



IEEE Webinar October 6<sup>th</sup> 2023

**Potential of Power Line  
Communications for Smart Grid,  
Residential and Industry  
Applications**

-----

**Narrowband PLC Technologies**

**Cédric Lavenu, EDF R&D**



# TABLE OF CONTENT

1. NB-PLC for smart metering infrastructure
2. Smart metering and smart grid use cases
3. Future Challenges for NB-PLC technologies

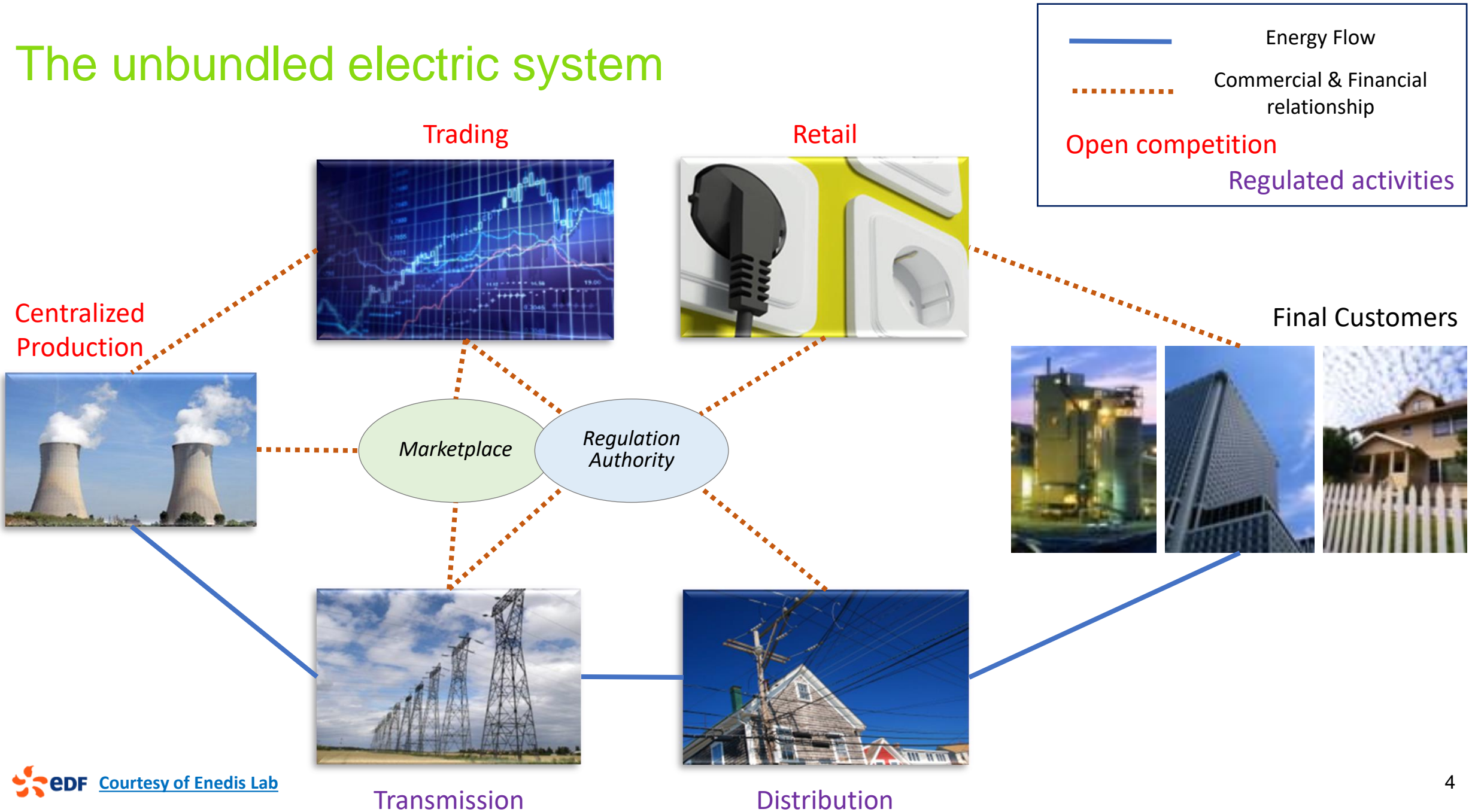




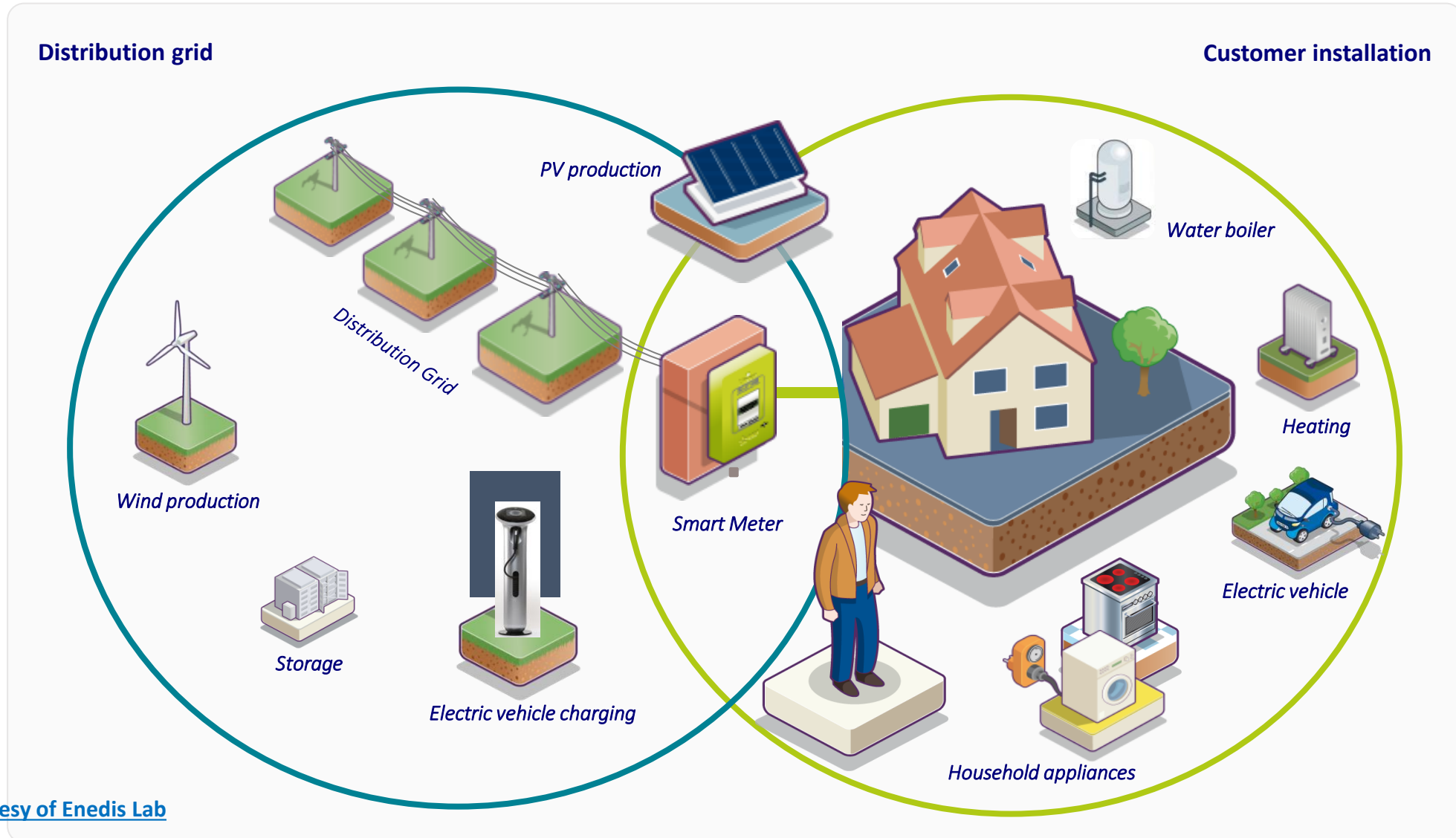
# TABLE OF CONTENT

1. NB-PLC for smart metering infrastructure
2. Smart metering and smart grid use cases
3. Future Challenges for NB-PLC technologies

