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STORK

Asset Tracker

User Guide

Document Type:	User Guide	
Document Number:	T0008710	
Document Version:	1.0	
Document Status:	Release	
Product Names and T-Codes:	STORK, Base	T0008781
	STORK, External Power	T0008396
Release Date:	December 12, 2023	

Document Revision History

Revision	Issue Date	Status	Editor	Comments
0.1	September 06, 2023	Obsolete	Ade Adegboye	First draft (based on T0008710_TRM_v0.1_Draft and T0006940_UG_ver1.1)
1.0	December 12 2023	Released	Carter Mudryk	• Updated based on review feedback. • Corrected product codes. • Minor grammatical and formatting changes.

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List of Acronyms

BER .... Bit Error Rate
BLE.................. Bluetooth Low-Energy
CNR................. Cahiers des charges sur les Normes Radioélectriques (RSS)
DL .... DownLink
EGNOS .... Wuropean Geostationary Navigation Overlay Service
EOS .... End Of Service
EU .... European Union
FCC.................. Federal Communications Commission
FSK.................. Frequency Shift Keying
FW .... FirmWare
GEO .... GEOstationary Orbit
GFSK .... Gaussian FSK
GNSS............... Global Navigation Satellite System
GPS .... Global Positioning System
GRB .... Geolocation Resolver Backend
GW .... GateWay
HW .... HardWare
ID.................... IDentifier
IGSO .... Inclined GeoSynchronous Orbit
IoT .... Internet of Things
IP .... Ingress Protection
ISM .... Industrial, Scientific, and Medical
LED .... Light-Emitting Diode
LoRa .... Long-Range
LoRaWAN....... LoRa Wide-Area Network
LoS.................. Line-of-Sight
LTC.................. Lithium-Thionyl Chloride
MAC................ Media Access Control
MCU .... MicroController Unit
NA .... North America
NLOS............... Near LoS
NS .... Network Server
OTA.... .... Over The Air
PCB .... Printed Circuit Board
PCBA.. .... PCB Assembly
Rev..... .... Revision
RF....... .... Radio Frequency
RH .... Relative Humidity
RSS..... .... Radio Standards Specifications (CNR)
RSSI.... .... Received Signal Strength Indicator
Rx....... .... Receive, receiver, etc.
SBAS .. .. Satellite Based Augmentation System
SW .... SoftWare
TLM ... . TeLeMetry
TRM ... . Technical Reference Manual
Tx....... .... Transmit, Transmitter, etc.
UG .... User Guide
UID .... Unique ID
UL .... UpLink
US .... United States
v......... .... version
WAAS .... Wide Area Augmentation System
Wi-Fi.. .... Wireless-Fidelity

1 Product Description

1.1 Overview

This document provides a user manual for the *STORK Asset Trackers* developed by TEKTELIC Communications Inc. This document includes descriptions of both STORK variants and instructions regarding the HW capabilities. For the functional operation and SW behaviour, please refer to the TRM document.

The STORK is a low-power LoRaWAN IoT sensor run on a single C-cell LTC battery and packed into a compact IP67 polycarbonate casing. Its primary purpose is to track assets indoors and outdoors using a combination of location-tracking technologies:

- ***Low-Power GNSS:*** Outdoor tracking using satellite geolocation.
- ***Wi-Fi Sniffing:*** Outdoor and/or indoor tracking using Wi-Fi access point geolocation.
- ***BLE Tracking:*** Indoor tracking using BLE beacon network localization.

The STORK is meant to be a component in an end-to-end asset tracking solution as shown in Figure 1-1.[1]

LoRaWAN is the LoRa wireless communications standard protocol. This technology provides a low-bandwidth, low-power, and long-range[2] means of transmitting small amounts of data. It has been developed with wireless sensing in mind, and to enable new means of gathering telemetry in numerous environments. The STORK supports LoRa and (G)FSK modulations according to the LoRaWAN L2 1.0.4 Specification [1]. The 150 MHz-960 MHz ISM bands are utilized to meet different application requirements from the standards and proprietary protocols of the given region.

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[1] **NOTE**: Only raw scan data is present in the LoRaWAN payloads, not sensor location information. In order to track and visualize a STORK's location, an application server must be set up, integrated with the NS, and enabled to use the proper cloud location services. The information in this document is for the STORK sensor only; for information about setting up the rest of the end-to-end solution shown in Figure 1-1, refer to the TEKTELIC support portal Knowledge Base [1].

[2] Up to 2 km NLoS and more than 22 km LoS.

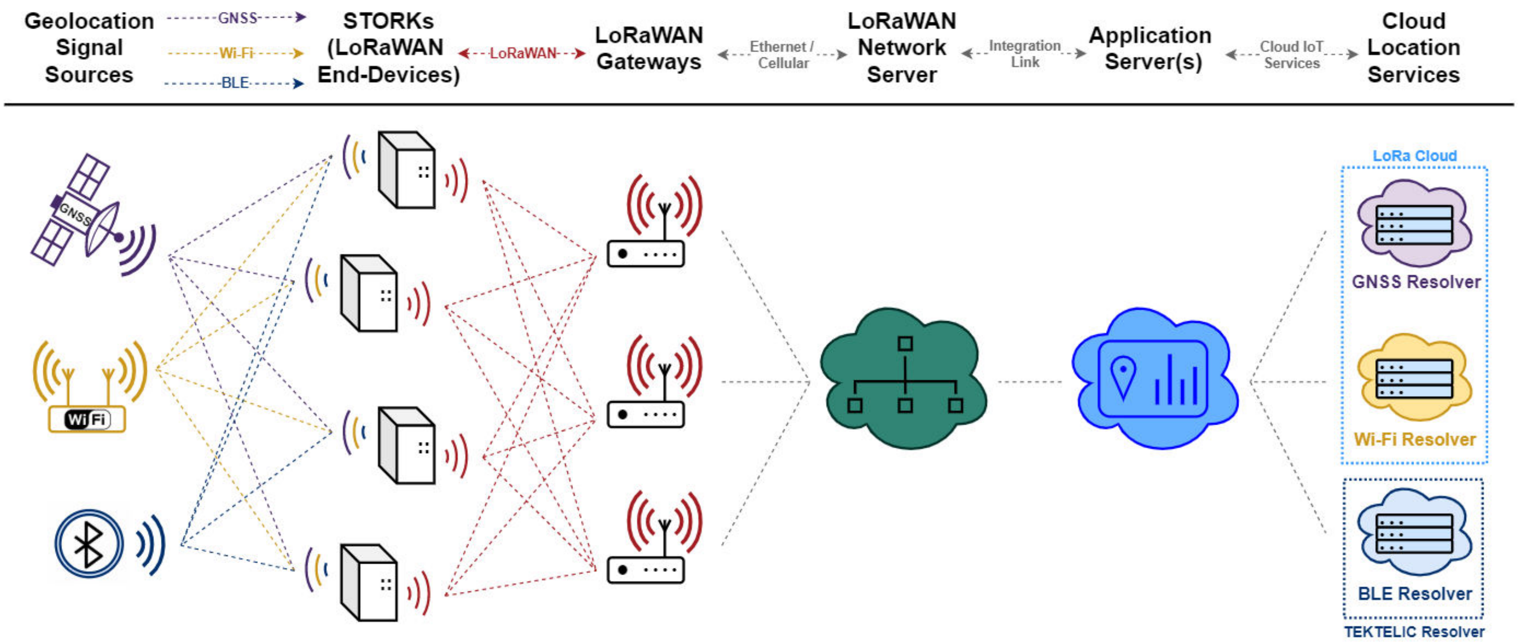

Figure 1-1: STORK Asset Tracking End-to-End Architecture

The asset location information flows in this order:

1. The STORK conducts GNSS, Wi-Fi, and/or BLE scans to gather raw information from the available geolocation signal sources.

2. The raw scan results are conveyed via LoRa transmissions to 1 or more *LoRaWAN GateWays* (*GW*s).

3. The GWs forward the packets to the *LoRaWAN Network Server* (*NS*) either by ethernet or cellular backhaul.

4. The raw scan results are forwarded to the application layer via *integration link*.

5. The application determines which *Cloud IoT Location Resolver Service*(s) to use depending on what type of scan data is forwarded. TEKTELIC's *LOCUS* application is designed to work natively with STORK, but any compatible 3rd-party application can be used.

6. The respective location resolver service processes the raw scan data to calculate a position fix.
   a. GNSS and Wi-Fi scan data messages are designed to be processed by Semtech's *LoRa Cloud* service, but any compatible cloud service can be used.
   b. BLE scan data messages are designed to be processed by TEKTELIC's *Geolocation Resolver Backend* (*GRB*), but any compatible cloud service can be used.

