Synetica - enLink LoRaWAN decoders

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Preamble

Synetica is a UK based company that designs and develops energy and environmental sensors. We specialise in highly accurate and reliable air quality monitoring using LoRaWAN long range wireless.

The **enLink** range of LoRaWAN devices are categorised into the following:

- Air Quality Monitors (Indoor and Outdoor, mains and battery powered)
- Indoor Environmental Sensors
- Modbus Reader - Serial RS485 RTU
- Pulse Counter
- Leak Sensor
- Differential Pressure / Air Flow
- Temperature Probes

This repository contains various decoders for the LoRaWAN data packets. The uplink data is telemetry data containing values like temperature, particulates and gas concentrations.

This version of the enLink firmware implements LoRa Mac 4.4.0 release from Semtech/StackForce LoRaMac-Node.

This LoRaWAN stack implements all regions defined in "LoRaWAN Regional Parameters v1.0.2rB" document. Class A and Class C endpoint implementation is fully compatible with "LoRaWAN specification 1.0.2".

Uplink Payload

The enLink payload structure is designed to be as efficient as possible. Data for multiple sensor values can be concatenated into a single payload which can be easily decoded. If the payload length is restricted due to channel time limits, the whole message will be split into multiple payloads. Each payload will always be split on a **Sensor Data** boundary. This is done so each payload can be easily decoded. A payload will always have the first byte as a **Data Type Identifier**.

Uplink Payload Structure

The payload is an array of **Sensor Data** messages.

Sensor #1 Data (2 or more bytes) | Sensor #2 Data | ... | Sensor *n* Data

Sensor data consists of a **Data Type Identifier** byte followed by the **Data Value** as one or more bytes. The number of bytes in the data value is determined by the Data Type Identifier and is fixed. Details are here: Sensor Details.

Example Payload (hexadecimal): `01 01 23 02 56 03 01 A4`

These bytes can be split up as follows:

Payload Data: 01 | 01 23 | 02 | 56 | 03 | 01 A4

Finally, decoding the data:

Data Type Identifier	Data Value Calculation	Result
`0x01` - Temperature	((`0x01` * 256) + `0x23`) / 10 = (256 + 35) / 10	29.1 °C
`0x02` - Humidity	`0x56`	86 %rH
`0x03` - Ambient Light	(`0x01` * 256) + `0xA4` = 256 + 164	420 Lux

Each Data Type can use 1 or more bytes to send the value according to the following table

Sensor Details

Type	Sensor	Sensor Range	Units	Num Bytes	Format	Scaling
`0x01`	Temperature	-40 to 85	°C	2	S16	/ 10
`0x02`	Humidity	0 to 100	%	1	U8	
`0x03`	Ambient Light	0.01 to 83k	lux	2	U16	
`0x04`	Pressure	300 to 1100	mbar	2	U16	
`0x05`	Volatile Organic Compounds (VOC)	0 to 500	IAQ	2	U16	
`0x06`	Oxygen	0 to 25	%	1	U8	/ 10

Type	Sensor	Sensor Range	Units	Num Bytes	Format	Scaling
0x07	Carbon Monoxide	0 to 100	ppm	2	U16	/ 100
0x08	Carbon Dioxide	0 to 2000	ppm	2	U16	
0x09	Ozone (O3)	0 to 1 0 to 1000	ppm ppb	2	U16	/ 10000 / 10
0x0A	Air Pollutants: CO, Ammonia, Ethanol, H2, Methane / Propane / Iso-Butane.	100 to 1500 (Typ)	kΩ	2	U16	/ 10
0x0B	Particulate Matter 2.5	0 to 1000	µg/m3	2	U16	
0x0C	Particulate Matter 10	0 to 1000	µg/m3	2	U16	
0x0D	Hydrogen Sulphide (H2S)	0 to 100	ppm	2	U16	/ 100
0x0E	Pulse ID + Pulse Counter	ID: 0 to 3 Value: 0 to 2^32	count	1 + 4	U32	
0x0F	MB ID + Modbus Exception	ID: 0 to 31 Error Num		1 + 1	U8	
0x10	MB ID + Modbus Interval value	ID: 0 to 31 Interval Value		1 + 4	F32	
0x11	MB ID + Modbus Cumulative value	ID: 0 to 31 Cumulative Value		1 + 4	F32	
0x12	bVOC – VOC concentration		ppm	4	F32	
0x13	Detection count (PIR etc.)		count	4	U32	
0x14	Total occupied time		seconds	4	U32	
0x15	Occupied Status	0 = Unoccupied 1 = Occupied	status	1	U8	
0x16	Liquid Level Status	0 = No Liquid 1 = Detected	status	1	U8	
0x17	Probe 1 Temperature	-55 to 125	°C	2	S16	/ 10
0x18	Probe 2 Temperature	-55 to 125	°C	2	S16	/ 10
0x19	Probe 3 Temperature	-55 to 125	°C	2	S16	/ 10
0x1A	Time temperature probe 1 has spent in 'in band' zone		seconds	4	U32	
0x1B	Time temperature probe 2 has spent in 'in band' zone		seconds	4	U32	