# The unbundled electric system

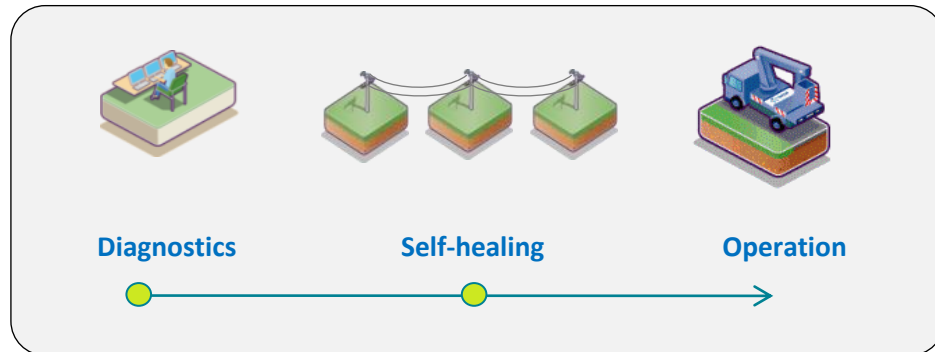
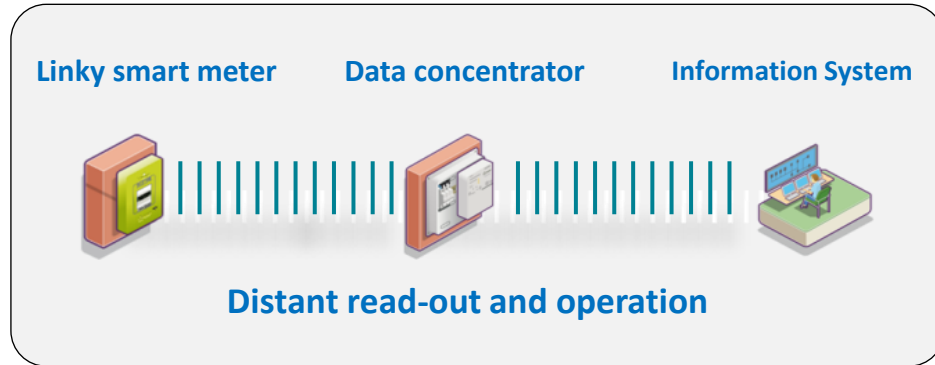


# The Smart Meter is at the interface between the grid and the customer



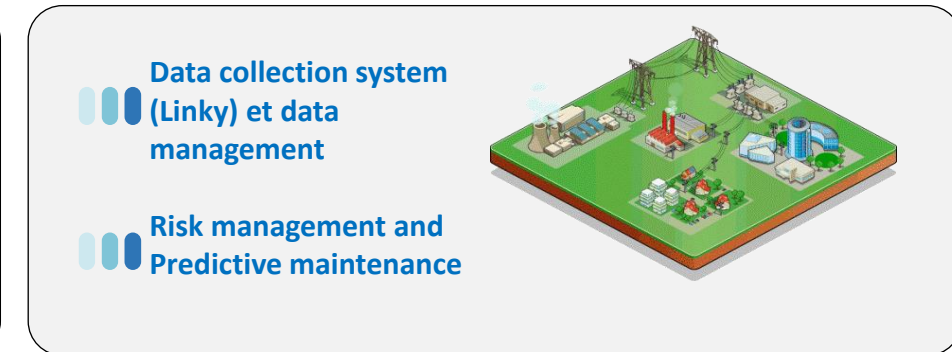
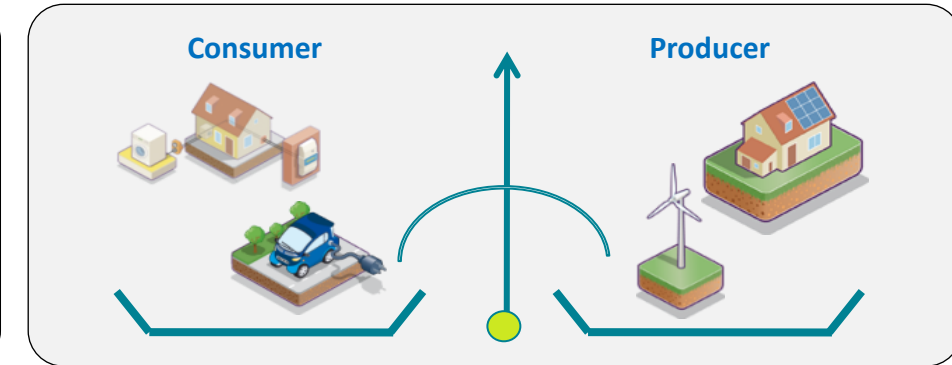
# Smart meter infrastructures constitute the first building block of the smart grid

## ||| Distant control (Automated Meter Management)



## ||| Reduce on-field operation delays

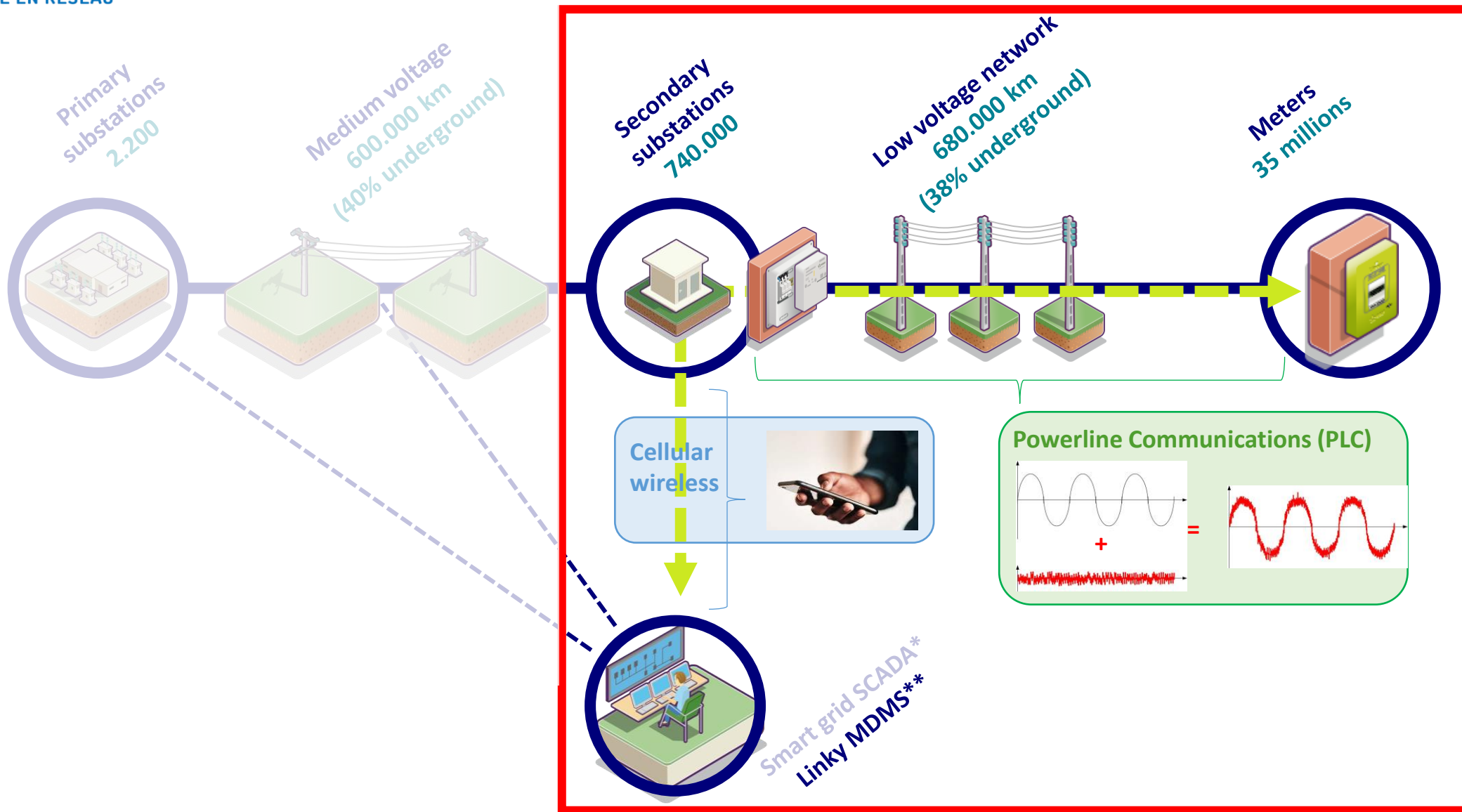
## ||| Manage local production/consumption balance



