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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

Authors:
LoRa Alliance Technical Committee Regional Parameters Workgroup

Revision: B
Date: 2018 January
Status: Released

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268 **1 Introduction**

269

270 This document describes the LoRaWAN™ regional parameters for different regulatory regions
271 worldwide. This document is a companion document to the LoRaWAN 1.1 protocol
272 specification [LORAWAN]. Separating the regional parameters from the protocol specification
273 allows addition of new regions to the former without impacting the latter document.

274

275 It must be noted here that, regardless of the specifications provided, at no time is any LoRa
276 equipment allowed to operate in a manner contrary to the prevailing local rules and regulations
277 where it is expected to operate. It is the responsibility of the LoRa device to insure that
278 compliant operation is maintained without any outside assistance from a LoRa network or any
279 other mechanism.

280 **1.1 Conventions**

281

282 The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD",
283 "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be
284 interpreted as described in RFC 2119.

285

286 **1.2 Quick cross reference table**

287

288 In order to support the identification of LoRaWAN channel plans for a given country, the table
289 below provides a quick reference of suggested channel plans listed in priority order for each
290 country.

291

292

Country name	Band / channels	Channel Plan
Afghanistan		None
Albania	433.05 - 434.79 MHz	EU433
	863 - 873 MHz	EU863-870
	918 - 921 MHz	Other
Algeria	433.05 - 434.79 MHz	EU433
	870-876MHz	Other
	880-885MHz	Other
	915 - 921 MHz	Other
	925 - 926 MHz	Other
Andorra	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Armenia	863 - 870 MHz	EU863-870
	433.05 - 434.79 MHz	EU433
Argentina	902 - 928 MHz (915-928 MHz usable)	AU915-928, US902-928
Austria	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Australia	915 - 928 MHz	AU915-928, AS923
Azerbaijan	433.05 - 434.79 MHz	EU433
	863 - 868 MHz	Others
Bahrain	862 - 870MHz	EU863-870
Bangladesh	433.05 - 434.79 MHz	EU433
	818 - 824 MHz	Other
	863 - 869 MHz	EU863-870
	925.0 - 927.0 MHz	Other
Belarus	433.05 - 434.79 MHz	EU433
	864.4 - 868.6 MHz	EU863-870
	869-869.2MHz	EU863-870
Belgium	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Burma (Myanmar)	433 - 435 MHz	EU433
	866 - 869MHz	EU863-870
	919 - 923 MHz	Other
Bolivia	915 - 930 MHz	AU915-928, AS923
Bosnia and Herzegovina	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Botswana		None
Brazil	902 - 907.5 MHz	Other
	915 - 928 MHz	AU915-928
	433 - 435 MHz	EU433
Brunei Darussalam	866 - 870 MHz	EU863-870
	920 - 925 MHz	AS923

	433 - 435 MHz	EU433
Bulgaria	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Cambodia	866 - 869 MHz	EU863-870
	923 - 925 MHz	AS923
Cameroon		None
Canada	902 - 928 MHz	US902-928, AU915-928
Chile	902 - 928 MHz (915-928MHz usable)	AU915-928, AS923, US902-928
China	920.5 - 924.5 MHz	AS923
	779 - 787 MHz	CN779-787
	470 - 510 MHz	CN470-510
	433.05 - 434.79 MHz	EU433
	314-316 MHz	Other
	430 - 432 MHz	Other
	840 - 845 MHz	Other
Colombia	902 - 928 MHz	AU915-928, US902-928
Congo Rep.		None
Costa Rica	920.5 - 928 MHz	AS923
Croatia	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Cuba	433.05 - 434.79 MHz	EU433
	915 - 921 MHz	Other
Cyprus	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Czech Republic	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Denmark	433.05 - 434.79 MHz	EU433
	863 - 873 MHz	EU863-870
	918 - 921 MHz	Other
Dominican Republic	915 - 928 MHz	AU915-928
Ecuador	902 - 928 MHz	AU915-928, US902-928, AS923
Egypt	433.05 - 434.79 MHz	EU433
	863 - 876 MHz	EU863-870
Estonia	433.05 - 434.79 MHz	EU433
	863 - 873 MHz	EU863-870
	918 - 921 MHz	Other
Finland	433.05 - 434.79 MHz	EU433
	863 - 873 MHz	EU863-870
France	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Georgia		None
Germany	433.05 - 434.79 MHz	EU433

	863 - 870 MHz	EU863-870
Ghana		None
Greece	433.05 - 434.79 MHz	EU433
	868 - 870 MHz	EU863-870
Guatemala	902 - 928 MHz (915-928 MHz usable)	AU915-928, AS923, US902-928
Haiti		None
Honduras	915-928 MHz	AU915-928
Hong Kong	433.05 - 434.79 MHz	EU433
	865 - 868 MHz	Other
	920 - 925 MHz	AS923
Hungary	433.05 - 434.79 MHz	EU433
	863 - 873 MHz	EU863-870
	918 - 921 MHz	Other
Iceland	433.05 - 434.79 MHz	EU433
	863 - 873 MHz	EU863-870
India	865 - 867 MHz	IN765-867
Indonesia	923 - 925 MHz	AS923
Iraq		None
Iran	433.05 - 434.79 MHz	EU433
	863 - 873 MHz	EU863-870
	915 - 918 MHz	Other
Ireland	433.05 - 434.79 MHz	EU433
	863 - 873 MHz	EU863-870
	918 - 921 MHz	Other
Israel	433.05 - 434.79 MHz	EU433
	915 - 917 MHz	Other
Italy	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Ivory Coast		None
Jamaica	902 - 928 MHz (915-928 MHz usable)	AU915-928, US902-928
Japan	920.6 - 928.0 MHz (steps of 200kHz)	AS923
	920.8 - 927.8 MHz (steps of 600kHz)	AS923
Jordan	865 - 868 MHz	Other
Kazakhstan	433.05 - 434.79 MHz	EU433
Kenya		None
Korea (DPR)		None
Kuwait	433.05 - 434.79 MHz	EU433
Kyrgyz Republic		None
Laos	433 - 435 MHz	EU433
	862 - 875 MHz	EU863-870
	923 - 925 MHz	AS923
Latvia	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870

Lebanon	433 - 435 MHz	EU433
	862 - 870 MHz	EU863-870
Liechtenstein	433.05 - 434.79 MHz	EU433
	863 - 873 MHz	EU863-870
Libya		None
Lithuania	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Luxembourg	433.05 - 434.79 MHz	EU433
	863 - 873 MHz	EU863-870
	918 - 921 MHz	Other
Macao		None
Macedonia, FYR	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Malaysia	433 - 435 MHz	EU433
	919 – 924 MHz	AS923
Maldives		None
Malta	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Mauritius		None
Mexico	902 - 928 MHz	US902-928, AU915-928
Moldova	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Mongolia		None
Montenegro	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Morocco	433.05 - 434.79 MHz	EU433
	867.6 - 869 MHz	EU863-870
Netherlands	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
New-Zealand	915 - 928 MHz	AS923, AU915-928
	819 - 824 MHz	Other
	864 - 870MHz	EU863-870
	433.05 - 434.79 MHz	EU433
Nicaragua	902 - 928 MHz (915-928 MHz usable)	AU915-928, US902-928
Nigeria	863 - 870 MHz	EU863-870
Norway	433.05 - 434.79 MHz	EU433
	863 - 873 MHz	EU863-870
	918 - 921 MHz	Other
Oman	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Pakistan	433.05 - 434.79 MHz	EU433
	865 - 869 MHz	EU863-870
	900 - 925 MHz	AS923

Panama	902 - 928 MHz	AU915-928, US902-928, AS923
Paraguay	433.05 - 434.79 MHz	EU433
	915 - 928 MHz	AU915-928, AS923
Peru	915 - 928 MHz	AU915-928, AS923
Papua New Guinea	915 - 925 MHz	AU915-928
Philippines	915 - 918 MHz	Other
	868 – 869.2 MHz	EU863-870
	869.7 - 870 MHz	EU863-870
	433.05 - 434.79 MHz	EU433
Poland	433.05 - 434.79 MHz	EU433
	863 - 873 MHz	EU863-870
	918 - 921 MHz	Other
Portugal	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Qatar	433.05 - 434.79 MHz	EU433
	868 - 868.6 MHz	EU863-870
	868.7 - 869.2 MHz	EU863-870
	869.4 - 869.65 MHz	EU863-870
	869.7 - 870 MHz	EU863-870
Romania	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Russian federation	866 - 868 MHz (Licensed)	RU864-870
	864 - 865 MHz	RU864-870
	868.7 - 869.2 MHz	RU864-870
	433.075 - 434.75 MHz	EU433
	916 - 921 MHz (Licensed)	Other
Salvador	915-928	AU915-928, AS923
Saudi Arabia	863 - 870 MHz	EU863-870
	433.05 - 434.79 MHz	EU433
Senegal		None
Serbia	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Singapore	920 - 925 MHz	AS923
	433.05 - 434.79 MHz	EU433
	866 - 869 MHz	EU863-870
Slovak Republic	433.05 - 434.79 MHz	EU433
	863 - 873 MHz	EU863-870
	918 - 921 MHz	Other
Slovenia	433.05 - 434.79 MHz	EU433
	863 - 873 MHz	EU863-870
	918 - 921 MHz	Other
South Africa	433.05 - 434.79 MHz	EU433
	865 – 868.6 MHz	EU863-870

