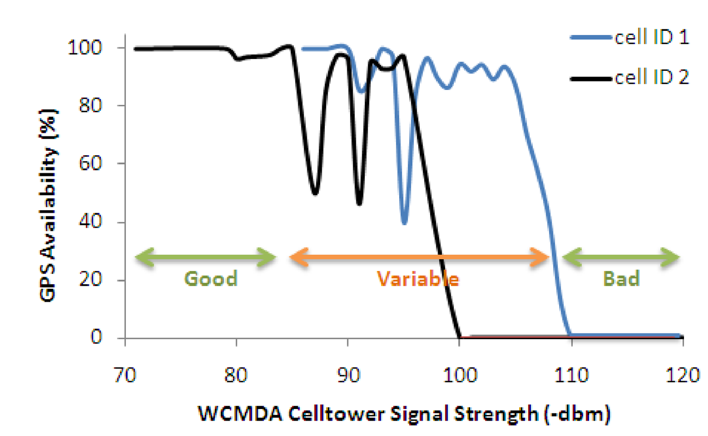






Cell-tower and RSS data cannot reliably measure user movement, but can detect GPS unavailability

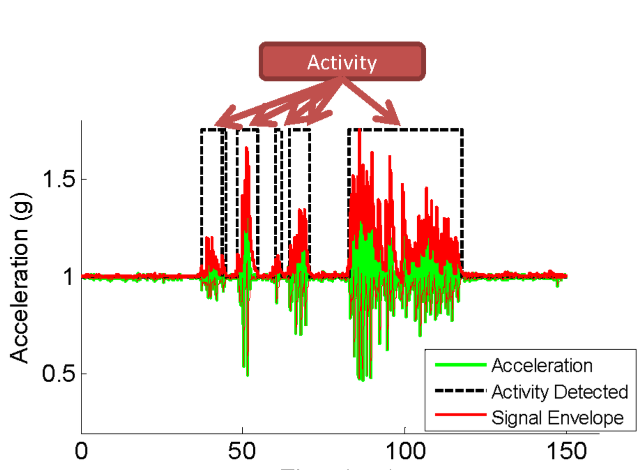




Design and Evaluation – "RAPS: Rate-Adaptive Positioning System"

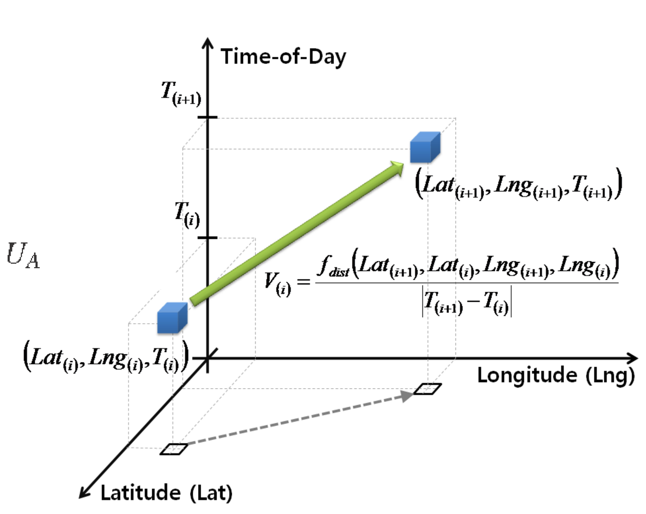
Design and Approach

- **Movement Detection**
  - Use ***duty-cycled accelerometer*** with onset detection algorithm to efficiently measure the activity ratio of the user.
- **Velocity Estimation**
  - Use ***space-time history*** of the past user movements along with their associated activity ratio to estimate current user velocity.
- **Unavailability Detection**
  - Use ***celltower-RSS blacklisting*** to detect GPS unavailability (e.g. indoors) and avoid turning on GPS in these places.
- **Position Synchronization**
  - Utilize ***Bluetooth-based position synchronization*** to communicate and reduce position uncertainty among neighboring devices.



