1. INTRODUCTION

This document describes the operation of the SensorData/SensorNode devices, and how to interpret the data messages that are sent on the network. For examples and other support documentation, visit https://support.digitalmatter.com

The Sigfox and LoRaWAN device operation and protocols are very similar, and both handled in this document.

1.1. Message Size Implications

We are limited to:

- **12-byte messages on the Sigfox network.**
- **11-byte (minimum) messages on the LoRaWAN network.**

The LoRaWAN maximum message size depends on the region and spreading factor (SF). 11 bytes is the worst case (EU868 region, SF12).

Because of these constraints, this data scheme aims to pack in data as efficiently as possible into the messages.

No date/time data is sent in the messages as the receiving software should use the date/time stamp from the network.

For the LoRaWAN devices, the LoRaWAN port is used as the first byte of the message; ie, **the port is the ID of the first data field in the message, and the data for that field starts at byte 0 of the payload.**

1.2. No Acknowledgement

In addition to the size limitation, the messages are not acknowledged by the network, so the data is sent on a “best effort” basis.

The implications of this are far-reaching as data cannot be guaranteed to have been delivered. The SensorData design therefore aims to send information that will not be adversely affected by missing messages. For example, for a tipping rain gauge the SensorData will record the count of the tips and send the total tip count each time, as opposed to trying to send a message for every tip, where if one was missed then the count on the server would be wrong.

1.3. Multi-part Data Avoided

As far as possible this data scheme avoids sending related data over more than one message due to the complexity of re-assembly on the server side and transmission limitations. Data fields are always contained within a single message.

More than one data field may appear in a single message.

In summary:

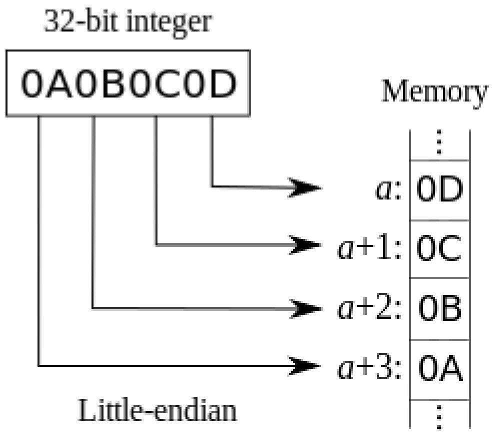
- One data field will not be split across multiple messages.
- Many data fields may appear in one message.

1.4. Number Formats

1.4.1. Little Endian

All data in the payloads is LITTLE ENDIAN. Be aware of this when converting data fields that consist of more than one byte from the data payload.

https://en.wikipedia.org/wiki/Endianness#Little



1.4.2. Signed (Negative) Numbers

Signed numbers are represented in "two's complement" form. Be aware of this when converting signed fields from the data payload.

https://en.wikipedia.org/wiki/Two's_complement

All multi-byte values are treated as little-endian.

1.4.3. Bit Numbering

Bit number is from the 'right' – ie the LSBit is b0

2. DATA FIELDS

Each item of data that the SensorData measures and/or transmits is referred to as a "Data Field".

Each Data Field is identified by a Data Field ID value (also known as a "key"), and the software decoding the information needs to have knowledge of the IDs being sent to it and what their corresponding lengths are.

Note that in the case of LoRaWAN, the first ID is given by the LoRaWAN Port number for the message. The data starts at byte 0 of the payload.

2.1. List of Data Fields

ID	Name	Size	Units
0	Reserved		
1	System Firmware version		
2	Debug Statistics	TBD	Struct
3	Reserved for Downlink Acknowledgement		