	868.7 – 869.2 MHz	EU863-870
	869.4 – 869.65 MHz	EU863-870
	869.7 – 870 MHz	EU863-870
	915 - 921 MHz	Other
South Korea	917 - 923.5 MHz	KR920-923
Spain	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Sri Lanka	433.05 - 434.79 MHz	EU433
Sudan		None
Sweden	433.05 - 434.79 MHz	EU433
	868 - 870 MHz	EU863-870
Switzerland	433.05 - 434.79 MHz	EU433
	863 - 873 MHz	EU863-870
Syrian Arab Rep.		None
Taiwan	920 - 925 MHz	AS923
Tajikistan		None
Tanzania		None
Thailand	433.05 - 434.79 MHz	EU433
	920 - 925 MHz	AS923
Trinidad and Tobago		None
Tunisia	433.05 - 434.79 MHz	EU433
	868 – 868.6 MHz	EU863-870
	868.7 – 869.2 MHz	EU863-870
	869.4 – 869.65 MHz	EU863-870
	869.7 – 870 MHz	EU863-870
Turkey	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Turkmenistan		None
Uganda	433.05 - 434.79 MHz	EU433
	865 - 867.6 MHz	Other
	869.25 - 869.7 MHz	Other
	923 - 925 MHz	AS923
Ukraine	433.05 - 434.79 MHz	EU433
	863 - 865 MHz	EU863-870
	868 - 868.6 MHz	EU863-870
United Arab Emirates	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
	870 - 875.8 MHz	Other
	915 - 921 MHz	Other
United Kingdom	433.05 - 434.79 MHz	EU433
	863 - 873 MHz	EU863-870
	918 - 921 MHz	Other
United States	902 - 928 MHz	US902-928, AU915-928

Uruguay	902 - 928 MHz (915 - 928 MHz usable)	AU915-928, AS923, US902-928
Uzbekistan	433.05 - 434.79 MHz	EU433
Venezuela	922 - 928 MHz	AS923
Vietnam	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
	918 - 923 MHz	Other
Yemen, Rep.		None
Zimbabwe		None

Table 1: Channel Plan per Country

293

2 LoRaWAN Regional Parameters

2.1 Regional Parameter Common Names

In order to support the identification of LoRaWAN channel plans referenced by other specification documents, the table below provides a quick reference of common channel plans listed for each formal plan name.

Channel Plan	Common Name
EU863-870	EU868
US902-928	US915
CN779-787	CN779
EU433	EU433
AU915-928	AU915
CN470-510	CN470
AS923	AS923
KR920-923	KR920
IN865-867	IN865
RU864-870	RU864

2.2 EU863-870MHz ISM Band

2.2.1 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 2: EU863-870 synch words

2.2.2 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 3: 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

317 hour. The ETSI regulations allow the choice of using either a duty-cycle limitation or a so-
 318 called **Listen Before Talk Adaptive Frequency Agility** (LBT AFA) transmissions
 319 management. The current LoRaWAN specification exclusively uses duty-cycled limited
 320 transmissions to comply with the ETSI regulations.

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

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

329 The following table gives the list of frequencies that SHALL be used by end-devices to
 330 broadcast the JoinReq message. The JoinReq message transmit duty-cycle SHALL follow the
 331 rules described in chapter "Retransmissions back-off" of the LoRaWAN specification
 332 document.
 333

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

334 **Table 4: EU863-870 JoinReq Channel List**

335 2.2.3 EU863-870 Data Rate and End-device Output Power encoding

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

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

340

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	

341

342

Table 5: EU863-870 TX Data rate table

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

343 EIRP¹ refers to the Equivalent Isotropically Radiated Power, which is the radiated output
 344 power referenced to an isotropic antenna radiating power equally in all directions and whose
 345 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

Table 6: EU863-870 TX power table

346
347
348
349
350
351
352
353

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.

354 2.2.4 EU863-870 JoinAccept CFList

355

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

358 In this case the CFList is a list of five channel frequencies for the channels three to seven
 359 whereby each frequency is encoded as a 24 bits unsigned integer (three octets). All these
 360 channels are usable for DR0 to DR5 125kHz LoRa modulation. The list of frequencies is
 361 followed by a single CFListType octet for a total of 16 octets. The CFListType SHALL be equal
 362 to zero (0) to indicate that the CFList contains a list of frequencies.

363

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

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

371 2.2.5 EU863-870 LinkAdrReq command

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

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

374

ChMaskCntl	ChMask applies to
0	Channels 0 to 15
1	RFU
..	..
4	RFU
5	RFU
6	All channels ON The device SHALL enable all currently defined channels independently of the ChMask field value.
7	RFU

375

Table 7: EU863-870 ChMaskCntl value table

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

378 2.2.6 EU863-870 Maximum payload size

379 The maximum **MACPayload** size length (M) is given by the following table. It is derived from
380 limitation of the PHY layer depending on the effective modulation rate used taking into account
381 a possible repeater encapsulation layer. The maximum application payload length in the
382 absence of the optional **FOpt** control field (N) is also given for information only. The value of
383 N MAY be smaller if the **FOpt** field is not empty:
384

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	

385

Table 8: EU863-870 maximum payload size

386 If the end-device will never operate with a repeater then the maximum application payload
387 length in the absence of the optional **FOpt** control field SHOULD be:
388

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	

389

Table 9 : EU863-870 maximum payload size (not repeater compatible)
390 2.2.7 EU863-870 Receive windows

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

395

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

396

Table 10: EU863-870 downlink RX1 data rate mapping

397

398 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
 399 869.525 MHz / DR0 (SF12, 125 kHz)

400

401 2.2.8 EU863-870 Class B beacon and default downlink channel

402 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

403

Table 11: EU863-870 beacon settings

404

405 The beacon frame content is:

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

406 The beacon default broadcast frequency is 869.525MHz.

407 The Class B default downlink pingSlot frequency is 869.525MHz

408

409 2.2.9 EU863-870 Default Settings

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

411	RECEIVE_DELAY1	1 s
412	RECEIVE_DELAY2	2 s (MUST be RECEIVE_DELAY1 + 1s)
413	JOIN_ACCEPT_DELAY1	5 s
414	JOIN_ACCEPT_DELAY2	6 s
415	MAX_FCNT_GAP	16384

416	ADR_ACK_LIMIT	64
417	ADR_ACK_DELAY	32
418	ACK_TIMEOUT	2 +/- 1 s (random delay between 1 and 3 seconds)
419	If the actual parameter values implemented in the end-device are different from those default	
420	values (for example the end-device uses a longer RECEIVE_DELAY1 and	
421	RECEIVE_DELAY2 latency), those parameters MUST be communicated to the network	
422	server using an out-of-band channel during the end-device commissioning process. The	
423	network server may not accept parameters different from those default values.	
424		

425 **2.3 US902-928MHz ISM Band**

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

428 **2.3.1 US902-928 Preamble Format**

429 The following synchronization words SHOULD be used:
 430

Modulation	Sync word	Preamble length
LORA	0x34	8 symbols

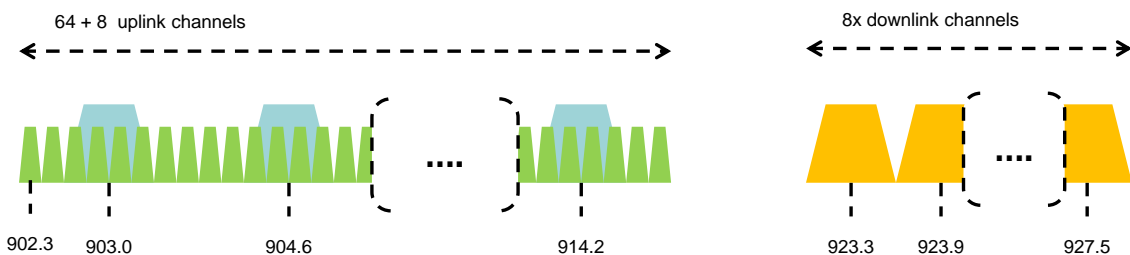
431

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

433 **2.3.2 US902-928 Channel Frequencies**

434 The 915 MHz ISM Band SHALL be divided into the following channel plans.

- 435 • Upstream – 64 channels numbered 0 to 63 utilizing LoRa 125 kHz BW varying from
 436 DR0 to DR3, using coding rate 4/5, starting at 902.3 MHz and incrementing linearly
 437 by 200 kHz to 914.9 MHz
- 438 • Upstream – 8 channels numbered 64 to 71 utilizing LoRa 500 kHz BW at DR4
 439 starting at 903.0 MHz and incrementing linearly by 1.6 MHz to 914.2 MHz
- 440 • Downstream – 8 channels numbered 0 to 7 utilizing LoRa 500 kHz BW at DR8 to
 441 DR13, starting at 923.3 MHz and incrementing linearly by 600 kHz to 927.5 MHz
 442



443
 444

Figure 1: US902-928 channel frequencies

445 915 MHz ISM band end-devices are required to operate in compliance with the relevant
 446 regulatory specifications, The following note summarizes some of the current (March 2017)
 447 relevant regulations.

448 Frequency-Hopping, Spread-Spectrum (FHSS) mode, which requires
 449 the device transmit at a measured conducted power level no greater
 450 than +30 dBm, for a period of no more than 400 msec and over at least
 451 50 channels, each of which occupy no greater than 250 kHz of
 452 bandwidth.

453 Digital Transmission System (DTS) mode, which requires that the
 454 device use channels greater than or equal to 500 kHz and comply to a
 455 conducted Power Spectral Density measurement of no more than +8
 456 dBm per 3kHz of spectrum. In practice, this limits the conducted output
 457 power of an end-device to +26 dBm.

458 Hybrid mode, which requires that the device transmit over multiple
 459 channels (this may be less than the 50 channels required for FHSS
 460 mode, but is recommended to be at least 4) while complying with the
 461 Power Spectral Density requirements of DTS mode and the 400 msec

462 dwell time of FHSS mode. In practice this limits the measured
 463 conducted power of the end-device to 21 dBm.

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

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

471
 472 If using the over-the-air activation procedure, the end-device **SHALL** transmit the Join-
 473 request message on random 125 kHz channels amongst the 64 125kHz channels defined
 474 using **DR0** and on 500 kHz channels amongst the 8 500kHz channels defined using **DR4**.
 475 The end-device **SHALL** change channels for every transmission.

476 For rapid network acquisition in mixed gateway channel plan environments, the device
 477 **SHOULD** follow a random channel selection sequence which efficiently probes the octet
 478 groups of eight 125 kHz channels followed by probing one 500 kHz channel each pass.
 479 Each consecutive pass **SHOULD NOT** select a channel that was used in a previous pass,
 480 until a Join-request is transmitted on every channel, after which the entire process can
 481 restart.

