G3-PLC Alliance

Enabling the smartest grid...together

ISPLC 2020
Keynote

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Where do we stand in 2020?

2006/2007
G3-PLC requirements:
- OFDM PHY
- IEEE 802.15.4 MAC
- 6LoWPAN
- IPv6
…

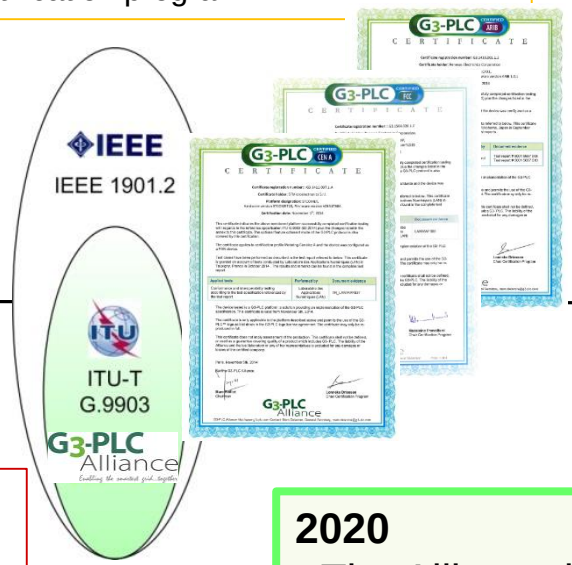
2009
Release of the first version of the G3-PLC specifications by Maxim Integrated and Sagemcom

2010
Field tests launched in the french distribution grid

2011
Creation of the G3-PLC Alliance

2012
Publication of the G3-PLC specifications as ITU-T recommendation

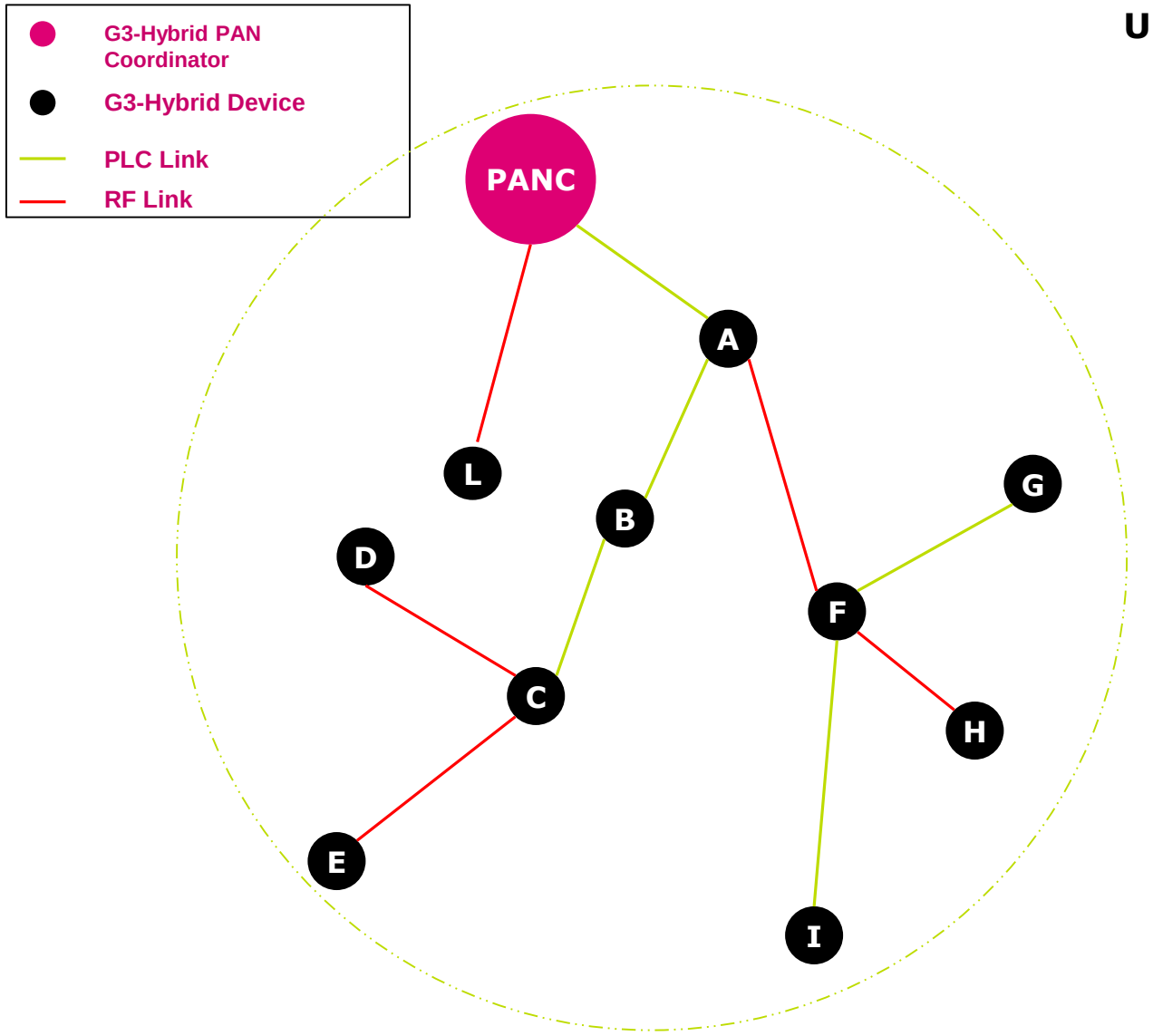
2014
- High level of convergence between ITU-T G.9903 and IEEE 1901.2
- Opening of the G3-PLC Alliance certification program



