

# Large Scale Tracking

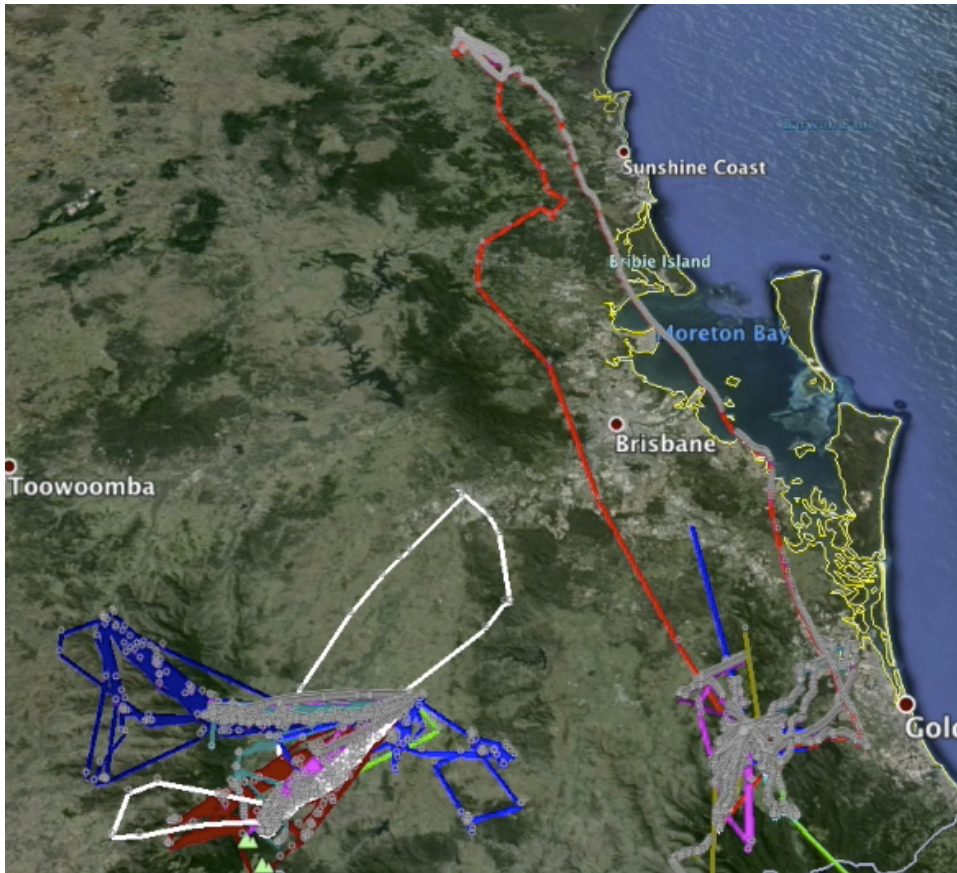
Long-term and large-scale tracking is important for a broad range of applications from livestock tracking for agricultural productivity to wildlife tracking for ecological preservation and management of disease risks. Wireless sensor network technology has enabled novel application scenarios in the field of animal monitoring, as it allows to track location and activity of animals at a high spatio-temporal resolution. While radio-frequency tags for animal location tracking have been used by domain scientists for decades, downloading data from the tags is either labour intensive or expensive if satellite technology is used. The process of downloading data from animals can be automated by deploying a fixed network of wireless receiver stations, so called base nodes or gateways, that download and forward data from nearby animals to a central server. However, many animals exhibit nomadic behaviour and can roam vast areas where sparse distribution of gateway nodes results in rare opportunities for wireless communication. The animal tag technology, therefore, needs to use local data buffering and delay-tolerant network algorithms to be able to collect meaningful datasets.

## Camazotz: long-term Tracking of Small Objects

**Camazotz** is a low power autonomous device that promises to revolutionise long-term tracking of mobile assets, from wildlife such as flying foxes to livestock and even public bicycle fleets.

It uses a low power system-on-a-chip with processing and short-range radio communication, multimodal sensors including a GPS module, inertial unit, temperature, pressure, audio and solar panels for long-term energy replenishment.

Camazotz's ability to operate sustainably without any human involvement or continuous connection make it suitable for most outdoor tracking applications. The technology's benefits include:



- **Autonomy:** As a fully autonomous tracking device, Camazotz can track mobile assets almost indefinitely with no human intervention. This feature is particularly useful for wildlife tracking where there is virtually no physical access to devices once deployed.
- **Configurability:** This technology supports full reconfiguration through remote wireless commands. A key feature that can be remotely configured is contact logging, where Camazotz tracking devices can be set to exchange information with other Camazotz devices. This enables data exchange from remote devices that may not return to a base node for a long time.

- **Sustainability:** Camazotz provides near-indefinite tracking for small highly mobile assets. It operates on a tiny 300mAh battery, but thanks to its dual solar panels, it can harvest energy from the sun to replenish its supplies.