482 Example: First pass: Random channel from [0-7], followed by [8-15]... [56-63], then 64
 483 Second pass: Random channel from [0-7], followed by [8-15]... [56-63], then
 484 65
 485 Last pass: Random channel from [0-7], followed by [8-15]... [56-63], then 71

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

488 2.3.3 US902-928 Data Rate and End-device Output Power encoding

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

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

493

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 12: US902-928 TX Data rate table

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

TXPower	Configuration (conducted power)
0	30 dBm – 2*TXpower
1	28 dBm
2	26 dBm
3 : 13
14	2 dBm
15	Defined in LoRaWAN

Table 13: US902-928 TX power table

2.3.4 US902-928 JoinAccept CFList

The US902-928 LoRaWAN supports the use of the optional **CFList** appended to the JoinResp message. If the **CFList** is not empty then the **CFListType** field SHALL contain the value one (0x01) to indicate the **CFList** contains a series of ChMask fields. The ChMask fields are interpreted as being controlled by a virtual ChMaskCntl that initializes to a value of zero (0) and increments for each ChMask field to a value of four (4). (The first 16 bits controls the channels 0 to 15, ..)

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

2.3.5 US902-928 LinkAdrReq command

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

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

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

514

Table 14: US902-928 ChMaskCntl value table

515 If **ChMaskCntl** = 5 then the corresponding bits in the ChMask enable and disable a bank of 8
 516 125kHz channels and the corresponding 500kHz channel defined by the following calculation:
 517 $[\text{ChannelMaskBit} * 8, \text{ChannelMaskBit} * 8 + 7], 64 + \text{ChannelMaskBit}$.

518

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

523

524 **Note:** FCC regulation requires hopping over at least 50 channels when
 525 using maximum output power. It is possible to have end-devices with
 526 less channels when limiting the end-device conducted transmit power to
 527 21 dBm.

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

534

535 2.3.6 US902-928 Maximum payload size

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

541

542

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	

543

Table 15: US902-928 maximum payload size (repeater compatible)

544

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

547 If the end-device will never operate under a repeater then the maximum application payload
 548 length in the absence of the optional **FOpt** control field SHOULD be:
 549

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	

550 **Table 16 : US902-928 maximum payload size (not repeater compatible)**

551 2.3.7 US902-928 Receive windows

- 552 • The RX1 receive channel is a function of the upstream channel used to initiate the
 553 data exchange. The RX1 receive channel can be determined as follows.
 554 ○ RX1 Channel Number = Transmit Channel Number modulo 8
- 555 • The RX1 window data rate depends on the transmit data rate (see Table 17 below).
- 556 • The RX2 (second receive window) settings uses a fixed data rate and frequency.
 557 Default parameters are 923.3MHz / DR8
 558

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

559 **Table 17: US902-928 downlink RX1 data rate mapping**

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

562 2.3.8 US902-928 Class B beacon

563 The beacons SHALL BE 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

564 **Table 18: US902-928 beacon settings**

565 The downstream channel used for a given beacon is:

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

- 567
- whereby beacon_time is the integer value of the 4 bytes “Time” field of the beacon frame
 - 568
 - whereby beacon_period is the periodicity of beacons , 128 seconds
 - 569
 - whereby floor(x) designates rounding to the integer immediately inferior or equal to x
 - 570
 - 571

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

574
575

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

576
577
578

The beacon frame content is:

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

579

580 2.3.9 US902-928 Default Settings

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

- 582 RECEIVE_DELAY1 1 s
- 583 RECEIVE_DELAY2 2 s (MUST be RECEIVE_DELAY1 + 1s)
- 584 JOIN_ACCEPT_DELAY1 5 s
- 585 JOIN_ACCEPT_DELAY2 6 s
- 586 MAX_FCNT_GAP 16384
- 587 ADR_ACK_LIMIT 64
- 588 ADR_ACK_DELAY 32
- 589 ACK_TIMEOUT 2 +/- 1 s (random delay between 1 and 3 seconds)

590 If the actual parameter values implemented in the end-device are different from those default
 591 values (for example the end-device uses a longer RECEIVE_DELAY1 & 2 latency), those
 592 parameters MUST be communicated to the network server using an out-of-band channel
 593 during the end-device commissioning process. The network server may not accept
 594 parameters different from those default values.

595

596 **2.4 CN779-787 MHz ISM Band**

 597 **2.4.1 CN779-787 Preamble Format**

598 The following synchronization words SHOULD be used :

599

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

600

Table 19: CN779-787 synch words

 601 **2.4.2 CN779-787 ISM Band channel frequencies**

602

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

605 The end-device transmit duty-cycle SHOULD be lower than 1%.

606 The LoRaWAN channels center frequency MAY be in the following range:

607

608

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

 609 CN780MHz end-devices SHALL be capable of operating in the 779 to 787 MHz frequency
 610 band and SHALL feature a channel data structure to store the parameters of at least 16
 611 channels. A channel data structure corresponds to a frequency and a set of data rates usable
 612 on this frequency.

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

 618 The following table gives the list of frequencies that SHALL be used by end-devices to
 619 broadcast the JoinReq message The JoinReq message transmit duty-cycle SHALL follow the
 620 rules described in chapter "Retransmissions back-off" of the LoRaWAN specification
 621 document.

622

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			

623

624

Table 20: CN779-787 JoinReq Channel List

 625 **2.4.3 CN779-787 Data Rate and End-device Output Power encoding**

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

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

630

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 21: CN779-787 Data rate and TX power table

631

632

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

636

637 By default MAXEIRP is considered to be +12.15dBm. If the end-device cannot achieve
638 12.15dBm EIRP, the Max EIRP SHOULD be communicated to the network server using an
639 out-of-band channel during the end-device commissioning process.

640

641 2.4.4 CN779-787 JoinAccept CFList

642 The CN780 ISM band LoRaWAN implements an optional **channel frequency list** (CFList) of
643 16 octets in the JoinAccept message.

644 In this case the CFList is a list of five channel frequencies for the channels three to seven
645 whereby each frequency is encoded as a 24 bits unsigned integer (three octets). All these
646 channels are usable for DR0 to DR5 125kHz LoRa modulation. The list of frequencies is
647 followed by a single CFListType octet for a total of 16 octets. The CFListType SHALL be equal
648 to zero (0) to indicate that the CFList contains a list of frequencies.

649

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

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

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

658 **2.4.5 CN779-787 LinkAdrReq command**

659

 660 The CN780 LoRaWAN only supports a maximum of 16 channels. When **ChMaskCntl** field is
 661 0 the ChMask field individually enables/disables each of the 16 channels.
 662

ChMaskCntl	ChMask applies to
0	Channels 0 to 15
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 22: CN779-787 ChMaskCntl value table

663

664

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

 667 **2.4.6 CN779-787 Maximum payload size**

 668 The maximum **MACPayload** size length (M) is given by the following table. It is derived from
 669 limitation of the PHY layer depending on the effective modulation rate used taking into account
 670 a possible repeater encapsulation layer. The maximum application payload length in the
 671 absence of the optional **FOpt** control field (N) is also given for information only. The value of
 672 N MAY be smaller if the **FOpt** field is not empty:
 673

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 23: CN779-787 maximum payload size

674

675

 676 If the end-device will never operate with a repeater then the maximum application payload
 677 length in the absence of the optional **FOpt** control field SHOULD be:
 678

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	

679 **Table 24 : CN779-787 maximum payload size (not repeater compatible)**

 680 **2.4.7 CN779-787 Receive windows**

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

 685

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

 686 **Table 25: CN779-787 downlink RX1 data rate mapping**

 687 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
 688 786 MHz / DR0.

 689 **2.4.8 CN779-787 Class B beacon and default downlink channel**

690 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

 691 **Table 26: CN779-787 beacon settings**

692 The beacon frame content is:

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

693 The beacon default broadcast frequency is 785MHz.

694 The class B default downlink pingSlot frequency is 785MHz

695

 696 **2.4.9 CN779-787 Default Settings**

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

698	RECEIVE_DELAY1	1 s
699	RECEIVE_DELAY2	2 s (MUST be RECEIVE_DELAY1 + 1s)
700	JOIN_ACCEPT_DELAY1	5 s
701	JOIN_ACCEPT_DELAY2	6 s
702	MAX_FCNT_GAP	16384
703	ADR_ACK_LIMIT	64
704	ADR_ACK_DELAY	32

- 705 ACK_TIMEOUT 2 +/- 1 s (random delay between 1 and 3 seconds)
- 706 If the actual parameter values implemented in the end-device are different from those default
707 values (for example the end-device uses a longer RECEIVE_DELAY1 and
708 RECEIVE_DELAY2 latency), those parameters **MUST** be communicated to the network
709 server using an out-of-band channel during the end-device commissioning process. The
710 network server may not accept parameters different from those default values.

711 2.5 EU433MHz ISM Band

712 2.5.1 EU433 Preamble Format

713 The following synchronization words SHOULD be used :
714

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

715 [Table 27: EU433 synch words](#)

716 2.5.2 EU433 ISM Band channel frequencies

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

719 The end-device transmit duty-cycle SHALL be lower than 10%¹

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

- 721 • Minimum frequency : 433.175 MHz
- 722 • Maximum frequency : 434.665 MHz

723 EU433 end-devices SHALL be capable of operating in the 433.05 to 434.79 MHz frequency
724 band and SHALL feature a channel data structure to store the parameters of at least 16
725 channels. A channel data structure corresponds to a frequency and a set of data rates usable
726 on this frequency.

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

732 The following table gives the list of frequencies that SHALL be used by end-devices to
733 broadcast the JoinReq message. The JoinReq message transmit duty-cycle SHALL follow the
734 rules described in chapter “Retransmissions back-off” of the LoRaWAN specification
735 document.

736

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%

737 [Table 28: EU433 JoinReq Channel List](#)
738

739 2.5.3 EU433 Data Rate and End-device Output Power encoding

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

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.

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

744

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 29: EU433 Data rate and TX power table

745

746

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

750

751 By default MAXEIRP is considered to be +12.15dBm. If the end-device cannot achieve
752 12.15dBm EIRP, the Max EIRP SHALL be communicated to the network server using an
753 out-of-band channel during the end-device commissioning process.

