Parking Lot Sensor

Communication Interface - Technical Description rev. 3
V0.23.3

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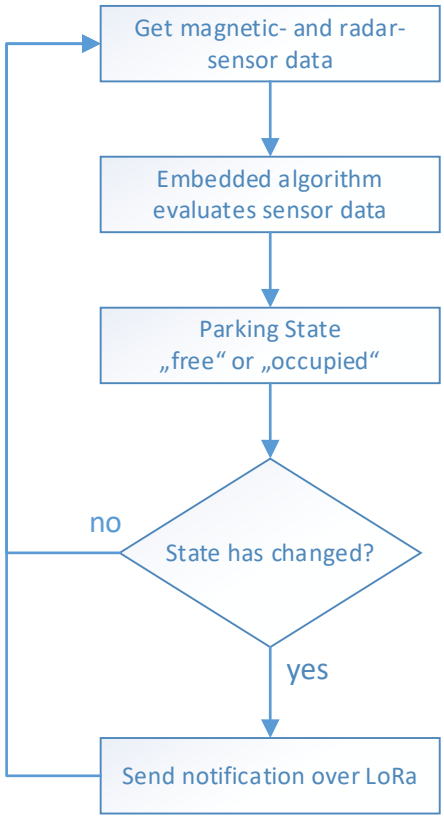
1 Principle of operation

The parking sensor device contains two independent sensing elements, a magnetometer for recognizing changes in the magnetic field of the environment and a RADAR sensor for measuring the reflectivity above the sensor device.



The sensors data are processed by the devices embedded algorithm. The algorithm output is the parking state “free” or “occupied”. The device checks, if the parking status has been changed since the last processing run and in case the parking state change will be communicated via the LoRa interface. This means, that the parking sensor will only report, if the parking state has changed.

Only stable parking states, occupied or free, for at least 35 seconds are considered for detection of parking state changes. This means, 2 or more parking status changes with less than 35 seconds between them will not be detected as such and will therefore not send LoRa parking status messages. If the new stable status after several fast changes is different to the previously known parking state, then the device will detect the new stable status and send a new LoRa parking status message. Considering the additional delay caused by the LoRa transmission and possibly re-transmissions, transmission time limitation of each device, transmission from the Gateway to the LoRa network and processing by the LoRa network, the complete delay from the new parking status until the state is visible in the LoRa application server may be 40 or more seconds.

2 First commissioning

Once the sensor has been installed on the mounting plate, the Firmware of the device will initialize and self-check itself for malfunction of Hardware components. This process takes approximately 2 minutes and it also delays the first LoRa join message. Considering that the device may need to re-send the LoRa join message if it does not receive a LoRa accept message on time (caused by radio attenuation, interference, or LoRa network unavailability), the complete time since installation until the sensor is first observed in the LoRa application server may take even longer than the 2 minutes required for initialization of the sensor.

Removing the sensor core from the mounting plate may in very unlikely situations make the device enter in malfunction mode. It is therefore strongly recommended to avoid this operation, unless intended for replacement of the sensor core due to battery depletion.

The parking sensor device is equipped with a self-learning algorithm. Thus it is not necessary to calibrate the sensor. Although the parking sensor device needs to learn how a parking event looks like. Therefore the detection performance after the installation and power-up is expected to be poor and reaches the optimal level after approximately 10 parking events. A parking event is defined as a parking status change from free to occupied or vice-versa. From this point on, the parking sensor devices learns with any new parking event. In case of a false detection or missing a parking state, the sensor will recover automatically after some parking events again.

After a reboot of the device, the sensor uses its pre-trained data until it has re-learnt the environment with 10 new parking events.

3 LoRaWAN Interface

The parking sensor device is equipped with a LoRa radio operated in Class A. The implemented functionality complies with the LoRaWAN Specification 1.0.2.

The frequencies supported and receive window parameters are according to the LoRaWAN v1.0.2 EU868 Regional Parameters rev. b. Both RX1 offset and RX2 can be reconfigured by the Join Accept message (CFList) or related MAC commands.

The battery level is not reported in the DevStatusAns MAC command.

3.1 Join Procedure

The Join procedure follows the Over-the-Air Activation (OTAA) described in the LoRaWAN Specification 1.0.2. Activation By Personalization (ABP) is not supported.

After powering up the parking sensor device, it will try to join a LoRaWAN Network by sending the join request message. In case the join request is not answered, the sensor will retry as soon as possible, according to transmission time limitations, up to 4 additional times (5 attempts in total). After the 5th unsuccessful attempt, the sensor will do an exponential reboot (see chapter 3.2) and repeat the process to try again for 5 more times.

If the Join request message is not answered with a Join accept message, the sensor will retry, following the next sequence:

Attempt	DataRate
1	Configured DR or default (DR2)
2	Configured DR or default (DR2)
3	DR2
4	DR1
5	DR0

In case the Join accept message is received at the attempt 3, 4 or 5, the sensor restores the configured DataRate to the default value (DR2). This behavior assumes that the configured DataRate does not allow communication with the Gateway.

