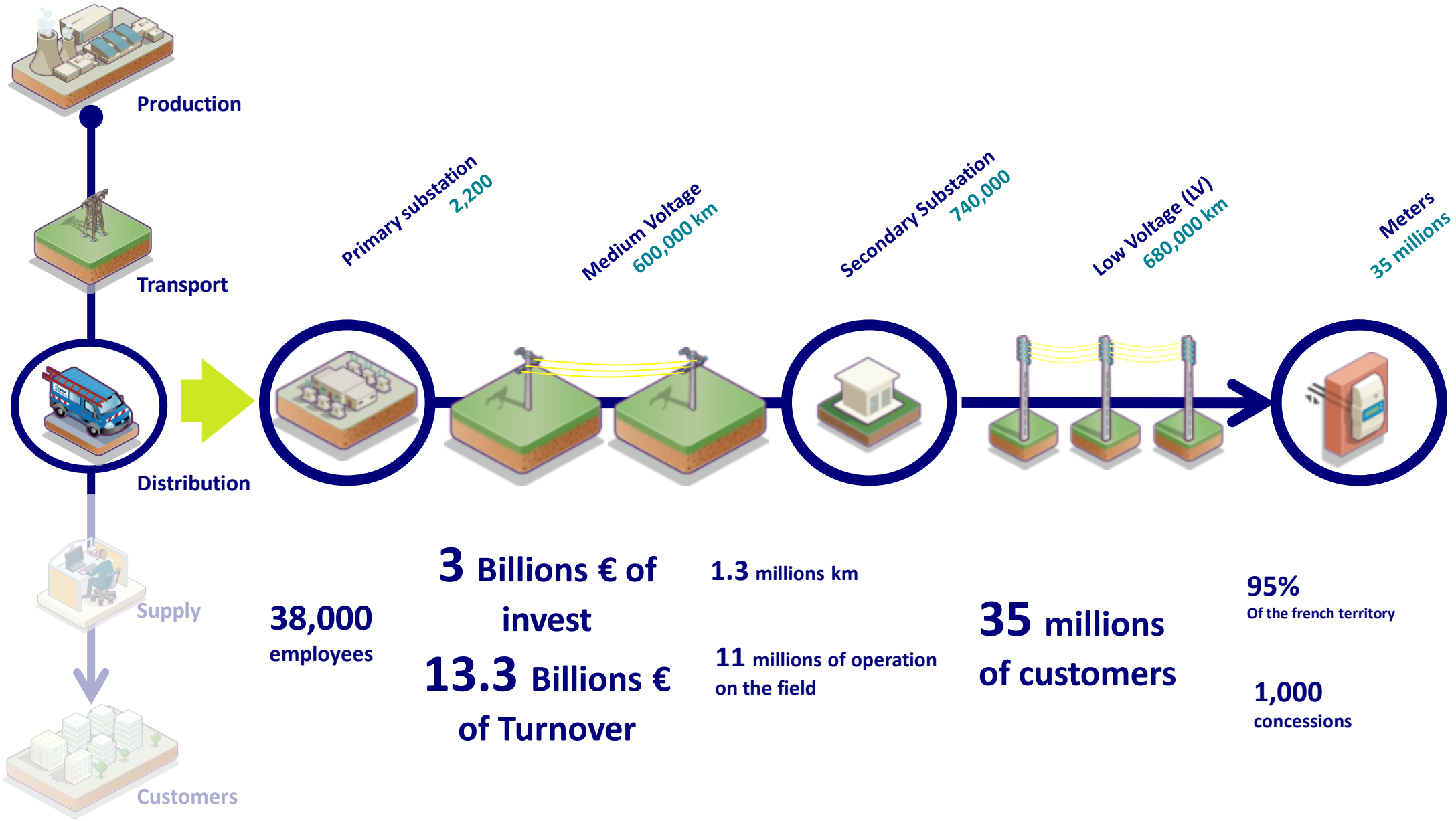
G3-PLC, the standard of the LINKY roll-out and beyond