7. The resolved fixes are returned to the application where they can then be visualized on a virtual dashboard.

In addition to geolocation, the STORK is a multipurpose device equipped with a variety of technology:

- **Core design**: Based on the low-power, IoT-targeted STM32WB55CWU6 MCU, which runs the system SW and has a built-in BLE module. The LR1110 transceiver from Semtech handles the LoRa, GNSS, and Wi-Fi operations.
- **Accelerometer**: Detects device motion state so geolocation updates can be sent more frequently while in motion. Motion alarms and the raw acceleration vector can also be reported if knowledge of sensor orientation is of interest.
- **BLE beacon mode**: In this mode, the sensor broadcasts BLE advertisements which make it discoverable by other nearby trackers or BLE-capable devices.
- **Ambient environment sensing**: The temperature and relative humidity of the surrounding environment can be reported, and additional reports can be sent if the conditions cross configurable thresholds.
- **Battery data**: The remaining capacity and lifetime can be reported. The battery lifetime has been estimated to be up to 4.3 years with default settings[3], or 16 months with default Beacon mode settings[4].
- **Magnetic detection**: A magnet can be used to wake from the DEEP SLEEP state (used for shipping) and to force ULs during normal operation.

1.2 Summary of HW Information, Streams, and Default Behaviour

Table 1-1 presents the currently available sensor HW variants, and Figure 1-2 shows the enclosures. The information streams supported by the SW are shown in Table 1-2 and the default configuration for reporting data has been shown in Table 1-3.

Table 1-1: STORK HW Models

Product Code, Module-Level T-Code	Product Code, PCBA-Level T-Code	Model Name	Description	LoRaWAN Regions Supported[5]
T0008781	T0008357	STORK, Base	GNSS-Wi-Fi-BLE Asset Tracking Sensor	EU868 US915
T0008396		STORK, External Power		

[3] Default settings with 8 hours of movement and 16 hours of stillness, operating at DR3 in the US region.
[4] Default settings with no event-based reports, operating at DR3 in the US region.
[5] Other regional variants available upon request.

Figure 1-2: (Top) STORK, Base Enclosure; (Bottom) STORK, External Power Enclosure

Table 1-2: List of STORK Information Streams

Stream Direction	Data Type	Sent on *LoRaWAN Port* [decimal]
UL (Sensor to NS)	Reports containing sensor data: • Battery life data • Accelerometer vectors and alarms • Ambient temperature • Ambient RH • Geolocation cycle failed message	**10**
	Reports containing GNSS diagnostic information	**16**
	Reports containing discovered BLE device data	**25**
	Responses to read/write configuration and control commands	**100/101**
	GNSS scan results to be forwarded to LoRa Cloud	**192**
	Wi-Fi scan results to be forwarded to LoRa Cloud	**197**
	LoRa Cloud requests	**199**
DL (NS to Sensor)	Putting sensor into DEEP SLEEP	**99**
	Configuration and control commands	**100**
	LoRa Cloud communications	**192/199**

Table 1-3: STORK Default Reporting Behavior

Report	Report Type	Default Periodicity
Battery data	Periodic	24 hours
	Event-based	When magnetic sensor is triggered
Geolocation Update	Periodic	10 min when in motion 1 hour when still
Acceleration vector	Periodic	Disabled
Accelerometer motion alarm	Event-based	When motion is detected When sensor becomes still
Ambient temperature	Periodic	1 hour
	Event-based	Disabled
Ambient RH	Periodic	1 hour
	Event-based	Disabled

1.3 External Appearance and Interfacing

The appearances and external interfacing are shown in Figure 1-3. These are the same for both the base and external power variants.

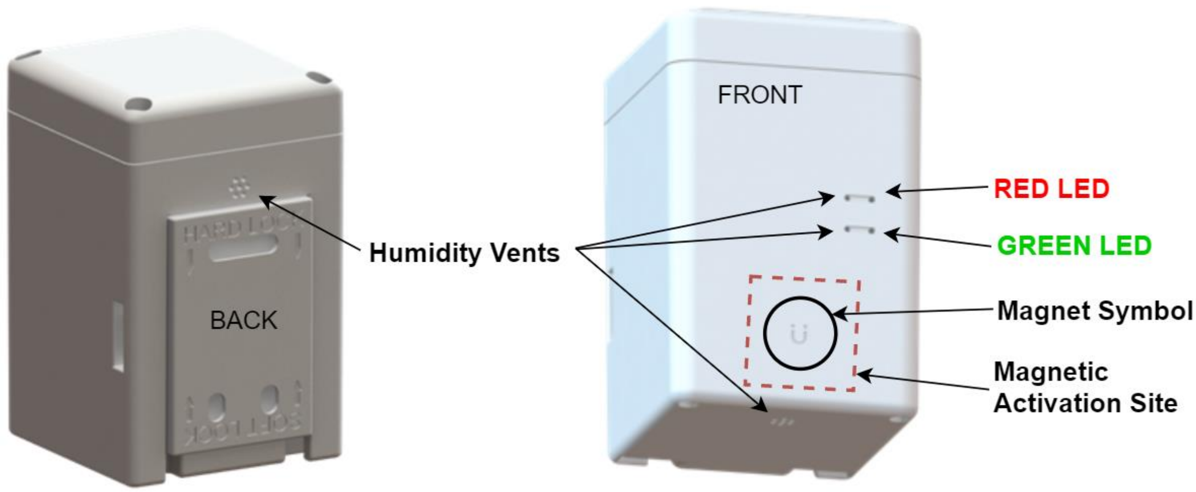

Figure 1-3: STORK Enclosure and External Interfacing

1.4 Specifications and Sensing Functions

The STORK specifications are listed in Table 1-4. The main sensing functions are described in the following subsections.

Table 1-4: STORK Specifications

Parameter	Specification
Environmental Rating	IP67
Enclosures and Mounting	Custom design by TEKTELIC
Operating Temperature	-40°C to 70°C
Storage Temperature	-25° to 55°C
Operating Relative Humidity	5% to 95% non-condensing
Storage Relative Humidity	10% to 100% non-condensing
Dimensions	65 mm x 45 mm x 41 mm (with bracket) 65 mm x 43 mm x 41 mm (without bracket)
Weight	63.5 g enclosure + 56.5 g battery = 120 g total (without bracket or probe)
Power Source	Battery: 1x C-cell LTC (3.6 V) External: 12 V DC Supply (external power variant only)

Parameter	Specification
Network Technology/Frequency Band	LoRaWAN in the following Global ISM bands[6] [2]: EU868, US915
Air Interfaces	LoRa, BLE, Wi-Fi, GNSS
Maximum Tx Power	• 15 dBm (LoRa) • 0 dBm (BLE)
Sensing Elements	GNSS receiver, Wi-Fi receiver, BLE transceiver, accelerometer, thermometer, hygrometer, magnetic hall-effect transducer, battery gauge
GNSS Constellations	• GPS L1 + GPS geostationary SBAS: EGNOS and WAAS • BeiDou B1 + BeiDou geostationary GEO/IGSO
Wi-Fi Compatibility	802.11b/g/n
Bluetooth Compatibility	BLE based on Bluetooth 5.3
LoRa RF Sensitivity	Up to -137 dBm (SF12, 125 kHz BW)
BLE Sensitivity (0.1% BER)	125 kbps: -103 dBm 500 kbps: -98 dBm 2 Mbps: -91 dBm
Accelerometer Sensitivity	Sample rate: 1, 10, 25, 50, 100, 200, 400 Hz Measurement range: ±2, ±4, ±8, ±16 *g* Precision: 16, 32, 64, 192 m*g*
LEDs	Green: Joining the network activity Red: LoRa Tx or Rx activity
Battery Gauge Features	Measures remaining capacity [%] and remaining lifetime [days]
Battery Lifetime	4.3 years[7]

1.4.1 Tracking with Geolocation

The primary purpose of the STORK is to track assets indoors and outdoors using a combination of location-tracking technologies: ***low-power GNSS***, ***Wi-Fi sniffing***, and ***BLE scanning***.

One or more geolocation scans are conducted during a *geolocation cycle*. A new geolocation cycle occurs at a regular period called the *geolocation update period*, as shown in Figure 1-4. By default, the geolocation update period is shorter when the sensor is in motion and longer when the sensor is still.

[6] Other regional variants available upon request.
[7] With default settings operating at DR3. Applicable to NA region only.

