

1
2 **LoRaWAN™ 1.0.2 Regional Parameters**

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LoRaWAN™ 1.0.2 Regional Parameters

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This document is a companion document to the LoRaWAN 1.0.2 protocol specification

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245 1 Introduction

246

247 This document describes the LoRaWAN™ regional parameters for different regulatory
248 regions worldwide. This document is a companion document to the LoRaWAN 1.0.2 protocol
249 specification [LORAWAN]. Separating the regional parameters from the protocol
250 specification allows addition of new regions to the former without impacting the latter
251 document.

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255

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 JoinReq message. The JoinReq 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

289

Table 3: EU863-870 JoinReq Channel List

290 2.1.3 EU863-870 Data Rate and End-device Output Power encoding

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

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

295

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..15	RFU	

296

Table 4: TX Data rate table

297

298 EIRP¹ refers to the Equivalent Isotropically Radiated Power, which is the radiated output
299 power referenced to an isotropic antenna radiating power equally in all directions and whose
300 gain is expressed in dBi.

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

301

Table 5: TX power table

302

303

304

¹ ERP = EIRP – 2.15dB; it is referenced to a half-wave dipole antenna whose gain is expressed in dBd

305 By default MaxEIRP is considered to be +16dBm. If the end-device cannot achieve 16dBm
 306 EIRP, the Max EIRP should be communicated to the network server using an out-of-band
 307 channel during the end-device commissioning process.
 308

309 2.1.4 EU863-870 JoinAccept CFList

310

311 The EU 863-870 ISM band LoRaWAN implements an optional **channel frequency list**
 312 (CFList) of 16 octets in the JoinAccept message.

313 In this case the CFList is a list of five channel frequencies for the channels four to eight
 314 whereby each frequency is encoded as a 24 bits unsigned integer (three octets). All these
 315 channels are usable for DR0 to DR5 125kHz LoRa modulation. The list of frequencies is
 316 followed by a single RFU octet for a total of 16 octets.

317

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

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

325 2.1.5 EU863-870 LinkAdrReq command

326 The EU863-870 LoRaWAN only supports a maximum of 16 channels. When **ChMaskCntl**
 327 field is 0 the ChMask field individually enables/disables each of the 16 channels.
 328

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

329

Table 6: ChMaskCntl value table

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

332 2.1.6 EU863-870 Maximum payload size

333 The maximum **MACPayload** size length (*M*) is given by the following table. It is derived from
 334 limitation of the PHY layer depending on the effective modulation rate used taking into
 335 account a possible repeater encapsulation layer. The maximum application payload length in

336 the absence of the optional **FOpt** control field (*M*) is also given for information only. The
 337 value of *N* might be smaller if the **FOpt** field is not empty:
 338

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	

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

340 If the end-device will never operate with a repeater then the maximum application payload
 341 length in the absence of the optional **FOpt** control field should be:
 342

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	

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

344 2.1.7 EU863-870 Receive windows

345 The RX1 receive window uses the same channel than the preceding uplink. The data rate is
 346 a function of the uplink data rate and the RX1DROffset as given by the following table. The
 347 allowed values for RX1DROffset are in the [0:5] range. Values in the [6:7] range are
 348 reserved for future use.
 349

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

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

351
 352 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
 353 869.525 MHz / DR0 (SF12, 125 kHz)
 354

355 **2.1.8 EU863-870 Class B beacon and default downlink channel**

356 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

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

358

359 The beacon frame content is:

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

360 The beacon default broadcast frequency is 869.525MHz.

361 The class B default downlink pingSlot frequency is 869.525MHz

362

 363 **2.1.9 EU863-870 Default Settings**

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

365	RECEIVE_DELAY1	1 s
366	RECEIVE_DELAY2	2 s (must be RECEIVE_DELAY1 + 1s)
367	JOIN_ACCEPT_DELAY1	5 s
368	JOIN_ACCEPT_DELAY2	6 s
369	MAX_FCNT_GAP	16384
370	ADR_ACK_LIMIT	64
371	ADR_ACK_DELAY	32
372	ACK_TIMEOUT	2 +/- 1 s (random delay between 1 and 3 seconds)

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

378

379 **2.2 US 902-928MHz ISM Band**

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

382 **2.2.1 US902-928 Preamble Format**

383 The following synchronization words should be used:
 384

Modulation	Sync word	Preamble length
LORA	0x34	8 symbols

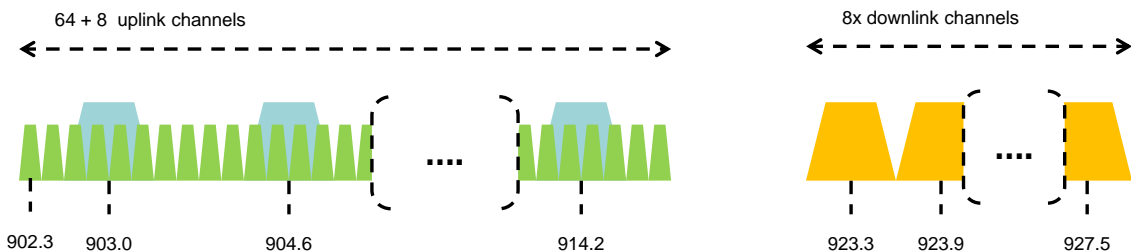
385

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

387 **2.2.2 US902-928 Channel Frequencies**

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

- 389 • Upstream – 64 channels numbered 0 to 63 utilizing LoRa 125 kHz BW varying from
 390 DR0 to DR3, using coding rate 4/5, starting at 902.3 MHz and incrementing linearly
 391 by 200 kHz to 914.9 MHz
- 392 • Upstream – 8 channels numbered 64 to 71 utilizing LoRa 500 kHz BW at DR4
 393 starting at 903.0 MHz and incrementing linearly by 1.6 MHz to 914.2 MHz
- 394 • Downstream – 8 channels numbered 0 to 7 utilizing LoRa 500 kHz BW at DR8 to
 395 DR13, starting at 923.3 MHz and incrementing linearly by 600 kHz to 927.5 MHz
 396



397
 398

Figure 1: US902-928 channel frequencies

399 915 MHz ISM band end-devices are required to operate in compliance with the relevant
 400 regulatory specifications, to include.

