www.csiro.au

Adaptive GPS Duty Cycling with Radio Ranging for Energy-Efficient Localization

Raja Jurdak
Peter Corke
Dhinesh Dharman
Guillaume Salagnac

CSIRO ICT Centre
Queensland University of Technology
INSA Lyon

CSIRO

Motivation

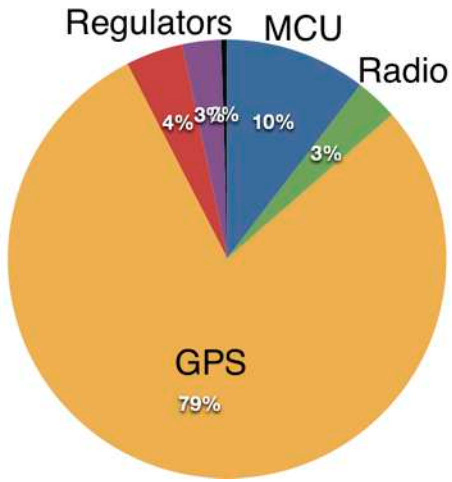
Motivation

Motivation

- Localization systems need absolute position references
  - GPS

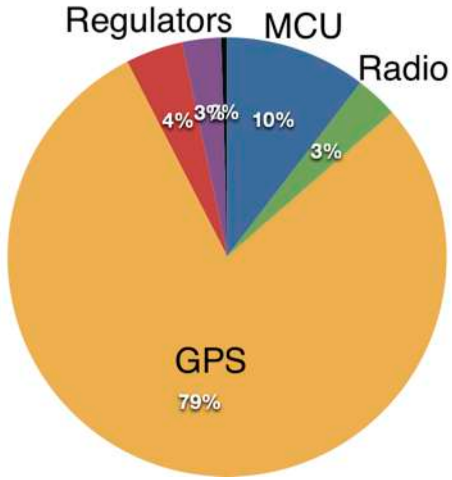
Motivation

- Localization systems need absolute position references
  - GPS
- GPS is energy-expensive



Motivation

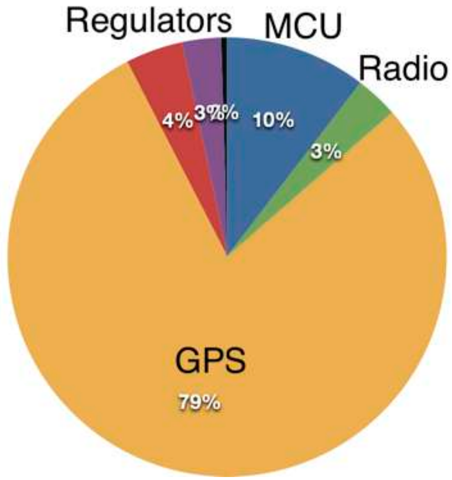
- Localization systems need absolute position references
  - GPS
- GPS is energy-expensive



- Key ideas of this work
  - Duty cycle GPS
  - Complement with energy-inexpensive signals
    - Radio beacons
    - Accelerometers
    - Magnetometers

Motivation

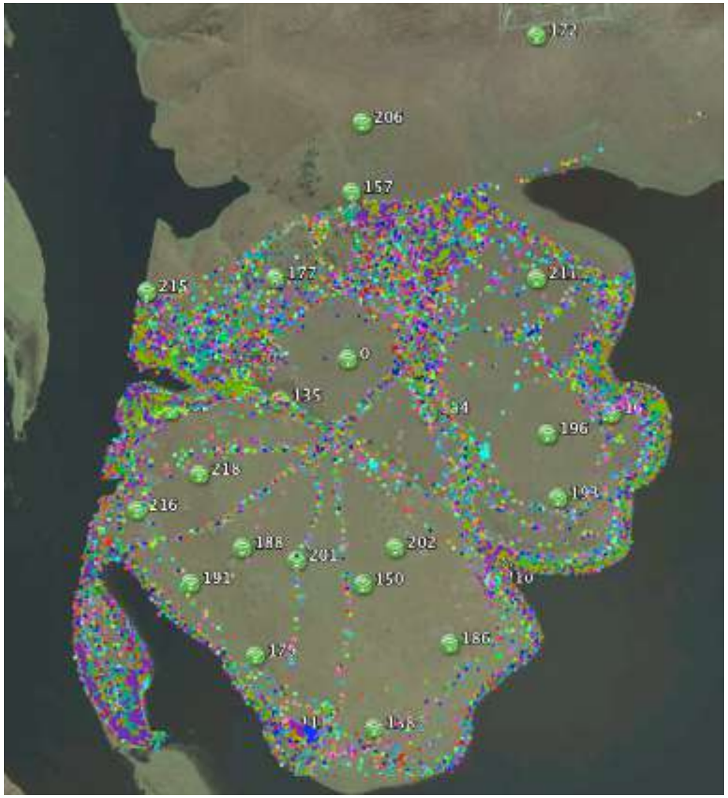
- Localization systems need absolute position references
  - GPS
- GPS is energy-expensive

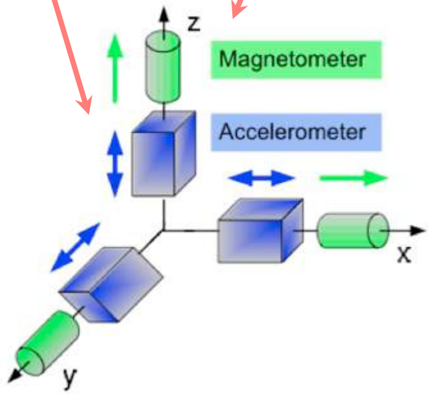


- Key ideas of this work
  - Duty cycle GPS
  - Complement with energy-inexpensive signals
    - Radio beacons
    - Accelerometers
    - Magnetometers

Cattle sensor networks

- Domain problems:
  - Herd behaviour
  - Grazing patterns
  - Social interaction





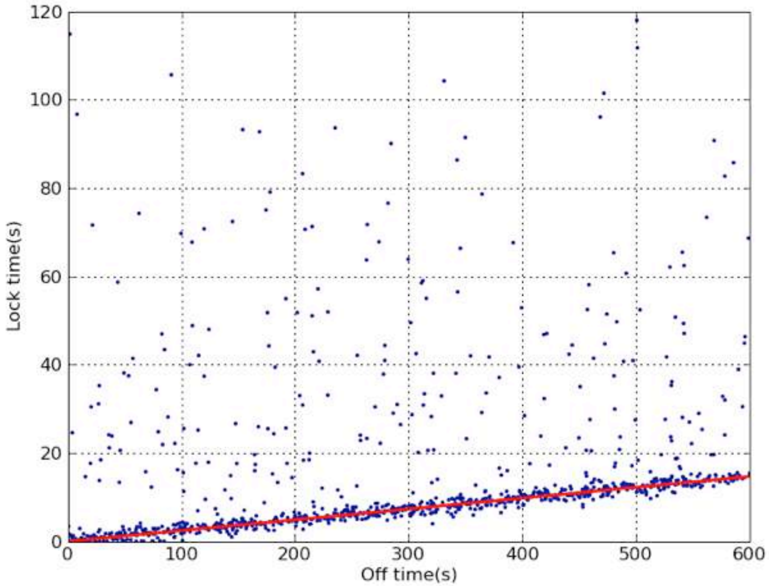
GPS + RF antennas

Virtual Fencing: Environmental protection

Virtual Fencing: Environmental protection

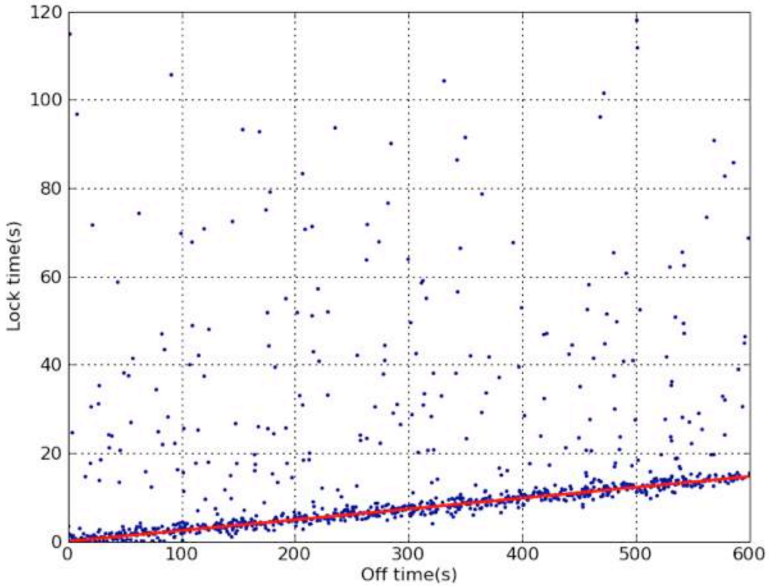
CSIRO

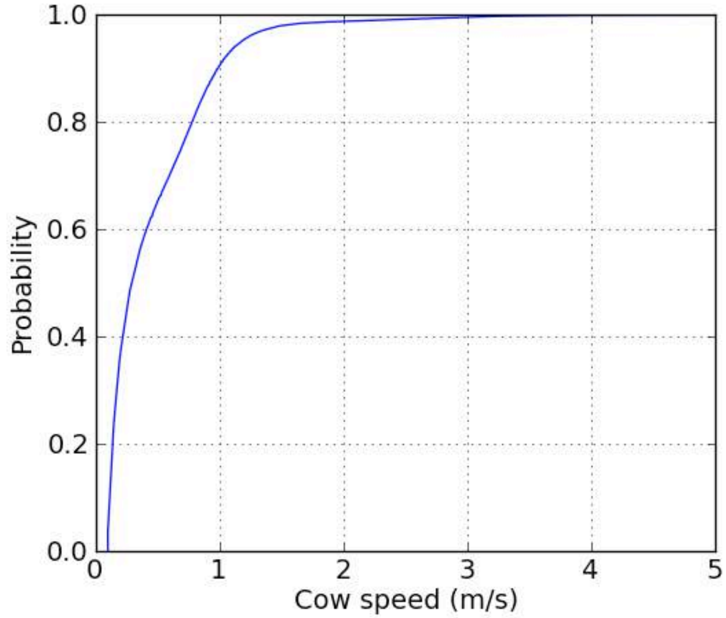
Design Considerations



GPS lock times loosely depend on off time

Design Considerations



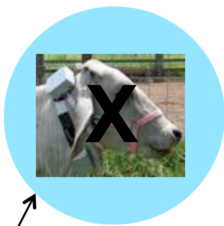


GPS lock times loosely depend on off time

Cows are slow!