## ||| Enhance efficiency of grid investments

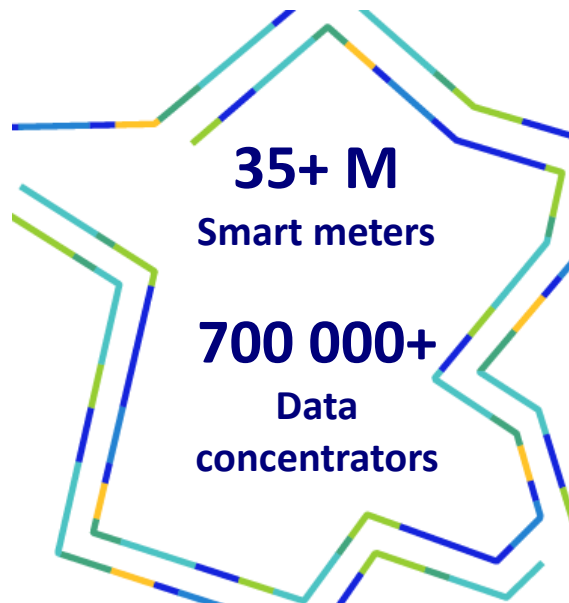
# ENEDIS's Linky infrastructure

L'ELECTRICITE EN RESEAU



# ENEDIS's Linky infrastructure

L'ELECTRICITE EN RESEAU



**6 years**



**2015 – 2021**  
Roll out

**4 billion €**



**Investment until**  
**2021**

**4 manufacturers**



**With production factories based**  
**in France**

## Conformance with:

**Energy Regulation Commission requirements**

**General Data Protection Regulation**

**Cybersecurity requirements**

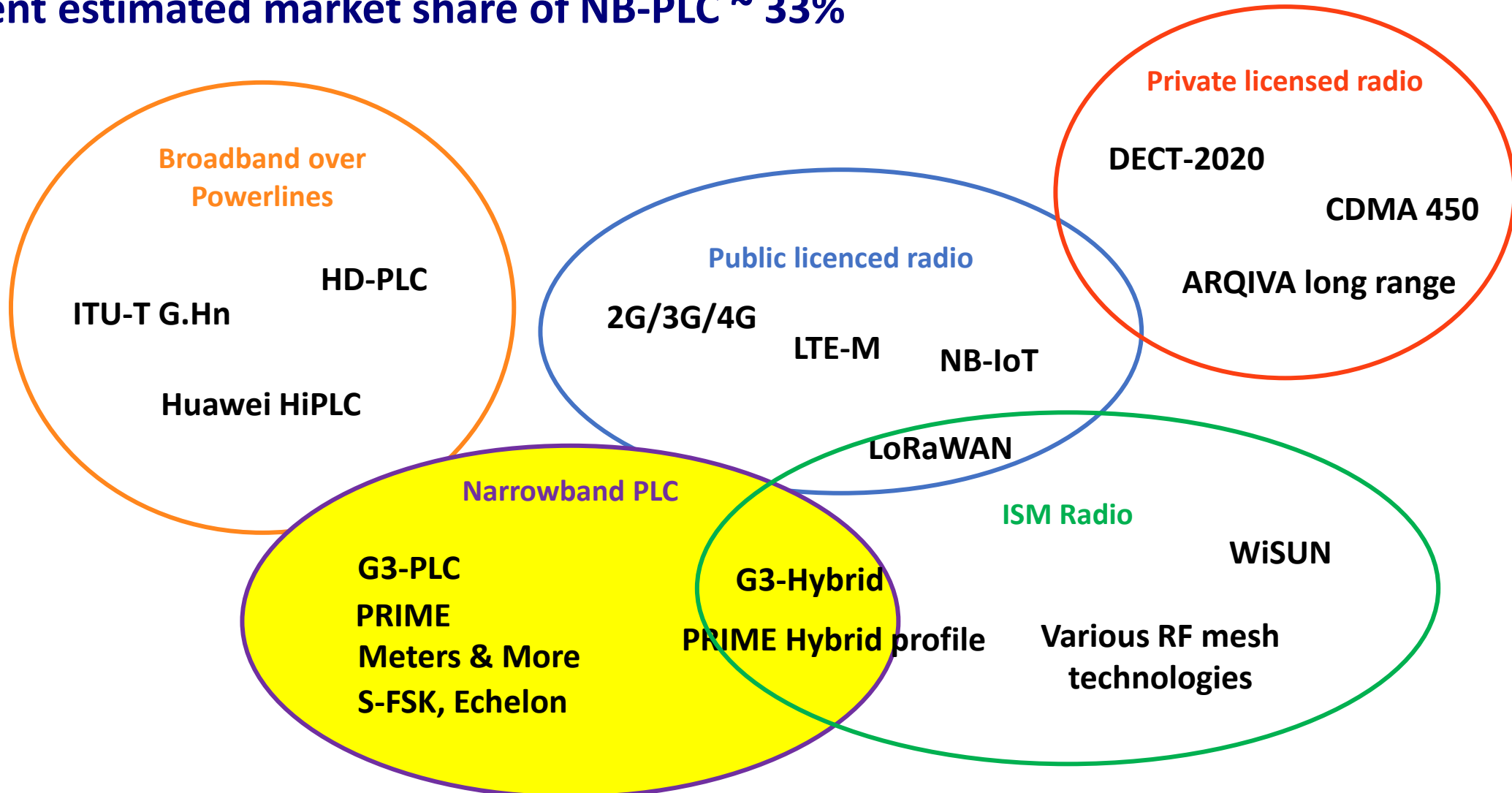


- **98 % success rate for daily data collection**
- **98 % success rate for remote operations (up to 40 000 / day)**
- **7 million customers monitor their electrical consumption online**



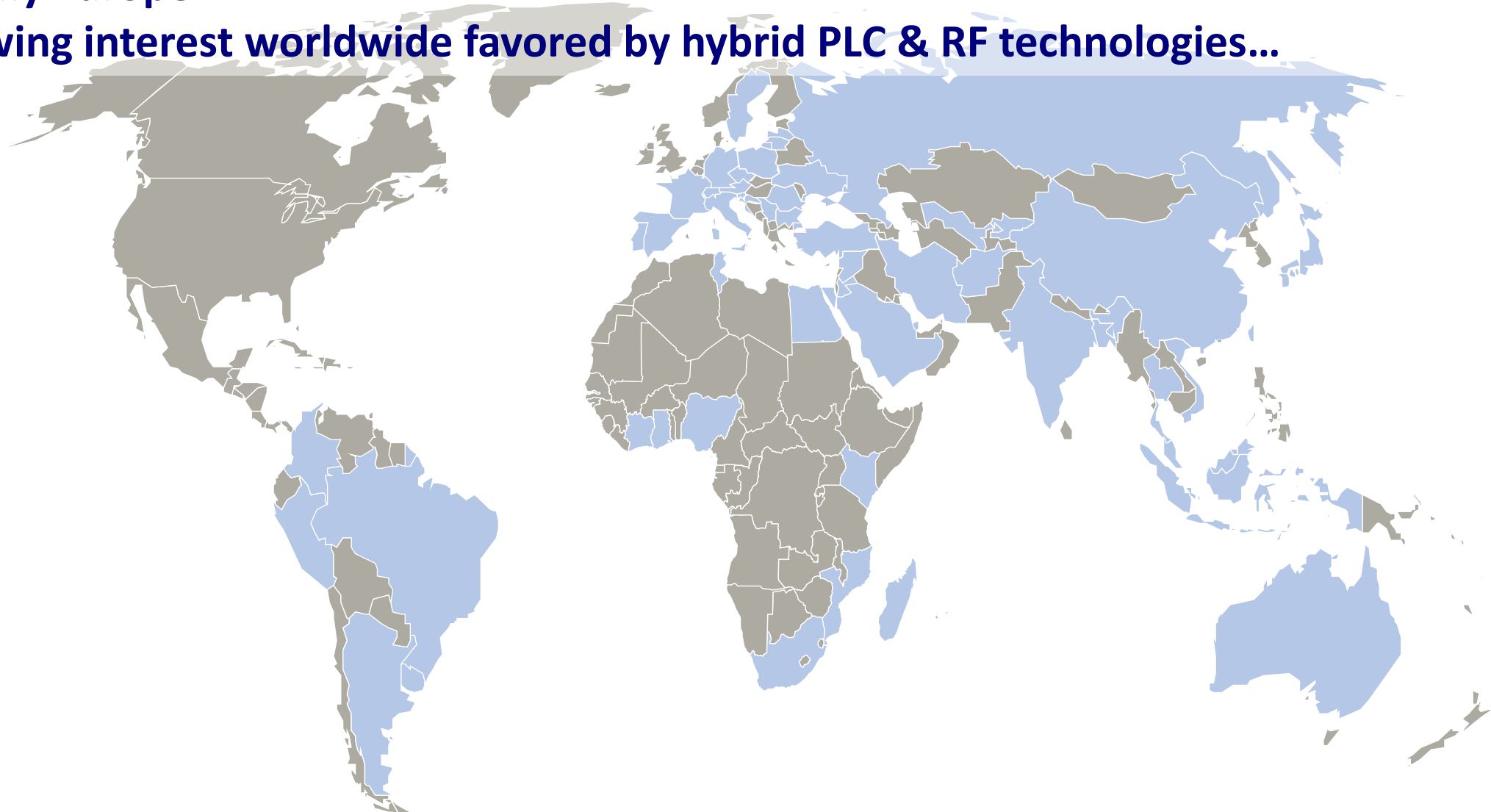
# Market penetration of NB-PLC in smart grid / smart metering