- 401 • Frequency-Hopping, Spread-Spectrum (FHSS) mode, which requires the device
 402 transmit at a measured conducted power level no greater than +30 dBm, for a period
 403 of no more than 400 msec and over at least 50 channels, each of which occupy no
 404 greater than 250 kHz of bandwidth.
- 405 • Digital Transmission System (DTS) mode, which requires that the device use
 406 channels greater than or equal to 500 kHz and comply to a conducted Power
 407 Spectral Density measurement of no more than +8 dBm per 3kHz of spectrum. In
 408 practice, this limits the conducted output power of an end-device to +26 dBm.
- 409 • Hybrid mode, which requires that the device transmit over multiple channels (this
 410 may be less than the 50 channels required for FHSS mode, but is recommended to
 411 be at least 4) while complying with the Power Spectral Density requirements of DTS
 412 mode and the 400 msec dwell time of FHSS mode. In practice this limits the
 413 measured conducted power of the end-device to 21 dBm.
- 414 • Devices which use an antenna system with a directional gain greater than +6 dBi, but
 415 reduce the specified conducted output power by the amount in dB of directional gain
 416 over +6 dBi.

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

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

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

431 2.2.3 US902-928 Data Rate and End-device Output Power encoding

432 FCC regulation imposes a maximum dwell time of 400ms on uplinks. The
 433 **TxParamSetupReq** is not implemented by US902-928 devices.

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

436

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
14:15	RFU	

Table 11: TX Data rate table

437

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

438

439

440

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

441

Table 12: TX power table

 442 **2.2.4 US902-928 JoinAccept CFList**

 443 The US902-928 LoRaWAN does not support the use of the optional **CFList** appended to the
 444 JoinAccept message. If the **CFList** is not empty it is ignored by the end-device.

 445 **2.2.5 US902-928 LinkAdrReq command**

 446 For the US902-928 version the **ChMaskCntl** field of the **LinkADRReq** command has the
 447 following meaning:
 448

ChMaskCntl	ChMask applies to
0	Channels 0 to 15
1	Channels 16 to 31
..	..
4	Channels 64 to 71
5	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

449

Table 13: ChMaskCntl value table

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

454

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

 459 **Note:** A common network server action may be to reconfigure a device
 460 through multiple LinkAdrReq commands in a contiguous block of MAC
 461 Commands. For example to reconfigure a device from 64 channel
 462 operation to the first 8 channels could contain two LinkAdrReq, the first
 463 (ChMaskCntl = 7) to disable all 125kHz channels and the second
 464 (ChMaskCntl = 0) to enable a bank of 8 125kHz channels.
 465

 466 **2.2.6 US902-928 Maximum payload size**

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

472

473

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	

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

474

475

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

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

480

DataRate	<i>M</i>	<i>N</i>
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	

Table 15 : US902-928 maximum payload size (not repeater compatible)

481

482 2.2.7 US902-928 Receive windows

483 • The RX1 receive channel is a function of the upstream channel used to initiate the
484 data exchange. The RX1 receive channel can be determined as follows.

485 ○ RX1 Channel Number = Transmit Channel Number modulo 8

486 • The RX1 window data rate depends on the transmit data rate (see Table 16 below).

487 • The RX2 (second receive window) settings uses a fixed data rate and frequency.

488 Default parameters are 923.3MHz / DR8

489

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

490 **Table 16: US902-928 downlink RX1 data rate mapping**

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

 493 **2.2.8 US902-928 Class B beacon**

494 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

 495 **Table 17: US902-928 beacon settings**

496 The downstream channel used for a given beacon is:

497
$$\text{Channel} = \left[\text{floor} \left(\frac{\text{beacon_time}}{\text{beacon_period}} \right) \right] \text{ modulo } 8$$

- 498
- 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 *floor(x)* designates rounding to the integer immediately inferior or equal to x

 503 **Example:** the first beacon will be transmitted on 923.3Mhz , the second
 504 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

 507
 508
 509 The beacon frame content is:

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

 510
 511 **2.2.9 US902-928 Default Settings**

 512 The following parameters are recommended values for the US902-928 band.
 513 RECEIVE_DELAY1 1 s
 514 RECEIVE_DELAY2 2 s (must be RECEIVE_DELAY1 + 1s)
 515 JOIN_ACCEPT_DELAY1 5 s
 516 JOIN_ACCEPT_DELAY2 6 s
 517 MAX_FCNT_GAP 16384

518	ADR_ACK_LIMIT	64
519	ADR_ACK_DELAY	32
520	ACK_TIMEOUT	2 +/- 1 s (random delay between 1 and 3 seconds)
521	If the actual parameter values implemented in the end-device are different from those default	
522	values (for example the end-device uses a longer RECEIVE_DELAY1 & 2 latency), those	
523	parameters must be communicated to the network server using an out-of-band channel	
524	during the end-device commissioning process. The network server may not accept	
525	parameters different from those default values.	
526		

527 **2.3 China 779-787MHz ISM Band**

528 **2.3.1 CN779-787 Preamble Format**

529 The following synchronization words should be used :

530

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

531

Table 18: CN779-787 synch words

532 **2.3.2 CN779-787 ISM Band channel frequencies**

533

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

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

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

538

- Minimum frequency : 779.5MHz

539

- Maximum frequency : 786.5 MHz

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

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

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

553

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			

554

Table 19: CN780 JoinReq Channel List

555

556 2.3.3 CN779-787 Data Rate and End-device Output Power encoding

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

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

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

Table 20: Data rate and TX power table

561

562

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

566

567 By default MaxEIRP is considered to be +12.15dBm. If the end-device cannot achieve
568 12.15dBm EIRP, the Max EIRP should be communicated to the network server using an out-
569 of-band channel during the end-device commissioning process.

570

571 2.3.4 CN779-787 JoinAccept CFList

572 The CN780 ISM band LoRaWAN implements an optional **channel frequency list** (CFList) of
573 16 octets in the JoinAccept message.

574 In this case the CFList is a list of five channel frequencies for the channels four to eight
575 whereby each frequency is encoded as a 24 bits unsigned integer (three octets). All these
576 channels are usable for DR0 to DR5 125kHz LoRa modulation. The list of frequencies is
577 followed by a single RFU octet for a total of 16 octets.

578

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

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

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

587 **2.3.5 CN779-787 LinkAdrReq command**

588

 589 The CN780 LoRaWAN only supports a maximum of 16 channels. When **ChMaskCntl** field is
 590 0 the ChMask field individually enables/disables each of the 16 channels.

591

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

592

593

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

 596 **2.3.6 CN779-787 Maximum payload size**

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

602

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

603

604

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

607

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

608

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

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

609 **2.3.7 CN779-787 Receive windows**

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

614

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

615

Table 24: CN780 downlink RX1 data rate mapping

616 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
 617 786 MHz / DR0.