Cédric Chauvenet

28/04/2016

ERDF manages the distribution network in France



38,000 employees

3 Billions € of invest

13.3 Billions € of Turnover

1.3 millions km

11 millions of operation on the field

35 millions of customers

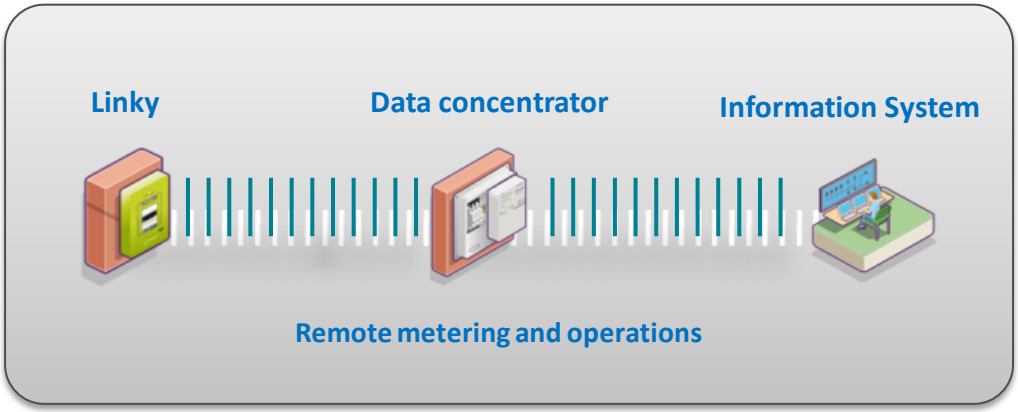
95% Of the french territory

1,000 concessions

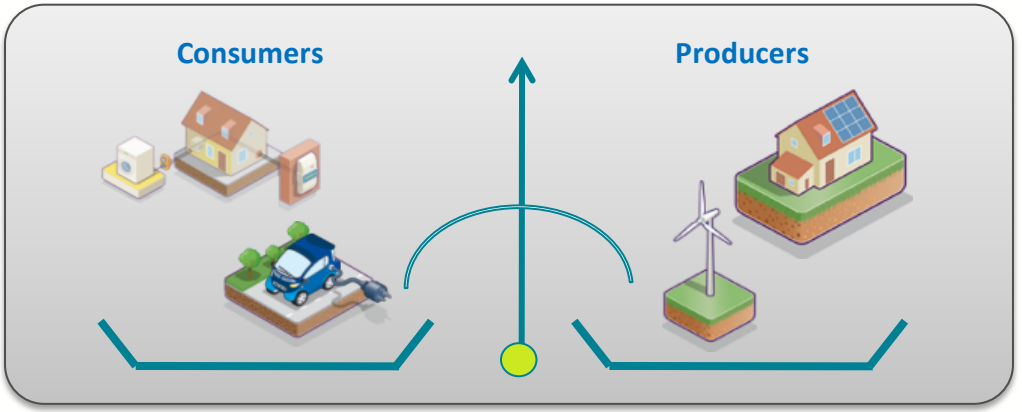
ERDF L'ÉLECTRICITÉ EN RÉSEAU

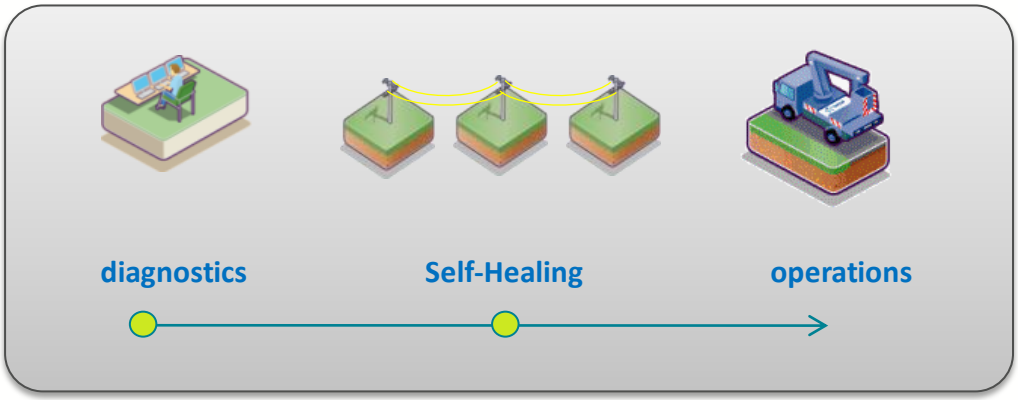
ERDF is moving toward its digital transformation through the Linky project

Remote Control
through AMM



Local balance adjustment
production / consumption





- Meter reading system (Linky) and data management
- Risk management and predictive maintenance

Reduce operational cost and delays on the grid

Adjust investments efficiency on the grid

Linky

Main fonctions & deployment

Perimeter of the Linky smart metering program

Linky : key figures

AN INDUSTRIAL ROLLOUT

6 YEARS

2015→ 2021

TECHNICAL ASPECTS

PLC
FROM THE SMART METERS TO THE DATA CONCENTRATOR

2G/3G
FROM THE DATA CONCENTRAROR TO THE CENTRAL I.T SYSTEM

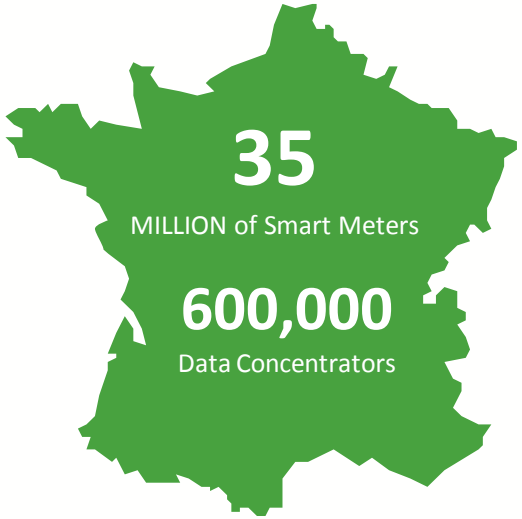
DAILY COLLECTION RATE TARGET REQUIRED BY FRENCH ENERGY REGULATOR

kWh

95%

10 ,000 jobs created in France

(direct or indirect)
(5,000 jobs for mass rollout)

