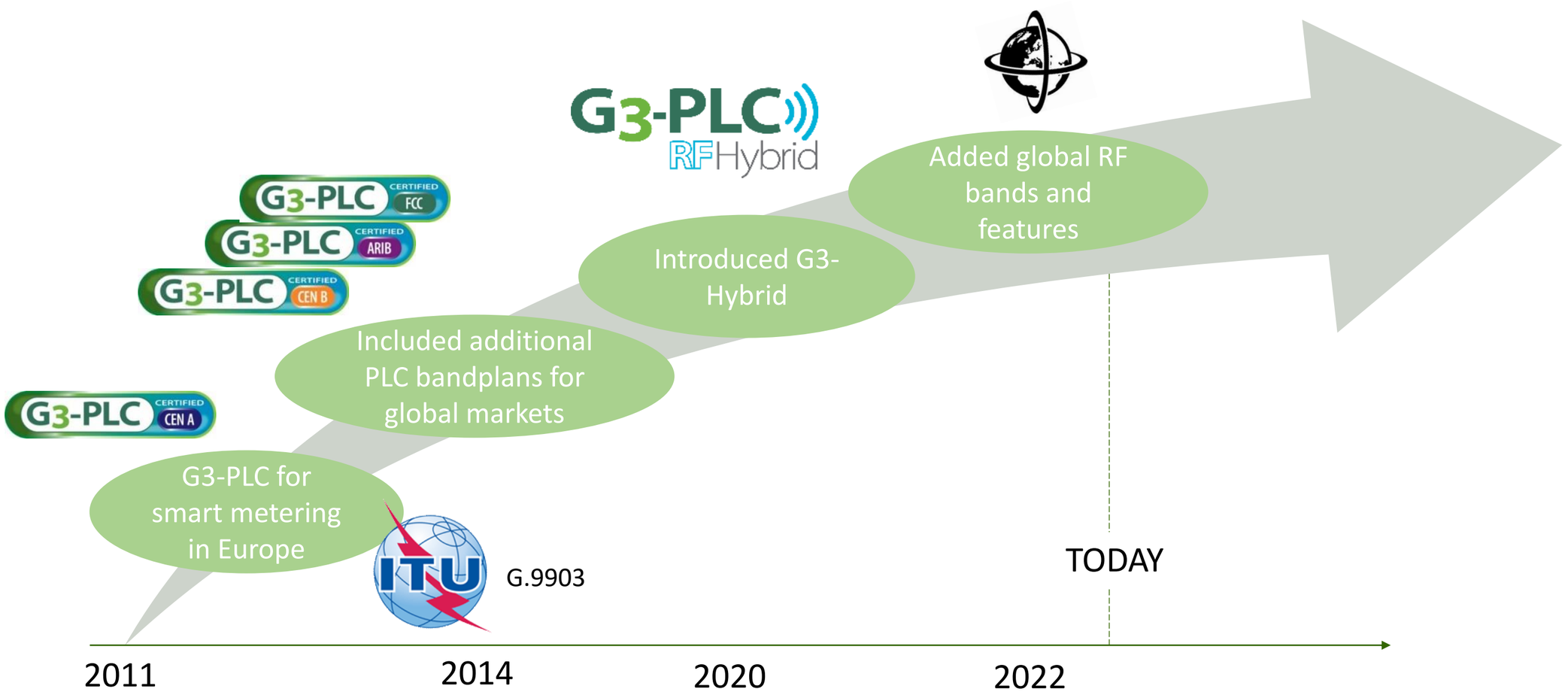

How G3-PLC Hybrid addresses global RF regulatory requirements
G3-PLC CERTIFIED CEN A HYB
G3-PLC CERTIFIED CEN B HYB
G3-PLC CERTIFIED FCC HYB
G3-PLC CERTIFIED ARIB HYB

Welcome to today's Webinar!

How G3-PLC Hybrid addresses global RF regulatory requirements

G3-PLC Alliance
November 16th, 2022

The evolution of G3-PLC



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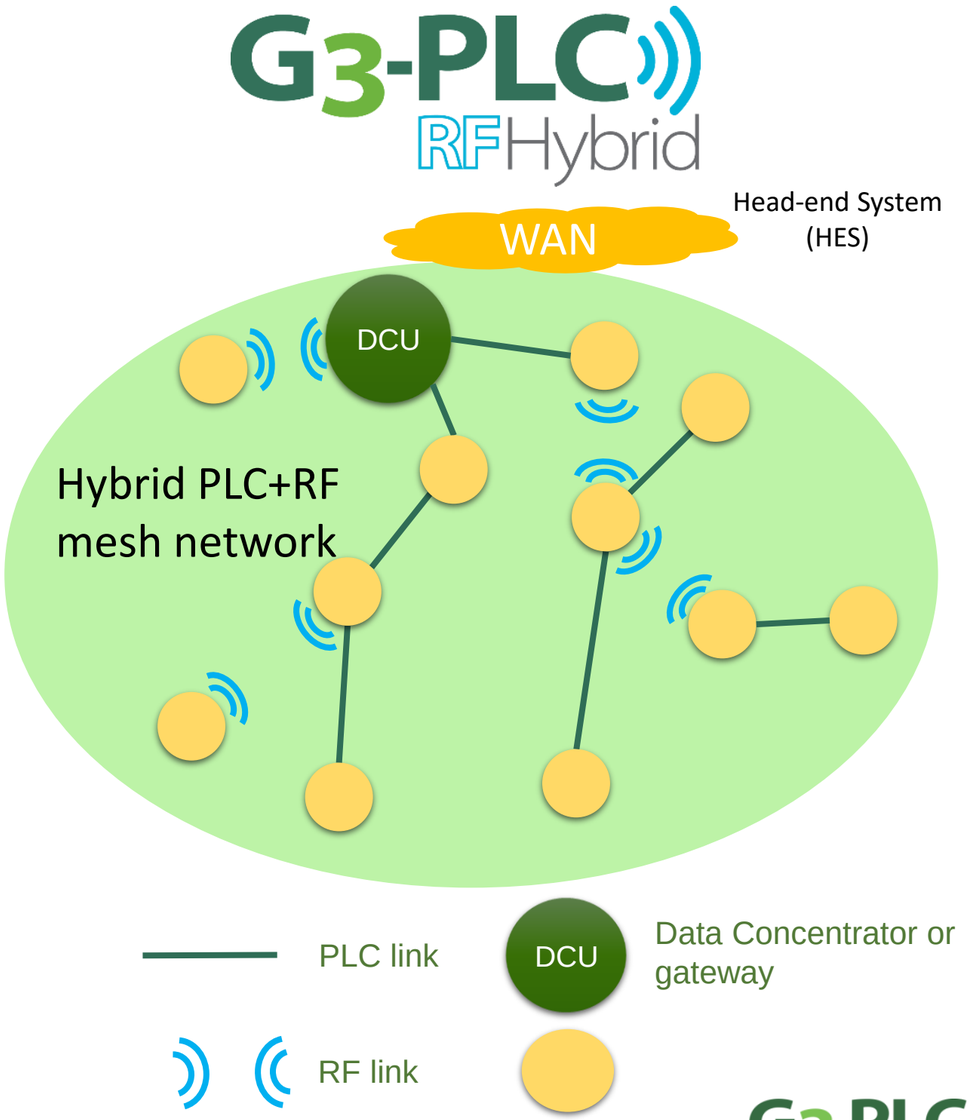
What is PLC+RF hybrid communication?

