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STORK

Technical Reference Manual (TRM)

Document Type	Technical Reference Manual
Document Number	T0008710_TRM
Document Version	v1.0
Product Name	STORK
Product Codes	T0008375 (1x C-Cell)
Release Date	September 13, 2023

Table of Contents

List of Tables

List of Figures

Acronyms and Glossary

ABP .... activation by personalization
ADR..... .... adaptive data rate
B .... byte
BeiDou .... BeiDou Navigation Satellite System (BDS)
BD_ADDR..................... Bluetooth Device Address
BLE...... .... Bluetooth Low Energy
CRC .... cyclic redundancy check
DC .... data converter
DL........ .... downlink
DR .... data rate
DZ .... designated/danger zone
EAR .... EMERGENCY App Request
EB........ .... emergency button
EIRP .... effective isotropically radiated power
EU .... European Union
flash.... .... a non-volatile memory, referring to either the MCU (internal) flash—containing application and configuration settings—or the GNSS receiver (external) flash memory—containing GNSS logs
FSM..... .... finite state machine
FW .... firmware
g .... gravity (unit of acceleration ≈ 9.8 m/s^2)
Galileo .... EU GNSS
GLONASS...................... GLObal NAvigation Satellite System
GNSS... .... Global Navigation Satellite System
GPS .... Global Positioning System
ID .... identity/identifier
IoT....... .... Internet of Things
IP .... Ingress Protection
JSON ... . JavaScript Object Notation
LAP...... .... lower address part
LED...... .... light-emitting diode
LID....... .... lithium-iron disulfide
LoRa.... .... a patented "long-range" IoT technology acquired by Semtech
LoRAMAC..................... LoRaWAN MAC
LoRaWAN .... LoRa wide area network (a network protocol based on LoRa)
LoS .... line-of-sight
LSb .... least significant bit
LSB .... least significant byte
MAC.... .... Medium Access Control

MB .... Mute Button
MCU.... .... microcontroller unit
min...... .... minute(s)
MSb .... most significant bit
MSB .... most significant byte
NA....... .... North America
NAR..... .... NORMAL App Request
NS .... network server
OTA..... .... over-the-air
OTAA .. .. OTA activation
OUI .... organizationally unique identifier
POST ... . power-on self-test
QZSS.... .... Quasi-Zenith Satellite System, Japanese SBAS for GPS
RF........ .... radio frequency
RFU .... reserved for future use
RO....... .... read-only
R/W .... read/write
RSSI..... .... received signal strength indicator
Rx........ .... receiver
SB........ .... sleep button
SBAS.... .... Satellite-Based Augmentation System
sec....... .... second(s)
SH .... safety hook
SW .... software
transducer.................... a sensing element in the STORK, such as the accelerometer
TRM .... technical reference manual (this document)
Tx........ .... transmitter
UL .... uplink
UTC..... .... Coordinated Universal Time
ver...... .... Version
STORK . ... Wearable GPS Sensor

1 Introduction

Stork is a low-power LoRaWAN device that can track assets indoors and outdoors while being more battery efficient than traditional GPS devices. Stork is ideal for monitoring and reporting geolocation using GNSS or Wi-Fi in industrial environments using an ultra-low powered indoor and outdoor position tracking system. The GNSS receiver of the Stork supports the following constellations:

- GPS L1 + GPS geostationary SBAS: EGNOS and WAAS
- BeiDou B1 + BeiDou geostationary GEO/IGSO

The Wi-Fi receiver returns MAC addresses and their respective RSSIs of the nearby Wi-Fi access points in an energy efficient manner.

Stork also supports BLE as an alternative positioning system and is capable of scanning and reporting neighboring BLE devices (up to the LoS range of approximately 100 m) to provide location information. This can be particularly helpful in indoor environments with poor GNSS satellite coverage. Stork is also equipped with an accelerometer, which, as a motion detector, helps detecting the sensor status change between stillness and mobility to optimize power usage by reporting the location when and how often needed. The accelerometer output vector can also be reported periodically if knowledge of the sensor orientation is of interest. Additional sensing functions on the Stork include on-board temperature, and the battery voltage.

The core design includes a low power, IoT targeted MCU, STM32WB55CEU6, with built-in Bluetooth module, an ultra-low powered, lora enabled, transceiver chip from Semtech, LR1110, that provides geolocation and Wi-Fi tracking applications, an ultra-low-power high-performance accelerometer from STMicroelectronics, LIS3DH, and a Sensirion SHTC3 ambient temperature and humidity sensor. It also has a current sense resistor for measuring the input battery current and estimating battery life.

Stork is built upon the LoRa wireless communications standard. This technology provides a low bandwidth, low power, long range (up to 2 km NLOS and more than 22 km LOS) means of transmitting data. The LoRa protocol has been developed with wireless sensing in mind, and to enable new means of gathering telemetry in numerous environments. It also supports LoRa and (G)FSK modulations. The device is highly configurable over the 150 MHz-960 MHz ISM bands to meet different application requirements utilizing the global LoRaWAN® Standard or proprietary protocols.

Stork has one basic function: gather data from the GNSS or Wi-Fi or BLE modules and transmit the data, via LoRa, to a NS which then forwards it to their respective position resolver components that returns position fixes that can be visualized using a third-party application. The data from other transducers like SHTC3/data from the coulomb counter that uses the current Sense resistor is sent directly to the third-party application through the NS.

Stork is a GNSS capable LoRaWAN IoT sensor running on 1X C-CELL batteries and packed into a small IP67 enclosure.

Table 1-1: STORK HW Models

Part Number			Description
Level 1 (module)	**Level 2 (PCBA)**	**Level 3 (PCB)**	
T0008375			Module, Stork, 1X C-Cell, LoRa
	T0008376		COVER, AMAZON BLE-GPS-LORA TRACKING SENSOR, C CELL
	T0008377		CHASSIS, AMAZON BLE-GPS-LORA TRACKING SENSOR, C CELL
	T0008395		BACK COVER, AMAZON BLE-GPS-LORA TRACKING SENSOR. EXTERNAL POWER
	T0008357		PCBA, AMAZON BLE-GPS-LORA TRACKING SENSOR
		T0008356	PCB, AMAZON BLE-GPS-LORA TRACKING SENSOR

Table 1-2: STORK Region Specific Variants

LoRaWAN Region	Corresponding HW Variant
EU868	T0008375
US915	

Note: Other LoRaWAN regions are available on request.

1.1 Installations

The following items are shipped with each sensor:

- 1x sensor inside an enclosure with 3.6V C-cell LTC battery installed.
- 1x user manual document.
- 1x mounting bracket (only for variants with mounting).
- 1x small magnet (only for C-cell variants).

1.2 Safety Precautions

The following safety precautions should be observed when operating the stork Sensor:

- All installation practices must be in accordance with the local and national electrical codes.
- Replace only with approved batteries
- The following sensor variants are intended for indoor use only: T0006779, T0006905, T0007126, T0007127, T0007128, T0007126, T0007327, T0007378, T0007379, T0007380.

- The Sensor contains an 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 [1]
    - 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.

1.3 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 re-configuration.

1.4 Commissioning and Activation

Each sensor has a set of commissioning information that must be entered into the network server in order 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*) [2].

The sensor is shipped in a secured enclosure with the battery preinstalled. The device is shipped in a state of deep sleep. The included magnet can be used to wake the sensor from sleep by applying the magnetic activation pattern at the location specified on the device in Figure 1-1. The magnetic pattern is illustrated in Figure 1-2.A “magnet presence” is achieved by attaching the magnet to the enclosure at the magnet symbol. A “magnet absence” is achieved by taking the magnet away from the enclosure. Figure 1-2 shows that the pattern involves sustaining a “magnet presence” continuously for at least 3 s but less than 10s. See section 2.4 for more information on how to wake up the sensor.

Figure 1-1: Sensor’s front view showing the location for applying magnetic pattern

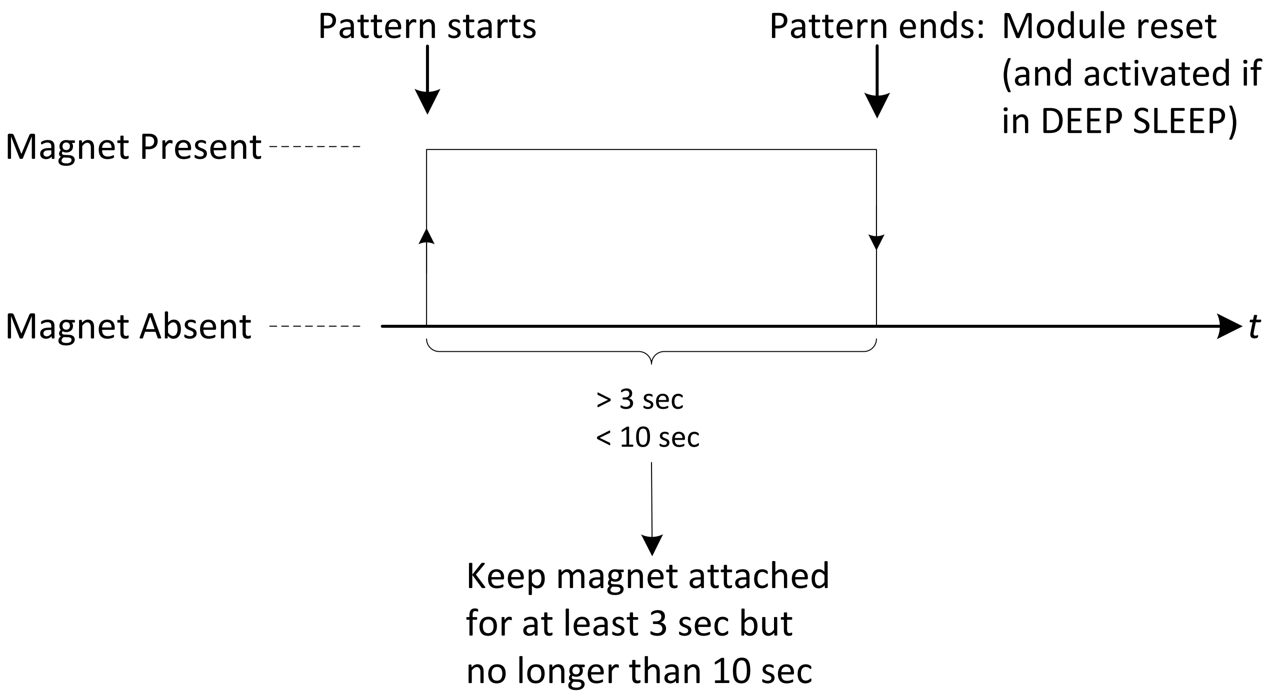


Figure 1-2: Stork's Magnetic Activation Pattern

When the sensor is activated, it displays an LED indication 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. The LED boot-up and join procedure is as follows.