618 **2.3.8 CN779-787 Class B beacon and default downlink channel**

619 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

620

Table 25: CN780 beacon settings

621 The beacon frame content is:

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

622 The beacon default broadcast frequency is 785MHz.

623 The class B default downlink pingSlot frequency is 785MHz

624

625 **2.3.9 CN779-787 Default Settings**

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

627	RECEIVE_DELAY1	1 s
628	RECEIVE_DELAY2	2 s (must be RECEIVE_DELAY1 + 1s)
629	JOIN_ACCEPT_DELAY1	5 s
630	JOIN_ACCEPT_DELAY2	6 s
631	MAX_FCNT_GAP	16384
632	ADR_ACK_LIMIT	64

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

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

640 2.4 EU 433MHz ISM Band

641 2.4.1 EU433 Preamble Format

642 The following synchronization words should be used :

643

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

644

Table 26: EU433 synch words

645 2.4.2 EU433 ISM Band channel frequencies

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

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

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

- 650 • Minimum frequency : 433.175 MHz
- 651 • Maximum frequency : 434.665 MHz

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

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

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

665

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%

666

Table 27: EU433 JoinReq Channel List

667

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.

668 2.4.3 EU433 Data Rate and End-device Output Power encoding

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

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

673

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

Table 28: Data rate and TX power table

674

675

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

679

680 By default MaxEIRP is considered to be +12.15dBm. If the end-device cannot achieve
681 12.15dBm EIRP, the Max EIRP should be communicated to the network server using an out-
682 of-band channel during the end-device commissioning process.

683

684

685 2.4.4 EU433 JoinAccept CFList

686

687 The EU433 ISM band LoRaWAN implements an optional **channel frequency list** (CFList) of
688 16 octets in the JoinAccept message.

689 In this case the CFList is a list of five channel frequencies for the channels four to eight
690 whereby each frequency is encoded as a 24 bits unsigned integer (three octets). All these
691 channels are usable for DR0 to DR5 125 kHz LoRa modulation. The list of frequencies is
692 followed by a single RFU octet for a total of 16 octets.

693

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

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

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

702 2.4.5 EU433 LinkAdrReq command

703 The EU433 LoRaWAN only supports a maximum of 16 channels. When **ChMaskCntl** field is
 704 0 the ChMask field individually enables/disables each of the 16 channels.
 705

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

706 **Table 29: ChMaskCntl value table**

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

709 2.4.6 EU433 Maximum payload size

710 The maximum **MACPayload** size length (M) is given by the following table. It is derived from
 711 limitation of the PHY layer depending on the effective modulation rate used taking into
 712 account a possible repeater encapsulation layer. The maximum application payload length in
 713 the absence of the optional **FOpt** control field (N) is also given for information only. The
 714 value of N might be smaller if the **FOpt** field is not empty:
 715

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	

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

717
 718 If the end-device will never operate with a repeater then the maximum application payload
 719 length in the absence of the optional **FOpt** control field should be:
 720

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)

 721
722

723 2.4.7 EU433 Receive windows

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

728

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

729

730 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
731 434.665MHz / DR0 (SF12, 125kHz).

732

733 2.4.8 EU433 Class B beacon and default downlink channel

734 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

735

736 The beacon frame content is:

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

737 The beacon default broadcast frequency is 434.665MHz.

738 The class B default downlink pingSlot frequency is 434.665MHz

739

740 2.4.9 EU433 Default Settings

741 The following parameters are recommended values for the EU433band.

742 RECEIVE_DELAY1 1 s
743 RECEIVE_DELAY2 2 s (must be RECEIVE_DELAY1 + 1s)
744 JOIN_ACCEPT_DELAY1 5 s

745 JOIN_ACCEPT_DELAY2 6 s
 746 MAX_FCNT_GAP 16384
 747 ADR_ACK_LIMIT 64
 748 ADR_ACK_DELAY 32
 749 ACK_TIMEOUT 2 +/- 1 s (random delay between 1 and 3 seconds)

750
 751 If the actual parameter values implemented in the end-device are different from those default
 752 values (for example the end-device uses a longer RECEIVE_DELAY1 & 2 latency) , those
 753 parameters must be communicated to the network server using an out-of-band channel
 754 during the end-device commissioning process. The network server may not accept
 755 parameters different from those default values.
 756

757 2.5 Australia 915-928MHz ISM Band

758 2.5.1 AU915-928 Preamble Format

759 The following synchronization words should be used:
 760

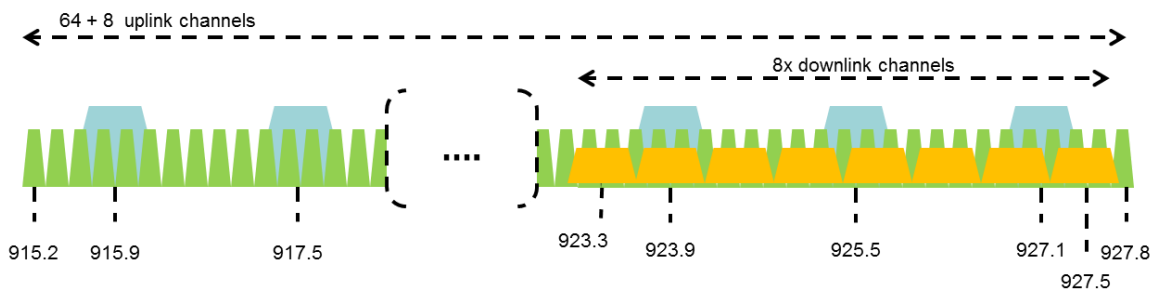
Modulation	Sync word	Preamble length
LORA	0x34	8 symbols

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

762 2.5.2 AU915-928 Channel Frequencies

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

- 764 • Upstream – 64 channels numbered 0 to 63 utilizing LoRa 125 kHz BW varying from
 765 DR0 to DR5, using coding rate 4/5, starting at 915.2 MHz and incrementing linearly
 766 by 200 kHz to 927.8 MHz
- 767 • Upstream – 8 channels numbered 64 to 71 utilizing LoRa 500 kHz BW at DR6
 768 starting at 915.9 MHz and incrementing linearly by 1.6 MHz to 927.1 MHz
- 769 • Downstream – 8 channels numbered 0 to 7 utilizing LoRa 500 kHz BW at DR8 to
 770 DR13) starting at 923.3 MHz and incrementing linearly by 600 kHz to 927.5 MHz
 771



772 **Figure 2: AU915-928 channel frequencies**
 773

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

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

779 If using the over-the-air activation procedure, the end-device should broadcast the JoinReq
 780 message alternatively on a random 125 kHz channel amongst the 64 channels defined using

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

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

784 2.5.3 AU915-928 Data Rate and End-point Output Power encoding

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

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

788

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
14:15	RFU	

Table 34: AU915-928 Data rate table

789

790

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

793

TXPower	Configuration (EIRP)
0	MaxEIRP
1:10	MaxEIRP – 2*TXPower
11:15	RFU

Table 35 : AU915-928 TX power table

794

795

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

799

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

803

804 2.5.4 AU915-928 JoinAccept CFList

805 The AU915-928 LoRaWAN does not support the use of the optional **CFList** appended to the
806 JoinAccept message. If the **CFList** is not empty it is ignored by the end-device.