- Combines PLC and RF communication in one single solution
- Each device can use PLC as well as RF for communication
- Automatic medium selection
- Certified platforms and products by G3-PLC Alliance



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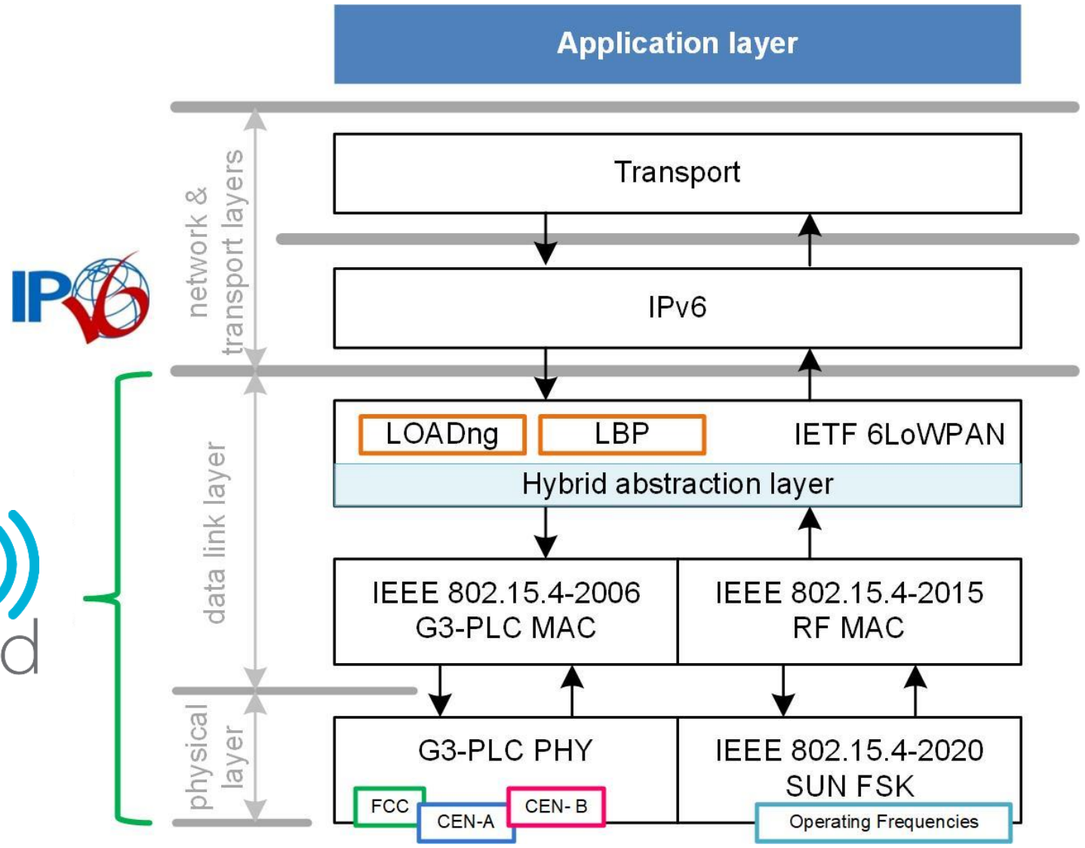
The G3-Hybrid: a *single* solution based on open standards

Unified G3-Hybrid PLC&RF protocol stack



- Unifies wired PLC and wireless RF communication
- One, seamlessly managed network for both media
- The hybrid protocol stack is built using open standards IEEE 802.15.4-2020 in addition to the existing G3-PLC protocol
- Switching between PLC and RF is decided above the hybrid abstraction layer

Today's presenters

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Regulatory & Advisory Working Group

G3-PLC Alliance

Agenda

1. Introduction

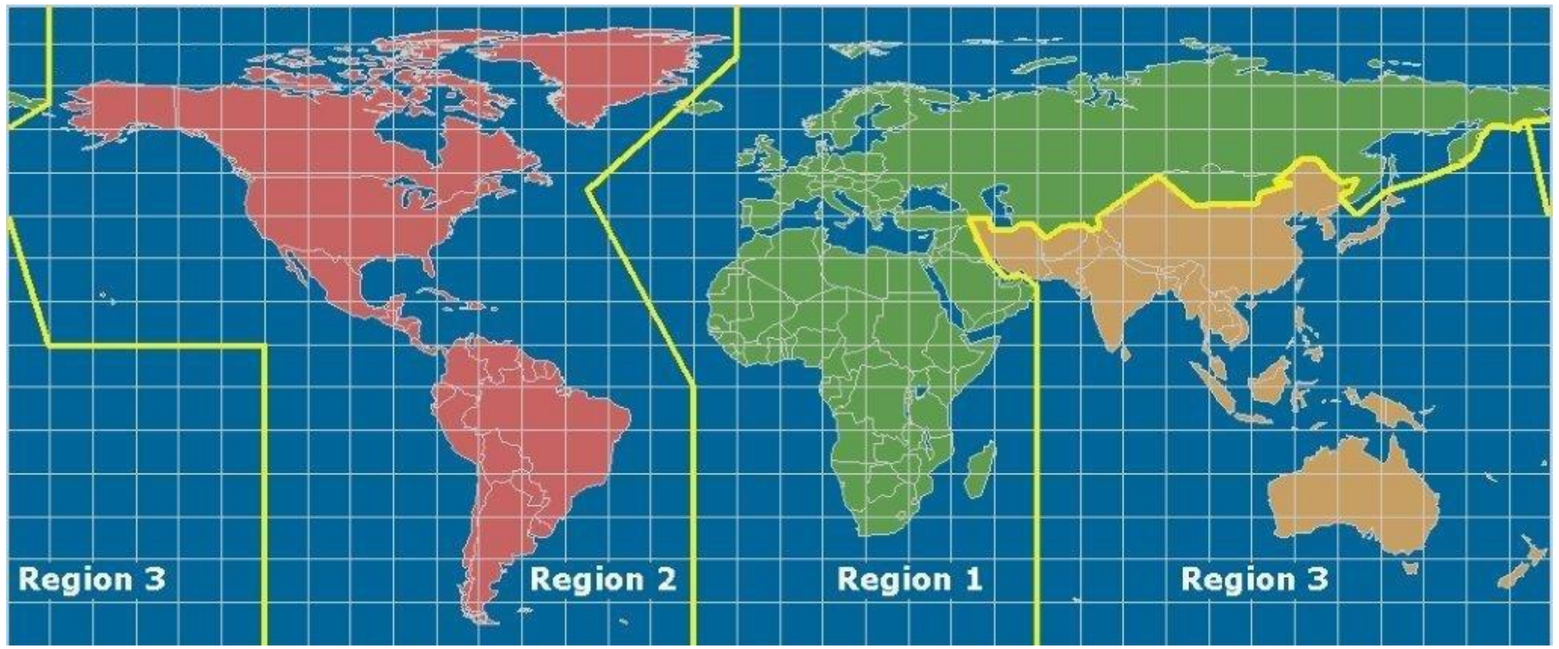
2. **Supported bands and modulations**

3. Regulatory constraints in different regions around the world
    1. Regulatory Checklist and G3 Alliance documents
    2. Regional requirements (Europe, Asia, Americas)
    3. Dedicated mechanisms (Duty Cycle handling, Adaptive Power Control and Frequency Hopping)

4. Conclusion & Questions

G3 PLC-RF Hybrid : Regional regulations

- The world is split in 3 regions according to the ITU (International Telecommunication Union):



- **Region 1:** Europe, Africa, the Commonwealth of Independent States, Mongolia, and the Middle East. And west of the Persian Gulf, including Iraq.
- **Region 2:** Americas including Greenland, and some of the eastern Pacific Islands.
- **Region 3:** Most of eastern Asian countries, Iran, and most of Oceania.

G3 PLC-RF Hybrid : 802.15.4 frequency bands definition

- The IEEE 802.15.4-2020 defines a set of frequency bands to address various regions.
- Those are informative only.
- Not listed country: can use an already defined band with the proper restrictions (using channel masking for instance).
- Note that when the frequency band of one region is included into one another, the support of that band is straightforward by using the appropriated channel mask (for instance 915-b is a subset of 915-a).

Band desig-nation MHz IEEE 802.15.4 (Table 10-1)	Frequency band (MHz)	Region (informative only)	Local requirement met by G3-PLC Hybrid
863	863-870	**Europe**	✓
866	865-867	**India**	✓
867	866-869	**Singapore**	Under investigation in WS4
870	870-876	**Europe**	✓
915	902-928	**North America**	✓
915-a	902-928 (alt.)	**North America & Mexico**	✓
915-b	902-907.5 & 915-928	**Brazil**	✓
915-c	915-928	**Australia & New Zealand**	✓
915-d	915-921	**Europe**	Under investigation in WS4
915-e	915-918	**Philippines**	Under investigation in WS4
917	917-923.5	**Korea**	Under investigation in WS4
919	919-923	**Malaysia**	✓
920	920-928	**Japan**	✓
920-a	920.5-924.5	**China**	Under investigation in WS4
920-b	920-925	**Hong Kong, Singapore, Thailand, Vietnam**	✓

Definition of the frequency bands (extracted from clause 19.3.1): **BAND DESIGNATION doesn't formally correspond to a dedicated region, only to an RF spectrum band.**

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G3 PLC-RF Hybrid : RF PHY – 863 & 915MHz bands examples

- For each frequency band, the IEEE 802.15.4-2020 defines several modes corresponding to different radio configuration based on the modulation index and the data rate.
- The ITU 9903 selected at least 2 modes for each bands, for « low » and « high » data rate applications.

