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LoRaWAN™ 1.1 Regional Parameters
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LoRaWAN™ 1.1 Regional Parameters

This document is a companion document to the LoRaWAN 1.1 protocol specification

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61 Contents

62	1	Introduction	7
63	2	LoRaWAN Regional Parameters.....	8
64	2.1	EU 863-870MHz ISM Band	8
65	2.1.1	EU863-870 Preamble Format.....	8
66	2.1.2	EU863-870 ISM Band channel frequencies	8
67	2.1.3	EU863-870 Data Rate and End-device Output Power encoding	9
68	2.1.4	EU863-870 Join-accept CFList.....	10
69	2.1.5	EU863-870 LinkAdrReq command	10
70	2.1.6	EU863-870 Maximum payload size	10
71	2.1.7	EU863-870 Receive windows.....	11
72	2.1.8	EU863-870 Class B beacon and default downlink channel	12
73	2.1.9	EU863-870 Default Settings	12
74	2.2	US 902-928MHz ISM Band	13
75	2.2.1	US902-928 Preamble Format.....	13
76	2.2.2	US902-928 Channel Frequencies	13
77	2.2.3	US902-928 Data Rate and End-device Output Power encoding	14
78	2.2.4	US902-928 Join-accept CFList.....	15
79	2.2.5	US902-928 LinkAdrReq command	15
80	2.2.6	US902-928 Maximum payload size	16
81	2.2.7	US902-928 Receive windows.....	17
82	2.2.8	US902-928 Class B beacon	17
83	2.2.9	US902-928 Default Settings	18
84	2.3	China 779-787MHz ISM Band.....	19
85	2.3.1	CN779-787 Preamble Format.....	19
86	2.3.2	CN779-787 ISM Band channel frequencies.....	19
87	2.3.3	CN779-787 Data Rate and End-device Output Power encoding.....	20
88	2.3.4	CN779-787 Join-accept CFList.....	20
89	2.3.5	CN779-787 LinkAdrReq command.....	21
90	2.3.6	CN779-787 Maximum payload size	21
91	2.3.7	CN779-787 Receive windows.....	22
92	2.3.8	CN779-787 Class B beacon and default downlink channel.....	22
93	2.3.9	CN779-787 Default Settings.....	22
94	2.4	EU 433MHz ISM Band	24
95	2.4.1	EU433 Preamble Format.....	24
96	2.4.2	EU433 ISM Band channel frequencies	24
97	2.4.3	EU433 Data Rate and End-device Output Power encoding	25
98	2.4.4	EU433 Join-accept CFList.....	25
99	2.4.5	EU433 LinkAdrReq command	26
100	2.4.6	EU433 Maximum payload size	26
101	2.4.7	EU433 Receive windows.....	27
102	2.4.8	EU433 Class B beacon and default downlink channel	27
103	2.4.9	EU433 Default Settings	27
104	2.5	Australia 915-928MHz ISM Band	28
105	2.5.1	AU915-928 Preamble Format.....	28
106	2.5.2	AU915-928 Channel Frequencies	28
107	2.5.3	AU915-928 Data Rate and End-point Output Power encoding	29
108	2.5.4	AU915-928 Join-accept CFList.....	29
109	2.5.5	AU915-928 LinkAdrReq command	30
110	2.5.6	AU915-928 Maximum payload size	30
111	2.5.7	AU915-928 Receive windows.....	31

112	2.5.8	AU915-928 Class B beacon	32
113	2.5.9	AU915-928 Default Settings	33
114	2.6	CN 470-510MHz Band	34
115	2.6.1	CN470-510 Preamble Format.....	34
116	2.6.2	CN470-510 Channel Frequencies	34
117	2.6.3	CN470-510 Data Rate and End-point Output Power encoding	35
118	2.6.4	CN470-510 Join-accept CFList.....	35
119	2.6.5	CN470-510 LinkAdrReq command.....	36
120	2.6.6	CN470-510 Maximum payload size	36
121	2.6.7	CN470-510 Receive windows.....	36
122	2.6.8	CN470-510 Class B beacon	37
123	2.6.9	CN470-510 Default Settings.....	38
124	2.7	AS923MHz ISM Band	39
125	2.7.1	AS923 Preamble Format.....	39
126	2.7.2	AS923 ISM Band channel frequencies	39
127	2.7.3	AS923 Data Rate and End-point Output Power encoding.....	40
128	2.7.4	AS923 Join-accept CFList.....	41
129	2.7.5	AS923 LinkAdrReq command	41
130	2.7.6	AS923 Maximum payload size	42
131	2.7.7	AS923 Receive windows	42
132	2.7.8	AS923 Class B beacon and default downlink channel	43
133	2.7.9	AS923 Default Settings	43
134	2.8	South Korea 920-923MHz ISM Band	45
135	2.8.1	KR920-923 Preamble Format.....	45
136	2.8.2	KR920-923 ISM Band channel frequencies	45
137	2.8.3	KR920-923 Data Rate and End-device Output Power encoding.....	46
138	2.8.4	KR920-923 Join-accept CFList.....	47
139	2.8.5	KR920-923 LinkAdrReq command	47
140	2.8.6	KR920-923 Maximum payload size	48
141	2.8.7	KR920-923 Receive windows.....	48
142	2.8.8	KR920-923 Class B beacon and default downlink channel.....	49
143	2.8.9	KR920-923 Default Settings	49
144	2.9	India 865-867 MHz ISM Band	50
145	2.9.1	INDIA 865-867 Preamble Format	50
146	2.9.2	INDIA 865-867 ISM Band channel frequencies.....	50
147	2.9.3	INDIA 865-867 Data Rate and End-device Output Power Encoding.....	50
148	2.9.4	INDIA 865-867 Join-accept CFList	51
149	2.9.5	INDIA 865-867 LinkAdrReq command.....	52
150	2.9.6	INDIA 865-867 Maximum payload size.....	52
151	2.9.7	INDIA 865-867 Receive windows	53
152	2.9.8	INDIA 865-867 Class B beacon and default downlink channel	53
153	2.9.9	INDIA 865-867 Default Settings.....	54
154	3	Revisions	55
155	3.1	Revision A.....	55
156	4	Bibliography	56
157	4.1	References.....	56
158			

159 **Tables**

160	Table 1: EU863-870 synch words	8
161	Table 2: EU863-870 default channels	8
162	Table 3: EU863-870 Join-request Channel List.....	9

163	Table 4: TX Data rate table	9
164	Table 5: TX power table	9
165	Table 6: ChMaskCntl value table	10
166	Table 7: EU863-870 maximum payload size	11
167	Table 8 : EU863-870 maximum payload size (not repeater compatible).....	11
168	Table 9: EU863-870 downlink RX1 data rate mapping	11
169	Table 10: EU863-870 beacon settings	12
170	Table 11: TX Data rate table	14
171	Table 12: TX power table	15
172	Table 13: ChMaskCntl value table.....	15
173	Table 14: US902-928 maximum payload size (repeater compatible).....	16
174	Table 15 : US902-928 maximum payload size (not repeater compatible).....	17
175	Table 16: US902-928 downlink RX1 data rate mapping	17
176	Table 17: US902-928 beacon settings	17
177	Table 18: CN779-787 synch words	19
178	Table 19: CN780 Join-request Channel List.....	19
179	Table 20: Data rate and TX power table.....	20
180	Table 21: ChMaskCntl value table.....	21
181	Table 22: CN780 maximum payload size	21
182	Table 23 : CN780 maximum payload size (not repeater compatible).....	22
183	Table 24: CN780 downlink RX1 data rate mapping	22
184	Table 25: CN780 beacon settings	22
185	Table 26: EU433 synch words	24
186	Table 27: EU433 Join-request Channel List	24
187	Table 28: Data rate and TX power table.....	25
188	Table 29: ChMaskCntl value table.....	26
189	Table 30: EU433 maximum payload size	26
190	Table 31 : EU433 maximum payload size (not repeater compatible).....	27
191	Table 32 : EU433 downlink RX1 data rate mapping	27
192	Table 33 : EU433 beacon settings	27
193	Table 34: AU915-928 Data rate table.....	29
194	Table 35 : AU915-928 TX power table	29
195	Table 36: ChMaskCntl value table.....	30
196	Table 37: AU915-928 maximum payload size	31
197	Table 38: AU915-928 maximum payload size (not repeater compatible).....	31
198	Table 39 : AU915-928 downlink RX1 data rate mapping	32
199	Table 40 : AU915-928 beacon settings	32
200	Table 41: CN470 Data rate and TX power table	35
201	Table 42: CN470 ChMaskCntl value table.....	36
202	Table 43: CN470-510 maximum payload size	36
203	Table 44 : CN470-510 maximum payload size (not repeater compatible).....	36
204	Table 45: CN470-510 downlink RX1 data rate mapping.....	37
205	Table 46 : CN470-510 beacon settings	37
206	Table 47: AS923 synch words.....	39
207	Table 48: AS923 default channels.....	39
208	Table 49: AS923 Join-request Channel List	40
209	Table 50: Data rate table.....	40
210	Table 51: TxPower table	41
211	Table 52: ChMaskCntl value table.....	42
212	Table 53: AS923 maximum payload size	42
213	Table 54: AS923 maximum payload size (not repeater compatible)	42
214	Table 55 : AS923 beacon settings.....	43
215	Table 56: Center frequency, bandwidth, maximum EIRP output power table	45

216	Table 57: KR920-923 default channels	45
217	Table 58: KR920-923 Join-request Channel List	46
218	Table 59: TX Data rate table	46
219	Table 60: TX power table	47
220	Table 61: ChMaskCntl value table.....	48
221	Table 62: KR920-923 maximum payload size	48
222	Table 63 : KR920-923 maximum payload size (not repeater compatible).....	48
223	Table 64 : KR920-923 downlink RX1 data rate mapping.....	49
224	Table 65 : KR920-923 beacon settings	49
225	Table 66: India 865-867 synch words.....	50
226	Table 67: INDIA 865-867 default channels.....	50
227	Table 68: INDIA 865-867 Join-request Channel List	50
228	Table 69: TX Data rate table	51
229	Table 70: TxPower table	51
230	Table 71: ChMaskCntl value table.....	52
231	Table 72: INDIA 865-867 maximum payload size.....	53
232	Table 73 : INDIA 865-867 maximum payload size (not repeater compatible)	53

233

234 **Figures**

235	Figure 1: US902-928 channel frequencies	13
236	Figure 2: AU915-928 channel frequencies	28
237	Figure 3: CN470-510 channel frequencies	34

238

239 1 Introduction

240

241 This document describes the LoRaWAN™ regional parameters for different regulatory
242 regions worldwide. This document is a companion document to the LoRaWAN 1.1 protocol
243 specification [LORAWAN]. Separating the regional parameters from the protocol
244 specification allows addition of new regions to the former without impacting the latter
245 document.

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2 LoRaWAN Regional Parameters

2.1 EU 863-870MHz ISM Band

2.1.1 EU863-870 Preamble Format

The following synchronization words should be used:

Modulation	Sync word	Preamble length
LORA	0x34	8 symbols
GFSK	0xC194C1	5 bytes

Table 1: EU863-870 synch words

2.1.2 EU863-870 ISM Band channel frequencies

This section applies to any region where the ISM radio spectrum use is defined by the ETSI [EN300.220] standard.

The network channels can be freely attributed by the network operator. However the three following default channels must be implemented in every EU868MHz end-device. Those channels are the minimum set that all network gateways should always be listening on.

Modulation	Bandwidth [kHz]	Channel Frequency [MHz]	FSK Bitrate or LoRa DR / Bitrate	Nb Channels	Duty cycle
LoRa	125	868.10 868.30 868.50	DR0 to DR5 / 0.3-5 kbps	3	<1%

Table 2: EU863-870 default channels

In order to access the physical medium the ETSI regulations impose some restrictions such maximum time the transmitter can be on or the maximum time a transmitter can transmit per hour. The ETSI regulations allow the choice of using either a duty-cycle limitation or a so-called **Listen Before Talk Adaptive Frequency Agility** (LBT AFA) transmissions management. The current LoRaWAN specification exclusively uses duty-cycled limited transmissions to comply with the ETSI regulations.

EU868MHz end-devices should be capable of operating in the 863 to 870 MHz frequency band and should feature a channel data structure to store the parameters of at least 16 channels. A channel data structure corresponds to a frequency and a set of data rates usable on this frequency.

The first three channels correspond to 868.1, 868.3, and 868.5 MHz / DR0 to DR5 and must be implemented in every end-device. Those default channels cannot be modified through the **NewChannelReq** command and guarantee a minimal common channel set between end-devices and network gateways.

The following table gives the list of frequencies that should be used by end-devices to broadcast the Join-request message. The Join-request message transmit duty-cycle shall follow the rules described in chapter "Retransmissions back-off" of the LoRaWAN specification document.

Modulation	Bandwidth [kHz]	Channel Frequency [MHz]	FSK Bitrate or LoRa DR / Bitrate	Nb Channels
LoRa	125	868.10 868.30 868.50	DR0 – DR5 / 0.3-5 kbps	3

283

Table 3: EU863-870 Join-request Channel List

284 2.1.3 EU863-870 Data Rate and End-device Output Power encoding

285 There is no dwell time limitation for the EU863-870 PHY layer. The ***TxParamSetupReq***
 286 MAC command is not implemented in EU863-870 devices.

