Using Internet of Things (IoT) Networks for Wildlife Tracking

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Hypothetical Scenario

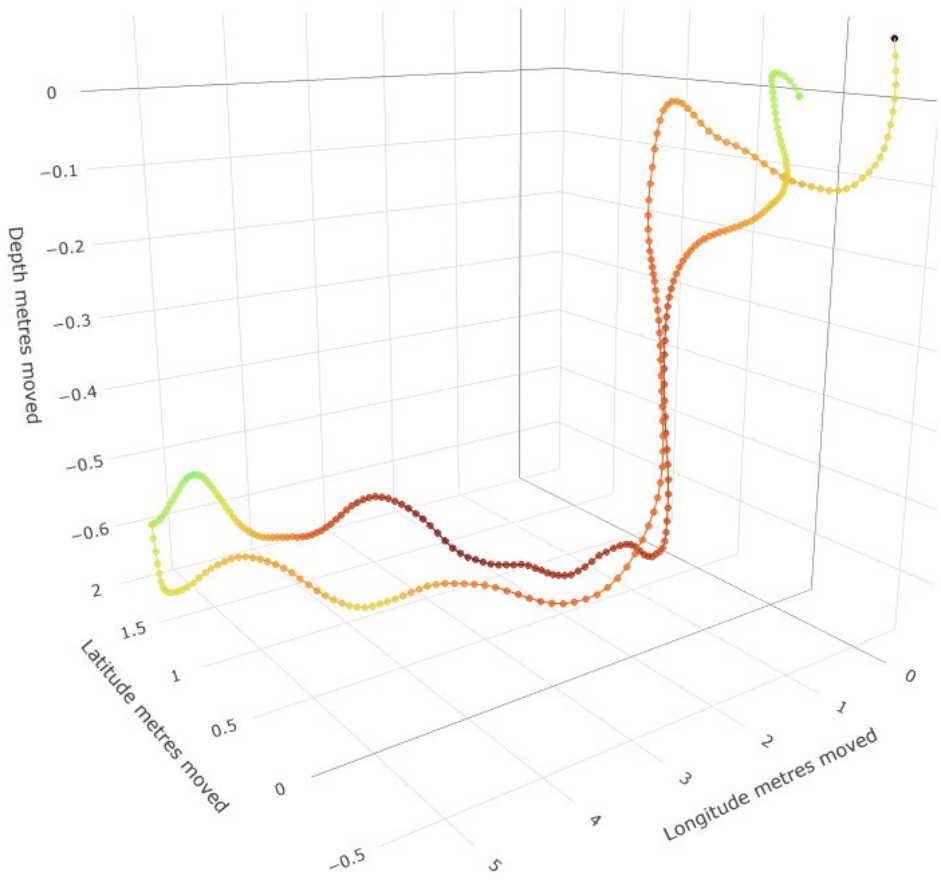
Outline

Introduction to Biologging

Figure: Animals With SigFox enabled biologging tags [18]

- 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 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 [11]

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 [12]

Data Transmission

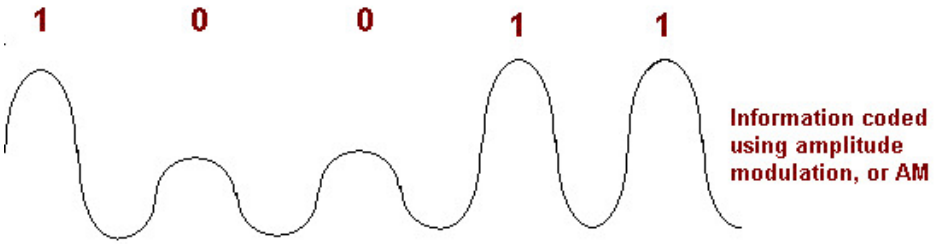


Figure: How data is represented using amplitude modulation [10]