GPS Duty Cycling

1. GPS acquires lock



GPS chip uncertainty

X Assumed position

Real position

Uncertainty

GPS Duty Cycling

1. GPS acquires lock

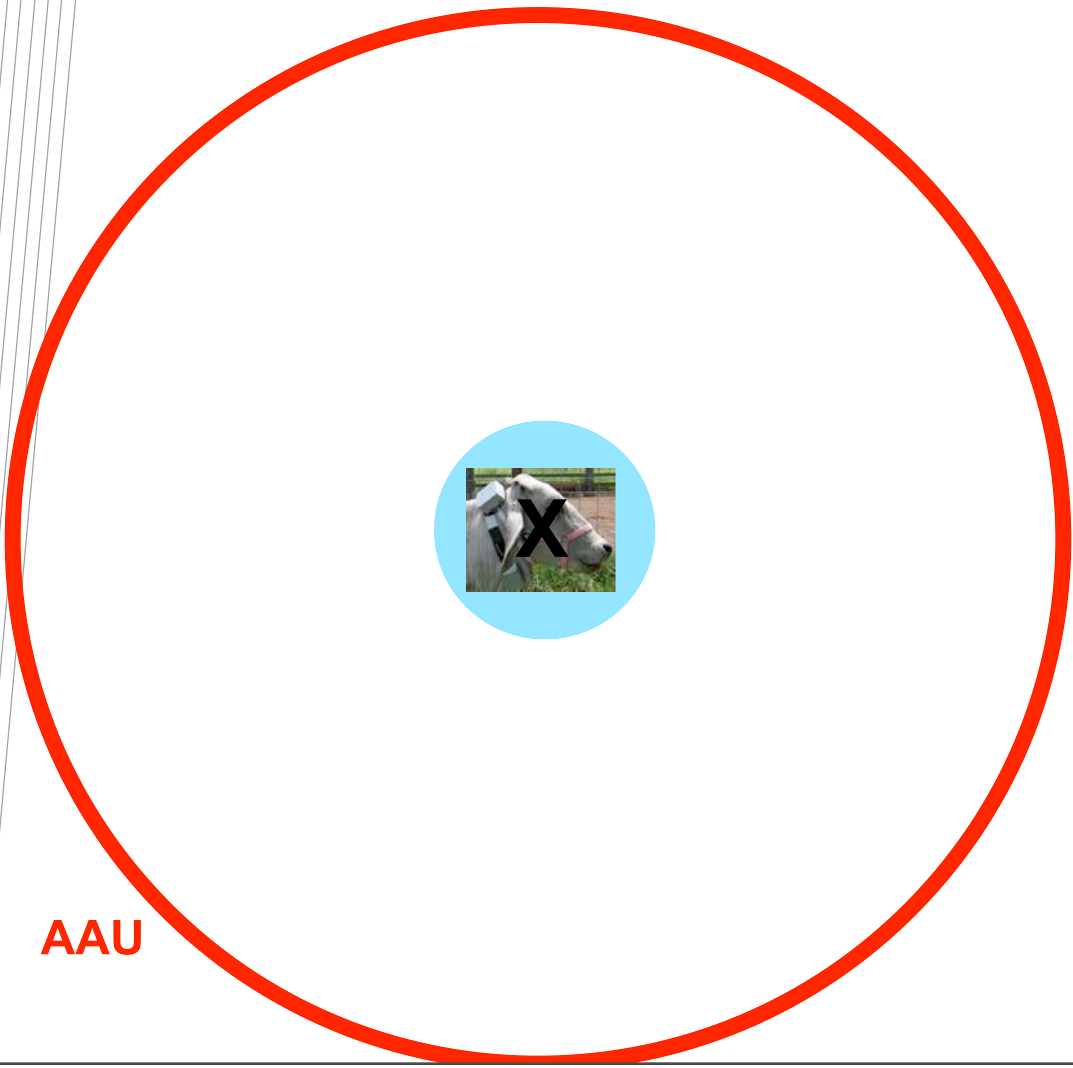
X Assumed position

 Real position

Uncertainty

GPS Duty Cycling

2. GPS powered off



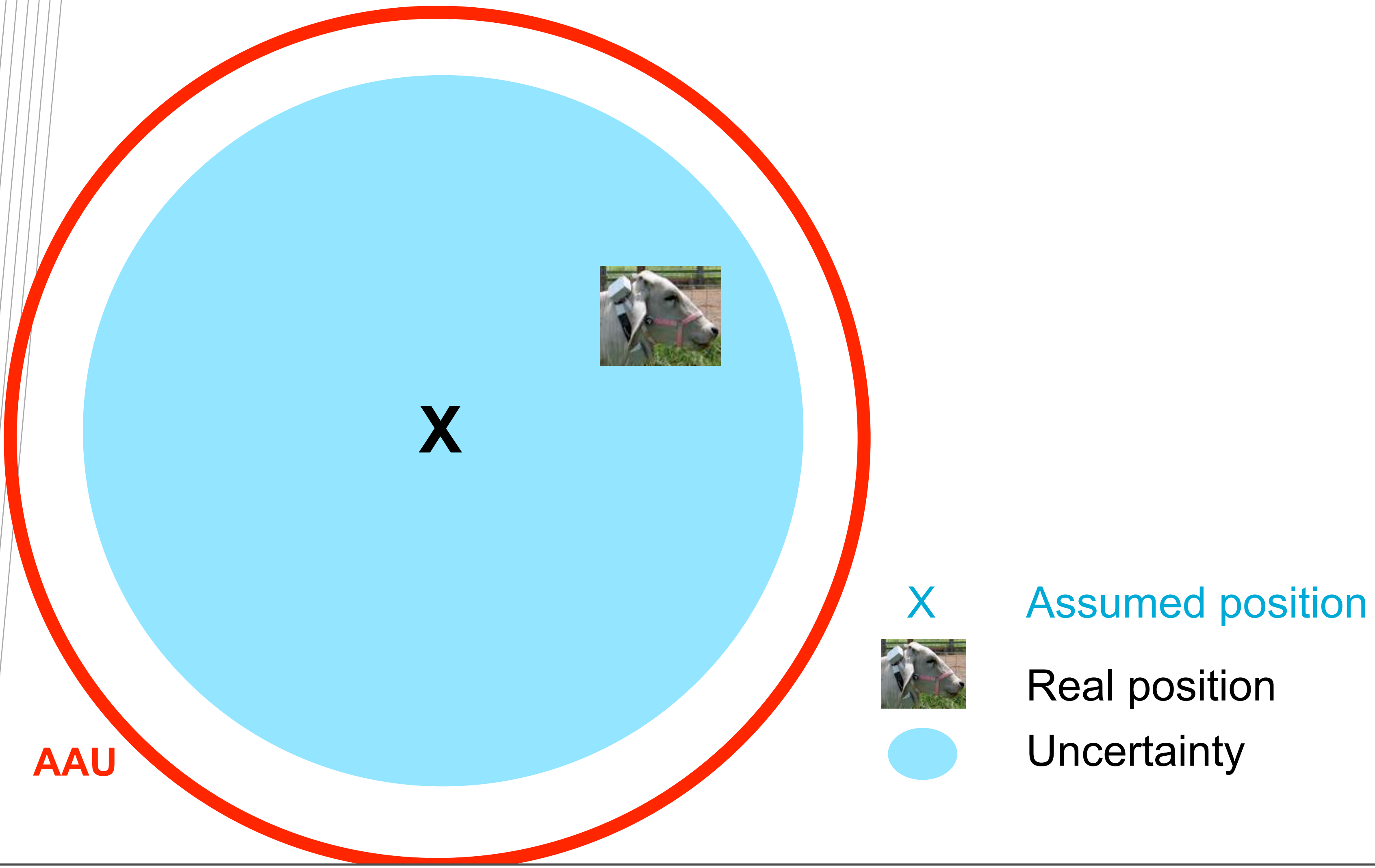
X Assumed position

 Real position

Uncertainty

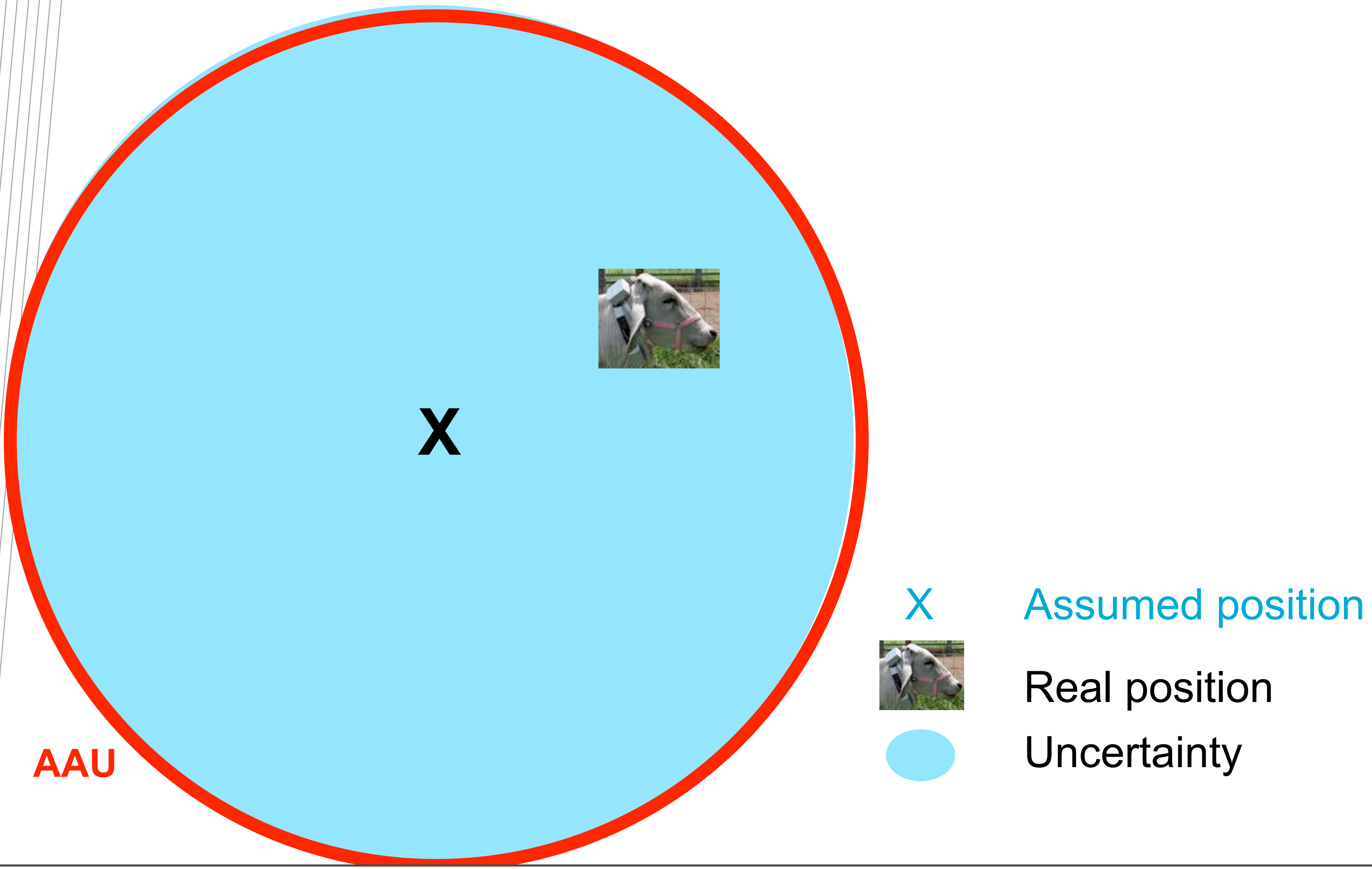
GPS Duty Cycling

4. GPS turns on prior to reaching AAU



GPS Duty Cycling

5. Node acquires GPS lock again



GPS Duty Cycling

Success: real position within uncertainty bound at next GPS lock

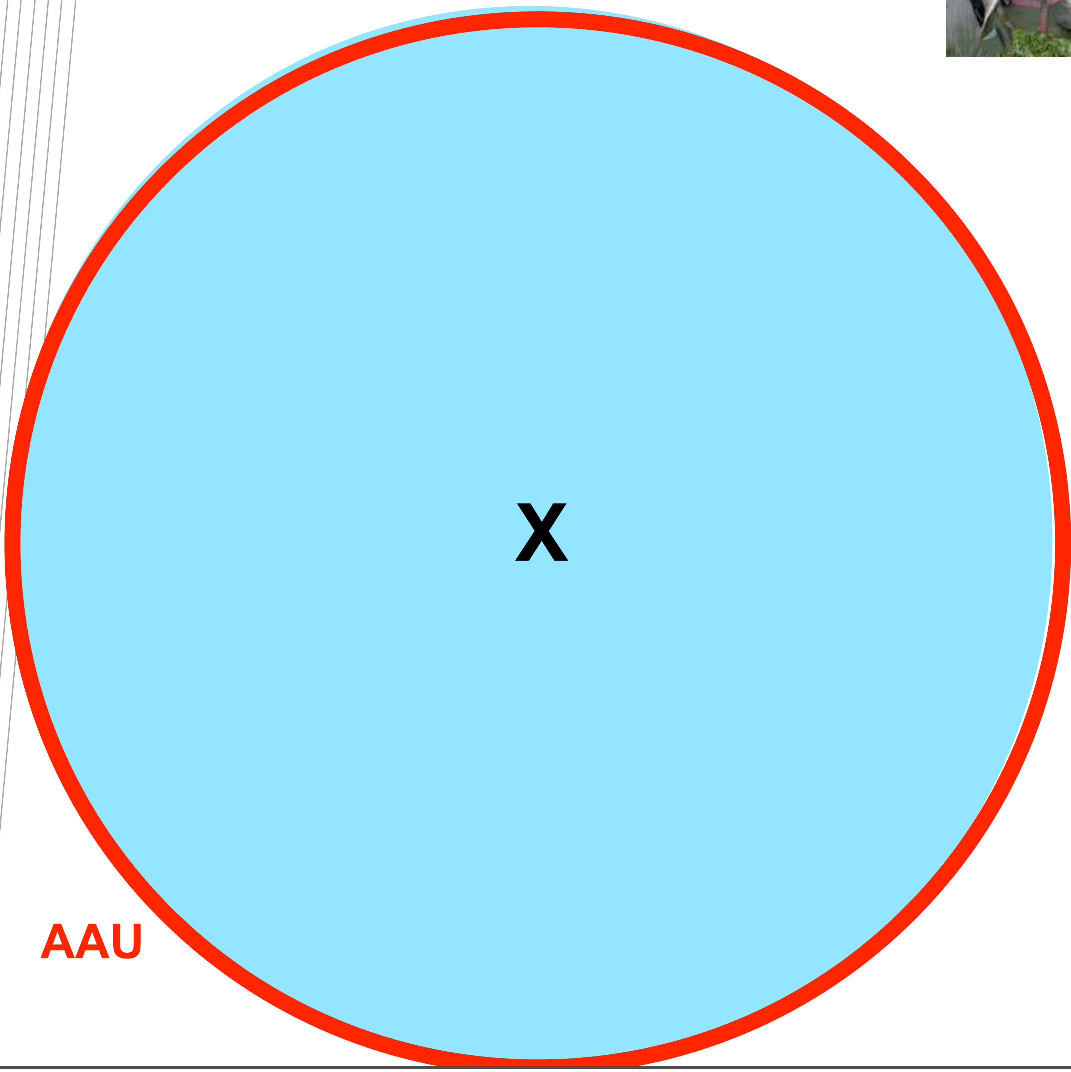