1. Both LEDs will come on briefly when power is first applied.
2. After a small delay (< 1 s) the LEDs will turn off and one of them will blink briefly.
    a. If the green system LED blinks, then all health checks on the board passed.
    b. If the red LoRa LED blinks, then one of the health checks failed. Consider replacing the battery, or moving the sensor to an environment within temperature range.
3. 8 seconds after the boot pattern, the join procedure will begin. During this time the green system LED will blink continuously until the sensor has joined a network.
4. The red LoRa LED will now blink whenever LoRa activity occurs on the sensor (transmitting or receiving packets, including the join request packets).

During normal operation,

- The red LoRa LED will blink whenever LoRa activity occurs on the sensor (transmitting or receiving packets), and

NOTE: Any other LED pattern behavior not described above most likely indicates a low battery. For example, if steps 1-2 repeat continuously, the battery no longer has enough charge to power the join procedure.

1.5 Battery Replacement

The battery cover is marked with a battery symbol and uses Phillips Head H1 screws. This is the cover that 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 as shown in Figure 1-3

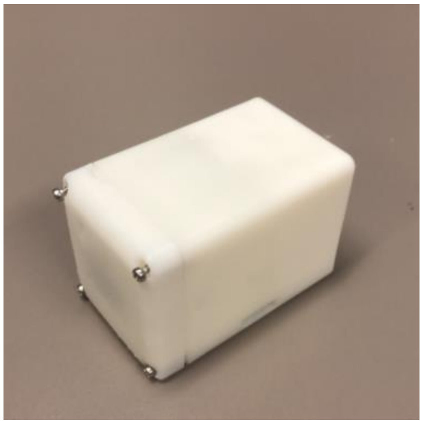
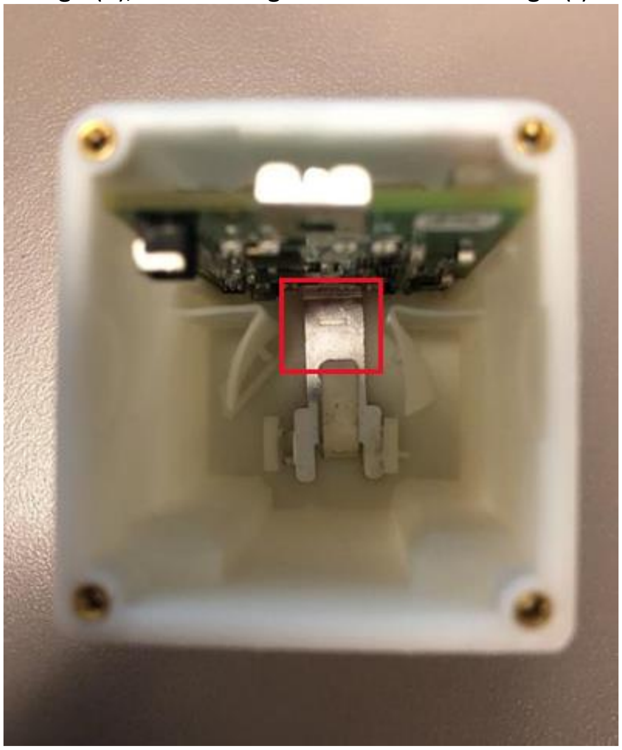


Figure 1-3: Removing the Battery Cover Screws

2. Remove 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 contacts are marked with their proper polarities (see Figure 1-4 with the positive terminal marked with a plus-sign (**+**), and the negative with a minus-sign (**-**).



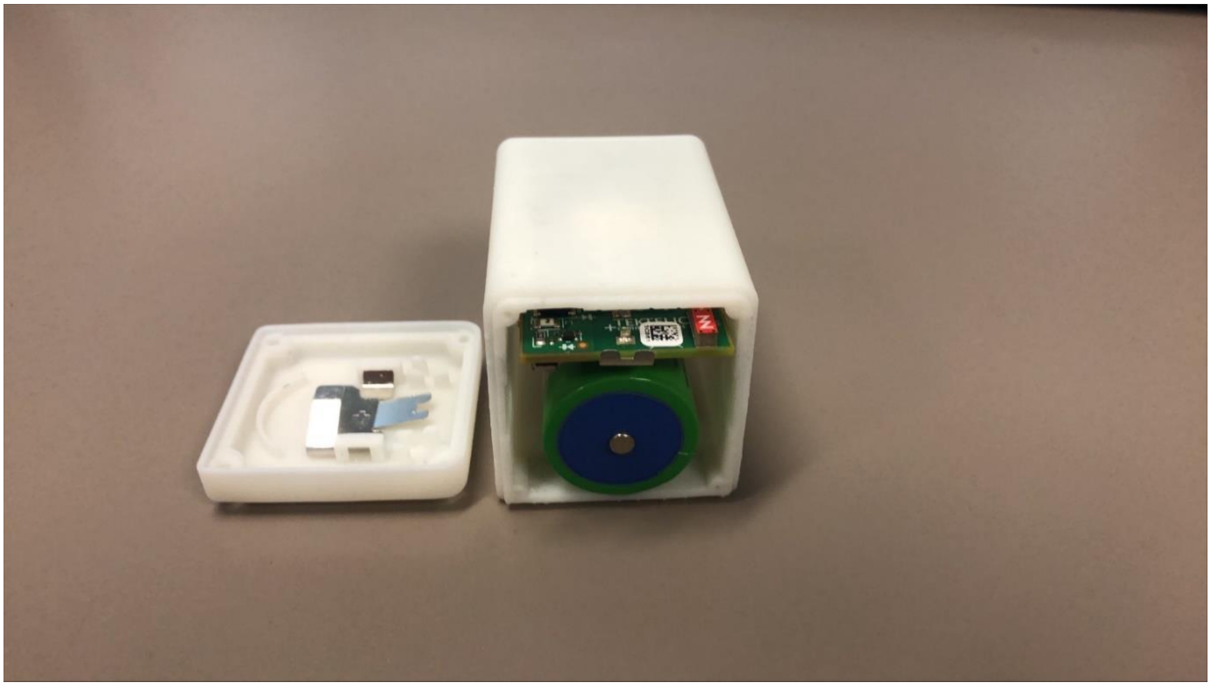


Figure 1-4: Battery Polarity Markers and Insertion

3. Check that the positive terminal contact is undamaged and still properly seated on the battery cover. It should look similar to Figure 1-5

Figure 1-5: Positive Terminal on Battery cover

4. Before reattaching the battery cover, ensure the proper orientation of the cover by placing the battery symbol next to the mounting feature.

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.

2 System Operations

2.1 Overview

Figure 2-1 shows the high-level system overview for Stork.

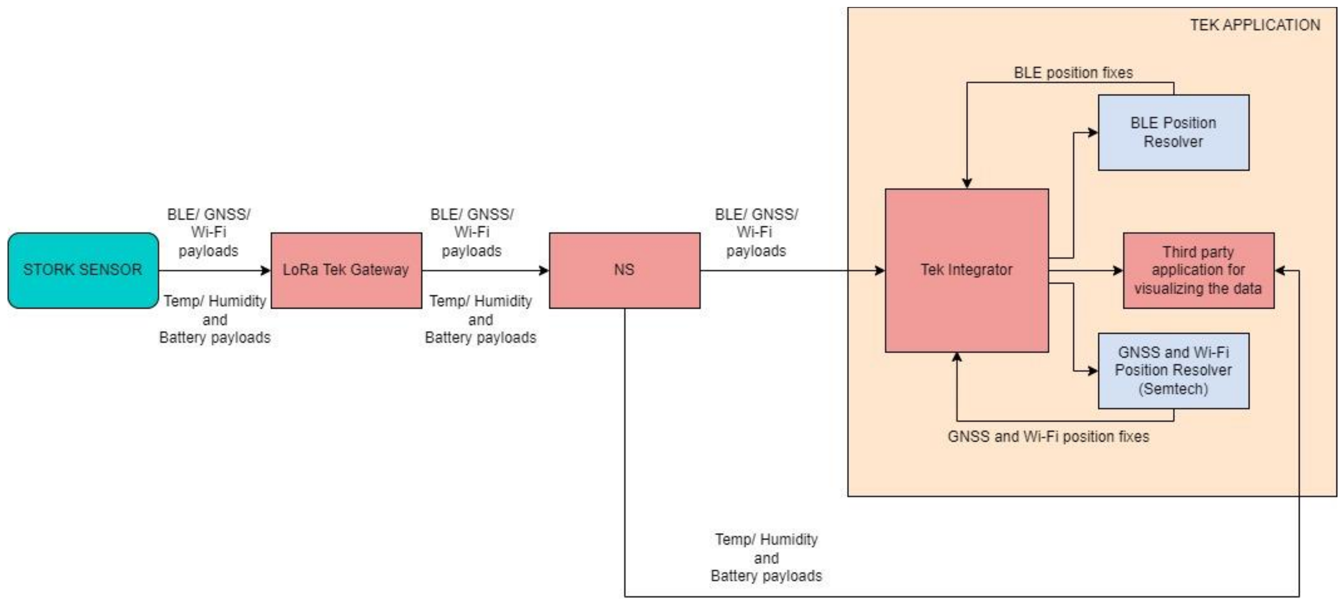


Figure 2-1: System Operation Overview for Stork

A summary of the current system operation is given as follows:

1. Stork sensor performs priority based GNSS/Wi-Fi/BLE scans and sends the scan results as an uplink to Tek NS through a gateway.

2. Tek NS forwards the relevant (BLE/GNSS and Wi-Fi) uplinks to the Tek application which will handle sending requests to position resolvers for both BLE and GNSS/Wi-Fi separately.

3. The position resolvers will return the position fixes to the Tek Application which then will be forwarded to a third-party application for visualization purposes.

4. Other uplinks such as Temperature and Humidity readings would pass through from the NS to the visualization application directly.

2.2 Geolocation Technologies

The table below shows the supported geolocation technologies, brief description of their functionalities, and their failure conditions.