754

755

756 2.5.4 EU433 JoinAccept CFList

757

758 The EU433 ISM band LoRaWAN implements an optional **channel frequency list** (CFList) of
759 16 octets in the JoinAccept message.

760 In this case the CFList is a list of five channel frequencies for the channels three to seven
761 whereby each frequency is encoded as a 24 bits unsigned integer (three octets). All these
762 channels are usable for DR0 to DR5 125 kHz LoRa modulation. The list of frequencies is
763 followed by a single CFListType octet for a total of 16 octets. The CFListType SHALL be equal
764 to zero (0) to indicate that the CFList contains a list of frequencies.

765

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

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

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

774 **2.5.5 EU433 LinkAdrReq command**

 775 The EU433 LoRaWAN only supports a maximum of 16 channels. When **ChMaskCntl** field is
 776 0 the ChMask field individually enables/disables each of the 16 channels.
 777

ChMaskCntl	ChMask applies to
0	Channels 0 to 15
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

 778 **Table 30: EU433 ChMaskCntl value table**

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

 781 **2.5.6 EU433 Maximum payload size**

 782 The maximum **MACPayload** size length (*M*) is given by the following table. It is derived from
 783 limitation of the PHY layer depending on the effective modulation rate used taking into account
 784 a possible repeater encapsulation layer. The maximum application payload length in the
 785 absence of the optional **FOpt** control field (*N*) is also given for information only. The value of
 786 *N* might be smaller if the **FOpt** field is not empty:
 787

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	

 788 **Table 31: EU433 maximum payload size**

789

790

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

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	

793
 794

Table 32 : EU433 maximum payload size (not repeater compatible)
795 2.5.7 EU433 Receive windows

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

800

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

801

Table 33 : EU433 downlink RX1 data rate mapping

802 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
 803 434.665MHz / DR0 (SF12, 125kHz).

804

805 2.5.8 EU433 Class B beacon and default downlink channel

806 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

807

Table 34 : EU433 beacon settings

808 The beacon frame content is:

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

809 The beacon default broadcast frequency is 434.665MHz.

810 The class B default downlink pingSlot frequency is 434.665MHz

811

812 2.5.9 EU433 Default Settings

813 The following parameters are recommended values for the EU433band.

814	RECEIVE_DELAY1	1 s
815	RECEIVE_DELAY2	2 s (MUST be RECEIVE_DELAY1 + 1s)
816	JOIN_ACCEPT_DELAY1	5 s
817	JOIN_ACCEPT_DELAY2	6 s
818	MAX_FCNT_GAP	16384

819	ADR_ACK_LIMIT	64
820	ADR_ACK_DELAY	32
821	ACK_TIMEOUT	2 +/- 1 s (random delay between 1 and 3 seconds)
822		
823	If the actual parameter values implemented in the end-device are different from those default	
824	values (for example the end-device uses a longer RECEIVE_DELAY1 & 2 latency) , those	
825	parameters MUST be communicated to the network server using an out-of-band channel	
826	during the end-device commissioning process. The network server may not accept	
827	parameters different from those default values.	
828		

829 **2.6 AU915-928MHz ISM Band**

830
 831 This section defines the regional parameters for Australia and all other countries whose ISM
 832 band extends from 915 to 928MHz spectrum.
 833

834 **2.6.1 AU915-928 Preamble Format**

835 The following synchronization words SHOULD be used:
 836

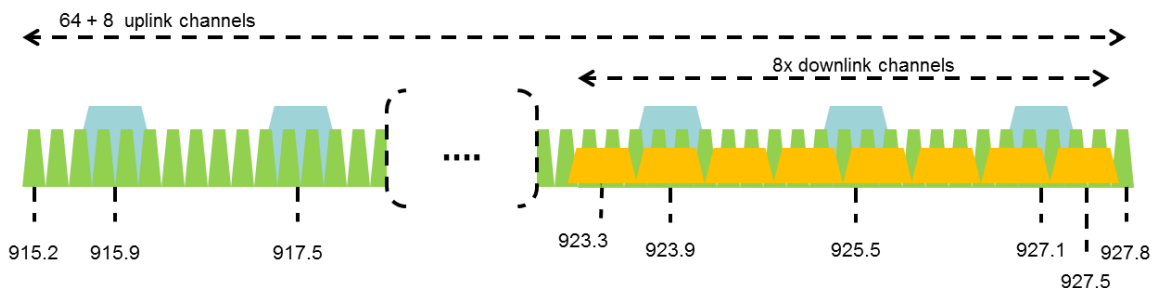
Modulation	Sync word	Preamble length
LORA	0x34	8 symbols

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

838 **2.6.2 AU915-928 Channel Frequencies**

839 The AU ISM Band SHALL be divided into the following channel plans.

- 840 • Upstream – 64 channels numbered 0 to 63 utilizing LoRa 125 kHz BW varying from
 841 DR0 to DR5, using coding rate 4/5, starting at 915.2 MHz and incrementing linearly
 842 by 200 kHz to 927.8 MHz
- 843 • Upstream – 8 channels numbered 64 to 71 utilizing LoRa 500 kHz BW at DR6
 844 starting at 915.9 MHz and incrementing linearly by 1.6 MHz to 927.1 MHz
- 845 • Downstream – 8 channels numbered 0 to 7 utilizing LoRa 500 kHz BW at DR8 to
 846 DR13) starting at 923.3 MHz and incrementing linearly by 600 kHz to 927.5 MHz
 847



848
 849

Figure 2: AU915-928 channel frequencies

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

851 AU915-928 end-devices SHALL be capable of operating in the 915 to 928 MHz frequency
 852 band and SHALL feature a channel data structure to store the parameters of 72 channels. A
 853 channel data structure corresponds to a frequency and a set of data rates usable on this
 854 frequency.

855 If using the over-the-air activation procedure, the end-device SHALL broadcast the JoinReq
 856 message alternatively on a random 125 kHz channel amongst the 64 channels defined using
 857 DR2 and a random 500 kHz channel amongst the 8 channels defined using DR6. The end-
 858 device SHOULD change channel for every transmission.

859 Personalized devices SHALL have all 72 channels enabled following a reset.

860

861 The default JoinReq Data Rate is DR2 (SF10/125KHz), this setting
 862 ensures that end-devices are compatible with the 400ms dwell time
 863 limitation until the actual dwell time limit is notified to the end-device by
 864 the network server via the MAC command TxParamSetupReq.

865 AU915-928 end-devices MUST consider UplinkDwellTime = 1 during
 866 boot stage until reception of the **TxParamSetupReq** command.
 867 AU915-928 end-devices MUST always consider DownlinkDwellTime =
 868 0, since downlink channels use 500KHz bandwidth without any dwell
 869 time limit.
 870

871 2.6.3 AU915-928 Data Rate and End-point Output Power encoding

872 The “TxParamSetupReq/Ans” MAC commands MUST be implemented by AU915-928
 873 devices.

874 If the field UplinkDwellTime is set to 1 by the network server in the
 875 **TxParamSetupReq** command, AU915-928 end-devices SHALL adjust
 876 the time between two consecutive uplink transmissions to meet the local
 877 regulation. Twenty seconds (20s) are recommended between 2 uplink
 878 transmissions when UplinkDwellTime = 1 but this value MAY be
 879 adjusted depending on local regulation.

880 There is no such constraint on time between two consecutive
 881 transmissions when UplinkDwellTime = 0.

882

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

885

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 35: AU915-928 Data rate table

886

887

888 DR6 is identical to DR12, DR8...13 MUST be implemented in end-devices and are reserved
 889 for future applications.

890

891

892

893

894

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

Table 36 : AU915-928 TX power table

895
896
897
898
899
900

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

901
902
903
904

By default MaxEIRP is considered to be +30dBm. The Max EIRP can be modified by the network server through the **TxParamSetupReq** MAC command and SHOULD be used by both the end-device and the network server once **TxParamSetupReq** is acknowledged by the device via **TxParamSetupAns**.

905

906 2.6.4 AU915-928 JoinAccept CFList

907
908
909
910
911
912
913

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

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

914

915 2.6.5 AU915-928 LinkAdrReq command

916
917

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

918
919

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 37: AU915-928 ChMaskCntl value table

920

921 If **ChMaskCntl** = 5 then the corresponding bits in the ChMask enable and disable a bank of 8
922 125kHz channels and the corresponding 500kHz channel defined by the following calculation:
923 [ChannelMaskBit * 8, ChannelMaskBit * 8 + 7],64+ChannelMaskBit.

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

928

929 2.6.6 AU915-928 Maximum payload size

930 The maximum **MACPayload** size length (M) is given by the following table for both uplink
 931 dwell time configurations: No Limit and 400ms. It is derived from the maximum allowed
 932 transmission time at the PHY layer taking into account a possible repeater encapsulation. The
 933 maximum application payload length in the absence of the optional **FOpt** MAC control field
 934 (N) is also given for information only. The value of N might be smaller if the **FOpt** field is not
 935 empty:

936

937

938

939

940

941

942

943

944

945

946

947

DataRate	UplinkDwellTime=0		UplinkDwellTime=1	
	M	N	M	N
0	59	51	N/A	N/A
1	59	51	N/A	N/A
2	59	51	19	11
3	123	115	61	53
4	230	222	133	125
5	230	222	250	242
6	230	222	250	242
7	Not defined		Not defined	
8	41	33	41	33
9	117	109	117	109
10	230	222	230	222
11	230	222	230	222
12	230	222	230	222
13	230	222	230	222
14:15	Not defined		Not defined	

948

949

Table 38: AU915-928 maximum payload size

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

952

953

954

For AU915-928, DownlinkDwellTime MUST be set to 0 (no limit). The 400ms dwell time MAY only apply to uplink channels depending on the local regulations.