- 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

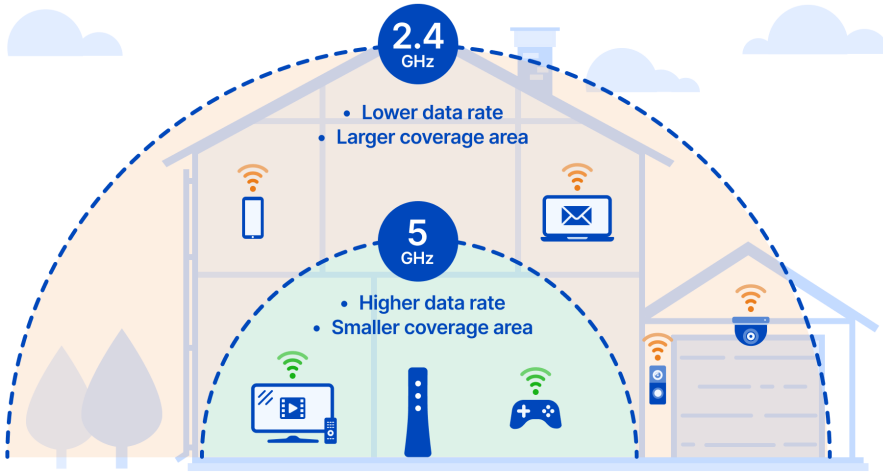


Figure: 5 GHz will give you more signal strength and faster speed over a shorter range, compared to 2.4 GHz [16]

Concepts of Wireless Frequencies

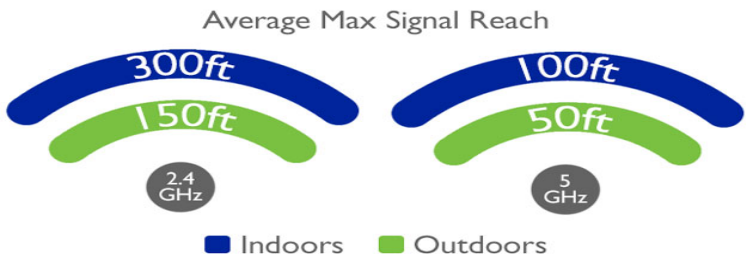


Figure: Comparing Range of frequencies [17]

Figure: Comparing Speed of frequencies [17]

- 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

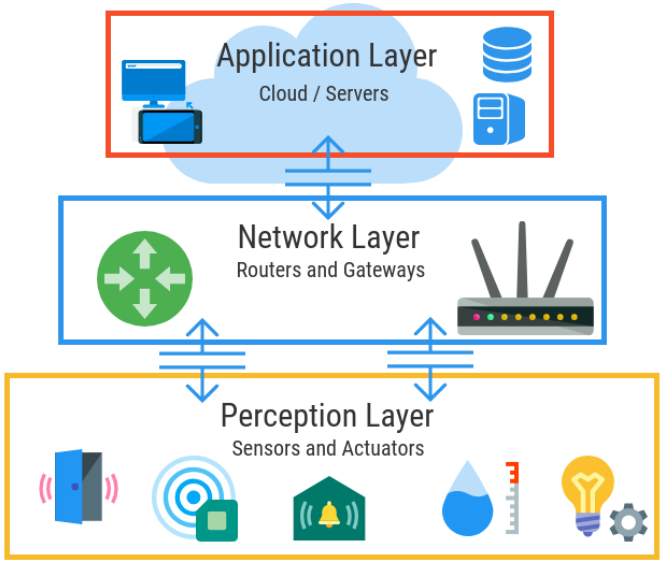


Figure: Layer Structure of an IoT System [6]