Type	Sensor	Sensor Range	Units	Num Bytes	Format	Scaling
0x1C	Time temperature probe 3 has spent in 'in band' zone		seconds	4	U32	
0x1D	Number of times in band alarm has been activated for temperature probe 1		count	2	U16	
0x1E	Number of times in band alarm has been activated for temperature probe 2		count	2	U16	
0x1F	Number of times in band alarm has been activated for temperature probe 3		count	2	U16	
0x20	Time temperature probe 1 has spent below low threshold		seconds	4	U32	
0x21	Time temperature probe 2 has spent below low threshold		seconds	4	U32	
0x22	Time temperature probe 3 has spent below low threshold		seconds	4	U32	
0x23	Number of times low threshold alarm has been activated for temperature probe 1		count	2	U16	
0x24	Number of times low threshold alarm has been activated for temperature probe 2		count	2	U16	
0x25	Number of times low threshold alarm has been activated for temperature probe 3		count	2	U16	
0x26	Time temperature probe 1 has spent above high threshold		seconds	4	U32	
0x27	Time temperature probe 2 has spent above high threshold		seconds	4	U32	
0x28	Time temperature probe 3 has spent above high threshold		seconds	4	U32	
0x29	Number of times high threshold alarm has been activated for temperature probe 1		count	2	U16	

Type	Sensor	Sensor Range	Units	Num Bytes	Format	Scaling
0x2A	Number of times high threshold alarm has been activated for temperature probe 2		count	2	U16	
0x2B	Number of times high threshold alarm has been activated for temperature probe 3		count	2	U16	
0x2C	Differential Pressure	+/- 5000	Pa	4	F32	
0x2D	Airflow	0 to 100	m/s	4	F32	
0x2E	Voltage	0 to 10	Volts	2	U16	/ 1000
0x2F	Current	0 to 20	mA	2	U16	/ 1000
0x30	Resistance	0 to 10	kΩ	2	U16	/ 1000
0x31	Leak Detection (resistance rope)	0 = No Leak 1 = Detected	status	1	U8	
0x3F	CO2e estimate equivalent		ppm	4	F32	
0x50	Sound Level Minimum		dB(A)	4	F32	
0x51	Sound Level Average		dB(A)	4	F32	
0x52	Sound Level Maximum		dB(A)	4	F32	
0x53	Nitric Oxide	0 - 100	ppm	2	U16	/ 100
0x54	Nitrogen Dioxide	0 – 5	ppm	2	U16	/ 10000
0x55	Nitrogen Dioxide	0 – 20	ppm	2	U16	/ 1000
0x56	Sulphur Dioxide	0 – 20	ppm	2	U16	/ 1000
0x57	Particulate matter mass concentration at PM1.0		$\mu g/m^3$	4	F32	
0x58	As above, PM2.5		$\mu g/m^3$	4	F32	
0x59	As above, PM4.0		$\mu g/m^3$	4	F32	
0x5A	As above, PM10.0		$\mu g/m^3$	4	F32	
0x5B	Particulate matter number concentration at PM0.5		$\#/cm^3$	4	F32	
0x5C	As above, PM1.0		$\#/cm^3$	4	F32	
0x5D	As above, PM2.5		$\#/cm^3$	4	F32	
0x5E	As above, PM4.0		$\#/cm^3$	4	F32	

Type	Sensor	Sensor Range	Units	Num Bytes	Format	Scaling
0x5F	As above, PM10.0		#/cm³	4	F32	
0x60	Particulate matter typical particle size		µm	4	F32	
0x61	Gas ID + Gas Concentration		ppb	1 + 4	F32	
0x62	Corrosion: Metal ID + Metal Thickness	~ 1000nm	nm	1 + 4	F32	
0x63	Corrosion: Metal ID + Minimum thickness		nm	1 + 2	U16	
0x64	Corrosion: Metal ID + Original thickness		nm	1 + 2	U16	
0x65	Corrosion: percentage of thickness between original thickness (100%) and minimum (0%)		%	1 + 4	F32	
0x66	Gas ID + Gas Concentration		µg/m³	1 + 4	F32	
0x67	Outdoor EPA Index Sensor Fast AQI (reading taken over 1 minute)	0 to 500	AQI	2	U16	
0x68	Outdoor EPA Index Sensor EPA AQI See: AirNow Technical Doc	0 to 500	AQI	2	U16	

Decoding Complex Messages

Most sensor data values are self-explanatory, additional information for decoding more complex sensor data is given in the sections below.