X Assumed position

 Real position

Uncertainty

GPS Duty Cycling

Error: If real position outside uncertainty region at next GPS lock



X Assumed position

Real position

Uncertainty

AAU

GPS Duty Cycling Strategy

$$T_{max} = \frac{AAU - U_{gps}(t_k)}{\bar{s}} - t_L$$

AAU: absolute acceptable uncertainty
U_{gps}: GPS chip uncertainty
s: assumed speed
t_L: lock time

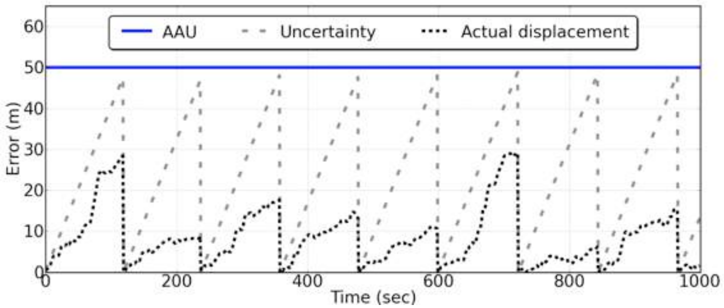
CSIRO

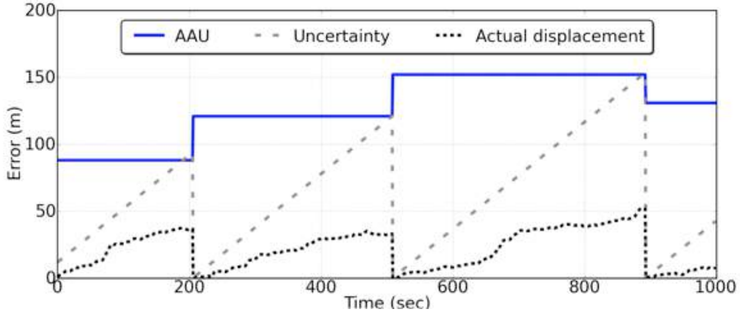
GPS Duty Cycling Strategy

$$T_{max} = \frac{AAU - U_{gps}(t_k)}{\bar{s}} - t_L$$

AAU: absolute acceptable uncertainty
U_{gps}: GPS chip uncertainty
s: assumed speed
t_L: lock time

