Energy Limits in Location Tracking

Are future improvements in energy efficiency possible?

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Abstract

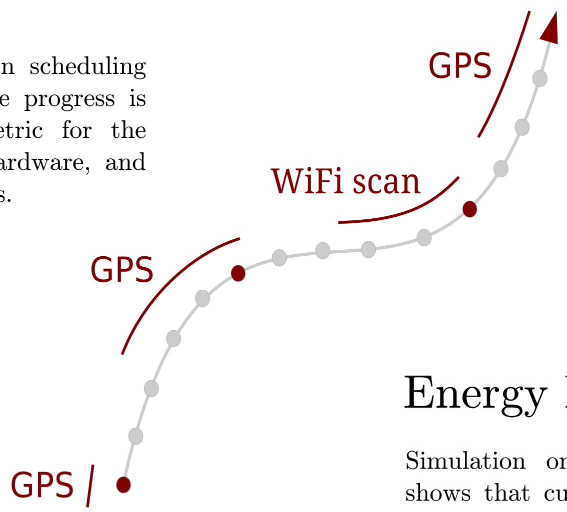
Existing work in energy-efficient location tracking uses relative energy use as the main evaluation metric.

We argue that comparisons of sensor scheduling algorithms should include the energy limit: the lower bound energy use achievable by any tracker on the same hardware and movement path.

The limit is independent of advances in scheduling algorithms, and shows how much future progress is possible in the area. It is also a metric for the inherent energy-efficiency of tracking hardware, and the energy complexity of movement paths.

Sensor scheduling

Sensor scheduling algorithms turn sensors on and off to save energy. In this example, GPS is activated three times, and WiFi fingerprints are scanned once. The scheduler has to account for predicted movement and time to first fix delays to ensure that a new position is received in time.

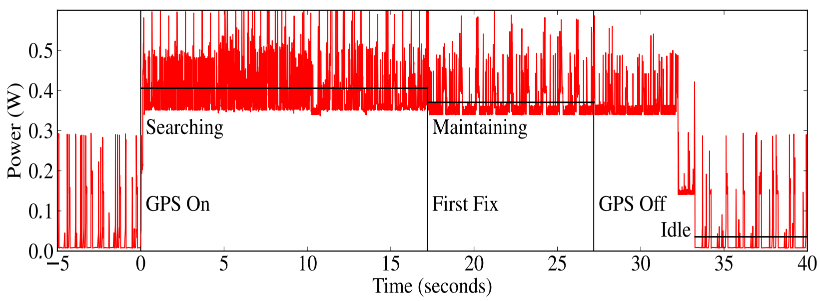


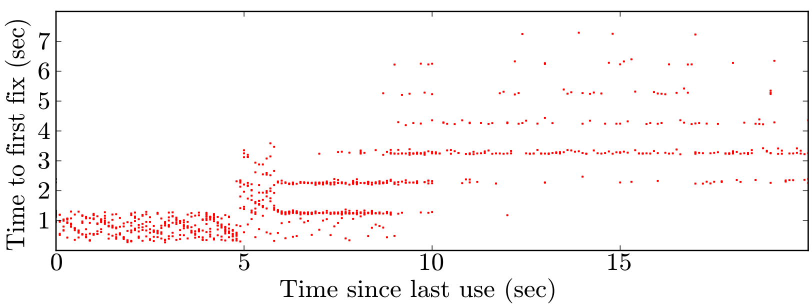
Power Models

Computing energy limits requires a model of the sensors. We have built and experimentally validated power models for the Nexus One and Nexus S smartphones.

Energy use of the GPS depends on the current state of the sensor. Less power is required to maintain a fix compared to searching for a fix. Power-down delays result in energy use after turning the sensor off, and time to first fix depends on time since last use.

As a result, it can be more efficient to keep GPS active rather than shutting it down for short periods.





Energy Limits of GPS

Simulation on a continuous 2-week sensor trace shows that current sensor scheduling algorithms do not yet approach the achievable energy limit, and further work in the area is possible.

The energy limit depends on the required tracking accuracy. At 30-meter accuracy, it would be feasible to track the movement at 10mW average power with the perfect sensor scheduling algorithm.

We believe the greatest energy savings will result from optimising energy use of the sleep state when the phone is stationary, not of active tracking when it is moving.