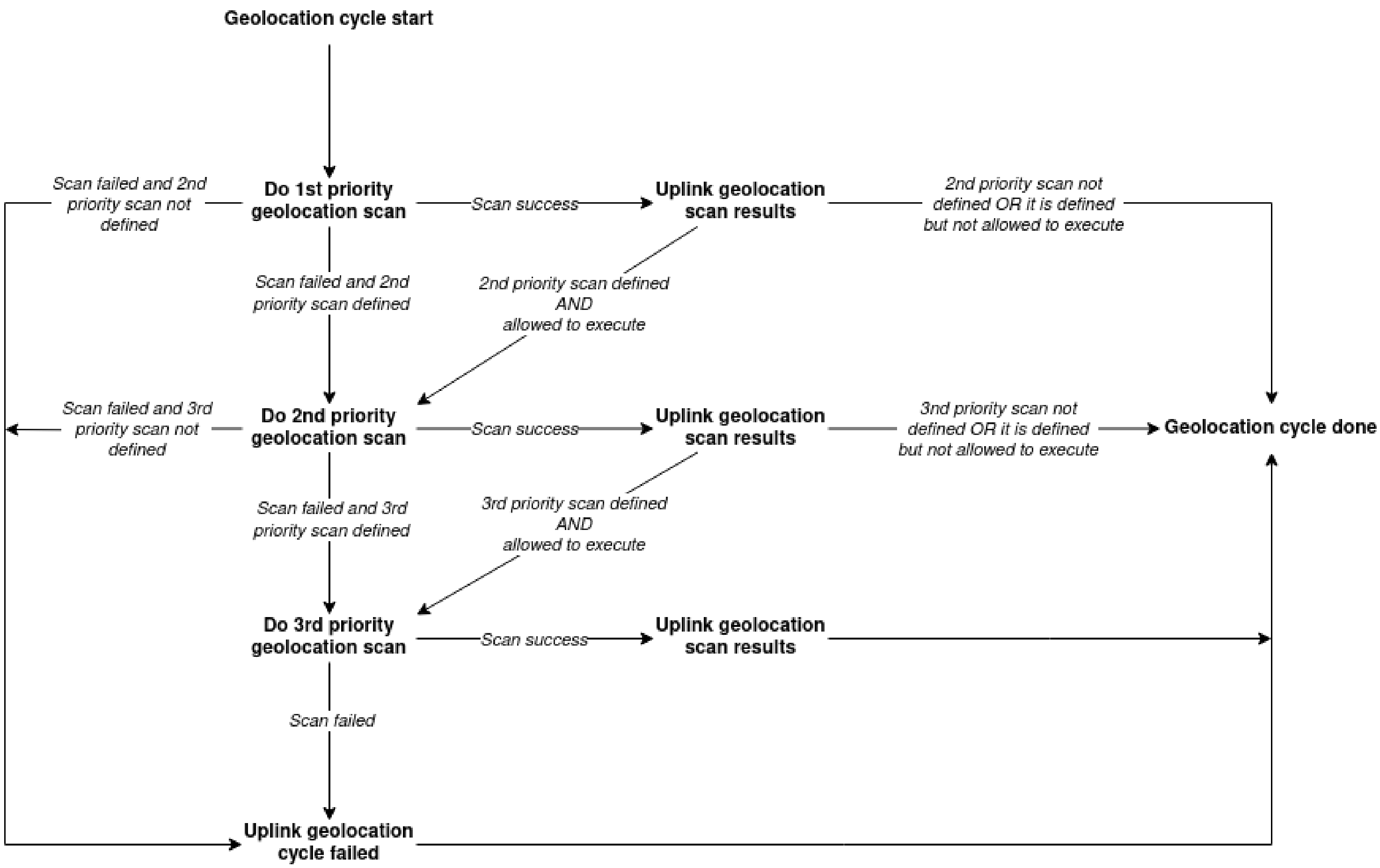
Table 2-1: Supported Geolocation Technologies

Technology	Functionality	Fail Condition
GNSS	Perform LR1110 GNSS scan and send scan results for LoRa Cloud to compute the position.	No valid scans from a scan group

Technology	Functionality	Fail Condition
Wi-Fi	Perform LR1110 WIFI scan and send scan results for LoRa Cloud to compute the position.	BSSID's found are greater than or equal to 3
BLE	Perform BLE scan for BLE beacons to create, and send, a list of MAC addresses, each with its corresponding RSSI. This data can then be handled by an application to compute the position.	No BLE beacons detected

A **geolocation cycle** is defined as a period when all geolocation scans are completed. These scans are prioritized and executed as per *geolocation_strategy* register (0x30) – see Section 4.1.4 for more information. The flow chart below outlines the flow of events within a geolocation cycle.

Figure 2-2: Geolocation Strategy Flow Chart



2.3 Bluetooth Low-Energy (BLE) Operation

Stork is equipped with a BLE module that is embedded in the MCU. It serves as a BLE central device that periodically searches to discover nearby BLE peripherals, and in some cases, periodically broadcasts advertising packets to be visible to other devices. It can be used as a standalone proximity sensor that can also help at positioning.

The BLE scan can be disabled entirely or enabled at any time. Figure 2-3 shows the BLE scan scheme when the BLE scan is enabled. As shown in the figure, BLE scans are performed periodically. Each scan duration is divided into scan intervals. The BLE scan is performed only in the scan window portion of the scan interval. The ratio of the scan window to the scan interval is the scan duty cycle. In the case of the scan window equaling the scan interval, the scan duty cycle is 100%. This represents a continuous scan over each scan duration. A larger duty cycle will increase the likelihood of receiving more beacon packets at the expense of consuming more power. The scan period, duration, interval, and window are all configurable. For all user configurable device settings, refer to the specific TRM document for that sensor).

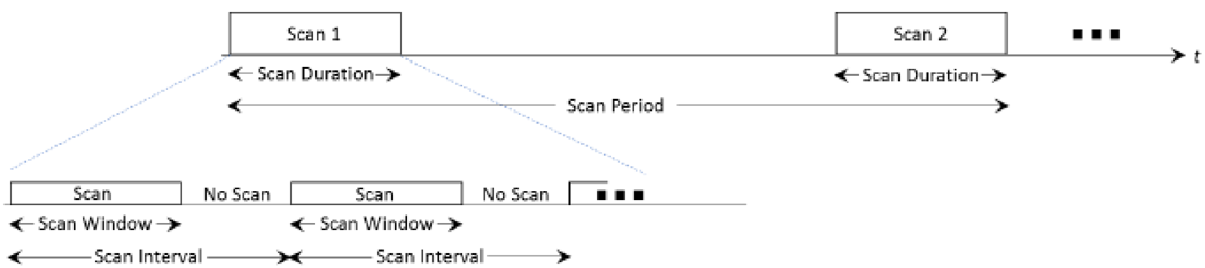


Figure 2-3: The BLE Scan Schematic Procedure.

At the end of each scan duration, up to *n* discovered BLE devices with the strongest RSSIs are reported over LoRaWAN. The value *n* is user configurable. If no devices are found, an empty list is uplinked. Over each scan duration, a BLE device beacon may be observed (discovered) more than once.

The Stork sensor supports BLE of Bluetooth 5.0. The BLE scan is performed in the passive mode only, meaning that the sensor listens to surrounding beacons, but does not transmit to them to request additional information.

NOTE: The BLE scan is exclusive to LoRa radio transmission; i.e., they do not overlap. If any reporting becomes due at the same time of a BLE scan, the reporting will be done after the BLE scan is complete.

2.4 Magnetic Reed Switch

The magnetic switch can be operated by the provided magnet, and is used for the following purposes:

A. **Device Wakeup from DEEP SLEEP, Put to DEEP SLEEP and Reset during System Operations:**

This is mainly used to wake up the Sensor from DEEP SLEEP and have it begin trying to join the network. When the Sensor exits the factory, it is in the low-power DEEP SLEEP mode and can be activated using the specified magnetic pattern. The same magnetic pattern can just be used to reset the Sensor during normal operation, causing it to try to rejoin the network.

The magnetic pattern in this application is illustrated in Figure 2-4. A "magnet presence" is achieved by placing the magnet against the enclosure by the magnet symbol. A "magnet absence" is achieved by taking the magnet away from the enclosure. Figure 1-2 shows that the pattern involves sustaining a "magnet presence" continuously for at least 3 sec but less than 10 sec.

When the specified magnetic pattern is applied to the Sensor, it displays an LED indication described in Section 2.7.1 to show that it has accepted the magnetic pattern. In all cases, the magnet pattern causes the Sensor to reset.

If the Sensor was in DEEP SLEEP when the pattern was applied, after resetting it will wake up and begin trying to join the network.

If the Sensor was in normal operation when the magnet pattern was applied, after resetting it will try to rejoin the network.

The same magnetic pattern can just be used to put the Sensor back into DEEP SLEEP. If the magnetic pattern is applied while the Sensor is trying to join the network, but before it receives the JOIN ACCEPT DL, the Sensor will go back into DEEP SLEEP mode. Applying the magnetic pattern again will cause it to wake up.

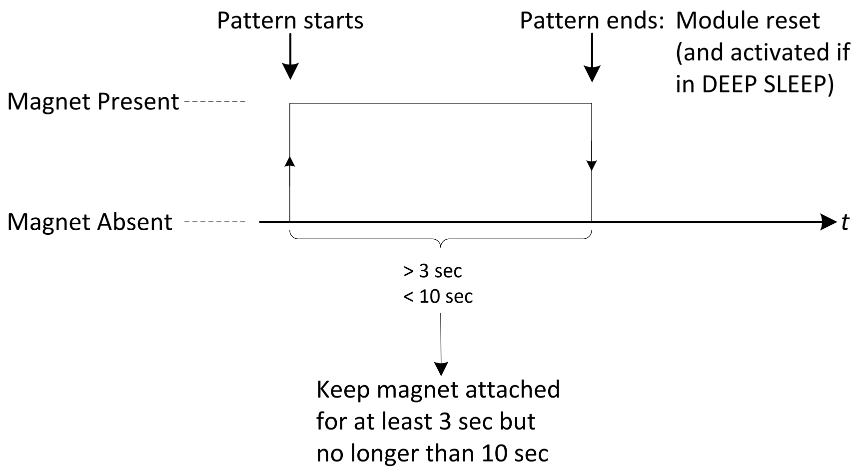


Figure 2-4: The Magnetic Reset/Wake-Up Pattern.

B. **Forced UL:**

This is used to get the LoRaWAN Class-A Sensor to open a receive window so it can receive DL commands from the NS, or simply to trigger the Sensor to uplink the battery voltage data prior to its next scheduled periodic report.

The magnetic pattern in this involves placing and taking away the magnet to and from the magnet sign at the bottom of the enclosure briefly for less than 2 seconds, as shown in Figure 2-5. *It is important to note here that mistakenly holding the magnet attached to the module for more than 3 sec may trigger a module reset, as explained in item A above.*

The magnetic-forced UL contains a regular battery life information payload uplink on ***LoRaWAN port 10***.

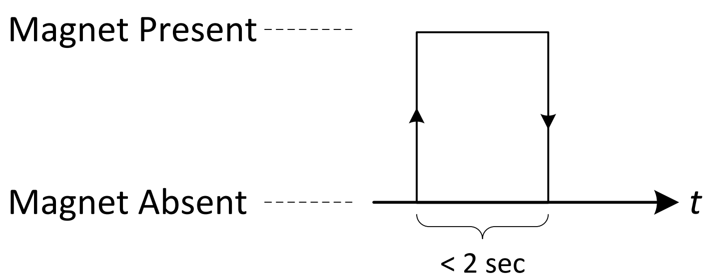


Figure 2-5: The Magnetic UL-Triggering Pattern

The position on the exterior of the enclosure on which the magnet must be placed to activate the reed switch is shown in figure below.

Figure 2-6: Magnetic Reed Switch Location

2.5 Temperature and Relative Humidity Transducer

The Stork sensor has 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. Two vents in the front and side 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. See figure below for the position of the vents.

The sensors can be configured to report temperature and RH values or to report alarms based on a customer-configured normal operating window. High and low alarm points can be set individually for temperature and humidity. 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.

2.6 Accelerometer Transducer

The Stork sensor 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 state from static to mobile, or vice versa.

The accelerometer generates an acceleration alarm when a motion event is detected that may or may not be reported OTA (user-configurable). 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.