287 The following encoding is used for Data Rate (DR) and End-device EIRP (TXPower) in the
 288 EU863-870 band:

289

DataRate	Configuration	Indicative physical bit rate [bit/s]
0	LoRa: SF12 / 125 kHz	250
1	LoRa: SF11 / 125 kHz	440
2	LoRa: SF10 / 125 kHz	980
3	LoRa: SF9 / 125 kHz	1760
4	LoRa: SF8 / 125 kHz	3125
5	LoRa: SF7 / 125 kHz	5470
6	LoRa: SF7 / 250 kHz	11000
7	FSK: 50 kbps	50000
8..14	RFU	
15	Defined in LoRaWAN ¹	

290

Table 4: TX Data rate table

291

292 EIRP² refers to the Equivalent Isotropically Radiated Power, which is the radiated output
 293 power referenced to an isotropic antenna radiating power equally in all directions and whose
 294 gain is expressed in dBi.

TXPower	Configuration (EIRP)
0	Max EIRP
1	Max EIRP – 2dB
2	Max EIRP – 4dB
3	Max EIRP – 6dB
4	Max EIRP – 8dB
5	Max EIRP – 10dB
6	Max EIRP – 12dB
7	Max EIRP – 14dB
8..14	RFU
15	Defined in LoRAWAN

295

Table 5: TX power table

296

297

¹ DR15 and TXPower15 are defined in the LinkADRReq MAC command of the LoRaWAN1.1 specification

² ERP = EIRP – 2.15dB; it is referenced to a half-wave dipole antenna whose gain is expressed in dBd

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302

By default MaxEIRP is considered to be +16dBm. If the end-device cannot achieve 16dBm EIRP, the Max EIRP should be communicated to the network server using an out-of-band channel during the end-device commissioning process.

303 2.1.4 EU863-870 Join-accept CFList

304

305 The EU 863-870 ISM band LoRaWAN implements an optional **channel frequency list**
306 (CFList) of 16 octets in the Join-accept message.

307 In this case the CFList is a list of five channel frequencies for the channels four to eight
308 whereby each frequency is encoded as a 24 bits unsigned integer (three octets). All these
309 channels are usable for DR0 to DR5 125kHz LoRa modulation. The list of frequencies is
310 followed by a single CFListType octet for a total of 16 octets. The CFListType shall be equal
311 to zero (0) to indicate that the CFList contains a list of frequencies.

312

Size (bytes)	3	3	3	3	3	1
CFList	Freq Ch4	Freq Ch5	Freq Ch6	Freq Ch7	Freq Ch8	CFListType

313 The actual channel frequency in Hz is 100 x frequency whereby values representing
314 frequencies below 100 MHz are reserved for future use. This allows setting the frequency of
315 a channel anywhere between 100 MHz to 1.67 GHz in 100 Hz steps. Unused channels have
316 a frequency value of 0. The **CFList** is optional and its presence can be detected by the
317 length of the Join-accept message. If present, the **CFList** replaces all the previous channels
318 stored in the end-device apart from the three default channels. The newly defined channels
319 are immediately enabled and usable by the end-device for communication.

320 2.1.5 EU863-870 LinkAdrReq command

321 The EU863-870 LoRaWAN only supports a maximum of 16 channels. When **ChMaskCntl**
322 field is 0 the ChMask field individually enables/disables each of the 16 channels.

323

ChMaskCntl	ChMask applies to
0	Channels 1 to 16
1	RFU
..	..
4	RFU
5	RFU
6	All channels ON The device should enable all currently defined channels independently of the ChMask field value.
7	RFU

324

Table 6: ChMaskCntl value table

325 If the ChMaskCntl field value is one of values meaning RFU, the end-device should reject
326 the command and unset the “**Channel mask ACK**” bit in its response.

327 2.1.6 EU863-870 Maximum payload size

328 The maximum **MACPayload** size length (*M*) is given by the following table. It is derived from
329 limitation of the PHY layer depending on the effective modulation rate used taking into

330 account a possible repeater encapsulation layer. The maximum application payload length in
 331 the absence of the optional **FOpt** control field (*M*) is also given for information only. The
 332 value of *N* might be smaller if the **FOpt** field is not empty:
 333

DataRate	<i>M</i>	<i>N</i>
0	59	51
1	59	51
2	59	51
3	123	115
4	230	222
5	230	222
6	230	222
7	230	222
8:15	Not defined	

334 **Table 7: EU863-870 maximum payload size**

335 If the end-device will never operate with a repeater then the maximum application payload
 336 length in the absence of the optional **FOpt** control field should be:
 337

DataRate	<i>M</i>	<i>N</i>
0	59	51
1	59	51
2	59	51
3	123	115
4	250	242
5	250	242
6	250	242
7	250	242
8:15	Not defined	

338 **Table 8 : EU863-870 maximum payload size (not repeater compatible)**

339 2.1.7 EU863-870 Receive windows

340 The RX1 receive window uses the same channel than the preceding uplink. The data rate is
 341 a function of the uplink data rate and the RX1DROffset as given by the following table. The
 342 allowed values for RX1DROffset are in the [0:5] range. Values in the [6:7] range are
 343 reserved for future use.
 344

RX1DROffset Upstream data rate	0	1	2	3	4	5
	Downstream data rate in RX1 slot					
DR0	DR0	DR0	DR0	DR0	DR0	DR0
DR1	DR1	DR0	DR0	DR0	DR0	DR0
DR2	DR2	DR1	DR0	DR0	DR0	DR0
DR3	DR3	DR2	DR1	DR0	DR0	DR0
DR4	DR4	DR3	DR2	DR1	DR0	DR0
DR5	DR5	DR4	DR3	DR2	DR1	DR0
DR6	DR6	DR5	DR4	DR3	DR2	DR1
DR7	DR7	DR6	DR5	DR4	DR3	DR2

345 **Table 9: EU863-870 downlink RX1 data rate mapping**

346
 347 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
 348 869.525 MHz / DR0 (SF12, 125 kHz)
 349

350 **2.1.8 EU863-870 Class B beacon and default downlink channel**

351 The beacons SHALL be transmitted using the following settings

DR	3	Corresponds to SF9 spreading factor with 125 kHz BW
CR	1	Coding rate = 4/5
Signal polarity	Non-inverted	As opposed to normal downlink traffic which uses inverted signal polarity

 352 **Table 10: EU863-870 beacon settings**

353

354 The beacon frame content is:

Size (bytes)	2	4	2	7	2
BCNPayload	RFU	Time	CRC	GwSpecific	CRC

355 The beacon default broadcast frequency is 869.525MHz.

356 The class B default downlink pingSlot frequency is 869.525MHz

357

 358 **2.1.9 EU863-870 Default Settings**

359 The following parameters are recommended values for the EU863-870MHz band.

360	RECEIVE_DELAY1	1 s
361	RECEIVE_DELAY2	2 s (must be RECEIVE_DELAY1 + 1s)
362	JOIN_ACCEPT_DELAY1	5 s
363	JOIN_ACCEPT_DELAY2	6 s
364	MAX_FCNT_GAP	16384
365	ADR_ACK_LIMIT	64
366	ADR_ACK_DELAY	32
367	ACK_TIMEOUT	2 +/- 1 s (random delay between 1 and 3 seconds)

368 If the actual parameter values implemented in the end-device are different from those default
 369 values (for example the end-device uses a longer RECEIVE_DELAY1 and
 370 RECEIVE_DELAY2 latency), those parameters must be communicated to the network
 371 server using an out-of-band channel during the end-device commissioning process. The
 372 network server may not accept parameters different from those default values.

373

374 **2.2 US 902-928MHz ISM Band**

375 This section defines the regional parameters for the USA, Canada and all other countries
 376 adopting the entire FCC-Part15 regulations in 902-928 ISM band.

377 **2.2.1 US902-928 Preamble Format**

378 The following synchronization words should be used:
 379

Modulation	Sync word	Preamble length
LORA	0x34	8 symbols

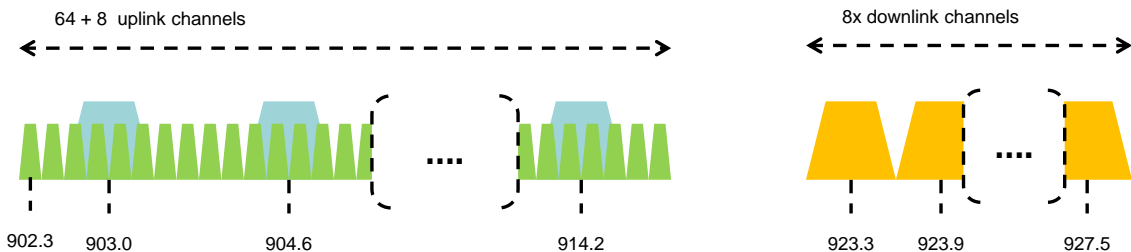
380

381 LoRaWAN does not make use of GFSK modulation in the US902-928 ISM band.

382 **2.2.2 US902-928 Channel Frequencies**

383 The 915 MHz ISM Band shall be divided into the following channel plans.

- 384 • Upstream – 64 channels numbered 0 to 63 utilizing LoRa 125 kHz BW varying from
 385 DR0 to DR3, using coding rate 4/5, starting at 902.3 MHz and incrementing linearly
 386 by 200 kHz to 914.9 MHz
- 387 • Upstream – 8 channels numbered 64 to 71 utilizing LoRa 500 kHz BW at DR4
 388 starting at 903.0 MHz and incrementing linearly by 1.6 MHz to 914.2 MHz
- 389 • Downstream – 8 channels numbered 0 to 7 utilizing LoRa 500 kHz BW at DR8 to
 390 DR13, starting at 923.3 MHz and incrementing linearly by 600 kHz to 927.5 MHz
 391



392
 393

Figure 1: US902-928 channel frequencies

394 915 MHz ISM band end-devices are required to operate in compliance with the relevant
 395 regulatory specifications,. The following note summarizes some of the current (March 2017)
 396 relevant regulations.

- 397 Frequency-Hopping, Spread-Spectrum (FHSS) mode, which requires
 398 the device transmit at a measured conducted power level no greater
 399 than +30 dBm, for a period of no more than 400 msec and over at least
 400 50 channels, each of which occupy no greater than 250 kHz of
 401 bandwidth.
- 402 Digital Transmission System (DTS) mode, which requires that the
 403 device use channels greater than or equal to 500 kHz and comply to a
 404 conducted Power Spectral Density measurement of no more than +8
 405 dBm per 3kHz of spectrum. In practice, this limits the conducted
 406 output power of an end-device to +26 dBm.
- 407 Hybrid mode, which requires that the device transmit over multiple
 408 channels (this may be less than the 50 channels required for FHSS
 409 mode, but is recommended to be at least 4) while complying with the

410 Power Spectral Density requirements of DTS mode and the 400 msec
 411 dwell time of FHSS mode. In practice this limits the measured
 412 conducted power of the end-device to 21 dBm.

413 Devices which use an antenna system with a directional gain greater
 414 than +6 dBi, but reduce the specified conducted output power by the
 415 amount in dB of directional gain over +6 dBi.

416 US902-928 end-devices MUST be capable of operating in the 902 to 928 MHz frequency
 417 band and MUST feature a channel data structure to store the parameters for 72 channels.
 418 This channel data structure contains a list of frequencies and the set of data rates available
 419 for each frequency.

420 If using the over-the-air activation procedure, it is recommended that the end-device transmit
 421 the Join-request message alternatively on a random 125 kHz channel amongst the 64
 422 channels defined using **DR0** and a random 500 kHz channel amongst the 8 channels
 423 defined using **DR4**. The end-device SHALL change channel for every transmission. For
 424 rapid network acquisition in mixed channel plan environments, it is further recommended
 425 that the device follow a channel selection sequence (still random) which efficiently probes
 426 the groups of nine (8 + 1) channels which are typically implemented by smaller gateways
 427 (channel groups 0-7+64, 8-15+65, etc.).

428 Personalized devices SHALL have all 72 channels enabled following a reset and shall use
 429 the channels for which the device's default data-rate is valid.

430 2.2.3 US902-928 Data Rate and End-device Output Power encoding

431 FCC regulation imposes a maximum dwell time of 400ms on uplinks. The
 432 **TxParamSetupReq** MAC command MUST not be implemented by US902-928 devices.

433 The following encoding is used for Data Rate (**DR**) and End-device conducted Power
 434 (**TXPower**) in the US902-928 band:

435

DataRate	Configuration	Indicative physical bit rate [bit/sec]
0	LoRa: SF10 / 125 kHz	980
1	LoRa: SF9 / 125 kHz	1760
2	LoRa: SF8 / 125 kHz	3125
3	LoRa: SF7 / 125 kHz	5470
4	LoRa: SF8 / 500 kHz	12500
5:7	RFU	
8	LoRa: SF12 / 500 kHz	980
9	LoRa: SF11 / 500 kHz	1760
10	LoRa: SF10 / 500 kHz	3900
11	LoRa: SF9 / 500 kHz	7000
12	LoRa: SF8 / 500 kHz	12500
13	LoRa: SF7 / 500 kHz	21900
14	RFU	
15	Defined in LoRaWAN ¹	

Table 11: TX Data rate table

436

437 Note: DR4 is purposely identical to DR12, DR8..13 must be
 438 implemented in end-devices and are reserved for future applications

¹ DR15 is defined in the LinkADRReq MAC command of the LoRaWAN1.1 specification

439

TXPower	Configuration (conducted power)
0	30 dBm – 2*TXpower
1	28 dBm
2	26 dBm
3 : 9
10	10 dBm
11:14	RFU
15	Defined in LoRaWAN

440

Table 12: TX power table

441 2.2.4 US902-928 Join-accept CFList

442

443 The US902-928 LoRaWAN supports the use of the optional **CFlist** appended to the Join-
 444 accept message. If the **CFlist** is not empty then the **CFlistType** field shall contain the value
 445 one (0x01) to indicate the **CFlist** contains a series of ChMask fields. The ChMask fields are
 446 interpreted as being controlled by a virtual ChMaskCntl that initializes to a value of zero (0)
 447 and increments for each ChMask field to a value of four (4). (The first 16 bits controls the
 448 channels 0 to 15, ..)

