Using Internet of Things (IoT) Networks for Wildlife Tracking

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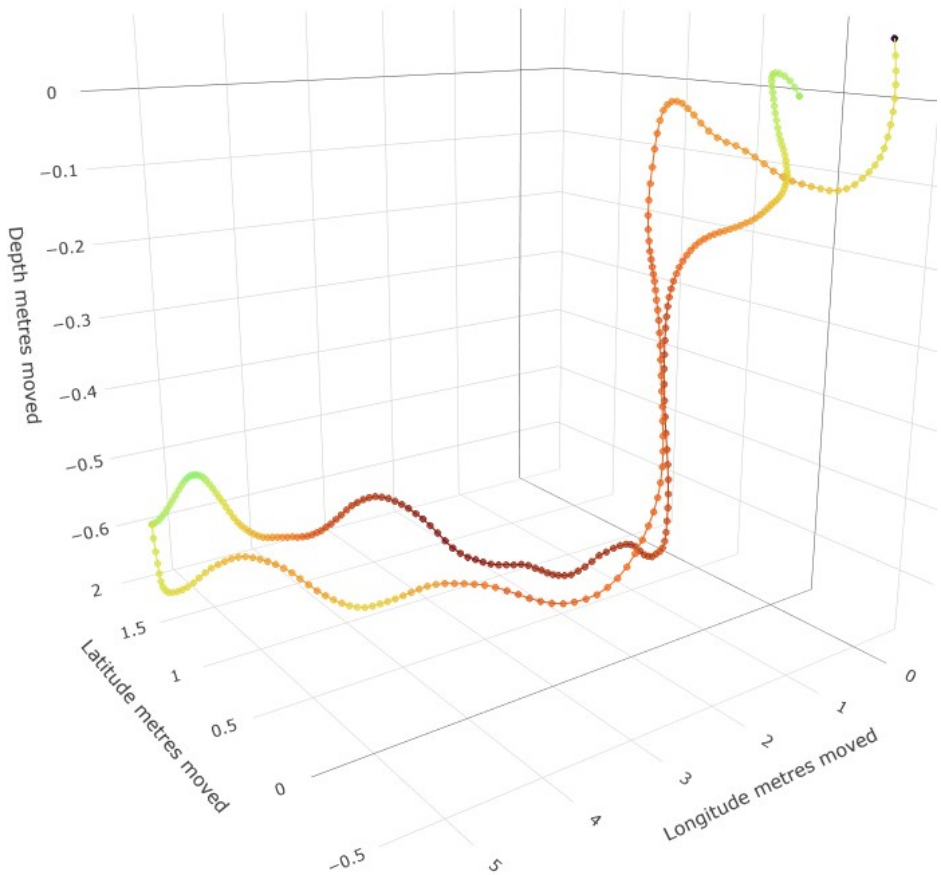
Outline

Introduction to Biologging

Figure: Animals With SigFox enabled biologging tags[13]

- Definition: "Investigation of phenomena in or around free-ranging organisms beyond human visibility or experience.[2]"
- Method: Tracking wild animals using electronic devices attached to the animal
- ↑ Popularity in early 2000s, practiced since the 60's
- Pivotal role in understanding animal behavior and ecology

Applications of Biologging



- Track animal movements, behaviors, and migration patterns
- Collect data on the animal's environment.
- Insights into organisms in hostile or hard-to-reach environments

Figure: 3D movement of a prairie dog [8]

Impact and Importance

- Study previously inaccessible aspects of animal life.
- Inform conservation efforts and protect endangered species.
- Important tool for data collection
- Interpretation and application are up to scientists and conservationists.