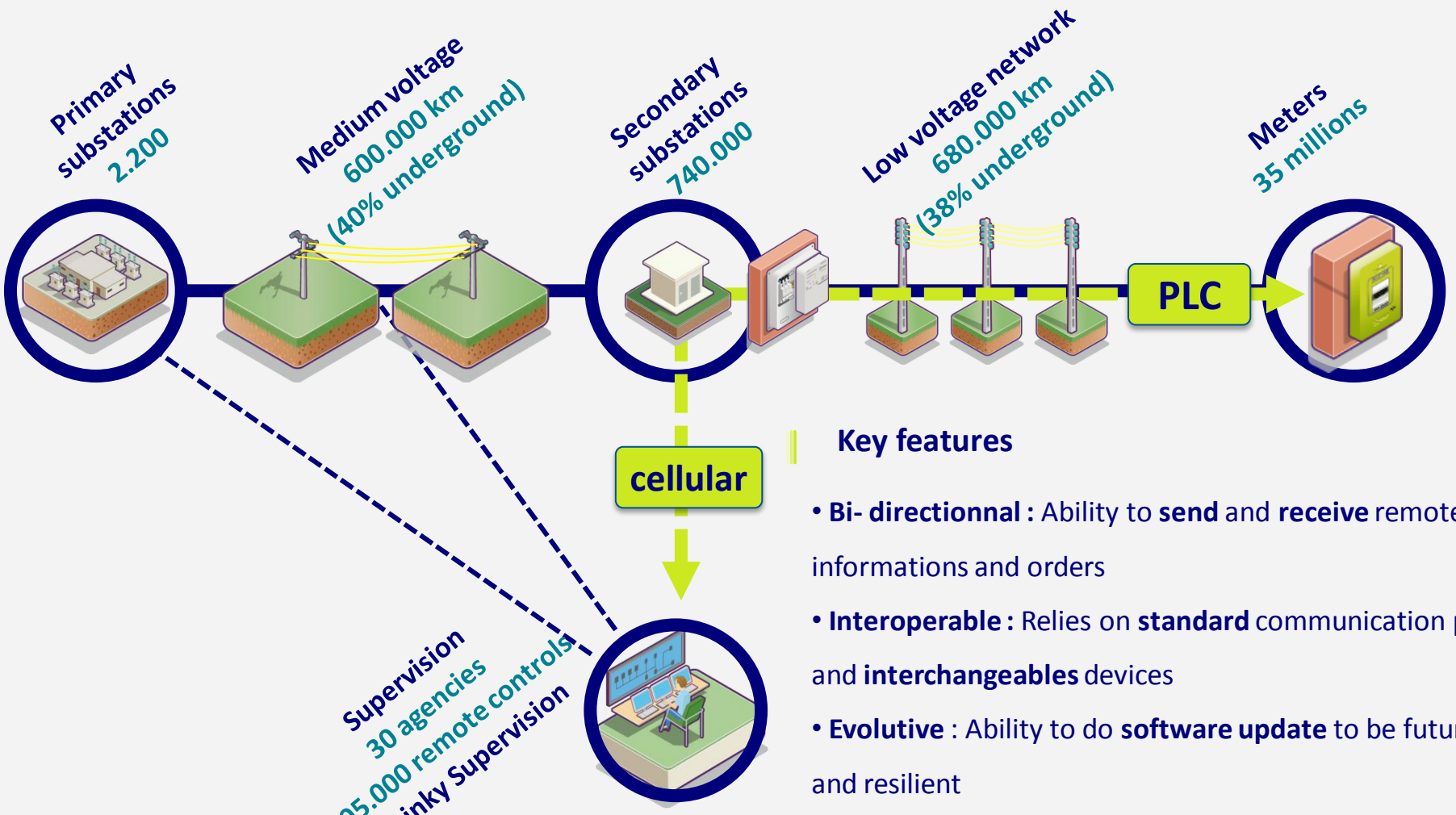


€ 5 B

Billion of current Euros of investment by 2021

Network topology and technology to be deployed

More than a meter, Linky is a complete system

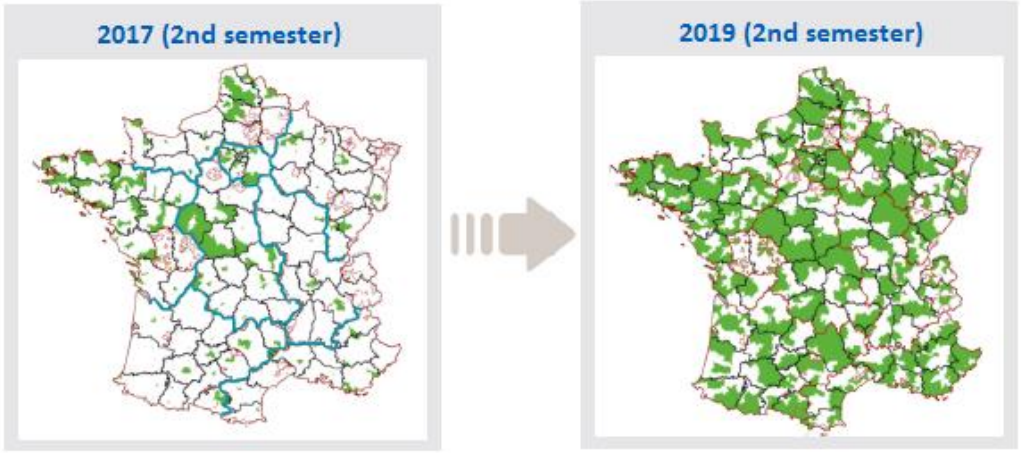


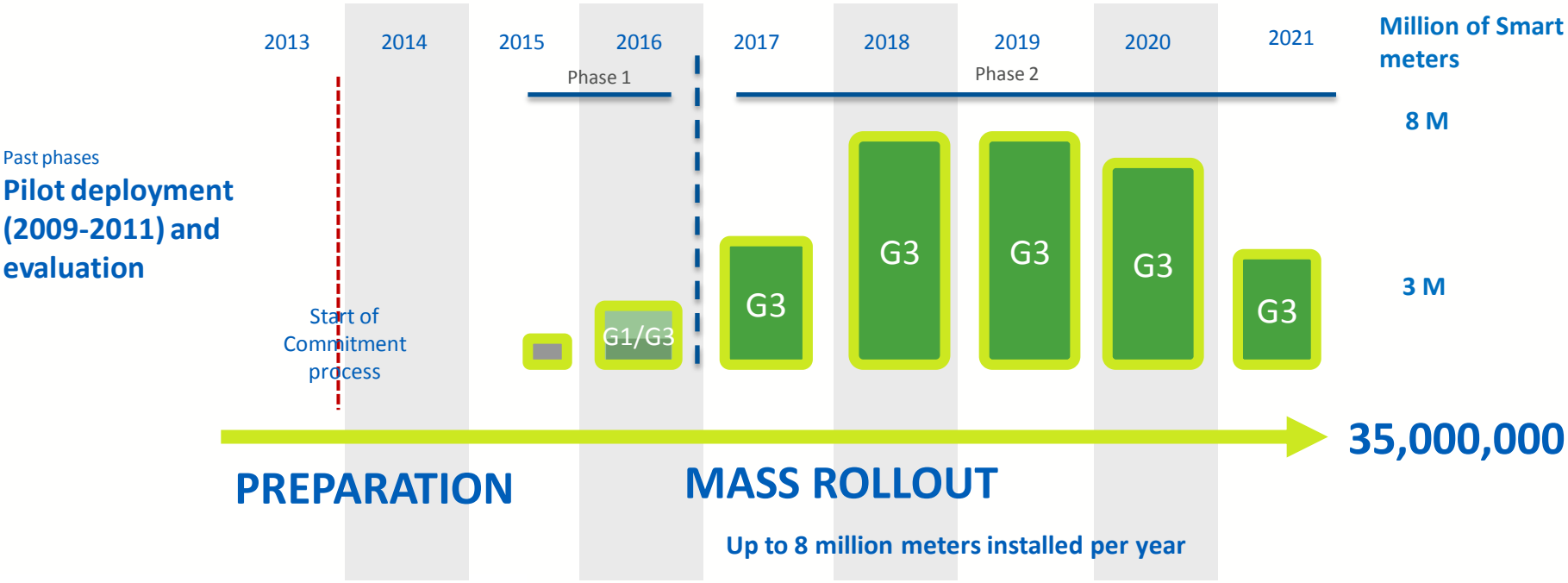
Key features

- **Bi- directionnal :** Ability to **send** and **receive** remote informations and orders
- **Interoperable :** Relies on **standard** communication protocols and **interchangeables** devices
- **Evolutive** : Ability to do **software update** to be future proof and resilient

Roll out strategy (2015-2021)

Leopard pattern rollout

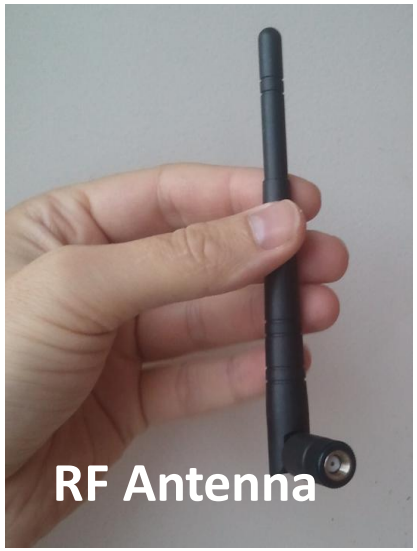




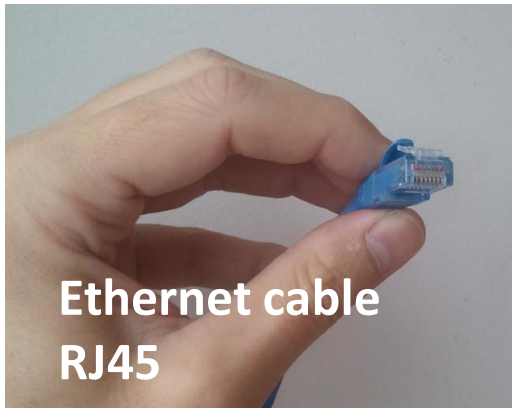
G3 PLC

Why PLC ? (Power Line Communication)

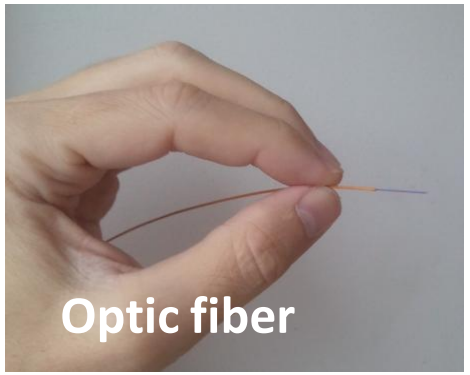
The electric wire as a communication manner



Example : Phone, mobile, TNT, Connected Objects…



Example : data exchanges, internet,...