807 **2.5.5 AU915-928 LinkAdrReq command**

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

810

811

ChMaskCntl	ChMask applies to
0	Channels 0 to 15
1	Channels 16 to 31
..	..
4	Channels 64 to 71
5	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

812

Table 36: ChMaskCntl value table

 813 If **ChMaskCntl** = 6 (resp 7) then 125 kHz channels are enabled (resp disabled).
 814 Simultaneously the channels 64 to 71 are set according to the **ChMask** bit mask.

 815 **2.5.6 AU915-928 Maximum payload size**

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

821

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	

822

Table 37: AU915-928 maximum payload size

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

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

827

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	

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

 829 **2.5.7 AU915-928 Receive windows**

- 830 • The RX1 receive channel is a function of the upstream channel used to initiate the
- 831 data exchange. The RX1 receive channel can be determined as follows.
- 832 ○ RX1 Channel Number = Transmit Channel Number modulo 8
- 833 • The RX1 window data rate depends on the transmit data rate (see Table 16 below).
- 834 • The RX2 (second receive window) settings uses a fixed data rate and frequency.
- 835 Default parameters are 923.3Mhz / DR8
- 836

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
DR5	DR13	DR12	DR11	DR10	DR9	DR8
DR6	DR13	DR13	DR12	DR11	DR10	DR9

 837 **Table 39 : AU915-928 downlink RX1 data rate mapping**

838

839 The allowed values for RX1DROffset are in the [0:5] range. Values in the range [6:7] are

840 reserved for future use.

841

 842 **2.5.8 AU915-928 Class B beacon**

843 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
--	--	---------------------------

844

Table 40 : AU915-928 beacon settings

845 The downstream channel used for a given beacon is:

846

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

847

- whereby beacon_time is the integer value of the 4 bytes “Time” field of the beacon frame

848

849

- whereby beacon_period is the periodicity of beacons , 128 seconds

850

- whereby $\text{floor}(x)$ designates rounding to the integer immediately inferior or equal to x

851

852

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

853

854

855

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

856

857

858

The beacon frame content is:

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

859

860 2.5.9 AU915-928 Default Settings

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

862 RECEIVE_DELAY1 1 s

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

864 JOIN_ACCEPT_DELAY1 5 s

865 JOIN_ACCEPT_DELAY2 6 s

866 MAX_FCNT_GAP 16384

867 ADR_ACK_LIMIT 64

868 ADR_ACK_DELAY 32

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

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

875

876 **2.6 CN 470-510MHz Band**

877 **2.6.1 CN470-510 Preamble Format**

878 The following synchronization words should be used:
879

Modulation	Sync word	Preamble length
LORA	0x34	8 symbols

880 **2.6.2 CN470-510 Channel Frequencies**

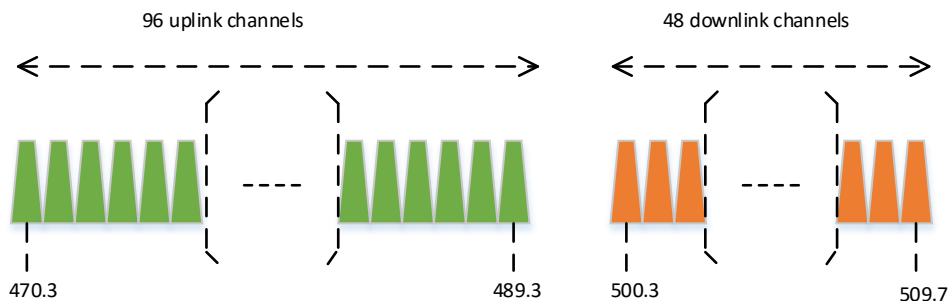
881
882 In China, this band is defined by SRRC to be used for civil metering applications.

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

- 884 • Upstream – 96 channels numbered 0 to 95 utilizing LoRa 125 kHz BW varying from
885 DR0 to DR5, using coding rate 4/5, starting at 470.3 MHz and incrementing linearly
886 by 200 kHz to 489.3 MHz.
887

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

- 891
892 • Downstream – 48 channels numbered 0 to 47 utilizing LoRa 125 kHz BW varying
893 from DR0 to DR5, using coding rate 4/5, starting at 500.3 MHz and incrementing
894 linearly by 200 kHz to 509.7 MHz
895



896
897 **Figure 3: CN470-510 channel frequencies**

898
899 The LoRaWAN can be used in the Chinese 470-510MHz band as long as

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

902
903
904
905 CN470-510 end-devices should be capable of operating in the 470 to 510 MHz frequency
906 band and should feature a channel data structure to store the parameters of 96 uplink
907 channels. A channel data structure corresponds to a frequency and a set of data rates
908 usable on this frequency.

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

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

913

914 2.6.3 CN470-510 Data Rate and End-point Output Power encoding

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

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

919

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

Table 41: CN470 Data rate and TX power table

920

921

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

925

926 By default MaxEIRP is considered to be +19.15dBm. If the end-device cannot achieve
927 19.15dBm EIRP, the Max EIRP should be communicated to the network server using an out-
928 of-band channel during the end-device commissioning process.

929

930 2.6.4 CN470-510 JoinResp CFList

931 The CN470-510 LoRaWAN does not support the use of the optional **CFList** appended to the
932 JoinAccept message. If the **CFList** is not empty it is ignored by the end-device.