Size (bytes)	[2]	[2]	[2]	[2]	[2]	[2]	[3]	[1]
CFlist	ChMask0	ChMask1	ChMask2	ChMask3	ChMask4	RFU	RFU	CFlistType

449

450

451 2.2.5 US902-928 LinkAdrReq command

452 For the US902-928 version the **ChMaskCntl** field of the **LinkADRReq** command has the
 453 following meaning:

454

ChMaskCntl	ChMask applies to
0	Channels 0 to 15
1	Channels 16 to 31
..	..
4	Channels 64 to 71
5	8LSBs controls Channel Blocks 0 to 7 8MSBs are RFU
6	All 125 kHz ON ChMask applies to channels 64 to 71
7	All 125 kHz OFF ChMask applies to channels 64 to 71

455

Table 13: ChMaskCntl value table

456 If **ChMaskCntl** = 5 then the corresponding bits in the ChMask enable and disable a bank of
 457 8 125kHz channels and the corresponding 500kHz channel defined by the following
 458 calculation: [ChannelMaskBit * 8, ChannelMaskBit * 8 +7],64+ChannelMaskBit.

459

460 If **ChMaskCntl** = 6 then 125 kHz channels are enabled, if **ChMaskCntl** = 7 then 125 kHz
 461 channels are disabled. Simultaneously the channels 64 to 71 are set according to the

462 **ChMask** bit mask. The DataRate specified in the command need not be valid for channels
 463 specified in the ChMask, as it governs the global operational state of the end-device.

464

465 **Note:** FCC regulation requires hopping over at least 50 channels when
 466 using maximum output power. It is possible to have end-devices with
 467 less channels when limiting the end-device conducted transmit power
 468 to 21 dBm.

469 **Note:** A common network server action may be to reconfigure a device
 470 through multiple LinkAdrReq commands in a contiguous block of MAC
 471 Commands. For example to reconfigure a device from 64 channel
 472 operation to the first 8 channels could contain two LinkAdrReq, the first
 473 (ChMaskCntl = 7) to disable all 125kHz channels and the second
 474 (ChMaskCntrl = 0) to enable a bank of 8 125kHz channels.
 475

476 **2.2.6 US902-928 Maximum payload size**

477 The maximum **MACPayload** size length (M) is given by the following table. It is derived from
 478 the maximum allowed transmission time at the PHY layer taking into account a possible
 479 repeater encapsulation. The maximum application payload length in the absence of the
 480 optional **FOpt** MAC control field (N) is also given for information only. The value of N might
 481 be smaller if the **FOpt** field is not empty:

482
 483

DataRate	M	N
0	19	11
1	61	53
2	133	125
3	250	242
4	250	242
5:7	Not defined	
8	41	33
9	117	109
10	230	222
11	230	222
12	230	222
13	230	222
14:15	Not defined	

484 **Table 14: US902-928 maximum payload size (repeater compatible)**

485

486 The greyed lines correspond to the data rates that may be used by an end-device behind a
 487 repeater.

488 If the end-device will never operate under a repeater then the maximum application payload
 489 length in the absence of the optional **FOpt** control field should be:

490

DataRate	M	N
0	19	11
1	61	53
2	133	125
3	250	242

4	250	242
5:7	Not defined	
8	61	53
9	137	129
10	250	242
11	250	242
12	250	242
13	250	242
14:15	Not defined	

491

Table 15 : US902-928 maximum payload size (not repeater compatible)
492 2.2.7 US902-928 Receive windows

493

494

495

496

497

498

499

- The RX1 receive channel is a function of the upstream channel used to initiate the data exchange. The RX1 receive channel can be determined as follows.
 - RX1 Channel Number = Transmit Channel Number modulo 8
- The RX1 window data rate depends on the transmit data rate (see Table 16 below).
- The RX2 (second receive window) settings uses a fixed data rate and frequency. Default parameters are 923.3MHz / DR8

Upstream data rate RX1DROffset	Downstream data rate			
	0	1	2	3
DR0	DR10	DR9	DR8	DR8
DR1	DR11	DR10	DR9	DR8
DR2	DR12	DR11	DR10	DR9
DR3	DR13	DR12	DR11	DR10
DR4	DR13	DR13	DR12	DR11

500

Table 16: US902-928 downlink RX1 data rate mapping

501

502

The allowed values for RX1DROffset are in the [0:3] range. Values in the range [4:7] are reserved for future use.

503 2.2.8 US902-928 Class B beacon

504

The beacons are transmitted using the following settings:

DR	8	Corresponds to SF12 spreading factor with 500kHz bw
CR	1	Coding rate = 4/5
Signal polarity	Non-inverted	As opposed to normal downlink traffic which uses inverted signal polarity
frequencies	923.3 to 927.5MHz with 600kHz steps	Beaconing is performed on the same channel that normal downstream traffic as defined in the Class A specification

505

Table 17: US902-928 beacon settings

506

The downstream channel used for a given beacon is:

507

$$\text{Channel} = \left\lfloor \frac{\text{beacon_time}}{\text{beacon_period}} \right\rfloor \text{ modulo } 8$$

508

509

510

511

512

- whereby beacon_time is the integer value of the 4 bytes "Time" field of the beacon frame
- whereby beacon_period is the periodicity of beacons , 128 seconds
- whereby $\text{floor}(x)$ designates rounding to the integer immediately inferior or equal to x

513
 514
 515
 516

Example: the first beacon will be transmitted on 923.3Mhz , the second on 923.9MHz, the 9th beacon will be on 923.3Mhz again.

Beacon channel nb	Frequency [MHz]
0	923.3
1	923.9
2	924.5
3	925.1
4	925.7
5	926.3
6	926.9
7	927.5

 517
 518
 519

The beacon frame content is:

Size (bytes)	5	4	2	7	3	2
BCNPayload	RFU	Time	CRC	GwSpecific	RFU	CRC

520

521 2.2.9 US902-928 Default Settings

522 The following parameters are recommended values for the US902-928 band.

523	RECEIVE_DELAY1	1 s
524	RECEIVE_DELAY2	2 s (must be RECEIVE_DELAY1 + 1s)
525	JOIN_ACCEPT_DELAY1	5 s
526	JOIN_ACCEPT_DELAY2	6 s
527	MAX_FCNT_GAP	16384
528	ADR_ACK_LIMIT	64
529	ADR_ACK_DELAY	32
530	ACK_TIMEOUT	2 +/- 1 s (random delay between 1 and 3 seconds)

531 If the actual parameter values implemented in the end-device are different from those default
 532 values (for example the end-device uses a longer RECEIVE_DELAY1 & 2 latency), those
 533 parameters must be communicated to the network server using an out-of-band channel
 534 during the end-device commissioning process. The network server may not accept
 535 parameters different from those default values.

536

537 **2.3 China 779-787MHz ISM Band**

 538 **2.3.1 CN779-787 Preamble Format**

539 The following synchronization words should be used :

540

Modulation	Sync word	Preamble length
LORA	0x34	8 symbols
GFSK	0xC194C1	5 bytes

541

Table 18: CN779-787 synch words

 542 **2.3.2 CN779-787 ISM Band channel frequencies**

543

 544 The LoRaWAN can be used in the Chinese 779-787MHz band as long as the radio device
 545 EIRP is less than 12.15dBm.

546 The end-device transmit duty-cycle should be lower than 1%.

547 The LoRaWAN channels center frequency can be in the following range:

- 548
- Minimum frequency : 779.5MHz
 - Maximum frequency : 786.5 MHz

 550 CN780MHz end-devices should be capable of operating in the 779 to 787 MHz frequency
 551 band and should feature a channel data structure to store the parameters of at least 16
 552 channels. A channel data structure corresponds to a frequency and a set of data rates
 553 usable on this frequency.

 554 The first three channels correspond to 779.5, 779.7 and 779.9 MHz with DR0 to DR5 and
 555 must be implemented in every end-device. Those default channels cannot be modified
 556 through the **NewChannelReq** command and guarantee a minimal common channel set
 557 between end-devices and gateways of all networks. Other channels can be freely distributed
 558 across the allowed frequency range on a network per network basis.

 559 The following table gives the list of frequencies that should be used by end-devices to
 560 broadcast the Join-request message The Join-request message transmit duty-cycle shall
 561 follow the rules described in chapter “Retransmissions back-off” of the LoRaWAN
 562 specification document.

563

Modulation	Bandwidth [kHz]	Channel Frequency [MHz]	FSK Bitrate or LoRa DR / Bitrate	Nb Channels	Duty cycle
LoRa	125	779.5	DR0 – DR5 / 0.3-5 kbps	6	<0.1%
		779.7			
		779.9			
		780.5			
		780.7			
780.9					

564

Table 19: CN780 Join-request Channel List

565

566 **2.3.3 CN779-787 Data Rate and End-device Output Power encoding**

567 There is no dwell time limitation for the CN779-787 PHY layer. The *TxParamSetupReq*
 568 MAC command is not implemented by CN779-787 devices.

569 The following encoding is used for Data Rate (DR) and End-device EIRP (TXPower) in the
 570 CN780 band:

DataRate	Configuration	Indicative physical bit rate [bit/s]	TXPower	Configuration (EIRP)
0	LoRa: SF12 / 125 kHz	250	0	Max EIRP
1	LoRa: SF11 / 125 kHz	440	1	Max EIRP – 2dB
2	LoRa: SF10 / 125 kHz	980	2	Max EIRP – 4dB
3	LoRa: SF9 / 125 kHz	1760	3	Max EIRP – 6dB
4	LoRa: SF8 / 125 kHz	3125	4	Max EIRP – 8dB
5	LoRa: SF7 / 125 kHz	5470	5	Max EIRP – 10dB
6	LoRa: SF7 / 250 kHz	11000	6..14	RFU
7	FSK: 50 kbps	50000		
8..14	RFU			
15	Defined in LoRaWAN		15	Defined in LoRaWAN

Table 20: Data rate and TX power table

571

572

573 EIRP refers to the Equivalent Isotropically Radiated Power, which is the radiated output
 574 power referenced to an isotropic antenna radiating power equally in all directions and whose
 575 gain is expressed in dBi.

576

577 By default MAXEIRP is considered to be +12.15dBm. If the end-device cannot achieve
 578 12.15dBm EIRP, the Max EIRP should be communicated to the network server using an out-
 579 of-band channel during the end-device commissioning process.

580

581 **2.3.4 CN779-787 Join-accept CFList**

582 The CN780 ISM band LoRaWAN implements an optional **channel frequency list** (CFList) of
 583 16 octets in the Join-accept message.

584 In this case the CFList is a list of five channel frequencies for the channels four to eight
 585 whereby each frequency is encoded as a 24 bits unsigned integer (three octets). All these
 586 channels are usable for DR0 to DR5 125kHz LoRa modulation. The list of frequencies is
 587 followed by a single CFListType octet for a total of 16 octets. The CFListType shall be equal
 588 to zero (0) to indicate that the CFList contains a list of frequencies.

589

Size (bytes)	3	3	3	3	3	1
CFList	Freq Ch4	Freq Ch5	Freq Ch6	Freq Ch7	Freq Ch8	CFListTYpe

590 The actual channel frequency in Hz is 100 x frequency whereby values representing
 591 frequencies below 100 MHz are reserved for future use. This allows setting the frequency of
 592 a channel anywhere between 100 MHz to 1.67 GHz in 100 Hz steps. Unused channels have
 593 a frequency value of 0. The **CFList** is optional and its presence can be detected by the
 594 length of the Join-accept message. If present, the **CFList** replaces all the previous channels
 595 stored in the end-device apart from the three default channels.

596 The newly defined channels are immediately enabled and usable by the end-device for
 597 communication.

598 **2.3.5 CN779-787 LinkAdrReq command**

599

 600 The CN780 LoRaWAN only supports a maximum of 16 channels. When **ChMaskCntl** field is
 601 0 the ChMask field individually enables/disables each of the 16 channels.
 602

ChMaskCntl	ChMask applies to
0	Channels 1 to 16
1	RFU
..	..
4	RFU
5	RFU
6	All channels ON The device should enable all currently defined channels independently of the ChMask field value.
7	RFU

Table 21: ChMaskCntl value table

603

604

 605 If the ChMask field value is one of values meaning RFU, then end-device should reject the
 606 command and unset the “**Channel mask ACK**” bit in its response.