Current estimated market share of NB-PLC ~ 33%



# Market penetration of NB-PLC in smart grid / smart metering

- **Mainly Europe**
- **Growing interest worldwide favored by hybrid PLC & RF technologies...**





# TABLE OF CONTENT

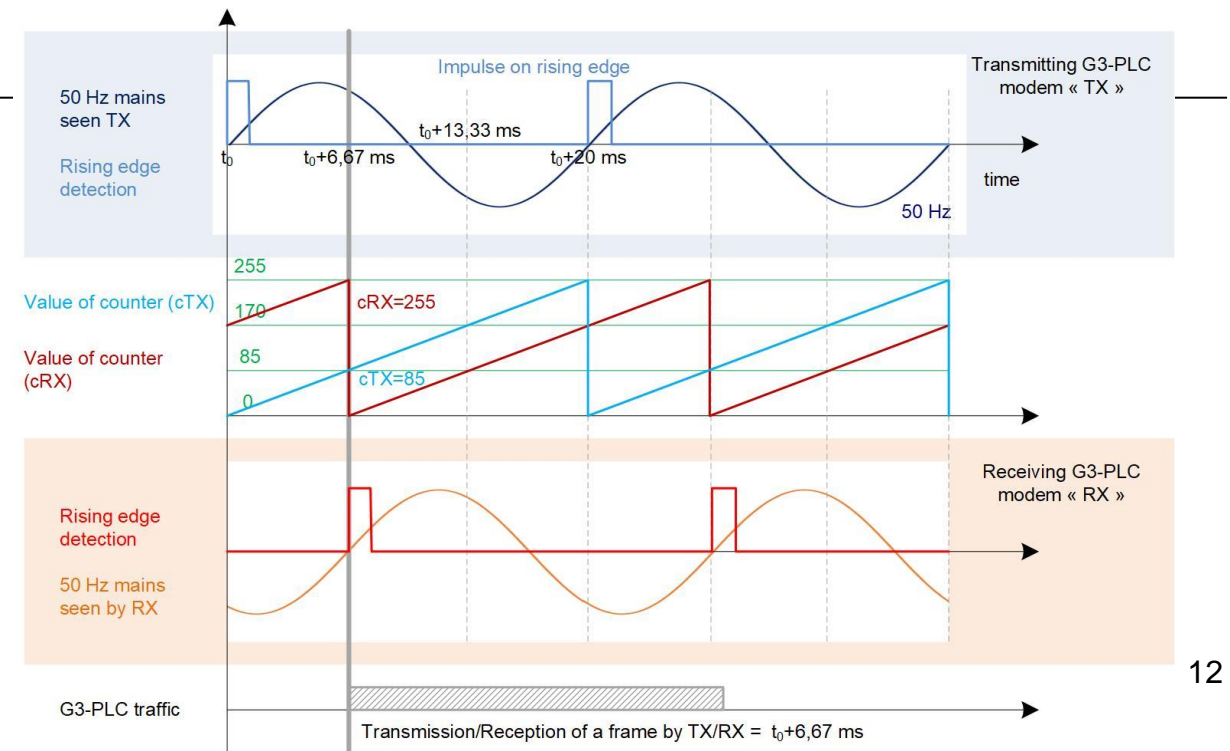
1. NB-PLC for smart metering infrastructure
2. Smart metering and smart grid use cases
3. Future Challenges for NB-PLC technologies

# Phase detection service 1/3

- **Phase connection information of customers is useful to:**
  - Balance load in the three-phase public distribution network
  - Detect phase-neutral inversion
  - Get fine-grained information about outages, surges, etc. → enables LV grid monitoring
- **Phase connection information is a need for some AMI programs and part of its business plans**
- **Continuous update of phase connection information during grid maintenance and operations is of great benefit from an operational perspective**

## G3-PLC provides relative phase detection between neighbors:

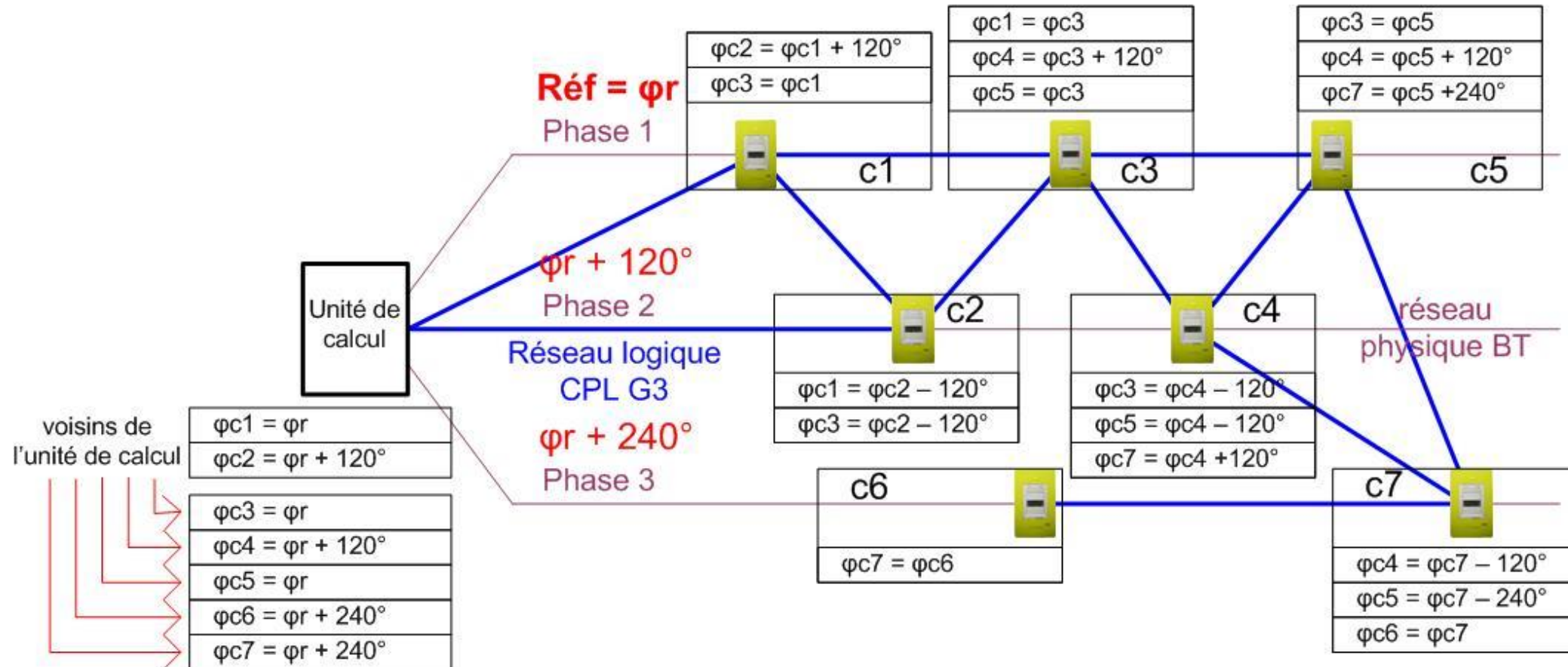
- Use of CSMA/CA (unlike some PLC standards using TDMA-like 50/60 Hz-bound medium access)
- Use of a « Phase Detection Counter » which value is included in the PHY header of each G3-PLC frame
- The PDC field of the received frame updates the « PhaseDifferential » attribute related to the transmitter node in the neighbor table



