

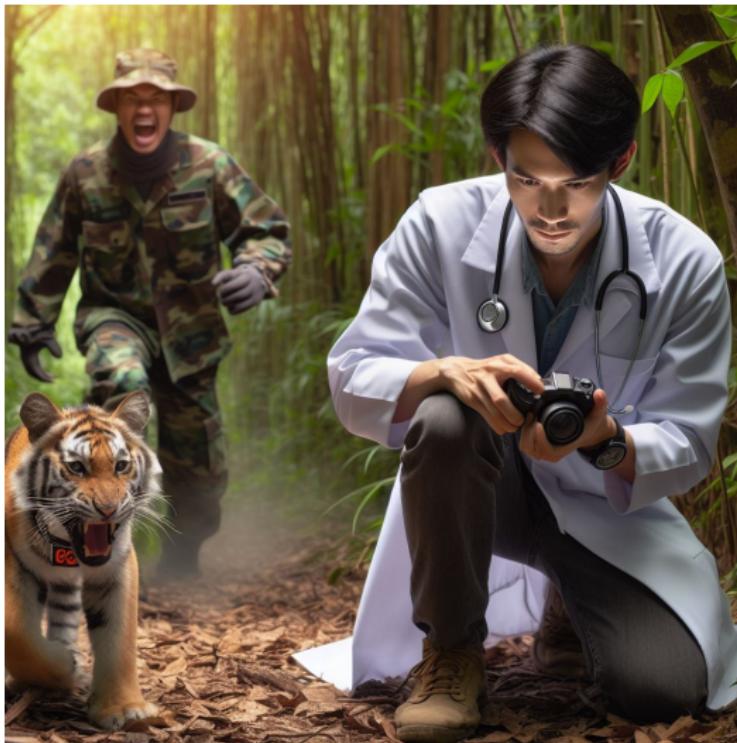
Using Internet of Things (IoT) Networks for Wildlife Tracking

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Hypothetical Scenario



Outline

- 1 Background
- 2 Components of a Modern Biologging System
- 3 Networks for a Biologging System
- 4 Conclusion
- 5 Questions

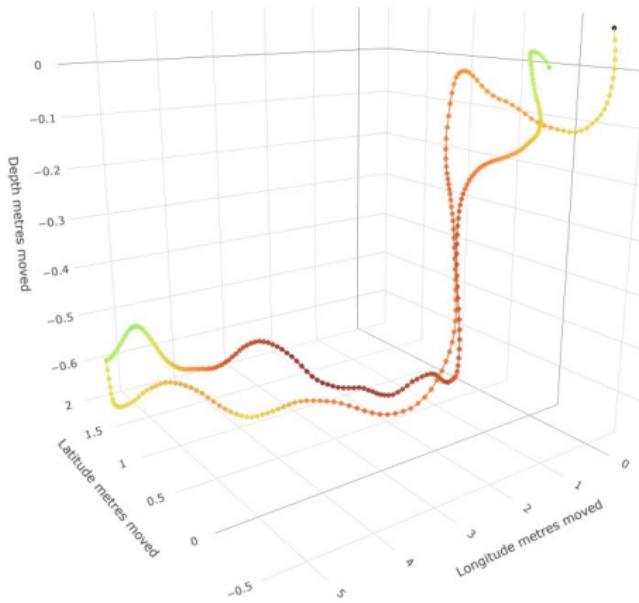
Introduction to Biologging



Figure: Animals With SigFox enabled biologging tags [14]

- **Definition:** "Investigation of phenomena in or around free-ranging organisms beyond human visibility or experience [4]"
- **Method:** Tracking wild animals using electronic devices attached to animals
- ↑ Popularity in early 2000s, practiced since 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.

