LoRaWAN Telecommunication Chain
Laboratory Assignment

Assignment
The main goal of this exercise is to understand the principles of individual components of the LoRaWAN network. LoRaWAN (https://lora-alliance.org/about-lora-alliance) is an LPWAN network. An excellent example of a freely accessible LoRaWAN platform is The Things Network (TTN) https://www.thethingsnetwork.org. This exercise is prepared in such a way that the student gets in touch with the end-to-end LoRaWAN network - client terminal (sensor) and Information Communication Technology (ICT) infrastructure, which is responsible for receiving individual messages and distributing them to the users' applications.

All used client terminals (sensors) come with pre-installed AT commands interpreter, which makes the LoRaWAN client network accessible. ICT infrastructure for this task can be controlled through the web portal of The Things Network via accounts created for subject B(E)2M32BTSA. These accounts enable setting communication parameters and the connected devices.

Measurement Instructions
Task 1 – Connect and Send
Task 1 consists of several sub-tasks. At the end of this process, the sensor device fully communicates with the LoRaWAN network.

1. Choose a sensor and learn about its function (**Appendix I**):
   - **STM32 B-L072Z-LRWAN1** – full configurable LoRaWAN client device
   - **HARDWARIO Sensor Family** – HARDWARIO Core module with LoRa module and selected sensors (temperature, Humidity, Pressure, Button)
2. Prepare a TTN App and register the selected sensor using by information in **Appendix** II.
3. Configure sensor by parameters from TTN App registration, choose between:
   a. OTAA – DEVEUI, APPEUI, APPKEY
   b. ABP – DEVEUI, APPSKEY, NWKSKEY
4. Send a message to TTN[1] and verify that it has been received.
   a. For a client device with a sensor (HARDWARIO), send a default message.
   b. For clients based on STM32 B-L072Z-LRWAN1 device, send a message in the following format:
      - **Timestamp** in UNIX EPOCH TIME format.
      - **RSSI** (Received Signal Strength Indicator) - the value of the received signal strength (in dBm) for the last received message.
      - **SNR** (Signal to Noise Ratio) - the value of the received signal quality (in dB) for the previously received message.
      - **String array** "BE2M32BTSA" based on ASCII.

[1] There are multiple ways how the message can be sent from the LoRaWAN device. However, by sending the message as an uncoded text string message may not fit in the transmission buffer and will not be received at the TTN. Therefore, the required information must be encoded into hexadecimal bytes.

- **Value of PI constant** with six digits after the decimal point.

Record your findings and answer our questions in the measurement report.

Task 2 – Receive and Parse

Receive sensor messages and parse their content to human-readable format in the environment of the TTN. Use hack and cheats in Appendix III.

Record your findings and answer our questions in the measurement report.

Clear everything you set in your account on the TTN network.

Home Preparation

What can I do at home?

- Practice using the command line (terminal), putty, minicom, picocom, hterm, etc.
- Be familiar with The Things Network service.
- Based on your class place (table row), log to TTN and check how it works by using information from Appendix II
- Be familiar with our sensor hardware in this laboratory (Appendix I).
  - Read all manuals.
  - Be familiar with command line interpreter applications (telnet, putty, etc.).
  - Read a payload format for the selected hardware.
- Parse and decode the following binary payload message and convert it into human-readable information. **The result will be checked at the beginning of the class!**
  - Message: `0a ff fb 0d60 1292`
  - Message format:

```
<ID (uint8)><RSSI (uint8)><SNR (int8)><Battery (uint16)><Noise (uint16)>
```

  - Decoded message:
    - ID:
    - RSSI:
    - SNR:
    - Voltage:
    - Noise:

Appendix I

STM32 B-L072Z-LRWAN1

- Datasheet: https://www.st.com/en/evaluation-tools/b-l072z-lrwan1.html
- Documentation: https://github.com/hardwario/lora-modem/wiki/AT-Command-Interface

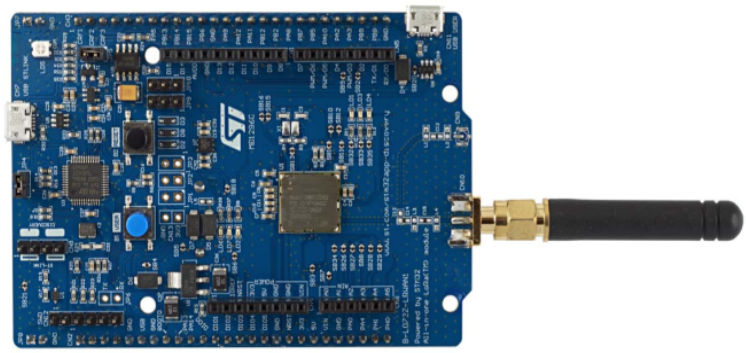

Fig. 1: STM32 B-L072Z-LRWAN1 device.