Varying the AAU according to the cow's distance from the fence



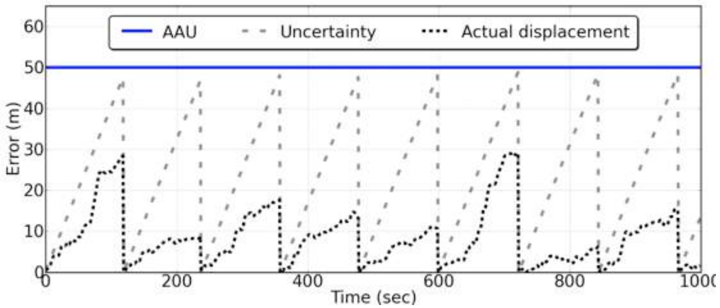


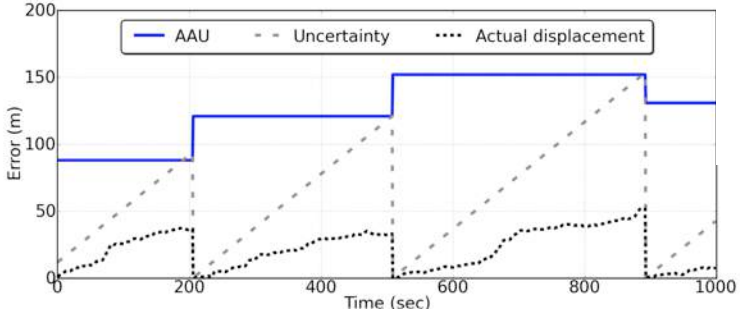
GPS Duty Cycling Strategy

$$T_{max} = \frac{AAU - U_{gps}(t_k)}{\bar{s}} - t_L$$

AAU: absolute acceptable uncertainty
U_{gps}: GPS chip uncertainty
s: assumed speed
t_L: lock time

Varying the AAU according to the cow's distance from the fence





Speed models

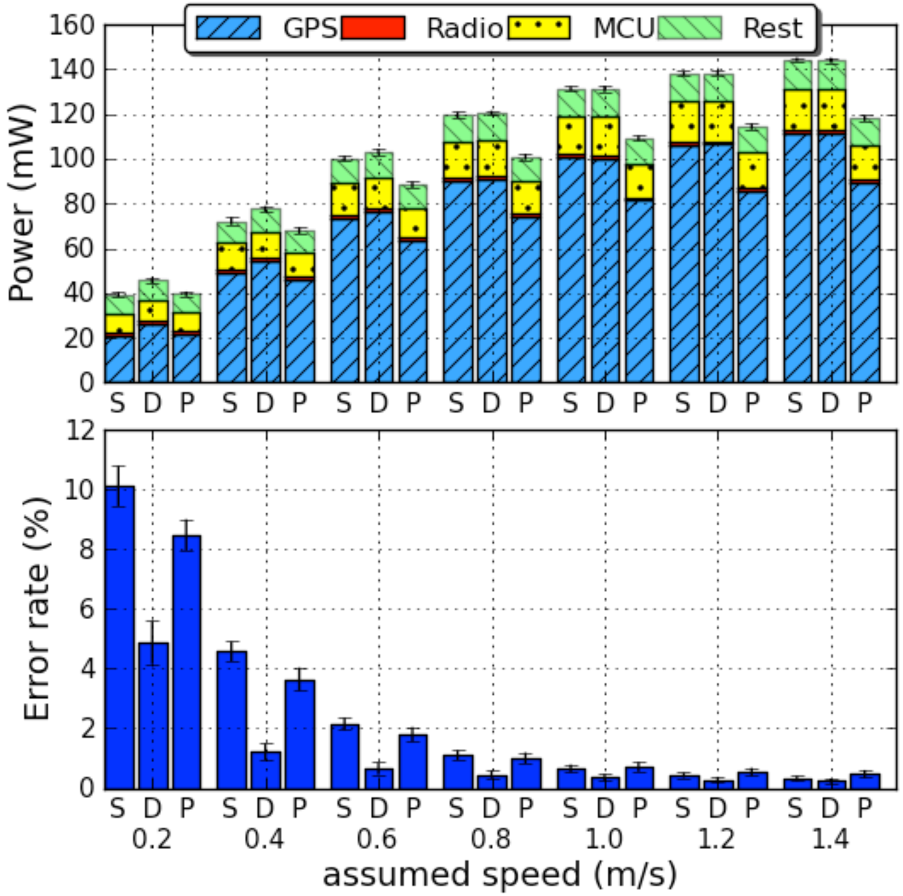
Static
$S_c = \bar{s}$

Dynamic
if (s(t)> $\bar{s}$)
 S_c=s(t)
 else
 $S_c = \bar{s}$

Probabilistic
i=t-lastlocktime
if (i==0)
 S_c=s(t)
 if ($S_c > \bar{s}$)
  $P = t_{22}$
 else
  $P = t_{11}$
else
 $S_c = P \times S_c + \bar{s}(1-P)$

GPS Duty Cycling Performance

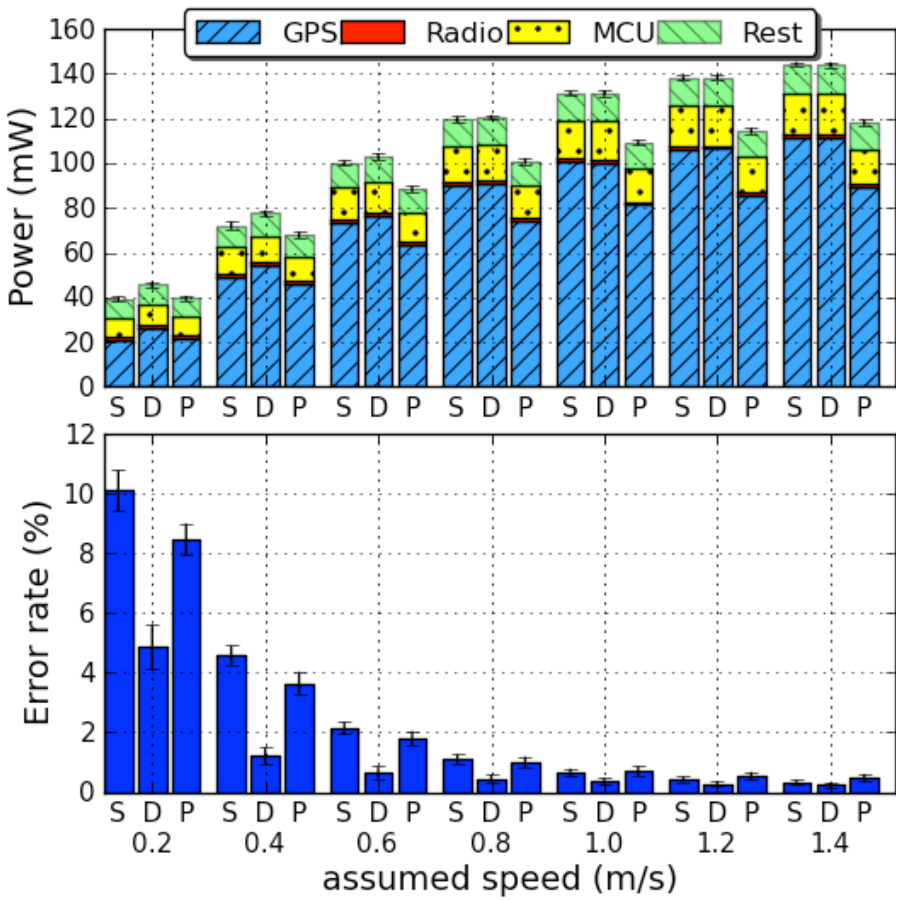
- Simulations based on 2-day empirical cow position dataset
- 30 cows, 1-second granularity for GPS positions



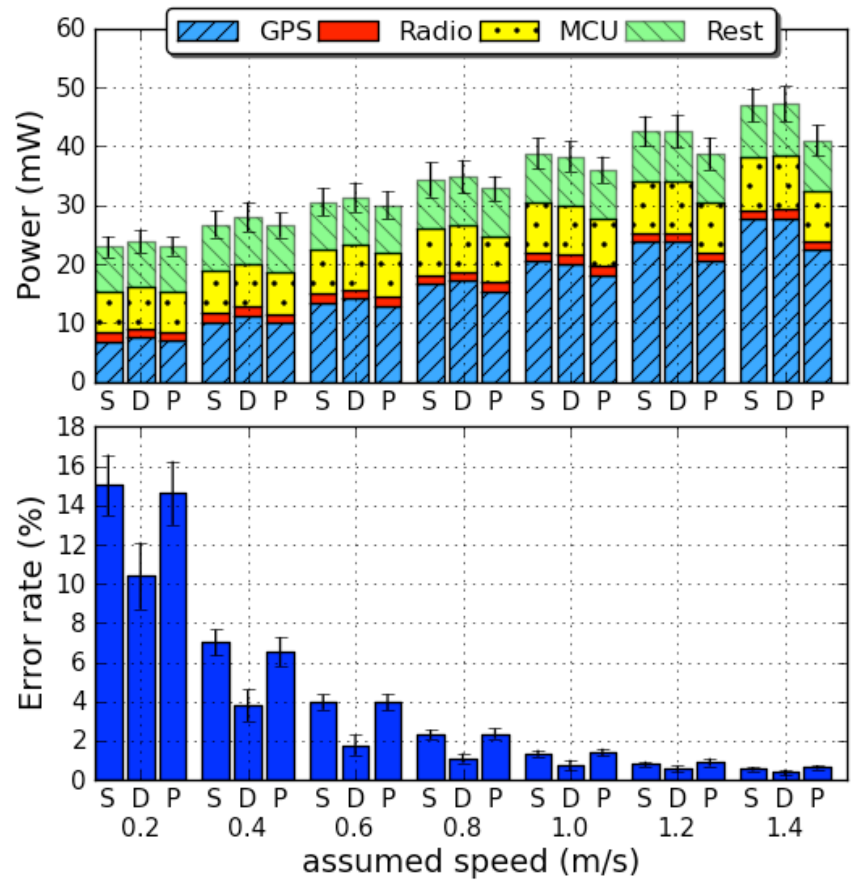
Static AAU

GPS Duty Cycling Performance

- Simulations based on 2-day empirical cow position dataset
- 30 cows, 1-second granularity for GPS positions