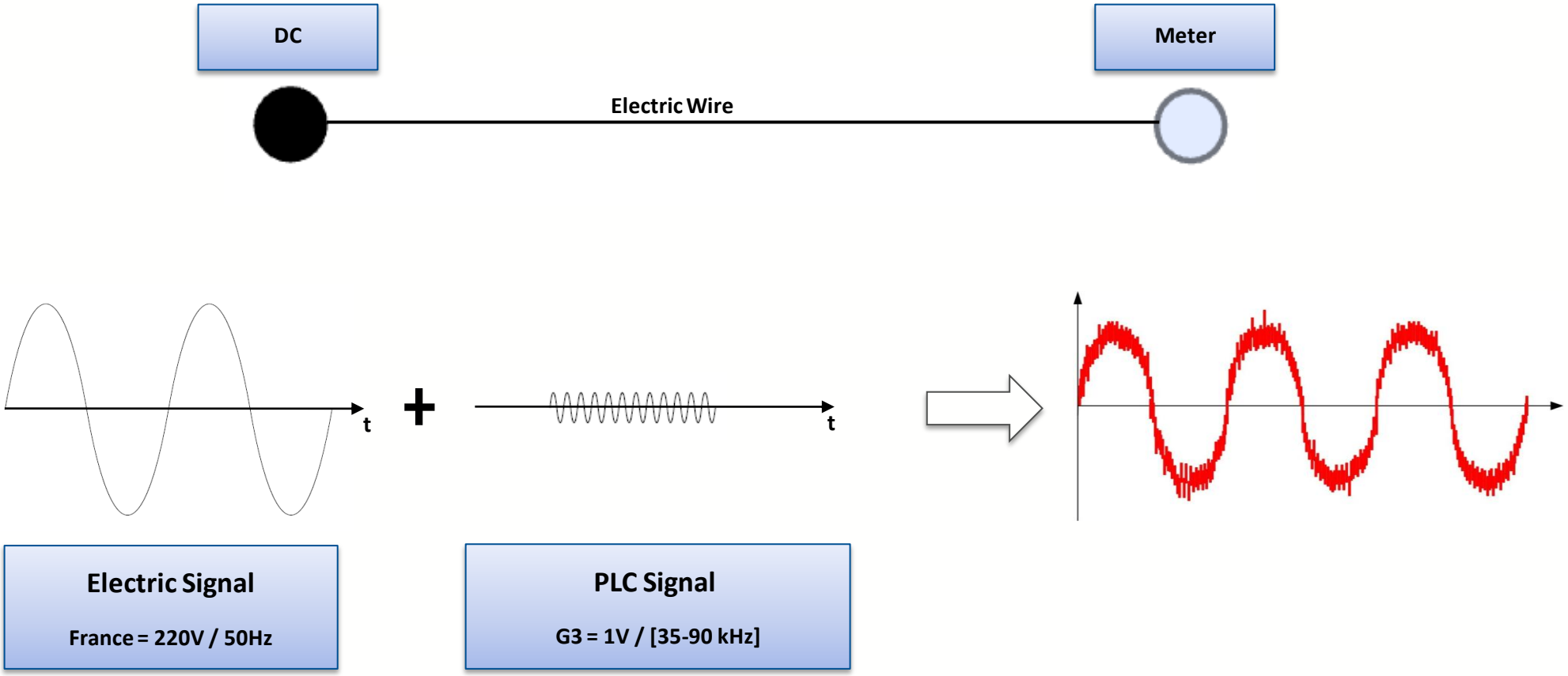
Example : internet data, video,…

We add the information ability to the electric wire…
Example : Smart meters, Smart Home, internet data…

The grid being maintained by ERDF, **PLC allows to be independant from telecom operators …** and related costs.

How does PLC works ?

- PLC baseline : Use the grid as a communication manner by **adding an electrical signal at a higher frequency over the 50 Hz**



How does CPL stands ?

Why using PLC technology ?

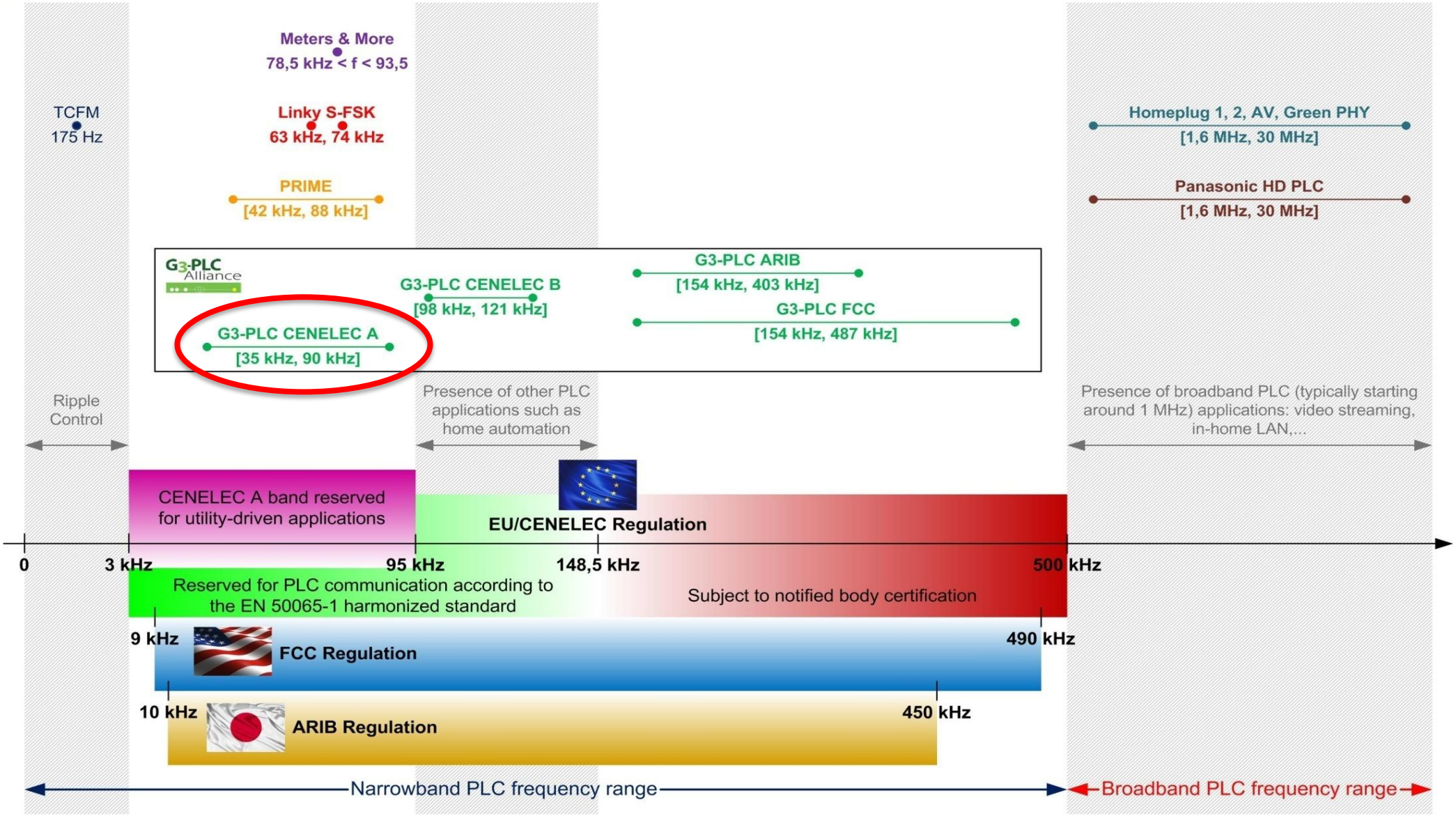
Pros

- The **communication support** is already there and **“ready to use”**
- The grid is just the **largest wired network on earth** and cover the vast majority of contries
- In **Europe**, a **frequency band** (CENELEC A) is **reserved** to distributors (**EN 50065-1** standard)
- The grid being maintained by ERDF, **PLC enable to maintain a power and a telecom network in the same time without additionnal costs**

Cons

- **Shared Media** : other devices can transmit in this band (not relevant in Europe → CENELEC A)
- **Disturbed Media** : noises phenomenons, attenuations
- **Open Media** : Everybody can access to it so security is a major concern

PLC technologies landscape



G3 PLC : An extension to the IP ubiquity

Internet relies on a **IP**, **standard architecture** , enabling to interconnect **machines**, **people** or **objects** to bring **services**

G3 PLC fits into this paradygm and extends this architecture to energy services and beyond

It uses state of the art technologies from the Internet and those from IoT in particular.