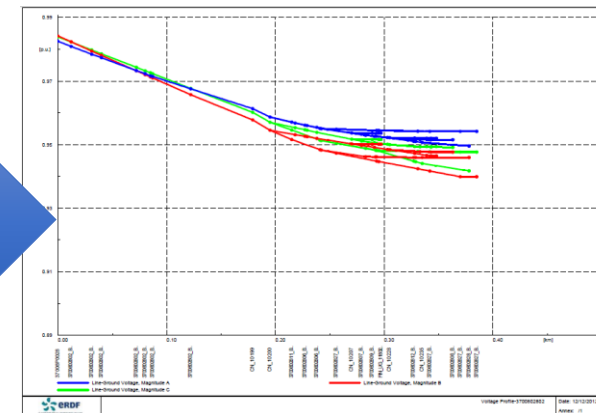
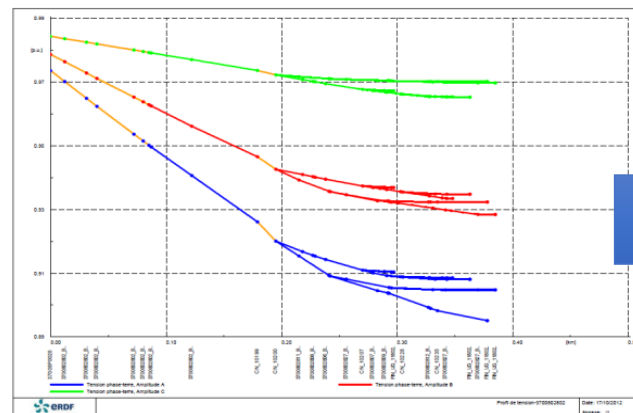
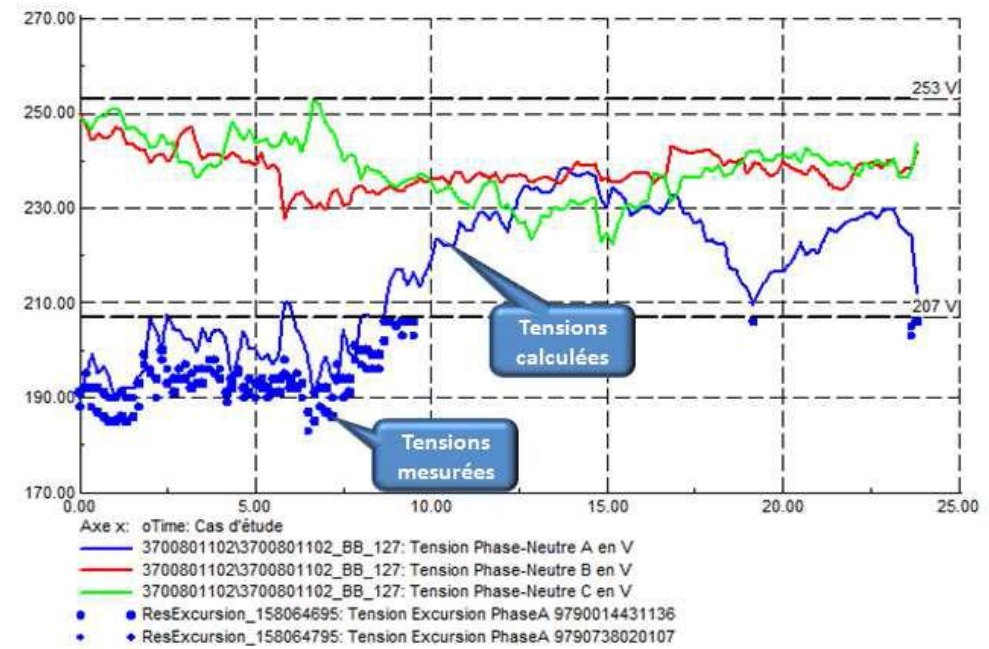
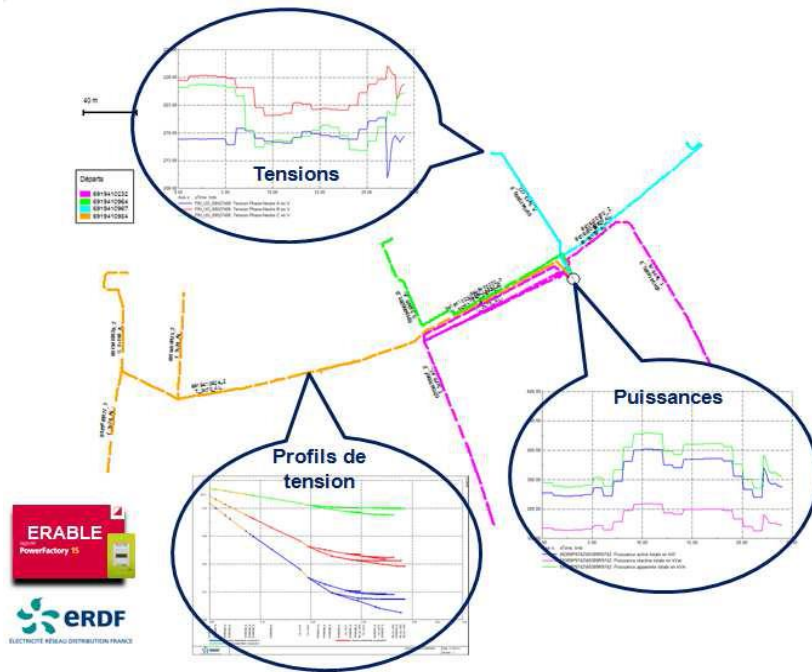


# Phase detection service 2/3

- The absolute phase differential with the data concentrator can be established using neighbour tables.

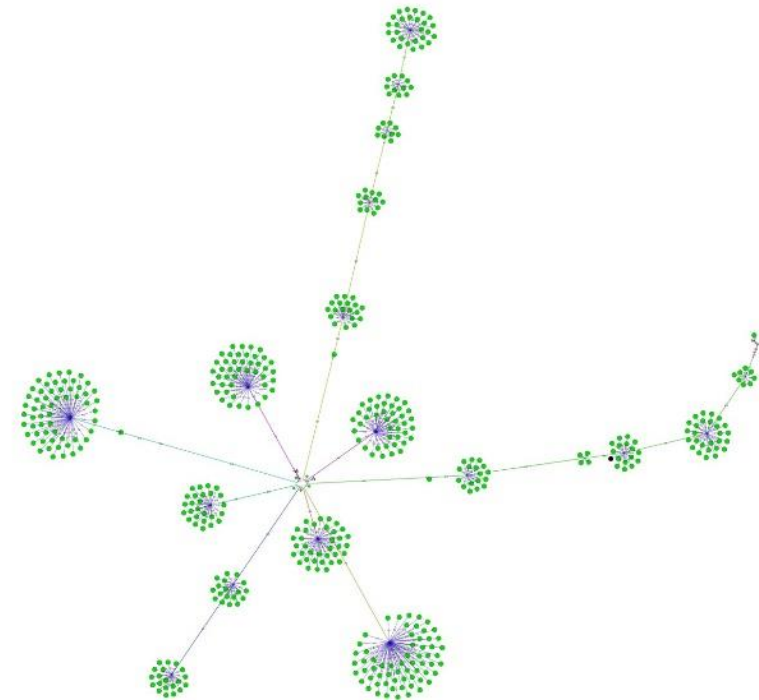
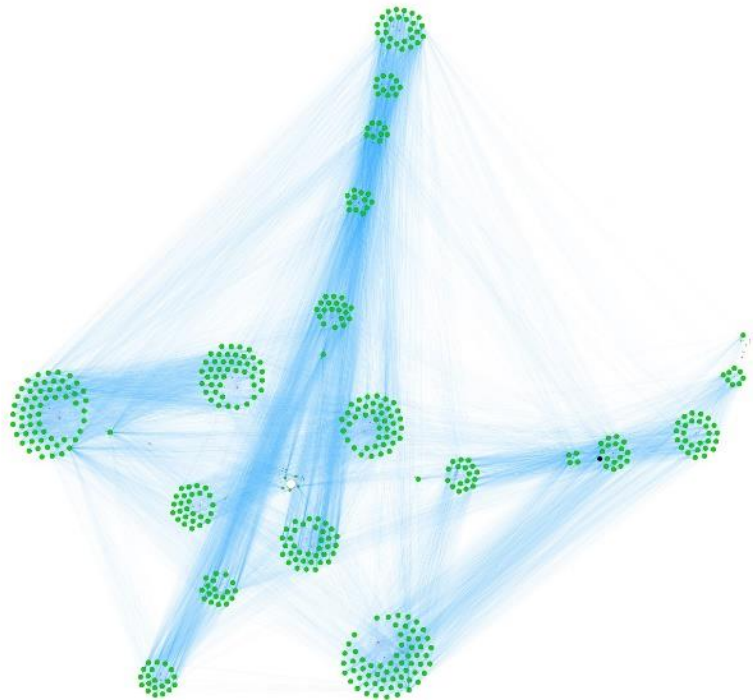