 607 **2.3.6 CN779-787 Maximum payload size**

 608 The maximum **MACPayload** size length (M) is given by the following table. It is derived from
 609 limitation of the PHY layer depending on the effective modulation rate used taking into
 610 account a possible repeater encapsulation layer. The maximum application payload length in
 611 the absence of the optional **FOpt** control field (N) is also given for information only. The
 612 value of N might be smaller if the **FOpt** field is not empty.
 613

DataRate	M	N
0	59	51
1	59	51
2	59	51
3	123	115
4	230	222
5	230	222
6	250	242
7	230	222
8:15	Not defined	

Table 22: CN780 maximum payload size

614

615

 616 If the end-device will never operate with a repeater then the maximum application payload
 617 length in the absence of the optional **FOpt** control field should be:
 618

DataRate	M	N
0	59	51
1	59	51
2	59	51
3	123	115
4	250	242
5	250	242
6	250	242
7	250	242

8:15	Not defined
------	-------------

 619 **Table 23 : CN780 maximum payload size (not repeater compatible)**

 620 **2.3.7 CN779-787 Receive windows**

 621 The RX1 receive window uses the same channel than the preceding uplink. The data rate is
 622 a function of the uplink data rate and the RX1DROffset as given by the following table. The
 623 allowed values for RX1DROffset are in the [0:5] range. Values in the range [6:7] are
 624 reserved for future use

625

RX1DROffset	0	1	2	3	4	5
Upstream data rate	Downstream data rate in RX1 slot					
DR0	DR0	DR0	DR0	DR0	DR0	DR0
DR1	DR1	DR0	DR0	DR0	DR0	DR0
DR2	DR2	DR1	DR0	DR0	DR0	DR0
DR3	DR3	DR2	DR1	DR0	DR0	DR0
DR4	DR4	DR3	DR2	DR1	DR0	DR0
DR5	DR5	DR4	DR3	DR2	DR1	DR0
DR6	DR6	DR5	DR4	DR3	DR2	DR1
DR7	DR7	DR6	DR5	DR4	DR3	DR2

 626 **Table 24: CN780 downlink RX1 data rate mapping**

 627 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
 628 786 MHz / DR0.

 629 **2.3.8 CN779-787 Class B beacon and default downlink channel**

630 The beacons SHALL be transmitted using the following settings

DR	3	Corresponds to SF9 spreading factor with 125 kHz BW
CR	1	Coding rate = 4/5
Signal polarity	Non-inverted	As opposed to normal downlink traffic which uses inverted signal polarity

 631 **Table 25: CN780 beacon settings**

632 The beacon frame content is:

Size (bytes)	2	4	2	7	2
BCNPayload	RFU	Time	CRC	GwSpecific	CRC

633 The beacon default broadcast frequency is 785MHz.

634 The class B default downlink pingSlot frequency is 785MHz

635

 636 **2.3.9 CN779-787 Default Settings**

637 The following parameters are recommended values for the CN779-787MHz band.

638	RECEIVE_DELAY1	1 s
639	RECEIVE_DELAY2	2 s (must be RECEIVE_DELAY1 + 1s)
640	JOIN_ACCEPT_DELAY1	5 s
641	JOIN_ACCEPT_DELAY2	6 s
642	MAX_FCNT_GAP	16384
643	ADR_ACK_LIMIT	64

644 ADR_ACK_DELAY 32
645 ACK_TIMEOUT 2 +/- 1 s (random delay between 1 and 3 seconds)

646 If the actual parameter values implemented in the end-device are different from those default
647 values (for example the end-device uses a longer RECEIVE_DELAY1 and
648 RECEIVE_DELAY2 latency), those parameters must be communicated to the network
649 server using an out-of-band channel during the end-device commissioning process. The
650 network server may not accept parameters different from those default values.

651 2.4 EU 433MHz ISM Band

652 2.4.1 EU433 Preamble Format

653 The following synchronization words should be used :

654

Modulation	Sync word	Preamble length
LORA	0x34	8 symbols
GFSK	0xC194C1	5 bytes

655

Table 26: EU433 synch words

656 2.4.2 EU433 ISM Band channel frequencies

657 The LoRaWAN can be used in the ETSI 433-434 MHz band as long as the radio device
658 EIRP is less than 12.15dBm.

659 The end-device transmit duty-cycle should be lower than 1%¹

660 The LoRaWAN channels center frequency can be in the following range:

- 661 • Minimum frequency : 433.175 MHz
- 662 • Maximum frequency : 434.665 MHz

663 EU433 end-devices should be capable of operating in the 433.05 to 434.79 MHz frequency
664 band and should feature a channel data structure to store the parameters of at least 16
665 channels. A channel data structure corresponds to a frequency and a set of data rates
666 usable on this frequency.

667 The first three channels correspond to 433.175, 433.375 and 433.575 MHz with DR0 to DR5
668 and must be implemented in every end-device. Those default channels cannot be modified
669 through the **NewChannelReq** command and guarantee a minimal common channel set
670 between end-devices and gateways of all networks. Other channels can be freely distributed
671 across the allowed frequency range on a network per network basis.

672 The following table gives the list of frequencies that should be used by end-devices to
673 broadcast the Join-request message. The Join-request message transmit duty-cycle shall
674 follow the rules described in chapter “Retransmissions back-off” of the LoRaWAN
675 specification document.

676

Modulation	Bandwidth [kHz]	Channel Frequency [MHz]	FSK Bitrate or LoRa DR / Bitrate	Nb Channels	Duty cycle
LoRa	125	433.175 433.375 433.575	DR0 – DR5 / 0.3-5 kbps	3	<1%

677

Table 27: EU433 Join-request Channel List

678

¹ The EN300220 ETSI standard limits to 10% the maximum transmit duty-cycle in the 433MHz ISM band. The LoRaWAN requires a 1% transmit duty-cycle lower than the legal limit to avoid network congestion.

679 **2.4.3 EU433 Data Rate and End-device Output Power encoding**

680 There is no dwell time limitation for the EU433 PHY layer. The *TxParamSetupReq* MAC
681 command is not implemented by EU433 devices.

682 The following encoding is used for Data Rate (DR) and End-device EIRP (TXPower) in the
683 EU433 band:

684

DataRate	Configuration	Indicative physical bit rate [bit/s]	TXPower	Configuration (EIRP)
0	LoRa: SF12 / 125 kHz	250	0	Max EIRP
1	LoRa: SF11 / 125 kHz	440	1	Max EIRP – 2dB
2	LoRa: SF10 / 125 kHz	980	2	Max EIRP – 4dB
3	LoRa: SF9 / 125 kHz	1760	3	Max EIRP – 6dB
4	LoRa: SF8 / 125 kHz	3125	4	Max EIRP – 8dB
5	LoRa: SF7 / 125 kHz	5470	5	Max EIRP – 10dB
6	LoRa: SF7 / 250 kHz	11000	6..14	RFU
7	FSK: 50 kbps	50000		
8..14	RFU			
15	Defined in LoRaWAN		15	Defined in LoRaWAN

Table 28: Data rate and TX power table

685

686

687 EIRP refers to the Equivalent Isotropically Radiated Power, which is the radiated output
688 power referenced to an isotropic antenna radiating power equally in all directions and whose
689 gain is expressed in dBi.

690

691 By default MAXEIRP is considered to be +12.15dBm. If the end-device cannot achieve
692 12.15dBm EIRP, the Max EIRP should be communicated to the network server using an out-
693 of-band channel during the end-device commissioning process.

694

695

696 **2.4.4 EU433 Join-accept CFList**

697

698 The EU433 ISM band LoRaWAN implements an optional **channel frequency list** (CFList) of
699 16 octets in the Join-accept message.

700 In this case the CFList is a list of five channel frequencies for the channels four to eight
701 whereby each frequency is encoded as a 24 bits unsigned integer (three octets). All these
702 channels are usable for DR0 to DR5 125 kHz LoRa modulation. The list of frequencies is
703 followed by a single CFListType octet for a total of 16 octets. The CFListType shall be equal
704 to zero (0) to indicate that the CFList contains a list of frequencies.

705

Size (bytes)	3	3	3	3	3	1
CFList	Freq Ch4	Freq Ch5	Freq Ch6	Freq Ch7	Freq Ch8	CFListType

706 The actual channel frequency in Hz is 100 x frequency whereby values representing
707 frequencies below 100 MHz are reserved for future use. This allows setting the frequency of
708 a channel anywhere between 100 MHz to 1.67 GHz in 100 Hz steps. Unused channels have
709 a frequency value of 0. The **CFList** is optional and its presence can be detected by the
710 length of the Join-accept message. If present, the **CFList** replaces all the previous channels
711 stored in the end-device apart from the three default channels.

712 The newly defined channels are immediately enabled and usable by the end-device for
713 communication.

714 2.4.5 EU433 LinkAdrReq command

715 The EU433 LoRaWAN only supports a maximum of 16 channels. When **ChMaskCntl** field is
716 0 the ChMask field individually enables/disables each of the 16 channels.
717

ChMaskCntl	ChMask applies to
0	Channels 1 to 16
1	RFU
..	..
4	RFU
5	RFU
6	All channels ON The device should enable all currently defined channels independently of the ChMask field value.
7	RFU

718 **Table 29: ChMaskCntl value table**

719 If the ChMask field value is one of the values meaning RFU, then end-device should reject
720 the command and unset the “**Channel mask ACK**” bit in its response.

721 2.4.6 EU433 Maximum payload size

722 The maximum **MACPayload** size length (M) is given by the following table. It is derived from
723 limitation of the PHY layer depending on the effective modulation rate used taking into
724 account a possible repeater encapsulation layer. The maximum application payload length in
725 the absence of the optional **FOpt** control field (N) is also given for information only. The
726 value of N might be smaller if the **FOpt** field is not empty:
727

DataRate	M	N
0	59	51
1	59	51
2	59	51
3	123	115
4	230	222
5	230	222
6	230	222
7	230	222
8:15	Not defined	

728 **Table 30: EU433 maximum payload size**

729

730 If the end-device will never operate with a repeater then the maximum application payload
731 length in the absence of the optional **FOpt** control field should be:
732

DataRate	M	N
0	59	51
1	59	51
2	59	51
3	123	115
4	250	242
5	250	242
6	250	242

7	250	242
8:15	Not defined	

Table 31 : EU433 maximum payload size (not repeater compatible)

733
734

735 **2.4.7 EU433 Receive windows**

736 The RX1 receive window uses the same channel than the preceding uplink. The data rate is
737 a function of the uplink data rate and the RX1DROffset as given by the following table. The
738 allowed values for RX1DROffset are in the [0:5] range. Values in the range [6:7] are
739 reserved for future use.

740

RX1DROffset	0	1	2	3	4	5
Upstream data rate	Downstream data rate in RX1 slot					
DR0	DR0	DR0	DR0	DR0	DR0	DR0
DR1	DR1	DR0	DR0	DR0	DR0	DR0
DR2	DR2	DR1	DR0	DR0	DR0	DR0
DR3	DR3	DR2	DR1	DR0	DR0	DR0
DR4	DR4	DR3	DR2	DR1	DR0	DR0
DR5	DR5	DR4	DR3	DR2	DR1	DR0
DR6	DR6	DR5	DR4	DR3	DR2	DR1
DR7	DR7	DR6	DR5	DR4	DR3	DR2

Table 32 : EU433 downlink RX1 data rate mapping

741

742 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
743 434.665MHz / DR0 (SF12, 125kHz).

744

745 **2.4.8 EU433 Class B beacon and default downlink channel**

746 The beacons SHALL be transmitted using the following settings

DR	3	Corresponds to SF9 spreading factor with 125 kHz BW
CR	1	Coding rate = 4/5
Signal polarity	Non-inverted	As opposed to normal downlink traffic which uses inverted signal polarity

Table 33 : EU433 beacon settings

747

748 The beacon frame content is:

Size (bytes)	2	4	2	7	2
BCNPayload	RFU	Time	CRC	GwSpecific	CRC

749 The beacon default broadcast frequency is 434.665MHz.

750 The class B default downlink pingSlot frequency is 434.665MHz

751

752 **2.4.9 EU433 Default Settings**

753 The following parameters are recommended values for the EU433band.

- 754 RECEIVE_DELAY1 1 s
- 755 RECEIVE_DELAY2 2 s (must be RECEIVE_DELAY1 + 1s)
- 756 JOIN_ACCEPT_DELAY1 5 s

757 JOIN_ACCEPT_DELAY2 6 s
 758 MAX_FCNT_GAP 16384
 759 ADR_ACK_LIMIT 64
 760 ADR_ACK_DELAY 32
 761 ACK_TIMEOUT 2 +/- 1 s (random delay between 1 and 3 seconds)

762
 763 If the actual parameter values implemented in the end-device are different from those default
 764 values (for example the end-device uses a longer RECEIVE_DELAY1 & 2 latency) , those
 765 parameters must be communicated to the network server using an out-of-band channel
 766 during the end-device commissioning process. The network server may not accept
 767 parameters different from those default values.
 768

769 **2.5 Australia 915-928MHz ISM Band**

770 **2.5.1 AU915-928 Preamble Format**

771 The following synchronization words should be used:
 772

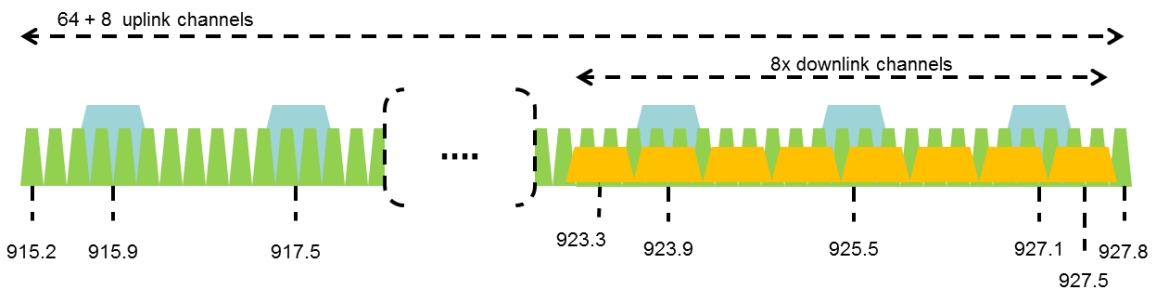
Modulation	Sync word	Preamble length
LORA	0x34	8 symbols

773 LoRaWAN does not make use of GFSK modulation in the AU915-928 ISM band.

774 **2.5.2 AU915-928 Channel Frequencies**

775 The AU ISM Band shall be divided into the following channel plans.

- 776 • Upstream – 64 channels numbered 0 to 63 utilizing LoRa 125 kHz BW varying from
 777 DR0 to DR5, using coding rate 4/5, starting at 915.2 MHz and incrementing linearly
 778 by 200 kHz to 927.8 MHz
- 779 • Upstream – 8 channels numbered 64 to 71 utilizing LoRa 500 kHz BW at DR6
 780 starting at 915.9 MHz and incrementing linearly by 1.6 MHz to 927.1 MHz
- 781 • Downstream – 8 channels numbered 0 to 7 utilizing LoRa 500 kHz BW at DR8 to
 782 DR13) starting at 923.3 MHz and incrementing linearly by 600 kHz to 927.5 MHz
 783



784 **Figure 2: AU915-928 channel frequencies**
 785

786 AU ISM band end-devices may use a maximum EIRP of +30 dBm.

787 AU915-928 end-devices should be capable of operating in the 915 to 928 MHz frequency
 788 band and should feature a channel data structure to store the parameters of 72 channels. A
 789 channel data structure corresponds to a frequency and a set of data rates usable on this
 790 frequency.