Static AAU

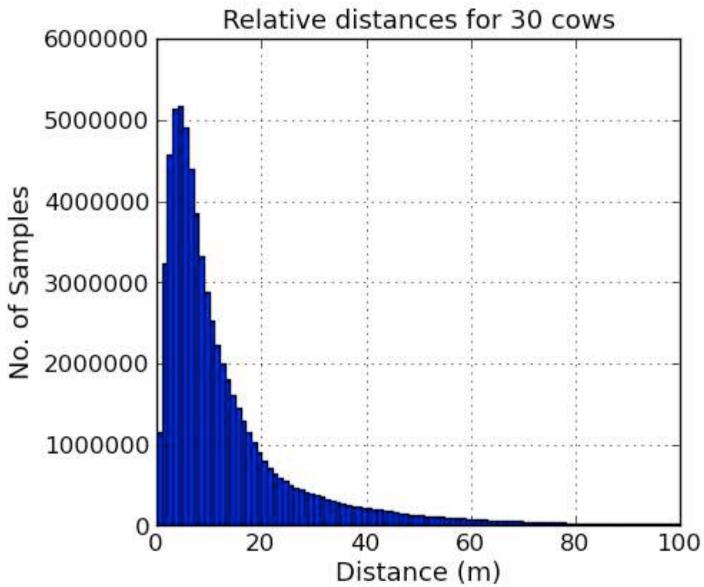


Dynamic AAU

Exploiting Radio Proximity Data

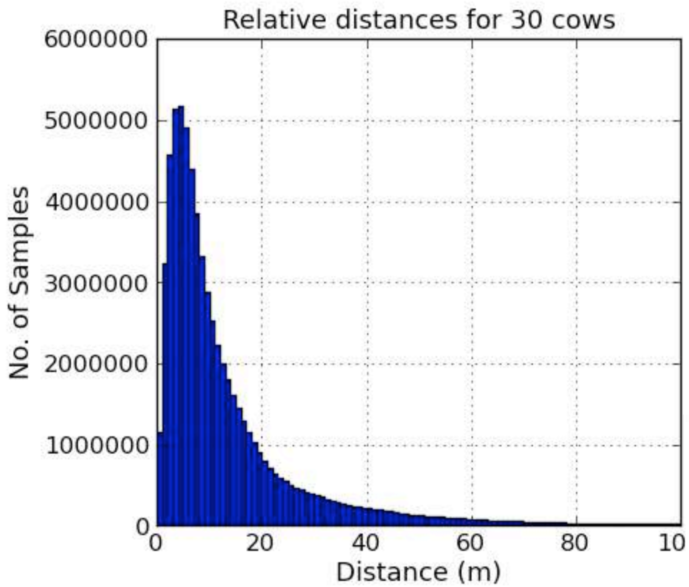
Exploiting Radio Proximity Data

Cows naturally herd closely together

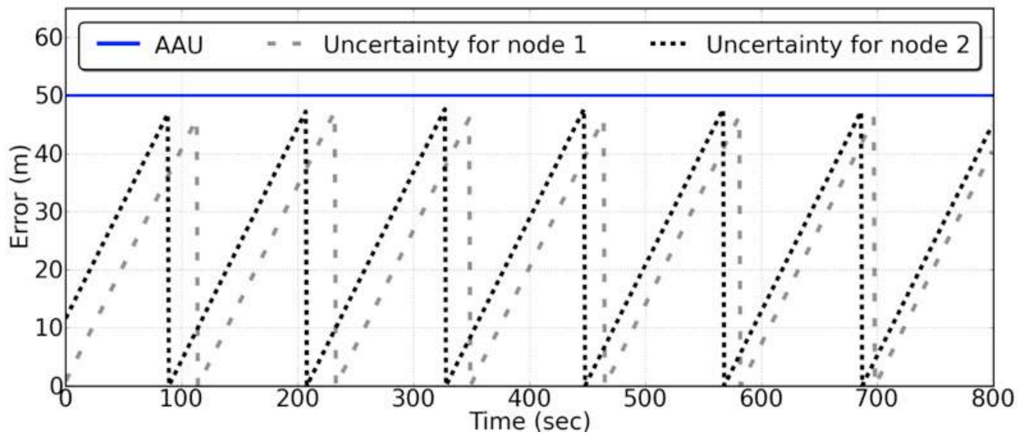


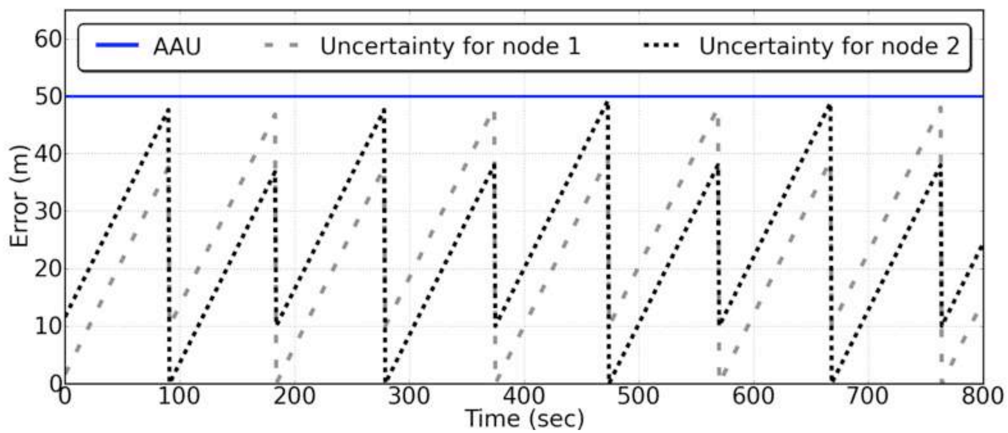
Exploiting Radio Proximity Data

Cows naturally herd closely together