Reusing existing components from the internet, G3 PLC directly benefits from already proven security solutions for all exchanges it conveys

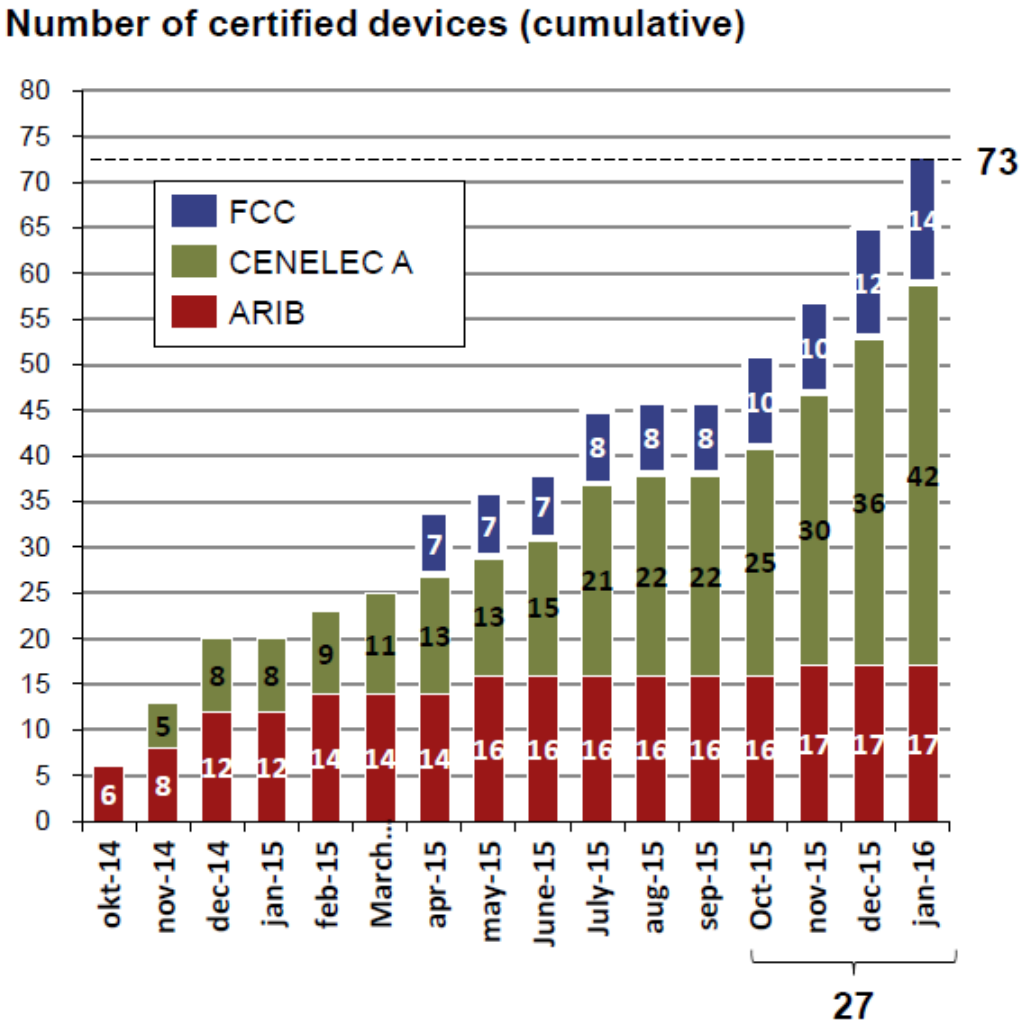
Synthetic view of main actors

Alliance/DSO	Utilities/Operators	Chip Manufacturer	Supplyers
G3-PLC Alliance	ERDF, EDF, ENEXIS, E.ON	ST life.augmented, maxim integrated, Texas Instruments, semitech semiconductor, Atmel, Renesas, Yitran	Sagemcom, elster, Cisco, Itron, Nexans, Panasonic, Landis+Gyr manage energy better, devolo The Network Innovation, ISKRAEMECO
PRIME ALLIANCE	IBERDROLA, gasNatural fenosa	ST life.augmented, Atmel, Texas Instruments, Renesas, NXP	Sagemcom, elster, ZIV, CURRENT, Landis+Gyr manage energy better, Itron, ISKRAEMECO, SIEMENS
meters AND more OPEN TECHNOLOGIES	Enel L'ENERGIA CHE TI ASCOLTA, E.ON, endesa	ST life.augmented, Atmel, Renesas	Landis+Gyr manage energy better, SIEMENS
HOMEPLUG POWERLINE ALLIANCE	Duke Energy, 国家电网公司 State Grid Corporation of China, SDGE, Southern California Edison, France Telecom	ST life.augmented, Qualcomm Atheros, Broadcom, Mstar semiconductor, Renesas	Cisco, Itron, Landis+Gyr manage energy better, devolo The Network Innovation, POWERPLUS COMMUNICATIONS
ITU WG G.Hnem	ERDF, NTT docomo	ST life.augmented, Texas Instruments, maxim integrated, Yitran	Panasonic
IEEE WG P1901.2	EDF, Duke Energy	ST life.augmented, Renesas, Atmel, Texas Instruments, freescale, maxim integrated, Yitran	Cisco, Itron, Landis+Gyr manage energy better, POWERPLUS COMMUNICATIONS, devolo The Network Innovation, SIEMENS, ABB, ISKRAEMECO