955

956

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

957

DataRate	UplinkDwellTime=0		UplinkDwellTime=1	
	M	N	M	N
0	59	51	N/A	N/A
1	59	51	N/A	N/A
2	59	51	19	11
3	123	115	61	53
4	250	242	133	125
5	250	242	250	242
6	250	242	250	242

958
959
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966
967
968
969

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

Table 39: AU915-payload size (not

compatible)

928 maximum repeater

970 2.6.7 AU915-928 Receive windows

- 971 • The RX1 receive channel is a function of the upstream channel used to initiate the
- 972 data exchange. The RX1 receive channel can be determined as follows.
- 973 ○ RX1 Channel Number = Transmit Channel Number modulo 8
- 974 • The RX1 window data rate depends on the transmit data rate (see Table 17 below).
- 975 • The RX2 (second receive window) settings uses a fixed data rate and frequency.
- 976 Default parameters are 923.3Mhz / DR8
- 977

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

Table 40 : AU915-928 downlink RX1 data rate mapping

978
979

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

982

983 2.6.8 AU915-928 Class B beacon

984 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

Table 41 : AU915-928 beacon settings

985

986 The downstream channel used for a given beacon is:

987
$$\text{Channel} = \left[\text{floor} \left(\frac{\text{beacon_time}}{\text{beacon_period}} \right) \right] \text{ modulo } 8$$

- 988
- whereby beacon_time is the integer value of the 4 bytes “Time” field of the beacon frame
- 989
- whereby beacon_period is the periodicity of beacons , 128 seconds
- 990
- whereby $\text{floor}(x)$ designates rounding to the integer immediately inferior or equal to x
- 991
- 992

993 | Example: the first beacon will be transmitted on 923.3Mhz , the second
 994 | 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

997
998
999

The beacon frame content is:

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

1000

1001 2.6.9 AU915-928 Default Settings

1002 The following parameters are recommended values for the AU915-928 band.

- 1003 RECEIVE_DELAY1 1 s
- 1004 RECEIVE_DELAY2 2 s (MUST be RECEIVE_DELAY1 + 1s)
- 1005 JOIN_ACCEPT_DELAY1 5 s
- 1006 JOIN_ACCEPT_DELAY2 6 s
- 1007 MAX_FCNT_GAP 16384
- 1008 ADR_ACK_LIMIT 64
- 1009 ADR_ACK_DELAY 32
- 1010 ACK_TIMEOUT 2 +/- 1 s (random delay between 1 and 3 seconds)

1011 If the actual parameter values implemented in the end-device are different from those default
 1012 values (for example the end-device uses a longer RECEIVE_DELAY1 & 2 latency), those
 1013 parameters MUST be communicated to the network server using an out-of-band channel
 1014 during the end-device commissioning process. The network server may not accept
 1015 parameters different from those default values.

1016

1017 **2.7 CN470-510MHz Band**

1018 **2.7.1 CN470-510 Preamble Format**

1019 The following synchronization words SHOULD be used:

1020

Modulation	Sync word	Preamble length
LORA	0x34	8 symbols

1021 **2.7.2 CN470-510 Channel Frequencies**

1022

1023 In China, this band is defined by SRRC to be used for civil metering applications.

1024 The 470 MHz ISM Band SHALL be divided into the following channel plans:

1025

- 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.

1026

1027

1028

1029

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

1030

1031

1032

1033

- 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

1034

1035

1036

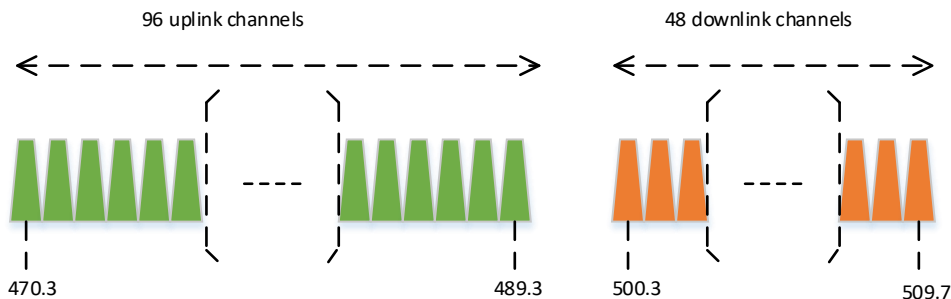


Figure 3: CN470-510 channel frequencies

1037

1038

1039

1040 The LoRaWAN can be used in the Chinese 470-510MHz band as long as

1041

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

1042

1043

1044

1045

1046 CN470-510 end-devices SHALL be capable of operating in the 470 to 510 MHz frequency band and SHALL feature a channel data structure to store the parameters of 96 uplink channels. A channel data structure corresponds to a frequency and a set of data rates usable on this frequency.

1047

1048

1049

1050 If using the over-the-air activation procedure, the end-device SHALL broadcast the JoinReq message on a random 125 kHz channel amongst the 96 uplink channels defined using **DR5 to DR0**.

1051

1052

1053 Personalized devices SHALL have all 96 channels enabled following a reset.

1054

1055 **2.7.3 CN470-510 Data Rate and End-point Output Power encoding**

1056 There is no dwell time limitation for the CN470-510 PHY layer. The *TxParamSetupReq* MAC
1057 command is not implemented by CN470-510 devices.

1058 The following encoding is used for Data Rate (**DR**) and End-point EIRP (**TXPower**) in the
1059 CN470-510 band:

1060

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 42: CN470-510 Data rate and TX power table

1061

1062

1063 EIRP refers to the Equivalent Isotropically Radiated Power, which is the radiated output
1064 power referenced to an isotropic antenna radiating power equally in all directions and whose
1065 gain is expressed in dBi.

1066

1067 By default MaxEIRP is considered to be +19.15dBm. If the end-device cannot achieve
1068 19.15dBm EIRP, the Max EIRP SHOULD be communicated to the network server using an
1069 out-of-band channel during the end-device commissioning process.

1070

1071 **2.7.4 CN470-510 JoinResp CFList**

1072

1073 The CN470-510 LoRaWAN supports the use of the optional **CFList** appended to the
1074 JoinResp message. If the **CFList** is not empty then the CFListType field SHALL contain the
1075 value one (0x01) to indicate the CFList contains a series of ChMask fields. The ChMask
1076 fields are interpreted as being controlled by a virtual ChMaskCntl that initializes to a value of
1077 zero (0) and increments for each ChMask field to a value of five (5). (The first 16 bits
1078 controls the channels 1 to 16, ..)

1079

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

1080 **2.7.5 CN470-510 LinkAdrReq command**

 1081 For the CN470-510 version the **ChMaskCntl** field of the **LinkADRReq** command has the
 1082 following meaning:

1083

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

1084

Table 43: CN470-510 ChMaskCntl value table

 1085 If the ChMask field value is one of the values meaning RFU, then end-device SHOULD reject
 1086 the command and unset the “**Channel mask ACK**” bit in its response.

 1087 **2.7.6 CN470-510 Maximum payload size**

 1088 The maximum **MACPayload** size length (M) is given by the following table. It is derived from
 1089 the maximum allowed transmission time at the PHY layer taking into account a possible
 1090 repeater encapsulation. The maximum application payload length in the absence of the
 1091 optional **FOpt** MAC control field (N) is also given for information only. The value of N might be
 1092 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	

1093

Table 44: CN470-510 maximum payload size

 1094 If the end-device will never operate with a repeater then the maximum application payload
 1095 length in the absence of the optional **FOpt** control field SHOULD be:

1096

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	

1097

Table 45 : CN470-510 maximum payload size (not repeater compatible)

1098

 1099 **2.7.7 CN470-510 Receive windows**

- 1100 • The RX1 receive channel is a function of the upstream channel used to initiate the
 1101 data exchange. The RX1 receive channel can be determined as follows.

- 1102 ○ RX1 Channel Number = Uplink Channel Number modulo 48, for example,
- 1103 when transmitting channel number is 49, the rx1 channel number is 1.
- 1104 • The RX1 window data rate depends on the transmit data rate (see Table below).
- 1105 • The RX2 (second receive window) settings uses a fixed data rate and frequency.
- 1106 Default parameters are 505.3 MHz / DR0
- 1107

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 46: CN470-510 downlink RX1 data rate mapping

1108
1109

1110 The allowed values for RX1DROffset are in the [0:5] range. Values in the range [6:7] are
1111 reserved for future use.

1112 2.7.8 CN470-510 Class B beacon

1113 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 47 : CN470-510 beacon settings

1114
1115

1116 The downstream channel used for a given beacon is:

$$1117 \text{ BeaconChannel} = \left[\text{floor} \left(\frac{\text{beacon_time}}{\text{beacon_period}} \right) \right] \text{ modulo } 8$$

- 1118 • whereby beacon_time is the integer value of the 4 bytes “Time” field of the beacon
- 1119 frame
- 1120 • whereby beacon_period is the periodicity of beacons , 128 seconds
- 1121 • whereby floor(x) designates rounding to the integer immediately inferior or equal to x
- 1122

1123 Example: the first beacon will be transmitted on 508.3Mhz, the second
1124 on 508.5MHz, the 9th beacon will be on 508.3Mhz again.

1125
1126

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
---	-------

1127
1128
1129

The beacon frame content is:

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

1130

1131 **2.7.9 CN470-510 Default Settings**

1132 The following parameters are recommended values for the CN470-510 band.

1133	RECEIVE_DELAY1	1 s
1134	RECEIVE_DELAY2	2 s (MUST be RECEIVE_DELAY1 + 1s)
1135	JOIN_ACCEPT_DELAY1	5 s
1136	JOIN_ACCEPT_DELAY2	6 s
1137	MAX_FCNT_GAP	16384
1138	ADR_ACK_LIMIT	64
1139	ADR_ACK_DELAY	32
1140	ACK_TIMEOUT	2 +/- 1 s (random delay between 1 and 3 seconds)

1141 If the actual parameter values implemented in the end-device are different from those default
1142 values (for example the end-device uses a longer RECEIVE_DELAY1 & 2 latency), those
1143 parameters MUST be communicated to the network server using an out-of-band channel
1144 during the end-device commissioning process. The network server may not accept
1145 parameters different from those default values.

1146 **2.8 AS923MHz ISM Band**

 1147 **2.8.1 AS923 Preamble Format**

1148 The following synchronization words SHOULD be used:

1149

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

1150

Table 48: AS923 synch words

 1151 **2.8.2 AS923 ISM Band channel frequencies**

 1152 This section applies to regions where the frequencies [923...923.5MHz] are comprised in the
 1153 ISM band.

 1154 The network channels can be freely attributed by the network operator. However the two
 1155 following default channels MUST be implemented in every AS923MHz end-device. Those
 1156 channels are the minimum set that all network gateways SHOULD always be listening on.