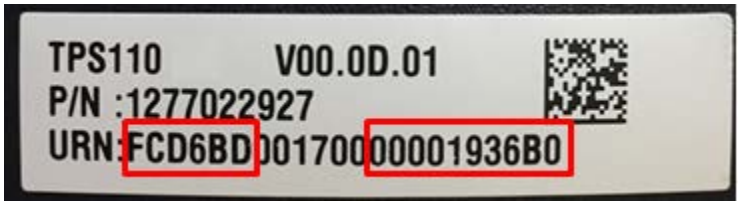
3.2 Exponential reboot

The sensor has been designed to save power and reduce the amount of messages sent while the LoRa network is not available. If the sensor detects that the LoRa network is not replying to its uplink messages, either LoRa join or regular uplink confirmed messages, the device will reboot and enter into an ultra low-power mode for an exponentially increasing amount of time.

Condition	Wait time until re-starting LoRa join request process
The device performs the first reboot, caused by either 5 unsuccessful attempts, to get a LoRa join accept message or 8 unsuccessful attempts to get an acknowledgement to a confirmed uplink message	1 minute
Subsequent reboots caused by 5 unsuccessful attempts to get a LoRa join accept message	Increasing with each reboot to 2, 4, 8, 16, 32 and 64 minutes. Once reached 64 minutes, the wait time is always 64 minutes

3.3 Device EUI

The device EUI of the sensor is pre-provisioned during production and can be derived from the URN printed on the sensor core. The URN can be found either on the bottom of the parking sensor core or on the label on top of the parking sensor core. Beside of the URN, also a barcode allowing a simplified installation process can be found. The device EUI can be derived from the URN as in this example:



DevEUI: 0xFC 0xD6 0xBD 0x00 0x00 0x19 0x36 0xB0

Exchanging the DevEUI of the sensor is not possible.

3.4 Application EUI

The AppEUI is pre-provisioned during production and will be delivered with the sensor batch. Exchanging the AppEUI of the sensor is not possible.

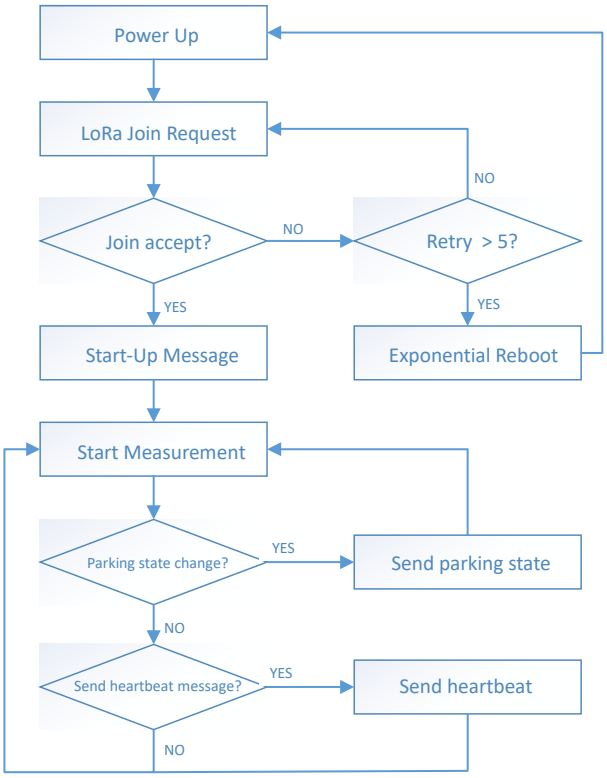
Note that the AppEUI needs to be transmitted as big endian. This is not conform with the LoRaWAN specification v1.0.2, which defines that all EUIs need to be sent as little endian. The endianness of the AppEUI will be corrected in future Firmware versions. The rest of EUIs need to be transmitted as little endian.

3.5 Application Key

The AppKey is pre-provisioned during production and will be delivered with the sensor batch. Exchanging the AppKey of the sensor is not possible.

4 Application protocol description

After a successful join (join accept message received) the sensor will send a start-up message, then begin with the normal operation and send park status messages whenever a change is detected. All application messages (start-up message, heart-beat message, and parking state message) are sent as confirmable by default. In case the confirmation is not received, the sensor will retry 7 more times, adapting the DataRate as recommended in the LoRaWAN v1.0.2 spec, chapter 18.4. Any confirmable message which does not receive a confirmation after the 7th re-transmission will initiate an exponential reboot. This behavior assumes that the connection with the network has been lost.



The parking state message can be configured as not confirmable. This reduces the use of duty cycle to acknowledge all messages, but may also reduce the percentage of successfully received messages by the Gateway.

If the network (Gateway or Backend) is down, the sensor behaves in the way described in LoRaWAN spec v1.0.2 chapter 18 and chapter 3 of this document.

The DataRate used in the uplink messages by the sensor is DR2 by default, but can be configured from DR0 to DR5.