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

2.7 LED Behaviour

The Sensor is equipped with two on-board LEDs: **GREEN** and **RED**. Their behaviour patterns reflect the internal device state and are described in the following subsections. The LED behaviour is not user-configurable.

2.7.1 Power-On and Network Join Operation

When the Sensor is activated or reset using the magnetic pattern in Figure 2-4:

1. Both **GREEN** and **RED** are turned off when the Sensor is powered on (including after a soft reset).
2. Both **GREEN** and **RED** are turned on when the POST begins.
3. When the POST ends, depending on the POST result:
    a. If the POST passes, **GREEN** is toggled ON and OFF every 50 ms for 0.5 sec, as shown in Figure 2-7. In this case, the LED pattern proceeds to step 4.
    b. If the POST fails, **RED** is toggled ON and OFF every 50 ms for 0.5 sec, as shown in Figure 2-7. In this case, the device restarts and the LED pattern begins again at step 1 after approximately 4 s.

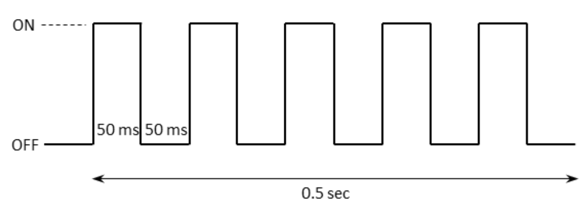


Figure 2-7: The GREEN or RED LED Pattern After the POST

4. Both **GREEN** and **RED** are turned off when the POST and the subsequent LED flashing specified in item 3 end.
5. While the Sensor is attempting to join:
   a. **GREEN** is toggled ON and OFF every 50 ms for the first hour. After that, it only flashes twice (ON time: 50 ms, OFF time: 50 ms) every 5 sec. This scheme has been shown in Figure 2-8.
   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 at decreasing regularity the longer the join process continues due to battery saving measures and possible duty-cycle limitations in certain regions [3].
      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.

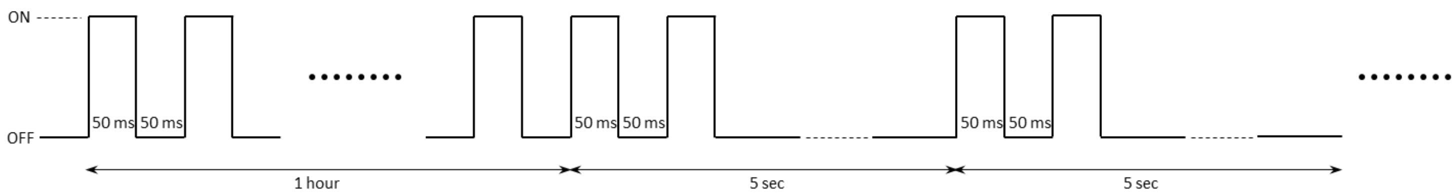


Figure 2-8: The GREEN LED Pattern During Join

2.7.2 Normal Operation

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 25 ms right after receiving a downlink.

2.7.3 DEEP SLEEP

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 toggled ON and OFF every 0.5 sec for 3 sec as shown in Figure 2-9.
2. After a 5 s pause, the normal Power-On and Network Join LED patterns described in Section 2.7.1 above occur after the device resets.

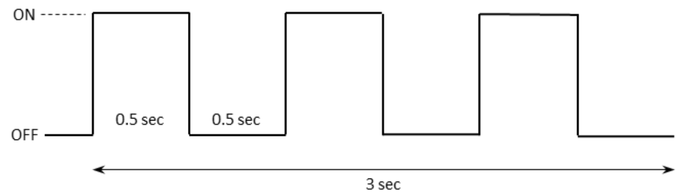


Figure 2-9: The GREEN LED Pattern After the Magnetic Wake-Up/Reset Pattern is Observed

There is another similar LED pattern for when the device is put back into DEEP SLEEP:

1. The POST LED pattern described in steps 1-4 in Section 2.7.1 above occurs after the device resets.
2. Immediately, **GREEN** is toggled ON and OFF every 0.1 sec for 0.6 sec as shown in Figure 2-10.

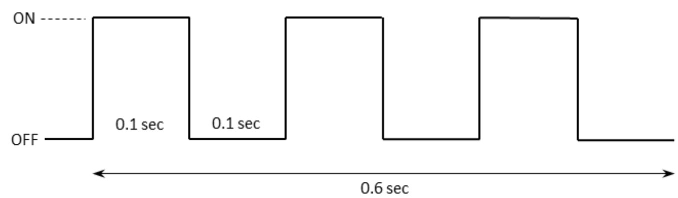


Figure 2-10: The GREEN LED Pattern Before Entering DEEP SLEEP

3 UL Payload Formats

The UL streams (from the Stork to the NS) supported by the SW are shown in Table 3-1.

Table 3-1: UL Information Streams

Data Type	Sent on LoRaWAN Port
All Real-time sensing data • Accelerometer vector report • Temperature • Humidity • Battery life information	**10**
Report GNSS Diagnostics Information	**61**
Report discovered BLE devices	**25**
Response to read/write commands from the NS	**101**
GNSS Scans	**192**
Wi-Fi Scans	**197**
Semtech Requests (Clock Sync, Almanac update, etc.)	**199**

3.1 Frame Payload to Report Real-Time Sensing Data

Each data field from the Stork is encoded in a frame format shown in Figure 3-1. A big-endian format (MSb/MSB first) is always followed.

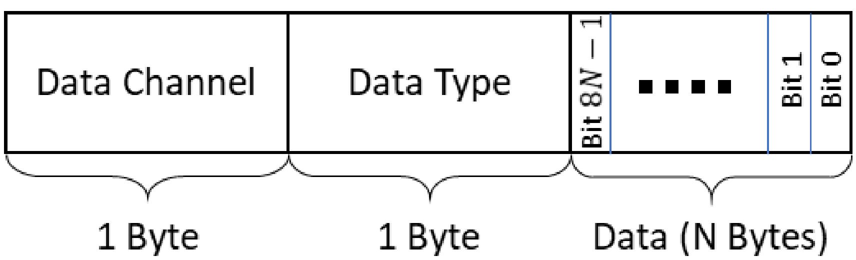


Figure 3-1: The frame format in an UL payload.

A Stork message payload can include multiple data frames from different sensing entities in the Stork. Frames can also be arranged in any order. The Stork frame payload values for real-time sensor data are shown in Table 3-2. In this table, the bit indexing scheme is as shown in Figure 3-1.

Table 3-2: UL Frame Payload Values for Present STORK Data

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)
Battery Lifetime in Percentage	0x00	0xD3	1 B	Percentage	• 1%/LSB (Unsigned)	*battery_lifetime_pct: <value> (number/%)*

Information Type	Channel ID	Type ID	Size	Data Type	Data Format	JSON Variable (Type/Unit)
Battery Lifetime in Days	0x00	0xBD	2 B	Days	• 1 day/LSB (Unsigned)	*battery_lifetime_dys: <value> (number/days)*
Acceleration Alarm Status	0x00	0x00	1 B	Digital Input	• 0x 00 = Alarm inactive • 0x FF = Alarm active	*acceleration_alarm (unsigned/no unit)*
Acceleration Vector	0x00	0x71	6 B	Acceleration	• 1 milli-g/LSB (signed) • Bits 32-47: x-axis acceleration • Bits 16-31: Y-axis acceleration • Bits 0-15: Z-axis acceleration	*acceleration_vector{ xaxis: <value>, (signed/g) yaxis: <value>, (signed/g) zaxis: <value>, (signed/g) }*
Temperature	0x03	0x67	2 B	Temperature	• 0.1°C/LSB (signed)	*temperature (signed/°C)*
Relative Humidity	0x04	0x68	2 B	Humidity	• 0.5%/LSB (unsigned)	*relative_humidity: <value> (unsigned/%)*

Table 3-3: Examples of Decoded Uplinks

Uplinks	Decoded Information
0x 00 D3 64 00 BD 01 99	{"raw": "00 D3 64 00 BD 01 99", "fport": 10, "battery_lifetime_pct": 100, "battery_lifetime_dys": 409}
00 71 01 01 01 01 01 01 00 67 01 2A	{ “raw": "00 71 01 01 01 01 01 01 03 67 01 2A", "fport": 10, "acceleration_x": "0.257", "acceleration_y": "0.257", "acceleration_z": "0.257", "temperature": "29.8"}

3.2 Reporting Discovered BLE Devices

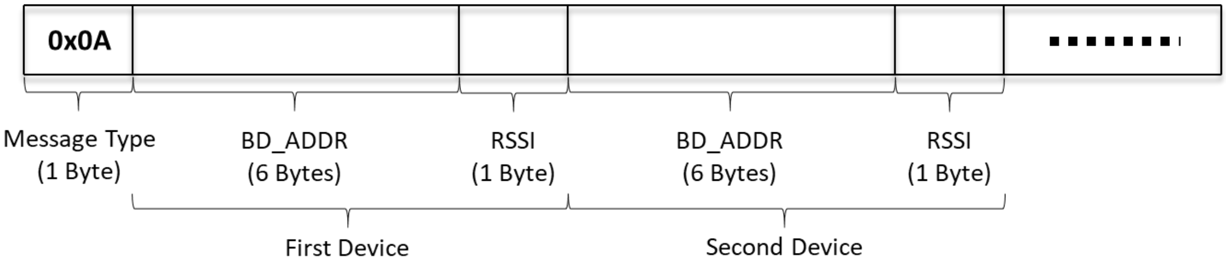
Discovered BLE devices are reported on ***LoRaWAN port 25***. The payload format to report such devices has been shown in Figure 3-2.

In the Basic mode of reporting (Figure 3-2-(a)), the header is **0x0A**. The BD_ADDR for each discovered device is a full 6-byte address, and is followed by the device RSSI, which is a signed 1-byte number. If no devices are found, an empty list consisting of only the header **(0x 0A)** is reported.

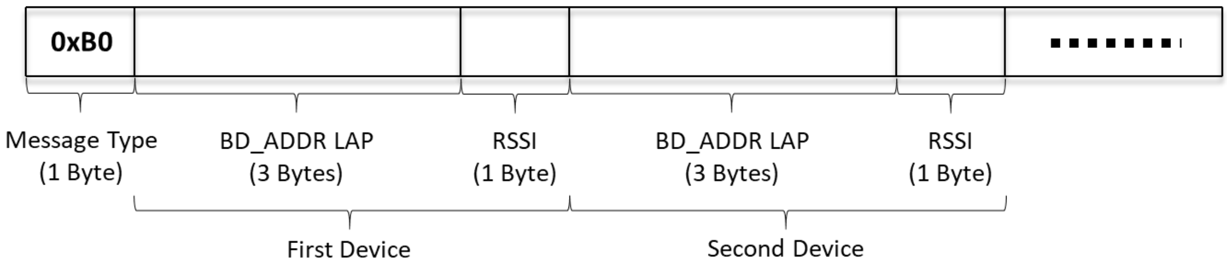
In the Whitelisting mode of reporting (Figure 3-2-(b-d)), up to 4 ranges of BD_ADDR can be defined for whitelisting discovered devices. The message type headers **0xB0, 0xB1, 0xB2, 0xB3** correspond to Ranges 0, 1, 2, and 3 respectively. A BD_ADDR consists of an Organizationally Unique Identifier (OUI) comprising the 3 MSBs followed by a Lower Address Part (LAP) comprising the 3 LSBs. Each BD_ADDR range is a 9-byte OUI:LAPstart-LAPend that determines the range of BD_ADDRs as OUI:LAPstart to OUI:LAPend. Therefore, OUI is the same and known for all devices in each range. The message type header determines the range, and thus the OUI for all devices in the message, such that the devices in each message can be uniquely identified by their LAPs only.