2018
- Chinese industry becomes active in G3-PLC
- Opening of a new band (CENELEC B) for certification

2020
- The Alliance has delivered more than **382 certificates**:
  - 215 CENELEC A
  - 11 CENELEC B
  - 126 FCC
  - 30 ARIB
- **The G3-PLC Alliance works on the first hybrid PLC/RF standard mixing G3-PLC and IEEE 802.15.4-based RF**

Towards a hybrid PLC/RF communication profile 1/2



Unaddressed challenges for a single technology:

- DSO's require >99% performance and in many grids none of the technologies can make that on their own
- Scattered deployments often reveal some weaknesses of PLC solutions.
- Both standalone PLC solutions and standalone RF solutions lack the versatility needed to cover the multiplicity of challenges encountered in the field.
- A solution suitable for most environment : **link diversity + interconnection of different smart energy ecosystems**

Towards a hybrid PLC/RF communication profile 2/2

Exploring the concept with G3-PLC and LoRa: The WSPLC 2016 Student Challenge

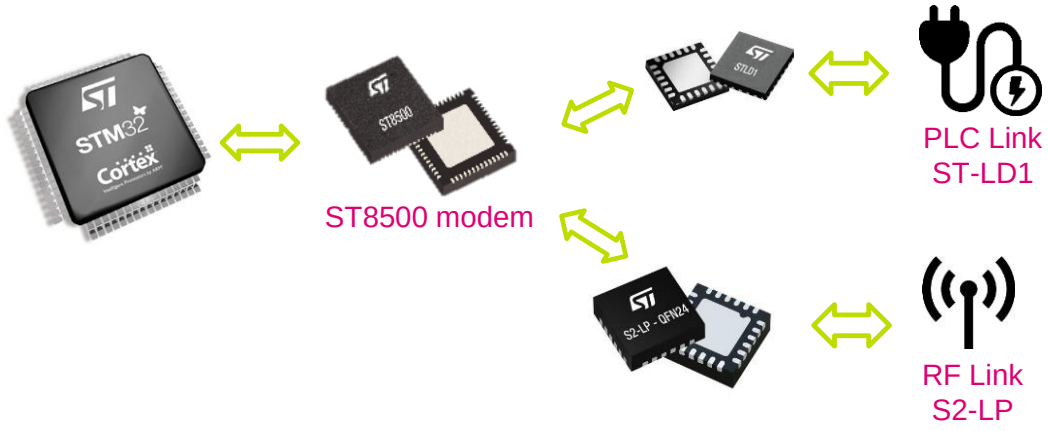
see http://www.wsplc2016.fr/student-challenge/

- Klagenfurt team (Austria): « *Implementation of a hybrid LoRa/PLC sensing network* »
- Umons team (Belgium): « *Hybrid communication architecture for time sensistive smart metering* »
- ECE Paris team (France): « *Connected in-home display (G3-PLC to the meter, LoRa to a remote price server)* »
- Telecom Bretagne team (France): « *Smart energy management for electric cars* »

Pilot Project from G3-PLC Alliance members

- ADD Group (Moldova): « ADDAX PLC+RF HYBRID solution »
- Andrea Informatique (France) with Enedis and EDF: « Centaur »

Both projects were presented at G3-PLC General Assembly in Nov. 2019

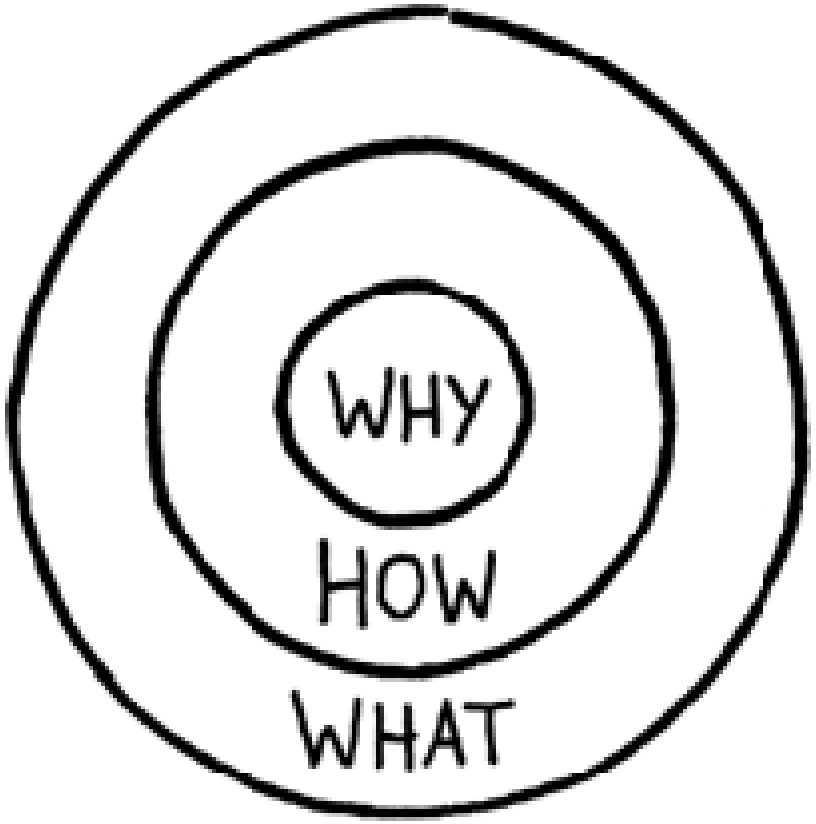


➔ A new challenge for the G3-PLC Alliance !