HARDWARIO

Hardware description

- HARDWARIO Core Module: https://docs.hardwario.com/tower/hardware-modules/about-core-module/
- HARDWARIO LoRa Module: https://docs.hardwario.com/tower/hardware-modules/about-lora-module
- HARDWARIO Sensors and Modules: https://docs.hardwario.com/tower/hardware-modules/

Software

- Climate sensors: https://github.com/hardwario/twr-lora-climate-monitor
- Button: https://github.com/hardwario/twr-lora-push-button
- LoRaWAN how-to: https://www.hackster.io/160709/lora-tester-with-lcd-gps-open-configurable-low-power-4a5b61#toc-lora-communication-keys-configuration-0

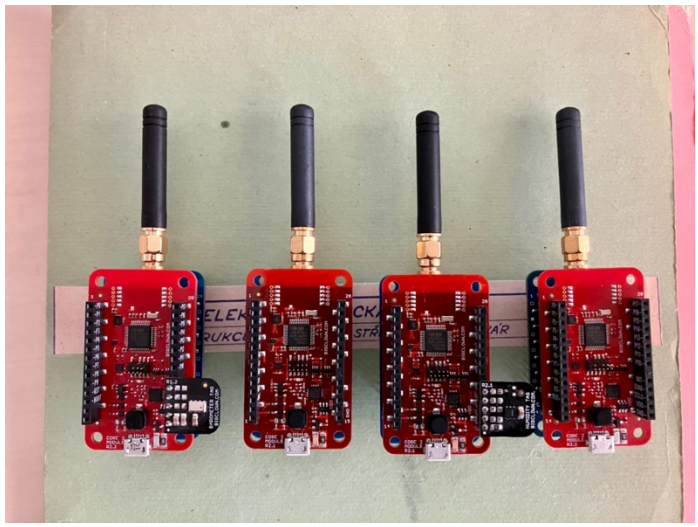

Fig. 2: Hardwario Core with LoRa module and sensors.

Appendix II

The Thing Network Guide

The guide on creating the infrastructure part for this task is available at the TTN website https://www.thethingsnetwork.org/docs/devices/node/quick-start.html. Check this guide to understand the whole procedure before following the steps to complete the lab. Focus primarily on registering new sensors in the network and diagnostics of their operability.

TTN Guide

1. Log into TTN via the provided information at https://eu1.cloud.thethings.network/console/.
2. Create an application (the necessary step before adding a device).
3. Register the sensor in the TTN network.
4. Use TTN sensor credentials in the sensor configuration.
5. Send a message from the sensor and observe its receiving in the "Live Data" field on TTN

Row	Username	Password	Email
1	be2m32bts_team1	BE2M32BTS	be2m32bts1@comtel.cz
2	be2m32bts_team2	BE2M32BTS	be2m32bts2@comtel.cz
3	be2m32bts_team3	BE2M32BTS	be2m32bts3@comtel.cz
4	be2m32bts_team4	BE2M32BTS	be2m32bts4@comtel.cz
5	be2m32bts_team5	BE2M32BTS	be2m32bts5@comtel.cz
6	be2m32bts_team6	BE2M32BTS	be2m32bts6@comtel.cz
7	be2m32bts_team7	BE2M32BTS	be2m32bts7@comtel.cz
8	be2m32bts_team8	BE2M32BTS	be2m32bts8@comtel.cz
9	be2m32bts_team9	BE2M32BTS	be2m32bts9@comtel.cz
10	be2m32bts_team10	BE2M32BTS	be2m32bts10@comtel.cz