For example, if the only discoverable BLE devices of interest all have MAC addresses that begin with AC233F (OUI) and only the last 3 bytes are different for each device (LAPs), the BD_ADDR range to filter for only these devices would be AC233F:000000-FFFFFF. In other words, this BD_ADDR range means that the Sensor will filter the discovered devices to include only those with MAC addresses from AC233F000000 to AC233FFFFFFF, **inclusive.**

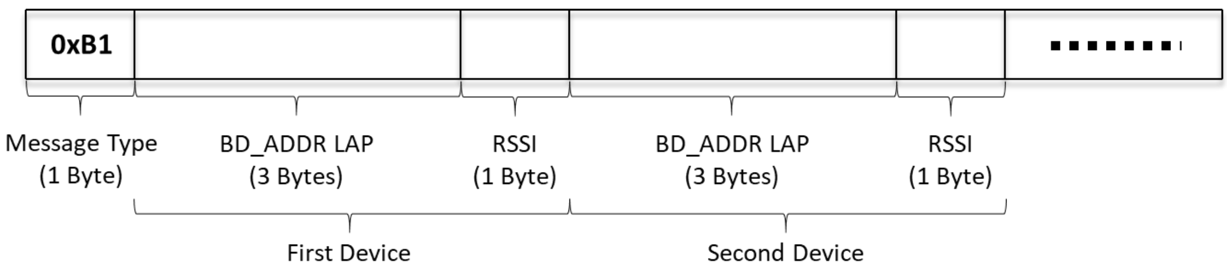
Note that in the Whitelisting mode, the devices from more than one range cannot be reported within the same packet. This is because the number of the devices for each range is not given in the corresponding header. Zero, one, or more devices can be reported in a single message, depending on the number of devices available to report and payload size limitation as determined by LoRaWAN regional restrictions. If the devices to be reported do not fit into one packet, more than one packet will be transmitted to report the devices.



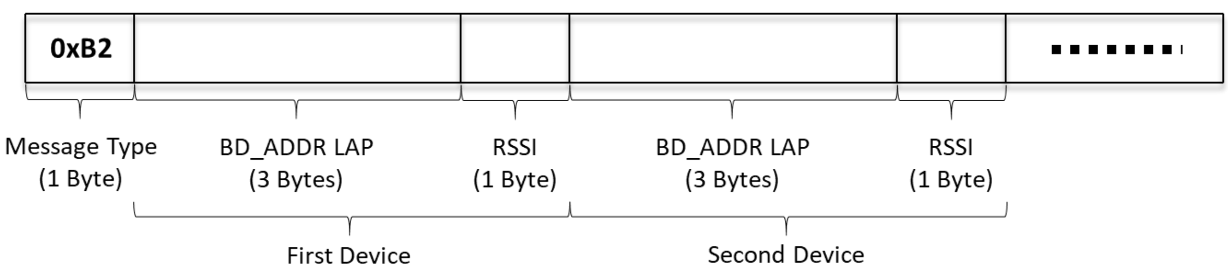
(a) Basic mode.



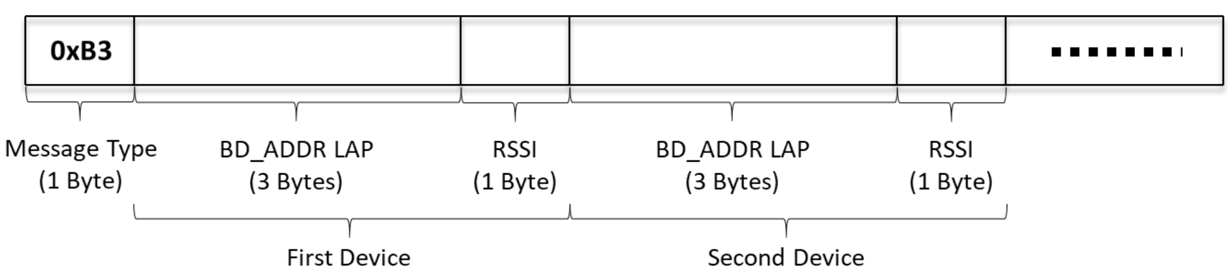
(b) Whitelisting mode, Range 0.



(c) Whitelisting mode, Range 1.



(d) Whitelisting mode, Range 2.



(e) Whitelisting mode, Range 3.

Figure 3-2: The UL payload format to report discovered BLE devices.

Table 3-4: Examples of BLE decoded ULs

<table>
<tr><th>Raw UL</th><th>Decoded Log UL Information</th></tr>
<tr><td>Basic mode

0x 0A AC 23 3F 8F 96 B1 AA AC 23 3F 8F 96 B2 AB</td><td>{
"data": {
"raw": "0A AC 23 3F 8F 96 B1 AA AC 23 3F 8F 96 B2 AB",
"fPort": 25,
"basic_report": [
{
"BD_ADDR_0": "ac 23 3f 8f 96 b1",
"RSSI_0": -86
},
{
"BD_ADDR_0": "ac 23 3f 8f 96 b2",
"RSSI_0": -85
}
]
},
"errors": [],
"warnings": []
}</td></tr>
<tr><td>Filter Range 0

0x B0 8F 97 B3 AC 8F 97 B4 AD</td><td>{
"data": {
"raw": "B0 8F 97 B3 AC 8F 97 B4 AD",
"fPort": 25,
"filter_report_0": [
{
"BD_ADDR_1": "8f 97 b3",
"RSSI_1": -84
},
{
"BD_ADDR_1": "8f 97 b4",
"RSSI_1": -83
}
]</td></tr>
</table>

Raw UL	Decoded Log UL Information
	}, "errors": [], "warnings": [] }

Filter Range 1
 	
0x B1 8F 96 BE AE 8F 96 BF AF 8F 96 B0 B1
	{
	"data": {
	"raw": "B1 8F 96 BE AE 8F 96 BF AF 8F 96 B0 B1",
	"fPort": 25,
	"filter_report_1": [
	{
	"BD_ADDR_2": "8f 96 be",
	"RSSI_2": -82
	},
	{
	"BD_ADDR_2": "8f 96 bf",
	"RSSI_2": -81
	},
	{
	"BD_ADDR_2": "8f 96 b0",
	"RSSI_2": -79
	}
	]
	},
	"errors": [],
	"warnings": []
	}

Filter Range 2
 	
0x B2 8F 96 C3 B2 8F 96 C4 B3 8F 96 B9 B4 8F 96 F4 B5
	{
	"data": {
	"raw": "B2 8F 96 C3 B2 8F 96 C4 B3 8F 96 B9 B4 8F 96 F4 B5",
	"fPort": 25,
	"filter_report_2": [
	{

Raw UL	Decoded Log UL Information

	"BD_ADDR_3": "8f 96 c3",
	"RSSI_3": -78
	},
	{
	"BD_ADDR_3": "8f 96 c4",
	"RSSI_3": -77
	},
	{
	"BD_ADDR_3": "8f 96 b9",
	"RSSI_3": -76
	},
	{
	"BD_ADDR_3": "8f 96 f4",
	"RSSI_3": -75
	}
	]
	},
	"errors": [],
	"warnings": []
	}

Filter Range 3
 	
0x B3 8F 96 B7 B6 8F 96 B8 B7 8F 96 B9 B8 96 B4 AD B9 96 B4 AA BA
	{
	"data": {
	"raw": "B3 8F 96 B7 B6 8F 96 B8 B7 8F 96 B9 B8 96 B4 AD B9 96 B4 AA BA",
	"fPort": 25,
	"filter_report_3": [
	{
	"BD_ADDR_4": "8f 96 b7",
	"RSSI_4": -74
	},
	{
	"BD_ADDR_4": "8f 96 b8",
	"RSSI_4": -73
	},

Raw UL	Decoded Log UL Information

	{
	"BD_ADDR_4": "8f 96 b9",
	"RSSI_4": -72
	},
	{
	"BD_ADDR_4": "96 b4 ad",
	"RSSI_4": -71
	},
	{
	"BD_ADDR_4": "96 b4 aa",
	"RSSI_4": -70
	}
	]
	},
	"errors": [],
	"warnings": []
	s

3.3 Response to Configuration and Control Commands

Stork responses to DL configuration and control commands (DL sent on LoRaWAN port 100; see Section 4.1) are sent in the UL on ***LoRaWAN port 100*** and/or ***LoRaWAN port 101***. These responses include the following:

- Returning the value of (a) configuration register(s) in response to an inquiry from the NS.
- Writing to (a) configuration register(s).

In the first case, Stork responds with the address and value of each of the registers under inquiry on **LoRaWAN port 100.** The response can be in one or more consecutive UL packets depending on the maximum frame payload size allowed.

In the second case, Stork responds by immediately sending the last byte of the LoRaWAN DL frame counter value followed by a size byte indicating the number of registers that were **NOT** successfully written to, and then the addresses of the failed registers on **LoRaWAN port 101**. The intent is to both inform the user which set of commands the Stork is referring to, and which (if any) of the write commands were seen as invalid. As a result, if a redundant write command is issued (i.e., the value of that register is not changing), then Stork will not report its address, because it was not an invalid command. In the case where all the write commands are performed successfully, Stork will send back a frame with only the last byte of the DL frame counter value and a size indication byte of “00” on **LoRaWAN port 101,** implying that all registers were successfully written to**.**

If the DL payload also had read commands, the address and value of each of the registers under inquiry are reported separately on **LoRaWAN port 100**. In this case, the UL response to read commands on **LoRaWAN port 100** is handled before the UL response to write commands on LoRaWAN port 101. Stork will respond this way to all read and/or write commands, except for the special case where the anti-bricking strategy is performed.

The default method in which Stork responds to write commands differs from previous iterations of TEKTELIC Sensors. Previously, Tektelic Sensors would respond with a CRC32 of the entire DL payload as the first 4 bytes of the UL frame. Users now have the option to select the desired response format through the configuration register detailed in Section 4.1.11. This option has been included to accommodate applications designed for previous iterations of TEKTELIC Sensors that can decode the CRC. However, it is strongly recommended that users update their data encoders and decoders to accommodate the new response format.