1157

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%

1158

Table 49: AS923 default channels

 1159 Those default channels MUST be implemented in every end-device and cannot be modified
 1160 through the **NewChannelReq** command and guarantee a minimal common channel set
 1161 between end-devices and network gateways.

1162 AS923MHz ISM band end-devices should use the following default parameters

1163

- Default EIRP: 16 dBm

 1164 AS923MHz end-devices SHALL feature a channel data structure to store the parameters of
 1165 at least 16 channels. A channel data structure corresponds to a frequency and a set of data
 1166 rates usable on this frequency.

 1167 The following table gives the list of frequencies that SHALL be used by end-devices to
 1168 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 to DR5	2	< 1%

1169

Table 50: AS923 JoinReq Channel List

1170

 1171 The default JoinReq Data Rate utilizes the range DR2-DR5 (SF10/125 kHz – SF7/125 kHz),
 1172 this setting ensures that end-devices are compatible with the 400ms dwell time limitation until
 1173 the actual dwell time limit is notified to the end-device by the network server via the MAC
 1174 command "TxParamSetupReq".

1175 The JoinReq message transmit duty-cycle SHALL follow the rules described in chapter

1176 “Retransmissions back-off” of the LoRaWAN specification document.
1177

1178 2.8.3 AS923 Data Rate and End-point Output Power encoding

1179 The “TxParamSetupReq/Ans” MAC command MUST be implemented by the AS923 devices.
1180 The following encoding is used for Data Rate (DR) in the AS923 band:

1181

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	

1182

Table 51: AS923 Data rate table

1183

1184 The TXPower table indicates power levels relative to the Max EIRP level of the end-device,
1185 as per the following table:
1186

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

1187

1188

1189 EIRP refers to the Equivalent Isotropically Radiated Power, which is the radiated output
1190 power referenced to an isotropic antenna radiating power equally in all directions and whose
1191 gain is expressed in dBi.

1192 By default Max EIRP SHALL be 16dBm. The Max EIRP can be modified by the network
1193 server through the **TxParamSetupReq** MAC command and SHOULD be used by both the
1194 end-device and the network server once **TxParamSetupReq** is acknowledged by the device
1195 via **TxParamSetupAns**,

1196

1197 **2.8.4 AS923 JoinAccept CFList**

1198 The AS923 LoRaWAN implements an optional channel frequency list (CFList) of 16 octets in
1199 the JoinAccept message.

1200 In this case the CFList is a list of five channel frequencies for the channels two to six whereby
1201 each frequency is encoded as a 24 bits unsigned integer (three octets). All these channels are
1202 usable for DR0 to DR5 125 KHz LoRa modulation. The list of frequencies is followed by a
1203 single CFListType octet for a total of 16 octets. The CFListType SHALL be equal to zero (0)
1204 to indicate that the CFList contains a list of frequencies.

1205

Size (bytes)	3	3	3	3	3	1
CFList	Freq Ch2	Freq Ch3	Freq Ch4	Freq Ch5	Freq Ch6	CFListType

1206 The actual channel frequency in Hz is 100 x frequency whereby values representing
1207 frequencies below 100 MHz are reserved for future use. This allows setting the frequency of
1208 a channel anywhere between 915 and 928MHz in 100 Hz steps. Unused channels have a
1209 frequency value of 0. The CFList is optional and its presence can be detected by the length of
1210 the join-accept message. If present, the CFList replaces all the previous channels stored in
1211 the end-device apart from the two default channels. The newly defined channels are
1212 immediately enabled and usable by the end-device for communication.

1213 **2.8.5 AS923 LinkAdrReq command**

1214 The AS923 LoRaWAN only supports a maximum of 16 channels. When **ChMaskCntl** field is
1215 0 the ChMask field individually enables/disables each of the 16 channels.

1216

ChMaskCntl	ChMask applies to
0	Channels 0 to 15
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 53: AS923 ChMaskCntl value table

1217

1218 If the ChMask field value is one of values meaning RFU, the end-device SHOULD reject the
1219 command and unset the “**Channel mask ACK**” bit in its response.

1220

1221 **2.8.6 AS923 Maximum payload size**

1222 The maximum **MACPayload** size length (M) is given by the following table for both dwell time
1223 configurations: No Limit and 400ms. It is derived from the PHY layer limitation depending on
1224 the effective modulation rate used taking into account a possible repeater encapsulation layer.

1225

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	

1226

Table 54: AS923 maximum payload size

1227 If the end-device will never operate with a repeater then the maximum MAC payload length
1228 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	

1229

Table 55: AS923 maximum payload size (not repeater compatible)

1230 The maximum application payload length in the absence of the optional **FOpt** control field (N)
1231 is eight bytes lower than the MACPayload value in the above table. The value of N might be
1232 smaller if the **FOpt** field is not empty.
1233

1234 2.8.7 AS923 Receive windows

1235 The RX1 receive window uses the same channel than the preceding uplink. The data rate is
1236 a function of the uplink data rate and the RX1DROffset as following:

1237 Downstream data rate in RX1 slot = $MIN(5, MAX(\text{MinDR}, \text{Upstream data rate} -$
1238 $\text{Effective_RX1DROffset}))$

1239 MinDR depends on the DownlinkDwellTime bit sent to the device in the **TxParamSetupReq**
1240 command:

- 1241 • Case DownlinkDwellTime = 0 (No limit): MinDR = 0
- 1242 • Case DownlinkDwellTime = 1 (400ms): MinDR = 2

1243 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

1244 Values in the [6:7] range allow setting the Downstream RX1 data rate higher than Upstream
1245 data rate.

1246 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
1247 923.2 MHz / DR2 (SF10/125KHz).

1248

1249 2.8.8 AS923 Class B beacon and default downlink channel

1250 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

1251

Table 56 : AS923 beacon settings

1252 The beacon frame content is:

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

1253 The beacon default broadcast frequency is 923.4MHz.

1254 The class B default downlink pingSlot frequency is 923.4MHz

1255

1256 2.8.9 AS923 Default Settings

1257 The following parameters are recommended values for the AS923MHz band.

1258	RECEIVE_DELAY1	1 s
1259	RECEIVE_DELAY2	2 s (MUST be RECEIVE_DELAY1 + 1s)
1260	JOIN_ACCEPT_DELAY1	5 s
1261	JOIN_ACCEPT_DELAY2	6 s
1262	MAX_FCNT_GAP	16384
1263	ADR_ACK_LIMIT	64
1264	ADR_ACK_DELAY	32
1265	ACK_TIMEOUT	2 +/- 1 s (random delay between 1 and 3 seconds)

1266 If the actual parameter values implemented in the end-device are different from those default
 1267 values (for example the end-device uses a longer RECEIVE_DELAY1 and
 1268 RECEIVE_DELAY2 latency), those parameters MUST be communicated to the network
 1269 server using an out-of-band channel during the end-device commissioning process. The
 1270 network server may not accept parameters different from those default values.

1271 **2.9 KR920-923MHz ISM Band**

 1272 **2.9.1 KR920-923 Preamble Format**

1273 The following synchronization words SHOULD be used:

1274

Modulation	Sync word	Preamble length
LORA	0x34	8 symbols

 1275 **2.9.2 KR920-923 ISM Band channel frequencies**

 1276 The center frequency, bandwidth and maximum EIRP output power for the South Korea
 1277 RFID/USN frequency band are already defined by Korean Government. Basically Korean
 1278 Government allocated LPWA based IoT network frequency band from 920.9 to 923.3MHz.

1279

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

1280

Table 57: KR920-923 Center frequency, bandwidth, maximum EIRP output power table

 1281 The three following default channels (922.1, 922.3 and 922.5MHz / DR0 to DR5) determined
 1282 by the network operator from the set of available channels as defined by the South Korean
 1283 regulation MUST be implemented in every KR920-923MHz end-device, and cannot be
 1284 alterable by the **NewChannelReq** command. Those channels are the minimum set that all
 1285 network gateways SHOULD always be listening on to guarantee a minimal common channel
 1286 set between end-devices and network gateways.

1287

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

1288

Table 58: KR920-923 default channels

 1289 In order to access the physical medium the South Korea regulations impose some restrictions.
 1290 The South Korea regulations allow the choice of using either a duty-cycle limitation or a so-
 1291 called Listen Before Talk Adaptive Frequency Agility (LBT AFA) transmissions management.
 1292 The current LoRaWAN specification for the KR920-923 ISM band exclusively uses LBT
 1293 channel access rule to maximize MACPayload size length and comply with the South Korea
 1294 regulations.

1295 KR920-923MHz ISM band end-devices SHALL use the following default parameters

- 1296 • Default EIRP output power for end-device(920.9~921.9MHz): 10 dBm
- 1297 • Default EIRP output power for end-device(922.1~923.3MHz): 14 dBm
- 1298 • Default EIRP output power for gateway: 23 dBm

1299 KR920-923MHz end-devices SHALL be capable of operating in the 920 to 923MHz frequency
 1300 band and SHALL feature a channel data structure to store the parameters of at least 16
 1301 channels. A channel data structure corresponds to a frequency and a set of data rates usable
 1302 on this frequency.

1303 The following table gives the list of frequencies that SHALL be used by end-devices to
 1304 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

1305 [Table 59: KR920-923 JoinReq Channel List](#)

1306 2.9.3 KR920-923 Data Rate and End-device Output Power encoding

1307 There is no dwell time limitation for the KR920-923 PHY layer. The *TxParamSetupReq* MAC
 1308 command is not implemented by KR920-923 devices.

1309 The following encoding is used for Data Rate (DR), and EIRP Output Power (TXPower) in the
 1310 KR920-923 band:

1311

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	

1312 [Table 60: KR920-923 TX Data rate table](#)

1313

1314

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

1315 [Table 61: KR920-923 TX power table](#)

1316

1317 EIRP refers to the Equivalent Isotropically Radiated Power, which is the radiated output
 1318 power referenced to an isotropic antenna radiating power equally in all directions and whose
 1319 gain is expressed in dBi.