Tab. 1: TTN Login Credentials

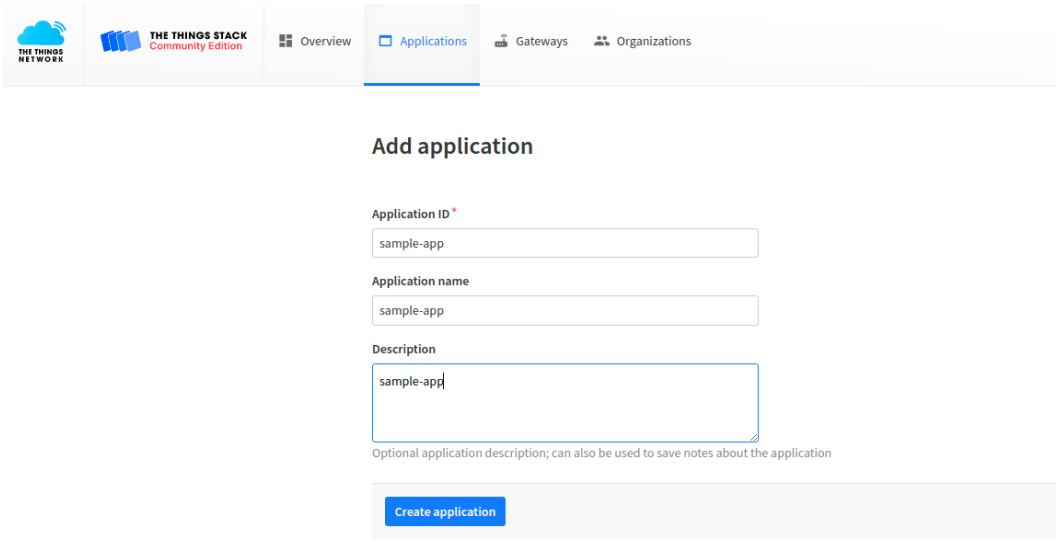

Fig. 3: TTN - GUI for adding a new application.

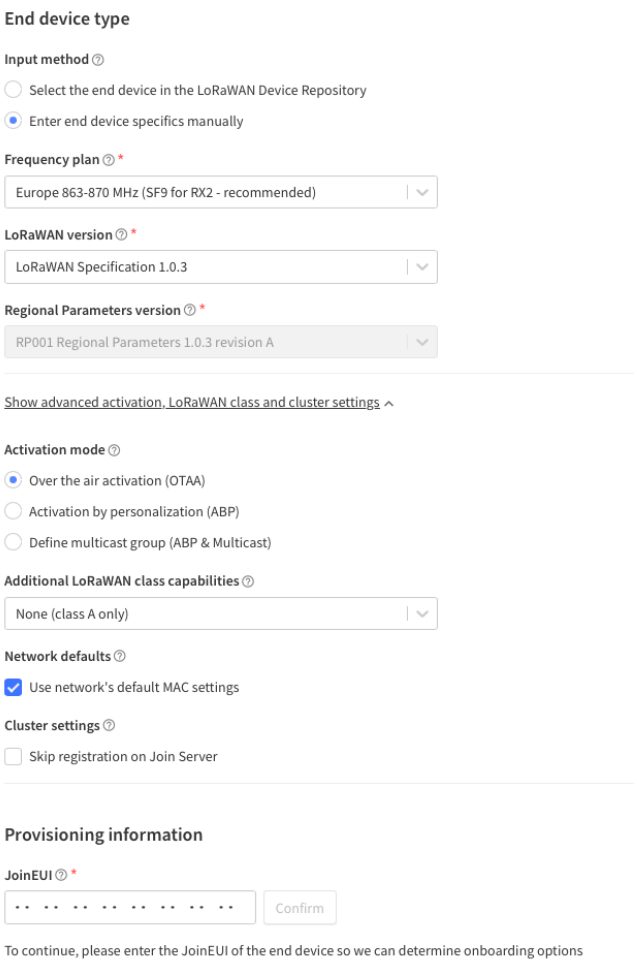

Fig. 4: TTN GUI for adding a new sensor with prefilled information.

Appendix III

This appendix contains a few hacks and helpers for helping with laboratory tasks.

Decoding the received messages

Samples from The Things Network web interface for decoding the received messages are placed below. Decoding is done by javascript code written to the Payload formatters window. The output by live parsing of received messages is shown in the Live data window.