# Phase detection service 3/3



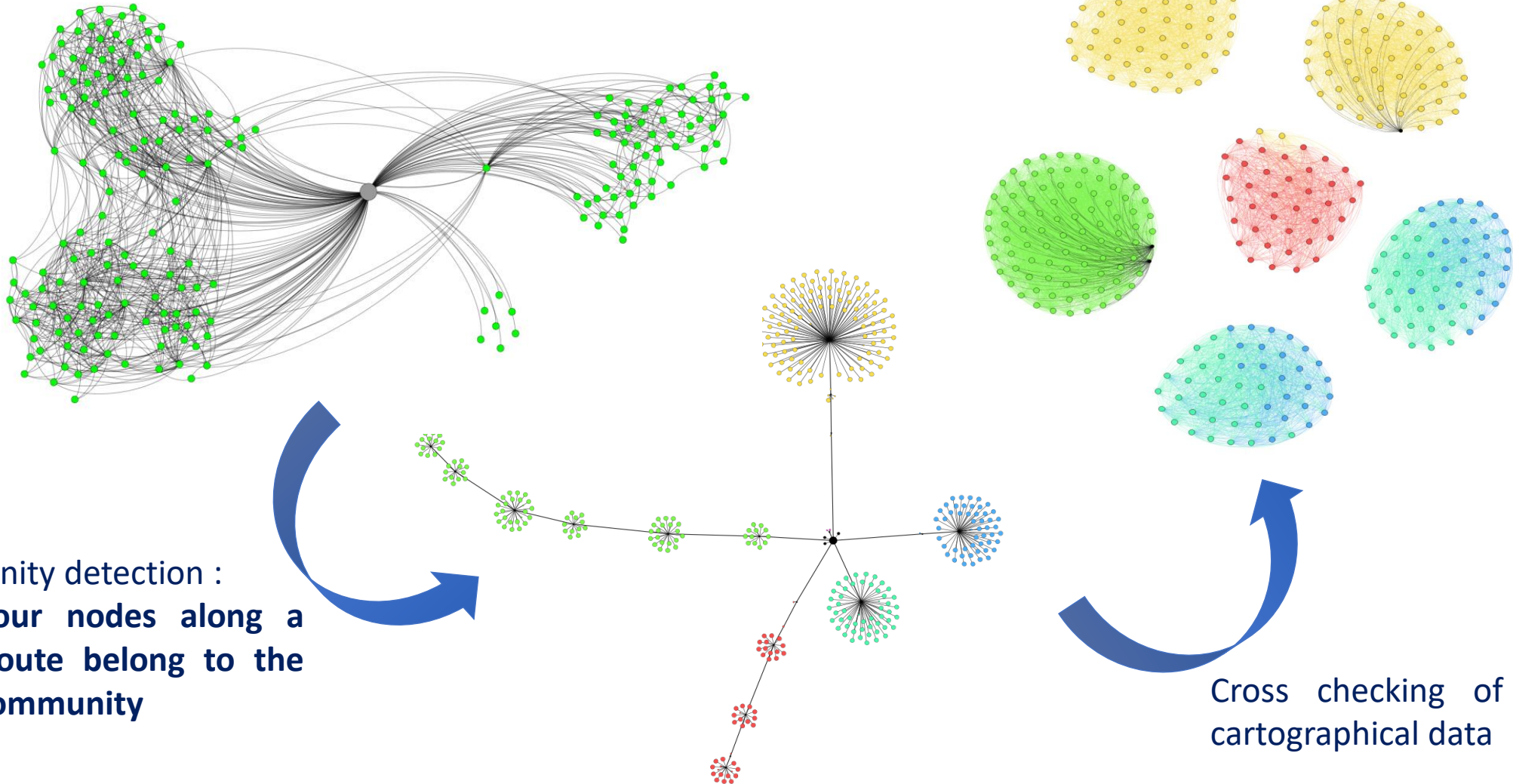
# Grid cartography consolidation 1/3

- As many utilities, **Enedis operates a public distribution network developed over many years**, some parts having been installed more than a century ago : **existing cartographic data is prone to approximations.**
- It is possible to **gather information about all links established between neighbour nodes** together with the **collection of all active paths/routes between nodes** (similar to the IP “traceroute” program).





# Grid cartography consolidation 2/3

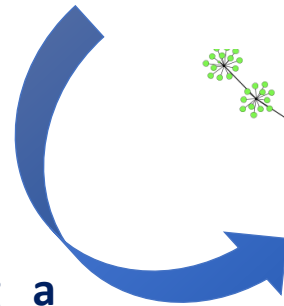
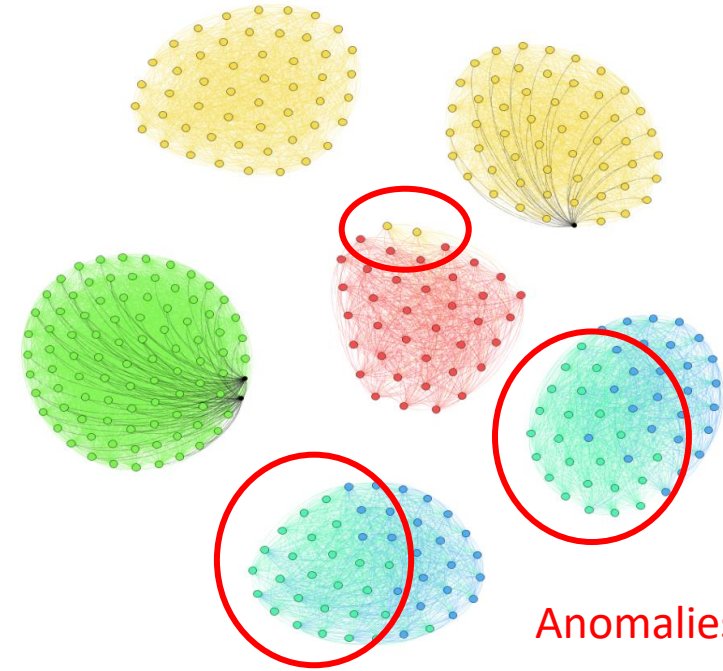
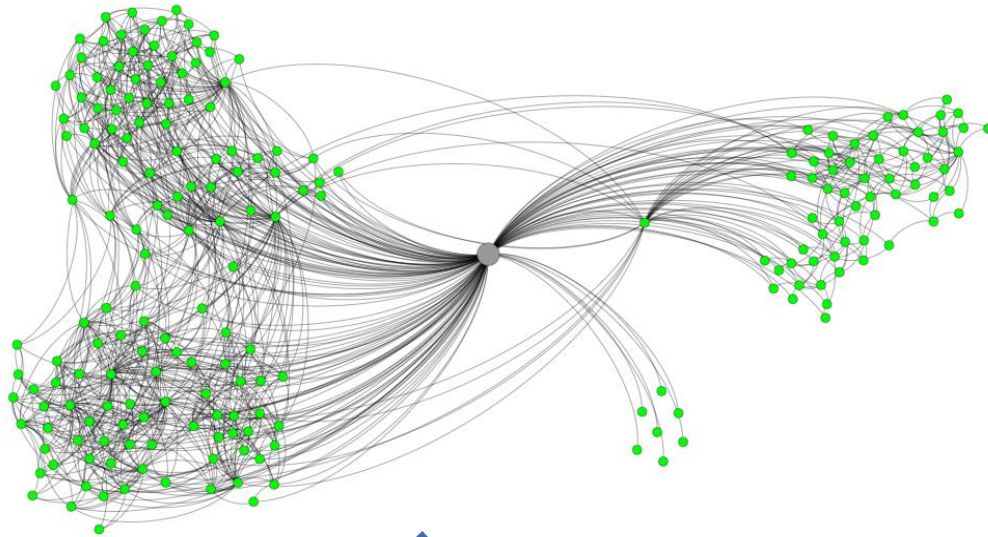


Community detection :  
Neighbour nodes along a  
same route belong to the  
same community