Other Biologging Methods

- Cellular networks; High Cost
  - High Cost/message
- Radio Frequency (5-1000m)
  - Periodic tracking records
  - Time stamped data

Figure: Pigeons Equipped with cellular trackers [9]

Data Transmission

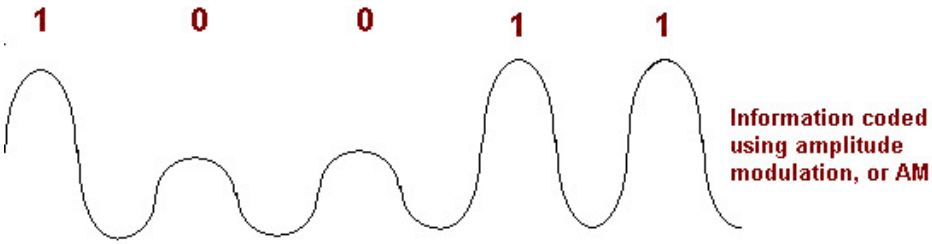


Figure: How data is represented using amplitude modulation[7]

- Data encoded into 1's and 0's
  - Represented by different amplitudes of radio waves
  - Received and translated by other devices

Common Wireless Network Frequencies

- Home WiFi Frequencies
  - 2.4GHz/5GHz/6GHz
- LPWAN Frequencies
  - $<$1GHz (depends on region)
- As frequency increases, range is sacrificed for higher data rates

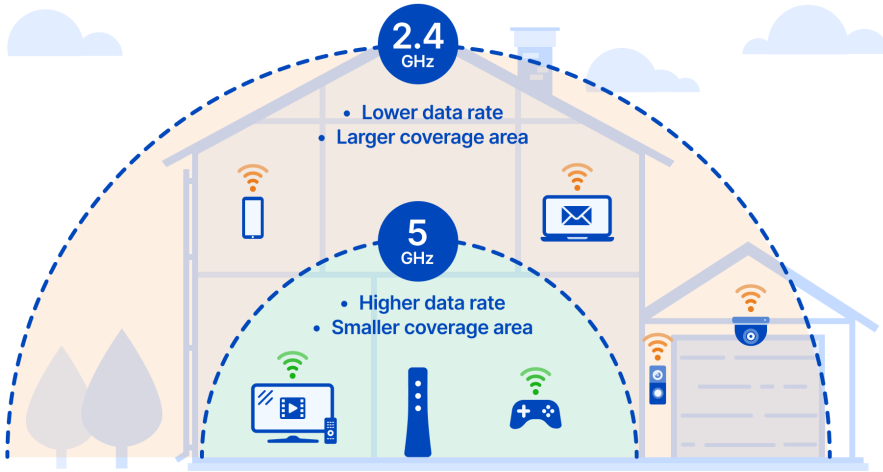


Figure: 5 GHz will give you more signal strength and faster speed over a shorter range, compared to 2.4 GHz.[11]

Concepts of Wireless Frequencies

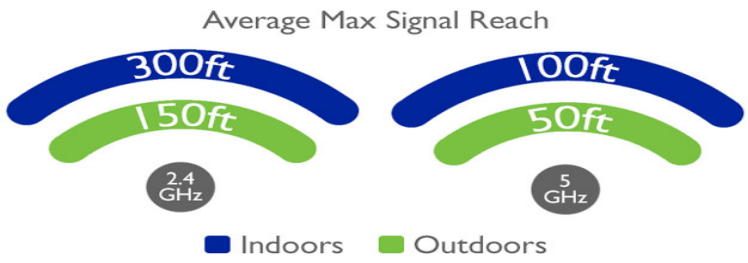


Figure: Comparing Range of frequencies[12]

Figure: Comparing Speed of frequencies[12]

- Higher frequency $\Rightarrow$ higher data rates
  - more ones and zeroes received per second
- Range is more important than speed in some Applications
- Lower frequencies can reach 10's of km vs. 100's of m

What is the Internet of Things?

- Empowering physical objects with sensors and software for autonomous interaction
- Can either connect via wired or wireless connection
- Many applications: Healthcare, agriculture, and of course conservation

Layers of an IoT System

- Application Layer
  - Processes and uses data
- Network Layer
  - Establishes connection to internet and IoT devices
  - Transmits data to and from the other layers
- Perception Layer
  - Collects data from the environment or...
  - Interacts with the physical device