G3-PLC certified devices

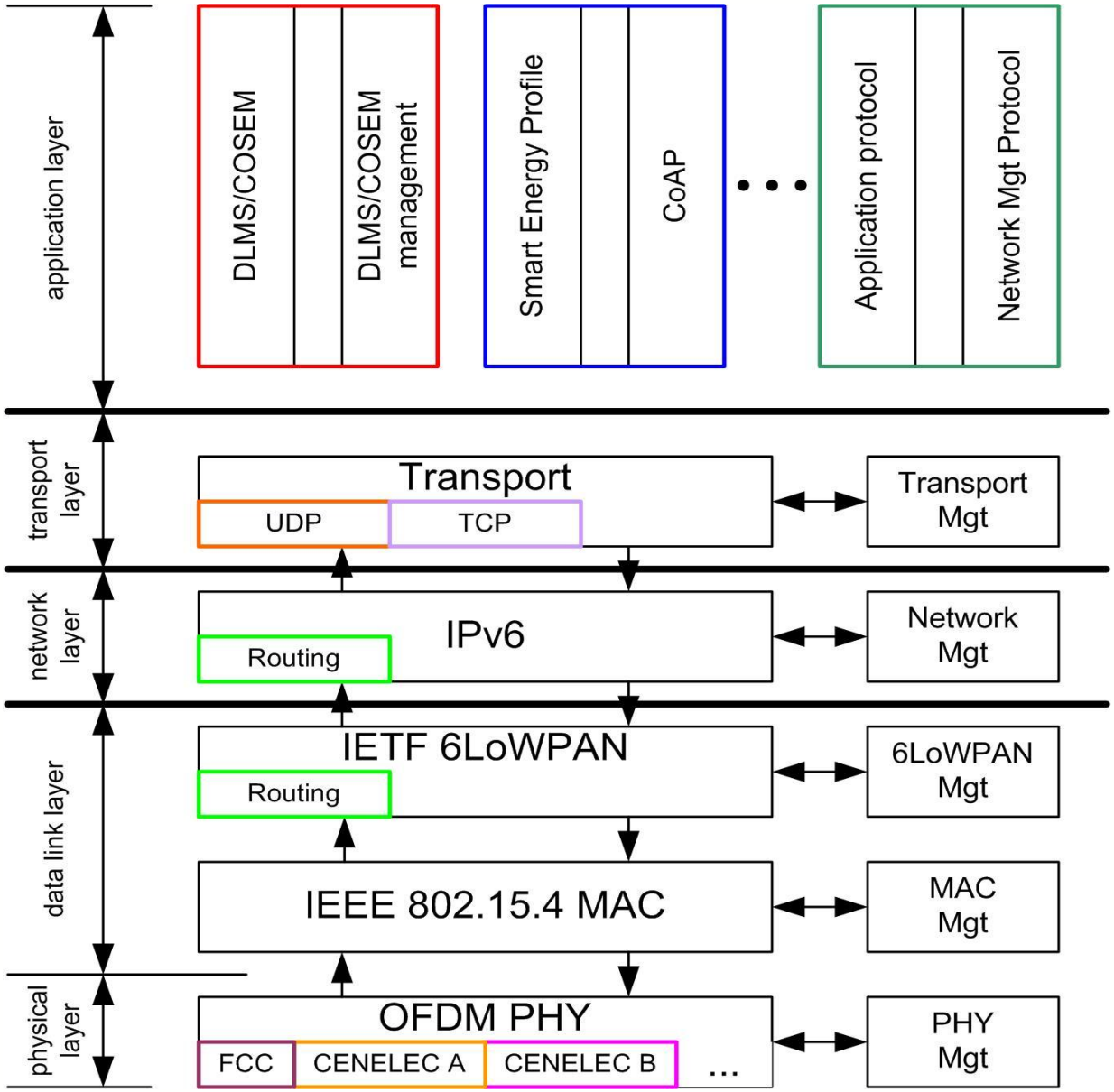
Availability

- 73 different devices certified in G3-PLC Alliance
- 54 platforms
- 19 products
- 15 different vendors



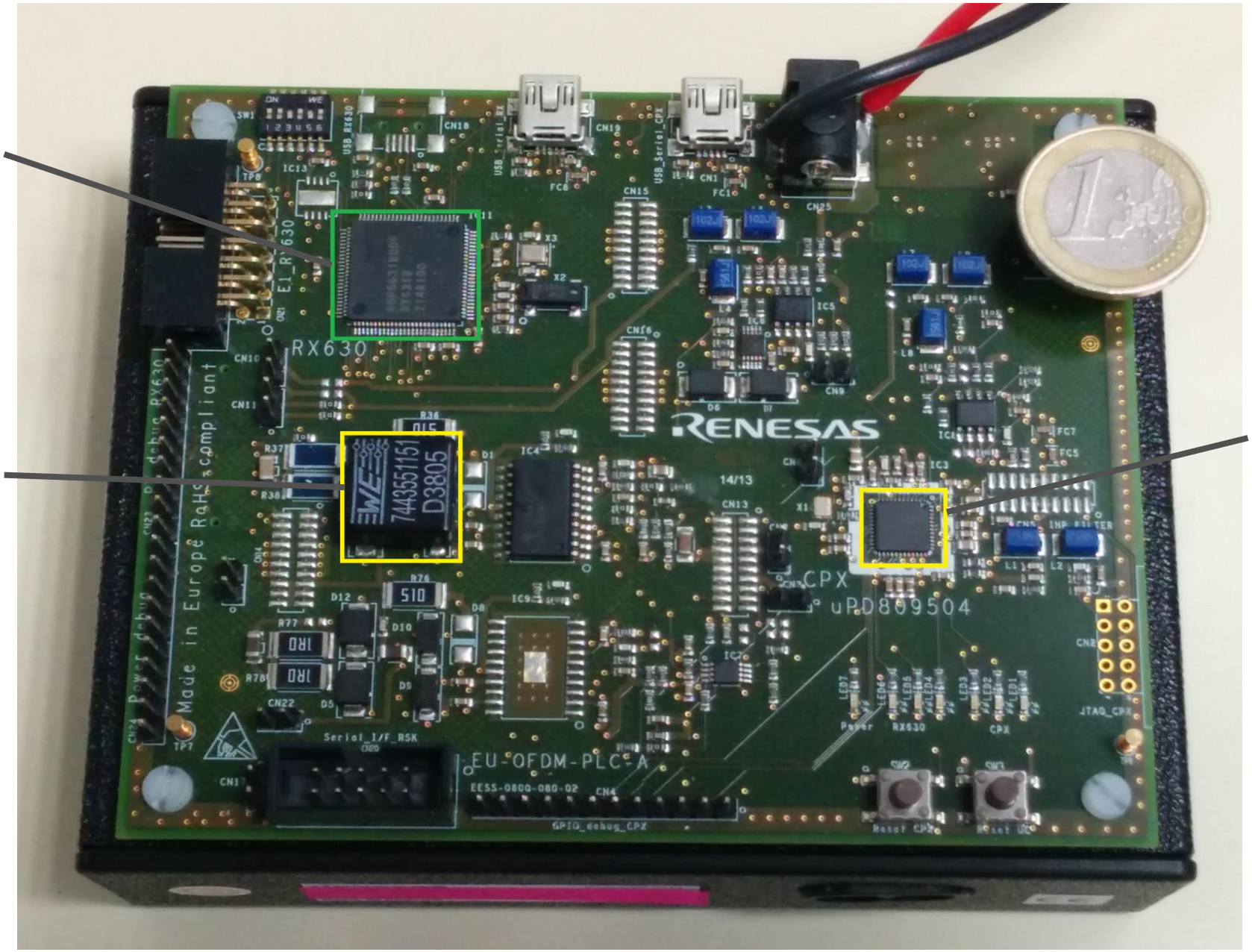
G3 : Overall view of the protocol stack

- G3 PLC, a multi application technology for the worldwide market
  - **A common trunk « PHY/MAC/6LoWPAN » defined by the G3 Alliance**
  - **Ability to connect with several applicative protocols**



Standard ITU-T G.9903

What does G3 looks like ?