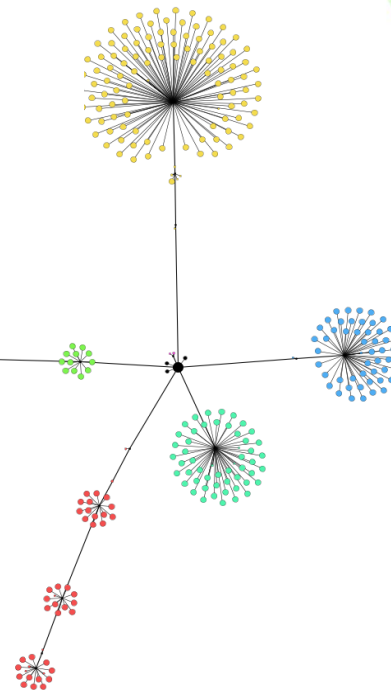
Cross checking of  
cartographical data



# Grid cartography consolidation 2/3



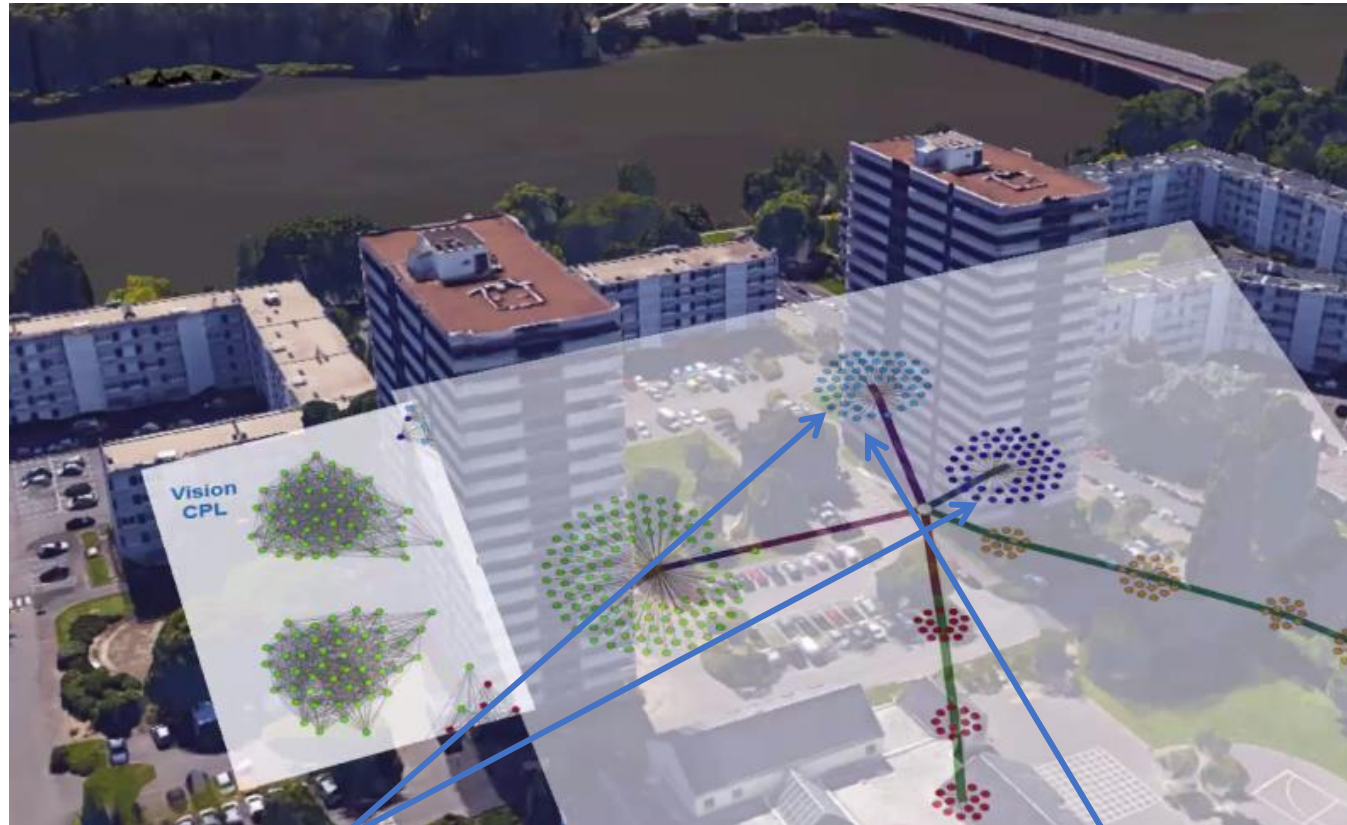
Community detection :  
Neighbour nodes along a  
same route belong to the  
same community



Cross checking of  
cartographical data

# Grid cartography consolidation 3/3

## Beauty of PLC : Telecom Links $\approx$ Electrical Links !



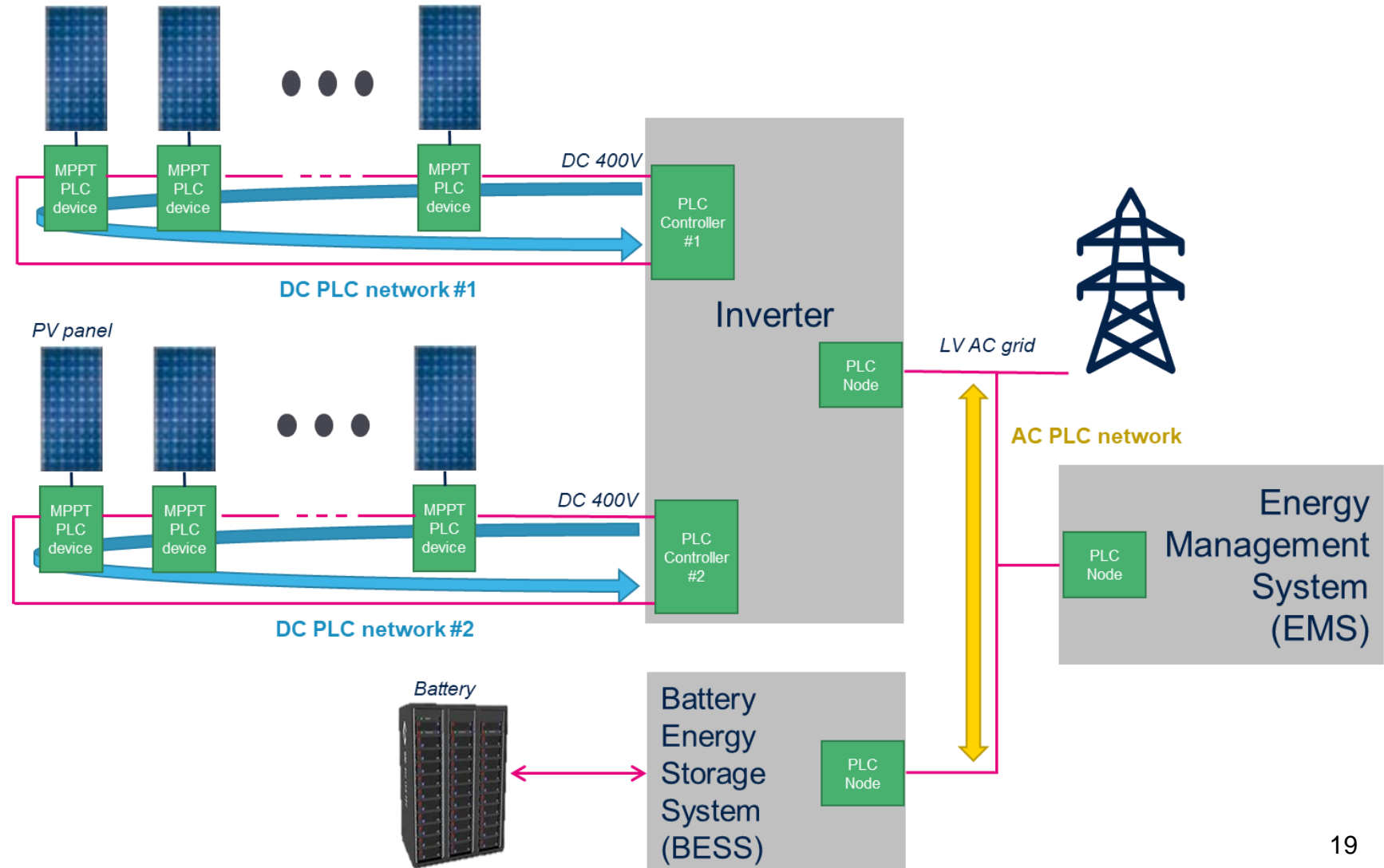
1 grid connection BUT PLC enables to look beyond the current knowledge of grid cartography (floors 1-8 + floors 9-16)