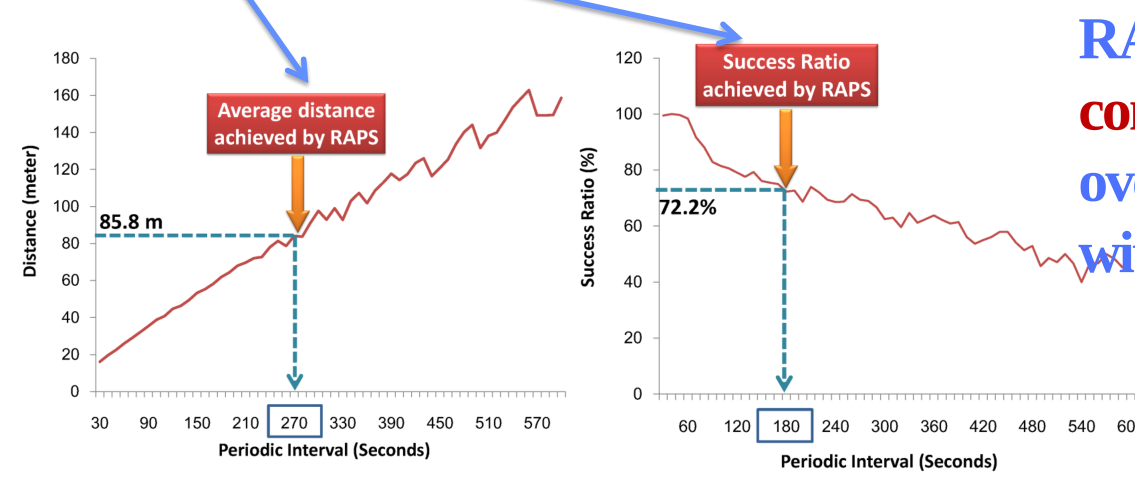
$$V(t) = \overline{V_A} * \frac{R(t)}{R_A}$$

$$U(t) = V(t) * (t - T_A) + U_A$$



Evaluation Results – promising!!

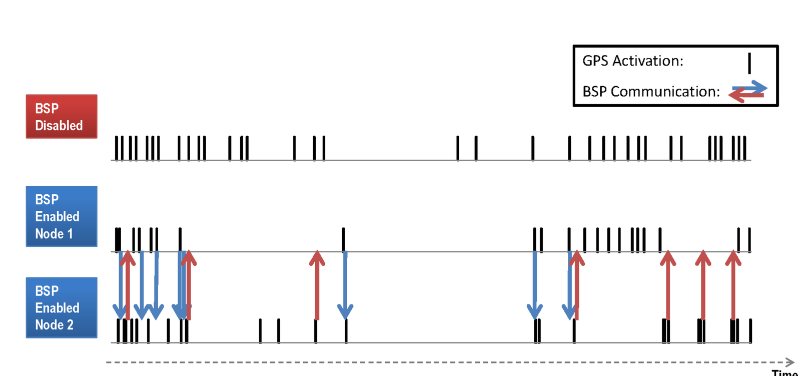
	Avg.GPS Interval	Avg.Uncertainty (Dev.)	Success Ratio	Avg.Power	Running time
RAPS	465.1 sec	85.8 m (69.2 m)	72.2%	0.064 W	35.2 hours
Periodic (T=180)	180.0 sec	61.9 m (84.6 m)	72.3%	0.123 W	23.8 hours
Periodic (T=270)	270.0 sec	84.1 m (88.6 m)	69.4%	0.082 W	30.8 hours



RAPS reduced energy consumption by 48% over fixed duty-cycles with comparable accuracy

	Accelerometer	*C-R Blacklist*	Avg.GPS Interval	Avg.Power	Avg.Uncertainty (Dev.)
Phone 1	enabled	enabled	465.1 sec	0.058 W	85.7 m (69.2 m)
Phone 2	enabled	disabled	402.5 sec	0.065 W	75.6 m (60.9 m)
Phone 3	disabled	disabled	529.9 sec	0.042 W	93.1 m (88.6 m)

Celltower-RSS blacklisting and activity ratio scheme contributes to energy saving



Bluetooth synchronization has potential benefits (43% in this example)

Jeongyeup Paek, Joongheon Kim, Ramesh Govindan, **Energy-Efficient Rate-Adaptive GPS-based Positioning for Smartphones**, *ACM MobiSys'10. To appear*

CENS Center for Embedded Networked Sensing