933 2.6.5 CN470-510 LinkAdrReq command

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

936

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

ChMaskCntl	ChMask applies to
	The device should enable all currently defined channels independently of the ChMask field value.
7	RFU

937

Table 42: CN470 ChMaskCntl value table

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

940 2.6.6 CN470-510 Maximum payload size

941 The maximum **MACPayload** size length (M) is given by the following table. It is derived from
 942 the maximum allowed transmission time at the PHY layer taking into account a possible
 943 repeater encapsulation. The maximum application payload length in the absence of the
 944 optional **FOpt** MAC control field (N) is also given for information only. The value of N might
 945 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	

946

Table 43: CN470-510 maximum payload size

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

949

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	

950

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

951

952 2.6.7 CN470-510 Receive windows

- 953 • The RX1 receive channel is a function of the upstream channel used to initiate the
 954 data exchange. The RX1 receive channel can be determined as follows.
 - 955 ○ RX1 Channel Number = Uplink Channel Number modulo 48, for example,
 956 when transmitting channel number is 49, the rx1 channel number is 1.
- 957 • The RX1 window data rate depends on the transmit data rate (see Table below).
- 958 • The RX2 (second receive window) settings uses a fixed data rate and frequency.
 959 Default parameters are 505.3 MHz / DR0

960

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

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

Table 45: CN470-510 downlink RX1 data rate mapping

961
962

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

965 2.6.8 CN470-510 Class B beacon

966 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

967
968

969 The downstream channel used for a given beacon is:

$$970 \text{ BeaconChannel} = \left[\text{floor} \left(\frac{\text{beacon_time}}{\text{beacon_period}} \right) \right] \text{ modulo } 8$$

- 971 • whereby beacon_time is the integer value of the 4 bytes “Time” field of the beacon
- 972 frame
- 973 • whereby beacon_period is the periodicity of beacons , 128 seconds
- 974 • whereby $\text{floor}(x)$ designates rounding to the integer immediately inferior or equal to x
- 975

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

976
977
978
979

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

980
981
982

The beacon frame content is:

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

983

984 2.6.9 CN470-510 Default Settings

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

986	RECEIVE_DELAY1	1 s
987	RECEIVE_DELAY2	2 s (must be RECEIVE_DELAY1 + 1s)
988	JOIN_ACCEPT_DELAY1	5 s
989	JOIN_ACCEPT_DELAY2	6 s
990	MAX_FCNT_GAP	16384
991	ADR_ACK_LIMIT	64
992	ADR_ACK_DELAY	32
993	ACK_TIMEOUT	2 +/- 1 s (random delay between 1 and 3 seconds)

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

999 2.7 AS923MHz ISM Band

1000 2.7.1 AS923 Preamble Format

1001 The following synchronization words should be used:

1002

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

1003

Table 47: AS923 synch words

1004 2.7.2 AS923 ISM Band channel frequencies

1005 This section applies to regions where the frequencies [923...923.5MHz] are comprised in the
1006 ISM band, which is the case for the following countries:

- 1007 ❖ Brunei [923-925 MHz]
- 1008 ❖ Cambodia [923-925 MHz]
- 1009 ❖ Indonesia [923-925 MHz]
- 1010 ❖ Japan [920-928 MHz]
- 1011 ❖ Laos [923-925 MHz]
- 1012 ❖ New Zealand [915-928 MHz]
- 1013 ❖ Singapore [920-925 MHz]
- 1014 ❖ Taiwan [922-928 MHz]
- 1015 ❖ Thailand [920-925 MHz]
- 1016 ❖ Vietnam [920-925 MHz]

1017 The network channels can be freely attributed by the network operator. However the two
1018 following default channels must be implemented in every AS923MHz end-device. Those
1019 channels are the minimum set that all network gateways should always be listening on.

1020

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%

1021

Table 48: AS923 default channels

1022 Those default channels must be implemented in every end-device and cannot be modified
1023 through the **NewChannelReq** command and guarantee a minimal common channel set
1024 between end-devices and network gateways.

1025 AS923MHz ISM band end-devices should use the following default parameters

- 1026 • Default EIRP: 16 dBm

1027 AS923MHz end-devices should feature a channel data structure to store the parameters of
1028 at least 16 channels. A channel data structure corresponds to a frequency and a set of data
1029 rates usable on this frequency.

1030 The following table gives the list of frequencies that should be used by end-devices to
 1031 broadcast the JoinReq 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%

Table 49: AS923 JoinReq Channel List

1032
 1033 The default JoinReq Data Rate is DR2 (SF10/125KHz), this setting ensures that end-devices
 1034 are compatible with the 400ms dwell time limitation until the actual dwell time limit is notified
 1035 to the end-device by the network server via the MAC command “TxParamSetupReq”.
 1036 The JoinReq message transmit duty-cycle shall follow the rules described in chapter
 1037 “Retransmissions back-off” of the LoRaWAN specification document.
 1038

1039 **2.7.3 AS923 Data Rate and End-point Output Power encoding**

1040 The “TxParamSetupReq/Ans” MAC command MUST be implemented by the AS923
 1041 devices.

1042 The following encoding is used for Data Rate (DR) in the AS923 band:

1043

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..15	RFU	

Table 50: Data rate table

1044

1045

1046 The TXPower table indicates power levels relative to the Max EIRP level of the end-device,
 1047 as per the following table:

1048

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

Table 51: TxPower table

1049

1050

1051 EIRP refers to the Equivalent Isotropically Radiated Power, which is the radiated output
 1052 power referenced to an isotropic antenna radiating power equally in all directions and whose
 1053 gain is expressed in dBi.

1054 By default Max EIRP shall be 16dBm. The Max EIRP can be modified by the network server
 1055 through the **TxParamSetupReq** MAC command and should be used by both the end-
 1056 device and the network server once **TxParamSetupReq** is acknowledged by the device via
 1057 **TxParamSetupAns**,

1058

1059 **2.7.4 AS923 JoinAccept CFList**

1060 The AS923 LoRaWAN implements an optional channel frequency list (CFList) of 16 octets in
 1061 the JoinAccept message.

1062 In this case the CFList is a list of five channel frequencies for the channels three to seven
 1063 whereby each frequency is encoded as a 24 bits unsigned integer (three octets). All these
 1064 channels are usable for DR0 to DR5 125 KHz LoRa modulation.

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

1065 The actual channel frequency in Hz is 100 x frequency whereby values representing
 1066 frequencies below 100 MHz are reserved for future use. This allows setting the frequency of
 1067 a channel anywhere between 915 and 928MHz in 100 Hz steps. Unused channels have a
 1068 frequency value of 0. The CFList is optional and its presence can be detected by the length
 1069 of the join-accept message. If present, the CFList replaces all the previous channels stored
 1070 in the end-device apart from the two default channels. The newly defined channels are
 1071 immediately enabled and usable by the end-device for communication.