Figure: 3D movement of a prairie dog [9]

Impact and Importance

- Insights into organisms in hostile or hard-to-reach environments
- Study previously inaccessible aspects of animal life
- Inform conservation efforts and protect endangered species
- Tool for general data collection

Other Biologging Methods

- Cellular networks; High Cost
 - \$250/device
 - 10¢/message
- Radio Frequency (5-1000m)
 - Periodic tracking records
 - Time stamped data



Figure: Pigeons Equipped with cellular trackers [10]

Data Transmission

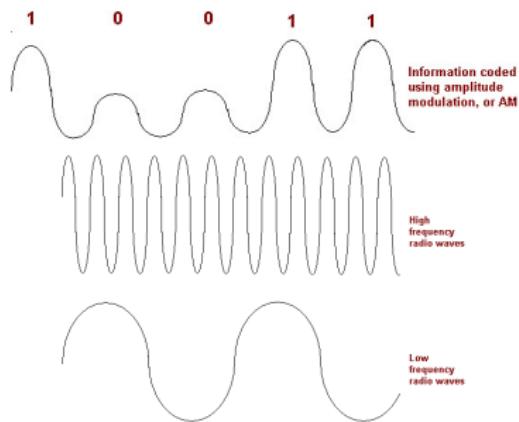


Figure: Data representation using amplitude modulation and frequency [8]

- Data encoded into 1's and 0's
 - Represented by amplitude
 - More complex methods are used
- Frequency determines data rate and range
 - higher freq \implies higher data-rate
 - higher freq \implies lower range
- Received and translated by other devices

Wireless Network Frequencies and Range

- WLAN frequencies
 - 2.4GHz/5GHz/6GHz
 - Range \approx 200m (2.4Ghz)
- LPWAN Frequencies
 - <1GHz (depends on region)
 - Range \approx 20-40km

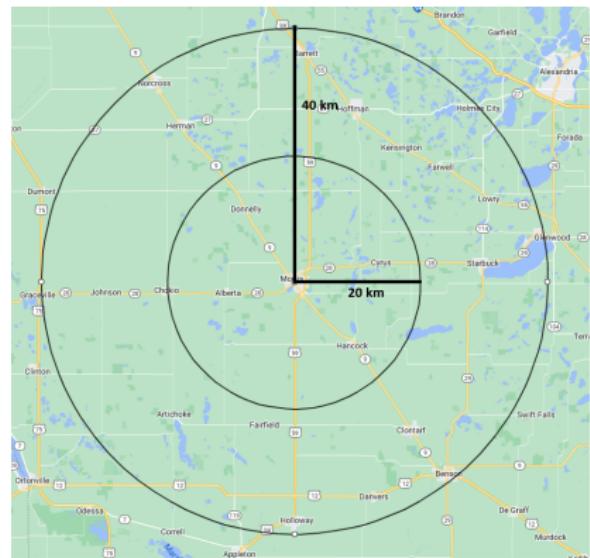
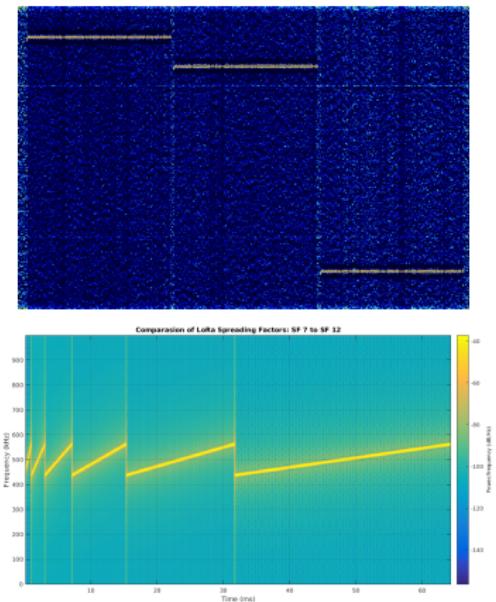


Figure: 200m, 20km, and 40km radius around Morris, MN

Frequency Hopping and Modulation



- Resistance to interference
- Ensures delivery
- Frequency hopping
 - Transmits message 3 times
 - Pseudo randomly hops to new frequency
- CHIRP (Compressed High Intensity Radar Pulse) spread spectrum
 - Gradually raises/lowers frequencies
 - ↑ SF ⇒ ↓ modulation rates