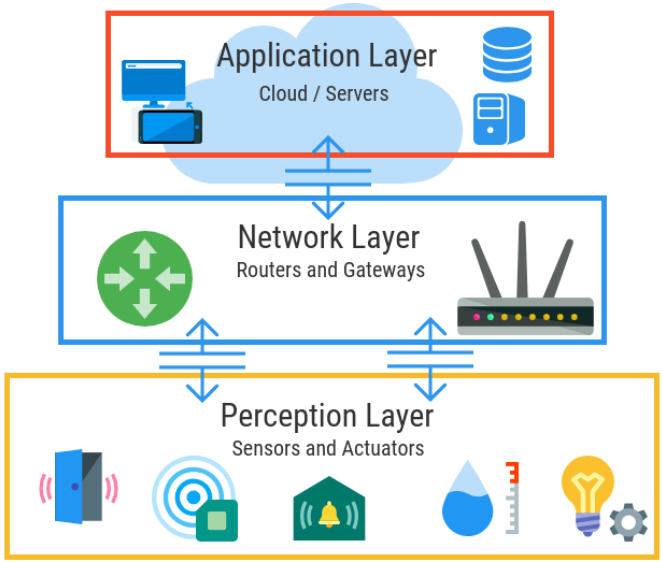


Figure: Layer Structure of an IoT System.[4]

Sensor Devices

Base Stations

Networking Outline

- Importance of a Strong Network for Biologging
- LPWAN Networks
  - SigFox
  - LoRa
- WLAN Networks
- Security of LPWAN and WLAN Networks
- Which Network is Best for Biologging?

Importance of a Strong Network for Biologging

- Data must be transmitted safely and securely
- Responsible for sending data to and from sensor device to application layer

Figure: Cartoon depiction of a strong wireless network.[DALL·E 3]

LPWAN Overview

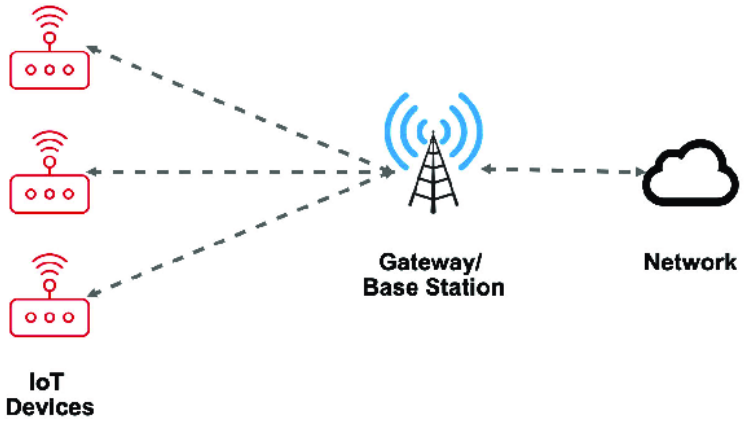


Figure: LPWAN technologies network architecture.[5]

- Low Power Wide Area Network
- Utilizes unlicensed Industrial, Scientific and Medical radio bands (ISM)
- 433MHz-928MHz Depending on region (U.S. 915MHz)
- Very long range (40km+)
- Very low power consumption

SigFox LPWAN Capabilities

- 140 messages/day (12bytes each)
- 40km+ of range depending on environment
- SigFox Atlas technology for estimating location
- 6.5yr battery life w/ 2 AAA batteries (more with solar panel)
- Up to 100bps