Clause	Title and remarks/modifications	Statement
19.3.1	General – At least one of the following frequency bands and operating modes shall be supported: – 863 MHz, mode #1 – 866 MHz, mode #1 – 870 MHz, mode #1 – 915 MHz, mode #1 – 915-a MHz, mode #1 – 915-b MHz, mode #1 – 915-c MHz, mode #1 – 919 MHz, mode #1 – 920 MHz, mode #1 – 920-b MHz, mode #1 – The following operating modes may be supported for the frequency band for which operating mode #1 is already available: – 863 MHz, mode #2 – 866 MHz, mode #2 – 870 MHz, mode #2 – 915 MHz, mode #3 – 915-a MHz, mode #4 – 915-b MHz, mode #4 – 915-c MHz, mode #4 – 919 MHz, mode #4 – 920 MHz, mode #6 (Note: Mode #6 is defined in [IEEE 802.15.4aa-2022]) – 920-b MHz, mode #4 – The operating mode shall be administratively configured	S

"low" data rate

"high" data rate

Extract from ITU 9903 (2022) – Amd. 2

Modes #1, #2 and #3 as defined in the IEEE 802.15.4:

Frequency band (MHz)	Operating Mode	datarate (kbps)	modulation	modulation index	channel spacing (kHz)	frequency/inner deviation (kHz)
863	1	50	2-FSK	0,5	100	12,5
	2	100	2-FSK	0,5	200	25
	3	150	2-FSK	0,5	200	37,5

Frequency band (MHz)	Operating Mode	datarate (kbps)	modulation	modulation index	channel spacing (kHz)	frequency/inner deviation (kHz)
915	1	50	2-FSK	1	200	25
	2	150	2-FSK	0,5	400	37,5
	3	200	2-FSK	0,5	400	50

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    1. **Regulatory Checklist and G3 Alliance documents**
    2. **Regional requirements (Europe, Asia, Americas)**
    3. **Dedicated mechanisms (Duty Cycle handling, Adaptive Power Control and Frequency Hopping)**

4. Conclusion & Questions

G3 PLC-RF Hybrid : Regional regulations

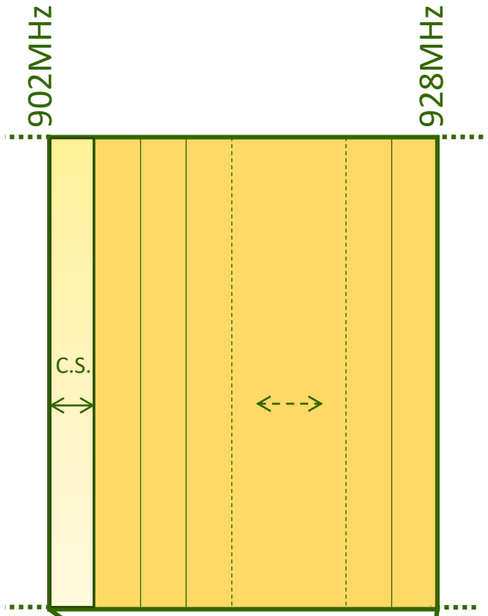
- **IEEE 802.15.4 - Clause 19.6.2** Regulatory compliance :

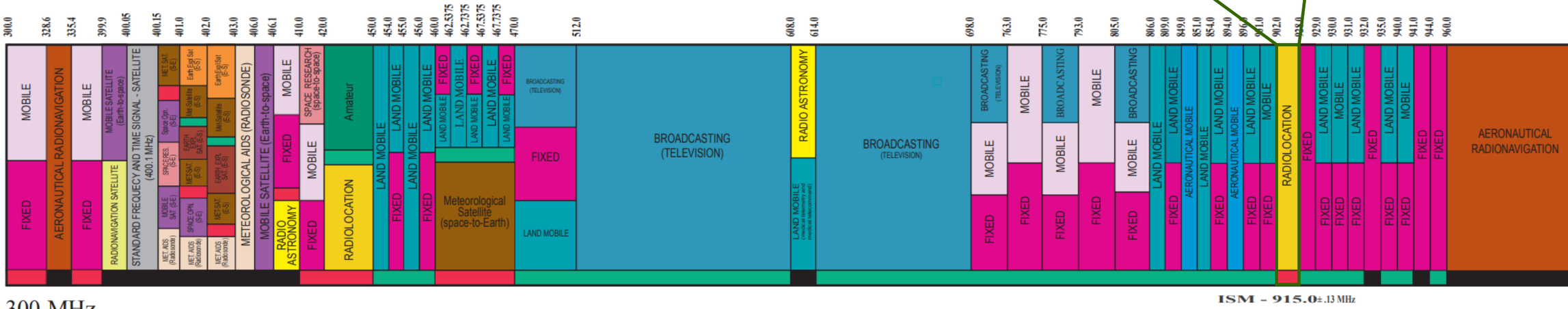
“It is the responsibility of the implementer to verify and ensure that the device is in compliance with all regulatory requirements in the geographic region where the device is deployed or sold. Conformance with this standard does not guarantee compliance with the relevant regulatory requirements that may apply”.

- **Main regional regulations:**
  - **Europe** : ETSI EN 300 220 & EN 303 204
  - **US and Middle/South America** : FCC: CFR-2009 § 15.249 and CFR-2013 § 15.247
  - **Japan** : Radio Law, Category Telemeter, Telecontrol 920.x to 928.0MHz (20mW, 1 or 2 channels)
  - **China**: SRRC
- **Other regions**: specific regulation applies. The official regional regulatory administration must be contacted if the requirements are not available. The support of a new regulation must be studied by WS4.
- **The G3 Hybrid specification** has anticipated the support of regional regulations, defining some parameters the manufacturer can configure to adapt to the targeted region/market.

Regional regulations – Band usage:

- How to use the ISM/SRD license-free band ?
  - Example of the RF band plan in the US:
    - ISM band : 902Mhz to 928MHz
    - Channel spacing (C.S.) as defined by IEEE 802.15.4-2020:
      - **Mode #1:** 200kHz -> 129 channels
      - **Mode #3:** 400kHz -> 64 channels
  - Regulation defines constraints on the ISM band usage to limit the channels occupancy : Duty cycle, Listen before talk and Frequency Hopping.





[january_2016_spectrum_wall_chart.pdf (doc.gov)]