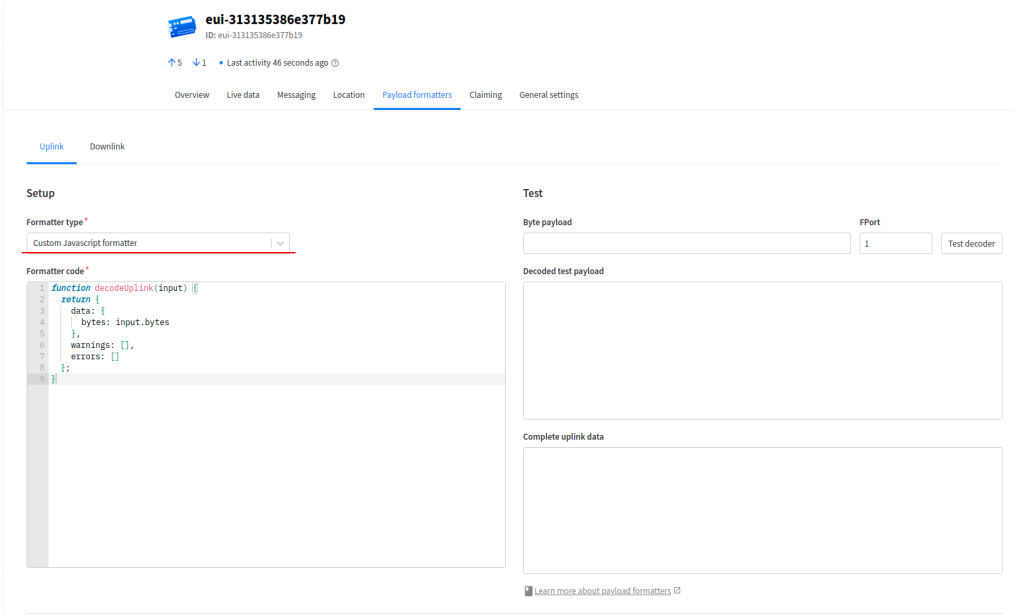

Fig. 5: An interface for inserting a Javascript code for decoding the data content of individual messages.

```
var inv = "";
for(var i = 0; i < 7; i++) inv += String.fromCharCode(bytes[i]);
decoded.inventoryNumber = inv;
```

Fig. 6: Example of decoding the first 8 bytes of a received message into a text string. The sorting bytes in the message are MSB.

```
var decoded = {};
var x = bytes[0] << 24 | bytes[1] << 16 | bytes[2] << 8 | bytes[3];
decoded.timestamp = x;
```

Fig. 7: Example of decoding a 4-byte number as a timestamp in UNIX TIMESTAMP format. The sorting bytes in the message are MSB. The decoding is done via JavaScript, which provides multiple options.

Obtaining RSSI and SNR

To get the RSSI and SNR information[2], you must invoke the DOWNLINK message of any content (see Figure 5) but in the same channel as the UPLINK message being sent. The best way is to use OTAA connection mode or generate the downlink message by TTN GUI.

Message encoding

Messages are transmitted by LPWAN mostly in binary form – a sequence of hexadecimal bytes. Thus, without proper editing, data such as "Hello123", "9.81", "-60", "12345678", etc. cannot be transferred. Data that do not have such conversion or should not use must be encoded manually. Below are some examples of how to convert your data into a binary sequence:

Input	Transfer	Output
Ahoj123	String → HEX (ASCII table)	0x41686f6a313233
9.81	9.81 * 100 →DEC → HEX	0x3D5
9.81	FLOAT → HEX (IEEE-754)	0x411cf5c3
-60	DEC → INTEGER (Two's complement)	0xC4
12345678	DEC → UNSIGNED INTEGER	0xBC614E

ATTENTION, when compiling a message, ensure the information is encoded correctly! Try to build the payload as short as possible due to the limited capabilities of LPWAN networks.