Centaur
The Hybrid Soft Solution

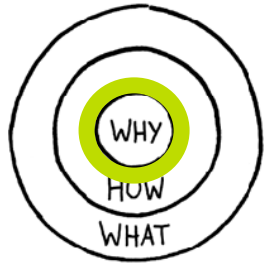
ANDREA

The G3-PLC Alliance Hybrid PLC/RF solution



The G3-PLC Alliance Hybrid PLC/RF solution

Why developing a hybrid solution?



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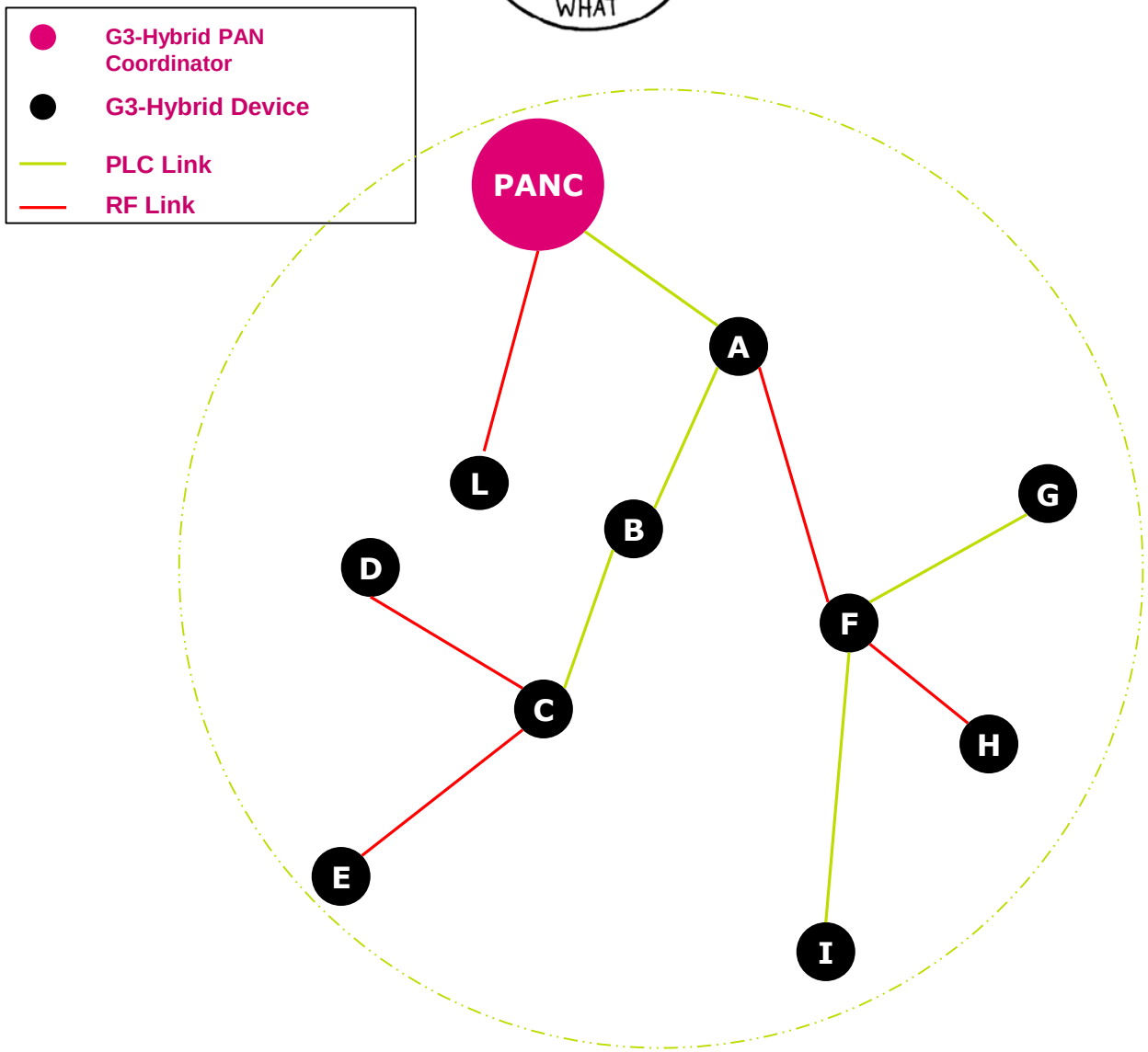
- By using both G3-PLC an RF media, the resulting **hybrid G3-PLC/RF meshed topology maximizes coverage and resilience**