Sensor Devices

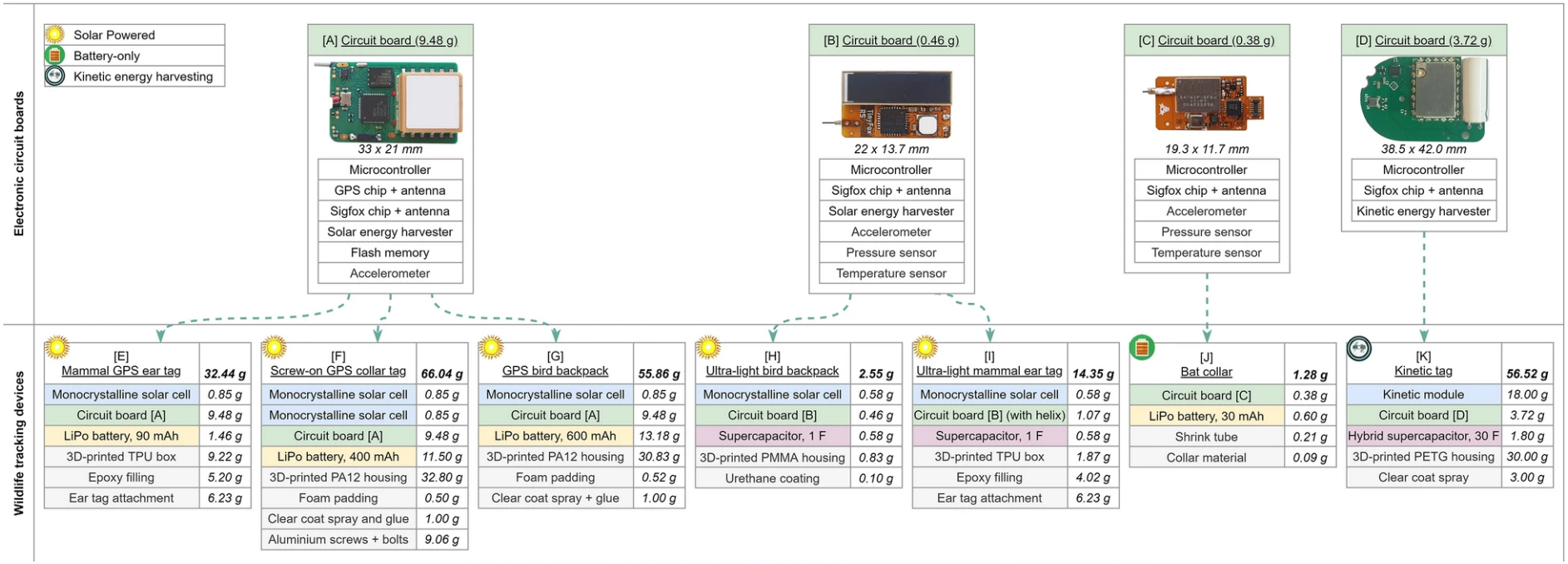


Figure: SigFox Biologging Sensor Device [18]

Sensor Devices

- 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]

Base Stations

Figure: YRP base station [14]

- RF Receiver and transmitter
- Connection to internet
- Packet forwarding engine
- Power source
- Local Storage (Optional)

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

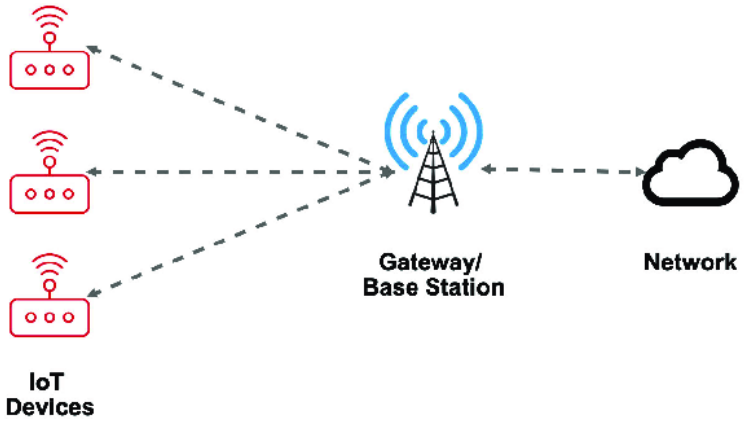


Figure: LPWAN technologies network architecture [8]