G3 Physical Layer: Overall view

OFDM Modulation : FFT over 256 points

- Frequency sampling of **400 kHz** (symbol time : 640 µs)
  - **CENELEC A** band **: 36 carriers from 35,9 to 90,6 kHz**
  - **CENELEC B** band **: 16 carriers from 98,4 to 121,9 kHz**
- Frequency sampling of **1,2 MHz** (symbol time : 213 µs)
  - **FCC** band **: 72 carriers from 154,7 to 487,5 kHz**
  - **ARIB** band **: 54 carriers from 154,7 to 403,1 kHz**

Various modulation scheme for sub-carriers :

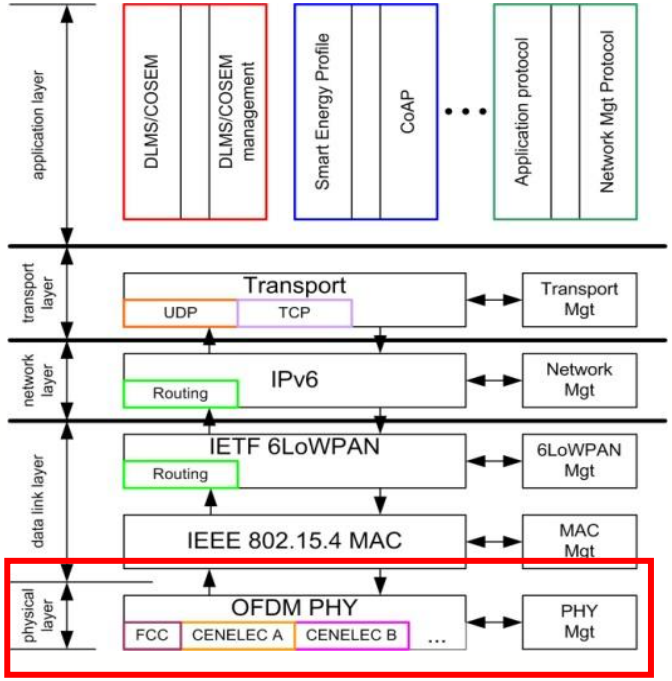
- **Differential Modulations :** D8PSK, DQPSK, DBPSK, ROBO
- **Coherent Modulations :** 8PSK, QPSK, BPSK, ROBO

Error Correction:

- **Reed Solomon**
- **Convolutive code** (efficiency 1/2)

Time-frequency diversity usage

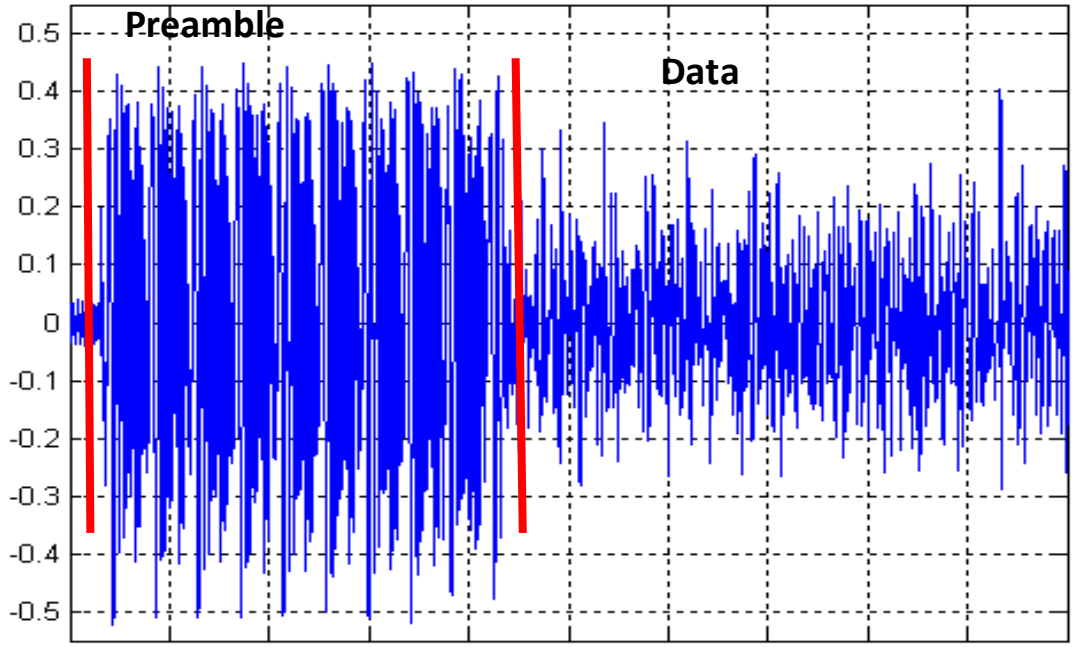
- **Interleaver**
- **Scrambler**



G3 Physical layer : Services

- Zoom on…
  - **OFDM modulation**
    - **OFDM** : Orthogonal Frequency Division Multiplex, modulation technique enabling to allocate N orthogonal sub-carriers in frequency

➢ Temporal shape of a G3 signal :



- *Maximal duration : ~**200 ms***
- *Composition:*
1. ***Synchronization Preamble***
2. ***FCH***
3. ***Useful data*** *(MAC layer)*

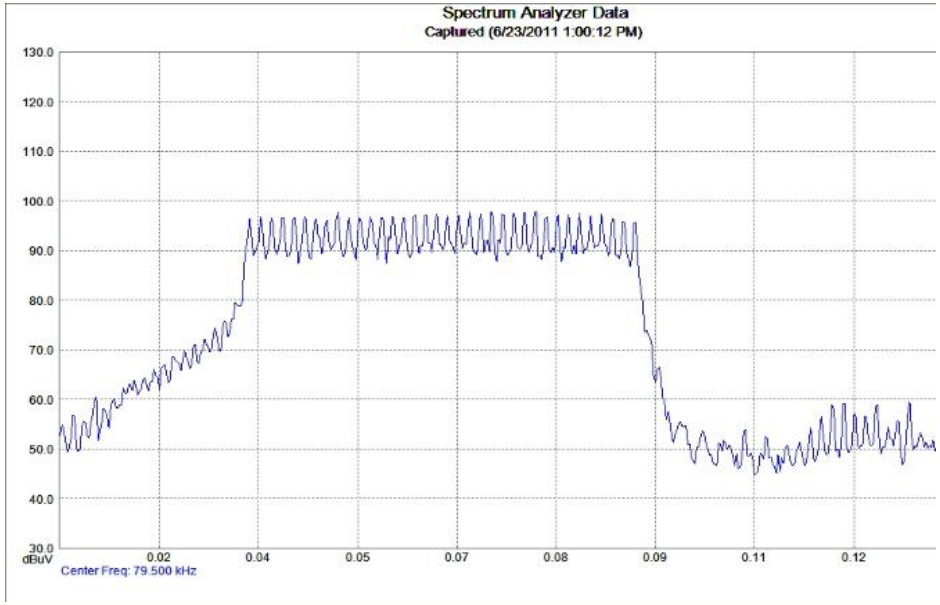
G3 Physical layer : Services

Zoom on…

➢ OFDM modulation

– **OFDM** : Orthogonal Frequency Division Multiplex, modulation technique enabling to allocate N orthogonal sub-carriers in frequency

➢ Frequency shape of a G3 signal (in Cenelec A band):



*- 36 orthogonal carriers in the **[35 ; 90] kHz band***
- Available Modulations :