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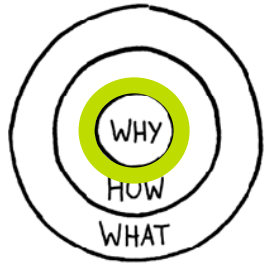
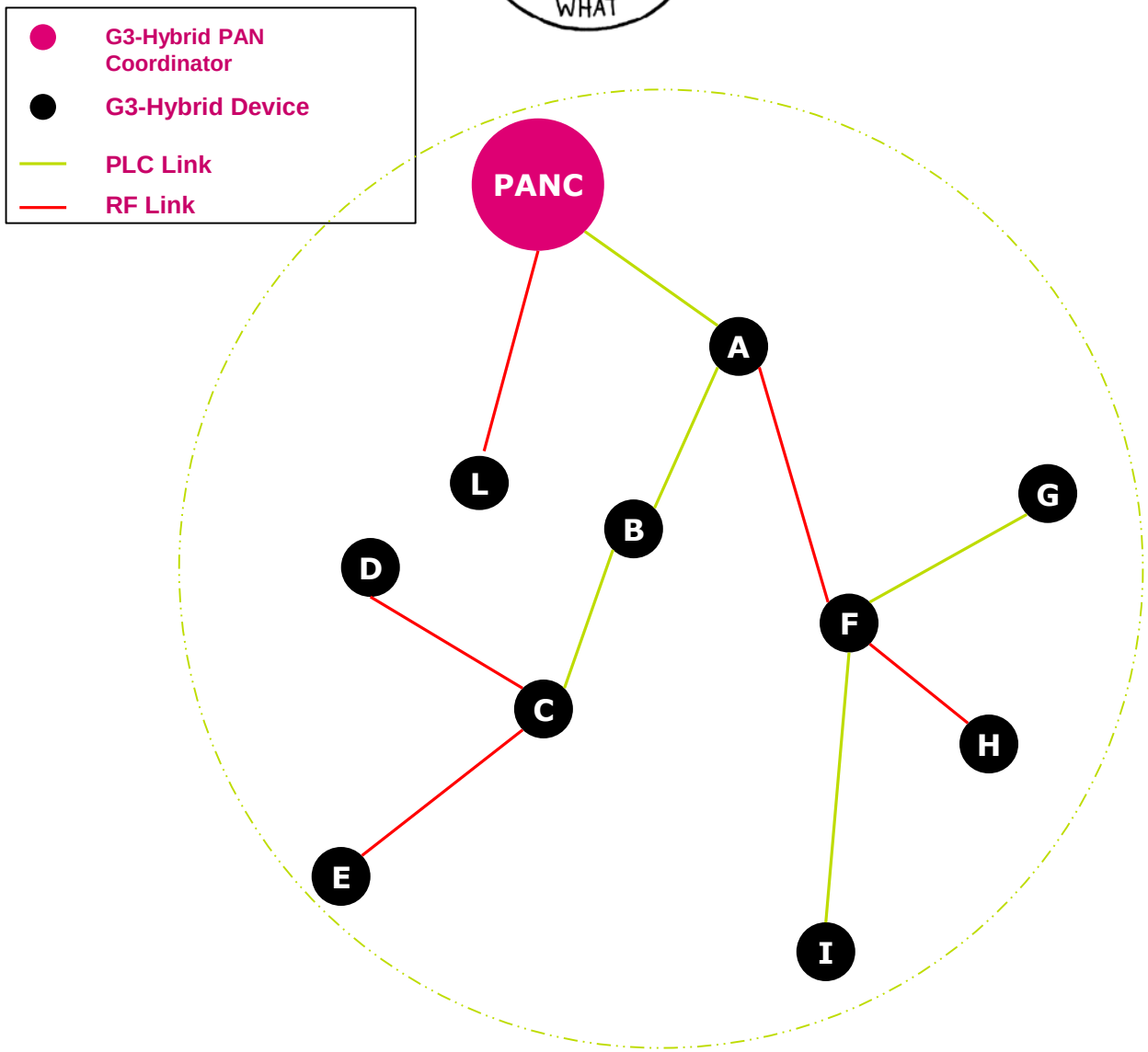


- By using both G3-PLC an RF media, the resulting **hybrid G3-PLC/RF meshed topology maximizes coverage and resilience**

- Hybrid G3-PLC/RF technology can provide a more efficient solution for smart grid and smart city use cases **enhancing the relevance of the G3-PLC technology**