- 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

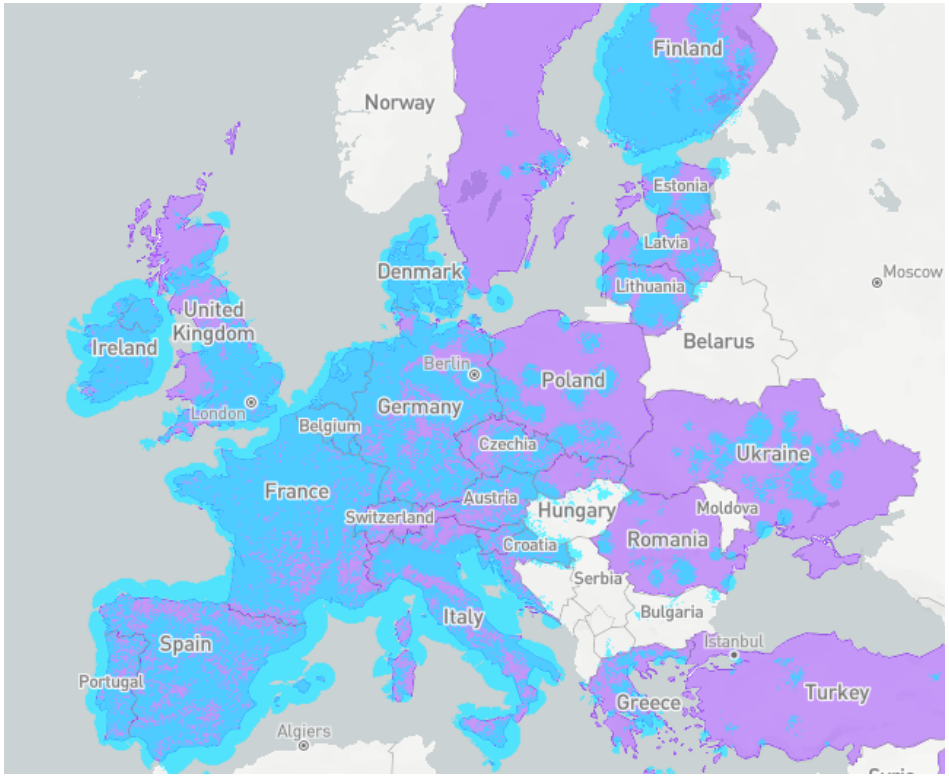


Figure: SigFox Europe Coverage [1]

SigFox LPWAN Operation

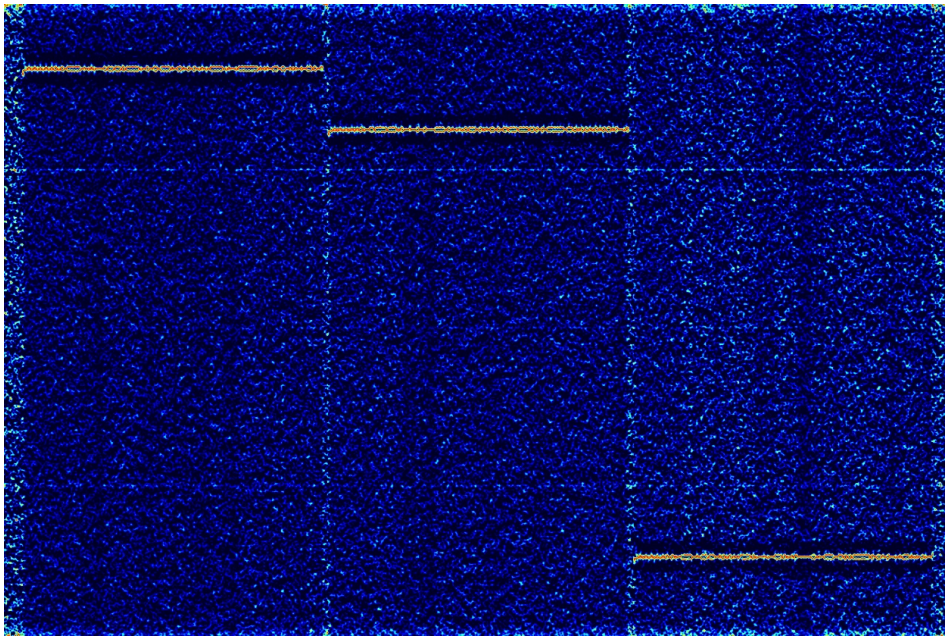


Figure: SigFox frequency hopping modulation [15]