Figure: CHIRP and frequency hopping modulation

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

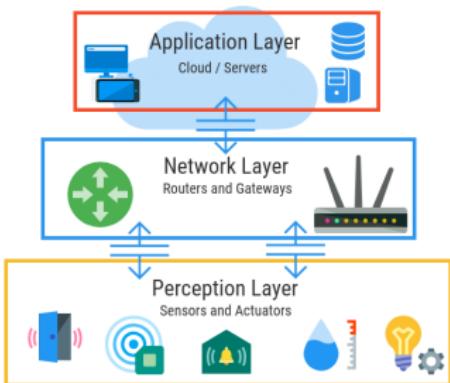


Figure: Layer Structure of an IoT System [6]

Sensor Devices (tags)

- IoT perception layer
- Required Components
 - Antenna
 - Microcontroller
 - Battery
 - Sensor(s)
- Optional Components
 - Solar panel
 - Extra storage

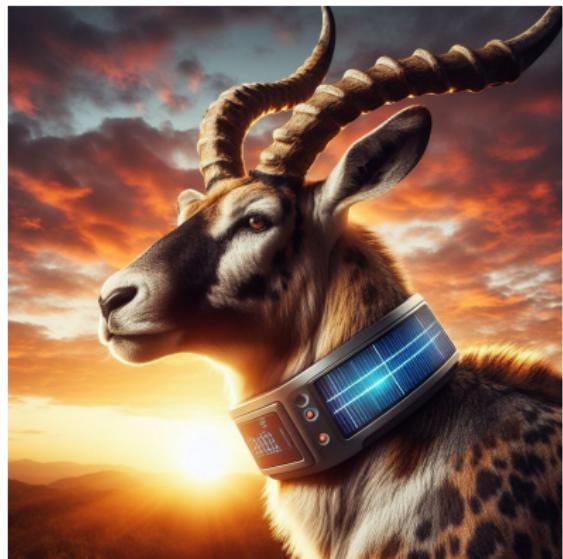


Figure: Animal wearing a solar powered biologging collar, looking majestic [DALL-E 3]

Sensor Devices

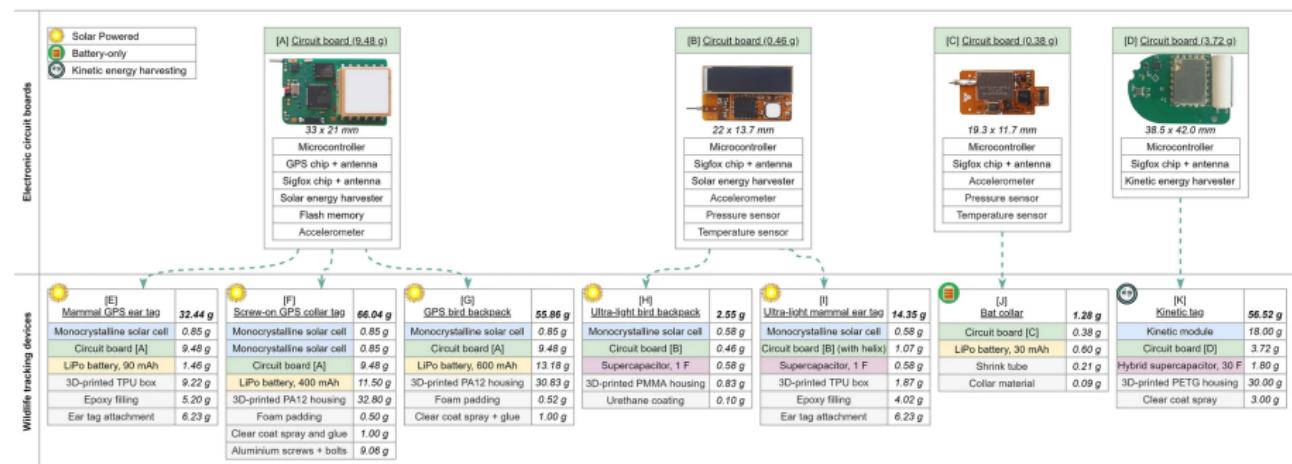


Figure: SigFox Biologging Sensor Device [14]