10	GPS Position	6	Struct
20	Battery Voltage	2	UINT16 (mV)
21	Analog In 1	2	UINT16 (mV)
22	Analog In 2	2	UINT16 (mV)
23	Analog In 3	2	UINT16 (mV)
30	Digital Input State	1	Bitfield
31	Input 1 Pulse Count	2	UINT16
32	Input 2 Pulse Count	2	UINT16
33	Input 3 Pulse Count	2	UINT16
39	Digital Input Alert	2 + 2*N	Struct
40	Internal Temperature	2	INT16 (x100 degC)
41	Digital Matter I2C Temperature Probe 1 (Red)	2	INT16 (x100 degC)
42	Digital Matter I2C Temperature Probe 2 (Blue)	2	INT16 (x100 degC)
43	Digital Matter I2C Temperature & Relative Humidity	3	Struct
50	Battery Energy Used Since Power Up. 65535 = Unknown	2	UINT16 (mAh)
51	Estimated Battery % Remaining. 255 = Unknown	1	BYTE (0.5%)
128	SDI-12 Measurement 1	N	Struct
129	SDI-12 Measurement 1 – Part 2	N	Struct
130	SDI-12 Measurement 2	N	Struct
131	SDI-12 Measurement 2 – Part 2	N	Struct
132	SDI-12 Measurement 3	N	Struct
133	SDI-12 Measurement 3 – Part 2	N	Struct
134	SDI-12 Measurement 4	N	Struct
135	SDI-12 Measurement 4 – Part 2	N	Struct
136	SDI-12 Measurement 5	N	Struct
137	SDI-12 Measurement 5 – Part 2	N	Struct
223	Reserved		
224 to 255	Reserved as the LoRaWAN specification reserves these ports		

2.2. GPS Position (10)

Length = 6 bytes

All 0xFF == no fix available

Offset	Type	Name	Units
0	INT24	Latitude	Deg x 10^7 / 256
3	INT24	Longitude	Deg x 10^7 / 256

INT24 for position gives 4m precision.

2.3. Digital Input State (30)

Contains a bitfield which correspond to the digital inputs. All unused/unsupported inputs will be set to 0.

Offset	Type	Name	Units
0.0	BOOL	Digital Input 1 state	
0.1	BOOL	Digital Input 2 State	
0.2	BOOL	Digital Input 3 State	
0.3-0.7	-	Reserved	

2.4. Digital Input Alert (39)

Length = 2 + 2 x Number of digital inputs on device.

Offset	Type	Name	Units
0	BYTE	Current digital input state	Bitfield
1	BYTE	Input that triggered the alert	Number
2+(n-1)*2	UINT16	Digital input n change count	Number of changes

By comparing the old and new states, it can be determined which input has triggered the alert. The change count shows the same values as data fields 31-33.

2.5. Digital Matter I2C Temperature & Relative Humidity (43)

Length = 3

Offset	Type	Name	Units
0	INT16	Temperature	x100 degC
2	UINT8	Relative Humidity	0.5%

2.6. SDI-12 Measurements

Offset	Type	Name	Units
0.0-0.3	UINT4	Number of data points	
0.4-0.7	UINT4	Data type for this measurement 0 = soil moisture UINT8 1 = temperature UINT8 2 = INT16 (x100) 3 = INT32 (x1000) 4 = INT12	The data type determines the data size, scale and offset to use (see below)
1	-	Data for the measurement Length depends on the data type and the number of data points	

2.6.1. SDI-12 Soil Moisture UINT8

The SensorData packs SDI-12 soil moisture values into UINT8 fields to get as many values in the message as possible.

SMP = (value in field / 2) – 5, yielding a range of -5 to 122.5 with 0.5 precision.

Using this data type the maximum number of readings that can be packed into a single message is 10. A “Part 2” data field allows for a second set of 10 readings.

2.6.2. SDI-12 Temperature UINT8

The SensorData packs SDI-12 temperature values into UINT8 fields to get as many values in the message as possible.

Temp = (value in field / 2) – 40, yielding a range of -40 to 87.5 with 0.5 precision.

Using this data type the maximum number of readings that can be packed into a single message is 10.

2.6.3. SDI-12 Generic INT16 * 100

This allows a SDI-12 reading to be ±327.67 with 2 decimal places.

Using this data type, the maximum number of data points that can be packed into a single message is 5.

2.6.4. SDI-12 Generic INT32 * 1000

This allows a SDI-12 reading to be ±2,147,483.647 with 3 decimal places.

Using this data type, the maximum number of data points that can be packed into a single message is 2.

2.6.5. SDI-12 Generic INT12

Designed to cover both soil moisture and temperature, INT12 covers -50 to +154.7, with a precision of 0.05.

Value = (value in field / 20) – 50

Using this data type, the maximum number of data points that can be packed into a single message is 6.

Care must be taken when decoding values, as they span across multiple byte boundaries.