791 If using the over-the-air activation procedure, the end-device should broadcast the Join-
 792 request message alternatively on a random 125 kHz channel amongst the 64 channels

793 defined using **DR0** and a random 500 kHz channel amongst the 8 channels defined using
 794 **DR6**. The end-device should change channel for every transmission.

795 Personalized devices shall have all 72 channels enabled following a reset.

796 **2.5.3 AU915-928 Data Rate and End-point Output Power encoding**

797 The *TxParamSetupReq* MAC command is not implemented by AU915-928 devices.

798 The following encoding is used for Data Rate (**DR**) and End-point EIRP (**TXPower**) in the
 799 AU915-928 band:

800

DataRate	Configuration	Indicative physical bit rate [bit/sec]
0	LoRa: SF12 / 125 kHz	250
1	LoRa: SF11 / 125 kHz	440
2	LoRa: SF10 / 125 kHz	980
3	LoRa: SF9 / 125 kHz	1760
4	LoRa: SF8 / 125 kHz	3125
5	LoRa: SF7 / 125 kHz	5470
6	LoRa: SF8 / 500 kHz	12500
7	RFU	
8	LoRa: SF12 / 500 kHz	980
9	LoRa: SF11 / 500 kHz	1760
10	LoRa: SF10 / 500 kHz	3900
11	LoRa: SF9 / 500 kHz	7000
12	LoRa: SF8 / 500 kHz	12500
13	LoRa: SF7 / 500 kHz	21900
14	RFU	
15	Defined in LoRaWAN	

Table 34: AU915-928 Data rate table

801

802

803 DR6 is identical to DR12, DR8...13 must be implemented in end-devices and are reserved
 804 for future applications.

805

TXPower	Configuration (EIRP)
0	Max EIRP
1:10	Max EIRP – 2*TXPower
11:14	RFU
15	Defined in LoRaWAN

Table 35 : AU915-928 TX power table

806

807

808 EIRP refers to the Equivalent Isotropically Radiated Power, which is the radiated output
 809 power referenced to an isotropic antenna radiating power equally in all directions and whose
 810 gain is expressed in dBi.

811

812 By default MaxEIRP is considered to be +30dBm. If the end-device cannot achieve 30dBm
 813 EIRP, the Max EIRP should be communicated to the network server using an out-of-band
 814 channel during the end-device commissioning process.

815

816 **2.5.4 AU915-928 Join-accept CFList**

817

818 The AU915-928 LoRaWAN supports the use of the optional **CFlist** appended to the Join-
 819 accept message. If the **CFlist** is not empty then the **CFListType** field shall contain the value
 820 one (0x01) to indicate the **CFList** contains a series of **ChMask** fields. The **ChMask** fields are
 821 interpreted as being controlled by a virtual **ChMaskCntl** that initializes to a value of zero (0)
 822 and increments for each **ChMask** field to a value of four(4). (The first 16 bits controls the
 823 channels 1 to 16, ..)

Size (bytes)	[2]	[2]	[2]	[2]	[2]	[2]	[3]	[1]
CFList	ChMask0	ChMask1	ChMask2	ChMask3	ChMask4	RFU	RFU	CFListType

824

825 2.5.5 AU915-928 LinkAdrReq command

826 For the AU915-928 version the **ChMaskCntl** field of the **LinkADRReq** command has the
 827 following meaning:

828

829

ChMaskCntl	ChMask applies to
0	Channels 0 to 15
1	Channels 16 to 31
..	..
4	Channels 64 to 71
5	8LSBs controls Channel Blocks 0 to 7 8MSBs are RFU
6	All 125 kHz ON ChMask applies to channels 64 to 71
7	All 125 kHz OFF ChMask applies to channels 64 to 71

Table 36: ChMaskCntl value table

830

831 If **ChMaskCntl** = 5 then the corresponding bits in the **ChMask** enable and disable a bank of
 832 8 125kHz channels and the corresponding 500kHz channel defined by the following
 833 calculation: $[\text{ChannelMaskBit} * 8, \text{ChannelMaskBit} * 8 + 7], 64 + \text{ChannelMaskBit}$.

834 If **ChMaskCntl** = 6 then 125 kHz channels are enabled, if **ChMaskCntl** = 7 then 125 kHz
 835 channels are disabled. Simultaneously the channels 64 to 71 are set according to the
 836 **ChMask** bit mask. The **DataRate** specified in the command need not be valid for channels
 837 specified in the **ChMask**, as it governs the global operational state of the end-device.

838

839 2.5.6 AU915-928 Maximum payload size

840 The maximum **MACPayload** size length (M) is given by the following table. It is derived from
 841 the maximum allowed transmission time at the PHY layer taking into account a possible
 842 repeater encapsulation. The maximum application payload length in the absence of the
 843 optional **FOpt** MAC control field (N) is also given for information only. The value of N might
 844 be smaller if the **FOpt** field is not empty:

845

DataRate	M	N
0	59	51
1	59	51
2	59	51

3	123	115
4	230	222
5	230	222
6	230	222
7	Not defined	
8	41	33
9	117	109
10	230	222
11	230	222
12	230	222
13	230	222
14:15	Not defined	

Table 37: AU915-928 maximum payload size

846

847 The greyed lines correspond to the data rates that may be used by an end-device behind a
848 repeater.

849 If the end-device will never operate with a repeater then the maximum application payload
850 length in the absence of the optional **FOpt** control field should be:
851

DataRate	<i>M</i>	<i>N</i>
0	59	51
1	59	51
2	59	51
3	123	115
4	250	242
5	250	242
6	250	242
7	Not defined	
8	61	53
9	137	129
10	250	242
11	250	242
12	250	242
13	250	242
14:15	Not defined	

Table 38: AU915-928 maximum payload size (not repeater compatible)

852

853 **2.5.7 AU915-928 Receive windows**

- 854 • The RX1 receive channel is a function of the upstream channel used to initiate the
855 data exchange. The RX1 receive channel can be determined as follows.
856 ○ RX1 Channel Number = Transmit Channel Number modulo 8
- 857 • The RX1 window data rate depends on the transmit data rate (see Table 16 below).
- 858 • The RX2 (second receive window) settings uses a fixed data rate and frequency.
859 Default parameters are 923.3Mhz / DR8
860

Upstream data rate RX1DROff set	Downstream data rate					
	0	1	2	3	4	5
DR0	DR8	DR8	DR8	DR8	DR8	DR8
DR1	DR9	DR8	DR8	DR8	DR8	DR8
DR2	DR10	DR9	DR8	DR8	DR8	DR8
DR3	DR11	DR10	DR9	DR8	DR8	DR8
DR4	DR12	DR11	DR10	DR9	DR8	DR8

Upstream data rate RX1DROff set	Downstream data rate					
	0	1	2	3	4	5
DR5	DR13	DR12	DR11	DR10	DR9	DR8
DR6	DR13	DR13	DR12	DR11	DR10	DR9

Table 39 : AU915-928 downlink RX1 data rate mapping

861
862

863 The allowed values for RX1DROffset are in the [0:5] range. Values in the range [6:7] are
864 reserved for future use.

865

866 **2.5.8 AU915-928 Class B beacon**

867 The beacons are transmitted using the following settings:

DR	10	Corresponds to SF10 spreading factor with 500kHz bw
CR	1	Coding rate = 4/5
Signal polarity	Non-inverted	As opposed to normal downlink traffic which uses inverted signal polarity
frequencies	923.3 to 927.5MHz with 600kHz steps	Beaconing is performed on the same channel that normal downstream traffic as defined in the Class A specification

Table 40 : AU915-928 beacon settings

868

869 The downstream channel used for a given beacon is:

870
$$\text{Channel} = \left[\text{floor} \left(\frac{\text{beacon_time}}{\text{beacon_period}} \right) \right] \text{ modulo } 8$$

- 871 • whereby beacon_time is the integer value of the 4 bytes “Time” field of the beacon
- 872 frame
- 873 • whereby beacon_period is the periodicity of beacons , 128 seconds
- 874 • whereby floor(x) designates rounding to the integer immediately inferior or equal to x

875

876 | Example: the first beacon will be transmitted on 923.3Mhz , the second
877 | on 923.9MHz, the 9th beacon will be on 923.3Mhz again.

878

879

Beacon channel nb	Frequency [MHz]
0	923.3
1	923.9
2	924.5
3	925.1
4	925.7
5	926.3
6	926.9
7	927.5

880

881

882 The beacon frame content is:

Size (bytes)	3	4	2	7	1	2
BCNPayload	RFU	Time	CRC	GwSpecific	RFU	CRC

883

884 2.5.9 AU915-928 Default Settings

885 The following parameters are recommended values for the AU915-928 band.

886	RECEIVE_DELAY1	1 s
887	RECEIVE_DELAY2	2 s (must be RECEIVE_DELAY1 + 1s)
888	JOIN_ACCEPT_DELAY1	5 s
889	JOIN_ACCEPT_DELAY2	6 s
890	MAX_FCNT_GAP	16384
891	ADR_ACK_LIMIT	64
892	ADR_ACK_DELAY	32
893	ACK_TIMEOUT	2 +/- 1 s (random delay between 1 and 3 seconds)

894 If the actual parameter values implemented in the end-device are different from those default
895 values (for example the end-device uses a longer RECEIVE_DELAY1 & 2 latency), those
896 parameters must be communicated to the network server using an out-of-band channel
897 during the end-device commissioning process. The network server may not accept
898 parameters different from those default values.
899

900 **2.6 CN 470-510MHz Band**

901 **2.6.1 CN470-510 Preamble Format**

902 The following synchronization words should be used:

903

Modulation	Sync word	Preamble length
LORA	0x34	8 symbols

904 **2.6.2 CN470-510 Channel Frequencies**

905

906 In China, this band is defined by SRRC to be used for civil metering applications.

907 The 470 MHz ISM Band shall be divided into the following channel plans:

908

- Upstream – 96 channels numbered 0 to 95 utilizing LoRa 125 kHz BW varying from DR0 to DR5, using coding rate 4/5, starting at 470.3 MHz and incrementing linearly by 200 kHz to 489.3 MHz.

909

910

911

912 Channel Index 6 to 38 and 45 to 77 are mainly used by China Electric
 913 Power. In the areas where these channels are used by China Electric
 914 Power, they should be disabled.

915

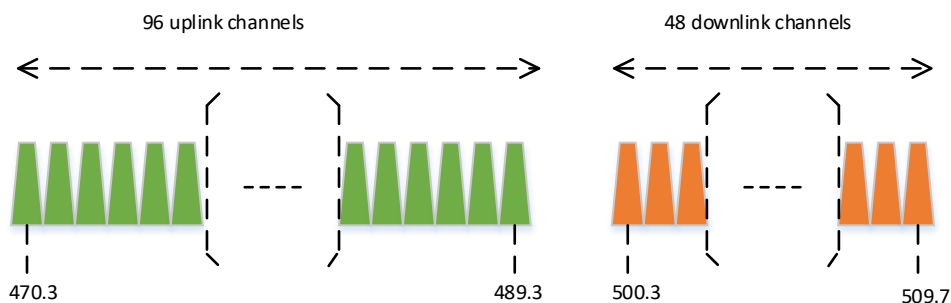
- Downstream – 48 channels numbered 0 to 47 utilizing LoRa 125 kHz BW varying from DR0 to DR5, using coding rate 4/5, starting at 500.3 MHz and incrementing linearly by 200 kHz to 509.7 MHz

916

917

918

919



920 **Figure 3: CN470-510 channel frequencies**

921

922

923 The LoRaWAN can be used in the Chinese 470-510MHz band as long as

924

- The radio device EIRP is less than 19.15dBm
- The transmission never lasts more than 5000 ms.

925

926

927

928

929 CN470-510 end-devices should be capable of operating in the 470 to 510 MHz frequency
 930 band and should feature a channel data structure to store the parameters of 96 uplink
 931 channels. A channel data structure corresponds to a frequency and a set of data rates
 932 usable on this frequency.