Base Stations



- IoT network layer
- Components
 - RF receiver and transmitter
 - Data forwarding engine
 - Power source
 - Connection to internet or ...
 - Local Storage

Figure: YRP hybrid base station [12]

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

- Safe and secure transmission
 - Poachers
- Efficient transmission
 - Battery life
- Easy access to data
 - Cloud access



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

LPWAN Overview

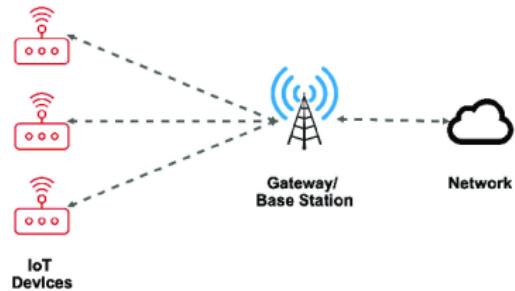


Figure: LPWAN technologies network architecture [7]

- **Low Power Wide Area Network**
- Uses unlicensed industrial, scientific and medical radio frequencies (ISM)
- 433MHz-928MHz Depending on region (U.S. 915MHz)
- Low power consumption
- Long range (40km+)

SigFox LPWAN



Figure: SigFox Logo

- Owns and operates global network
- Began operation in 2010
- Proprietary service
- Subscription based service

SigFox LPWAN Capabilities

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

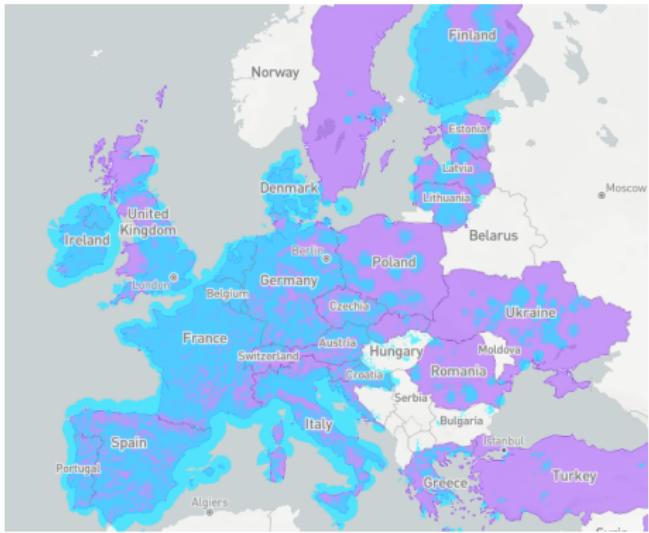


Figure: SigFox Europe Coverage,
blue=live coverage, purple=roll-out [1]

SigFox Operation

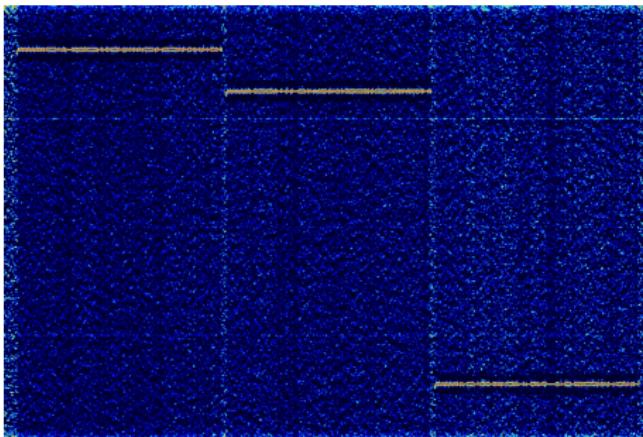


Figure: SigFox frequency hopping modulation [13]

- Transmission modulation
 - Frequency hopping
- Proprietary base stations
- Devices certification

LoRaWAN LPWAN



Figure: LoRa Logo

- Standards based system
- Public networks available
- Self deployable networks
- Open source implementations