1320

1321 By default MaxEIRP is considered to be +14dBm. If the end-device cannot achieve 14dBm
 1322 EIRP, the MaxEIRP SHOULD be communicated to the network server using an out-of-band
 1323 channel during the end-device commissioning process.

1324 When the device transmits in a channel whose frequency is <922MHz, the transmit power
 1325 SHALL be limited to +10dBm EIRP even if the current transmit power level set by the
 1326 network server is higher.

1327 2.9.4 KR920-923 JoinAccept CFList

1328 The KR920-923 ISM band LoRaWAN implements an optional **channel frequency list** (CFList)
 1329 of 16 octets in the JoinAccept message.

1330 In this case the CFList is a list of five channel frequencies for the channels three to seven
 1331 whereby each frequency is encoded as a 24 bits unsigned integer (three octets). All these
 1332 channels are usable for DR0 to DR5 125kHz LoRa modulation.

1333 The list of frequencies is followed by a single CFListType octet for a total of 16 octets. The
 1334 CFListType SHALL be equal to zero (0) to indicate that the CFList contains a list of
 1335 frequencies.

1336

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

1337 The actual channel frequency in Hz is 100 x frequency whereby values representing
 1338 frequencies below 100 MHz are reserved for future use. This allows setting the frequency of
 1339 a channel anywhere between 100 MHz to 1.67 GHz in 100 Hz steps. Unused channels have
 1340 a frequency value of 0. The **CFList** is optional and its presence can be detected by the length
 1341 of the join-accept message. If present, the **CFList** replaces all the previous channels stored
 1342 in the end-device apart from the three default channels. The newly defined channels are
 1343 immediately enabled and usable by the end-device for communication.

1344 2.9.5 KR920-923 LinkAdrReq command

1345 The KR920-923 LoRaWAN only supports a maximum of 16 channels. When **ChMaskCntl**
 1346 field is 0 the ChMask field individually enables/disables each of the 16 channels.

1347

ChMaskCntl	ChMask applies to
0	Channels 0 to 15
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 62: KR920-923 ChMaskCntl value table

1348
 1349

1350 If the ChMaskCntl field value is one of values meaning RFU, the end-device SHOULD reject
 1351 the command and unset the “**Channel mask ACK**” bit in its response.

1352 2.9.6 KR920-923 Maximum payload size

1353 The maximum **MACPayload** size length (M) is given by the following table for the regulation
 1354 of dwell time; less than 4 sec with LBT. It is derived from limitation of the PHY layer depending
 1355 on the effective modulation rate used taking into account a possible repeater encapsulation
 1356 layer. The maximum application payload length in the absence of the optional **FOpt** control
 1357 field (N) is also given for information only. The value of N might be smaller if the **FOpt** field is
 1358 not empty:

1359

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 63: KR920-923 maximum payload size

1360

1361 If the end-device will never operate with a repeater then the maximum application payload
 1362 length in the absence of the optional **FOpt** control field SHOULD be:

1363

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

1364

1365

1366 2.9.7 KR920-923 Receive windows

1367 The RX1 receive window uses the same channel than the preceding uplink. The data rate is
 1368 a function of the uplink data rate and the RX1DROffset as given by the following table. The
 1369 allowed values for RX1DROffset are in the [0:5] range. Values in the [6:7] range are reserved
 1370 for future use.

1371

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

1372 **Table 65 : KR920-923 downlink RX1 data rate mapping**

1373 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
 1374 921.90MHz / DR0 (SF12, 125 kHz).

1375 **2.9.8 KR920-923 Class B beacon and default downlink channel**

1376 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

1377 **Table 66 : KR920-923 beacon settings**

1378

1379 The beacon frame content is:

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

1380 The beacon default broadcast frequency is 923.1MHz.

1381 The class B default downlink pingSlot frequency is 923.1MHz

1382

1383 **2.9.9 KR920-923 Default Settings**

1384 The following parameters are recommended values for the KR920-923Mhz band.

1385	RECEIVE_DELAY1	1 s
1386	RECEIVE_DELAY2	2 s (MUST be RECEIVE_DELAY1 + 1s)
1387	JOIN_ACCEPT_DELAY1	5 s
1388	JOIN_ACCEPT_DELAY2	6 s
1389	MAX_FCNT_GAP	16384
1390	ADR_ACK_LIMIT	64
1391	ADR_ACK_DELAY	32
1392	ACK_TIMEOUT	2 +/- 1 s (random delay between 1 and 3 seconds)

1393 If the actual parameter values implemented in the end-device are different from those default
 1394 values (for example the end-device uses a longer RECEIVE_DELAY1 and
 1395 RECEIVE_DELAY2 latency), those parameters MUST be communicated to the network
 1396 server using an out-of-band channel during the end-device commissioning process. The
 1397 network server may not accept parameters different from those default values.
 1398

1399 **2.10 IN865-867 MHz ISM Band**

 1400 **2.10.1 IN865-867 Preamble Format**

1401 The following synchronization words SHOULD be used:

1402

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

1403

Table 67: IN865-867 synch words

 1404 **2.10.2 IN865-867 ISM Band channel frequencies**

1405 This section applies to the Indian sub-continent.

 1406 The network channels can be freely attributed by the network operator. However the three
 1407 following default channels MUST be implemented in every India 865-867MHz end-device.
 1408 Those channels are the minimum set that all network gateways SHOULD always be listening
 1409 on.

1410

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

1411

Table 68: IN865-867 default channels

 1412 End-devices SHALL be capable of operating in the 865 to 867 MHz frequency band and
 1413 should feature a channel data structure to store the parameters of at least 16 channels. A
 1414 channel data structure corresponds to a frequency and a set of data rates usable on this
 1415 frequency.

 1416 The first three channels correspond to 865.0625, 865.4025, and 865.985 MHz / DR0 to DR5
 1417 and MUST be implemented in every end-device. Those default channels cannot be modified
 1418 through the **NewChannelReq** command and guarantee a minimal common channel set
 1419 between end-devices and network gateways.

 1420 The following table gives the list of frequencies that SHALL be used by end-devices to
 1421 broadcast the JoinReq message. The JoinReq message transmit duty-cycle SHALL follow the
 1422 rules described in chapter "Retransmissions back-off" of the LoRaWAN specification
 1423 document.

1424

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

1425

Table 69: IN865-867 JoinReq Channel List

 1426 **2.10.3 IN865-867 Data Rate and End-device Output Power Encoding**

 1427 There is no dwell time or duty-cycle limitation for the INDIA 865-867 PHY layer. The
 1428 **TxParamSetupReq** MAC command is not implemented by INDIA 865-867 devices.

 1429 The following encoding is used for Data Rate (DR) and End-device Output Power (TXPower)
 1430 in the INDIA 865-867 band:

1431

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 70: IN865-867 TX Data rate table

1432

1433

1434

1435

1436

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

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 71: IN865-867 TxPower table

1437

1438

1439

1440

1441

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

1442

1443

1444

1445

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

1446

2.10.4 IN865-867 JoinAccept CFList

1447

1448

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

1449

1450

1451

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

1452 The list of frequencies is followed by a single CFListType octet for a total of 16 octets. The
 1453 CFListType SHALL be equal to zero (0) to indicate that the CFList contains a list of
 1454 frequencies.

1455

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

1456 The actual channel frequency in Hz is 100 x frequency whereby values representing
 1457 frequencies below 100 MHz are reserved for future use. This allows setting the frequency of
 1458 a channel anywhere between 100 MHz to 1.67 GHz in 100 Hz steps. Unused channels have
 1459 a frequency value of 0. The **CFList** is optional and its presence can be detected by the length
 1460 of the join-accept message. If present, the **CFList** replaces all the previous channels stored
 1461 in the end-device apart from the three default channels. The newly defined channels are
 1462 immediately enabled and usable by the end-device for communication.

1463 2.10.5 IN865-867 LinkAdrReq command

1464 The INDIA 865-867 LoRaWAN only supports a maximum of 16 channels. When **ChMaskCntl**
 1465 field is 0 the ChMask field individually enables/disables each of the 16 channels.

1466

ChMaskCntl	ChMask applies to
0	Channels 0 to 15
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

1467

Table 72: IN865-867 ChMaskCntl value table

1468 If the ChMaskCntl field value is one of values meaning RFU, the end-device SHOULD reject
 1469 the command and unset the “**Channel mask ACK**” bit in its response.

1470 2.10.6 IN865-867 Maximum payload size

1471 The maximum **MACPayload** size length (*M*) is given by the following table. It is derived from
 1472 limitation of the PHY layer depending on the effective modulation rate used taking into account
 1473 a possible repeater encapsulation layer. The maximum application payload length in the
 1474 absence of the optional **FOpt** control field (*N*) is also given for information only. The value of
 1475 *N* might be smaller if the **FOpt** field is not empty:

1476

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	

1477

Table 73: IN865-867 maximum payload size

1478 If the end-device will never operate with a repeater then the maximum application payload
 1479 length in the absence of the optional **FOpt** control field SHOULD be:
 1480

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	

1481

Table 74 : IN865-867 maximum payload size (not repeater compatible)

1482 2.10.7 IN865-867 Receive windows

1483 The RX1 receive window uses the same channel than the preceding uplink. The data rate is
 1484 a function of the uplink data rate and the RX1DROffset as given by the following table. The
 1485 allowed values for RX1DROffset are in the [0:7] range. Values in the [6:7] range allow setting
 1486 the Downstream RX1 data rate higher than Upstream data rate.

1487 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

1488 Downstream data rate in RX1 slot = $MIN(5, MAX(0, \text{Upstream data rate} -$
 1489 $\text{Effective_RX1DROffset}))$

1490 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
 1491 866.550 MHz / DR2 (SF10, 125 kHz).