933

934

935

If using the over-the-air activation procedure, the end-device should broadcast the Join-request message on a random 125 kHz channel amongst the 96 uplink channels defined using **DR5 to DR0**.

936 Personalized devices shall have all 96 channels enabled following a reset.

937

938 **2.6.3 CN470-510 Data Rate and End-point Output Power encoding**

939 There is no dwell time limitation for the CN470-510 PHY layer. The *TxParamSetupReq*
940 MAC command is not implemented by CN470-510 devices.

941 The following encoding is used for Data Rate (**DR**) and End-point EIRP (**TXPower**) in the
942 CN470-510 band:

943

DataRate	Configuration	Indicative physical bit rate [bit/sec]	TXPower	Configuration (EIRP)
0	LoRa: SF12 / 125 kHz	250	0	Max EIRP
1	LoRa: SF11 / 125 kHz	440	1	Max EIRP – 2dB
2	LoRa: SF10 / 125 kHz	980	2	Max EIRP – 4dB
3	LoRa: SF9 / 125 kHz	1760	3	Max EIRP – 6dB
4	LoRa: SF8 / 125 kHz	3125	4	Max EIRP – 8dB
5	LoRa:SF7 / 125 kHz	5470	5	Max EIRP – 10dB
6:14	RFU		6	Max EIRP – 12dB
			7	Max EIRP – 14dB
			8...14	RFU
15	Defined in LoRaWAN		15	Defined in LoRaWAN

Table 41: CN470 Data rate and TX power table

944

945

946 EIRP refers to the Equivalent Isotropically Radiated Power, which is the radiated output
947 power referenced to an isotropic antenna radiating power equally in all directions and whose
948 gain is expressed in dBi.

949

950 By default MaxEIRP is considered to be +19.15dBm. If the end-device cannot achieve
951 19.15dBm EIRP, the Max EIRP should be communicated to the network server using an out-
952 of-band channel during the end-device commissioning process.

953

954 **2.6.4 CN470-510 Join-accept CFList**

955

956 The CN470-510 LoRaWAN supports the use of the optional **CFlist** appended to the Join-
957 accept message. If the **CFlist** is not empty then the CFListType field shall contain the value
958 one (0x01) to indicate the CFList contains a series of ChMask fields. The ChMask fields are
959 interpreted as being controlled by a virtual ChMaskCntl that initializes to a value of zero (0)
960 and increments for each ChMask field to a value of five (5). (The first 16 bits controls the
961 channels 1 to 16, ..)

962

Size (bytes)	[2]	[2]	[2]	[2]	[2]	[2]	[3]	[1]
CFList	ChMask0	ChMask1	ChMask2	ChMask3	ChMask4	ChMask5	RFU	CFListType

963 **2.6.5 CN470-510 LinkAdrReq command**

 964 For the CN470-510 version the **ChMaskCntl** field of the **LinkADRReq** command has the
 965 following meaning:

966

ChMaskCntl	ChMask applies to
0	Channels 0 to 15
1	Channels 16 to 31
2	Channels 32 to 47
3	Channels 48 to 63
4	Channels 64 to 79
5	Channels 80 to 95
6	All channels ON The device should enable all currently defined channels independently of the ChMask field value.
7	RFU

967

Table 42: CN470 ChMaskCntl value table

 968 If the ChMask field value is one of the values meaning RFU, then end-device should reject
 969 the command and unset the “**Channel mask ACK**” bit in its response.

 970 **2.6.6 CN470-510 Maximum payload size**

 971 The maximum **MACPayload** size length (M) is given by the following table. It is derived from
 972 the maximum allowed transmission time at the PHY layer taking into account a possible
 973 repeater encapsulation. The maximum application payload length in the absence of the
 974 optional **FOpt** MAC control field (N) is also given for information only. The value of N might
 975 be smaller if the **FOpt** field is not empty:

DataRate	M	N
0	59	51
1	59	51
2	59	51
3	123	115
4	230	222
5	230	222
6:15	Not defined	

976

Table 43: CN470-510 maximum payload size

 977 If the end-device will never operate with a repeater then the maximum application payload
 978 length in the absence of the optional **FOpt** control field should be:

979

DataRate	M	N
0	59	51
1	59	51
2	59	51
3	123	115
4	250	242
5	250	242
6:15	Not defined	

980

Table 44 : CN470-510 maximum payload size (not repeater compatible)

981

 982 **2.6.7 CN470-510 Receive windows**

- 983
- The RX1 receive channel is a function of the upstream channel used to initiate the
 984 data exchange. The RX1 receive channel can be determined as follows.

- 985 ○ RX1 Channel Number = Uplink Channel Number modulo 48, for example,
- 986 when transmitting channel number is 49, the rx1 channel number is 1.
- 987 • The RX1 window data rate depends on the transmit data rate (see Table below).
- 988 • The RX2 (second receive window) settings uses a fixed data rate and frequency.
- 989 Default parameters are 505.3 MHz / DR0
- 990

RX1DROffset	0	1	2	3	4	5
Upstream data rate	Downstream data rate in RX1 slot					
DR0	DR0	DR0	DR0	DR0	DR0	DR0
DR1	DR1	DR0	DR0	DR0	DR0	DR0
DR2	DR2	DR1	DR0	DR0	DR0	DR0
DR3	DR3	DR2	DR1	DR0	DR0	DR0
DR4	DR4	DR3	DR2	DR1	DR0	DR0
DR5	DR5	DR4	DR3	DR2	DR1	DR0

Table 45: CN470-510 downlink RX1 data rate mapping

991
992

993 The allowed values for RX1DROffset are in the [0:5] range. Values in the range [6:7] are
994 reserved for future use.

995 2.6.8 CN470-510 Class B beacon

996 The beacons are transmitted using the following settings:

DR	2	Corresponds to SF10 spreading factor with 125kHz bw
CR	1	Coding rate = 4/5
Signal polarity	Non-inverted	As opposed to normal downlink traffic which uses inverted signal polarity
frequencies	508.3 to 509.7MHz with 200kHz steps	

Table 46 : CN470-510 beacon settings

997
998

999 The downstream channel used for a given beacon is:

$$1000 \text{ BeaconChannel} = \left[\text{floor} \left(\frac{\text{beacon_time}}{\text{beacon_period}} \right) \right] \text{ modulo } 8$$

- 1001 • whereby beacon_time is the integer value of the 4 bytes “Time” field of the beacon
- 1002 frame
- 1003 • whereby beacon_period is the periodicity of beacons , 128 seconds
- 1004 • whereby $\text{floor}(x)$ designates rounding to the integer immediately inferior or equal to x
- 1005

1006 Example: the first beacon will be transmitted on 508.3Mhz, the second
1007 on 508.5MHz, the 9th beacon will be on 508.3Mhz again.

1008
1009

Beacon channel nb	Frequency [MHz]
0	508.3
1	508.5
2	508.7
3	508.9
4	509.1
5	509.3
6	509.5

7	509.7
---	-------

1010
1011
1012

The beacon frame content is:

Size (bytes)	3	4	2	7	1	2
BCNPayload	RFU	Time	CRC	GwSpecific	RFU	CRC

1013

1014 **2.6.9 CN470-510 Default Settings**

1015 The following parameters are recommended values for the CN470-510 band.

1016	RECEIVE_DELAY1	1 s
1017	RECEIVE_DELAY2	2 s (must be RECEIVE_DELAY1 + 1s)
1018	JOIN_ACCEPT_DELAY1	5 s
1019	JOIN_ACCEPT_DELAY2	6 s
1020	MAX_FCNT_GAP	16384
1021	ADR_ACK_LIMIT	64
1022	ADR_ACK_DELAY	32
1023	ACK_TIMEOUT	2 +/- 1 s (random delay between 1 and 3 seconds)

1024 If the actual parameter values implemented in the end-device are different from those default
1025 values (for example the end-device uses a longer RECEIVE_DELAY1 & 2 latency), those
1026 parameters must be communicated to the network server using an out-of-band channel
1027 during the end-device commissioning process. The network server may not accept
1028 parameters different from those default values.

1029 **2.7 AS923MHz ISM Band**

 1030 **2.7.1 AS923 Preamble Format**

1031 The following synchronization words should be used:

1032

Modulation	Sync word	Preamble length
LORA	0x34	8 symbols
GFSK	0xC194C1	5 bytes

1033

Table 47: AS923 synch words

 1034 **2.7.2 AS923 ISM Band channel frequencies**

 1035 This section applies to regions where the frequencies [923...923.5MHz] are comprised in the
 1036 ISM band, which is the case for the following countries:

- 1037 ❖ Brunei [923-925 MHz]
- 1038 ❖ Cambodia [923-925 MHz]
- 1039 ❖ Indonesia [923-925 MHz]
- 1040 ❖ Japan [920-928 MHz]
- 1041 ❖ Laos [923-925 MHz]
- 1042 ❖ New Zealand [915-928 MHz]
- 1043 ❖ Singapore [920-925 MHz]
- 1044 ❖ Taiwan [922-928 MHz]
- 1045 ❖ Thailand [920-925 MHz]
- 1046 ❖ Vietnam [920-925 MHz]

 1047 The network channels can be freely attributed by the network operator. However the two
 1048 following default channels must be implemented in every AS923MHz end-device. Those
 1049 channels are the minimum set that all network gateways should always be listening on.

1050

Modulation	Bandwidth [kHz]	Channel Frequency [MHz]	FSK Bitrate or LoRa DR / Bitrate	Nb Channels	Duty cycle
LoRa	125	923.20 923.40	DR0 to DR5 / 0.3-5 kbps	2	< 1%

1051

Table 48: AS923 default channels

 1052 Those default channels must be implemented in every end-device and cannot be modified
 1053 through the **NewChannelReq** command and guarantee a minimal common channel set
 1054 between end-devices and network gateways.

1055 AS923MHz ISM band end-devices should use the following default parameters

1056

- Default EIRP: 16 dBm

 1057 AS923MHz end-devices should feature a channel data structure to store the parameters of
 1058 at least 16 channels. A channel data structure corresponds to a frequency and a set of data
 1059 rates usable on this frequency.

1060 The following table gives the list of frequencies that should be used by end-devices to
1061 broadcast the Join-request message.

Modulation	Bandwidth [kHz]	Channel Frequency [MHz]	FSK Bitrate or LoRa DR / Bitrate	Nb Channels	Duty cycle
LoRa	125	923.20 923.40	DR2	2	< 1%

1062 **Table 49: AS923 Join-request Channel List**

1063 The default Join-request Data Rate is DR2 (SF10/125KHz), this setting ensures that end-
1064 devices are compatible with the 400ms dwell time limitation until the actual dwell time limit is
1065 notified to the end-device by the network server via the MAC command
1066 “TxParamSetupReq”.

1067 The Join-request message transmit duty-cycle shall follow the rules described in chapter
1068 “Retransmissions back-off” of the LoRaWAN specification document.
1069

1070 2.7.3 AS923 Data Rate and End-point Output Power encoding

1071 The “TxParamSetupReq/Ans” MAC command MUST be implemented by the AS923
1072 devices.

1073 The following encoding is used for Data Rate (DR) in the AS923 band:

1074

DataRate	Configuration	Indicative physical bit rate [bit/s]
0	LoRa: SF12 / 125 kHz	250
1	LoRa: SF11 / 125 kHz	440
2	LoRa: SF10 / 125 kHz	980
3	LoRa: SF9 / 125 kHz	1760
4	LoRa: SF8 / 125 kHz	3125
5	LoRa: SF7 / 125 kHz	5470
6	LoRa: SF7 / 250 kHz	11000
7	FSK: 50 kbps	50000
8..14	RFU	
15	Defined in LoRaWAN	

1075 **Table 50: Data rate table**

1076

1077

1078 The TXPower table indicates power levels relative to the Max EIRP level of the end-device,
1079 as per the following table:

1079

TXPower	Configuration (EIRP)
0	Max EIRP
1	Max EIRP – 2dB
2	Max EIRP – 4dB
3	Max EIRP – 6dB
4	Max EIRP – 8dB
5	Max EIRP – 10dB
6	Max EIRP – 12dB
7	Max EIRP – 14dB
8..14	RFU

15	Defined in LoRaWAN
----	-----------------------

Table 51: TxPower table

 1080
1081

1082 EIRP refers to the Equivalent Isotropically Radiated Power, which is the radiated output
1083 power referenced to an isotropic antenna radiating power equally in all directions and whose
1084 gain is expressed in dBi.

1085 By default Max EIRP shall be 16dBm. The Max EIRP can be modified by the network server
1086 through the **TxParamSetupReq** MAC command and should be used by both the end-
1087 device and the network server once **TxParamSetupReq** is acknowledged by the device via
1088 **TxParamSetupAns**,

1089

1090 2.7.4 AS923 Join-accept CFList

1091 The AS923 LoRaWAN implements an optional channel frequency list (CFList) of 16 octets in
1092 the Join-accept message.

1093 In this case the CFList is a list of five channel frequencies for the channels three to seven
1094 whereby each frequency is encoded as a 24 bits unsigned integer (three octets). All these
1095 channels are usable for DR0 to DR5 125 KHz LoRa modulation. The list of frequencies is
1096 followed by a single CFListType octet for a total of 16 octets. The CFListType shall be equal
1097 to zero (0) to indicate that the CFList contains a list of frequencies.