- 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

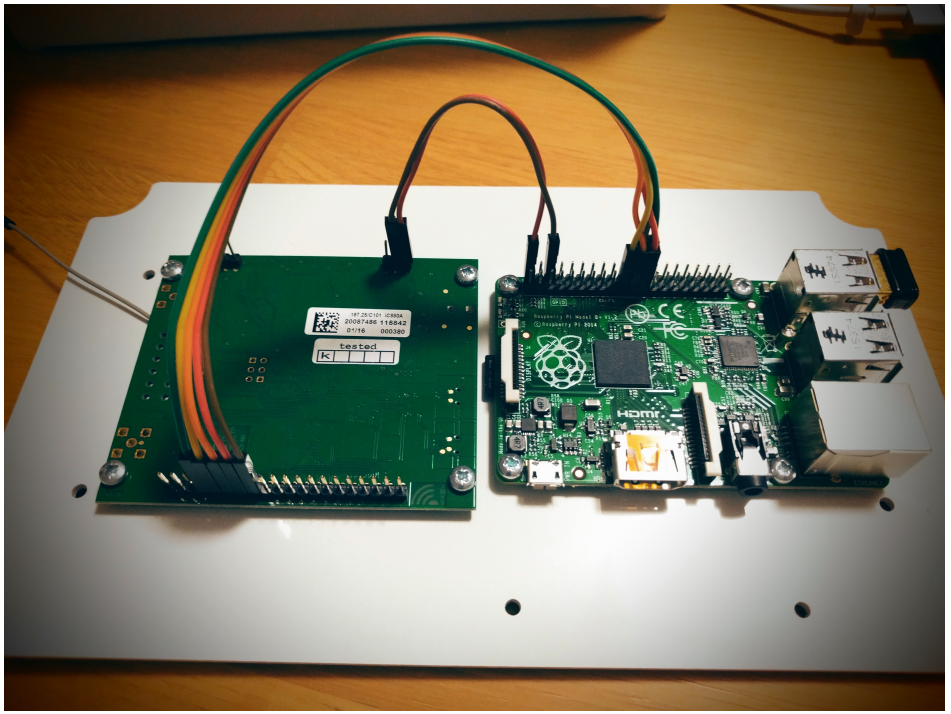


Figure: DIY LoRa gateway w/ Raspberry Pi [5]

LoRa LPWAN Operation

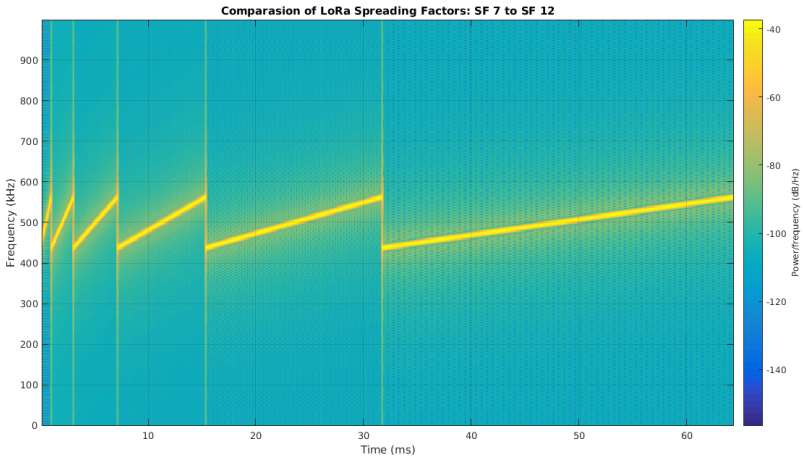


Figure: CHIRP Spread Spectrum modulation SF7-SF12 [9]