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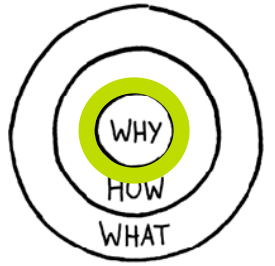
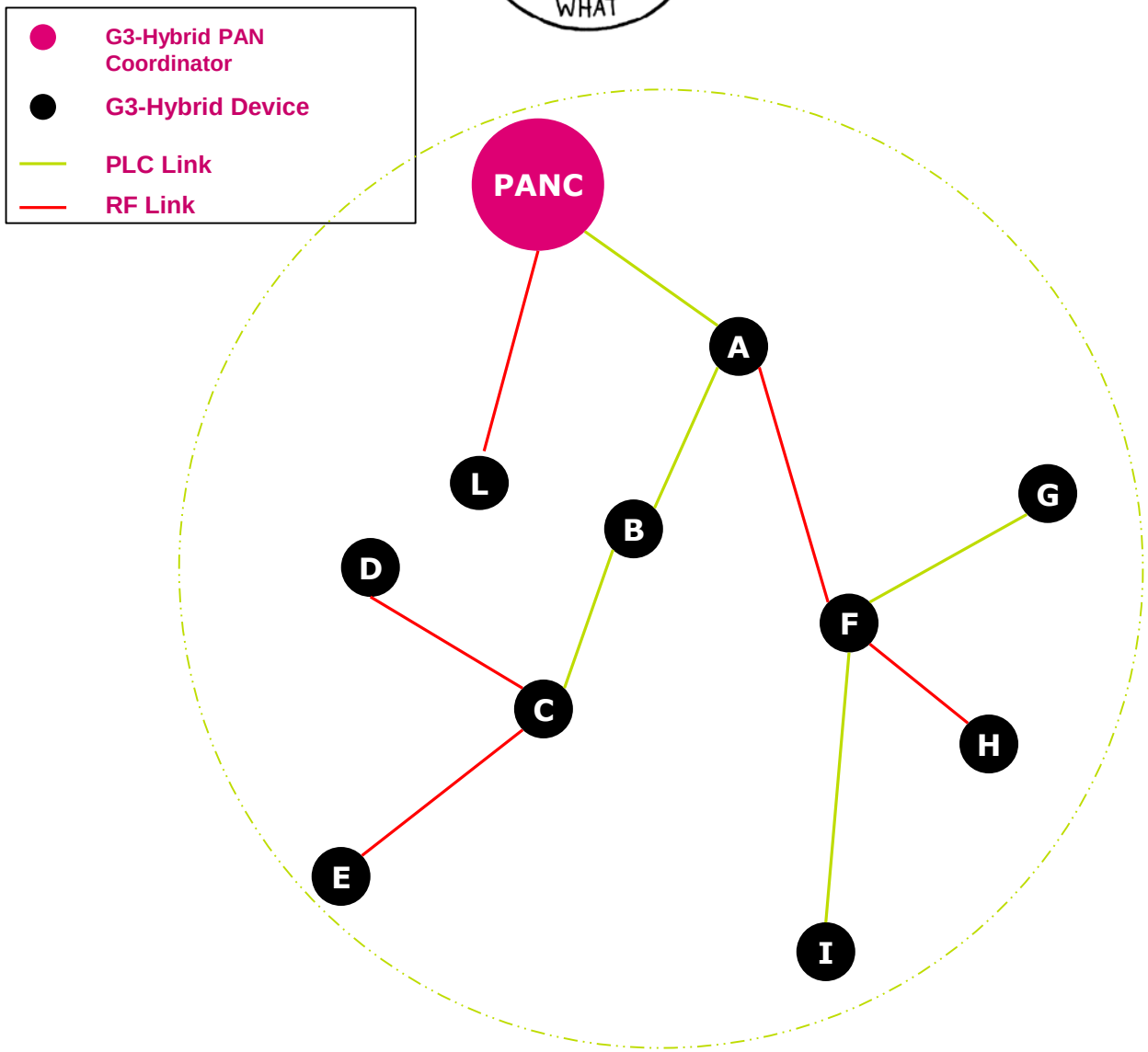


- By using both G3-PLC an RF media, the resulting **hybrid G3-PLC/RF meshed topology maximizes coverage and resilience**
- Hybrid G3-PLC/RF technology can provide a more efficient solution for smart grid and smart city use cases **enhancing the relevance of the G3-PLC technology**
- Hybrid G3-PLC/RF technology **favours new use cases beyond smart metering** such as **smart grid**, **smart city**, **lighting control**, **building automation**, **demand response**, **railway applications**.



The G3-PLC Alliance Hybrid PLC/RF solution

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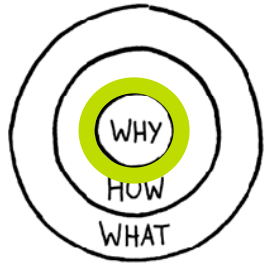

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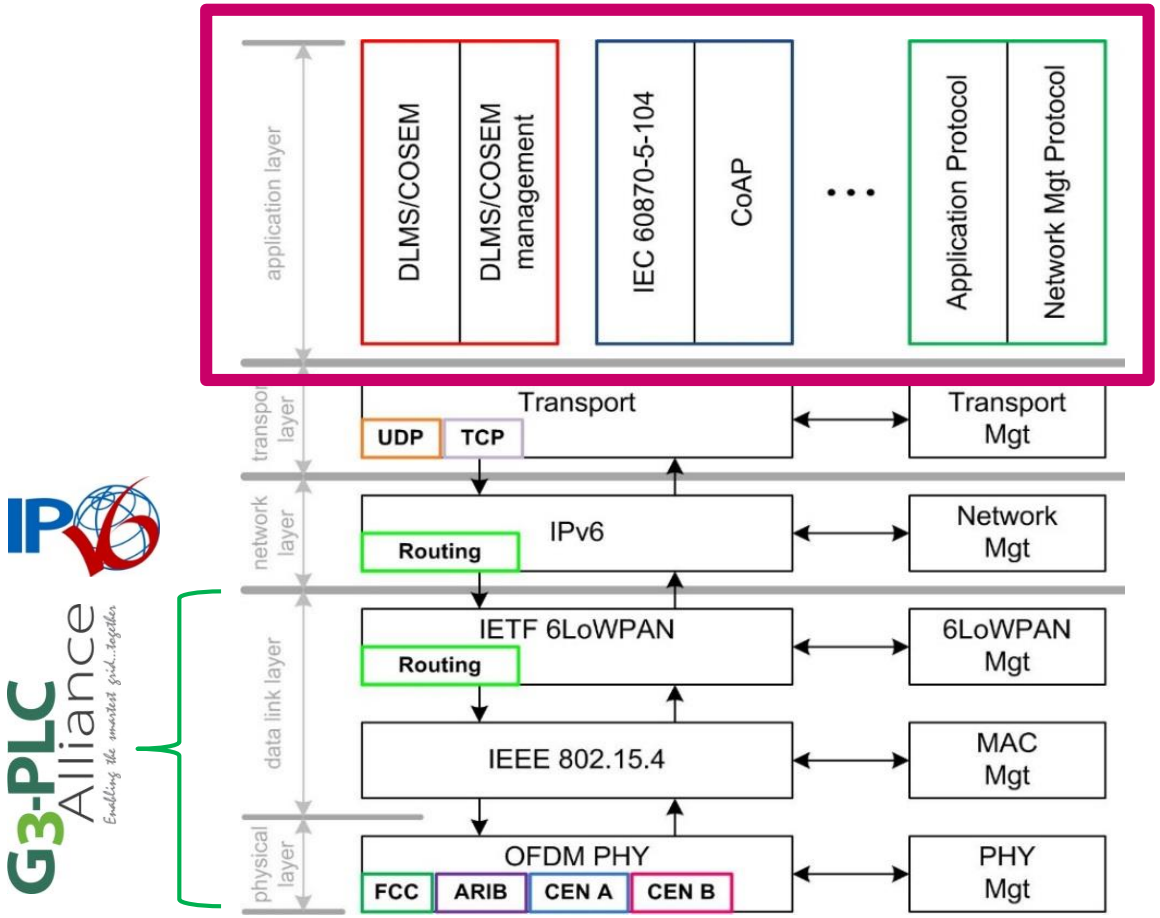
- Hybrid G3-PLC/RF technology **favours new use cases beyond smart metering** such as **smart grid**, **smart city**, **lighting control**, **building automation**, **demand response**, **railway applications**.