The application protocol may be subject of change. The functionality may be extended in the next versions.

4.1 Uplink messages

4.1.1 Parking status message

Parking status message uses the **port 1** and is **confirmable by default**. It can be configured to not confirmable.

Byte [0]	
Bit [7 ... 1] **Reserved**	**Bit [0]** **Parking status**
Reserved	0: Free parking space 1: Occupied parking space

4.1.2 Heartbeat message

Heartbeat message uses the **port 2** and is **always confirmable**. The heartbeat message contains the same information as the parking status message and it is sent every 24 hours.

Byte [0]	
Bit [7 ... 1] **Reserved**	**Bit [0]** **Parking status**
Reserved	0: Free parking space 1: Occupied parking space

4.1.3 Start-up message

Start-up message uses the **port 3** and is **always confirmable**. It is sent after every start-up / reboot / (re-) join event.

Byte [16] **Parking status**		**Byte [15]** **Reset cause**	**Byte [14 : 12]** **FW version**	**Byte [11 :10]**	**Byte [9 : 0]** **Debug**
Bit [7 ... 1]	**Bit [0]**	0x01 - Watchdog reset 0x02 - Power On Reset 0x03 - System Request Reset 0x04 - Other Resets	Firmware Version (Currently 0.23.3)	Reserved	Debug information
Reserved	0: Free parking space 1: Occupied parking space				

Note that if a confirmable message is not acknowledged (8 attempts) or the Join request is not accepted (5 attempts), the system schedules a reset, showing in the Start-up message the value 0x03 (System Request Reset) as Reset cause. This is generally a good indication that the Gateways are not able to maintain stable communication with the sensor.
The PLS produces and stores debug codes and tries to send them to the Network using the Start-up message. The debug codes are produced by different reasons, for example in case the user is sending an invalid parameter in a downlink message, the network is not answering confirmed messages or several failure conditions which may or may not lead to a Software requested reboot.

Debug Information

Byte [9 : 8] Sequence number	Byte [7 : 4] Debug code	Byte [3 : 0] Timestamp
Sequence number	Debug code (see Debug codes)	Timestamp

Debug Code

Byte [3 : 2] Debug code	Byte [1 : 0] Reserved
Debug code(See debug codes List)	Reserved for internal use

Debug codes list

Codes (decimal)	Description	Leads to Software requested reboot
501	LoRa join request failed	YES
517	Cause for last reset: Watchdog	NO
518	Cause for last reset: Power-on	NO
520	Cause for last reset: Unknown	NO
710	Park detection algorithm recalibrating	YES
1000	Invalid downlink message port	NO
1001	Invalid length for DataRate (port 52)	NO
1002	Invalid value for DataRate (port 52)	NO
1003	Invalid value for Parking status confirmable configuration (port 51)	NO
1004	Invalid length for Parking status confirmable configuration (port 51)	NO
1005	Confirmed uplink message not acknowledged after 8 re-tries	YES
1006	Invalid downlink message length	NO
1010	Configuration selected was already active	NO

4.2 Downlink messages

The sensor supports confirmable and not confirmable downlink messages.

4.2.1 Confirmable configuration

Confirmable configuration uses the **port 51** and it applies only to the parking status message. The default value is Confirmable (0x00). The configuration selected is persistent.

Byte [0] **Confirmable configuration**
0x00: Confirmable (up to 8 retries) 0x01: Not confirmable (0 repetitions)

4.2.2 DataRate configuration

DataRate configuration uses the **port 52** and it applies to all uplink messages. The default value is DR2 (0x02). The configuration selected is persistent, unless overwritten in the join procedure.
The DataRates DR0 and DR1 are not supported in AS923 as the payload is 0 with dwell time enabled. If a user tries to configure the DataRate to DR0 or DR1 the resulting DataRate will be DR2.

Byte [0] **DataRate configuration**
0x00: DR0 (SF12) 0x01: DR1 (SF11) 0x02: DR2 (SF10) 0x03: DR3 (SF9) 0x04: DR4 (SF8) 0x05: DR5 (SF7)

5 Changelog

v0.23.3 24 Oct 2018

Features

- LoRaWAN v1.0.2 compliant
- Configurable DataRate and confirmed/unconfirmed park status messages
- Parking status message with new simplified format
- Hearbeat with new format
- Startup with new format
- Uplink messages queue
- Improved LoRa join retry handling and exponential reboots

Known issues and limitations

- MIC errors may lead to a reboot of the device
- Repeated downlink messages with same Frame Counter may lead to a reboot of the device
- AppEUI needs to be sent in big endian format, which is not LoRaWAN compliant
- A power cycle of the device while running may lead to malfunction in very unlikely scenarios

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v0.17.1 01 May 2018 – Prototype PoC

Features

- Payload based on Type-Length-Value format

Known issues and limitations

- Not completely LoRaWAN v1.0.2 compliant
- Lack of uplink messages queue may silently drop messages when there is not enough duty cycle
- This is a Prototype release, which is only intended for experimental use cases

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