LoRaWAN Operation and Capabilities

- Unlimited messages/day
- CHIRP Spread Spectrum modulation
- 20km+ of range depending on environment
- Up to 50kbps

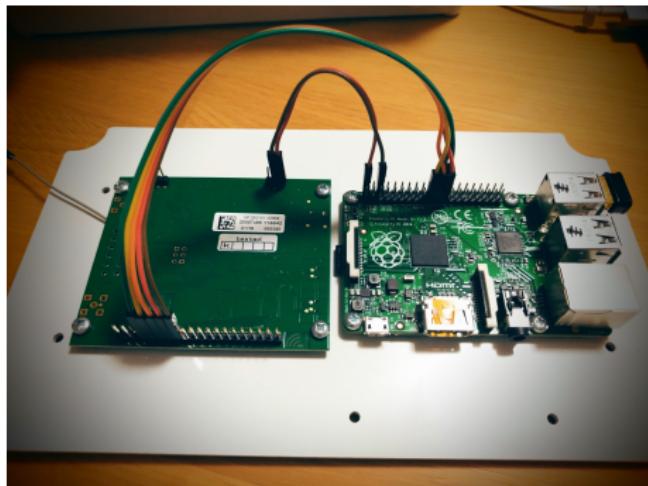


Figure: DIY LoRa gateway w/
Raspberry Pi [5]

WLAN Capabilities

- 200m+ of range depending on environment
- Unlimited messages/day
- 24/7 data transmission
- 1840kbps+ (depending on implementation)



Figure: Wavlink AX1800 Outdoor Router

WLAN Operation

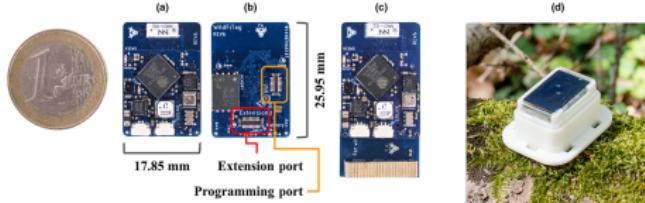


Figure: WildFi tag with GPS extension and solar panel [15]

- Can be entirely self developed
- Can last an animals lifetime with solar
- Cheap, Open Source, common hardware
- Maintained entirely by user

Security with AES-128 Encryption

- Proven track record
- Secures data over the air
- Small 128bit encryption keys
- Not computationally expensive
- Security on battery powered devices

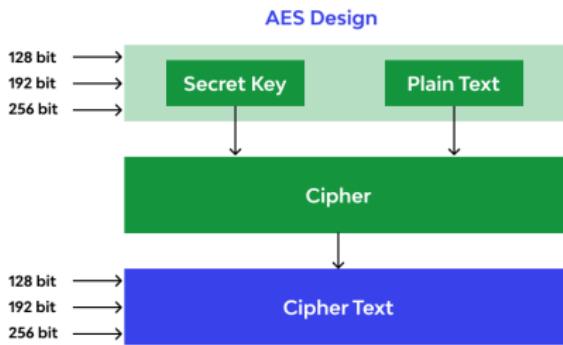
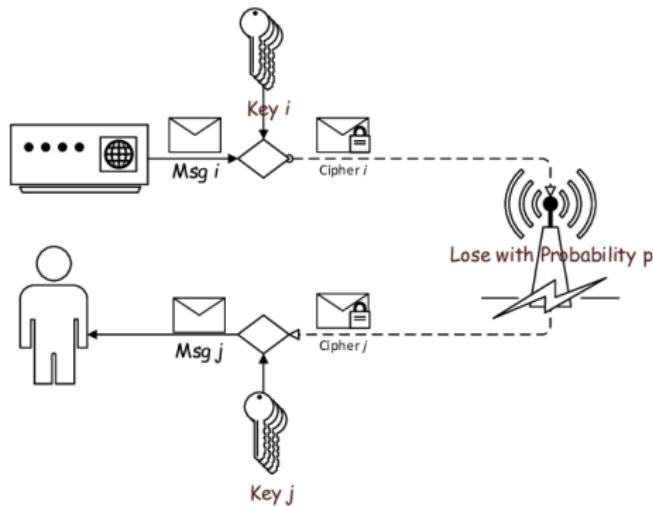