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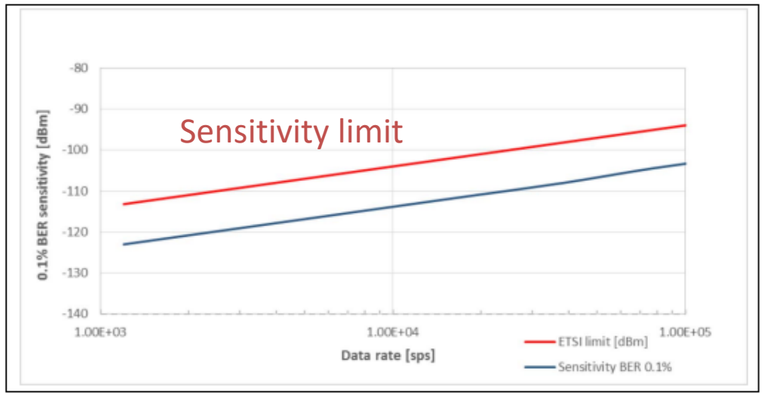
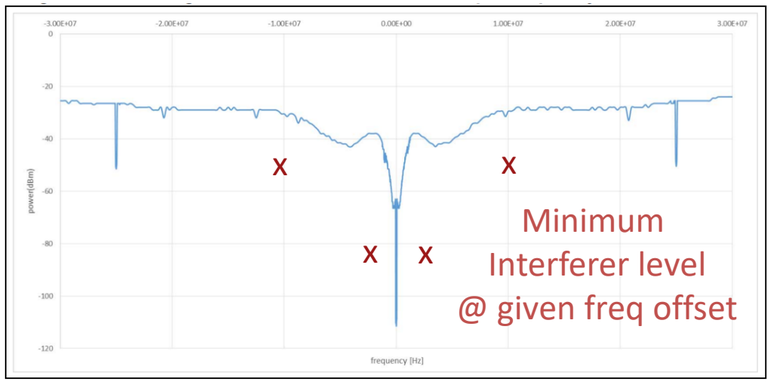
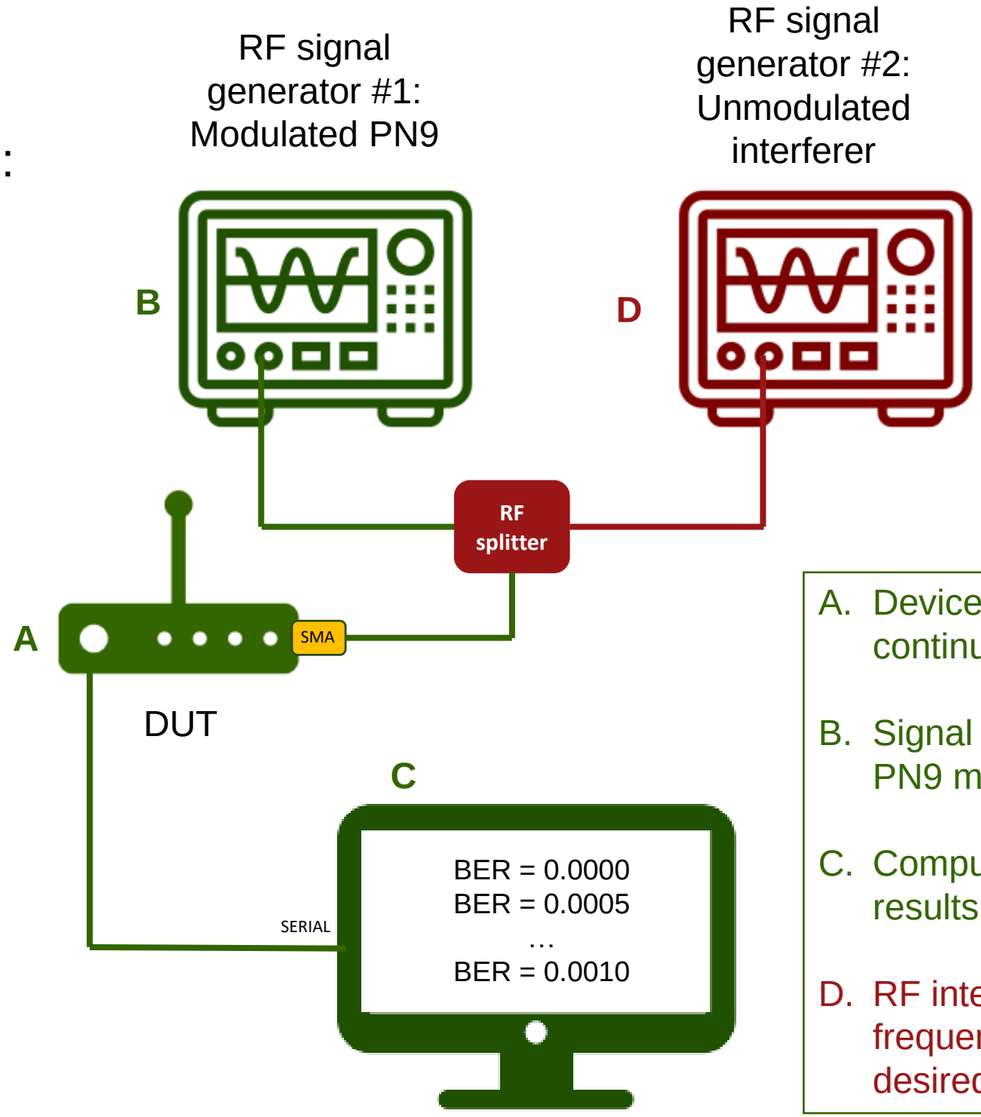
Regional regulations – RX characteristics (transceiver related):

- Main receiver requirements (Regions 1 and 3):
  - **Receiver sensitivity**



  - **Receiver interference rejection**





A. Device Under test in continuous reception.

B. Signal generator sending PN9 modulated signal.

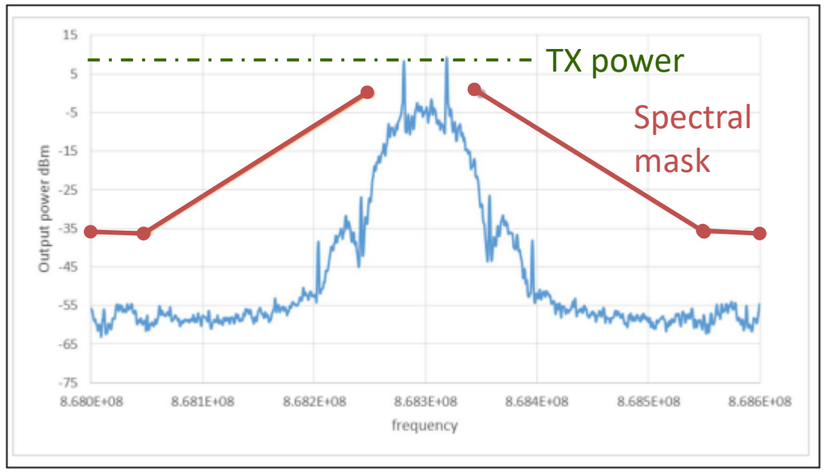
C. Computer to output the test results.

D. RF interferer at different frequency offsets from desired frequency.

Snapshots from:
https://www.st.com/resource/en/application_note/an4962-s2lp-etsi-compliance-test-at-868-mhz-srd-band-stmicroelectronics.pdf

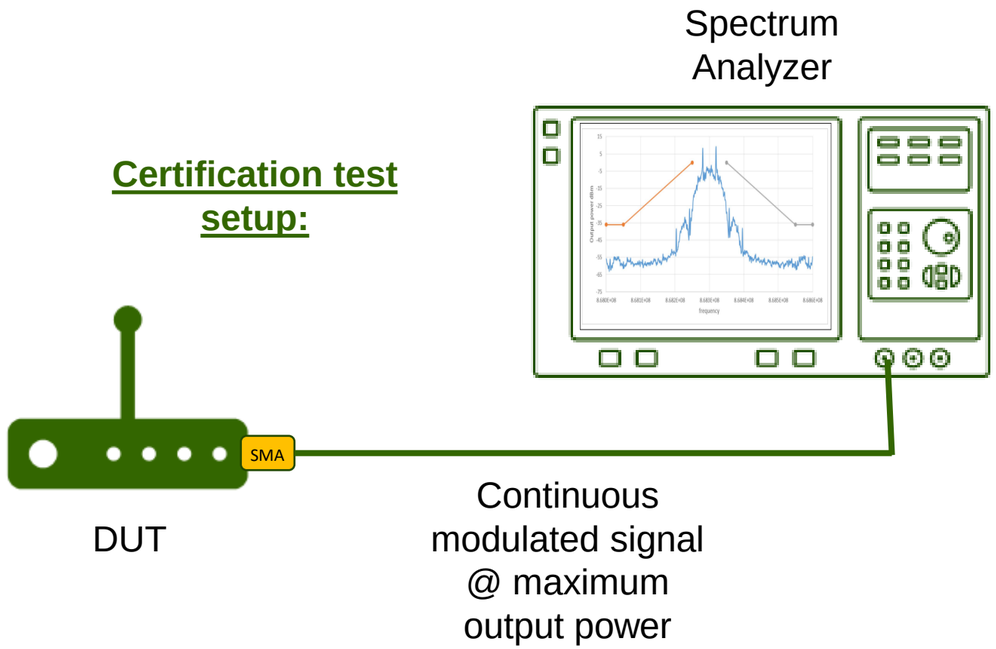
Regional regulations – TX characteristics (transceiver related):

- Main transmitter requirements (all regions):
  - **Transmit spectral mask**
  - **Transmit power**
  - **Spurious Emissions (Note: Interference created during transmission)**



  - Frequency tolerance (frequency deviation, zero crossing, radio frequency).
  - Channel switch time

Certification test setup:



Snapshots from:
https://www.st.com/resource/en/application_note/an4962-s2lp-etsi-compliance-test-at-868-mhz-srd-band-stmicroelectronics.pdf

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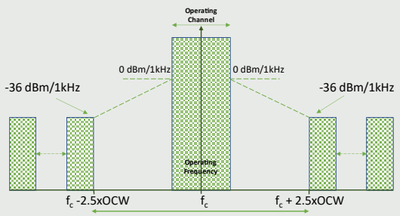
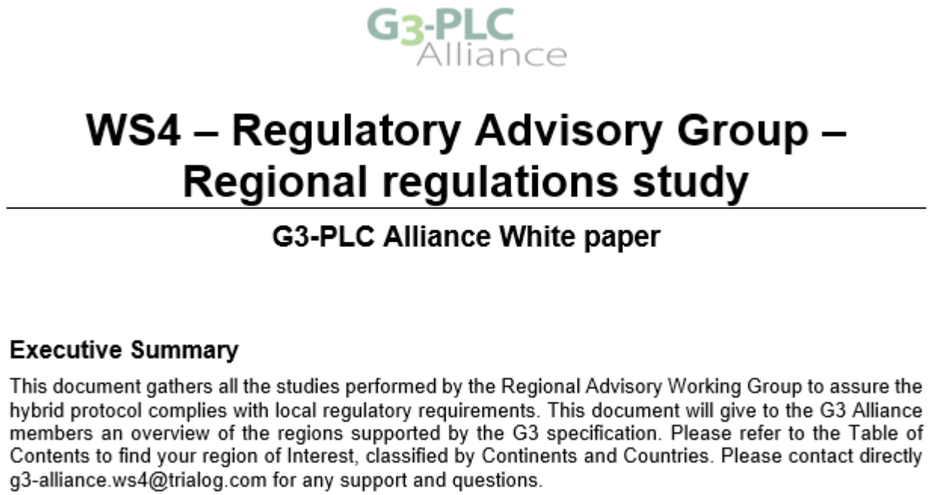
Regional regulations – checklist example:

- G3 PLC/RF Hybrid - New Regional regulation addition - Checklist

	IEEE 802.15.4-2020	ETSI EN 300 220-2 V3.2.1 (2018-06) & ETSI EN 300 220-1 V3.1.1 (2017-02)	ETSI EN 303 204 V3.1.1 (2021-03)	Japan (Specified low-power radio stations)	Other countries
Transmitter Requirements					
• **Frequency deviation tolerance**	30%	Not specified	Not specified	Not specified	…
• **Zero crossing tolerance**	30%	Not specified	Not specified	Not specified	…
• **Radio frequency tolerance**	20ppm	Not specified	The smaller of: ±20 ppm ±10 % Nominal CS	20ppm	…
• **Channel switch time**	500µs	Not specified	Not specified	Not specified	…
• **Transmitter symbol rate**	+/-300ppm	Not specified	Not specified	Not specified	…
• **Transmit spectral mask**	Transmit spectral mask content: -25dB at +/-M1 = 1.5 x R x (1+h) -35dB at +/-M2 = 3 x R x (1 + h) with R: data rate and h: modulation index		same as ETSI EN 300 220-1 V3.3.1 but no limit for flow/high +/-400kHz	• 915 ~ fc-0.3MHz, -36dBm/100kHz fc+0.3 ~ 930MHz, -36dBm/100kHz (1 channel) • 915 ~ fc-0.4MHz, -36dBm/100kHz fc+0.4 ~ 930MHz, -36dBm/100kHz (2 channel)	…
• **Transmit power**	-3dBm min	• 869,4 MHz to 869,65 MHz : 500 mW (27dBm) • 869,7 MHz to 870 MHz : 5 mW (7dBm) • otherwise : 25 mW (1	500 mW (27dBm) APC	d deviation	…

Regional regulations – Whitepaper

- Checklists are included in the whitepaper ‘RF Regional regulations study’
- Study performed by the regulatory advisory group of the G3-PLC Alliance
- Whitepaper is available for all members from today on our website: https://g3-plc.com/g3-plc/hybrid-plc-rf-2/



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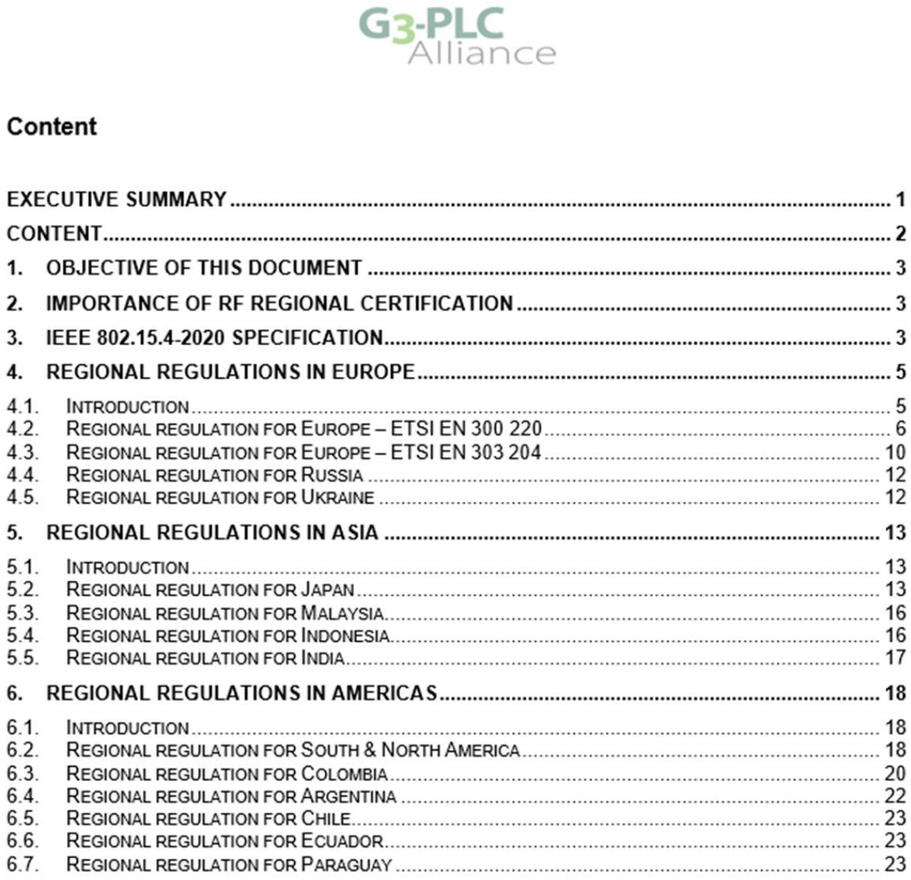
WS4 – Regulatory Advisory Group – Regional regulations study

G3-PLC Alliance White paper

Executive Summary

This document gathers all the studies performed by the Regional Advisory Working Group to assure the hybrid protocol complies with local regulatory requirements. This document will give to the G3 Alliance members an overview of the regions supported by the G3 specification. Please refer to the Table of Contents to find your region of Interest, classified by Continents and Countries. Please contact directly g3-alliance.ws4@trialog.com for any support and questions.



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Content

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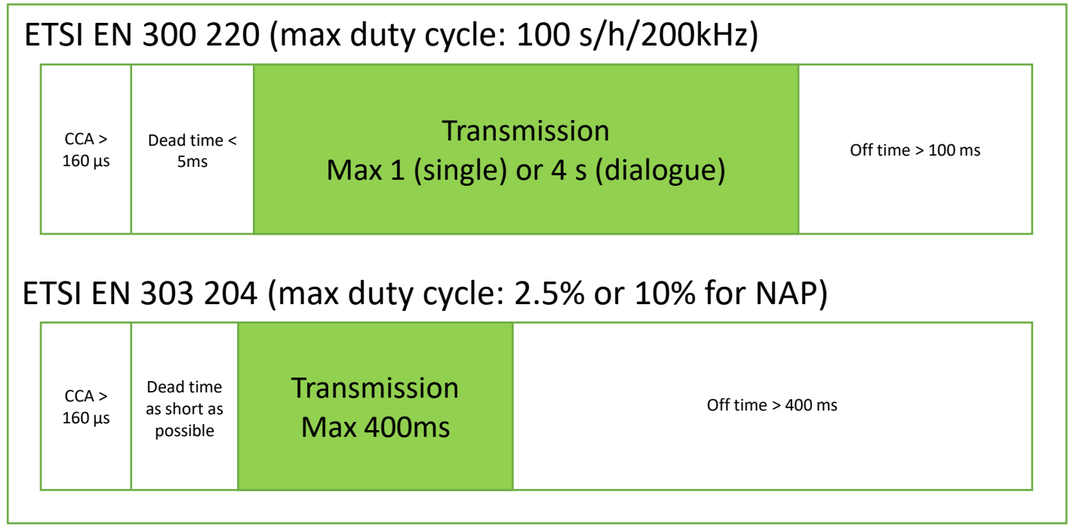
Regional regulations – Europe:

- In Europe, the RF Short-Range Devices are usually certified using the ETSI EN 300 220, with 14dBm maximum output power:



Restrictions for polite spectrum access transmissions

	ETSI EN 300 220-2 V3.2.1 (2018-06) & ETSI EN 300 220-1 V3.1.1 (2017-02)	ETSI EN 303-204 V3.1.1 (2021-03)
Transmit power	869,4 MHz to 869,65 MHz: 500 mW (27dBm) 869,7 MHz to 870 MHz : 5 mW (7dBm) otherwise : 25 mW (14dBm)	870 to 876MHz : 500 mW (27dBm) APC Limit: +7dBm
Channel Access Requirements		
Carrier sense required	Not specified	The listen before talk requirement shall apply to NAPs operating at > 2,5 % long term behavior duty cycle
Carrier sense time	160µs minimum	160µs minimum
Carrier sense detection level	Not specified	10dB above receiver sensitivity
Maximum transmission time (Ton_max)	1s for a single transmission 4s for a transmission dialogue or a polling sequence	Ton_max = 400ms (maximum duration of a transmission from the EUT in the operating channel)
Minimum pause time (Toff_min)	100ms minimum pause time	Toff_min = 400ms (minimum interval between two transmissions from the EUT in the operating channel)
Total transmission time per equipment	100s / 1h per 200kHz spectrum	2.5% or 10% (for NAPs) duty cycle
Total transmission time per channel	100s / 1h per 200kHz spectrum	Refer to Ton_max
Total transmission time per band	Not specified	Not specified