Combining GPS duty cycling with short range radio beaconing

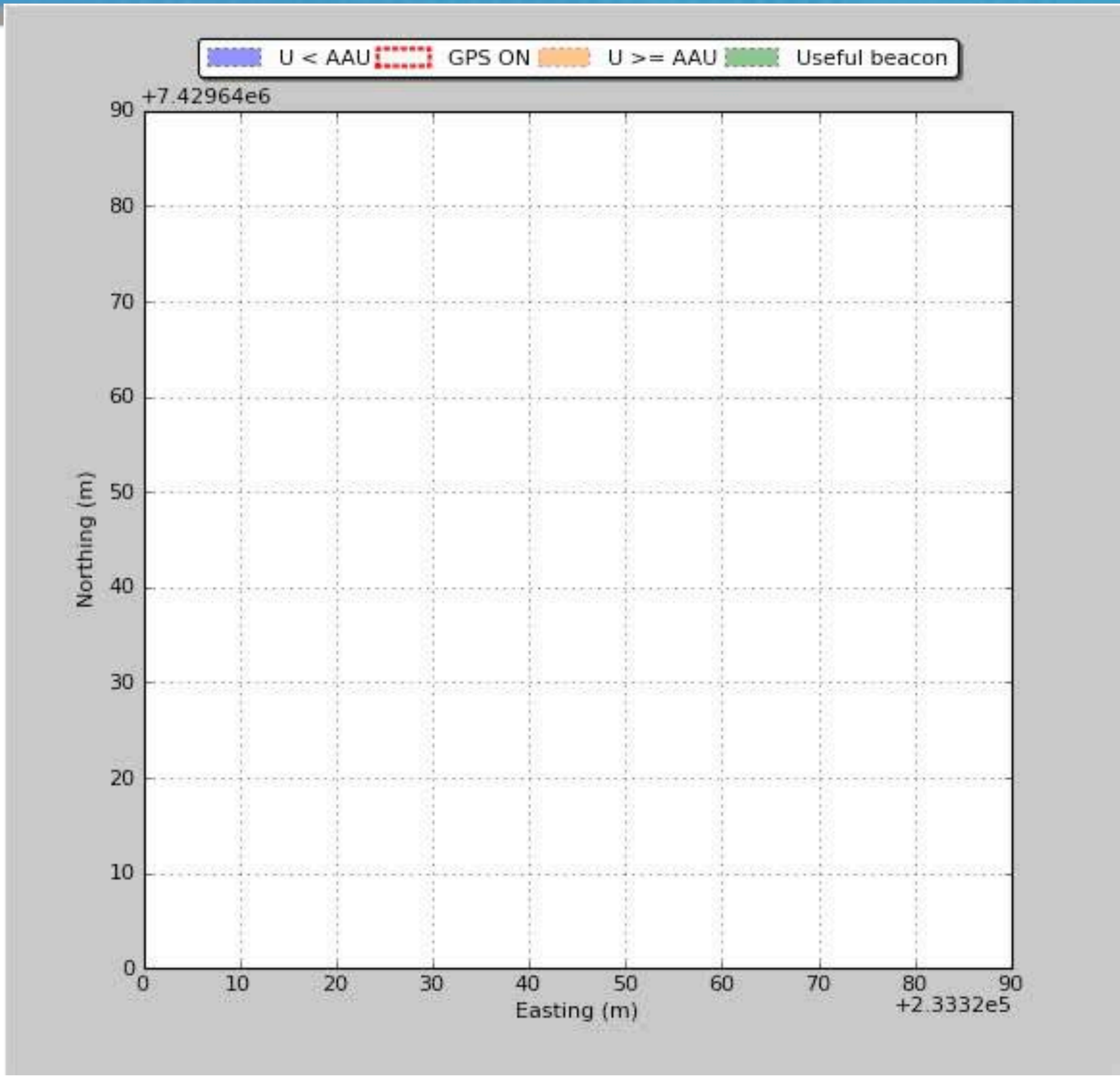




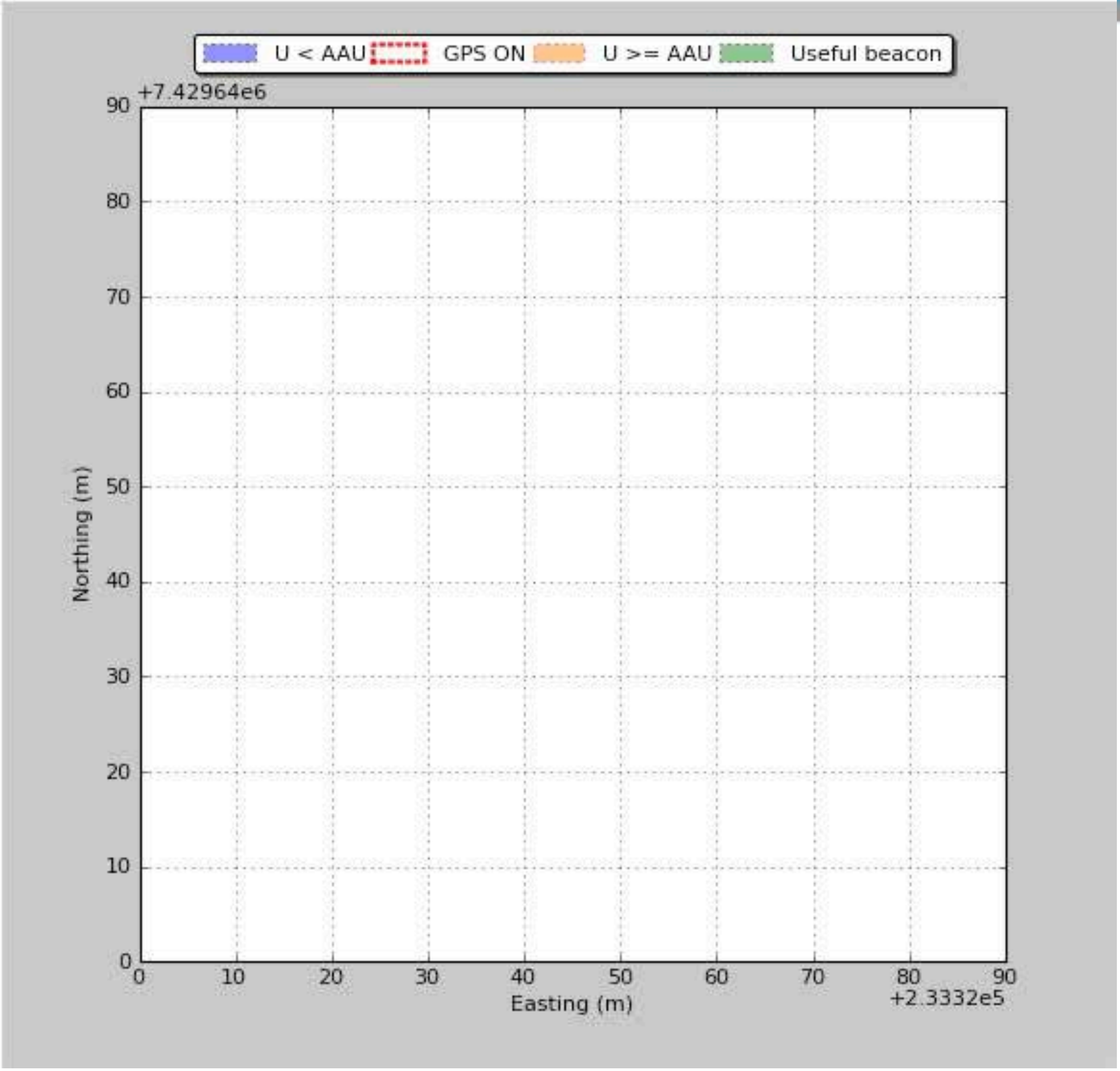
GPS duty cycling vs GPS DC and contact logging

A Visual Simulator

A Visual Simulator



A Visual Simulator



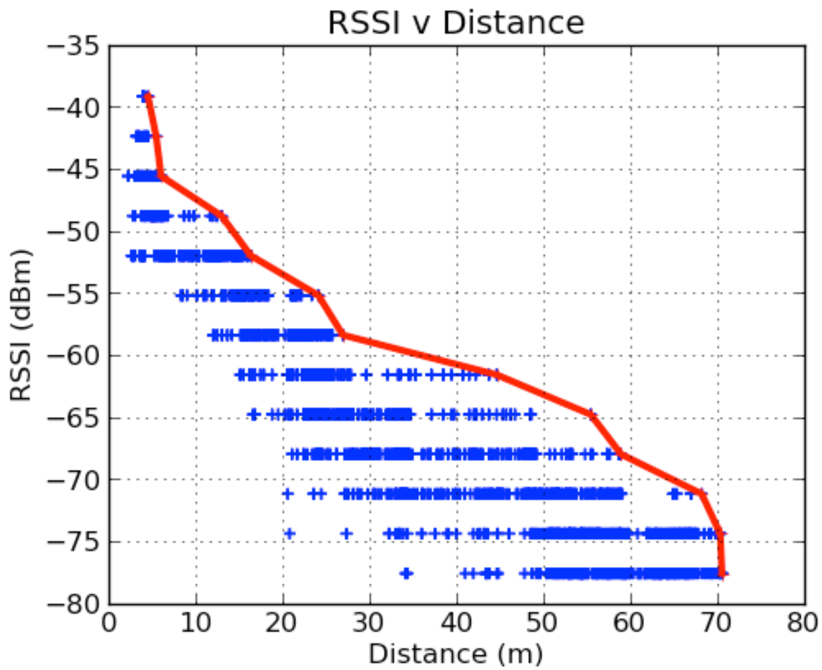
Contact Radius

- Static or dynamic?

Contact Radius

- Static or dynamic?