- 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
- 24/7 data transmission
- 1840kbps+ (depending on implementation)
- Can use any 2.4GHz network

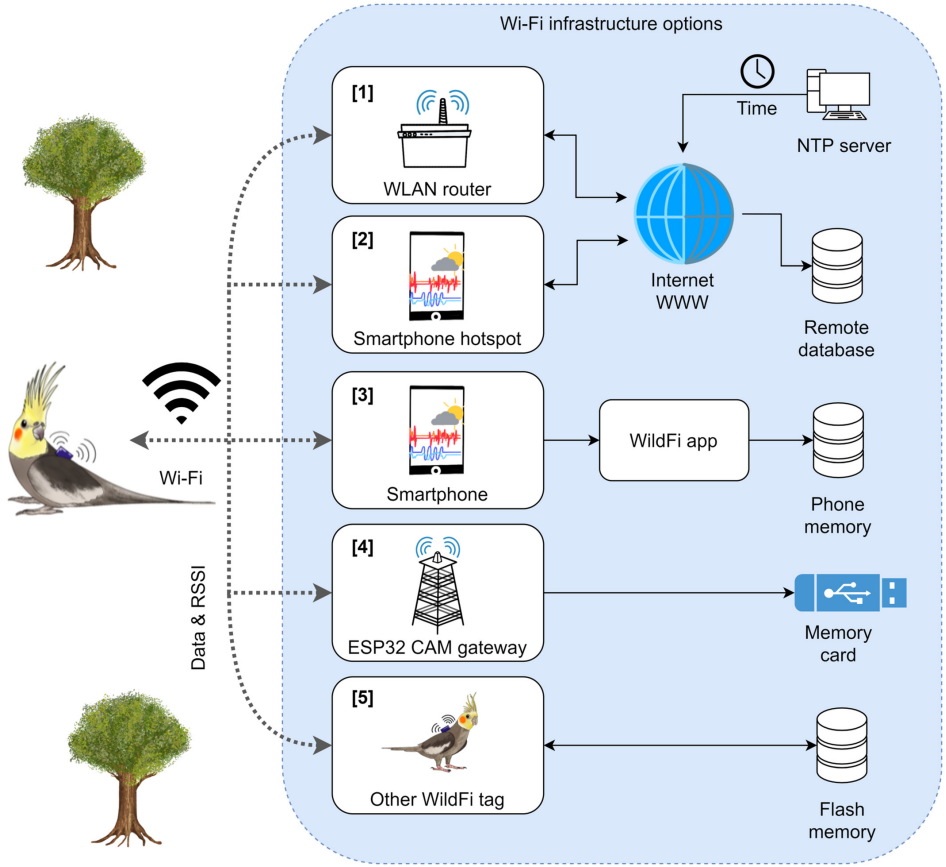


Figure: WildFi infrastructure overview [19]

WLAN Operation

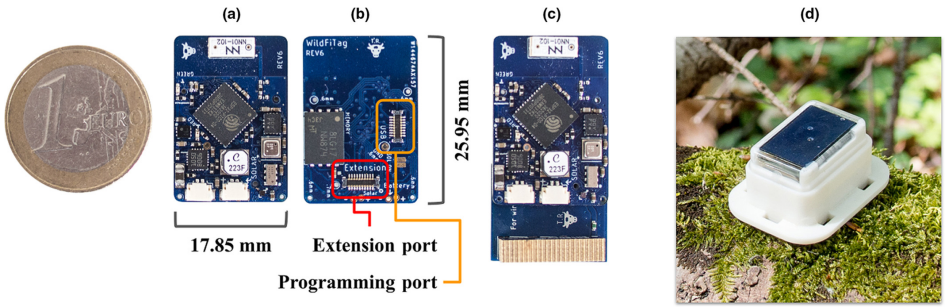


Figure: WildFi tag with GPS extension and solar panel [19]