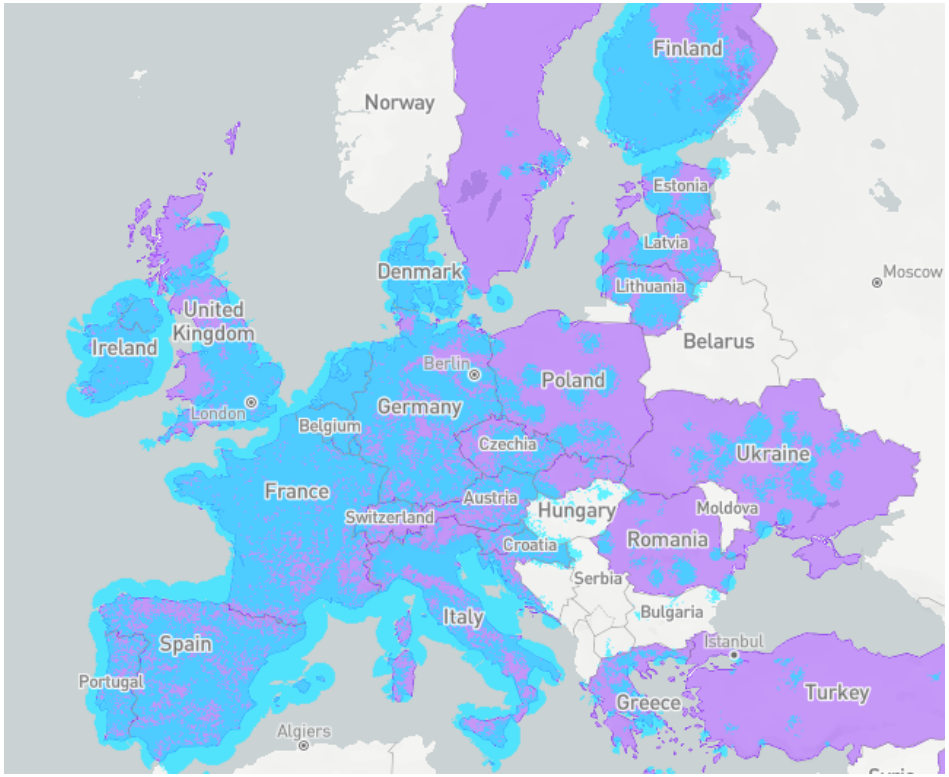


Figure: SigFox Europe Coverage.[1]

SigFox LPWAN Operation

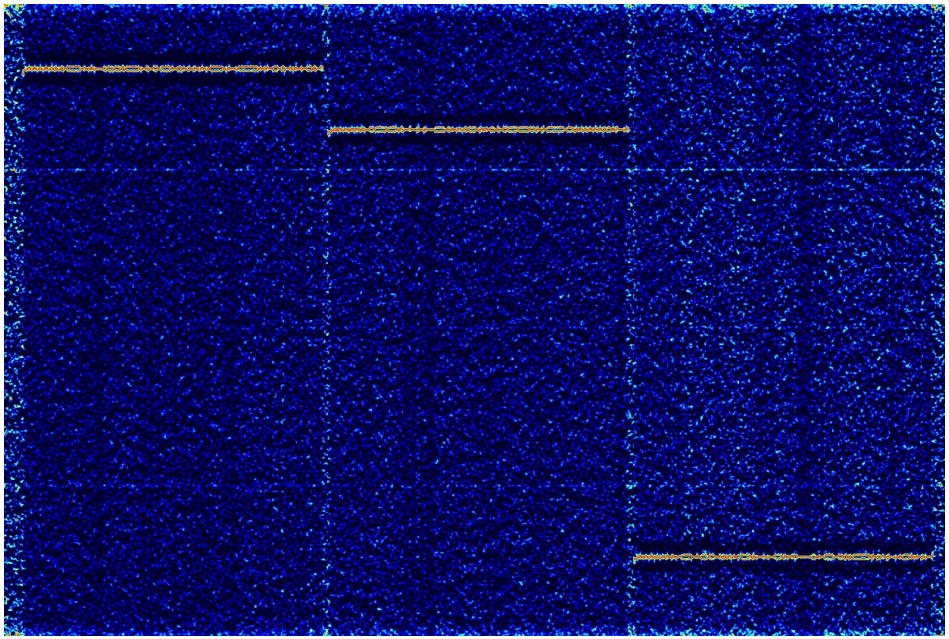


Figure: SigFox frequency hopping modulation.[10]

- Transmission modulation
  - transmits message 3 times
  - pseudo randomly hops to new frequency
- Proprietary base stations and framework
- Subscription based connection to network

LoRa LPWAN Capabilities

- Unlimited messages/day
- Easier to develop and implement
- 20km+ of range depending on environment
- Up to 50kbps