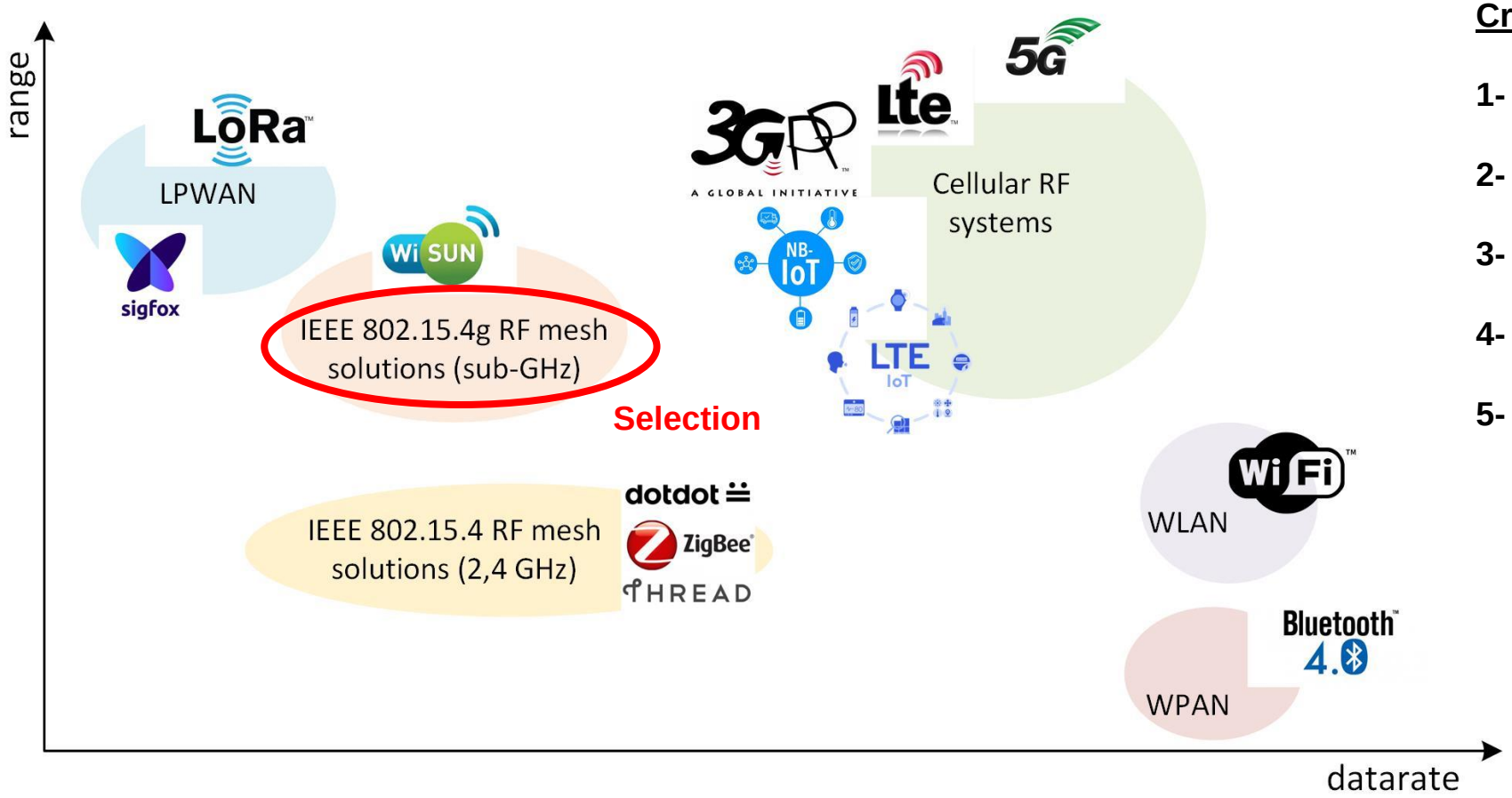
G3-PLC is already a multi-purpose technology; a hybrid profile will even further leverage its ability to address different application use cases !