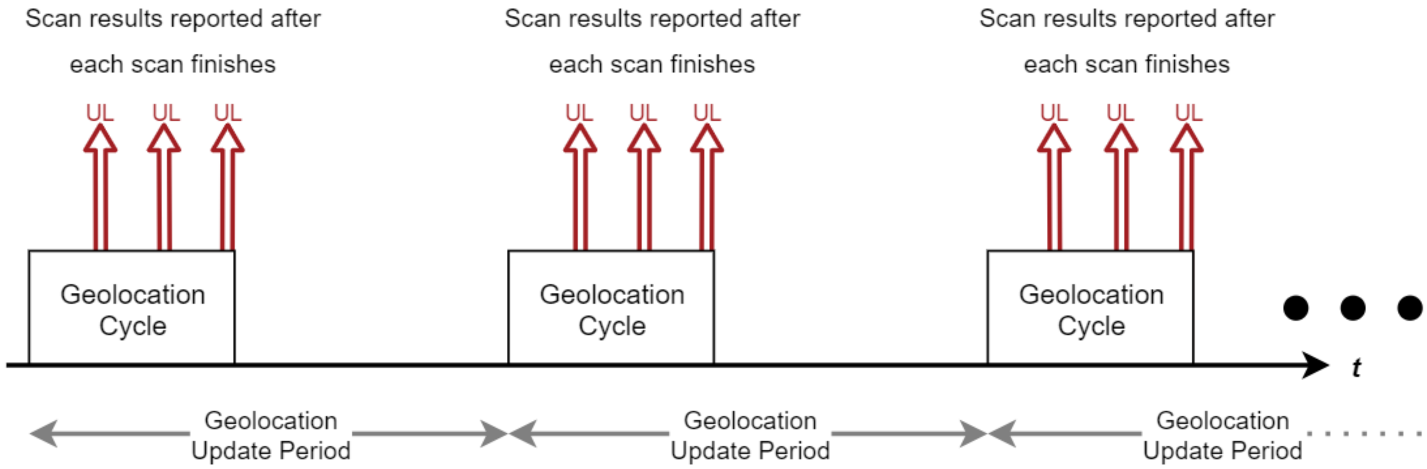

Figure 1-4: Periodic Geolocation Cycles and ULs

During a geolocation cycle, up to 3 scans can be defined and occur in sequence. After each scan concludes, if successful, the raw results are reported in a LoRaWAN UL before the next scan begins[8].

The duration of each geolocation cycle may vary from 10s of seconds to a few minutes, depending on several factors (e.g.: satellite signal strength, user configurable BLE scan duration, regional duty cycle limitations, etc.). It is important to configure the geolocation update period to be greater than the expected geolocation cycle duration, otherwise scans may not complete, and data may be lost. <u>If GNSS scanning is enabled, it is not recommended to set the geolocation update period to less than 3.5 min. If BLE scanning is enabled, it is not recommended to set the geolocation update to less than 20 s.</u>

The supported scan type options and behaviours are summarized in Table 1-5.

Table 1-5: Supported Geolocation Scan Technologies

Technology	Function	Results Format	Scan Failure Behaviour	Configurable Options
GNSS	LR1110 performs a low-power GNSS scan, then sends the scan results via LoRaWAN UL for LoRa Cloud to compute the position.	NAV message or message fragments containing satellite information.	Fail criteria: too few satellites are detected, almanac is out of date, or clock is out of sync. No UL is sent unless all other scans in the cycle also fail.	• Clock sync parameters • Almanac update parameters • Assist coordinates • Satellite constellation (GPS/BeiDou/both) • Scan mode (mobile/static)

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[8] If sending BLE scan results is paused due to regional duty cycle restrictions, the next scan (GNSS or Wi-Fi), if defined, will not begin until the duty cycle timeout expires and the BLE results are sent.

Technology	Function	Results Format	Scan Failure Behaviour	Configurable Options
Wi-Fi	LR1110 performs a Wi-Fi scan then sends the scan results via LoRaWAN UL for LoRa Cloud to compute the position.	Discovered Wi-Fi access point MAC addresses and RSSIs [dBm].	Fail criterion: less than 3 Wi-Fi access points are discovered. No UL is sent unless all other scans in the cycle also fail.	None
BLE	MCU performs a BLE scan then sends the scan results via LoRaWAN UL for the GRB to compute the position.	Discovered BLE device MAC addresses and RSSIs [dBm].	Fail criterion: 0 BLE beacons detected. UL containing an empty list is sent.	• Scan duration • Scan duty cycle • Up to 4 discovered BLE device filters

The *scan order logic* within the geolocation cycle is also configurable to allow the cycle to end upon a successful scan before the other defined scans occur. Doing so can save battery life in use-cases where the scan types can be prioritized by how likely they are to succeed, e.g.: if it is known that GNSS will be the available geolocation signal source 90% of the time. The supported scan order logic options are shown in Table 1-6.

Table 1-6: Scan Order Logic Options

A:	1st scan	→	2nd scan if 1st scan fails	→	3rd scan if 2nd scan fails
B:	1st scan	→	2nd scan	→	3rd scan if 2nd scan fails
C:	1st scan	→	2nd scan if 1st scan fails	→	3rd scan
D:	1st scan	→	2nd scan	→	3rd scan

1.4.1.1 Geolocation Strategies

The ability to define up to 3 scan types and choose 1 of 4 scan order logic options results in 12 possible configurational combinations. This combination is called the *geolocation strategy*. Of the 12 geolocation strategies, only 7 result in unique device behaviour, as shown by the green shaded boxes in Table 1-7.

Table 1-7: Geolocation Strategies

Strategy Description	Scan Order Logic	Number of Defined Scans		
		3	2	1
FALLBACK • 1st priority scan always done. • Fallback to other scan(s) upon failure. • End cycle upon successful scan.	A	**#1**	**#2**	#7
1 BACKUP • 1st and 2nd priority scans always done. • 3rd scan if both 1st and 2nd scans failed.	B	**#3**	#6	#7
2 BACKUPS • 1st priority scan always done. • 2nd and 3rd scans done if 1st scan failed.	C	**#4**	#2	#7
ALL SCANS • All defined scans always done.	D	**#5**	**#6**	**#7**

The geolocation strategy used should be tailored to the use case of the STORK deployment. Some example use-cases and strategies are:

- Delivery vehicle tracking: FALLBACK with (1) GNSS, (2) Wi-Fi, (3) BLE

  Likely to be outside for most of the time, so GNSS is likely to succeed most of the time. Wi-Fi is next most likely, then BLE.

- Pallet tracking in a multi-building site: 2 BACKUP with (1) BLE, (2) Wi-Fi, (3) GNSS

  Likely to be in an indoor BLE Beacon network most of the time, so BLE is likely to succeed most of the time. If BLE fails, try both other methods to get a position estimate.

The default geolocation strategy is fallback (scan order logic A) with all 3 scans defined in priority order GNSS, Wi-Fi, BLE. The operational flow of this strategy is depicted in Figure 1-5. All other strategy flow depictions are shown in Appendix 3.