1072 **2.7.5 AS923 LinkAdrReq command**

1073 The AS923 LoRaWAN only supports a maximum of 16 channels. When **ChMaskCntl** field is
 1074 0 the ChMask field individually enables/disables each of the 16 channels.

1075

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 52: ChMaskCntl value table

1076

1077 If the ChMask field value is one of values meaning RFU, the end-device should reject the
 1078 command and unset the “**Channel mask ACK**” bit in its response.

1079

1080 **2.7.6 AS923 Maximum payload size**

1081 The maximum **MACPayload** size length (M) is given by the following table for both dwell
 1082 time configurations: No Limit and 400ms. It is derived from the PHY layer limitation
 1083 depending on the effective modulation rate used taking into account a possible repeater
 1084 encapsulation layer.

1085

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	

1086

Table 53: AS923 maximum payload size

1087 If the end-device will never operate with a repeater then the maximum MAC payload length
 1088 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	

1089

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

1090 The maximum application payload length in the absence of the optional **FOpt** control field
 1091 (M) is eight bytes lower than the MACPayload value in the above table. The value of N might
 1092 be smaller if the **FOpt** field is not empty.

1093

1094 **2.7.7 AS923 Receive windows**

1095 The RX1 receive window uses the same channel than the preceding uplink. The data rate is
 1096 a function of the uplink data rate and the RX1DROffset as following:

1097 Downstream data rate in RX1 slot = $MIN(5, MAX(\text{MinDR}, \text{Upstream data rate} -$
 1098 $\text{Effective_RX1DROffset}))$

1099 MinDR depends on the DownlinkDwellTime bit sent to the device in the **TxParamSetupReq**
 1100 command:

- 1101 • Case DownlinkDwellTime = 0 (No limit): MinDR = 0
- 1102 • Case DownlinkDwellTime = 1 (400ms): MinDR = 2

1103 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

1104 Values in the [6:7] range allow setting the Downstream RX1 data rate higher than Upstream
1105 data rate.

1106 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
1107 923.2 MHz / DR2 (SF10/125KHz).

1108

1109 **2.7.8 AS923 Class B beacon and default downlink channel**

1110 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

1111 [Table 55 : AS923 beacon settings](#)

1112 The beacon frame content is:

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

1113 The beacon default broadcast frequency is 923.4MHz.

1114 The class B default downlink pingSlot frequency is 923.4MHz

1115

1116 **2.7.9 AS923 Default Settings**

1117 The following parameters are recommended values for the AS923MHz band.

1118	RECEIVE_DELAY1	1 s
1119	RECEIVE_DELAY2	2 s (must be RECEIVE_DELAY1 + 1s)
1120	JOIN_ACCEPT_DELAY1	5 s
1121	JOIN_ACCEPT_DELAY2	6 s
1122	MAX_FCNT_GAP	16384
1123	ADR_ACK_LIMIT	64
1124	ADR_ACK_DELAY	32
1125	ACK_TIMEOUT	2 +/- 1 s (random delay between 1 and 3 seconds)

1126 If the actual parameter values implemented in the end-device are different from those default
1127 values (for example the end-device uses a longer RECEIVE_DELAY1 and
1128 RECEIVE_DELAY2 latency), those parameters must be communicated to the network
1129 server using an out-of-band channel during the end-device commissioning process. The
1130 network server may not accept parameters different from those default values.

1131 **2.8 South Korea 920-923MHz ISM Band**

 1132 **2.8.1 KR920-923 Preamble Format**

1133 The following synchronization words should be used:

1134

Modulation	Sync word	Preamble length
LORA	0x34	8 symbols

 1135 **2.8.2 KR920-923 ISM Band channel frequencies**

 1136 The center frequency, bandwidth and maximum EIRP output power for the South Korea
 1137 RFID/USN frequency band are already defined by Korean Government. Basically Korean
 1138 Government allocated LPWA based IoT network frequency band from 920.9 to 923.3MHz.

1139

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

1140

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

 1141 The three following default channels (922.1, 922.3 and 922.5MHz / DR0 to DR5) determined
 1142 by the network operator from the set of available channels as defined by the South Korean
 1143 regulation must be implemented in every KR920-923MHz end-device, and cannot be
 1144 alterable by the **NewChannelReq** command. Those channels are the minimum set that all
 1145 network gateways should always be listening on to guarantee a minimal common channel
 1146 set between end-devices and network gateways.

1147

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

1148

Table 57: KR920-923 default channels

 1149 In order to access the physical medium the South Korea regulations impose some
 1150 restrictions. The South Korea regulations allow the choice of using either a duty-cycle
 1151 limitation or a so-called Listen Before Talk Adaptive Frequency Agility (LBT AFA)
 1152 transmissions management. The current LoRaWAN specification for the KR920-923 ISM

1153 band exclusively uses LBT channel access rule to maximize MACPayload size length and
 1154 comply with the South Korea regulations.

1155 KR920-923MHz ISM band end-devices should use the following default parameters

- 1156 • Default EIRP output power for end-device(920.9~921.9MHz): 10 dBm
- 1157 • Default EIRP output power for end-device(922.1~923.3MHz): 14 dBm
- 1158 • Default EIRP output power for gateway: 23 dBm

1159 KR920-923MHz end-devices should be capable of operating in the 920 to 923MHz
 1160 frequency band and should feature a channel data structure to store the parameters of at
 1161 least 16 channels. A channel data structure corresponds to a frequency and a set of data
 1162 rates usable on this frequency.

1163 The following table gives the list of frequencies that should be used by end-devices to
 1164 broadcast the JoinReq 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

1165 **Table 58: KR920-923 JoinReq Channel List**

1166 2.8.3 KR920-923 Data Rate and End-device Output Power encoding

1167 There is no dwell time limitation for the KR920-923 PHY layer. The *TxParamSetupReq*
 1168 MAC command is not implemented in KR920-923 devices.

1169 The following encoding is used for Data Rate (DR), and EIRP Output Power (TXPower) in
 1170 the KR920-923 band:

1171

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..15	RFU	

1172 **Table 59: TX Data rate table**

1173

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

1174 **Table 60: TX power table**

1175

1176 EIRP refers to the Equivalent Isotropically Radiated Power, which is the radiated output
 1177 power referenced to an isotropic antenna radiating power equally in all directions and whose
 1178 gain is expressed in dBi.