Extracted from G3 Alliance WS4 checklist

- The ETSI EN 303 204 defines a frequency range (870-876MHz) where it is possible to transmit up to 27dBm. But this is not available in all EU countries (refer to ERC/REC 70-03):

Annexes to ERC/REC 70-03	ALB	AND	AUT	AZE	BEL	BIH	BLR	BUL	CVA	CYP	CZE	D	DNK	E	EST	F	FIN	G	GEO	GRC	HNG	HOL	HRV	I	IRL	ISL	LIE	LTU	LUX	LVA	MCO	MDA	MKD	MLT	MNE	NOR	POL	POR	ROU	RUS	S	SMR	SRB	SUI	SVK	SVN	TUR	UKR
ANNEX 1: NON-SPECIFIC SHORT RANGE DEVICES																																																		
Annex h2: 870-874.4 MHz	Y	N	U	N		N	N	Y				N	Y	Y	Y	N	L	Y			Y	N	U		Y	Y	L	L	Y			*				Y		N		P	Y	*	N	L	Y	Y	N	N
ANNEX 2: TRACKING, TRACING AND DATA AQUISITION																																																	
Annex c2: 870-874.4 MHz	Y	N	U	N	L	Y	N	Y		Y		N	Y	Y	Y	P	Y	Y	P		Y	N	U	U	Y	Y	L	L	Y	U		Y	U			Y	P	L		P	Y		N	L	N	Y	P	N
Highlighted yellow = not implemented or no information	Y = implemented				L = limited implementation							P = planned						U = under study						N = not implemented						R = not regulated																		

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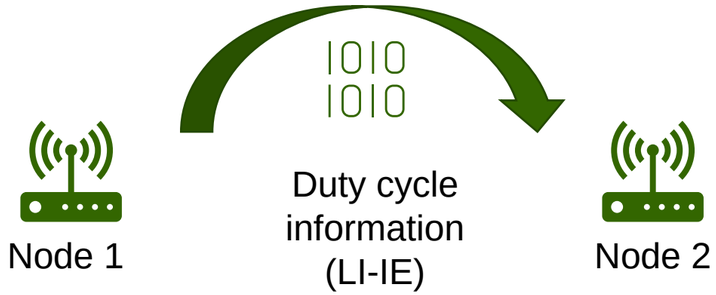
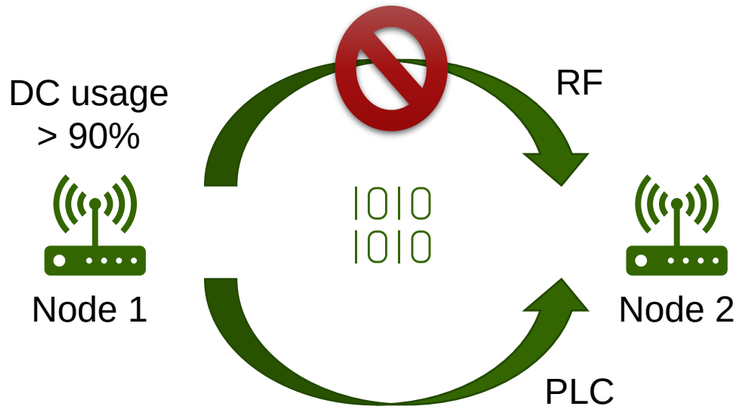
G3 PLC-RF Hybrid : Duty Cycle Management

- Channel access fairness is key in unlicensed bands
  - If one or few devices transmit all the time, others cannot transmit
  - Regulation limits transmission time per node in sliding window via “duty cycle” (typically 0.1%~10%)
  - Duty cycle consumption is tracked in each node and information shared with neighborhood

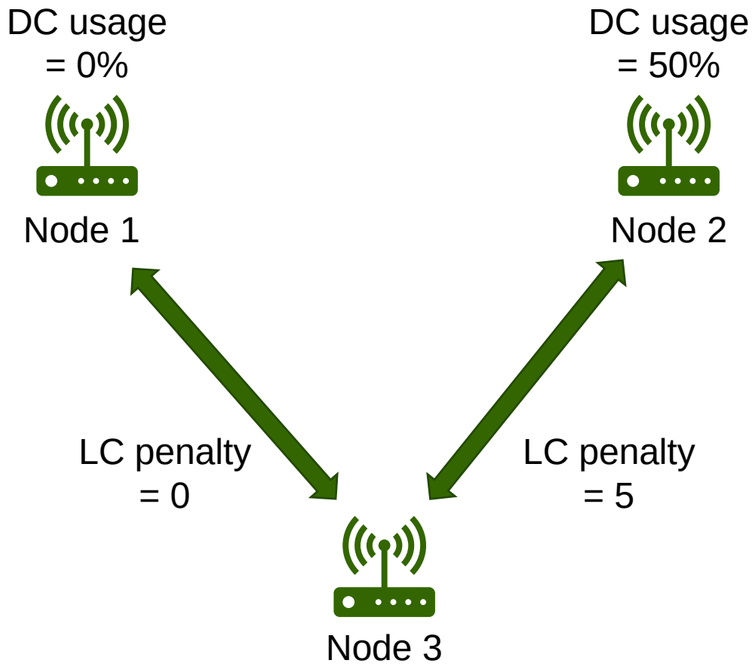


- Switch from RF to PLC if duty cycle limit is about to be reached (default threshold 90%)



G3 PLC-RF Hybrid : Duty Cycle Management

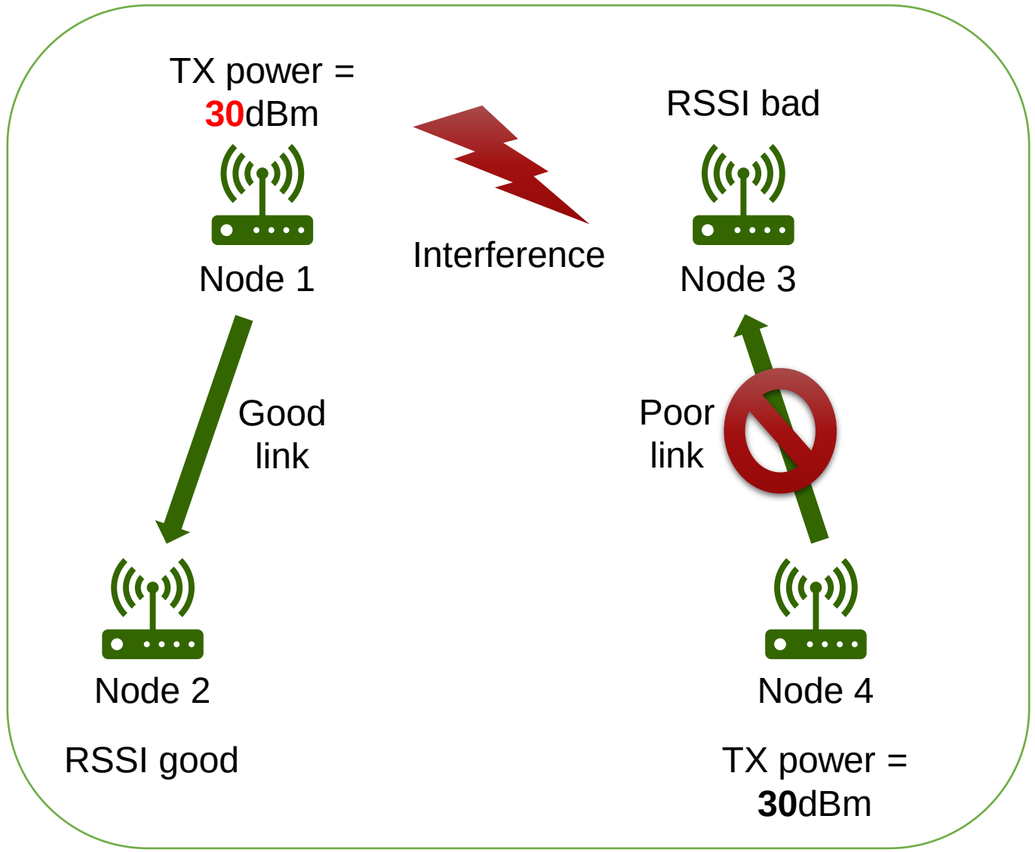
- Prefer nodes with lower duty cycle usage during route establishment
  - Duty cycle usage integrated into link cost computation via new parameter “adpKdc” (default: 10)
  - Nodes with already high duty cycle usage will lead to less preferred higher link cost