1098

Size (bytes)	3	3	3	3	3	1
CFList	Freq Ch3	Freq Ch4	Freq Ch5	Freq Ch6	Freq Ch7	CFListType

1099 The actual channel frequency in Hz is 100 x frequency whereby values representing
1100 frequencies below 100 MHz are reserved for future use. This allows setting the frequency of
1101 a channel anywhere between 915 and 928MHz in 100 Hz steps. Unused channels have a
1102 frequency value of 0. The CFList is optional and its presence can be detected by the length
1103 of the Join-accept message. If present, the CFList replaces all the previous channels stored
1104 in the end-device apart from the two default channels. The newly defined channels are
1105 immediately enabled and usable by the end-device for communication.

1106 2.7.5 AS923 LinkAdrReq command

1107 The AS923 LoRaWAN only supports a maximum of 16 channels. When **ChMaskCntl** field is
1108 0 the ChMask field individually enables/disables each of the 16 channels.
1109

ChMaskCntl	ChMask applies to
0	Channels 1 to 16
1	RFU
..	..
4	RFU
5	RFU
6	All channels ON The device should enable all currently defined channels independently of the ChMask field value.

ChMaskCntl	ChMask applies to
7	RFU

1110

Table 52: ChMaskCntl value table

1111 If the ChMask field value is one of values meaning RFU, the end-device should reject the
1112 command and unset the “Channel mask ACK” bit in its response.

1113

1114 2.7.6 AS923 Maximum payload size

1115 The maximum **MACPayload** size length (M) is given by the following table for both dwell
1116 time configurations: No Limit and 400ms. It is derived from the PHY layer limitation
1117 depending on the effective modulation rate used taking into account a possible repeater
1118 encapsulation layer.

1119

DataRate	Uplink MAC Payload Size (M)		Downlink MAC Payload Size (M)	
	UplinkDwellTime = 0	UplinkDwellTime = 1	DownlinkDwellTime = 0	DownlinkDwellTime = 1
0	59	N/A	59	N/A
1	59	N/A	59	N/A
2	59	19	59	19
3	123	61	123	61
4	230	133	230	133
5	230	250	230	250
6	230	250	230	250
7	230	250	230	250
8:15	RFU		RFU	

1120

Table 53: AS923 maximum payload size

1121 If the end-device will never operate with a repeater then the maximum MAC payload length
1122 should be:

DataRate	Uplink MAC Payload Size (M)		Downlink MAC Payload Size (M)	
	UplinkDwellTime = 0	UplinkDwellTime = 1	DownlinkDwellTime = 0	DownlinkDwellTime = 1
0	59	N/A	59	N/A
1	59	N/A	59	N/A
2	59	19	59	19
3	123	61	123	61
4	250	133	250	133
5	250	250	250	250
6	250	250	250	250
7	250	250	250	250
8:15	RFU		RFU	

1123

Table 54: AS923 maximum payload size (not repeater compatible)

1124 The maximum application payload length in the absence of the optional **FOpt** control field
1125 (M) is eight bytes lower than the MACPayload value in the above table. The value of N might
1126 be smaller if the **FOpt** field is not empty.

1127

1128 2.7.7 AS923 Receive windows

1129 The RX1 receive window uses the same channel than the preceding uplink. The data rate is
1130 a function of the uplink data rate and the RX1DROffset as following:

1130

1131 Downstream data rate in RX1 slot = $MIN(5, MAX(\text{MinDR}, \text{Upstream data rate} -$
 1132 $\text{Effective_RX1DROffset}))$

1133 MinDR depends on the DownlinkDwellTime bit sent to the device in the **TxParamSetupReq**
 1134 command:

- 1135 • Case DownlinkDwellTime = 0 (No limit): MinDR = 0
- 1136 • Case DownlinkDwellTime = 1 (400ms): MinDR = 2

1137 The allowed values for RX1DROffset are in the [0:7] range, encoded as per the below table:

RX1DROffset (Coded value)	0	1	2	3	4	5	6	7
Effective_RX1DROffset	0	1	2	3	4	5	-1	-2

1138 Values in the [6:7] range allow setting the Downstream RX1 data rate higher than Upstream
 1139 data rate.

1140 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
 1141 923.2 MHz / DR2 (SF10/125KHz).

1142

1143 2.7.8 AS923 Class B beacon and default downlink channel

1144 The beacons SHALL be transmitted using the following settings

DR	3	Corresponds to SF9 spreading factor with 125 kHz BW
CR	1	Coding rate = 4/5
Signal polarity	Non-inverted	As opposed to normal downlink traffic which uses inverted signal polarity

1145 [Table 55 : AS923 beacon settings](#)

1146 The beacon frame content is:

Size (bytes)	2	4	2	7	2
BCNPayload	RFU	Time	CRC	GwSpecific	CRC

1147 The beacon default broadcast frequency is 923.4MHz.

1148 The class B default downlink pingSlot frequency is 923.4MHz

1149

1150 2.7.9 AS923 Default Settings

1151 The following parameters are recommended values for the AS923MHz band.

- 1152 RECEIVE_DELAY1 1 s
- 1153 RECEIVE_DELAY2 2 s (must be RECEIVE_DELAY1 + 1s)
- 1154 JOIN_ACCEPT_DELAY1 5 s
- 1155 JOIN_ACCEPT_DELAY2 6 s
- 1156 MAX_FCNT_GAP 16384
- 1157 ADR_ACK_LIMIT 64
- 1158 ADR_ACK_DELAY 32
- 1159 ACK_TIMEOUT 2 +/- 1 s (random delay between 1 and 3 seconds)

1160 If the actual parameter values implemented in the end-device are different from those default
 1161 values (for example the end-device uses a longer RECEIVE_DELAY1 and
 1162 RECEIVE_DELAY2 latency), those parameters must be communicated to the network

1163 server using an out-of-band channel during the end-device commissioning process. The
1164 network server may not accept parameters different from those default values.

1165 **2.8 South Korea 920-923MHz ISM Band**

 1166 **2.8.1 KR920-923 Preamble Format**

1167 The following synchronization words should be used:

1168

Modulation	Sync word	Preamble length
LORA	0x34	8 symbols

 1169 **2.8.2 KR920-923 ISM Band channel frequencies**

 1170 The center frequency, bandwidth and maximum EIRP output power for the South Korea
 1171 RFID/USN frequency band are already defined by Korean Government. Basically Korean
 1172 Government allocated LPWA based IoT network frequency band from 920.9 to 923.3MHz.

1173

Center frequency (MHz)	Bandwidth (kHz)	Maximum EIRP output power (dBm)	
		For end-device	For gateway
920.9	125	10	23
921.1	125	10	23
921.3	125	10	23
921.5	125	10	23
921.7	125	10	23
921.9	125	10	23
922.1	125	14	23
922.3	125	14	23
922.5	125	14	23
922.7	125	14	23
922.9	125	14	23
923.1	125	14	23
923.3	125	14	23

1174

Table 56: Center frequency, bandwidth, maximum EIRP output power table

 1175 The three following default channels (922.1, 922.3 and 922.5MHz / DR0 to DR5) determined
 1176 by the network operator from the set of available channels as defined by the South Korean
 1177 regulation must be implemented in every KR920-923MHz end-device, and cannot be
 1178 alterable by the **NewChannelReq** command. Those channels are the minimum set that all
 1179 network gateways should always be listening on to guarantee a minimal common channel
 1180 set between end-devices and network gateways.

1181

Modulation	Bandwidth [kHz]	Channel Frequency [MHz]	FSK Bitrate or LoRa DR / Bitrate	Nb Channels
LoRa	125	922.10 922.30 922.50	DR0 to DR5 / 0.3-5 kbps	3

1182

Table 57: KR920-923 default channels

 1183 In order to access the physical medium the South Korea regulations impose some
 1184 restrictions. The South Korea regulations allow the choice of using either a duty-cycle
 1185 limitation or a so-called Listen Before Talk Adaptive Frequency Agility (LBT AFA)
 1186 transmissions management. The current LoRaWAN specification for the KR920-923 ISM

1187 band exclusively uses LBT channel access rule to maximize MACPayload size length and
 1188 comply with the South Korea regulations.

1189 KR920-923MHz ISM band end-devices should use the following default parameters

- 1190 • Default EIRP output power for end-device(920.9~921.9MHz): 10 dBm
- 1191 • Default EIRP output power for end-device(922.1~923.3MHz): 14 dBm
- 1192 • Default EIRP output power for gateway: 23 dBm

1193 KR920-923MHz end-devices should be capable of operating in the 920 to 923MHz
 1194 frequency band and should feature a channel data structure to store the parameters of at
 1195 least 16 channels. A channel data structure corresponds to a frequency and a set of data
 1196 rates usable on this frequency.

1197 The following table gives the list of frequencies that should be used by end-devices to
 1198 broadcast the Join-request message.

Modulation	Bandwidth [kHz]	Channel Frequency [MHz]	FSK Bitrate or LoRa DR / Bitrate	Nb Channels
LoRa	125	922.10 922.30 922.50	DR0 to DR5 / 0.3-5 kbps	3

1199 **Table 58: KR920-923 Join-request Channel List**

1200 **2.8.3 KR920-923 Data Rate and End-device Output Power encoding**

1201 There is no dwell time limitation for the KR920-923 PHY layer. The *TxParamSetupReq*
 1202 MAC command is not implemented by KR920-923 devices.

1203 The following encoding is used for Data Rate (DR), and EIRP Output Power (TXPower) in
 1204 the KR920-923 band:

1205

DataRate	Configuration	Indicative physical bit rate [bit/s]
0	LoRa: SF12 / 125 kHz	250
1	LoRa: SF11 / 125 kHz	440
2	LoRa: SF10 / 125 kHz	980
3	LoRa: SF9 / 125 kHz	1760
4	LoRa: SF8 / 125 kHz	3125
5	LoRa: SF7 / 125 kHz	5470
6..14	RFU	
15	Defined in LoRAWAN	

Table 59: TX Data rate table

1206

1207

1208

TXPower	Configuration (EIRP)
0	Max EIRP
1	Max EIRP – 2dB
2	Max EIRP – 4dB
3	Max EIRP – 6dB
4	Max EIRP – 8dB
5	Max EIRP – 10dB
6	Max EIRP – 12dB
7	Max EIRP – 14dB
8..14	RFU
15	Defined in LoRAWAN

Table 60: TX power table

1209
1210

1211 EIRP refers to the Equivalent Isotropically Radiated Power, which is the radiated output
1212 power referenced to an isotropic antenna radiating power equally in all directions and whose
1213 gain is expressed in dBi.

1214

1215 By default MaxEIRP is considered to be +14dBm. If the end-device cannot achieve 14dBm
1216 EIRP, the MaxEIRP should be communicated to the network server using an out-of-band
1217 channel during the end-device commissioning process.

1218 When the device transmits in a channel whose frequency is <922MHz, the transmit power
1219 SHALL be limited to +10dBm EIRP even if the current transmit power level set by the
1220 network server is higher.

1221 **2.8.4 KR920-923 Join-accept CFList**

1222 The KR920-923 ISM band LoRaWAN implements an optional **channel frequency list**
1223 (CFList) of 16 octets in the Join-accept message.

1224 In this case the CFList is a list of five channel frequencies for the channels four to eight
1225 whereby each frequency is encoded as a 24 bits unsigned integer (three octets). All these
1226 channels are usable for DR0 to DR5 125kHz LoRa modulation.

1227 The list of frequencies is followed by a single CFListType octet for a total of 16 octets. The
1228 CFListType shall be equal to zero (0) to indicate that the CFList contains a list of
1229 frequencies.

1230

Size (bytes)	3	3	3	3	3	1
CFList	Freq Ch4	Freq Ch5	Freq Ch6	Freq Ch7	Freq Ch8	CFListType

1231 The actual channel frequency in Hz is 100 x frequency whereby values representing
1232 frequencies below 100 MHz are reserved for future use. This allows setting the frequency of
1233 a channel anywhere between 100 MHz to 1.67 GHz in 100 Hz steps. Unused channels have
1234 a frequency value of 0. The **CFList** is optional and its presence can be detected by the
1235 length of the Join-accept message. If present, the **CFList** replaces all the previous channels
1236 stored in the end-device apart from the three default channels. The newly defined channels
1237 are immediately enabled and usable by the end-device for communication.

1238 **2.8.5 KR920-923 LinkAdrReq command**

1239 The KR920-923 LoRaWAN only supports a maximum of 16 channels. When **ChMaskCntl**
1240 field is 0 the ChMask field individually enables/disables each of the 16 channels.

1241

ChMaskCntl	ChMask applies to
0	Channels 1 to 16
1	RFU
..	..
4	RFU
5	RFU
6	All channels ON The device should enable all currently defined channels independently of the ChMask field value.

ChMaskCntl	ChMask applies to
7	RFU

Table 61: ChMaskCntl value table

1242
1243

1244 If the ChMaskCntl field value is one of values meaning RFU, the end-device should reject
1245 the command and unset the “**Channel mask ACK**” bit in its response.

1246 2.8.6 KR920-923 Maximum payload size

1247 The maximum **MACPayload** size length (M) is given by the following table for the regulation
1248 of dwell time; less than 4 sec with LBT. It is derived from limitation of the PHY layer
1249 depending on the effective modulation rate used taking into account a possible repeater
1250 encapsulation layer. The maximum application payload length in the absence of the optional
1251 **FOpt** control field (N) is also given for information only. The value of N might be smaller if
1252 the **FOpt** field is not empty:

1253

DataRate	M	N
0	59	51
1	59	51
2	59	51
3	123	115
4	230	222
5	230	222
6:15	Not defined	

Table 62: KR920-923 maximum payload size

1254

1255 If the end-device will never operate with a repeater then the maximum application payload
1256 length in the absence of the optional **FOpt** control field should be:

1257

DataRate	M	N
0	59	51
1	59	51
2	59	51
3	123	115
4	250	242
5	250	242
6:15	Not defined	

Table 63 : KR920-923 maximum payload size (not repeater compatible)

1258

1259

1260 2.8.7 KR920-923 Receive windows

1261 The RX1 receive window uses the same channel than the preceding uplink. The data rate is
1262 a function of the uplink data rate and the RX1DROffset as given by the following table. The
1263 allowed values for RX1DROffset are in the [0:5] range. Values in the [6:7] range are
1264 reserved for future use.