Table 3-5: Example of response to config commands

DL command	Decoded Log UL Information

Response to Read Command on port 100
 	
DL: 0x 20 21 22
	{
	"raw": "20 00 00 00 3C 21 05 A0 22 00 0F",
	"port": 100,
	"seconds_per_core_tick": 60,
	"ticks_battery": 1440,
	"ticks_normal_state": 15
	}

Response to successful Write command on port 101
 	
0x A0 00 00 00 3C
 	
DL above is expected to set the seconds per tick to 60s successfully
	{
	"0": "All write commands from DL:1 were successfull",
	"raw": "04 00",
	"port": 101
	}

Response to unsuccessful Write command on port 101
 	
Attempt to write invalid command to register 0x20
 	
0xA0 00 00
 	
Error: register 0x20 expects 4 bytes of data
	{
	"0": "1 Invalid write command(s) from DL:1 for register(s): 0x20",
	"raw": "01 01 20",
	"port": 101
	}

4 DL Payload Formats

The DL streams (from the NS to the Stork) supported by the SW are shown in Table 4-1.

Table 4-1: DL Information Streams

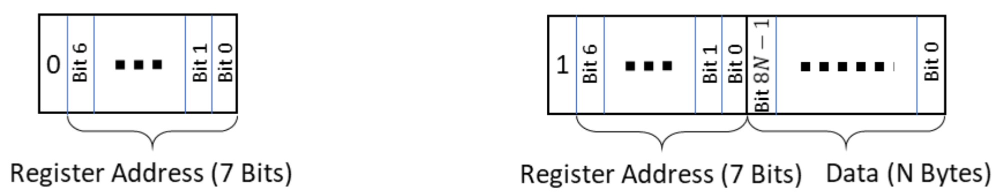
Data Type	Sent on LoRaWAN Port
Configuration and Control Commands	**100**

4.1 Configuration and Control Commands

A single DL configuration and control message can contain multiple command blocks, with a possible mix of read and write commands. Each message block is formatted as shown in Figure 4-1. A big-endian format (MSB first) is always followed.

The Register Address is used to access various configuration parameters. These addresses are bound between 0x00 and 0x7F.

Bit 7 of the first byte determines whether a read or write action is being performed, as shown in Figure 4-1. All read commands are one-byte long. Data following a read access command will be interpreted as a new command block. Read commands are processed last. For example, in a single DL message, if there is a read command from a register and a write command to the same register, the write command is executed first.



(a) The read command. (b) The write command.

Figure 4-1: Format of a DL configuration and control message block.

All DL configuration and control commands are sent on ***LoRaWAN port 100***.

Examples:

- Read Registers 0x10, 0x11, and 0x12:
  - DL command: {0x 10 11 12}
- Read Register 0x13 and Write value 0x8000 to Register 0x10:
  - DL command: {0x 13 90 80 00}

When a read or write or write-and-read command is sent to the Stork, the Stork immediately responds on port 100 with the format described in Section 3.3.

DL configuration and control commands fall into one of the following categories and are discussed in Sections 0–4.1.11:

- Operational mode Configuration
- LoRaMAC Configuration
- Periodic Tx Configuration
- Geolocation Scanning Configuration

- GNSS Configuration
- Temperature/Relative humidity Configuration
- Accelerometer Configuration
- Battery Management Configuration
- BLE Scanning (Sensor mode) Configuration
- BLE Advertising (Beacon mode)
- Command and Control

4.1.1 Operational Mode Configuration

Stork can be configured to operate as a Sensor or as a Beacon, depending on the use case. By default, Stork is programmed as a Sensor i.e., the device can track other BLE devices around it but it can't be tracked/discovered by other BLE Sensors.

Address	Name	Size	Description	Default	JSON Variable (Type/Unit)
0x0A	Operational Mode	1 B	• 0x00: Sensor Mode • 0x01: Beacon Mode	Sensor Mode • **0x00**	*operational_mode: <value> (unsigned/no unit)*

Figure 4-2: Operation mode Configuration Registers

4.1.2 LoRaMAC Configuration

LoRaMAC options can be configured using the LoRaWAN DL. These configuration options change the default MAC configuration that the STORK loads on start-up. They can also change certain run-time parameters. Table 4-2 shows the MAC configuration registers. In this table, the bit indexing scheme is as shown in Figure 4-1. All the registers have R/W access.

Table 4-2: LoRaMAC Configuration Registers

Address	Name	Size	Description	Default	JSON Variable (Type/Unit)
0x11	LoRaMAC Options	1 B	• Bit 0: 0 / 1 = Unconfirmed / Confirmed UL • Bit 1: Ignored • Bit 2: Ignored • Bit 3: 0/1 = Disable/Enable ADR • Bits 4-15: Ignored	• ADR Disabled • Unconfirmed UL **0x00 0E**	*operational_mode: <value> (unsigned/no unit)*
0x12	DR and TX Power Offset	2 B	• Bits 8-11: Default DR number • Bits 0-3: Default Tx power number • Bits 4-7, 12-15: Ignored	• Tx Power 0 • DR3 **0x 04 00**	*loramac_dr_tx { dr_number: <value>, (unsigned/no unit) tx_power_number: <value> (unsigned/no unit)}*

Note: Modifying these values only changes them in the Stork. Options for the Stork in the NS may also need to be changed to not strand a Stork. Modifying configuration parameters in the NS is outside the scope of this document. Unlike Tektelic's other sensors, register 0x10 and 0x12 (and parts of 0x11) configuration are not supported (due to using a different LoRaMAC stack, i.e., LoRa Basics Modem).

4.1.2.1 LoRa Configuration DL Examples

- Set default DR number to 3, default Tx power number to 4:
  - DL payload: {0x 92 03 04}

4.1.3 Periodic Tx Configuration

All periodic reporting is synchronized around ticks. A tick is simply a user configurable time base that is used to schedule Stork measurements. Table 4-3 shows a list of registers used to configure the STORK periodic transmissions. All the registers have R/W access.

The reporting period in each case (e.g., Battery, Accelerometer, Temperature) is obtained as "Ticks" in that case multiplied by "Seconds per Core Tick". A reporting period being 0 means that the corresponding periodic report is disabled.

<Transducer> ***Reporting Period*** $=$ ***Seconds per Core Tick*** $\times$ ***Ticks per*** **<Transducer>**,

Table 4-3: Periodic Transmission Configuration Registers

Address	Name	Size	Description	Default	JSON Variable (Type/Unit)
0x 20	Seconds per Core Tick	4 B	• Tick value for periodic events • Acceptable values: 0, 3, 4..., 86400 • 0 disables all periodic transmissions. • Other values: Invalid and ignored	3600 seconds **0x 00 00 0E 10**	*seconds_per_core_tick:<value> (unsigned/sec)*
0x21	Ticks per Battery	2 B	• Ticks between battery reports • Acceptable values: 0, 1, 2, ..., 65535 • 0 disables periodic battery reports	24 ticks = 1 day period **0x 00 18**	*ticks_per_battery: <value> (unsigned/no unit)*
0x22	Ticks per Ambient Temperature	2 B	• Ticks between ambient temperature reports • Acceptable values: 0, 1, 2, ..., 65535 • 0 disables periodic ambient temperature reports	1 tick = 1 hour period **0x0001**	*ticks_per_ambient_temperature: <value> (unsigned/no unit)*
0x23	Ticks per Ambient Humidity	2 B	• Ticks between ambient humidity reports	1 tick = 1 hour period	*ticks_per_ambient_humidity:<value> (unsigned/no unit)*

Address	Name	Size	Description	Default	JSON Variable (Type/Unit)
			• Acceptable values: 0, 1, 2, ..., 65535 • 0 disables periodic ambient humidity reports	**0x0001**	
0x24	Ticks per Accelerometer	2 B	• Ticks between accelerometer reports • Acceptable values: 0, 1, 2, ..., 65535 • 0 disables periodic accelerometer reports	Periodic reporting disabled **0x 00 00**	*ticks_per_accelerometer: <value> (unsigned/no unit)*

Examples:

- Read current value of Seconds per Core Tick:
  - DL payload: {0x 20}
    - Register 20 with the write bit set to false.
- Report Temperature every core tick:
  - DL payload: {0x A2 00 01}
    - Register 22 with its write bits set to true.
    - Ticks per Temperature set to 1 (one)

4.1.4 Geolocation Scanning Strategy Configuration

Table 4-4 shows the configuration registers for the geolocation scanning strategy. In this table, the bit indexing scheme is as shown in Figure 4-1. These registers have R/W access.

Table 4-4: Geolocation Strategy Configuration Registers

Address	Name	Size	Description	Default	JSON Variable (Type/Unit)
0x30	Geolocation strategy	1 B	• Bits 0-1: 1st scan • Bits 2-3: 2nd scan • Bits 4-5: 3rd scan These scans can be: • 00: Not defined • 01: BLE • 10: WIFI • 11: GNSS The following rules apply: • 1st scan must be defined.	• BLE 1st • WIFI 2nd • GNSS 3rd 1st scan → 2nd scan if 1st scan fails → 3rd scan if 2nd scan fails **b00 11 10 01** or **0x39**	*geolocation_strategy: <value> (unsigned/no unit)*

Address	Name	Size	Description	Default	JSON Variable (Type/Unit)
			• 2nd scan must be defined to set 3rd scan. • A scan technology (i.e., BLE, WIFI, and GNSS) can only be in one scan priority. Bits 6 - 7: Order of operation • 00: 1st scan → 2nd scan if 1st scan fails → 3rd scan if 2nd scan fails • 01: 1st scan → 2nd scan → 3rd scan if 2nd scan fails • 10: 1st scan → 2nd scan if 1st scan fails → 3rd scan • 11: 1st scan → 2nd scan → 3rd scan • Please see notes below for more information		
0x31	Motion cleared / Device settled Geolocation scan frequency	4 B	Period in seconds over which geolocation scans are initiated when device has settled (i.e., motion cleared) • 0: disables geolocation scans when device has settled	900 seconds **0x 00 00 03 84**	*geolocation_scan_frequency: <value> (unsigned/sec)*
0x32	Motion detected scan frequency	4 B	Period in seconds over which geolocation scans are initiated when motion is detected. • 0: No change in geolocation scanning frequency when motion is detected. keep motion cleared / device settled geolocation scan frequency	300 seconds **0x 00 00 01 2C**	*Motion_detected_ geolocation_scan_frequency:<value>(unsigned/sec)*

NOTES

1. If scan 2 is not defined, only scan 1 is executed. Note that scan 2 must be defined to define scan 3, therefore, there is no such case where scan 3 is defined but not scan 2.
2. If both scan 2 and 3 are not defined only scan 1 is executed.
3. If scan 3 is undefined the geolocation scan cycle ends after scan 2 or 1 depending on bits 6-7 value.
4. By default, Stork periodically reports geolocation at the frequency defined on register 0x31 (*geolocation_scan_frequency) – see Section 4.1.4.* The frequency of reporting changes to the value defined in register 0x32 (*motion_detected_geolocation_scan_frequency*), when motion is detected. *motion_detected_geolocation_scan_frequency* is sustained until motion is cleared (i.e., *acceleration_event_grace_period* has passed since the last time the accelerometer has detected motion).
5. If accelerometer is turned off, then *geolocation_scan_frequency* is set as the default scan frequency.