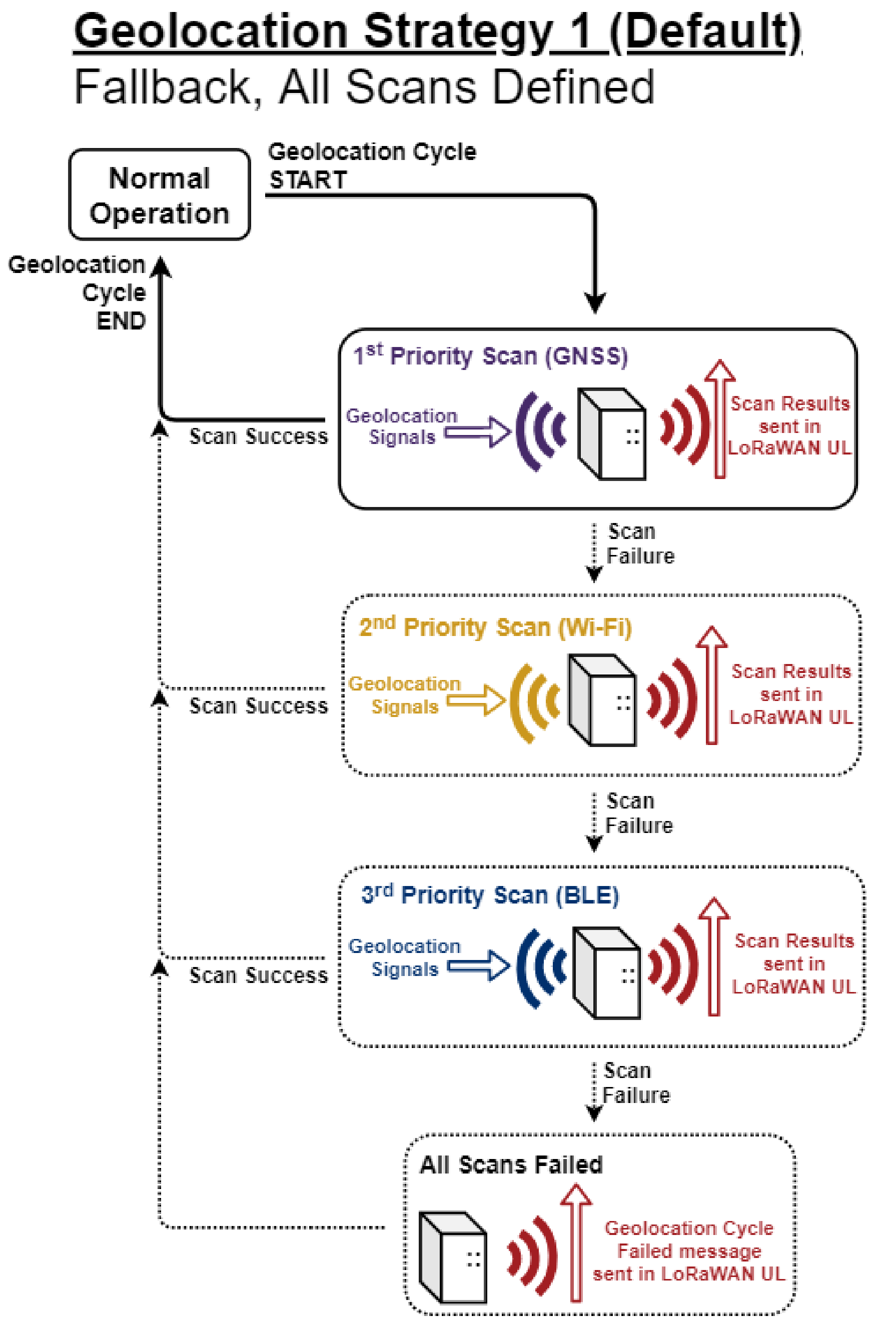


Figure 1-5: Default Geolocation Strategy Cycle Flow

With all geolocation strategies, if all scans fail, the *geolocation cycle failed* message is sent.

1.4.1.2 GNSS and Wi-Fi Operation with LoRa Cloud Resolvers

The GNSS and Wi-Fi scan results are formatted in such a way that the edge based LoRa Cloud service can resolve the sensor's position. Both UL and DL communications are exchanged between the STORK and LoRa Cloud server to transfer all the information needed for the positions to be resolvable.

For GNSS scan results to be valid and resolvable, the following are needed:

- Valid clock synchronization: The internal time of the sensor must be synchronized periodically. The sync interval, sync expiration timeout, and sync service option are all configurable.
- Valid almanac: The almanac in the sensor must be kept up-to-date. The update check period and update request UL interval are configurable.
- Assist coordinates: These help the resolver with an initial estimate of the sensor's location. These can be configured specifically by the user if desired, but the SW will automatically communicate with LoRa cloud to obtain assist coordinates upon startup if none are defined.

Other user-configurable options for GNSS scanning include the choice of satellite constellation (GPS, BeiDou, or both) and mobile or static scanning. The Wi-Fi scanning has no configurable options.

1.4.1.3 BLE Operation with LOCUS and the GRB

The BLE scan results are formatted in such a way that the TEKTELIC LOCUS application can resolve and display the sensor's position. Indoor BLE beacon networks can be built virtually in LOCUS to match the physical setup. When LOCUS receives a sensor UL with raw BLE scan data, it forwards it to the *Geolocation Resolver Backend* (GRB) cloud service, which computes and returns the position estimate within the beacon network.

For information about setting up LOCUS, refer to the TEKTELIC support portal *Knowledge Base* articles [2]. For a description of BLE scan behaviour, see the TRM.

1.4.2 Temperature and Relative Humidity Transducer

The STORK is equipped with a temperature and relative humidity (RH) transducer. Note that because the transducer element is located inside the sensor housing, sense response time will not be immediate. Vents in the front, bottom, and back of the enclosure are designed to allow ambient air to contact the transducer. Response time can be reduced by forcing air to move over the sensor in the region of the transducer opening.

Temperature and RH values can be reported on a threshold basis; a window of "good operational range" can be user-defined. High and low alarm points can be set individually for ambient temperature and RH. The sample rate for checking the transducers is user configurable with different sample rates settable if the measured value is inside or outside the normal operating window.

1.4.3 Accelerometer Transducer

The STORK supports motion sensing through an integrated 3-axis accelerometer which can optionally be disabled. The main role of the accelerometer in the is to detect motion that can indicate a change of the sensor's status from stillness to mobility, or vice versa.

The accelerometer generates an acceleration alarm when a motion event is detected that can be reported OTA. An acceleration event report is based on exceeding a defined acceleration alarm threshold count in a defined alarm threshold period. These thresholds can be customized such that there will not be multiple reports for a single event, depending on the definition of an event in a particular use case. An alarm event can only be registered after a configurable grace period elapses since the last registered alarm event. Carefully setting the grace period is important and prevents from repeatedly registering an accelerometer event.

In addition to alarms, detected motion can trigger the transitions between geolocation update periods. That is, when the ***Accelerometer Assist*** function is enabled,

- When new motion is detected:
  - A new geolocation cycle begins immediately.
  - New geolocation cycles occur periodically according to the MOBILE geolocation update period.
- When the motion has ended:
  - A new geolocation cycle begins immediately.
  - New geolocation cycles occur periodically according to the STILL geolocation update period.

The geolocation update periods are both configurable.

For asset tracking, Accelerometer Assisted geolocation scans help to get location updates at appropriate rates: faster when the asset is moving and slower when still. Accelerometer Assist also helps to update the location at 2 critical times; when assets leave old locations and settle in new ones. Accelerometer Assist is enabled by default.

The accelerometer can also be polled periodically for its output acceleration vector for applications in which the sensor's orientation is of interest.

1.4.4 BLE Beacon Mode

The STORK supports a *beacon mode* function as an alternative to geolocation tracker mode. The default mode of the sensor is tracker mode, so it must be switched into beacon mode.

When in beacon mode, no geolocation scans occur and the BLE operates in Tx only. It sends out periodic *advertisements* which are small packets of data. These packets are discoverable by other STORKs operating in tracker mode, as well as any other device capable of BLE scanning.

When in beacon mode, the sensor is still LoRaWAN-backhauled. That is, it can still send sensor data in LoRaWAN ULs and be reconfigured through LoRaWAN DLs. Furthermore, all other transducer functions are accessible in either beacon or tracker mode.

After a beacon joins the LoRaWAN network, it begins broadcasting BLE advertisements. This continues throughout normal operation as a background process.

The *advertising interval* is the time between the beginnings of consecutive advertisement transmissions as shown in Figure 1-6. It is user-configurable in units of [ms].

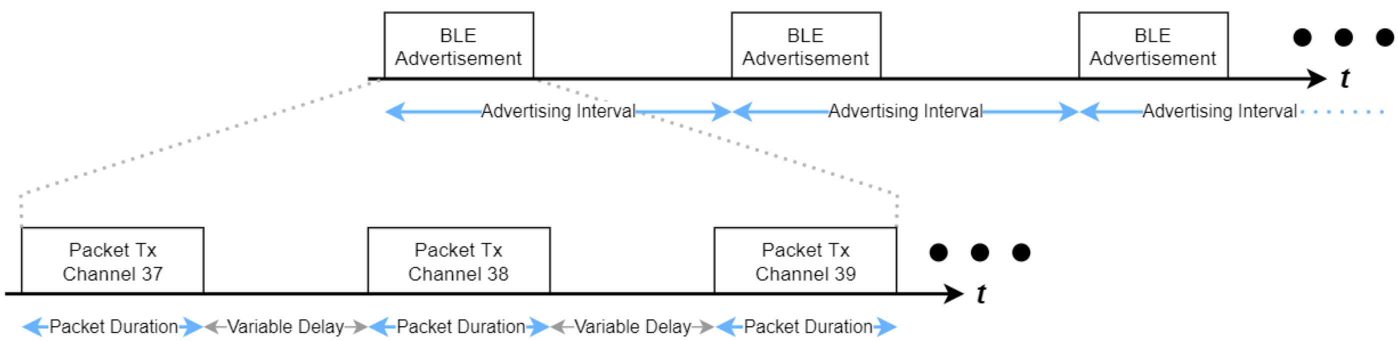


Figure 1-6: The BLE Advertisement Scheme

Figure 1-6 also shows that each single BLE advertisement comprises 3 individual packet transmissions, sent one after another on BLE channels 37, 38, and 39 [3]. This is to maximize the chances of a BLE device scanning on a single channel receiving 1 packet per advertising interval.

In addition to the advertising interval, the advertisement *Tx power* level is also a configurable operational parameter.