1492 2.10.8 IN865-867 Class B beacon and default downlink channel

1493 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

1494

1495 The beacon frame content is:

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

1496 The beacon default broadcast frequency is 866.550MHz.

1497 The class B default downlink pingSlot frequency is 866.550MHz

1498

1499 2.10.9 IN865-867 Default Settings

1500 The following parameters are recommended values for the INDIA 865-867MHz band.

1501

1502 RECEIVE_DELAY1 1 s

1503 RECEIVE_DELAY2 2 s (MUST be RECEIVE_DELAY1 + 1s)

1504 JOIN_ACCEPT_DELAY1 5 s

1505 JOIN_ACCEPT_DELAY2 6 s

1506 MAX_FCNT_GAP 16384

1507 ADR_ACK_LIMIT 64

1508 ADR_ACK_DELAY 32

1509 ACK_TIMEOUT 2 +/- 1 s (random delay between 1 and 3 seconds)

1510 If the actual parameter values implemented in the end-device are different from those default
1511 values (for example the end-device uses a longer RECEIVE_DELAY1 and
1512 RECEIVE_DELAY2 latency), those parameters MUST be communicated to the network
1513 server using an out-of-band channel during the end-device commissioning process. The
1514 network server may not accept parameters different from those default values.

1515

1516

1517

1518 **2.11 RU864-870 MHz ISM Band**

 1519 **2.11.1 RU864-870 Preamble Format**

1520 The following synchronization words SHOULD be used:

1521

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

1522

Table 75: RU864-870 synch words

 1523 **2.11.2 RU864-870 ISM Band channel frequencies**

 1524 The network channels can be freely attributed by the network operator in compliance with the
 1525 allowed sub-bands defined by the Russian regulation. However the two following default
 1526 channels MUST be implemented in every RU864-870 MHz end-device. Those channels are
 1527 the minimum set that all network gateways SHOULD always be listening on.

1528

Modulation	Bandwidth [kHz]	Channel Frequency [MHz]	FSK Bitrate or LoRa DR / Bitrate	Nb Channels	Duty cycle
LoRa	125	868.9 869.1	DR0 to DR5 / 0.3-5 kbps	2	<1%

1529

Table 76: RU864-870 default channels

 1530 RU864-870 MHz end-devices SHALL be capable of operating in the 864 to 870 MHz
 1531 frequency band and SHALL feature a channel data structure to store the parameters of at
 1532 least 8 channels. A channel data structure corresponds to a frequency and a set of data rates
 1533 usable on this frequency.

 1534 The first two channels correspond to 868.9 and 869.1 MHz / DR0 to DR5 and MUST be
 1535 implemented in every end-device. Those default channels cannot be modified through the
 1536 **NewChannelReq** command and guarantee a minimal common channel set between end-
 1537 devices and network gateways.

 1538 The following table gives the list of frequencies that SHALL be used by end-devices to
 1539 broadcast the JoinReq message. The JoinReq message transmit duty-cycle SHALL follow the
 1540 rules described in chapter "Retransmissions back-off" of the LoRaWAN specification
 1541 document.

1542

Modulation	Bandwidth [kHz]	Channel Frequency [MHz]	FSK Bitrate or LoRa DR / Bitrate	Nb Channels
LoRa	125	868.9 869.1	DR0 – DR5 / 0.3-5 kbps	2

1543

Table 77: RU864-870 JoinReq Channel List

 1544 **2.11.3 RU864-870 Data Rate and End-device Output Power encoding**

 1545 There is no dwell time limitation for the RU864-870 PHY layer. The *TxParamSetupReq* MAC
 1546 command is not implemented in RU864-870 devices.

 1547 The following encoding is used for Data Rate (DR) and End-device EIRP (TXPower) in the
 1548 RU864-870 band:

1549

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	

Table 78: RU864-870 TX Data rate table

1550

1551

 1552 EIRP² refers to the Equivalent Isotropically Radiated Power, which is the radiated output
 1553 power referenced to an isotropic antenna radiating power equally in all directions and whose
 1554 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

Table 79: RU864-870 TX power table

1555

1556

1557

1558

 1559 By default MaxEIRP is considered to be +16dBm. If the end-device cannot achieve +16dBm
 1560 EIRP, the Max EIRP SHOULD be communicated to the network server using an out-of-band
 1561 channel during the end-device commissioning process.

1562

 1563 **2.11.4 RU864-870 JoinAccept CFList**

1564

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

1565 The RU 864-870 ISM band LoRaWAN implements an optional **channel frequency list**
 1566 (CFList) of 16 octets in the JoinAccept message.

1567 In this case the CFList is a list of five channel frequencies for the channels two to six whereby
 1568 each frequency is encoded as a 24 bits unsigned integer (three octets). All these channels are
 1569 usable for DR0 to DR5 125kHz LoRa modulation. The list of frequencies is followed by a single
 1570 CFListType octet for a total of 16 octets. The CFListType SHALL be equal to zero (0) to
 1571 indicate that the CFList contains a list of frequencies.

1572

Size (bytes)	3	3	3	3	3	1
CFList	Freq Ch2	Freq Ch3	Freq Ch4	Freq Ch5	Freq Ch6	CFListType

1573 The actual channel frequency in Hz is 100 x frequency whereby values representing
 1574 frequencies below 100 MHz are reserved for future use. This allows setting the frequency of
 1575 a channel anywhere between 100 MHz to 1.67 GHz in 100 Hz steps. Unused channels have
 1576 a frequency value of 0. The **CFList** is optional and its presence can be detected by the length
 1577 of the join-accept message. If present, the **CFList** replaces all the previous channels stored
 1578 in the end-device apart from the two default channels. The newly defined channels are
 1579 immediately enabled and usable by the end-device for communication.

1580 **2.11.5 RU864-870 LinkAdrReq command**

1581 The RU864-870 LoRaWAN only supports a maximum of 16 channels. When **ChMaskCntl**
 1582 field is 0 the ChMask field individually enables/disables each of the 16 channels.
 1583

ChMaskCntl	ChMask applies to
0	Channels 0 to 15
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

1584 **Table 80: RU864-870 ChMaskCntl value table**

1585 If the ChMaskCntl field value is one of values meaning RFU, the end-device SHOULD reject
 1586 the command and unset the “**Channel mask ACK**” bit in its response.

1587 **2.11.6 RU864-870 Maximum payload size**

1588 The maximum **MACPayload** size length (*M*) is given by the following table. It is derived from
 1589 limitation of the PHY layer depending on the effective modulation rate used taking into account
 1590 a possible repeater encapsulation layer. The maximum application payload length in the
 1591 absence of the optional **FOpt** control field (*N*) is also given for information only. The value of
 1592 *N* might be smaller if the **FOpt** field is not empty:
 1593

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	

1594

Table 81: RU864-870 maximum payload size

1595 If the end-device will never operate with a repeater then the maximum application payload
 1596 length in the absence of the optional **FOpt** control field SHOULD be:
 1597

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	

1598

Table 82 : RU864-870 maximum payload size (not repeater compatible)

1599 2.11.7 RU864-870 Receive windows

1600 The RX1 receive window uses the same channel as the preceding uplink. The data rate is a
 1601 function of the uplink data rate and the RX1DROffset as given by the following table. The
 1602 allowed values for RX1DROffset are in the [0:5] range. Values in the [6:7] range are reserved
 1603 for future use.
 1604

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

1605

Table 83: RU864-870 downlink RX1 data rate mapping

1606

1607 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
 1608 869.1MHz / DR0 (SF12, 125 kHz)

1609

1610 2.11.8 RU864-870 Class B beacon and default downlink channel

1611 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

1612

Table 84: RU864-870 beacon settings

1613

1614 The beacon frame content is:

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

1615 The beacon default broadcast frequency is 869.1 MHz.

1616 The class B default downlink pingSlot frequency is 868.9 MHz.

1617

1618 2.11.9 RU864-870 Default Settings

1619 The following parameters are recommended values for the RU864-870 MHz band.

1620	RECEIVE_DELAY1	1 s
1621	RECEIVE_DELAY2	2 s (MUST be RECEIVE_DELAY1 + 1s)
1622	JOIN_ACCEPT_DELAY1	5 s
1623	JOIN_ACCEPT_DELAY2	6 s
1624	MAX_FCNT_GAP	16384
1625	ADR_ACK_LIMIT	64
1626	ADR_ACK_DELAY	32
1627	ACK_TIMEOUT	2 +/- 1 s (random delay between 1 and 3 seconds)

1628 If the actual parameter values implemented in the end-device are different from those default
 1629 values (for example the end-device uses a longer RECEIVE_DELAY1 and
 1630 RECEIVE_DELAY2 latency), those parameters MUST be communicated to the network
 1631 server using an out-of-band channel during the end-device commissioning process. The
 1632 network server may not accept parameters different from those default values.

1633

1634

1635 3 Revisions**1636 3.1 Revision A**

- 1637 • Initial 1.1 revision, the regional parameters were extracted from the LoRaWANv1.0.2
- 1638 revision B
- 1639 • Modified meaning of ChMaskCntl=5 for the US900 region and AU900 (TC11
- 1640 CR1274)
- 1641 • DR=15 and TXPower=15 are now reserved for all regions , meaning is defined in
- 1642 LoRaWAN1.1
- 1643 • Added Latin America draft language
- 1644 • Added Russia draft language
- 1645 • Fixed AU beacon data rate
- 1646 • General cleanup of table names, etc.

1647 3.2 Revision B

- 1648 • Moved to Revision B in anticipation of next release
- 1649 • First pass at standardizing regional names using standard country 2 letter
- 1650 abbreviations where applicable
- 1651 • First pass at capitalizing all normative text
- 1652 • Added statement to require LoRa devices to always act in compliance with local rules
- 1653 and regulations.
- 1654 • Added section 1.1 Conventions
- 1655 • Added Country to channel plan cross reference table
- 1656 • Updated as per LoRaWANv1.1 CR TC19.00002.000.20170614
- 1657 • Updated AS923 JoinReq data rates to reflect a range of DR2-DR5
- 1658 • Added in Region Names for use by Back-End specification as per CR
- 1659 TC19.00016.001
- 1660 • Added changes as per CR TC20 00006.001
- 1661

1662 **4 Bibliography**

1663 **4.1 References**

1664

1665 [LORAWAN] LoRaWAN Specification, V1.1, the LoRa Alliance, May 2017.

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