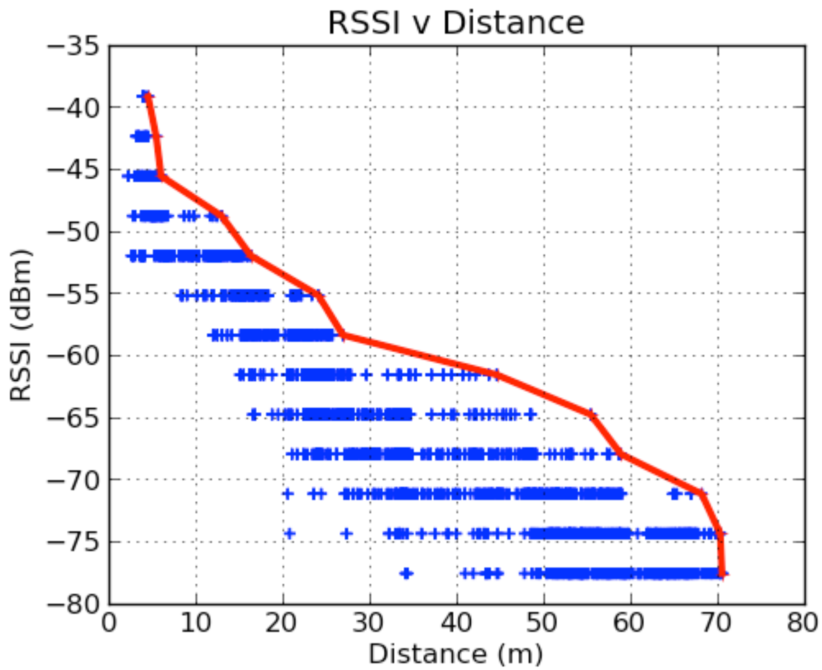
Use RSSI for bounding contact distance



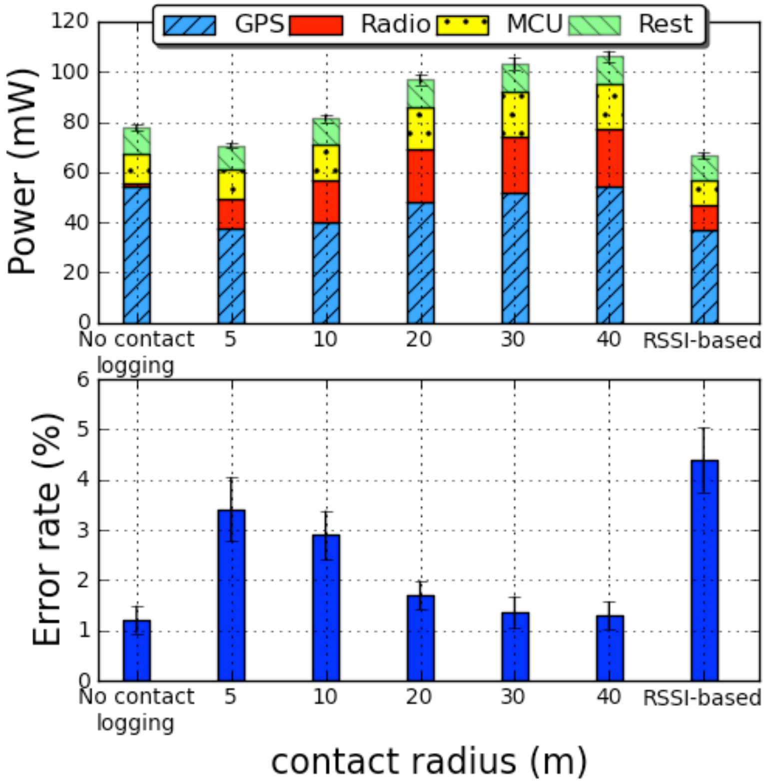
Contact Radius

- Static or dynamic?

Use RSSI for bounding contact distance



Effect of contact radius on energy and error rate



CSIRO

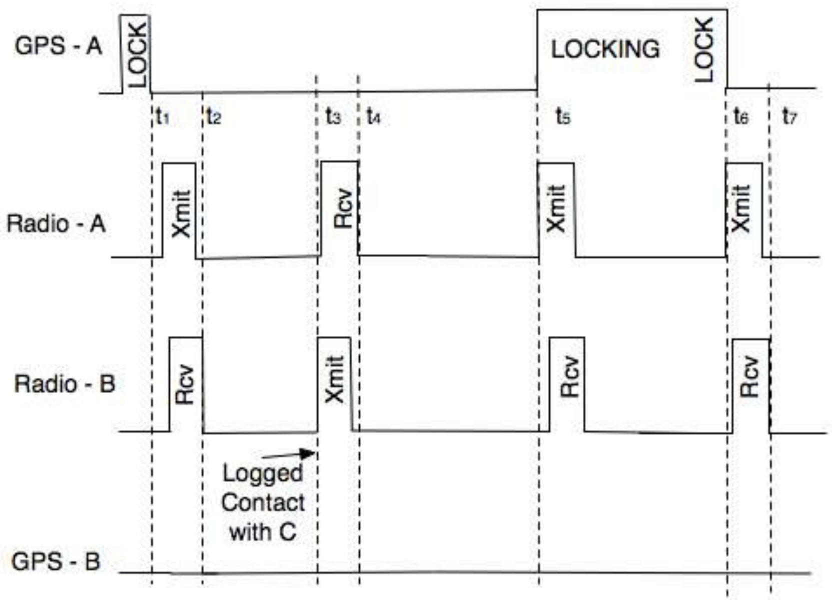
Beacon Period

- Static or dynamic?

Beacon Period

- Static or dynamic?

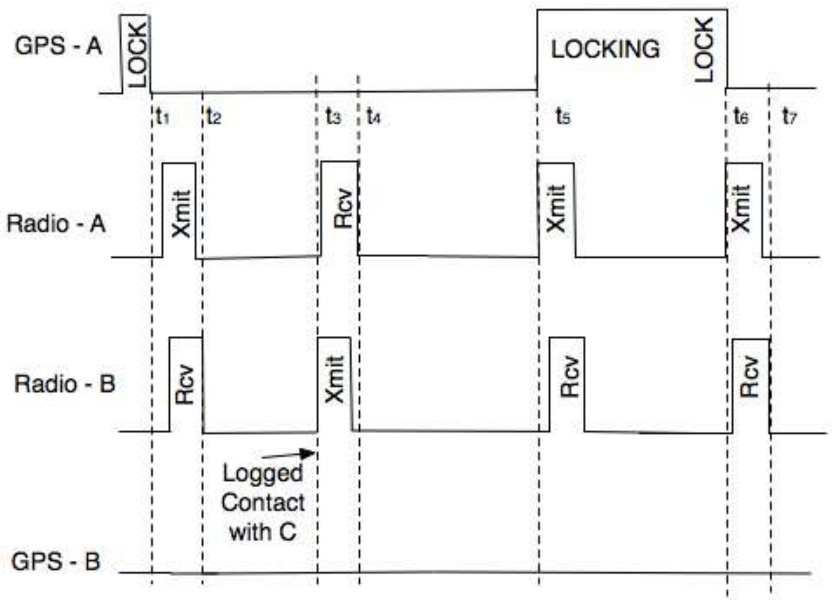
Send radio beacons only when local uncertainty drops



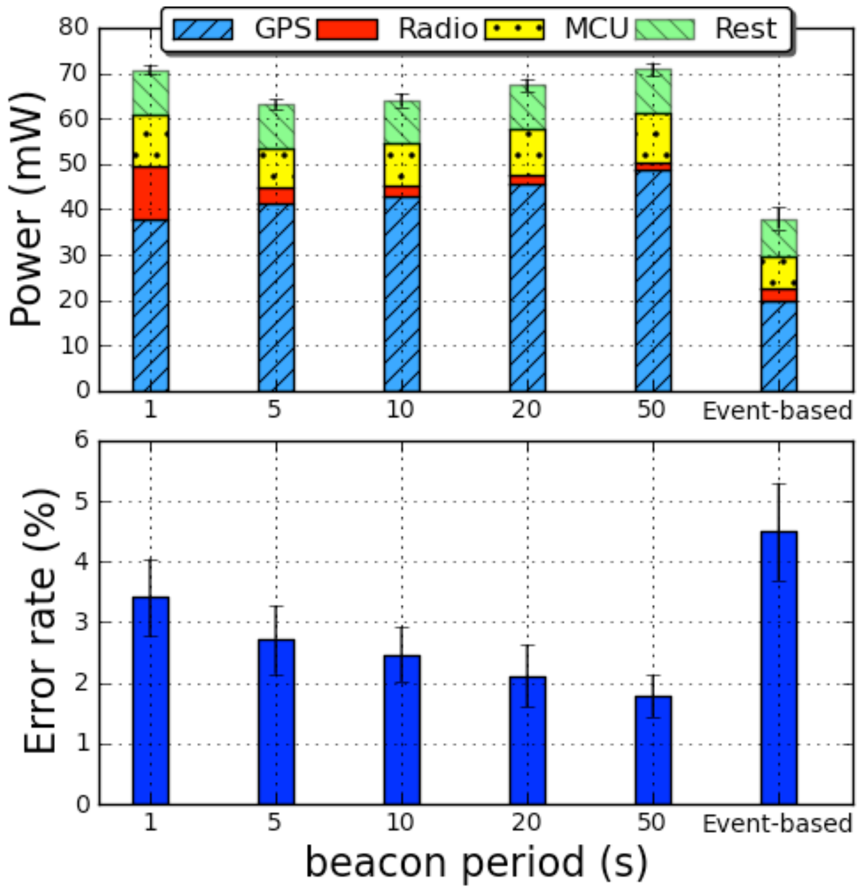
Beacon Period

- Static or dynamic?