The BLE advertisement and LoRa radio transmission are mutually exclusive and never overlap. If any reporting becomes due, the BLE advertisements are paused while the LoRa activity is occurring.

The BLE advertising packet formatting supports 3 major BLE standards: iBeacon, Eddystone UID, and Eddystone TLM. By default, only iBeacon is enabled.

1.4.5 Magnetic Sensor

The STORK is equipped with a magnetic hall-effect sensor[9]. Since the enclosures are fully sealed, there is no ability to have a battery pull-tab or reset button pinhole. The magnetic sensor therefore is included to address these purposes:

1. To wake the device from sleep (the sensors are shipped in a state of DEEP SLEEP).
2. To put the device to sleep.
3. To reset the device.
4. To force a LoRaWAN UL.

The position on the exterior of the enclosure on which the magnet must be placed to activate the reed switch is shown in Figure 1-3.

For more information on how to wake the device from sleep, refer to Section 2.4. For more information on how to use the magnetic sensor for the other purposes, refer to the TRM.

[9] A magnet is not included with the STORK.

2 Installation

2.1 Included Product and Installation Material

The following items are shipped with each sensor:

- 1x sensor inside an enclosure with 3.6 V C-cell LTC battery installed.
- 1x corresponding sensor Quick Start Guide.
- 1x mounting bracket.

2.2 Safety Precautions

The following safety precautions should be observed for all STORK variants:

- All installation practices must be in accordance with the local and national electrical codes.
- Replace only with approved batteries (see §2.6).
- The external power variant (T0008396) is intended for indoor use only.
- The sensor contains a single LTC C-cell battery. When used correctly, lithium batteries provide a safe and dependable source of power. However, if they are misused or abused, leakage, venting, explosion, and/or fire can occur. The following are recommended safety precautions for battery usage [4].

  - **Keep batteries out of the reach of children.**
  - **Do not allow children to replace batteries without adult supervision.**
  - **Do not insert batteries in reverse.**
  - **Do not short-circuit batteries.**
  - **Do not charge batteries.**
  - **Do not force discharge batteries.**
  - **Do not mix batteries.**
  - **Do not leave discharged batteries in equipment.**
  - **Do not overheat batteries.**
  - **Do not weld or solder directly to batteries.**
  - **Do not open batteries.**
  - **Do not deform batteries.**
  - **Do not dispose of batteries in fire.**
  - **Do not expose contents to water.**
  - **Do not encapsulate and/or modify batteries.**
  - **Store unused batteries in their original packaging away from metal objects.**
  - **Do not mix or jumble batteries.**

2.3 Unpacking and Inspection

The following should be considered during the unpacking of a new sensor.

1. Inspect the shipping carton and report any significant damage to TEKTELIC.
2. Unpacking should be conducted in a clean and dry location.
3. Do not discard the shipping box or inserts as they will be required if a unit is returned for repair or reprogramming.

2.4 Commissioning and Activation

Each sensor has a set of commissioning information that must be entered into the network server for the sensor to be able to join the network and begin normal operation once activated. For instructions on how to do this please refer to the Network Server Quick Start Guide (available online in the *Knowledge Base*) [5]. The commissioning info should be included on the package labels.

The sensor is shipped in a secured enclosure with the battery preinstalled in a state of DEEP SLEEP. The magnetic activation/reset pattern is illustrated in Figure 2-1. A "magnet presence" is achieved by placing a sufficiently strong magnet[10] against the enclosure at the magnetic activation site as shown in Figure 1-3. A "magnet absence" is achieved by taking the magnet away from the enclosure. Figure 2-1 shows that the pattern involves sustaining a "magnet presence" continuously for at least 3 s but less than 10 s.

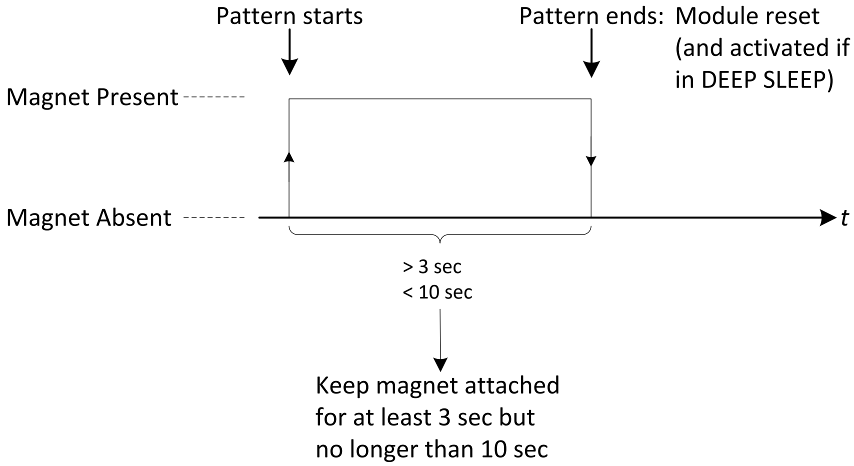


Figure 2-1: The Magnetic Activation/Reset Pattern.

When the STORK is activated it will display an LED indication (described in §3.3) to show that it is beginning to join the network. It may take up to 10 seconds between the time of activation and the beginning of the LED join attempt pattern.

Once activated, the sensor will automatically begin the join process. To turn the sensor off, the battery must be removed. To reset the device, the magnetic activation/reset pattern can be applied again.

[10] A magnet is not included with the STORK.

2.5 Mounting Procedure

1. The mounting bracket needs to be secured to a wall or another solid surface by using an adhesive or mounting screws. The mounting bracket can be seen in the back view in Figure 1-3.

    a. For use cases that require easily removable, less permanent mounting, ensure that the “SOFT LOCK” indication is installed with the arrows pointing up.

    b. For use cases that require more securely fastened and permanent mounting, ensure that the “HARD LOCK” indication is installed with the arrow pointing up.

    c. After the bracket has been secured, the sensor can be mounted by sliding the enclosure into the bracket ridges until a click is heard, indicating it is fully inserted.

2.6 Battery Replacement

The battery cover is marked with a battery symbol and uses Phillips Head H1 screws. This cover needs to be removed to replace the battery.

1. In a non-hazardous location, remove the battery cover by unscrewing the 4x phillips head screws using a size #1 phillips head screwdriver (see Figure 2-2).

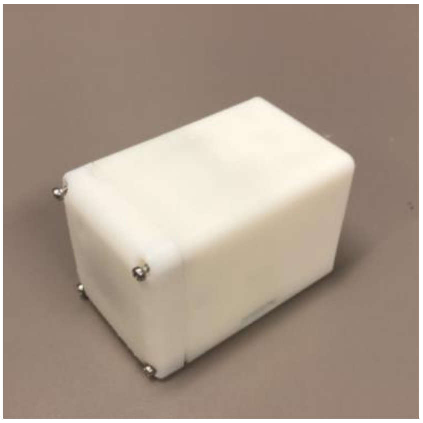


Figure 2-2: Removing the Battery Cover Screws

2. Remove and the used battery and replace it with a new 3.6V XENO XL-145F battery **ONLY**. When inserting the new battery, insert the negative terminal side first. The battery contact on the battery cover is the positive contact and is marked with a plus-sign (**+**) as shown in Figure 2-3.