1179

1180 By default MaxEIRP is considered to be +14dBm. If the end-device cannot achieve 14dBm
 1181 EIRP, the MaxEIRP should be communicated to the network server using an out-of-band
 1182 channel during the end-device commissioning process.
 1183 When the device transmits in a channel whose frequency is <922MHz, the transmit power
 1184 SHALL be limited to +10dBm EIRP even if the current transmit power level set by the
 1185 network server is higher.

1186 **2.8.4 KR920-923 JoinAccept CFList**

1187 The KR920-923 ISM band LoRaWAN implements an optional **channel frequency list**
 1188 (CFList) of 16 octets in the JoinAccept message.

1189 In this case the CFList is a list of five channel frequencies for the channels four to eight
 1190 whereby each frequency is encoded as a 24 bits unsigned integer (three octets). All these
 1191 channels are usable for DR0 to DR5 125kHz LoRa modulation. The list of frequencies is
 1192 followed by a single RFU octet for a total of 16 octets.

1193

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

1194 The actual channel frequency in Hz is 100 x frequency whereby values representing
 1195 frequencies below 100 MHz are reserved for future use. This allows setting the frequency of
 1196 a channel anywhere between 100 MHz to 1.67 GHz in 100 Hz steps. Unused channels have
 1197 a frequency value of 0. The **CFList** is optional and its presence can be detected by the
 1198 length of the join-accept message. If present, the **CFList** replaces all the previous channels
 1199 stored in the end-device apart from the three default channels. The newly defined channels
 1200 are immediately enabled and usable by the end-device for communication.

1201 **2.8.5 KR920-923 LinkAdrReq command**

1202 The KR920-923 LoRaWAN only supports a maximum of 16 channels. When **ChMaskCntl**
 1203 field is 0 the ChMask field individually enables/disables each of the 16 channels.

1204

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 61: ChMaskCntl value table

1205

1206

1207 If the ChMaskCntl field value is one of values meaning RFU, the end-device should reject
 1208 the command and unset the “**Channel mask ACK**” bit in its response.

1209 2.8.6 KR920-923 Maximum payload size

1210 The maximum **MACPayload** size length (M) is given by the following table for the regulation
 1211 of dwell time; less than 4 sec with LBT. It is derived from limitation of the PHY layer
 1212 depending on the effective modulation rate used taking into account a possible repeater
 1213 encapsulation layer. The maximum application payload length in the absence of the optional
 1214 **FOpt** control field (N) is also given for information only. The value of N might be smaller if
 1215 the **FOpt** field is not empty:

1216

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	

1217

Table 62: KR920-923 maximum payload size

1218 If the end-device will never operate with a repeater then the maximum application payload
 1219 length in the absence of the optional **FOpt** control field should be:

1220

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	

1221

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

1222

1223 2.8.7 KR920-923 Receive windows

1224 The RX1 receive window uses the same channel than the preceding uplink. The data rate is
 1225 a function of the uplink data rate and the RX1DROffset as given by the following table. The
 1226 allowed values for RX1DROffset are in the [0:5] range. Values in the [6:7] range are
 1227 reserved for future use.

1228

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

1229

Table 64 : KR920-923 downlink RX1 data rate mapping

1230 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
 1231 921.90MHz / DR0 (SF12, 125 kHz).

1232 **2.8.8 KR920-923 Class B beacon and default downlink channel**

1233 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

1234 [Table 65 : KR920-923 beacon settings](#)

1235

1236 The beacon frame content is:

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

1237 The beacon default broadcast frequency is 923.1MHz.

1238 The class B default downlink pingSlot frequency is 923.1MHz

1239

1240 **2.8.9 KR920-923 Default Settings**

1241 The following parameters are recommended values for the KR920-923Mhz band.

- 1242 RECEIVE_DELAY1 1 s
- 1243 RECEIVE_DELAY2 2 s (must be RECEIVE_DELAY1 + 1s)
- 1244 JOIN_ACCEPT_DELAY1 5 s
- 1245 JOIN_ACCEPT_DELAY2 6 s
- 1246 MAX_FCNT_GAP 16384
- 1247 ADR_ACK_LIMIT 64
- 1248 ADR_ACK_DELAY 32
- 1249 ACK_TIMEOUT 2 +/- 1 s (random delay between 1 and 3 seconds)

1250 If the actual parameter values implemented in the end-device are different from those default
 1251 values (for example the end-device uses a longer RECEIVE_DELAY1 and
 1252 RECEIVE_DELAY2 latency), those parameters must be communicated to the network
 1253 server using an out-of-band channel during the end-device commissioning process. The
 1254 network server may not accept parameters different from those default values.
 1255

1256 2.9 India 865-867 MHz ISM Band

1257 2.9.1 INDIA 865-867 Preamble Format

1258 The following synchronization words should be used:

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

1260 [Table 66: India 865-867 synch words](#)

1261 2.9.2 INDIA 865-867 ISM Band channel frequencies

1262 This section applies to the Indian sub-continent.

1263 The network channels can be freely attributed by the network operator. However the three
 1264 following default channels must be implemented in every India 865-867MHz end-device.
 1265 Those channels are the minimum set that all network gateways should always be listening
 1266 on.

1267

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

1268 [Table 67: INDIA 865-867 default channels](#)

1269 End-devices should be capable of operating in the 865 to 867 MHz frequency band and
 1270 should feature a channel data structure to store the parameters of at least 16 channels. A
 1271 channel data structure corresponds to a frequency and a set of data rates usable on this
 1272 frequency.

1273 The first three channels correspond to 865.0625, 865.4025, and 865.985 MHz / DR0 to DR5
 1274 and must be implemented in every end-device. Those default channels cannot be modified
 1275 through the **NewChannelReq** command and guarantee a minimal common channel set
 1276 between end-devices and network gateways.

1277 The following table gives the list of frequencies that should be used by end-devices to
 1278 broadcast the JoinReq message. The JoinReq message transmit duty-cycle shall follow the
 1279 rules described in chapter "Retransmissions back-off" of the LoRaWAN specification
 1280 document.

1281

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

1282 [Table 68: INDIA 865-867 JoinReq Channel List](#)

1283 2.9.3 INDIA 865-867 Data Rate and End-device Output Power Encoding

1284 There is no dwell time or duty-cycle limitation for the INDIA 865-867 PHY layer. The
 1285 **TxParamSetupReq** MAC command is not implemented by INDIA 865-867 devices.