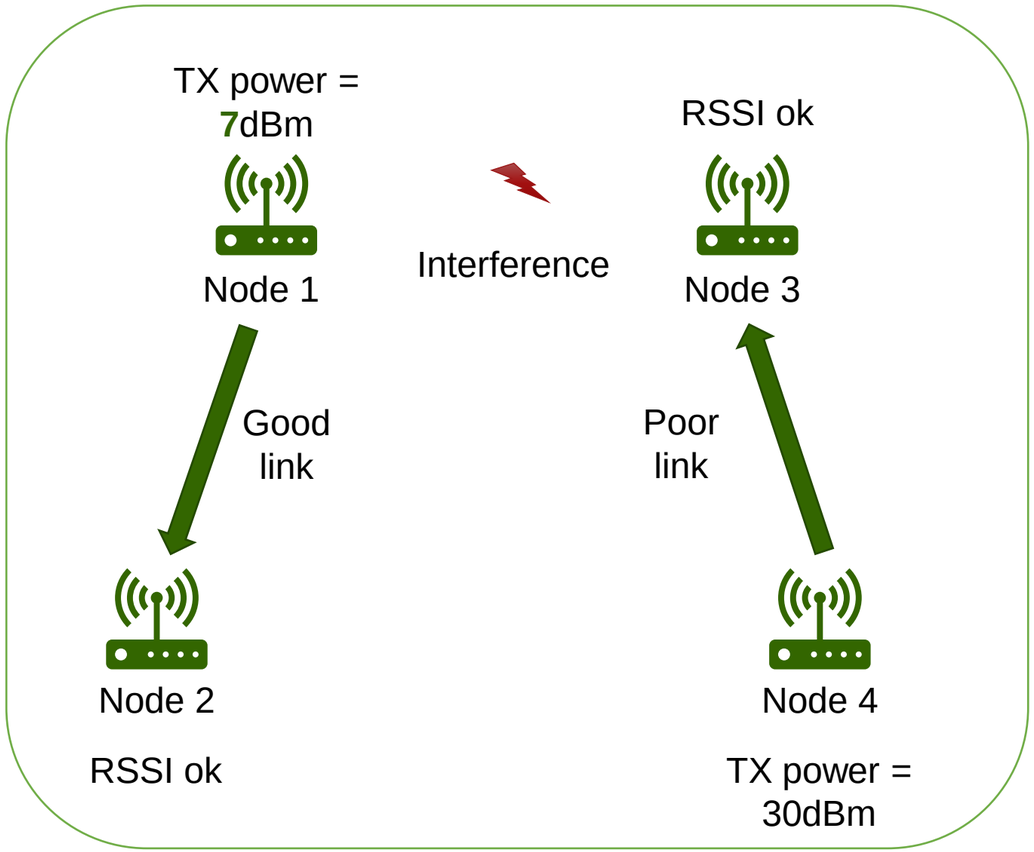
- Penalty for 50% duty cycle usage is larger than adpKh (default: 4), encouraging nodes to prefer another hop to avoid high duty cycle usage

G3 PLC-RF Hybrid : Adaptive Power Control (APC)

- Transmit power is one of the key parameters in RF regulation
  - Some bands allow up to 27dBm/30dBm, but that power is not always needed
  - To avoid interference, reduce transmit power to the minimum required for stable communication



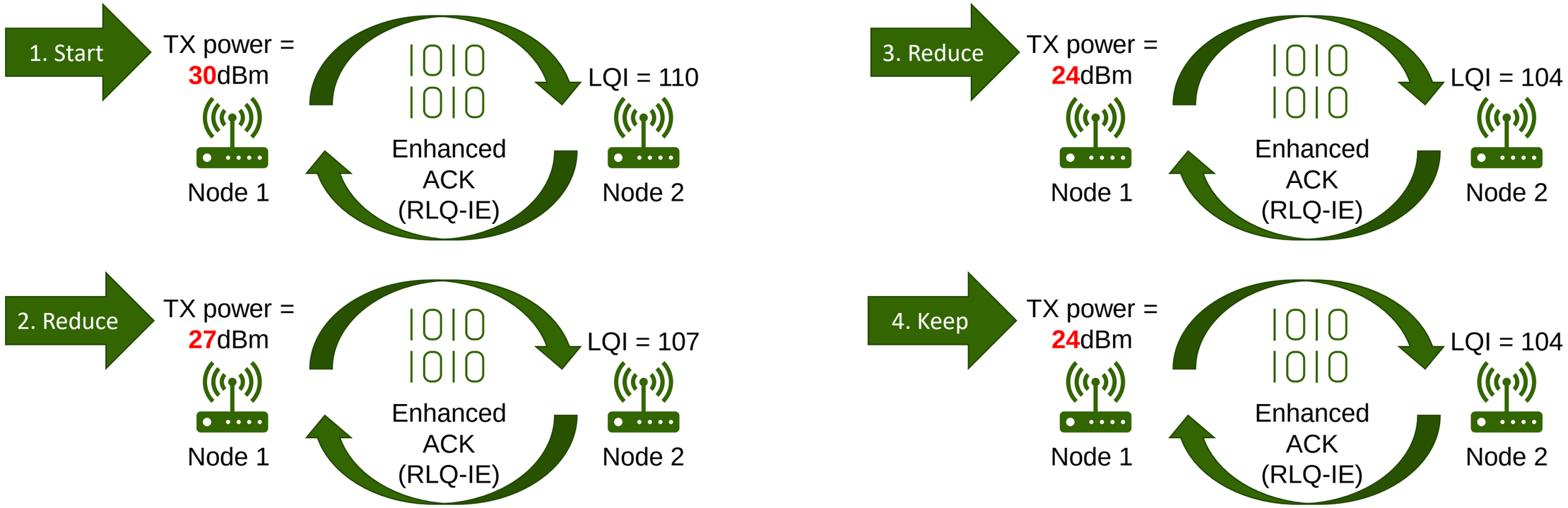
Without APC



With APC

G3 PLC-RF Hybrid : Adaptive Power Control (APC)

- Adaptive power control based on reverse LQI from RLQ-IE
  - If RLQI is higher than “macAdaptivePowerHighBound” (default: 104), reduce TX power
  - If RLQI is lower than “macAdaptivePowerLowBound” (default: 0), increase TX power
  - Adaptation shall be done in steps of ”macAdaptativePowerStep” (default: 3dBm)



- Fall-back: Gradually increase TX power in case of missing Enhanced ACK
- APC deactivation: macAdaptivePowerHighBound = 255 **and** macAdaptivePowerLowBound = 0

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Regional regulations – Americas:

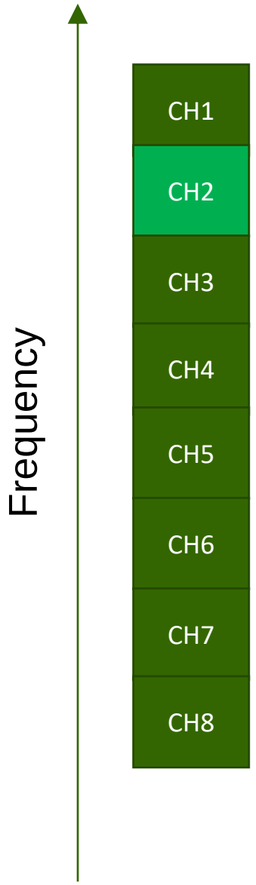
- Most South American countries are under the regulation of **ITU region 2**, that is, the spectrum for Sub-GHz SRDs is assigned mainly in the **900 MHz bands**.
- The FCC defines 2 types of Short-Range Devices, depending on the EMC constraints:

FCC - Class A	FCC - Class B
Industrial environment	Residential use

- Only the class B is considered for data acquisition networks.
- WS4 assumes that the FCC applies to both North America and South America.
- Due to the high duty cycle constraints, **the FCC strongly suggests the use of the frequency hopping** to implement data acquisition network.
- With the use of frequency hopping also **the maximum emitted radio power can go up to 1W** (+30dBm) to enable **longer range** connectivity.