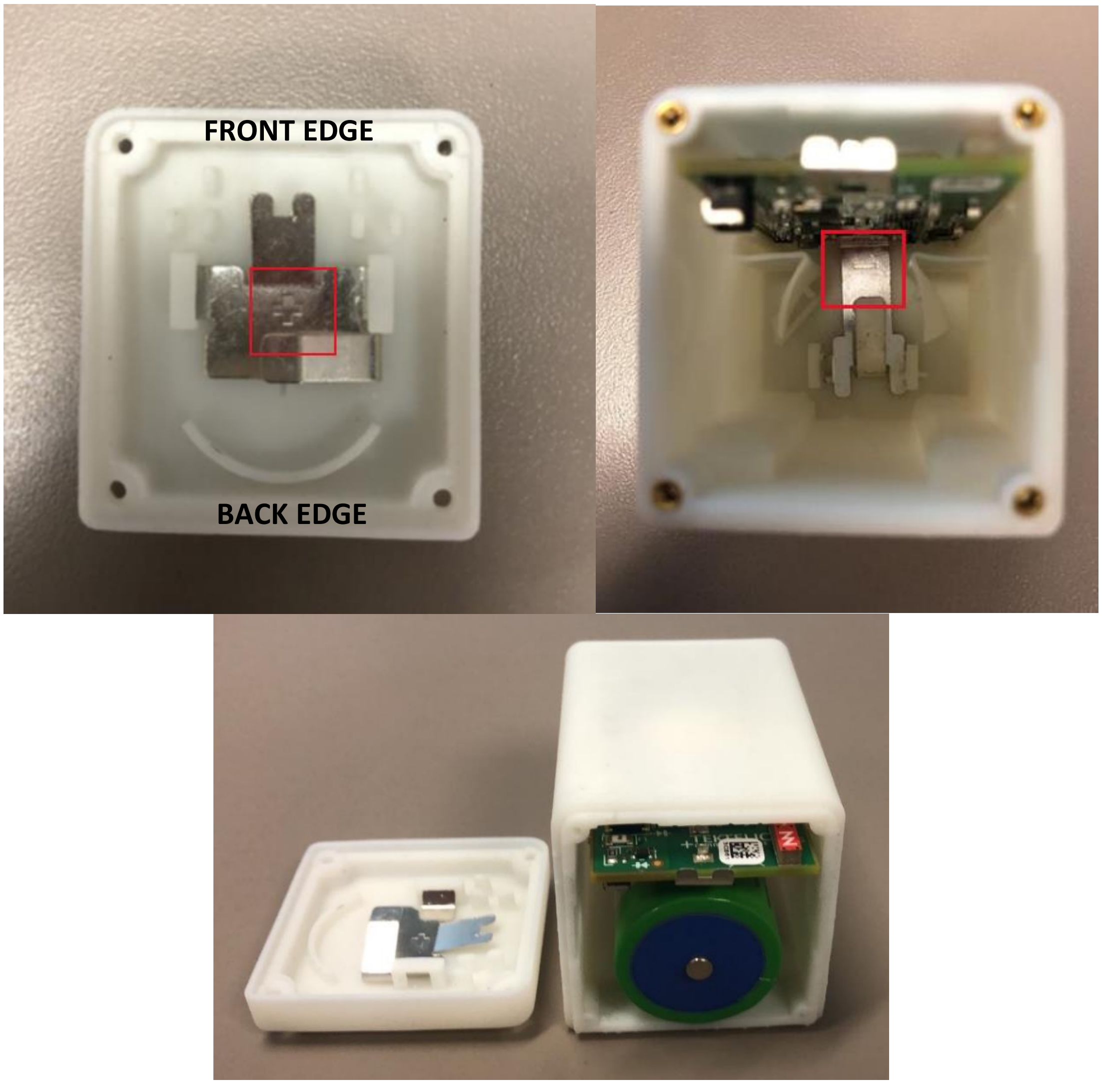


Figure 2-3: Polarity Markers and Battery Insertion

3. Check that the gasket is undamaged and still properly seated with an adhesive on the battery cover.

4. Before reattaching the battery cover, ensure the proper orientation of the cover with respect to the front and back of the sensor chassis. The front of the sensor has rounder corners, and the back of the sensor has sharper corners, as seen in Figure 2-3.

5. Reassemble the cover to the chassis by using the 4x phillips head screws, using a #1 size screwdriver and up to 0.23 Nm of torque.

3 Operation, Alarms, and Management

3.1 Configuration

The STORK supports a full range of OTA configuration options. Specific technical details are available in the corresponding TRM documents. All configuration commands need to be sent OTA during the sensor's DL Rx windows.

3.2 Default Configuration

Table 3-1 lists the default reporting behaviour of the STORK. Reporting behaviour can be changed from default through OTA DL commands.

Table 3-1: Default Reporting Periods

Reported Data	Reporting Period
Battery Data	24 hours
Geolocation Update Data	1 hour when STILL 10 minutes when MOBILE
Ambient Temperature	1 hour
Ambient Relative Humidity	1 hour
Acceleration Vector	Disabled

3.3 RF LED Behaviour

The LED behaviour is not user configurable.

The LEDs are normally off. Their blinking patterns reflect different actions and states of the sensor. At a high-level, the main patterns are summarized in Table 3-2. The detailed sequence and timings for each are described in the following subsections.

Table 3-2: Summary of LED Patterns

LED Pattern	Meaning
GREEN blinking rapidly and single **RED** flash every 10 s	JOIN mode; attempting to join the network
Single **RED** flash	UL sent
Single **GREEN** flash	DL received
3 quick **RED** flashes	Entering DEEP SLEEP

3.3.1 Power-On and Network Join Patterns

When the sensor is activated or reset:

1. Both **GREEN** and **RED** are OFF for approximately 0.5 s after any reset occurs.
2. Upon startup, the SW conducts its POST. Both **GREEN** and **RED** are turned on when the POST begins.
3. When the POST ends (about 2 s), both **GREEN** and **RED** are turned off. Immediately following, the sensor will do 1 of 2 things, depending on the POST result:
    a. If the POST passes, **GREEN** is toggled ON and OFF 3 times: every 100 ms for 0.6 s, as shown in Figure 3-1. In this case, the LED pattern proceeds to step 4.
    b. If the POST fails, **RED** is toggled ON and OFF 3 times: every 100 ms for 0.6 s, as shown in Figure 3-1. In this case, the device restarts and the LED pattern begins again at step 1 after approximately 4 s.

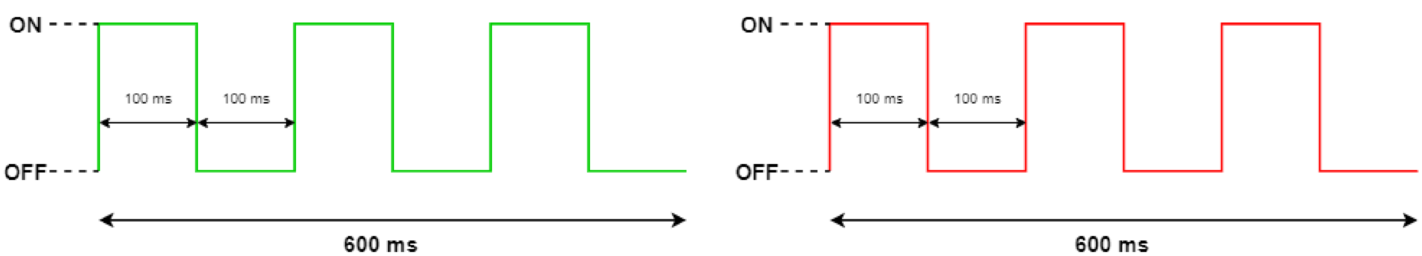


Figure 3-1: The GREEN POST Pass (left) and RED POST Failure (right) LED Patterns

4. After a successful POST, both **GREEN** and **RED** are turned off. Immediately following this, the sensor will enter JOIN mode and begin attempting to join the network. For the first hour[11]:
    a. **GREEN** is toggled ON and OFF every 50 ms for the first hour.
    b. **RED** flashes just once:
        i. with a pulse duration of 25 ms right after transmitting a JOIN REQUEST. This occurs at approximately 10 s intervals at the beginning of the join process, but

[11] The very first time a sensor is activated out of the box or after a battery replacement, there might be some ramp-up time required due to battery passivation. See §**Error! Reference source not found.** for details.

at decreasing regularity the longer the join process continues due to battery saving measures and possible duty-cycle limitations in certain regions [6].

ii. with a pulse duration of 100 ms right after receiving a JOIN ACCEPT. This will occur once, after which, the device will have joined the network and normal operation begins.

If the sensor has been unsuccessfully trying to join for more than an hour, it enters *join back-off* to conserve power. While the sensor still attempts to join, **GREEN** stops flashing and **RED** flashes twice (ON time: 10 ms, OFF time: 10 ms) every 8 s. The JOIN LED pattern is shown in Figure 3-2

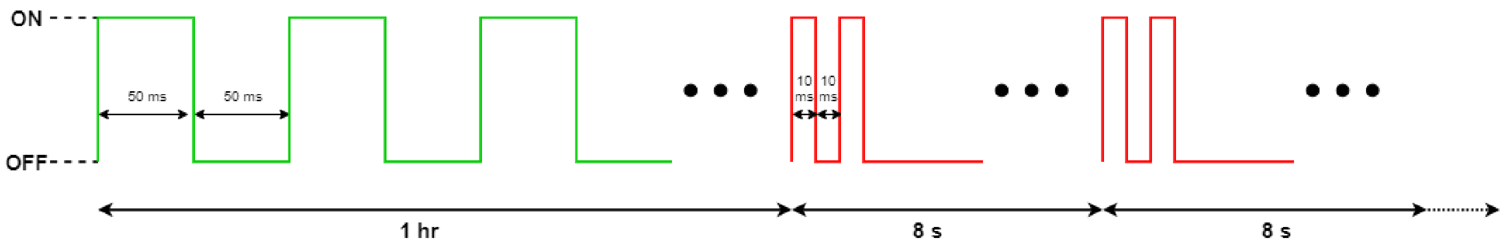


Figure 3-2: The LED Patterns During JOIN Mode

3.3.2 Normal Operation Patterns

After the Sensor has joined the network:

a. **RED** flashes just once with a pulse duration of 25 ms right after transmitting an uplink.

b. **GREEN** flashes just once with a pulse duration of 100 ms right after receiving a downlink.