Byte 1	Byte 2		Byte 3
Sample 1 MSB	Sample 1 LSB	Sample 2 MSB	Sample 2 LSB

The length of the sdi12 data can be determined by using the table below:

Number of Samples	1	2	3	4	5	6
Length (bytes)	2	3	5	6	8	9

Example: 3 samples returned – 25.60, 17.55, 12.30

Received: {0x5E, 0x85, 0x47, 0x4D, 0xE0} (5 bytes, last 4 bits can be ignored)

0x5E8 = 1512 -> 1512 / 20 - 50 = 25.60

0x547 = 1351 -> 1351 / 20 – 50 = 17.55

0x4DE = 1246 -> 1246 / 20 – 50 = 12.30

2.6.6. SDI-12 Error format

If the SensorData fails to take a reading from the specific sensor, the number of data points will be set to 0, and the type will be left as set. The total length will be 1 byte (no data section).

3. NON-VOLATILE COUNTER STORAGE

Where it makes sense the counter values will be written to non-volatile storage periodically (if they have changed). This is to allow them to be read if the device is reset or has its batteries changed.

4. MESSAGE PACKING

Data fields are packed into Sigfox/LoRaWAN messages as key/value pairs. The key is the ID of the data field and this is followed by the data.

The data field size is implied from the ID, or in some cases where the data is variable length then the length of the data field is encoded at the start of the data field itself.

This data layout allows us to fit as many of the data fields as we can into a limited byte size message in a flexible manner.

The SensorData firmware will determine the order and best way to pack the data fields into messages, possibly splitting the data fields across multiple messages. However, a single key/value will always be totally contained within a single message.

5. SCHEDULES

The SensorData is setup to transmit based on schedules.

Several different schedules can be setup (currently up to 5), and the schedule parameters contain information that allow the SensorData to determine the schedule timing.

Each schedule is defined to send messages that contain data from a selected list of data fields for the transmission schedule.

For example:

Schedule 1	Every 30 minutes Transmit the temperature, humidity and tipping rain gauge count
Schedule 2	Every 1 day Transmit the GPS data (location)

5.1. Message Queueing

It is important to be aware of message restrictions in terms of duty cycle depending on the region that you are located in. Sigfox networks have a maximum of 140 messages per day per device.

If a schedule results in more than one message to be sent then the messages will be sent one after another, as duty cycle limitations allow.

5.2. Schedule Expiry

On the LoRaWAN devices, due to duty cycle limitations (depending on the region), a schedule data expiry has been added to guard against transmitting data that is too old. If the expiry time passes while waiting for a transmission, the schedule will be cancelled, and no more data will be sent.

If data is constantly being expired (only receiving the first payload of a schedule), the schedules should be changed to a more appropriate period for the region. For example, a schedule can be split into multiple schedules/periods.

6. PARAMETERS

6.1. Schedules

Each schedule is defined in a FlexiParam block.

Currently the design caters for a time interval and an offset.

6.2. Data Fields

Certain data fields may need to have additional parameters set for them on an installation of a SensorData (eg SDI-12 sensor data) and this is done by setting data field specific parameters on the SensorData.

6.2.1. SDI-12 Measurement Parameters

Offset	Type	Name	Units
0	CHAR	Address of the SDI-12 probe	'0'..'9'
1	CHAR	Measurement number	'0'..'9'
2	UINT8	Number of data points	1-15
3	UINT8	Data type for this measurement See 2.6 for more detail	

7. DOWNLINK MESSAGES

Downlink payloads are limited to 8 bytes on Sigfox and can be as small as 11 bytes on LoRaWAN. Therefore we split downlink configuration messages up in to separate structures where each can configure a certain part of the devices functionality. The payload structure is determined by the payload ID; this is either the first byte in Sigfox payloads, or the port number in LoRaWAN payloads. Please note: Currently only one downlink request is supported per LoRaWAN downlink. All data after the first will be ignored.

7.1. Acknowledgement Uplink

When a downlink message is received, the SensorData/SensorNode will send an explicit acknowledgement uplink (data field ID 3) on reception of a downlink. It sends this acknowledgement only once, as soon as possible (limited by network, and after any already pending messages). The uplink includes a sequence number to help identify the specific downlink being acknowledged, despite any queuing / buffering in the network. 'Confirmed' and 'unconfirmed' downlinks are handled in the same way.

7.1.1. Sigfox Payload

Offset	Description
0	Field ID (3)
1.0-1.6	Sequence number (identifies downlink to server)
1.7	0: Downlink rejected, 1: Downlink accepted
2	Firmware major version
3	Firmware minor version

7.1.2. LoRaWAN Payload (Port 3)

Offset	Description
0.0-0.6	Sequence number (identifies downlink to server)
0.7	0: Downlink rejected, 1: Downlink accepted

1	Firmware major version
2	Firmware minor version

7.2. Downlink Message Formats

For LoRaWAN devices, the first byte (downlink type) is moved to the port number.