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

SigFox and LoRa Security

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

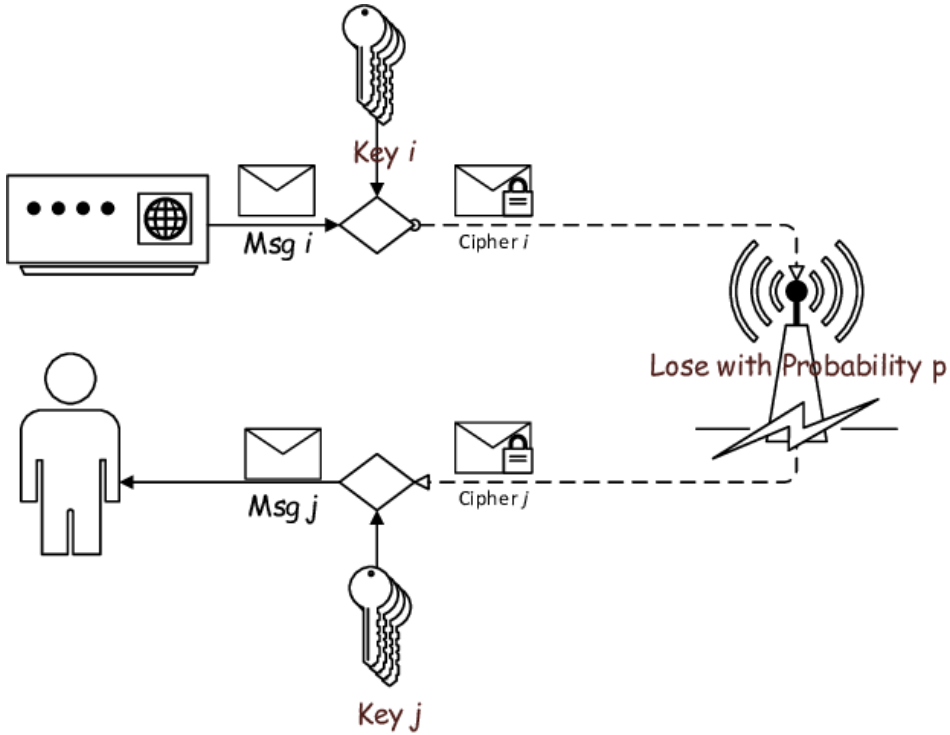


Figure: Model of LPWAN Chaining Encryption [3]

WildFi (WLAN) Security

- WildFi use WPA2/HTTPS → AES-128
- End-to-End encryption
- Depends on individual implementation

Why Use AES-128?

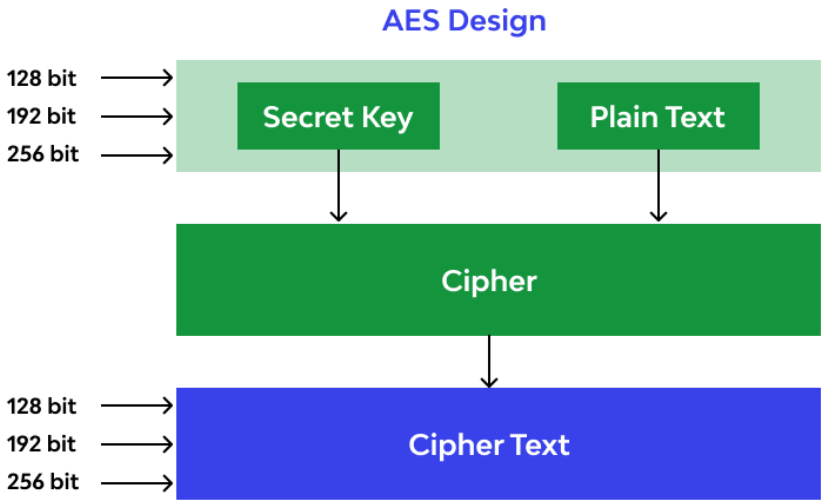


Figure: AES Design [2]