The G3-PLC Alliance Hybrid PLC/RF solution

Identifying the ideal complementary RF solution

- IEEE 802.15.4:2015 + IEEE 802.15.4v:2017 amendment
- Use of SUN FSK PHY
- Use of 802.15.4 MAC



Criteria:

1- Open Standard

2- Compatible datarate

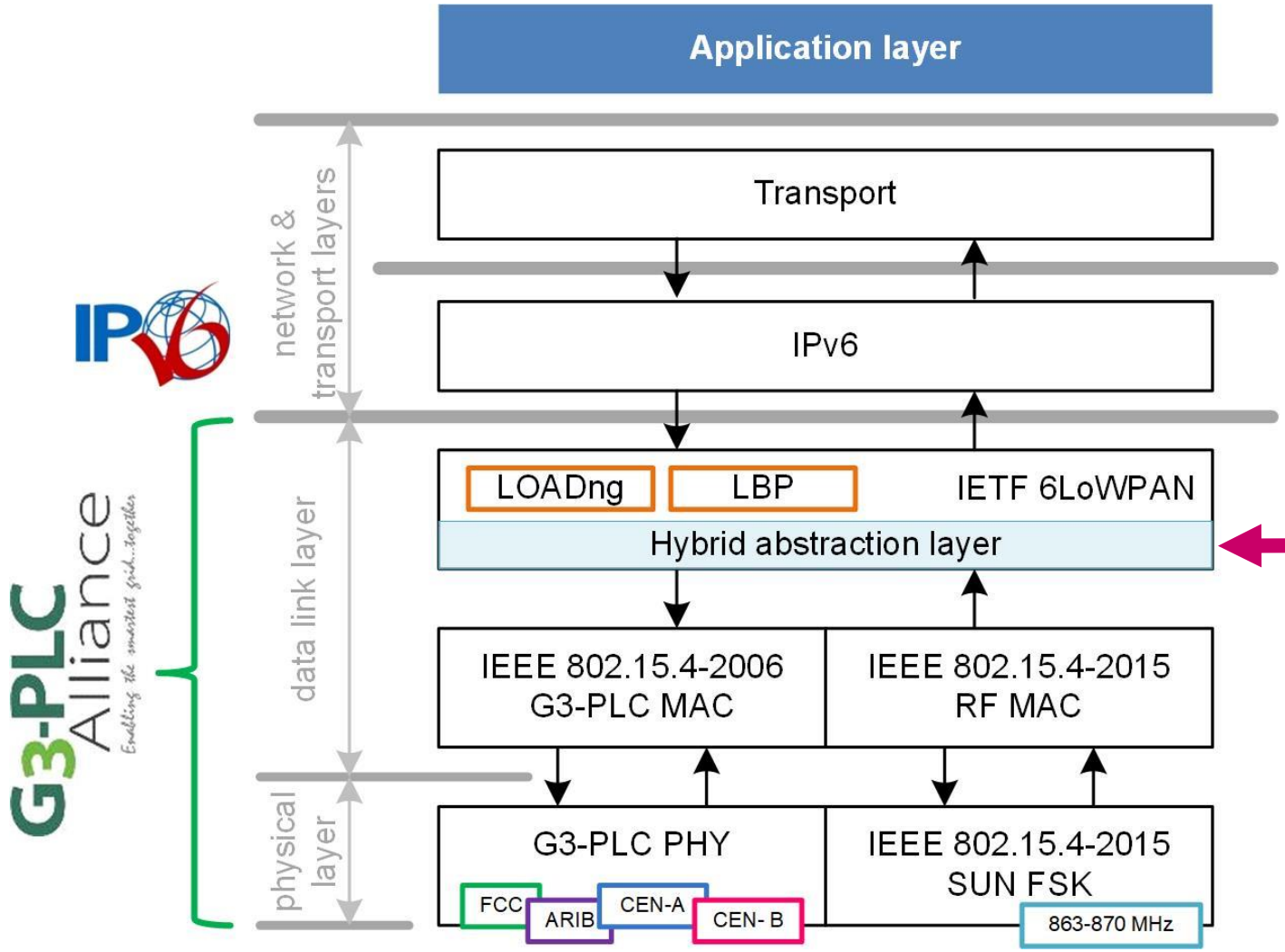
3- Private-owned nwk

4- km-range (star and mesh topology)

5- lower layers vs communication profile

The G3-PLC Alliance Hybrid PLC/RF solution

Target protocol stack

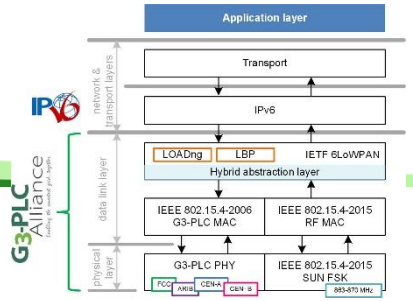


Fully backwards compatible with any G3-PLC network

Switching between PLC and RF is decided above the hybrid abstraction layer which provides appropriate services to the 6LoWPAN-based adaptation layer

- PLC is the primary medium
- RF is the secondary medium

Main features (work in progress): RF PHY & MAC layers



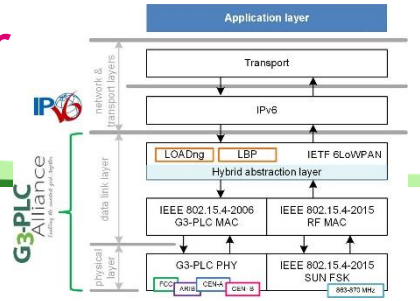
- **SUN FSK PHY** according to IEEE 802.15.4:2015 and IEEE 802.15.4v:2017
- Support of **863-870 MHz** band (other frequency bands may be supported too)
- **Operating modes #1 and #2**, configured administratively