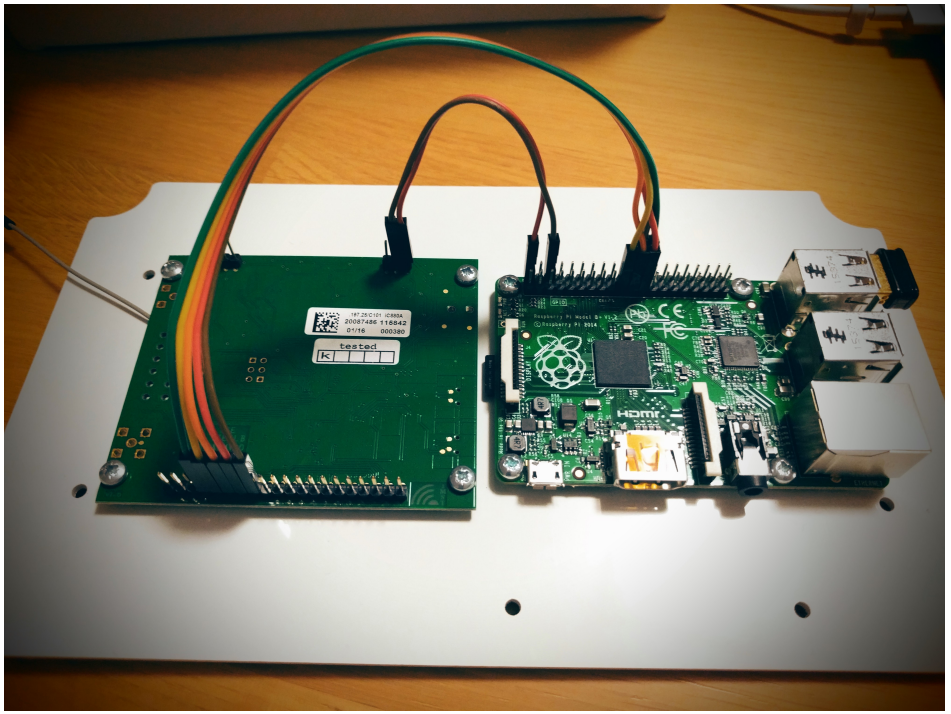


Figure: DIY LoRa gateway w/ Raspberry Pi.[3]

LoRa LPWAN Operation

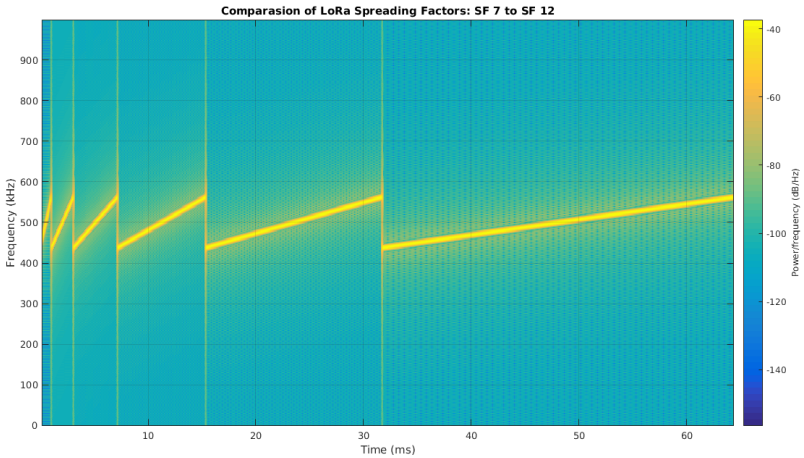


Figure: CHIRP Spread Spectrum modulation SF7-SF12.[6]

- CHIRP (Compressed High Intensity Radar Pulse) Spread Spectrum
  - gradually raises/lowers frequencies
  - $\uparrow$ SF $\rightarrow$ $\downarrow$ modulation rates
- Standards based system
- Private or public networks

WLAN Capabilities

- 200m+ of range depending on environment
- Unlimited messages/day
- Can be entirely self developed
- 1840kbps+ (depending on implementation)