Dec	Hx	Oct	Char	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr
0	0	000	NUL (null)	32	20	040		Space	64	40	100	@	@	96	60	140	`	`
1	1	001	SOH (start of heading)	33	21	041	!	!	65	41	101	A	A	97	61	141	a	a
2	2	002	STX (start of text)	34	22	042	"	"	66	42	102	B	B	98	62	142	b	b
3	3	003	ETX (end of text)	35	23	043	#	#	67	43	103	C	C	99	63	143	c	c
4	4	004	EOT (end of transmission)	36	24	044	$	$	68	44	104	D	D	100	64	144	d	d
5	5	005	ENQ (enquiry)	37	25	045	%	%	69	45	105	E	E	101	65	145	e	e
6	6	006	ACK (acknowledge)	38	26	046	&	&	70	46	106	F	F	102	66	146	f	f
7	7	007	BEL (bell)	39	27	047	'	'	71	47	107	G	G	103	67	147	g	g
8	8	010	BS (backspace)	40	28	050	(	(	72	48	110	H	H	104	68	150	h	h
9	9	011	TAB (horizontal tab)	41	29	051	)	)	73	49	111	I	I	105	69	151	i	i
10	A	012	LF (NL line feed, new line)	42	2A	052	*	*	74	4A	112	J	J	106	6A	152	j	j
11	B	013	VT (vertical tab)	43	2B	053	+	+	75	4B	113	K	K	107	6B	153	k	k
12	C	014	FF (NP form feed, new page)	44	2C	054	,	,	76	4C	114	L	L	108	6C	154	l	l
13	D	015	CR (carriage return)	45	2D	055	-	-	77	4D	115	M	M	109	6D	155	m	m
14	E	016	SO (shift out)	46	2E	056	.	.	78	4E	116	N	N	110	6E	156	n	n
15	F	017	SI (shift in)	47	2F	057	/	/	79	4F	117	O	O	111	6F	157	o	o
16	10	020	DLE (data link escape)	48	30	060	0	0	80	50	120	P	P	112	70	160	p	p
17	11	021	DC1 (device control 1)	49	31	061	1	1	81	51	121	Q	Q	113	71	161	q	q
18	12	022	DC2 (device control 2)	50	32	062	2	2	82	52	122	R	R	114	72	162	r	r
19	13	023	DC3 (device control 3)	51	33	063	3	3	83	53	123	S	S	115	73	163	s	s
20	14	024	DC4 (device control 4)	52	34	064	4	4	84	54	124	T	T	116	74	164	t	t
21	15	025	NAK (negative acknowledge)	53	35	065	5	5	85	55	125	U	U	117	75	165	u	u
22	16	026	SYN (synchronous idle)	54	36	066	6	6	86	56	126	V	V	118	76	166	v	v
23	17	027	ETB (end of trans. block)	55	37	067	7	7	87	57	127	W	W	119	77	167	w	w
24	18	030	CAN (cancel)	56	38	070	8	8	88	58	130	X	X	120	78	170	x	x
25	19	031	EM (end of medium)	57	39	071	9	9	89	59	131	Y	Y	121	79	171	y	y
26	1A	032	SUB (substitute)	58	3A	072	:	:	90	5A	132	Z	Z	122	7A	172	z	z
27	1B	033	ESC (escape)	59	3B	073	;	;	91	5B	133	[	[	123	7B	173	{	{
28	1C	034	FS (file separator)	60	3C	074	<	<	92	5C	134	\	\	124	7C	174			|
29	1D	035	GS (group separator)	61	3D	075	=	=	93	5D	135	]	]	125	7D	175	}	}
30	1E	036	RS (record separator)	62	3E	076	>	>	94	5E	136	^	^	126	7E	176	~	~
31	1F	037	US (unit separator)	63	3F	077	?	?	95	5F	137	_	_	127	7F	177	&#127;	DEL

Source: www.LookupTables.com

[2] https://lora.readthedocs.io/en/latest/

Useful links

- The Things Network - https://www.thethingsnetwork.org
- TTN Device management FAQ - https://www.thethingsindustries.com/docs/devices/
- TTN Application management FAQ - https://www.thethingsindustries.com/docs/integrations/
- LoRaWAN Alliance - https://lora-alliance.org/about-lorawan
- Binary online calculator- https://www.binaryhexconverter.com/hex-to-decimal-converter
- String to HEX online converter - https://codebeautify.org/string-hex-converter
- Unix timestamp converter - https://www.unixtimestamp.com
- Float to HEX - https://gregstoll.com/~gregstoll/floattohex/
- Bit shifting tutorial (TTN) - https://www.thethingsnetwork.org/docs/devices-and-gateways/bytes/