3.3.3 DEEP SLEEP and Magnetic Reset Patterns

The sensor displays an LED indication when it is brought out of DEEP SLEEP or reset by applying the magnetic pattern. The following LED pattern is displayed about 3 sec after the pattern is applied:

1. **GREEN** is turned ON for 75 ms, then turned OFF.

2. After a 100-500 ms pause while the device resets, the normal Power-On and Network Join LED patterns described in §3.3.1 occur.

There is another LED pattern for when the device is put back into DEEP SLEEP. The following LED pattern is displayed about 3 s after the pattern is applied:

1. After a 100-500 ms pause while the device resets, the Power-On POST LED patterns described in steps 1-3 in §3.3.1 occur.
2. Immediately, **RED** is toggled ON and OFF 3 times: every 100 ms for 0.6 sec as shown in Figure 3-3.

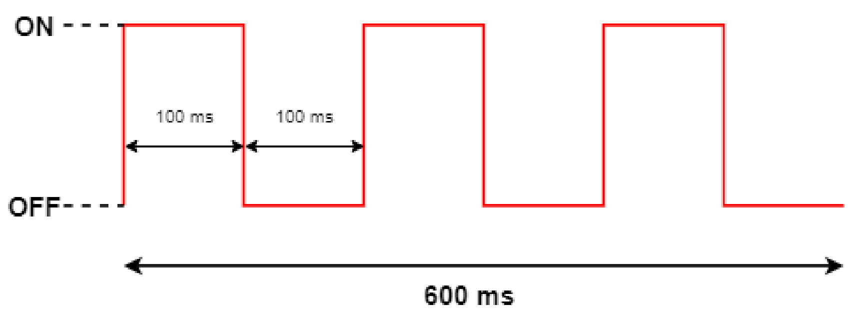


Figure 3-3: The RED LED Pattern Before Entering DEEP SLEEP

3.4 Reset Function

The STORK capable of a physically triggered reset. This type of reset powers down the MCU and restarts it, causing the network join procedure to begin again. The reset is triggered by applying the magnetic pattern as shown in Figure 2-1. While this pattern causes the sensor to wake from deep sleep before activation, during normal operation this pattern causes a reset.

NOTE: Shutting down or resetting the sensor will cause all unsaved user configurations to be lost. Save the desired configuration to the sensor flash before powering off or resetting.

4 Compliance Statements

Federal Communications Commission:

This device complies with Part 15 of the FCC Rules [7]. Operation is subject to the following two conditions:

1. This device may not cause harmful interference, and
2. This device must accept any interference received, including interference that may cause undesired operation.

To comply with FCC exposure limits for general population / uncontrolled exposure, this device should be installed at a distance of 20 cm from all persons and must not be co-located or operating in conjunction with any other transmitter.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment. This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in an industrial installation. This equipment generates uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Innovation, Science and Economic Development Canada (Industry Canada):

This device contains licence-exempt transmitter(s)/receiver(s) that comply with Innovation, Science and Economic Development Canada's licence-exempt RSS(s) [8]. Operation is subject to the following two conditions:

i. This device may not cause interference, and

ii. This device must accept any interference, including interference that may cause undesired operation of the device.

This device should be installed and operated with minimum distance 0.2 m from human body.

L'émetteur/récepteur exempt de licence contenu dans le présent appareil est conforme aux CNR d'Innovation, Sciences et Développement économique Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes:

(1) L'appareil ne doit pas produire de brouillage.

(2) L'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Cet appareil doit être installé et utilise à une distance minimale de 0.2 m du corps humain.

California Proposition 65:

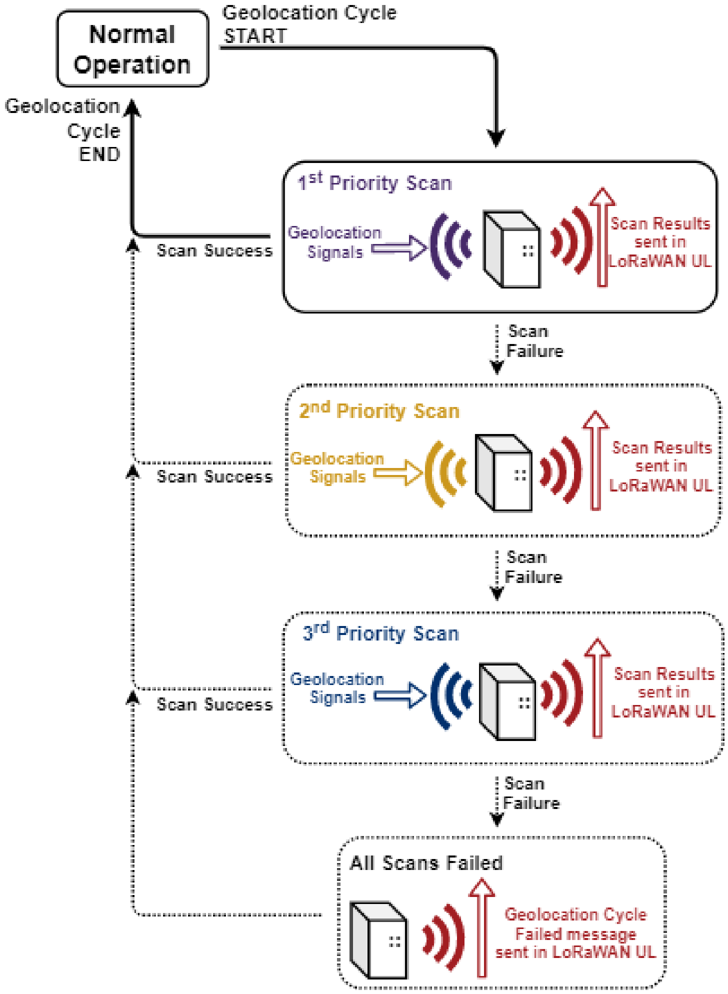
⚠ **WARNING:** This product can expose you to chemicals including lead, nickel, and carbon black, which are known to the State of California to cause cancer, birth defects or other reproductive harm. For more information, go to www.P65Warnings.ca.gov [9].

Appendix 1 - List of Geolocation Strategies

Solid lines: process always done. Dotted lines: process done under certain conditions.