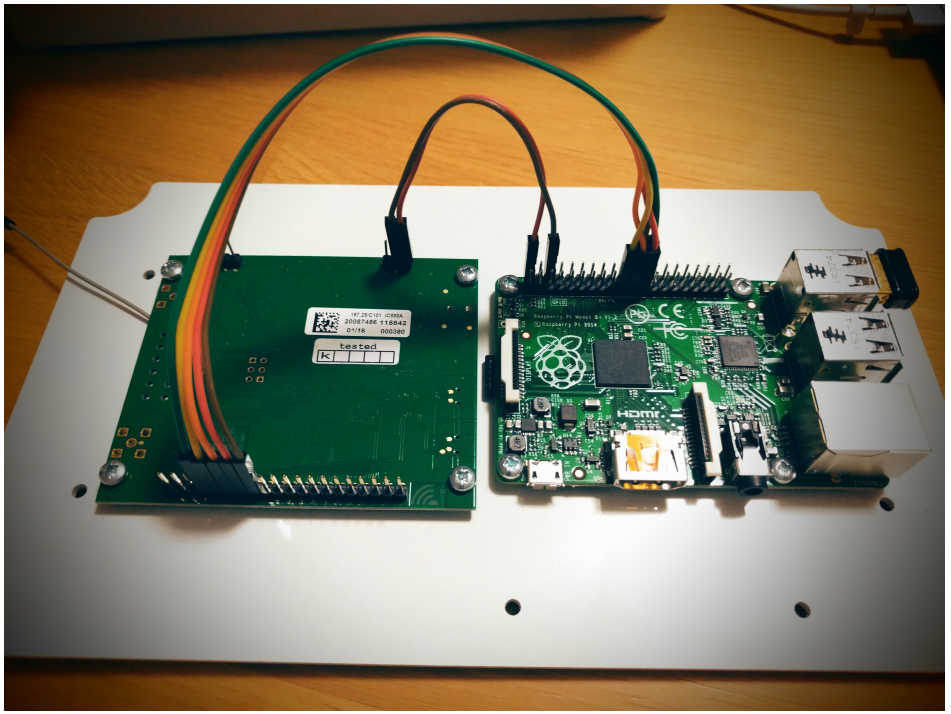


Figure: DIY LoRa gateway w/ Raspberry Pi.[3]

Cost

References I

[1] Mar. 2024. URL: https://www.sigfox.com/coverage/.

[2] Ian L. Boyd, Akiko Kato, and Yan Ropert-Coudert. "Bio-logging science: sensing beyond the boundaries". In: *Memoirs of National Institute of Polar Research. Special issue* 58 (Mar. 2004), pp. 1–14.

[3] *Build your own gateway*. URL: https://www.thethingsnetwork.org/docs/gateways/start/build/.

[4] Adam Calihman. *IOT architectures - common approaches and ways to design IOT at scale*. Aug. 2021. URL: https://www.netburner.com/learn/architectural-frameworks-in-the-iot-civilization/.

References II

[5] Lara Fernandez et al. “Assessing LoRa for Satellite-to-Earth Communications Considering the Impact of Ionospheric Scintillation”. In: *IEEE Access* 8 (Jan. 2020), pp. 165570–165582. DOI: 10.1109/ACCESS.2020.3022433.

[6] Sakshama Ghoslya. “LoRa: Symbol Generation”. In: *All About LoRa and LoRaWAN* (2017).

[7] *How is data put on radio waves?* URL: https://www.qrg.northwestern.edu/projects/vss/docs/communications/1-how-is-data-put-on-radio-waves.html.

References III

[8] Abhishyant Kidangoor. *New trackers bring Prairie Dogs' little-known underground life to light*. Mar. 2024. URL: https://news.mongabay.com/2024/03/new-trackers-bring-prairie-dogs-little-known-underground-life-to-light/#:~:text=While%20accelerometers%20measure%20if%20and,the%20direction%20of%20their%20movements..

[9] Glen Martin. *San Jose / in studying pollution, this professor will wing it / ...* Feb. 2006. URL: https://www.sfgate.com/bayarea/article/SAN-JOSE-In-studying-pollution-this-professor-2542456.php.

[10] *SIGFOX - Signal Identification Wiki*. URL: https://www.sigidwiki.com/wiki/SIGFOX.

References IV

[11] *The difference between 2.4 GHz and 5 GHz WiFi*. URL: https://www.centurylink.com/home/help/internet/wireless/which-frequency-should-you-use.html.

[12] *Wi-Fi Frequencies Explained*. URL: https://www.imon.net/imon-difference/news-events/wi-fi-frequencies-explained.

[13] Timm A Wild et al. "A multi-species evaluation of digital wildlife monitoring using the Sigfox IoT network". In: *Animal Biotelemetry* 11.1 (2023), pp. 1–17. DOI: https://doi.org/10.1186/s40317-023-00326-1. URL: https://doi.org/10.1186/s40317-023-00326-1.