Figure: AES Design [2]

SigFox, LoRa, and WLAN Security



- SigFox, LoRa and WLAN can use AES-128
- End-to-End encryption
- Encrypted at the source (sensor device)
- Per device keys for physical protection

Figure: Model of LPWAN Chaining Encryption [3]

LPWAN Network Comparisons

- SigFox
 - Better range and coverage
 - Worse latency and payload
- LoRa
 - Easier to deploy (Private)
 - Less data restrictions

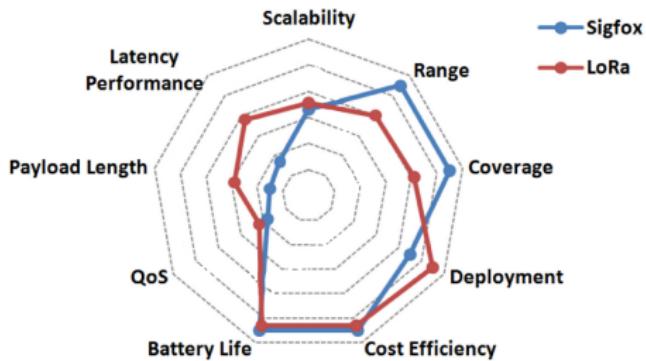
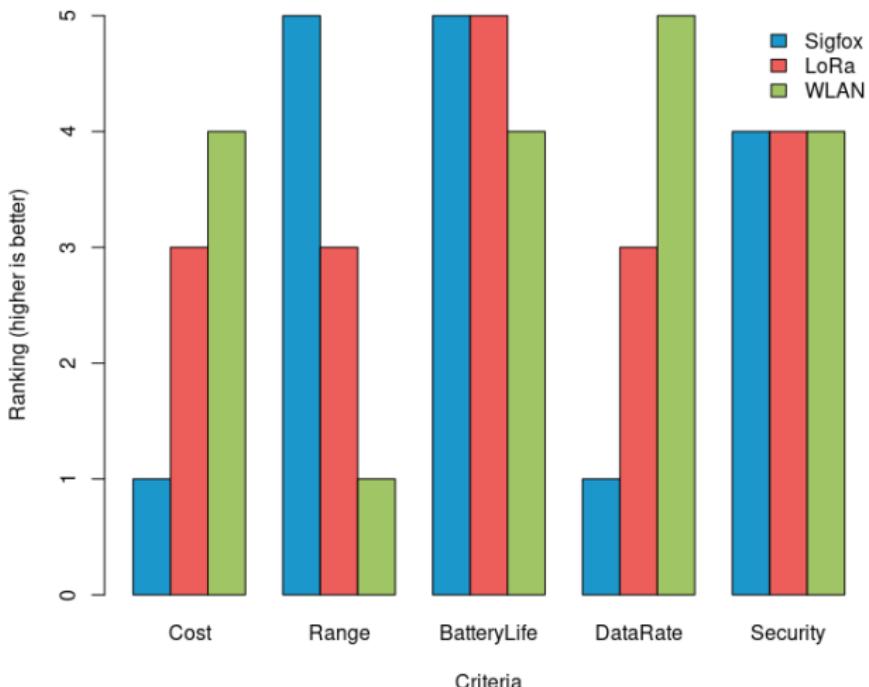


Figure: LPWAN Comparisons [11]

Final comparisons

Performance Rankings of Networks by Criteria



Benefits of IoT for biologging

- Why use IoT for biologging?
 - Bigger data rates and size
 - Highly customizable
 - Many existing components
 - Battery lasts for a lifetime
 - Less disruptive tagging



Figure: IoT sensor device on an animal in the wild [DALL·E 3]

Questions

Thanks for Listening!
Any Questions?



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