Modbus - Types: `0x0F`, `0x10`, `0x11`

The enLink Modbus data types for Interval and Cumulative values use 5 bytes to encode the item index and value.

- Modbus Exception – standard Modbus exception codes, e.g. Code 2 – Illegal Data Address.
- Modbus Interval Value – for Modbus data types which do not accumulate, e.g. Voltage, Current, Temperature etc.
- Modbus Cumulative Value – for Modbus data types which are linked to a value which accumulates, e.g. kWh, Volume etc.

The first byte indicates which of the 32 available Modbus items is being accessed (0 to 31), followed by the Modbus Value represented as a 32 bit floating point value (IEEE754 format). Interval Value types are used for instantaneous values, such as Voltage, Current, Temperature, Pressure etc. Cumulative Values are used for items such as energy consumption and total volume.

Example Modbus Payload (hexadecimal): `10 04 41 BC 7A E1`

Payload Data: 10 04 41 BC 7A E1

This is an interval data value, from configured item number 5. The value is 23.56.

For an online converter, see Hex to Float Converter

Gas Readings – Types: `0x61`, `0x66`

The full message is sent as 6 bytes. For example:

Payload (hexadecimal): `61 19 41 BC 7A E1`

Payload Data: 61 19 41 BC 7A E1

Ths translates to Gas Type `0x19` or 25 which is **Carbon Monoxide**. The value is 23.56ppb.

The Gas types are listed here:

`0x17` - Formaldehyde - HCHO / CH_2O	`0x1E` - Hydrogen Cyanide - HCN
`0x18` - Volatile Organic Compounds	`0x1F` - Hydrogen Fluoride - HF
`0x19` - Carbon Monoxide - CO	`0x20` - Ammonia - NH_2
`0x1A` - Chlorine - Cl_2	`0x21` - Nitrogen Dioxide - NO_2
`0x1B` - Hydrogen - H_2	`0x22` - Oxygen - O_2
`0x1C` - Hydrogen Sulphide - H_2S	`0x23` - Ozone - O_3
`0x1D` - Hydrogen Chloride - HCl	`0x24` - Sulphur Dioxide / Sulfur Dioxide (IUPAC) - SO_2

Corrosion – Types: `0x62`, `0x63`, `0x64`, `0x65`

The full message is sent as 6 bytes. The second byte indicates the coupon and sacrificial metal of the sensor.

Payload (hexadecimal): `62 01 44 58 D0 27`

Payload Data: 62 01 44 58 D0 27

The example shows Coupon #1 is Copper and the thickness is 867.252 nanometres (equivalent to 8672.52 Ångströms).

Other Coupon/Metal types are:

Coupon #1	**Coupon #2**
`0x00` - Unknown Metal / Error	`0x80` - Unknown Metal / Error
`0x01` - Copper	`0x81` - Copper
`0x02` - Silver	`0x82` - Silver