Example for the 863-870 MHz band according to IEEE 802.15.4:2015:

Parameters	Operating mode #1	Operating mode #2
Data rate	50 kbps	100 kbps
Modulation	2-FSK	2-FSK
Modulation index	1.0	1.0
Channel spacing	200 kHz	200 kHz

- **Unslotted CSMA/CA for non-beacon-enabled network**
- **RF information** is **shared** between **neighbouring nodes** using **Information Elements**
- **Nodes maintain RF information** (duty cycle consumption, link quality) related to neighbouring nodes in a dedicated "**RF POS table**"

Main features (work in progress): The Hybrid Abstraction layer



- Definition of **Media types**

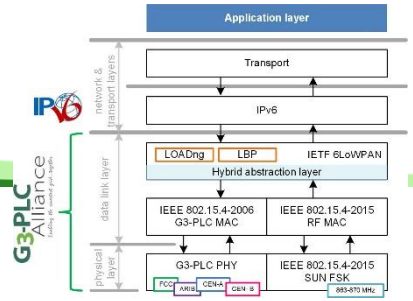
- A **set of primitives ensuring that data is sent/received over/from the appropriate (RF or PLC) MAC layer**:
  - HyAL-DATA.request/confirm/indication

- A **set of primitives ensuring that PAN information is propagated to the higher layers**
  - HyAL-SCAN.request/confirm
  - HyAL-BEACON-NOTIFY.indication
  - HyAL-COMM-STATUS.indication

- Ensures a **second transmission attempt using backup medium**

MediaType	Description
0x00	**PLC interface** Backup RF interface
0x01	**RF interface** Backup PLC interface
0x02	**Both PLC and RF** interfaces
0x03	**PLC interface** No backup interface
0x04	**RF interface** No backup interface

Main features (work in progress): Shared Adaptation layer 1/2



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- The **shared adaptation layer uses existing data sets** (routing table, blacklist table) to route packet over the appropriate medium.

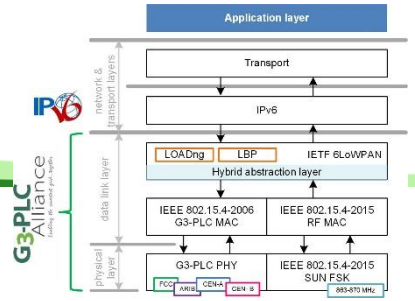
Routing table entry			
Field	Terminology used in Annex D for routing set	Length	Description
Destination Address	R_dest_addr	16 bits	Address of the destination.
Next Hop Address	R_next_addr	16 bits	Address of the next hop on the route towards the destination.
Route Cost	R_metric	16 bits	Cumulative link cost along the route towards the destination (see Annex B).
Hop count	R_hop_count	4 bits	Number of hops of the selected route to the destination.
Weak Link Count	R_weak_link_count	4 bits	Number of weak links to destination. It ranges from 0 to adpMaxHops.
Valid Time		16 bits	Remaining time in minutes until when this entry in the routing table is considered valid.
Media Type		1 bit	The medium to be used to transmit to the next hop (0 PLC, 1 RF)

Allows **forwarding** of RF or PLC link **towards the next hop**

Blacklisted neighbour table entry			
Field	Terminology used in Annex D for routing set	Length	Description
Blacklisted Neighbour Address	B_neighbour_address	16 bits	The 16-bit address of the blacklisted neighbour.
Valid Time		16 bits	Remaining time in minutes until when this entry in the blacklisted neighbour table is considered valid.
Media Type		1 bit	The medium on which the neighbour is blacklisted (0 PLC, 1 RF)

Allows **blacklisting** of RF or PLC link in case of **delivery failure**
Blacklisting **forces forwarding over the backup medium**

Main features (work in progress): Shared Adaptation layer 2/2



- **PLC/RF link selection is done during LOADng route construction process**.
- The **updated metric** also contains weighing factors for:
  - Duty cycle consumption
  - RF link quality

Routing table penalty **Hop count penalty**

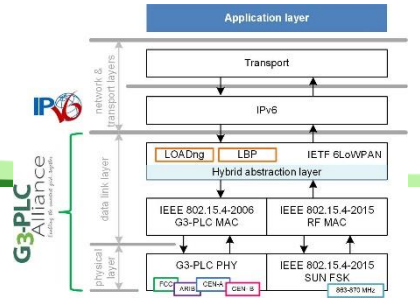
$$LinkCost_{RF} = max\left(C_{i\rightarrow j}, C_{j\rightarrow i}\right) + AdpKrt_{RF} * \frac{NumberOfActiveRoutes_{RF}}{MaximumNumberOfActiveRoutes} + adpKh_{RF}$$

$$DirectionalLinkCost_{RF} = adpKq_{RF} * MAX\left(0, MIN\left(1, \frac{adpHighLQIValue_{RF} - LQI_{RF}}{adpHighLQIValue_{RF} - adpLowLQIValue_{RF}}\right)\right) + \frac{adpKdc_{RF} * DutyCyclePenalty}{100}$$

Link cost penalty

Duty cycle penalty

Next steps



- **The draft specification has been completed and agreed in the technical working group;**
- **We expect we can soon prove interoperability of several implementations of the hybrid PLC/RF profile;**
- **The G3-PLC Alliance is working hard to include certification of the hybrid profile to its mature and successful international certification program.**

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Thank you !

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