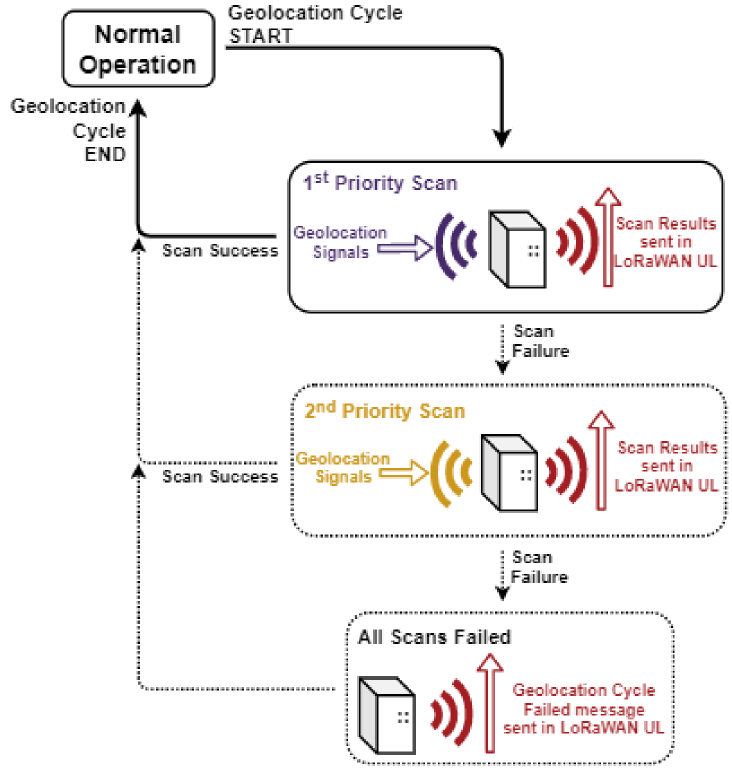
Geolocation Strategy 1

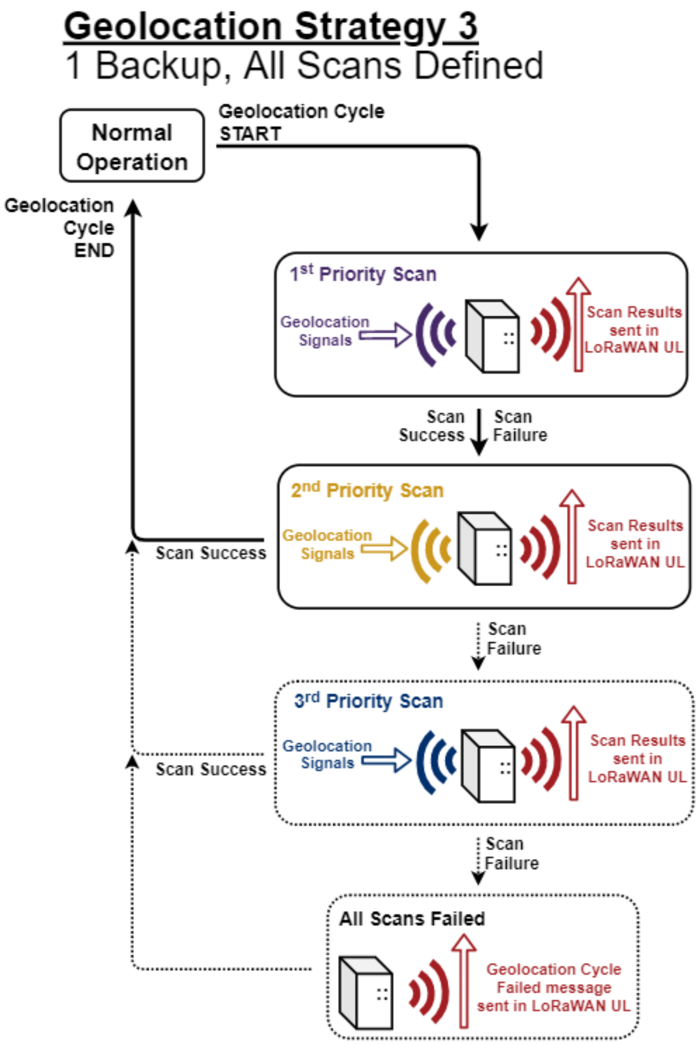
Fallback, All Scans Defined

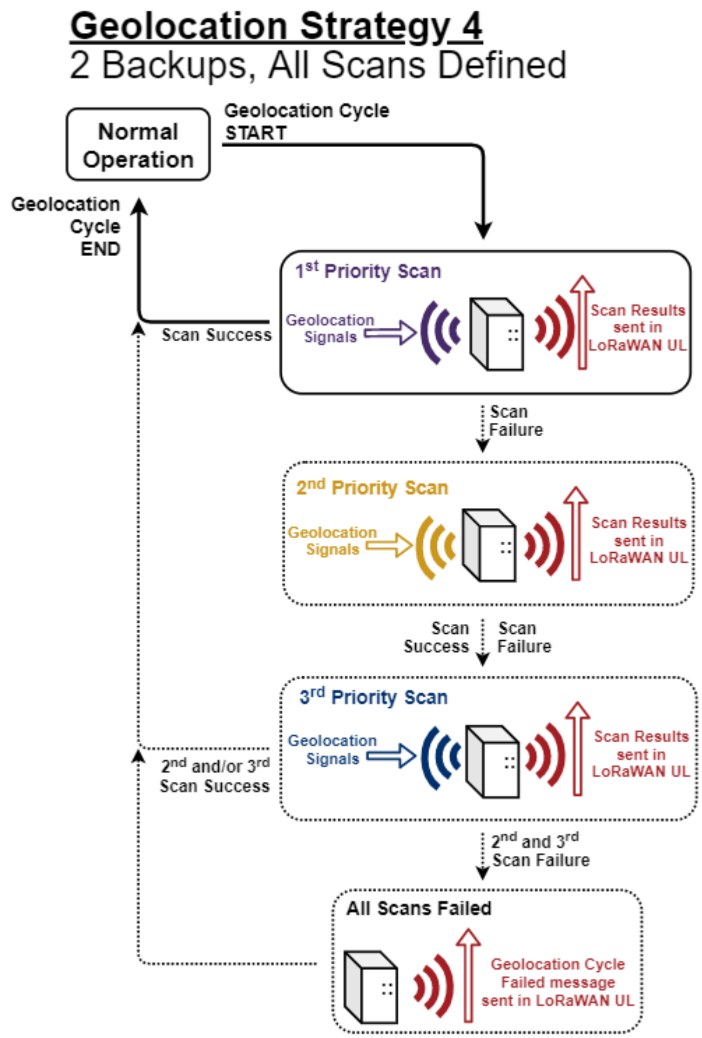


Geolocation Strategy 2

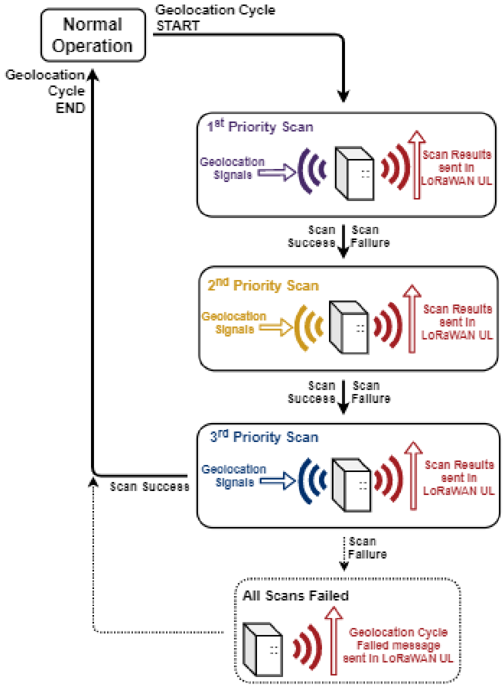
Fallback, 2 Scans Defined



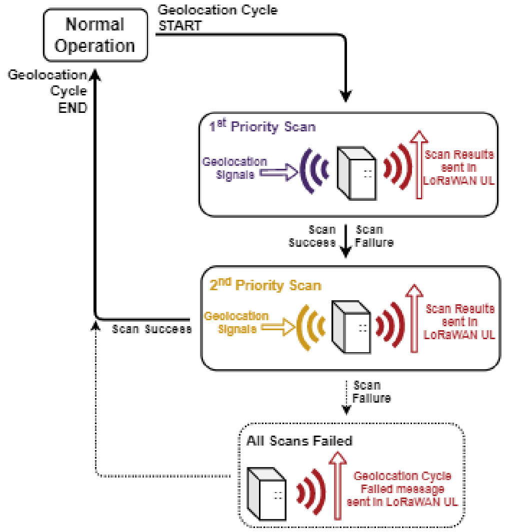

Geolocation Strategy 3
1 Backup, All Scans Defined
Normal Operation
Geolocation Cycle START
Geolocation Cycle END
1st Priority Scan
Geolocation Signals
Scan Results sent in LoRaWAN UL
Scan Success
Scan Failure
2nd Priority Scan
Geolocation Signals
Scan Results sent in LoRaWAN UL
Scan Success
Scan Failure
3rd Priority Scan
Geolocation Signals
Scan Results sent in LoRaWAN UL
Scan Success
Scan Failure
All Scans Failed
Geolocation Cycle Failed message sent in LoRaWAN UL


Geolocation Strategy 4
2 Backups, All Scans Defined
Normal Operation
Geolocation Cycle START
Geolocation Cycle END
Scan Success
1st Priority Scan
Geolocation Signals
Scan Results sent in LoRaWAN UL
Scan Failure
2nd Priority Scan
Geolocation Signals
Scan Results sent in LoRaWAN UL
Scan Success
Scan Failure
3rd Priority Scan
Geolocation Signals
Scan Results sent in LoRaWAN UL
2nd and/or 3rd Scan Success
2nd and 3rd Scan Failure
All Scans Failed
Geolocation Cycle Failed message sent in LoRaWAN UL

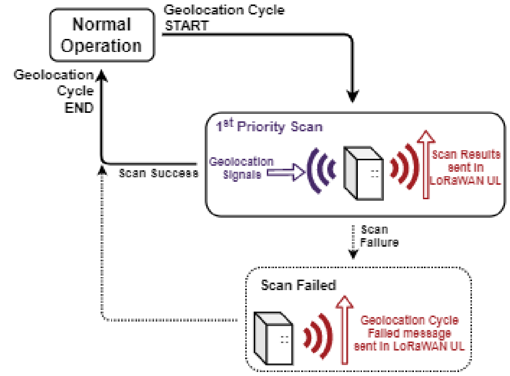
Geolocation Strategy 5
All Scans, All Scans Defined



Geolocation Strategy 6
All Scans, 2 Scans Defined



Geolocation Strategy 7
All Scans, 1 Scan Defined



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