4.1.5 GNSS Configuration

Table 4-5 shows the configuration registers for the GNSS Configuration. In this table, the bit indexing scheme is as shown in Figure 4-1. These registers have R/W access.

Table 4-5: GNSS Configuration Registers

Address	Name	Size	Description	Default	JSON Variable (Type/Unit)
0x33	Clock Sync Configuration	1 B	• Bits 0-3: clock sync interval *m*, 1 day/bit ○ 0 disables clock sync • Bits 4-6: Invalid clock delay multiplier *n* ○ 1 ≤ n ≤ 7 ○ 0: invalid and ignored • Bit 7: Clock sync service ○ 0: LoRa MAC clock sync • LoRa Cloud clock sync	• m = 7 days (or 1 week) • n = 4 (therefore, clock is invalid in n x m days = 4 weeks) LoRa Cloud Clock Sync **0xC7**	clock_sync_type { m_value: <value> (unsigned/day) n_value :<value> (unsigned,no unit) }
0x34	Almanac Update Request interval	2 B	Interval between almanac update requests in seconds (1 second/bit). • 10 - 65535: valid values	30 seconds **0x00 1E**	*almanac_update_request_backoff:<value>(unsigned/sec)*
0x35	Almanac Update Check Period	1 B	Period (in days) on which we send an uplink to check for almanac updates. • 0: disable almanac update check • 1-90: valid values	1 day **0x01**	*almanac_update_check_period: <value> (unsigned/sec)*

Address	Name	Size	Description	Default	JSON Variable (Type/Unit)
0x36	Assist Coordinates	9 B	• Bits 0-31: latitude x (floating point) ○ -90 ≤ *x* ≤ 90 • Bits 32-63: longitude *y* (floating point) ○ -180 ≤ *y* ≤ 180 • Bit 64: 0/1 disable/enable assist coordinates. • Bits 65-72: ignored and not used	• x = 0 • y = 0 • Assist coordinates disabled. **0x 00 00 00 00 00 00 00 00 00**	*assist_coordinates_type {* *latitude:<value>* *(float/degrees)* *longitude:* *<value>* *(float/degrees),* *enable:<value>* *(unsigned, no unit)* *}*
0x37	GNSS satellite constellation option	1 B	• 0x00: GPS • 0x01: Beidou • 0x02: GPS and Beidou • Anything else, invalid and ignored	GPS and Beidou **0x02**	*gnss_constellation_option:* *<value>* *(unsigned, no unit)*
0x38	Default GNSS scan mode	1 B	Default GNSS scan mode when the accelerometer is not enabled • 0x00: Static scanning mode • 0x01: Mobile scanning mode • Anything else, invalid and ignored	Mobile scanning mode **0x01**	*default_gnss_scan_mode:* *<value>* *(unsigned, no unit)*

4.1.6 Temperature/RH Configuration

Table 4-6 shows a list of configuration registers for the Stork's temperature/RH sensor. In this table, the bit indexing scheme is as shown in Figure 4-1. All the registers have R/W access.

Table 4-6: Temperature/RH Configuration Registers

Address	Name	Size	Description	Default	JSON Variable (Type/Unit)
0x39	Temperature/ RH Sample Period: Idle	4 B	• Sample period of ambient temperature/RH transducer: Idle state (1 sec / LSB) • Acceptable values: 10, 11, …, 86400 • Other values: Invalid and ignored		*temp_rh_sample_period_idle: <value>* *(unsigned/sec)*
0x3A	Temperature/ RH Sample Period: Active	4 B	• Sample period of ambient temperature/RH transducer: Active state (1 sec / LSB) • Acceptable values: 10, 11, …, 86400 • Other values: Invalid and ignored		*temp_rh_sample_period_active: <value>* *(unsigned/sec)*
0x3B	Low/High Temperature Thresholds	2 B	• Bits 8-15: High temperature threshold (signed, 1°C / LSB) • Bits 0-7: Low temperature threshold (signed, 1°C / LSB) • High threshold Low threshold: Invalid and ignored		*temp_threshold_high: <value>* *(signed/°C)* *temp_threshold_low: <value>* *(signed/°C)*
0x3C	Temperature Thresholds Enabled	1 B	• Bit 0: 0/1 Thresholds disabled/enabled. • Bits 1-7: Ignored		*temp_thresholds_enabled: <value>* *(string/no unit)*
0x3D	Low/High RH Thresholds	2 B	• Bits 8-15: High RH threshold (unsigned, 1% RH / LSB)		*rh_threshold_high: <value>* *(unsigned/%)*

Address	Name	Size	Description	Default	JSON Variable (Type/Unit)
			• Bits 0-7: Low RH threshold (unsigned, 1% RH / LSB) • High threshold Low threshold: Invalid and ignored		*rh_threshold_low: <value>* *(unsigned/%)*
0x3E	RH Thresholds Enabled	1 B	• Bit 0: 0/1 Thresholds disabled/enabled. • Bits 1-7: Ignored		*rh_thresholds_enabled: <value>* *(string/no unit)*

4.1.7 Accelerometer Configuration

Table 4-7 shows a list of configuration registers for the accelerometer. In this table, the bit indexing scheme is as shown in Figure 4-1. All the registers have R/W access.

Table 4-7: Accelerometer Configuration Registers

Address	Name	Size	Description	Default	JSON Variable (Type/Unit)
0x 40	Mode	1 B	• Bit 0: 0/1 = X-axis disabled/enabled • Bit 1: 0/1 = Y-axis disabled/enabled • Bit 2: 0/1 = Z-axis disabled/enabled • Bits 3-6: Ignored • Bit 7: 0/1 = Accelerometer off/on	• X-axis enabled • Y-axis enabled • Z-axis enabled • Accelerometer on **0x 87**	*accelerometer_mode {* *xaxis_enabled: <value>,* *(unsigned/no unit)* *yaxis_enabled: <value>,* *(unsigned/no unit)* *zaxis_enabled: <value>,* *(unsigned/no unit)* *poweron: <value>* *(unsigned/no unit)*

Address	Name	Size	Description	Default	JSON Variable (Type/Unit)
					}
0x 41	Sensitivity	1 B	• Bits 0-2 (Sample Rate): 0: Invalid and ignored 1/2/3/4/5/6/7 = 1/10/25/50/100/200/400 Hz • Bits 4-5 (Measurement Range[1]): 0/1/2/3 = ±2/±4/±8/±16 *g* • Bits 3, 6, 7: Ignored.	• Sample Rate 10 Hz Measurement Range ±8 *g* **0x 22**	*accelerometer_sensitivity {* *sample_rate: <value>,* *(unsigned/Hz)* *measurement_range: <value>* *(unsigned/g)* *}*
0x 42	Acceleration Event Threshold Count	2 B	• Number of acceleration events before an acceleration alarm is registered. • Acceptable values: • 0: Invalid and ignored	1 event **0x 00 01**	*acceleration_event_threshold_count: <value>* *(unsigned/no unit)*
0x 43	Acceleration Event Threshold Period	2 B	• Period in sec over which acceleration events are counted for threshold detection. • Acceptable values: • 0-4: Invalid and ignored	10 seconds **0x 00 0A**	*acceleration_event_threshold_period: <value>* *(unsigned/sec)*
0x 44	Acceleration Event Threshold	2 B	• Unsigned, 1 milli-/LSB	2 *g* **0x 07 D0**	*acceleration_event_threshold: <value>* *(unsigned/g)*
0x 45	Acceleration Event Grace Period	2 B	• Time to pass, in sec, after the last acceleration alarm before the alarm can be cleared) • Acceptable values: • 0-14: Invalid and ignored	5 min **0x 01 2C**	*acceleration_event_grace_period: <value>* *(unsigned/sec)*

Address	Name	Size	Description	Default	JSON Variable (Type/Unit)
0x 46	Acceleration Event actions	1 B	• Bit 0:0/1 = Acceleration alarm UL report disabled/enabled • Bi 1: 0/1 = Geolocation scan disable/enable • Bits 2-7: Ignored	• Acceleration alarm report UL enabled. Acceleration alarm starts geolocation scan **0x 03**	*acceleration_event_tx {* *acceleration_alarm : <value>,* *(unsigned/no unit)* *ble: <value>* *(unsigned/no unit)* *}*

4.1.8 Battery Management Configuration

Table 4-8 shows a list of battery configuration registers. In this table, the bit indexing scheme is as shown in Figure 4-1. All the registers have R/W access.

Table 4-8: Battery Management Configuration Registers

Address	Name	Size	Description	Default	JSON Variable (Type/Unit)
0x 4A	Battery Report Options	1 B	• Bit 0: 0/1 = Remaining battery capacity [%] not reported/reported • Bit 1: 0/1 = Remaining battery lifetime [days] not reported/reported • Bits 0-1 all set to 0: Invalid and ignored. • Bits 2-7: Ignored	Remaining battery capacity [%] and remaining battery lifetime [days] reported. **0x 03**	*battery_tx {* *report_voltage_enabled: <value>,* *(unsigned/no unit)* *report_capacity_enabled: <value>* *(unsigned/no unit)* *report_lifetime_enabled: <value>,* *(unsigned/no unit)* *}*
0x 4B	Average Energy Trend Window	1 B	• Bits 0-7: Number of core ticks, ***w*** [1 update/LSB]	10 core ticks **0x 0A**	*avg_energy_trend_window: <value>* *(unsigned/no unit)*

Address	Name	Size	Description	Default	JSON Variable (Type/Unit)
			Acceptable values: 1, 2, …, 255 • 0: Invalid and ignored		

4.1.9 BLE Configurations – Sensor mode

Table 4-9 shows a list of BLE Sensor mode configuration registers. In this table, the bit indexing scheme is as shown in Figure 4-1. All the registers have R/W access.

Table 4-9: BLE Sensor mode configuration.