7.2.1. Downlink 1 – 5: Set Schedule Parameters

Sets parameters for schedules 1 to 5.

Offset	Description
0	Downlink type (1 – 5)
1.0-1.6	Downlink sequence number (reported in acknowledgement)
1.7	Reserved. Set to zero
2 (BYTE)	Schedule period. 1-127: 1-127 minutes, 129-255: 1-127 Hours, 0 or 128 disables
3 (BYTE)	Schedule Expiry time (10 seconds)
4 (BYTE)	Item type 1 (See list of data fields)
5 (BYTE)	Item type 2
6 (BYTE)	Item type 3
7 (BYTE)	Item type 4

7.2.2. Downlink 10: Analog Input Parameters

Any parameters unsupported on the specific device should be set to 0.

Offset	Description
0	Downlink type (10)
1.0-1.6	Downlink sequence number (reported in acknowledgement)
1.7	Reserved. Set to zero
2.0	Input 1 enable 3.3v out on sample. Default 0 (disabled)
2.1	Input 1 enable Vout on sample. Default 0 (disabled)
2.2	Input 2 enable 3.3v out on sample. Default 0 (disabled)
2.3	Input 2 enable Vout on sample. Default 0 (disabled)
2.4	Input 3 enable 3.3v out on sample. Default 0 (disabled)
2.5	Input 3 enable Vout on sample. Default 0 (disabled)
2.6-2.7	Reserved. Set to zero

3 (BYTE)	Input 1 power on delay (seconds). Default 0
4 (BYTE)	Input 2 power on delay (seconds). Default 0
5 (BYTE)	Input 3 power on delay (seconds). Default 0

7.2.3. Downlink 12: Digital Input Parameters

Any parameters unsupported on the specific device should be set to 0.

Offset	Description
0	Downlink type (12)
1.0-1.6	Downlink sequence number (reported in acknowledgement)
1.7	Reserved. Set to zero
2 (BYTE)	Global maximum alarm rate. 1-127: 10-1270 seconds, 129-255: 10-1270 minutes, 0 or 128 disables. Default 600s (188)
3.0	Input 1: Transmit on low to high, default off (0)
3.1	Input 1: Transmit on high to low, default off (0)
3.2	Input 2: Transmit on low to high, default off (0)
3.3	Input 2: Transmit on high to low, default off (0)
3.4	Input 3: Transmit on low to high, default off (0)
3.5	Input 3: Transmit on high to low, default off (0)
3.6-3.7	Reserved. Set to zero
4 (BYTE)	Input 1 debounce period (10 ms). Default 1s (100)
5 (BYTE)	Input 2 debounce period (10 ms). Default 1s (100)
6 (BYTE)	Input 3 debounce period (10 ms). Default 1s (100)

7.2.4. Downlink 14: GPS Parameters

Offset	Description
0	Downlink type (14)
1.0-1.6	Downlink sequence number (reported in acknowledgement)
1.7	Reserved. Set to zero
2 (BYTE)	Required PDOP for valid GPS, 25-100: 2.5 to 10.0. Default 10.0 (100)
3 (BYTE)	Required position accuracy for valid GPS, 5-100: 5-100 m. Default 75 m
4 (BYTE)	Required speed accuracy for valid GPS, 0.1 km/h, 2.9-19.8 km/h. Default 10 km/h (100)

5 (BYTE)	Discard first N GPS points to allow solution to settle, 0-32: 0-32 positions. Default 3
6 (BYTE)	Fix timeout (seconds). Default 90

7.2.5. Downlink 16: SDI-12 General Parameter

Offset	Description
0	Downlink type (16)
1.0-1.6	Downlink sequence number (reported in acknowledgement)
1.7	Reserved. Set to zero
2 (BYTE)	Global power up delay (seconds). Default 5

7.2.6. Downlink 17-21: SDI-12 Measurement Parameters

Downlink type 17 = measurement 1, downlink type 18 = measurement 2 etc.