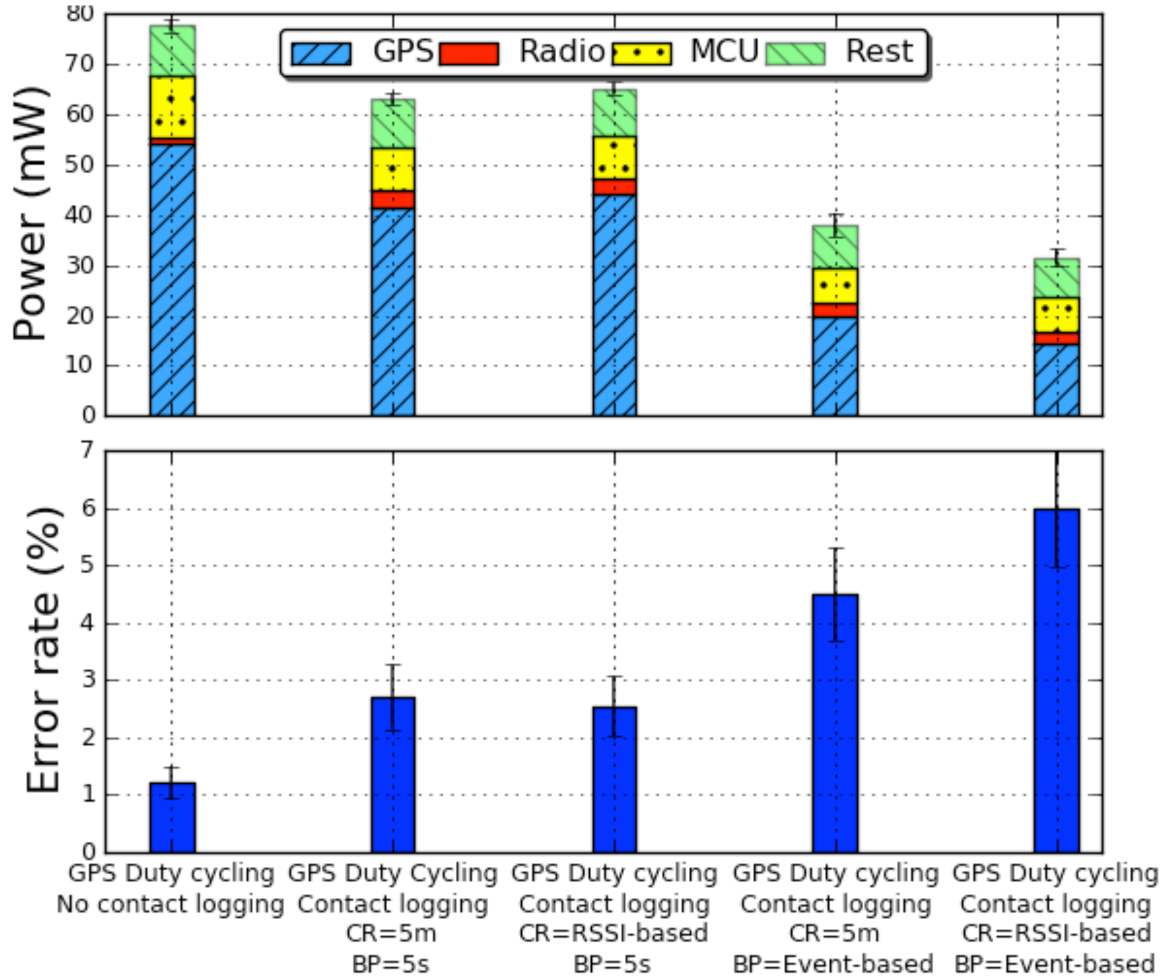
Send radio beacons only when local uncertainty drops



Effect of beacon scheduling on energy and error rate



Summary of results



Event-driven with 5m contact radius provides best balance for our application

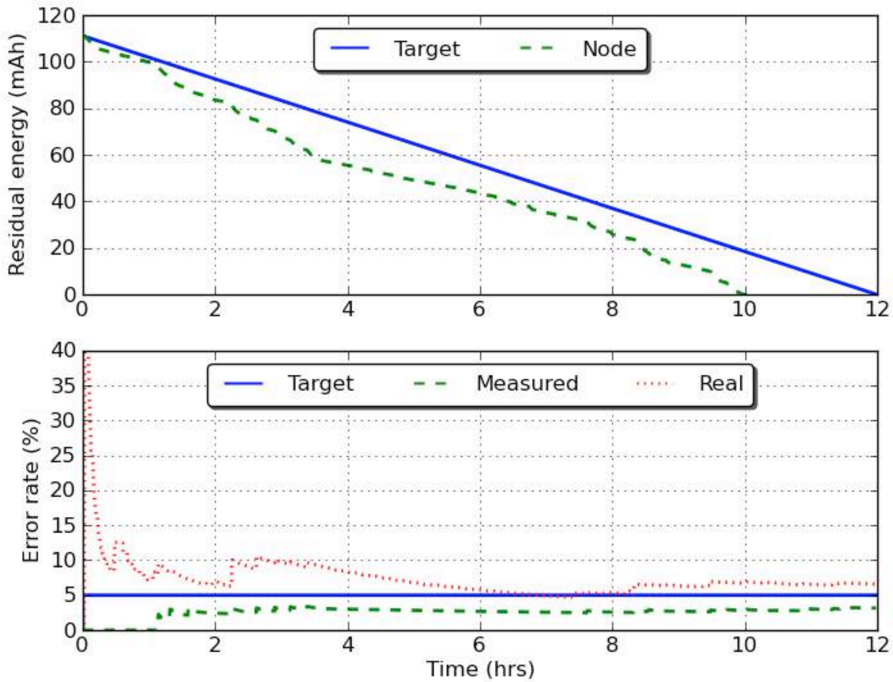
Adaptive Duty Cycling

- Define error rate and energy targets
- Nodes keep track of their error rate and energy
- If error rate is high OR node has reserve energy, increase speed estimate
- If error rate is low, decrease speed estimate
- User preference to break ties

CSIRO

Adaptive Duty Cycling

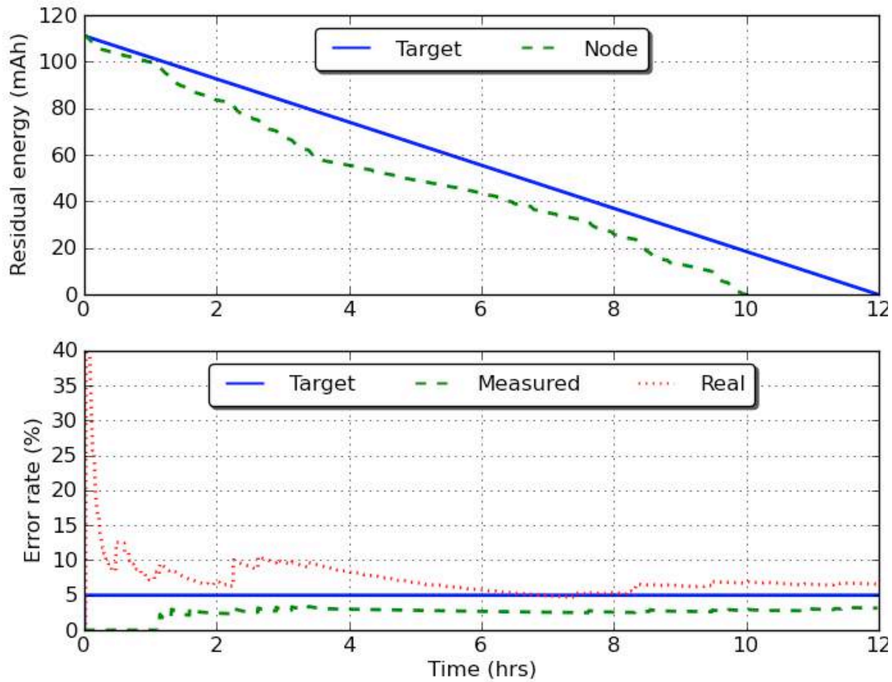
- Define error rate and energy targets
- Nodes keep track of their error rate and energy
- If error rate is high OR node has reserve energy, increase speed estimate
- If error rate is low, decrease speed estimate
- User preference to break ties



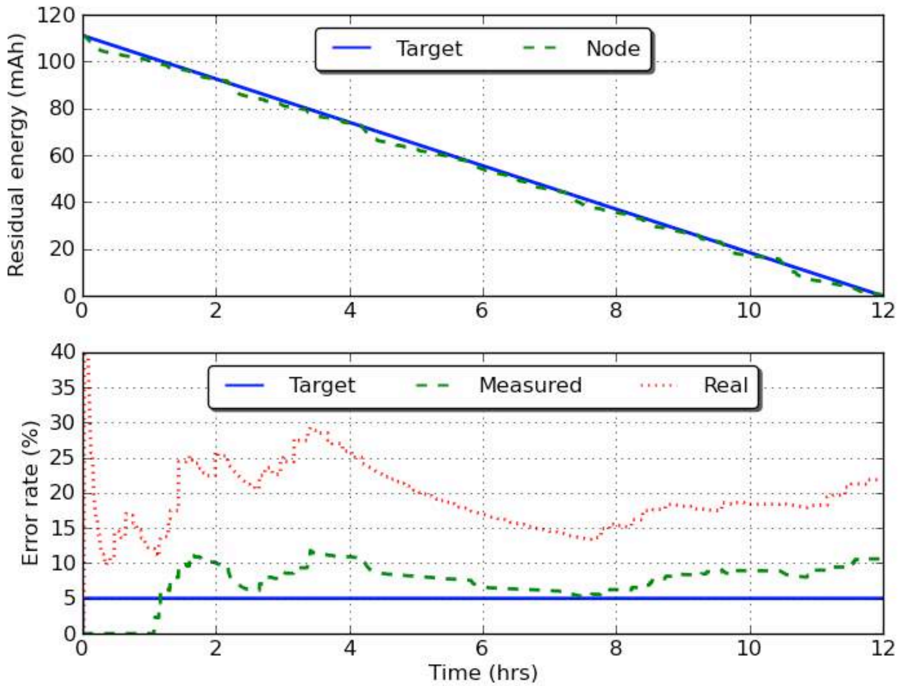
User favors accuracy

Adaptive Duty Cycling

- Define error rate and energy targets
- Nodes keep track of their error rate and energy
- If error rate is high OR node has reserve energy, increase speed estimate
- If error rate is low, decrease speed estimate
- User preference to break ties



User favors accuracy



User favors energy

CSIRO

Conclusion

- Strategy for energy efficient localization
  - GPS duty cycling
  - Contact logging
- Use dynamic configuration
  - Dynamic AAU (depending on application)
  - Dynamic speed
  - Event-driven beacons
  - RSSI-based range bounding
- Future work
  - Estimating error rates with sparse sampling
  - Using inertial sensors as motion triggers
  - Leveraging group and mobility models
  - Exploring multi-hop contact logging

CSIRO ICT Centre
Raja Jurdak
Principal Research Scientist

Phone: +61 (0)7 3327 4059
Email: raja.jurdak@csiro.au

www.csiro.au

Thank you

CSIRO