Address	Name	Size	Description	Default	JSON Variable (Type/Unit)
0x 50	Mode	1 B	• Bits 0-6: ***N*** ○ Number of reported devices (1–127) ○ 0: Disables BLE • Bit 7: ***A*** • 0/1 = Averaging mode off/on	• Up to 8 reported devices. • Averaging mode on. **0x 88**	*ble_mode: {* *num_reported_devices : <value>,* *(unsigned/no unit)* *averaging_mode: <value>* *(unsigned/no unit)* *}*
0x 51	Scan Duration	2 B	• Bits 0-7: Scan duration for periodic reports (1 sec/LSb) ○ Acceptable values: 1, 2, …, 255 ○ 0: Invalid and ignored • Bits 8-15: Scan duration for event-based reports (1 sec/LSb) ○ Acceptable values: 1, 2, …, 255 • 0: Invalid and ignored	• 3 seconds for periodic scans • 1 second for event-based scans **0x 01 03**	*ble_scan_duration: {* *periodic: <value>,* *(unsigned/sec)* *event_based: <value>* *(unsigned/sec)* *}*
0x 52	Scan Interval	2 B	• Scan interval (1 ms/LSb) • Acceptable values: "Scan Window", …, 10000	30 ms **0x 00 1E**	*ble_scan_interval: <value>* *(unsigned/sec)*

Address	Name	Size	Description	Default	JSON Variable (Type/Unit)
			• Other values: Invalid and ignored		
0x 53	Scan Window	2 B	• Scan window (1 ms/LSb) • Acceptable values: 3, …, “Scan Interval” • Other values: Invalid and ignored	30 ms **0x 00 1E**	*ble_scan_window: <value>* *(unsigned/sec)*
0x 54	Filter Range 0	9 B	• Range 0 for filtered BD_ADDRs • B_0:B_1:B_2:B_3:B_4:B_5 to B_0:B_1:B_2:B_6:B_7:B_8 • OUI = B_0:B_1:B_2 • LAP_{start} = B_3:B_4:B_5 nhjk • LAP_{end} = B_6:B_7:B_8	Range inactive **0x 00 00 00 00 00 00 00 00 00**	*filter_range_0: {* *oui: <value>,* *(unsigned/no unit)* *lap_start: <value>,* *(unsigned/no unit)* *lap_end: <value>* *(unsigned/no unit)* *}*
0x 55	Filter Range 1	9 B	• Range 1 for filtered BD_ADDRs • B_0:B_1:B_2:B_3:B_4:B_5 to B_0:B_1:B_2:B_6:B_7:B_8 • OUI = B_0:B_1:B_2 • LAP_{start} = B_3:B_4:B_5 • LAP_{end} = B_6:B_7:B_8	Range inactive **0x 00 00 00 00 00 00 00 00 00**	*filter_range_1: {* *oui: <value>,* *(unsigned/no unit)* *lap_start: <value>,* *(unsigned/no unit)* *lap_end: <value>* *(unsigned/no unit)* *}*
0x 56	Filter Range 2	9 B	• Range 2 for filtered BD_ADDRs • B_0:B_1:B_2:B_3:B_4:B_5 to B_0:B_1:B_2:B_6:B_7:B_8 • OUI = B_0:B_1:B_2	Range inactive **0x 00 00 00 00 00 00 00 00 00**	*filter_range_2: {* *oui: <value>,*

Address	Name	Size	Description	Default	JSON Variable (Type/Unit)
			• LAP_{start} = B_3:B_4:B_5 • LAP_{end} = B_6:B_7:B_8		*(unsigned/no unit)* *lap_start: <value>,* *(unsigned/no unit)* *lap_end: <value>* *(unsigned/no unit)* *}*
0x 57	Filter Range 3	9 B	• Range 3 for filtered BD_ADDRs • B_0:B_1:B_2:B_3:B_4:B_5 to B_0:B_1:B_2:B_6:B_7:B_8 • OUI = B_0:B_1:B_2 • LAP_{start} = B_3:B_4:B_5 • LAP_{end} = B_6:B_7:B_8	Range inactive **0x 00 00 00 00 00 00 00 00 00**	*filter_range_3: {* *oui: <value>,* *(unsigned/no unit)* *lap_start: <value>,* *(unsigned/no unit)* *lap_end: <value>* *(unsigned/no unit)* *}*

4.1.10 BLE Beacon Mode Configuration

Table 4-10 shows a list of BLE beacon mode configuration registers. In this table, the bit indexing scheme is as shown in Figure 4-1. All the registers have R/W access.

Table 4-10: BLE Beacon mode configuration.

Address	Name	Size	Description	Default	JSON Variable (Type/Unit)
0x 58	Advertising Enable / Disable	1 B	• Bits 7-1: ignored • Bit 0: Advertising enable/disable • 0/1 = Advertising off/on	Advertising disabled **0x 00**	*advertising_enabled: <value>* *(unsigned/no unit)*
0x 59	Advertising Interval	2 B	Advertising interval (1 ms / LSb)	100 ms **0x 00 64**	*min_advertising_interval: <value>* *(unsigned/ms)*

Address	Name	Size	Description	Default	JSON Variable (Type/Unit)
			• Acceptable values: 30 ms – 10240 ms • Other values: invalid and ignored		
0x 5B	Tx Advertising Power	1 B	BLE Tx Power (dBm) • 0x00 = 0 dBm • 0x01 = -0.85 dBm • 0x02 = -1.8 dBm • 0x03 = -3.15 dBm • 0x04 = -4 dBm • 0x05 = -4.95 dBm • 0x06 = -5.9 dBm • 0x07 = -6.9 dBm • 0x08 = -7.8 dBm • 0x09 = -8.85 dBm • 0x0A = -9.9 dBm • 0x0B = -12.05 dBm • 0x0C = -14.1 dBm • 0x0D = -16.5 dBm • 0x0E = -20.85 dBm • 0x0F = -40 dBm • Other values: invalid and ignored	0 dBm **0x 00**	*tx_advertising_power:* *<value>* *(unsigned/no unit)*
0x 5C	Advertisement Packet Format	1 B	• Bit 0: 0/1 = iBeacon advertising disabled/enabled • Bit 1: 0/1 = Eddystone UID advertising disabled/enabled • Bit 2: 0/1 = Eddystone TLM advertising disabled/enabled • Bits 3-7: RFU • All set to 0: invalid and ignored	iBeacon enabled Eddystone UID and TLM disabled **0x 01**	*advertising_packet_format: {* *ibeacon: <value>,* *(unsigned/no unit)* *eddystone_uid: <value>,* *(unsigned/no unit)* *eddystone_tlm: <value>* *(unsigned/no unit)* *}*

Address	Name	Size	Description	Default	JSON Variable (Type/Unit)
0x 5F	BLE MAC Address	6 B	• READ ONLY • This contains the 6-Byte MAC address that will be present in BLE advertisement packets	**Different for every device**	*mac_address:* *<value>,* *(unsigned/no unit)*
0x 58	Advertising Enable / Disable	1 B	• Bits 7-1: ignored • Bit 0: Advertising enable/disable • 0/1 = Advertising off/on	Advertising disabled **0x 00**	*advertising_enabled: <value>* *(unsigned/no unit)*
0x 59	Advertising Interval	2 B	Advertising interval (1 ms / LSb) • Acceptable values: 30 ms – 10240 ms • Other values: invalid and ignored	100 ms **0x 00 64**	*min_advertising_interval: <value>* *(unsigned/ms)*
0x 5B	Tx Advertising Power	1 B	BLE Tx Power (dBm) • 0x00 = 0 dBm • 0x01 = -0.85 dBm • 0x02 = -1.8 dBm • 0x03 = -3.15 dBm • 0x04 = -4 dBm • 0x05 = -4.95 dBm • 0x06 = -5.9 dBm • 0x07 = -6.9 dBm • 0x08 = -7.8 dBm • 0x09 = -8.85 dBm • 0x0A = -9.9 dBm • 0x0B = -12.05 dBm • 0x0C = -14.1 dBm • 0x0D = -16.5 dBm • 0x0E = -20.85 dBm • 0x0F = -40 dBm • Other values: invalid and ignored	0 dBm **0x 00**	*tx_advertising_power:* *<value>* *(unsigned/no unit)*

4.1.11 Response to DL Commands Configuration

The Stork includes the ability for the user to select the format of UL responses to DL commands. Details on the response formats can be found in Section 3.3. Table 4-11 shows the response to DL commands register. This register has R/W access.

Table 4-11: Response to DL Commands Configuration Register

Address	Name	Size	Description	JSON Variable (Type/Unit)
0x6F	Format Option	1 B	• Bit 0: 0: Invalid-write response format 1: 4-byte CRC • Bits 1-7: Ignored	*resp_format: <value>* *(unsigned/no unit)*

4.1.11.1 Format Option

The value of the Format Option register determines how the Sensor responds to DL commands. Setting Bit 0 to 0 (zero) selects the invalid-write response format, while a value of 1 (one) selects the 4-byte CRC method. Please refer to Section 3.3 for more details.

4.1.11.2 Default Configuration

Table 4-12 shows the default value for the response to DL commands configuration register.

Table 4-12: Default Value of Response to DL Commands Configuration Register

Format Option	Invalid-write response format

4.1.12 Command and Control

Configuration changes are not retained after a power cycle unless they are saved in the flash. Table 4-13 shows the structure of the command-and-control registers. In this table, the bit indexing scheme is as shown in Figure 4-1.

Table 4-13: Command and Control Registers

Address	Access	Name	Size	Description	JSON Variable (Type/Unit)
0x70	W	Flash Write Command	2 B	• Bit 15: Ignored • Bit 14: 0/1 = Do not write/Write LoRaMAC Configuration • Bit 13: 0/1 = Do not write/Write App Configuration • Bits 1-12: Ignored • Bit 0: 0/1 = Do not restart/Restart STORK	• *write_to_flash_loramac_config: <value>* *(string/no unit)* • *write_to_flash_app_config: <value>* *(string/no unit)* • *restart_sensor: <value>* *(string/no unit)*
0x71	R	Metadata	7 B	• Bits 48-55: App version major	• *app_ver_major: <value>* *(number/no unit)*

Address	Access	Name	Size	Description	JSON Variable (Type/Unit)
				• Bits 40-47: App version minor • Bits 32-39: App version revision • Bits 24-31: LoRaMAC version major • Bits 16-23: LoRaMAC version minor • Bits 8-15: LoRaMAC version revision • Bits 0-7: LoRaWAN region ID	• *app_ver_minor: <value>* *(number/no unit)* • *app_ver_revision: <value>* *(number/no unit)* • *loramac_ver_major: <value>* *(number/no unit)* • *loramac_ver_minor: <value>* *(number/no unit)* • *loramac_ver_revision: <value>* *(number/no unit)* • *lorawan_region_id: <value>* *(number/no unit)*
0x72	W	Reset to Factory Defaults[1]	1 B	• 0xB0 = Reset LoRaMAC Configuration • 0x0A = Reset App Configuration • 0xBA = Reset both LoRaMAC and App Configurations • Any other value: Invalid and ignored	• *factory_reset_config_app: <value>* *(string/no unit)* • *factory_reset_config_loramac: <value>* *(string/no unit)*

Note: The command-and-control registers are always executed after the full DL configuration message has been decoded. A reset command should always be sent as an unconfirmed DL message. Failure to do so may cause a poorly designed NS to continually reboot the STORK.

The LoRaWAN region is the last byte of the FW Version register (Register 0x71). Current LoRaWAN regions and corresponding region IDs are listed in Table 4-14.

Table 4-14: LoRaWAN Regions and Region IDs

LoRaWAN Region	Region ID
EU868	0
US915	1
AS923	2
AU915	3
IN865	4
KR920	6
RU864	7

[1] After sending the reset-to-factory-defaults command, the Stork is automatically reset with corresponding default configuration values.

Example:

- Write Application and LoRa Configurations to flash and reboot the device:
  - DL payload: 0x F0 60 01
- Get FW version, and reset App Configuration to factory defaults
  - DL payload: 0x 71 F2 0A

References

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[3] LoRa Alliance, "LoRaWAN Regional Parameters," ver. 1.0.2, rev. B, Feb 2017.

[4] LoRa Alliance, "LoRaWAN Specification," ver. 1.0.2, July 2016.

[5] LoRa Alliance, "LoRaWAN Regional Parameters," ver. 1.0.2, rev. B, Feb 2017.