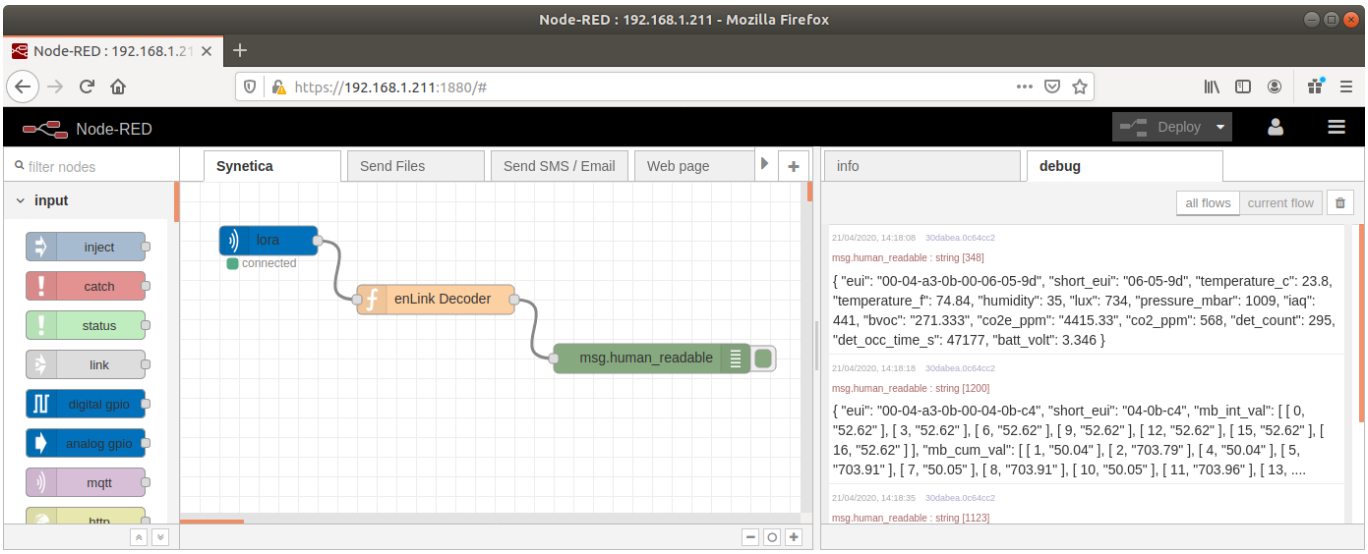
Coupon #1	Coupon #2
0x03 - Chromium	0x83 - Chromium

enLink KPI Payload Data

Each enLink end-node device can have optional Key Perfomance Indicators (KPI) added to the payload message. Each KPI can use 1 or more bytes to send the value according to the following table.

Type	KPI	Comments	Units	Num Bytes	Format
0x40	CPU Temperature	Packed Byte. See JS Code	°C	2	S16
0x41	Battery Status	0=Charging; 1 - 254 (1.8 - 3.3V); 255=Ext Power	status	1	U8
0x42	Battery Voltage	0 -> 3600 mV (3600=Ext Power)	mV	2	U16
0x43	RX RSSI	Received Signal Strength	dBm	2	S16
0x44	RX SNR	Received Signal-Noise Ratio	dB	1	S8
0x45	RX Count	Downlink message count	count	2	U16
0x46	TX Time	Time to send message	ms	2	U16
0x47	TX Power	Transmit power	dBm	1	S8
0x48	TX Count	Uplink message count	count	2	U16
0x49	Power up count	Number of times unit powered up	count	2	U16
0x4A	USB insertions count	Number of times USB activated	count	2	U16
0x4B	Login OK count	Successful logon count	count	2	U16
0x4C	Login fail count	Failed logon count	count	2	U16
0x4D	Fan runtime	Total time the air intake fan has run (AIR models only)	seconds	4	U32
0x4E	CPU Temperature	New from Ver: 4.9	°C	2	S16 /10

Example code for different LoRaWAN Network Servers (LNS) is including in the folders on this site.



Screenshot of example using NodeRED

Downlink Payload

Downlink payloads are sent to re-configure the device. When the device processes the payload, it acknowledges the message by transmitting an ACK/NACK and the identifier code. This is to notify the user that the message has been received. There is an extra decoder example that can decode the ACK/NACK messages that are sent from the end-node to the LNS.

Configuration Payload Structure

Header	Msg Len	Command	Value
1 byte	1 byte	1 byte	*n* bytes

The header byte is is always `0xA5`.

Msg Len is the number of bytes in the settings data. The settings data starts with a **Command** byte and then the command **Value**. The Value can be blank.

Settings Data Details

Name	Msg Len	Command	Value	Reboot Required?
Reboot	1	`0xFF`		
Public Network	2	`0x02`	`0`/`1` (Disable/Enable)	Yes
AppEUI	9	`0x05`	8 Bytes for the **EUI**	Yes
AppKey	17	`0x06`	16 bytes for the **Key**	Yes
Auto Data Rate (ADR)	2	`0x07`	`0`/`1` (Disable/Enable)	
Duty Cycle	2	`0x08`	`0`/`1` (Disable/Enable)	
Message Confirmation	2	`0x09`	`0`/`1` (Disable/Enable)	
Transmit Port	2	`0x0A`	`1` to `223`	
Default Data Rate Index	2	`0x0B`	`1` to `6` (Requires ADR disabled)	
Transmit Interval Index	2	`0x0C`	`1` to `10`	
Transmit Power Index	2	`0x0D`	`1` to `6`	
Receive Port	2	`0x0E`	`0` to `223` (`0` indicates **All** Ports)	