1265

RX1DROffset Upstream data rate	0	1	2	3	4	5
	Downstream data rate in RX1 slot					
DR0	DR0	DR0	DR0	DR0	DR0	DR0
DR1	DR1	DR0	DR0	DR0	DR0	DR0
DR2	DR2	DR1	DR0	DR0	DR0	DR0
DR3	DR3	DR2	DR1	DR0	DR0	DR0

RX1DROffset Upstream data rate	0	1	2	3	4	5
	Downstream data rate in RX1 slot					
DR4	DR4	DR3	DR2	DR1	DR0	DR0
DR5	DR5	DR4	DR3	DR2	DR1	DR0

1266 [Table 64 : KR920-923 downlink RX1 data rate mapping](#)

1267 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
1268 921.90MHz / DR0 (SF12, 125 kHz).

1269 **2.8.8 KR920-923 Class B beacon and default downlink channel**

1270 The beacons SHALL be transmitted using the following settings

DR	3	Corresponds to SF9 spreading factor with 125 kHz BW
CR	1	Coding rate = 4/5
Signal polarity	Non-inverted	As opposed to normal downlink traffic which uses inverted signal polarity

1271 [Table 65 : KR920-923 beacon settings](#)

1272

1273 The beacon frame content is:

Size (bytes)	2	4	2	7	2
BCNPayload	RFU	Time	CRC	GwSpecific	CRC

1274 The beacon default broadcast frequency is 923.1MHz.

1275 The class B default downlink pingSlot frequency is 923.1MHz

1276

1277 **2.8.9 KR920-923 Default Settings**

1278 The following parameters are recommended values for the KR920-923Mhz band.

- 1279 RECEIVE_DELAY1 1 s
- 1280 RECEIVE_DELAY2 2 s (must be RECEIVE_DELAY1 + 1s)
- 1281 JOIN_ACCEPT_DELAY1 5 s
- 1282 JOIN_ACCEPT_DELAY2 6 s
- 1283 MAX_FCNT_GAP 16384
- 1284 ADR_ACK_LIMIT 64
- 1285 ADR_ACK_DELAY 32
- 1286 ACK_TIMEOUT 2 +/- 1 s (random delay between 1 and 3 seconds)

1287 If the actual parameter values implemented in the end-device are different from those default
1288 values (for example the end-device uses a longer RECEIVE_DELAY1 and
1289 RECEIVE_DELAY2 latency), those parameters must be communicated to the network
1290 server using an out-of-band channel during the end-device commissioning process. The
1291 network server may not accept parameters different from those default values.

1292

1293 2.9 India 865-867 MHz ISM Band

1294 2.9.1 INDIA 865-867 Preamble Format

1295 The following synchronization words should be used:

1296

Modulation	Sync word	Preamble length
LORA	0x34	8 symbols
GFSK	0xC194C1	5 bytes

1297

Table 66: India 865-867 synch words

1298 2.9.2 INDIA 865-867 ISM Band channel frequencies

1299 This section applies to the Indian sub-continent.

1300 The network channels can be freely attributed by the network operator. However the three
 1301 following default channels must be implemented in every India 865-867MHz end-device.
 1302 Those channels are the minimum set that all network gateways should always be listening
 1303 on.

1304

Modulation	Bandwidth [kHz]	Channel Frequency [MHz]	FSK Bitrate or LoRa DR / Bitrate	Nb Channels
LoRa	125	865.0625 865.4025 865.985	DR0 to DR5 / 0.3-5 kbps	3

1305

Table 67: INDIA 865-867 default channels

1306 End-devices should be capable of operating in the 865 to 867 MHz frequency band and
 1307 should feature a channel data structure to store the parameters of at least 16 channels. A
 1308 channel data structure corresponds to a frequency and a set of data rates usable on this
 1309 frequency.

1310 The first three channels correspond to 865.0625, 865.4025, and 865.985 MHz / DR0 to DR5
 1311 and must be implemented in every end-device. Those default channels cannot be modified
 1312 through the **NewChannelReq** command and guarantee a minimal common channel set
 1313 between end-devices and network gateways.

1314 The following table gives the list of frequencies that should be used by end-devices to
 1315 broadcast the Join-request message. The Join-request message transmit duty-cycle shall
 1316 follow the rules described in chapter “Retransmissions back-off” of the LoRaWAN
 1317 specification document.

1318

Modulation	Bandwidth [kHz]	Channel Frequency [MHz]	FSK Bitrate or LoRa DR / Bitrate	Nb Channels
LoRa	125	865.0625 865.4025 865.9850	DR0 – DR5 / 0.3-5 kbps	3

1319

Table 68: INDIA 865-867 Join-request Channel List

1320 2.9.3 INDIA 865-867 Data Rate and End-device Output Power Encoding

1321 There is no dwell time or duty-cycle limitation for the INDIA 865-867 PHY layer. The
 1322 **TxParamSetupReq** MAC command is not implemented by INDIA 865-867 devices.

1323 The following encoding is used for Data Rate (DR) and End-device Output Power (TXPower)
 1324 in the INDIA 865-867 band:

1325

DataRate	Configuration	Indicative physical bit rate [bit/s]
0	LoRa: SF12 / 125 kHz	250
1	LoRa: SF11 / 125 kHz	440
2	LoRa: SF10 / 125 kHz	980
3	LoRa: SF9 / 125 kHz	1760
4	LoRa: SF8 / 125 kHz	3125
5	LoRa: SF7 / 125 kHz	5470
6	RFU	RFU
7	FSK: 50 kbps	50000
8..14	RFU	
15	Defined in LoRaWAN	

Table 69: TX Data rate table

1326

1327

1328 The TXPower table indicates power levels relative to the Max EIRP level of the end-device,
 1329 as per the following table:

1330

TXPower	Configuration (EIRP)
0	Max EIRP
1	Max EIRP – 2dB
2	Max EIRP – 4dB
3	Max EIRP – 6dB
4	Max EIRP – 8dB
5	Max EIRP – 10dB
6	Max EIRP – 12dB
7	Max EIRP – 14dB
8	Max EIRP – 16dB
9	Max EIRP – 18dB
10	Max EIRP – 20dB
11..14	RFU
15	Defined in LoRAWAN

Table 70: TxPower table

1331

1332

1333 EIRP refers to the Equivalent Isotropically Radiated Power, which is the radiated output
 1334 power referenced to an isotropic antenna radiating power equally in all directions and whose
 1335 gain is expressed in dBi.

1336 By default MaxEIRP is considered to be 30dBm. If the end-device cannot achieve 30dBm
 1337 EIRP, the Max EIRP should be communicated to the network server using an out-of-band
 1338 channel during the end-device commissioning process.

1339

1340 **2.9.4 INDIA 865-867 Join-accept CFList**

1341 The India 865-867 ISM band LoRaWAN implements an optional **channel frequency list**
 1342 (CFList) of 16 octets in the Join-accept message.

1343 In this case the CFList is a list of five channel frequencies for the channels four to eight
 1344 whereby each frequency is encoded as a 24 bits unsigned integer (three octets). All these
 1345 channels are usable for DR0 to DR5 125kHz LoRa modulation.

1346 The list of frequencies is followed by a single CFListType octet for a total of 16 octets. The
 1347 CFListType shall be equal to zero (0) to indicate that the CFList contains a list of
 1348 frequencies.

1349

Size (bytes)	3	3	3	3	3	1
CFList	Freq Ch4	Freq Ch5	Freq Ch6	Freq Ch7	Freq Ch8	CFListType

1350 The actual channel frequency in Hz is 100 x frequency whereby values representing
 1351 frequencies below 100 MHz are reserved for future use. This allows setting the frequency of
 1352 a channel anywhere between 100 MHz to 1.67 GHz in 100 Hz steps. Unused channels have
 1353 a frequency value of 0. The **CFList** is optional and its presence can be detected by the
 1354 length of the Join-accept message. If present, the **CFList** replaces all the previous channels
 1355 stored in the end-device apart from the three default channels. The newly defined channels
 1356 are immediately enabled and usable by the end-device for communication.

1357 **2.9.5 INDIA 865-867 LinkAdrReq command**

1358 The INDIA 865-867 LoRaWAN only supports a maximum of 16 channels. When
 1359 **ChMaskCntl** field is 0 the ChMask field individually enables/disables each of the 16
 1360 channels.
 1361

ChMaskCntl	ChMask applies to
0	Channels 1 to 16
1	RFU
..	..
4	RFU
5	RFU
6	All channels ON The device should enable all currently defined channels independently of the ChMask field value.
7	RFU

Table 71: ChMaskCntl value table

1362

1363 If the ChMaskCntl field value is one of values meaning RFU, the end-device should reject
 1364 the command and unset the “**Channel mask ACK**” bit in its response.

1365 **2.9.6 INDIA 865-867 Maximum payload size**

1366 The maximum **MACPayload** size length (*M*) is given by the following table. It is derived from
 1367 limitation of the PHY layer depending on the effective modulation rate used taking into
 1368 account a possible repeater encapsulation layer. The maximum application payload length in
 1369 the absence of the optional **FOpt** control field (*N*) is also given for information only. The
 1370 value of N might be smaller if the **FOpt** field is not empty:
 1371

DataRate	<i>M</i>	<i>N</i>
0	59	51
1	59	51
2	59	51
3	123	115

4	230	222
5	230	222
6	230	222
7	230	222
8:15	Not defined	

1372

Table 72: INDIA 865-867 maximum payload size

1373 If the end-device will never operate with a repeater then the maximum application payload
 1374 length in the absence of the optional **FOpt** control field should be:
 1375

DataRate	M	N
0	59	51
1	59	51
2	59	51
3	123	115
4	250	242
5	250	242
6	250	242
7	250	242
8:15	Not defined	

1376

Table 73 : INDIA 865-867 maximum payload size (not repeater compatible)

1377 2.9.7 INDIA 865-867 Receive windows

1378 The RX1 receive window uses the same channel than the preceding uplink. The data rate is
 1379 a function of the uplink data rate and the RX1DROffset as given by the following table. The
 1380 allowed values for RX1DROffset are in the [0:7] range. Values in the [6:7] range allow
 1381 setting the Downstream RX1 data rate higher than Upstream data rate.

1382 The allowed values for RX1DROffset are in the [0:7] range, encoded as per the below table:

RX1DROffset (Coded value)	0	1	2	3	4	5	6	7
Effective_RX1DROffset	0	1	2	3	4	5	-1	-2

1383 Downstream data rate in RX1 slot = $MIN(5, MAX(0, \text{Upstream data rate} -$
 1384 $\text{Effective_RX1DROffset}))$

1385 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
 1386 866.550 MHz / DR2 (SF10, 125 kHz).

1387 2.9.8 INDIA 865-867 Class B beacon and default downlink channel

1388 The beacons are transmitted using the following settings

DR	4	Corresponds to SF8 spreading factor with 125 kHz BW
CR	1	Coding rate = 4/5
Signal polarity	Non-inverted	As opposed to normal downlink traffic which uses inverted signal polarity

1389

1390 The beacon frame content is:

Size (bytes)	1	4	2	7	3	2
BCNPayload	RFU	Time	CRC	GwSpecific	RFU	CRC

1391 The beacon default broadcast frequency is 866.550MHz.

1392 The class B default downlink pingSlot frequency is 866.550MHz

1393

1394 **2.9.9 INDIA 865-867 Default Settings**

1395 The following parameters are recommended values for the INDIA 865-867MHz band.

1396

1397 RECEIVE_DELAY1 1 s

1398 RECEIVE_DELAY2 2 s (must be RECEIVE_DELAY1 + 1s)

1399 JOIN_ACCEPT_DELAY1 5 s

1400 JOIN_ACCEPT_DELAY2 6 s

1401 MAX_FCNT_GAP 16384

1402 ADR_ACK_LIMIT 64

1403 ADR_ACK_DELAY 32

1404 ACK_TIMEOUT 2 +/- 1 s (random delay between 1 and 3 seconds)

1405 If the actual parameter values implemented in the end-device are different from those default
 1406 values (for example the end-device uses a longer RECEIVE_DELAY1 and
 1407 RECEIVE_DELAY2 latency), those parameters must be communicated to the network
 1408 server using an out-of-band channel during the end-device commissioning process. The
 1409 network server may not accept parameters different from those default values.

1410

1411

1412 3 Revisions**1413 3.1 Revision A**

- 1414 • Initial 1.1 revision, the regional parameters were extracted from the LoRaWANV1.0.2
- 1415 revision B
- 1416 • Modified meaning of ChMaskCntl=5 for the US900 region and AU900 (TC11
- 1417 CR1274)
- 1418 • DR=15 and TXPower=15 are now reserved for all regions , meaning is defined in
- 1419 LoRaWAN1.1
- 1420 • Introduced CFlistType field in the Join-accept message

1421 **4 Bibliography**

1422 **4.1 References**

1423

1424 [LORAWAN] LoRaWAN Specification, V1.1, the LoRa Alliance, October 2017.

1425