1286 The following encoding is used for Data Rate (DR) and End-device Output Power (TXPower)
 1287 in the INDIA 865-867 band:

1288

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..15	RFU	

Table 69: TX Data rate table

1289

1290

1291 The TXPower table indicates power levels relative to the Max EIRP level of the end-device,
 1292 as per the following table:

1293

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

Table 70: TxPower table

1294

1295

1296 EIRP refers to the Equivalent Isotropically Radiated Power, which is the radiated output
 1297 power referenced to an isotropic antenna radiating power equally in all directions and whose
 1298 gain is expressed in dBi.

1299 By default MaxEIRP is considered to be 30dBm. If the end-device cannot achieve 30dBm
 1300 EIRP, the Max EIRP should be communicated to the network server using an out-of-band
 1301 channel during the end-device commissioning process.

1302

1303 2.9.4 INDIA 865-867 JoinAccept CFList

1304 The India 865-867 ISM band LoRaWAN implements an optional **channel frequency list**
 1305 (CFList) of 16 octets in the JoinAccept message.

1306 In this case the CFList is a list of five channel frequencies for the channels four to eight
 1307 whereby each frequency is encoded as a 24 bits unsigned integer (three octets). All these

1308 channels are usable for DR0 to DR5 125kHz LoRa modulation. The list of frequencies is
 1309 followed by a single RFU octet for a total of 16 octets.

1310

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

1311 The actual channel frequency in Hz is 100 x frequency whereby values representing
 1312 frequencies below 100 MHz are reserved for future use. This allows setting the frequency of
 1313 a channel anywhere between 100 MHz to 1.67 GHz in 100 Hz steps. Unused channels have
 1314 a frequency value of 0. The **CFList** is optional and its presence can be detected by the
 1315 length of the join-accept message. If present, the **CFList** replaces all the previous channels
 1316 stored in the end-device apart from the three default channels. The newly defined channels
 1317 are immediately enabled and usable by the end-device for communication.

1318 2.9.5 INDIA 865-867 LinkAdrReq command

1319 The INDIA 865-867 LoRaWAN only supports a maximum of 16 channels. When
 1320 **ChMaskCntl** field is 0 the ChMask field individually enables/disables each of the 16
 1321 channels.

1322

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

1323

1324 If the ChMaskCntl field value is one of values meaning RFU, the end-device should reject
 1325 the command and unset the “**Channel mask ACK**” bit in its response.

1326 2.9.6 INDIA 865-867 Maximum payload size

1327 The maximum **MACPayload** size length (M) is given by the following table. It is derived from
 1328 limitation of the PHY layer depending on the effective modulation rate used taking into
 1329 account a possible repeater encapsulation layer. The maximum application payload length in
 1330 the absence of the optional **FOpt** control field (N) is also given for information only. The
 1331 value of N might be smaller if the **FOpt** field is not empty:

1332

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	

1333

Table 72: INDIA 865-867 maximum payload size

1334 If the end-device will never operate with a repeater then the maximum application payload
 1335 length in the absence of the optional **FOpt** control field should be:
 1336

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	

1337

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

1338 **2.9.7 INDIA 865-867 Receive windows**

1339 The RX1 receive window uses the same channel than the preceding uplink. The data rate is
 1340 a function of the uplink data rate and the RX1DROffset as given by the following table. The
 1341 allowed values for RX1DROffset are in the [0:7] range. Values in the [6:7] range allow
 1342 setting the Downstream RX1 data rate higher than Upstream data rate.

1343 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

1344 Downstream data rate in RX1 slot = $MIN(5, MAX(0, \text{Upstream data rate} -$
 1345 $\text{Effective_RX1DROffset}))$

1346 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
 1347 866.550 MHz / DR2 (SF10, 125 kHz).

1348 **2.9.8 INDIA 865-867 Class B beacon and default downlink channel**

1349 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

1350

1351 The beacon frame content is:

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

1352 The beacon default broadcast frequency is 866.550MHz.

1353 The class B default downlink pingSlot frequency is 866.550MHz

1354

1355 2.9.9 INDIA 865-867 Default Settings

1356 The following parameters are recommended values for the INDIA 865-867MHz band.

1357

1358 RECEIVE_DELAY1 1 s

1359 RECEIVE_DELAY2 2 s (must be RECEIVE_DELAY1 + 1s)

1360 JOIN_ACCEPT_DELAY1 5 s

1361 JOIN_ACCEPT_DELAY2 6 s

1362 MAX_FCNT_GAP 16384

1363 ADR_ACK_LIMIT 64

1364 ADR_ACK_DELAY 32

1365 ACK_TIMEOUT 2 +/- 1 s (random delay between 1 and 3 seconds)

1366 If the actual parameter values implemented in the end-device are different from those default
1367 values (for example the end-device uses a longer RECEIVE_DELAY1 and
1368 RECEIVE_DELAY2 latency), those parameters must be communicated to the network
1369 server using an out-of-band channel during the end-device commissioning process. The
1370 network server may not accept parameters different from those default values.

1371

1372

1373 **3 Revisions**1374 **3.1 Revision A**

- 1375 • Initial revision, the regional parameters were extracted from the LoRaWANV1.0.1
- 1376 and the Asia/PAC regional cluster definition was added
- 1377 • The ADR command for the US902-928 physical layer was amended to include ADR
- 1378 MAC command blocks
- 1379 • Added KR920-923 frequency band support
- 1380 • Modified EU868 PHY layer power limit from 14dBm EIRP to 1dBm ERP

1381 **3.2 Revision B**

- 1382 • expressed all powers either as EIRP or as conducted power depending on regions
- 1383 • Modified SF of US900 classB beacon to SF12/500kHz
- 1384 • Added for each region whether TxParamSetupReq must be supported or not
- 1385 • Added India frequency plan
- 1386 • Added precision regarding FCC profiles that must be supported by US900 devices
- 1387 • Added missing table in 2.6.6
- 1388 • Specified that device must limit power to 10dBm EIRP at frequencies lower than
- 1389 922MHz in KR920 2.8.4
- 1390 • Added signal polarity in india classB beacon definition
- 1391 • Corrected Missing field names in classB beacon of EU433
- 1392 • Update of the AU915 available data rates : SF12 and SF11 are now allowed
- 1393 • Update of INDIA865 available data rate and TX power definition
- 1394

1395 **4 Bibliography**

1396 **4.1 References**

1397

1398 [LORAWAN] LoRaWAN Specification, V1.0.2, the LoRa Alliance, October 2016.

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