Offset	Description
0	Downlink type (17-21)
1.0-1.6	Downlink sequence number (reported in acknowledgement)
1.7	Reserved. Set to zero
2 (BYTE)	Measurement address (0-9)
3 (BYTE)	Measurement type (see SDI-12 protocol specifications)
3 (BYTE)	Measurement count (0-20). See SDI-12 measurements for limitations
4 (BYTE)	Measurement data type (see SDI-12 measurements)

7.2.7. Downlink 30: Power Parameters

Offset	Description
0	Downlink type (30)
1.0-1.6	Downlink sequence number (reported in acknowledgement)
1.7	Enable Vout Boost. Default off (0)
2.0-2.1	0 = Disable battery level sensing, 1 = mAh sensing only, 2 = mAh & % sensing, 3 = reserved.
2.2-2.7	Reserved. Set to zero

7.2.8. Downlink 40: Set LoRaWAN Channels

Only applies to LoRaWAN devices. Port 40.

Offset	Description
0.0-0.6	Downlink sequence number (reported in acknowledgement)
0.7	Reserved. Set to zero
1.0-1.3	Minimum data rate to use when ADR is disabled. Default is 0 (DR0)
1.4-1.7	Maximum data rate to use when ADR is disabled. Default is 2 (DR2)
2-10	Uplink channel mask, set bits are enabled channels, LSb of the 1st byte is channel 0, MSb of the 9th byte is channel 71, set all zeros (default) for the region-specific defaults

The SensorData/SensorNode will spread its transmissions out over the allowed data rates in such a way as to equalize the time spent on-air at each data rate. For the default setting of DR0-DR2, this gives a 16 / 30 / 54% split between the three data rates, and maximizes the gateway's capacity. However, the relative range of the three data rates are 100, 75, and 50% respectively. When ADR is enabled, the network server controls the data rate instead.

The uplink channel mask should be left 0 (default) in regions where the network join channels are fixed: EU863-870, IN865-867, AS923, and KR920-923. In these regions, the gateway will tell the device which channels to use, during the join procedure.

In regions where the join channels are not specified (US902-928, AU915-928), you should set the channel mask to avoid continued transmission on unused channels. In these regions the gateway will usually not tell the device which channels to use, resulting in significant packet loss if the mask hasn't been programmed.

7.2.9. Downlink 41: Set LoRaWAN Application

Only applies to LoRaWAN devices. Port 41.

Offset	Description
0.0-0.6	Downlink sequence number (reported in acknowledgement)
0.7	Set AppEUI. 0 = Use default AppEUI, 1 = Use supplied AppEUI. Default 0
1-8	AppEUI, big endian, ie. default AppEUI 70-B3-D5-70-50-00-00-05 is encoded with first byte as 0x70 and the second byte 0xB3, where 70-B3-D5-70-5 is the manufacturer identifying portion of the AppEUI

The acknowledgement will be transmitted **once** on the existing AppEUI, and then the device will switch to the new AppEUI. It continues to use the already provisioned AppKey, which cannot be programmed over the air.

7.2.10. Downlink 42: Set Advanced LoRaWAN Options

Only applies to LoRaWAN devices. Port 42.

Offset	Description
0.0-0.6	Downlink sequence number (reported in acknowledgement)
0.7	Reserved. Set to zero
1 (BYTE)	Days between network joins, 0 disables. Default 14
2.0-2.1	ADR support. 0 = never, 2 = Always. Other options are reserved. Default never.
2.2-2.7	Reserved. Set to zero

By default, the SensorData/SensorNode rejoins the network once a fortnight, in case the network server has somehow forgotten the session keys. This period can be extended to up to 255 days, or disabled entirely. However, if a device is accidentally deleted on the network server, or the network server suffers a database failure and loses the session keys, the server will be unable to decrypt any device data until it has rejoined. Rejoining fortnightly generates several extra transmissions, but lowers the time spent out of service in the event of an accident.

By default, the device does not request Adaptive Data Rate (ADR) when sending uplinks, choosing instead to control its data rate according to the configured range. However, you may wish to enable ADR when the device is mostly stationary, to optimize power usage and network capacity.

Please remember that the ADR adaptation rate in LoRaWAN 1.0 is extremely slow. If the device loses connectivity, it takes 96 lost transmissions before it will attempt to increase its transmit range. This adaptation rate will be adjustable in a future LoRaWAN release.

8. CONTACT INFORMATION

View our website and online knowledge base for the latest documentation and FAQs.
http://www.digitalmatter.com/support

Contact: http://www.digitalmatter.com/contact

Sign up for our product news and updates: http://eepurl.com/buyjvb