2 meters were incorrectly referenced

# ... NB-PLC gains attraction for a growing number of applications

## Example of PLC over DC bus for photovoltaic production systems

- Adding flexible, state-of-the-art communication **to enable key functions:**
  - Energy efficiency (e.g. MPPT – Maximum Power Point Tracker)
  - Safety (e.g. Rapid Shut Down)
  - Integration with Energy Management Systems
- Enabling local and remote DER management **to support grid digitalization**





# ... NB-PLC gains attraction for a growing number of applications



Known pilots and roll-outs of G3-PLC Smart Metering Worldwide

**Smart Metering**



**VATTENFALL**

Connected street lighting implemented in Sweden:

- Already operational in 4 municipalities
- Thousands of poles connected and growing
- Response times as low as 0,1 second
- Combined with smart charging

**Street Lighting**



LEF Group SMART STATION  
OPTIMIZED MONITORING AND REMOTE CONTROLLING

These stations can be remotely controlled: temperature, time of day, etc.

G3-PLC

Renesas Power Line Communication IC Adopted by Panasonic for Intelligent Lighting Control System

Lighting System at the New Tanabe Gateway Station For Platforms in Tokyo  
(Left: Daylight Color, Right: Warm White Color)

**Railway Applications**



Heating, Ventilation, and Air Conditioning system (HVAC)

Building Energy Management System

Robot Control

**Building & Industrial Automation**



Sensor Network for Underground Power Transmission

**Grid Control/Monitoring**



Digital distribution grid with G3-PLC communication to prevent overload situations caused by growth in electro mobility

- The G3-PLC based Gateway is installed at the secondary substation
- Off the shelf G3-PLC modems are installed near the charging stations
- The gateway monitors the power grid with locally connected power quality instruments

**E-Mobility & Renewables**





# TABLE OF CONTENT

1. NB-PLC for smart metering infrastructure
2. Smart metering enabling smart grid use cases
3. Future Challenges for NB-PLC technologies

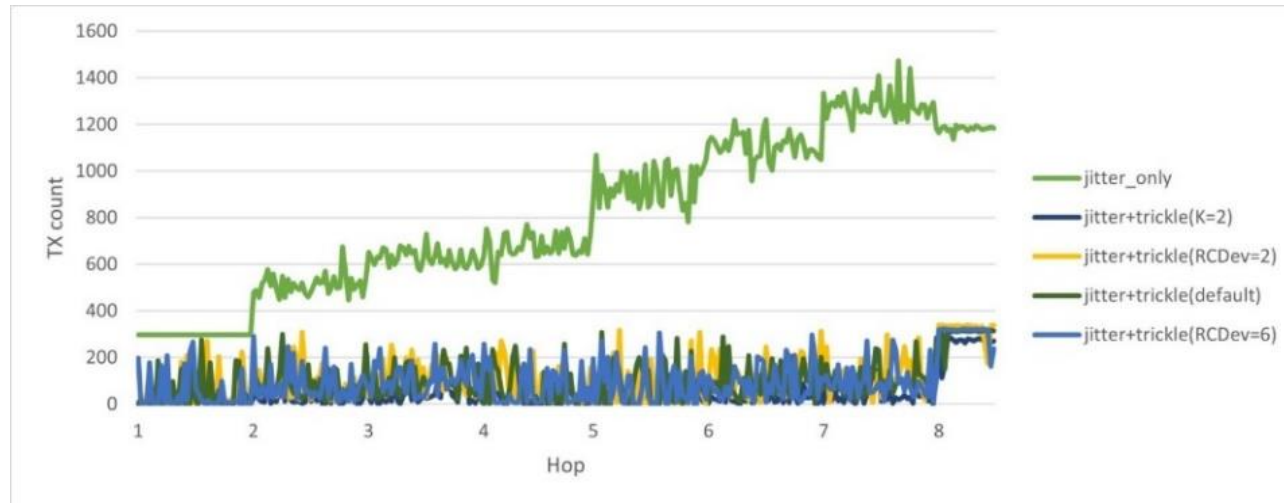


# Future Challenges for NB-PLC technologies

The reduction of overhead, in particular due to routing, is still an important area of improvement. Many smart grid NB-PLC technology-based infrastructures will be operated for years while facing a growing demand for increased bandwidth (new application use cases, etc.).

## - Enhancement of routing

- **Dense network enhancements** (return on experience still required)
- **Path-Aware Semantic Addressing** aka “PASA” (see <https://datatracker.ietf.org/doc/draft-ietf-6lo-path-aware-semantic-addressing/>)



Improved performances of G3-PLC networks implementing dense network enhancements (lab)

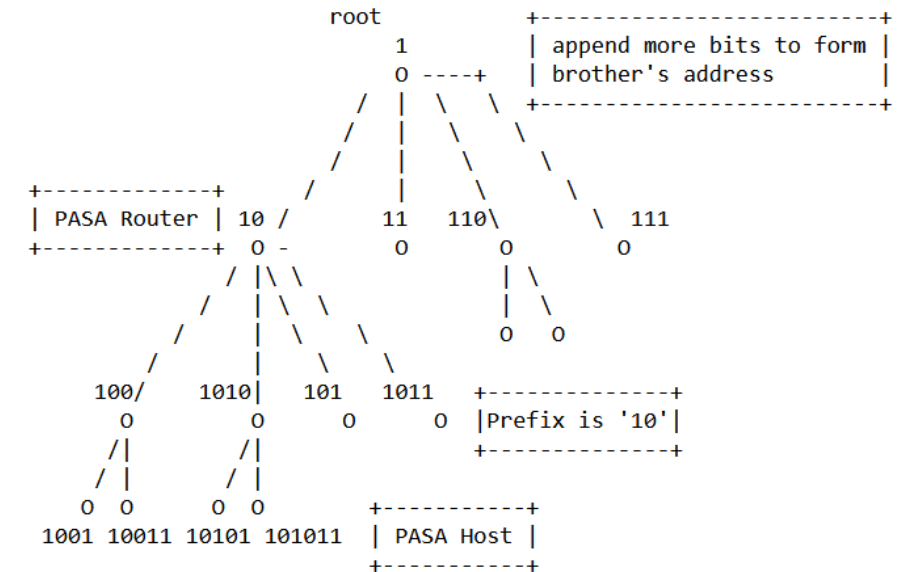


Figure 6: An example of PASA addresses allocation.

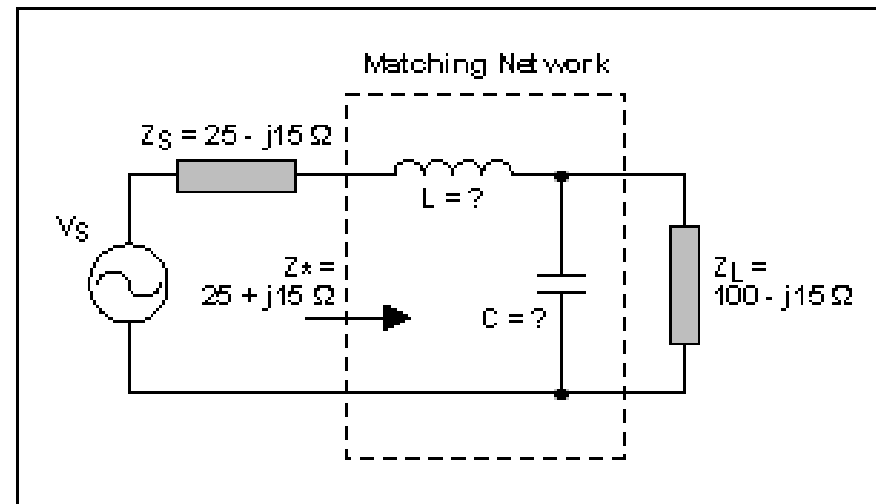




# Future Challenges for NB-PLC technologies

Last but not least, there is still room for improvement of PLC coupling techniques to allow for enhanced impedance matching (at a reasonable cost) and to enable the derivation of data which is valuable to end-users (such as Power Quality information).

- **Enhancement of PLC coupling techniques**
  - **Dynamic impedance matching**
  - **Additional benefits of PLC couplers (PQ, etc.)**





Thank  
you!