The following are used in the AQM/Air, Zone and ZonePlus (with Light Sensor)

Name	Msg Len	Command	Value	Scaling
Lux Scale Parameter	3	`0x20`	`0` to `65535`	/1000 (`0xFFFF` represents 65.535)
Lux Offset Parameter	3	`0x21`	`0` to `65535`	None (`0xFFFF` represents 65535)

The following are used in the AQM/Air

Name	Msg Len	Command	Value
Case Fan Run Time	3	0x22	10 to 600 Seconds
HPM Particulate Fan Run Time (Discontinued)	3	0x23	10 to 60 Seconds

The following are used in devices with CO_2 sensor

Name	Msg Len	Command	Value
Enable/Disable Auto-Calibration	2	0x24	0/1 (Disable/Enable)
Set Target CO_2 Level	3	0x25	100 to 1000 ppm
Set to Known CO_2 Level	3	0x26	10 to 2000 ppm
Reset to factory Calibration **Only Sunrise model**	1	0x27	
Set Regular Auto-Cal Interval	3	0x28	24 to 8760 hours
Set the Out-of-Bounds limits **Only GSS model**	3	0x29	10 to 5000 ppm
Set initial auto-cal interval **Only GSS model**	3	0x2A	1 to 8760 hours

Downlink Message Examples

Reboot

Payload Data: A5 01 FF

Enable Message Confirmation

Payload Data: A5 02 09 01

Downlink Message Index Tables

The Indexes for some settings depend on the region the unit is programmed for.

0x0B - Data Rate Index

Index	EU868	Index	US915 Hybrid
0	DR0 SF12 BW125	0	DR0 SF10 BW125
1	DR1 SF11 BW125	1	DR1 SF9 BW125
2	DR2 SF10 BW125	2	DR2 SF8 BW125
3	DR3 SF9 BW125	3	DR3 SF7 BW125

Index	EU868	Index	US915 Hybrid
4	DR4 SF8 BW125	4	DR4 SF8 BW500
5	DR5 SF7 BW125		

`0x0C` - Transmit Interval Index

Index	Transmit Interval	Message
1	30 s	`A5 02 0C 01`
2	1 min	`A5 02 0C 02`
3	2 min	`A5 02 0C 03`
4	5 min	`A5 02 0C 04`
5	10 min	`A5 02 0C 05`
6	15 min	`A5 02 0C 06`
7	20 min	`A5 02 0C 07`
8	30 min	`A5 02 0C 08`
9	1 hour	`A5 02 0C 09`
10	2 hours	`A5 02 0C 0A`
11	3 hours	`A5 02 0C 0B`

`0x0D` - Transmit Power Index

Index	EU868	Index	US195 Hybrid
1	16 dBm	6	20 dBm
2	14 dBm	7	18 dBm
3	11 dBm	8	16 dBm
4	9 dBm	9	14 dBm
5	8 dBm	10	12 dBm
6	6 dBm	11	10 dBm
7	4 dBm		
8	2 dBm		

Settings for Lux Sensor

To scale the lux reading to compensate for the enclosure light pipe, a scaling factor is applied to the sensor value:

> Adjusted_Reading = (Sensor_Value x Scale) + Offset

Defaults are:

- Scale = **2.0** (AQM/AIR), **1.678** (Zone and ZonePlus)
- Offset = **0** (All devices)

For example, set Scale to **12.345** (12345 in hexadecimal is `0x3039`)

Message is: `A5 03 20 30 39`

Settings for CO_2 Sensors

To Enable Auto-Calibration:

Message is: `A5 02 24 01`

To set the auto-calibration target to 450ppm

Message is: `A5 03 25 01 C2`

To set the sensor to known CO2 concentration of 780ppm (`0x030C`)

Message is: `A5 03 26 03 0C`

To reset the sensor back to factory calibration (Sunrise Only)

Message is: `A5 01 27`

To set the auto-calibration interval to 10 days (240 hours, 0x00F0)

Message is: `A5 03 28 00 F0`

Uplink Replies to Downlink Messages

Successfully changed the Message Confirmation Option - **ACK**

Return code: `A5 06 09`

Failed to change the Transmit Port - **NACK**

Return code: `A5 15 0A`

Example code for decoding the **Uplink replies to Downlink messages** is included in the folders on this site.