G3 PLC-RF Hybrid : Frequency Hopping

- Spectrum is defined as “frequency band” composed of dedicated channels
- In fixed channel operation, the entire network is using the same pre-defined channel



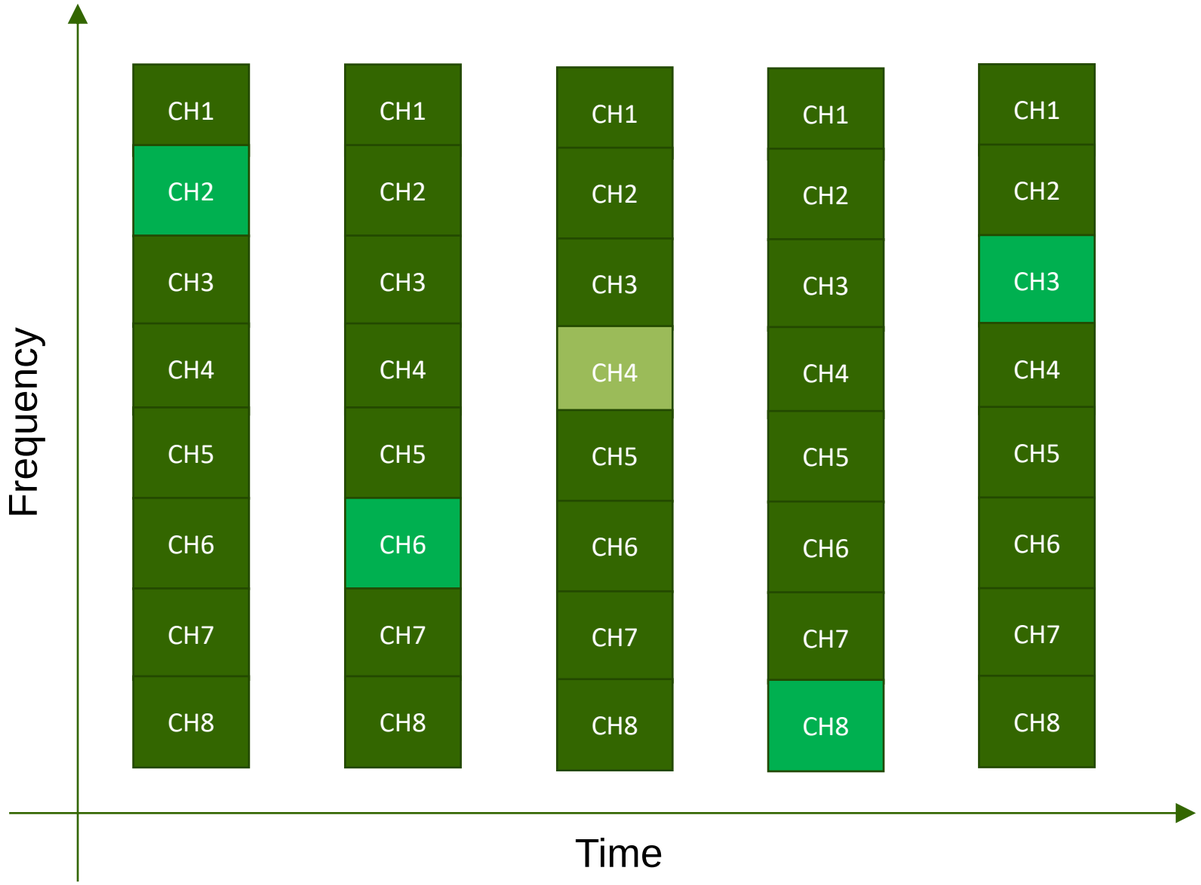
Selected channel

Fixed channel operation
- Selected channel will be heavily used (collisions)
- Poor channels conditions degrade the entire system (interference)
- Difficult to use the full band efficiently

Make use of the full band by employing frequency hopping

G3 PLC-RF Hybrid : Frequency Hopping

- Hop through all channels of the frequency band over time
- Hopping sequence is pseudo-random and makes use of the entire frequency band



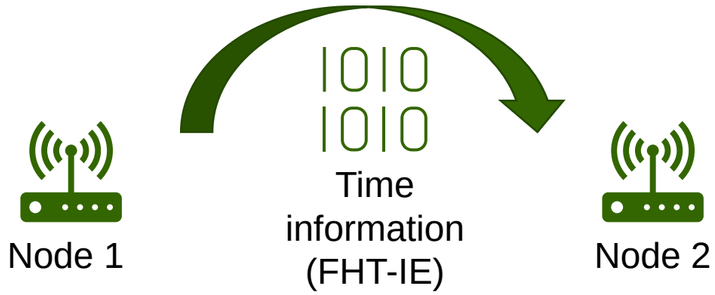
Frequency hopping operation

- Each channel will only be partly used (fewer collisions)
- Poor channel conditions degrade communication only partly (higher robustness)
- The full band is evenly used

Nice features, but how do transmitter and receiver know which channel to use at what time?

G3 PLC-RF Hybrid : Frequency Hopping

- Time synchronization between nodes is key
  - Time is divided into equally spaced slots, channel is changed each slot
  - Time information (slot number and offset) exchanged via FHT-IE



- Transmission channel computed by channel function as pseudo-random sequence
  - Input to channel function: Slot number, short address & PAN ID
  - Input known to both, “Node 1” and “Node 2”, same channel will be used

Regional regulations – Asian/Japan:

- In Japan, SRDs can operate in the **920 MHz band** under various regulatory constraints.
- The regulation defines different sets of rules, referred to as parts.

Part 1	Part 2	Part 3
Land mobile stations	Specified low-power radio stations	Frequency hopping and low duty cycle configuration

- Considering the G3 hybrid technology and its anticipated use cases, **part 2 appears to be the most appropriate regulation**.
- The tolerated **duty cycle** in part 2 can be further increased if the transmission switched between **multiple channels**, which can be achieved by activating the **G3 hybrid frequency hopping mechanism.**

Regional regulations – Asia/other countries:

Malaysia:

Frequency band	Maximum transmit power / field strength / Conditions
916-919MHz	25mW EIRP with Duty Cycle <1% Or Frequency Hopping Or LBT
919-923MHz	500mW EIRP
923-924MHz	500mW EIRP with Duty Cycle <1% Or Frequency Hopping Or LBT

Indonesia:

Frequency band	Maximum TX power	Additional parameters	Maximum Ch BW	Radio standard
920-923MHz	400mW (NAP) 250mW (other)	- 36dBm (Spurious emission limit) - Duty Cycle < 10% for Network Access Point (i.e. coordinator) - Duty Cycle < 1% otherwise	200kHz	FCC Part 15 §15.249 ANSI C63.10-2013 EN 300 220-1 EN 302 208

India:

Frequency band	Maximum TX power	Additional parameters	Maximum Ch BW	Radio standard
865-868MHz	500mW EIRP	APC required and the following Duty Cycle restrictions: - Duty Cycle < 10% for Network Access Point (i.e. coordinator) - Duty Cycle < 2,5% otherwise	200kHz	EN 300 220

Mix of FCC and ETSI

Based on ETSI

Agenda

1. Introduction

2. Supported bands and modulations

3. Regulatory constraints in different regions around the world
    1. Regulatory Checklist and G3 Alliance documents
    2. Regional requirements (Europe, Asia, Americas)
    3. Dedicated mechanisms (Duty Cycle handling, Adaptive Power Control and Frequency Hopping)

4. **Conclusion & Questions**

New certification version of the G3-Hybrid will be released in Q1 2023

The new certification version will include the following:

1. Additional RF frequencies bands as shown in the table

2. The mechanisms presented in this webinar:
   - Frequency Hopping
   - Adaptive power control (APC)
   - Duty-cycle handling

3. Last gasp mechanism
4. Certification profile for ARIB Hybrid
5. Performance testing for RF
6. Improvement of Conformance test coverage for both PLC and RF

ISM band designation	RF frequency bands
863	863-870 MHz
866	865-867 MHz
870	870-876 MHz
915	902-928 MHz
915-a	902-928 MHz (alt.)
915-b	902-907.5 MHz & 915-928 MHz
915-c	915-928 MHz
919	919-923 MHz
920-b	920-923 MHz
920	920-928 MHz

G3-Hybrid: A global, fully fledged RF+PLC solution extending the capabilities for the smart grid and IoT!

- ✓ Fully-fledged RF as well as PLC mesh communication solution
- ✓ PLC and RF technology on a *single* solution
- ✓ Maximises coverage and connectivity and strongly reduces complexity of roll-out
- ✓ Standards based, certified and interoperable
- ✓ Global solution: complies to regulatory requirements in any part of the world!

Discussion

Thank you for attending this webinar today! Do not hesitate to get in touch:

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