## Case Study: Continental-Scale Tracking of Flying Foxes

Flying foxes present health, economic and conservation challenge in Australia. On the one hand, flying foxes spread the Hendra virus and cause crop damage of around \$20 million a year. While the Hendra virus has caused significant public concern in Australia, similar diseases that spread through flying foxes, including Ebola, cause hundreds of deaths each year in countries like the Asia and Africa, occasionally wiping out village or livestock. This is particularly a problem in industrial farming where a large number of animals are grouped together within close physical proximity. On the other hand, conservation ecologists believe that flying fox populations are in decline, and that certain species may be reaching critically low numbers. One of the key barriers to an increased understanding of these animals is the highly dynamic distribution of their populations and the large-scale traveling distances. For instance, a single animal might travel up to 90 km per night from one roosting camp to another. An individual animal may use up to 3 roosting camp per month, and occasionally, traveling across national borders as far as Malaysia or Sumatra. There are currently no existing technologies for tracking the size of populations, the movement of individual animals, and interactions among animals that spread disease. Satellite transmitters have been tested in a very limited scale for tracking flying Fox positions, but these devices have very low position accuracy and a very limited operational lifetime. Manual techniques for population census are very labor-intensive and accurate as well, particularly because not all camps are known. The inadequacy of current tracking methods leads to the design of and investment in agricultural protection programs and conservation that may not be appropriate. This project will address this gap by applying adaptive duty cycling techniques and by combining multiple sensor inputs for accurate and energy-efficient position tracking of flying foxes.

The main goal of the project is to provide tracking for at least 6 months with at most 100m uncertainty, and working on more advanced algorithms for progressively reducing the tracking uncertainty.

([Overview presentation ppt slides from MLSDA'14 Keynote](#))



Camazotz on a flying fox in Cairns bat hospital



Network of base stations across Australia

## Project Partners

This SSN-TCP project has partner projects that are part of the National Flying Fox Monitoring Program, and that are currently in the Biodiversity Portfolio (BRABA) and the Biosecurity Flagship.

The funding for these projects includes internal CSIRO contributions and external partners

- Federal Department of Sustainability, Environment, Water, Population, and Communities (SEWPaC)
- Five state governments
- Rural Industries Research and Development Corporation (RIRDC)

## Science and Impact Highlights

- Platform adopted for the National Flying Fox Monitoring Program
- >100 nodes deployed and >20 base stations from Port Douglas to Northern NSW
- Publications:
  - L. Salt, B. Kusy, R. Jurdak, "Adaptive Threshold Triggering of GPS for Long-term Tracking in WSN," In proceedings of the 7th IEEE International Conference on Soft Computing and Pattern Recognition (SoCPaR), Fukuoka, Japan, November, 2015.