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

LPWAN Network Comparisons

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

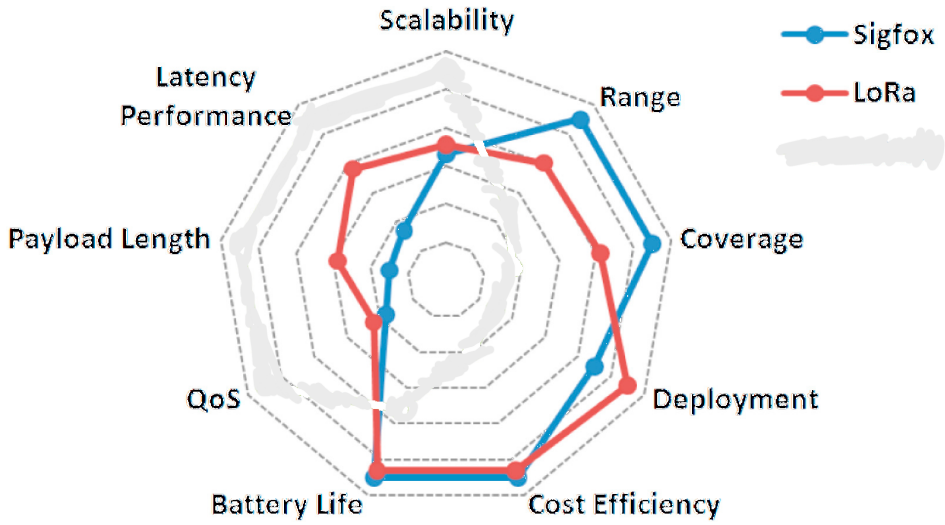


Figure: LPWAN Comparisons [13]

LPWAN vs WLAN

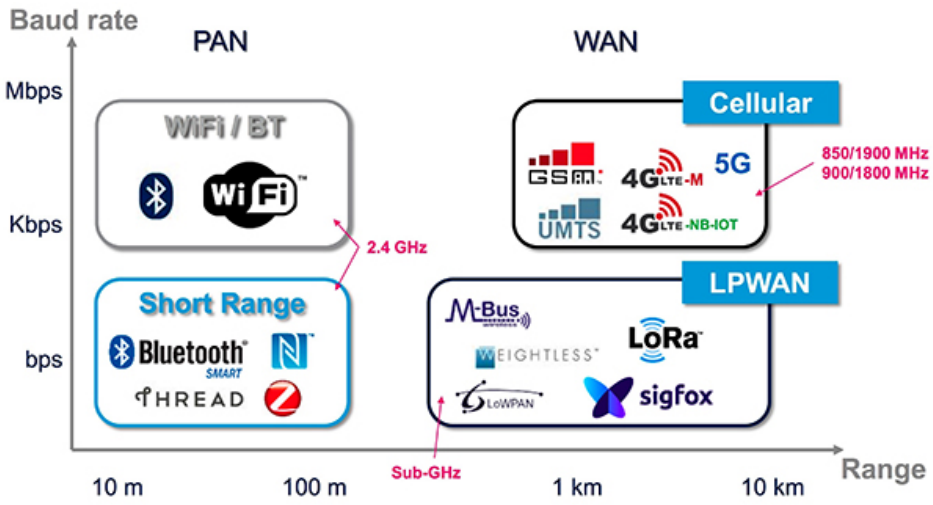


Figure: Data Rate vs Range [7]

- Cost: LoRa & WLAN $<$ SigFox
- Range: LoRa & SigFox $<$ WLAN
- Battery Life: LoRa $\approx$ SigFox $\approx$ WLAN
- Data Rate: WLAN $>$ LoRa $>$ SigFox
- Security: LoRa $\approx$ SigFox $\approx$ WLAN

IoT for Biologging

- More, diverse data can be sent
- Highly customizable
- Many different options to choose from
- Lasts for a lifetime
- Less disruptive

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

Questions

Thanks for Listening!

Any Questions?

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