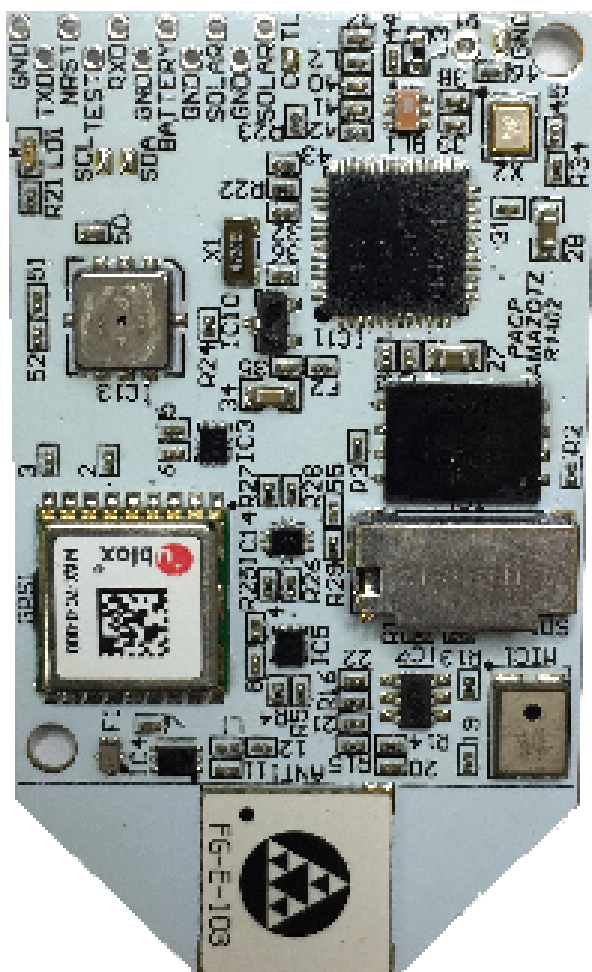
- M. Kaviani, B. Kusy, R. Jurdak, N. Bergmann, K. Zhao, V. Liu, "Delay Tolerant Routing Protocols for Energy-Neutral Animal Tracking," In proceedings of The 3rd International Workshop on Energy Harvesting and Energy-Neutral Sensing Systems (ENSsys), co-located with ACM Sensys, Seoul, South Korea, November, 2015.
- A. El Shoughry, B. Kusy, R. Jurdak, N. Bergmann, "Augur: A Delay Aware Forwarding Protocol for Delay-tolerant Networks," In proceedings of the IEEE International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob), Abu Dhabi, UAE, October, 2015.
- P. Sommer, B. Kusy, R. Jurdak, N. Kottege, J. Liu, K. Zhao, A. McKeown, D. Westcott, "From the Lab into the Wild: Design and Deployment Methods for Multi-Modal Tracking Platforms," Published online at Pervasive and Mobile Computing, September, 2015.
- P. Sommer, B. Kusy, P. Valencia, R. Dungavell, R. Jurdak, "Delay-tolerant networking for long-term animal tracking," arxiv: 1506.01792, 2015.
- R. Jurdak, A. Elfes, B. Kusy, A. Tews, W. Hu, E. Hernandez, N. Kottege, P. Sikka, "Autonomous Surveillance for Biosecurity", Trends in Biotechnology, published online March 3, 2015 doi:[10.1016/j.tibtech.2015.01.003](https://doi.org/10.1016/j.tibtech.2015.01.003)
- K. Zhao, R. Jurdak, J. Liu, D. Westcott, B. Kusy, H. Parry, P. Sommer, A. McKeown, "Optimal Lévy-flight foraging in a finite landscape", Journal of the Royal Society Interface 12, 20141158 January 2015.
- Liu, K. Zhao, P. Sommer, S. Shang, B. Kusy, & R. Jurdak Bounded Quadrant System: Error-bounded Trajectory Compression on the Go," To appear in proceedings of the 31st IEEE International Conference on Data Engineering (ICDE), Seoul, Korea, April, 2015.
- R. Jurdak, "Long-term tracking in Batmon: Lessons and Open Challenges," Keynote Speech Abstract, in proceedings of the second Machine Learning for Sensory Data Analysis (MLSDA) Workshop, Gold Coast, Australia, December 2014.
- G. Murtaza, S. Kanhere, A. Ignjatovic, R. Jurdak, and S. Jha, "Trajectory Approximation for Resource Constrained Mobile Sensor Networks," In proceedings of the 9th IEEE Conference on Distributed Computing in Sensor Systems (DCOSS), Marina Del Rey, CA, USA, May, 2014.
- K. Li, B. Kusy, R. Jurdak, A. Ignjatovic, S. Kanhere, S. Jha, "-FSOM: Fair Link Scheduling Optimization for Energy-Aware Data Collection in Mobile Sensor Networks," In Proceedings of the 11th European Conference on Wireless Sensor Networks (EWSN), Oxford, UK, February 2014.
- H. Parry, D. Westcott, A. McKeown, K. Zhao, Philipp Sommer, R. Jurdak, and B. Kusy, "Empirical agent-based simulation of movement: the integration of high frequency Flying-fox tracking data with a simulation model of population dynamics in time and space," In MODSIM2013, 20th International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, December 2013, pp. 2506–2512. ISBN: 978-0-9872143-3-1.
- P. Sommer, B. Kusy, and R. Jurdak, "The Big Night Out: Experiences from Tracking Flying Foxes with Delay Tolerant Wireless Networking," To appear in proceedings of the Fifth Workshop on Real-World Wireless Sensor Networks (RealWSN), Como Lake, Italy, September 2013.
- R. Jurdak, P. Corke, A. Cotillon, D. Dharman, C. Crossman, and G. Salagnac, "Energy-efficient Localisation: GPS Duty Cycling with Radio Ranging," ACM Transactions on Sensor Networks, Vol. 9, Iss. 2, May 2013.
- R. Jurdak, B. Kusy, P. Sommer, N. Kottege, C. Crossman, A. McKeown, D. Westcott, "Camazotz: Multimodal Activity-based GPS Sampling," In proceedings of the 12th International Conference on Information Processing in Sensor Networks (IPSN), Philadelphia, USA, April, 2013.
- R. Jurdak, B. Kusy, and A. Cotillon, "Group-based Motion Detection for Energy-efficient Localization," Journal of Sensor and Actuator Networks. 1(3):183-216, October 2012. (Invited paper)
- Keynote and Invited Talks:
  - AIIA Summit on the Internet of Things: "Internet of Nomadic Things: Tracking flying foxes across Australia," Canberra, Australia, March 2015.
  - Keynote Speech at Machine Learning for Sensor Data Analysis: "Long-term Tracking in Batmon: Lessons and Open Challenges," Gold Coast Australia, December 2014.
  - Keynote Speech at IEEE Senseapp: "Long-term continental-scale tracking of flying foxes," Sydney, Australia, October 2013.
  - Invited talk at IEEE ISSNIP: "Towards Continental-scale Tracking of Flying Foxes," Melbourne, Australia, April 2013.

## Videos

Introducing Camazotz: A Platform for Sustainable Tracking	Large Scale Tracking: The Internet of Nomadic Things
Camazotz wins the QLD State Merit iAward 2014	



Sample Trajectory of Flying Fox tracked with Camazotz over A



Camazotz Overview