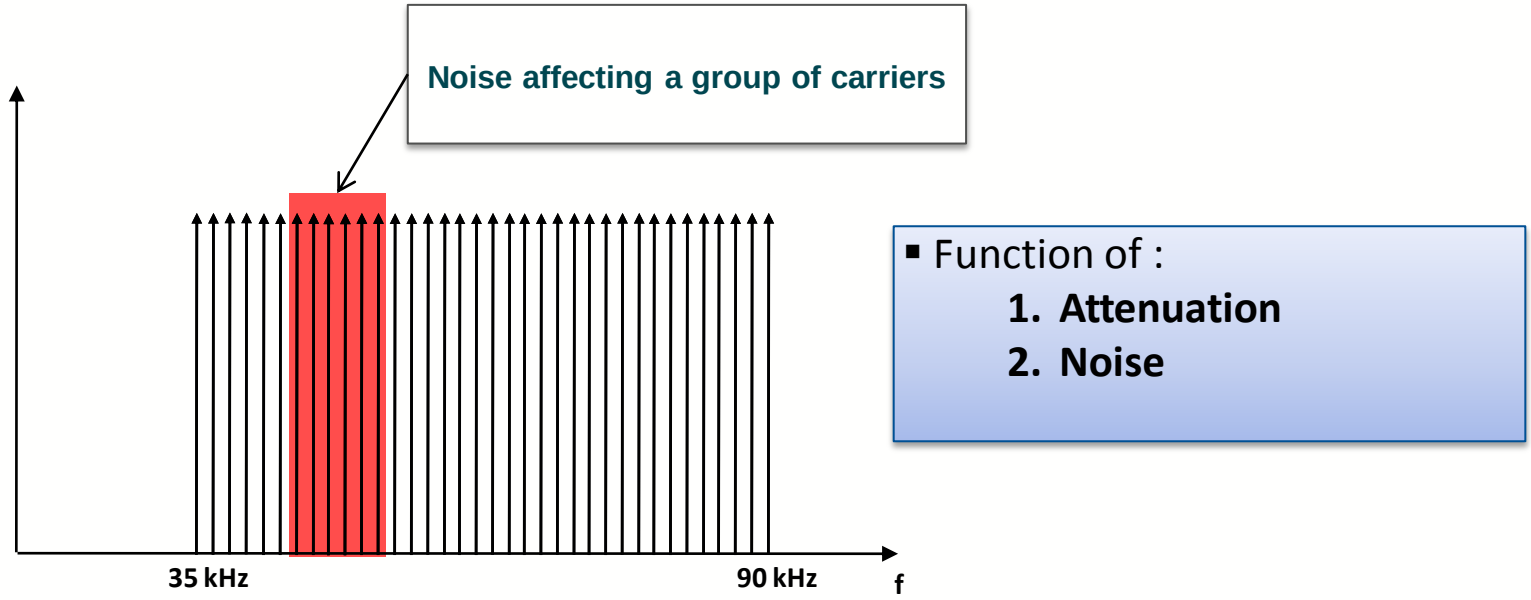
1. ***D8PSK** (3 bits/carrier)*
2. ***DQPSK** (2 bits/carrier)*
3. ***DBPSK** (1 bit/carrier)*
4. ***« ROBO Mode»** (DBPSK with x4 repetition code)*

Frequency Band	ROBO PHY D.R. (kbps)	DBPSK PHY D.R. (kbps)	DQPSK PHY D.R. (kbps)	D8PSK PHY D.R. (kbps)
CENELEC A (36kHz to 91kHz)	4,5	14,6	29,3	43,9
FCC (150kHz to 487.5kHz)	21	62,3	124,5	186,9

G3 MAC Layer : Services

Zoom on…

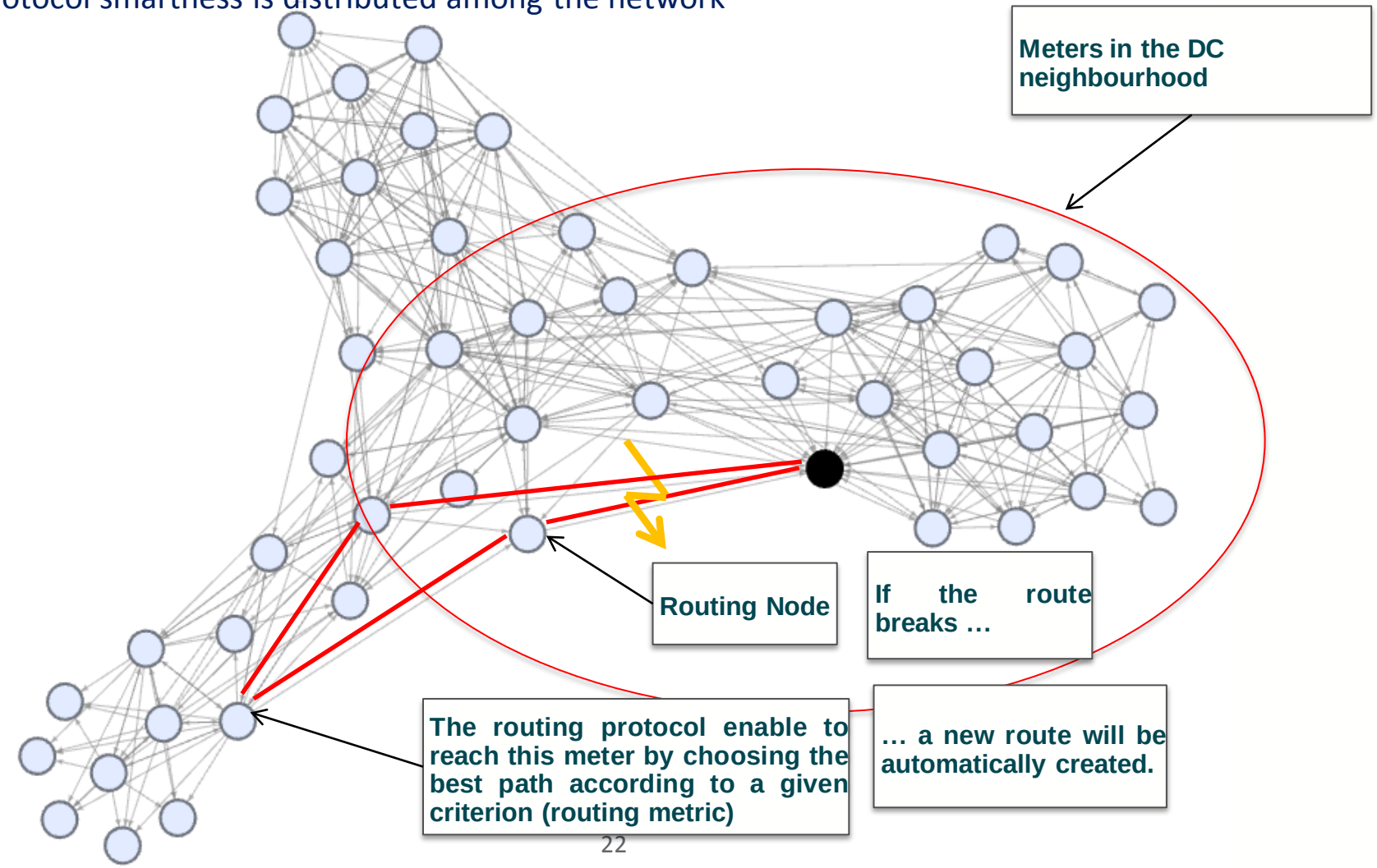
- **Link quality adapation : the Tone Mapping mechanism**
  - Throughput is automatically adapted according to the **Link Quality Indicator (LQI)**
  - The **Tone Map** mechanism has two parameters :
    1) Order (⇔ nb of bits) of modulations : D8PSK, DQPSK, DBPSK, ROBO
    2) Nb of active carriers (between 6 and 36)



- Function of :
  1. **Attenuation**
  2. **Noise**

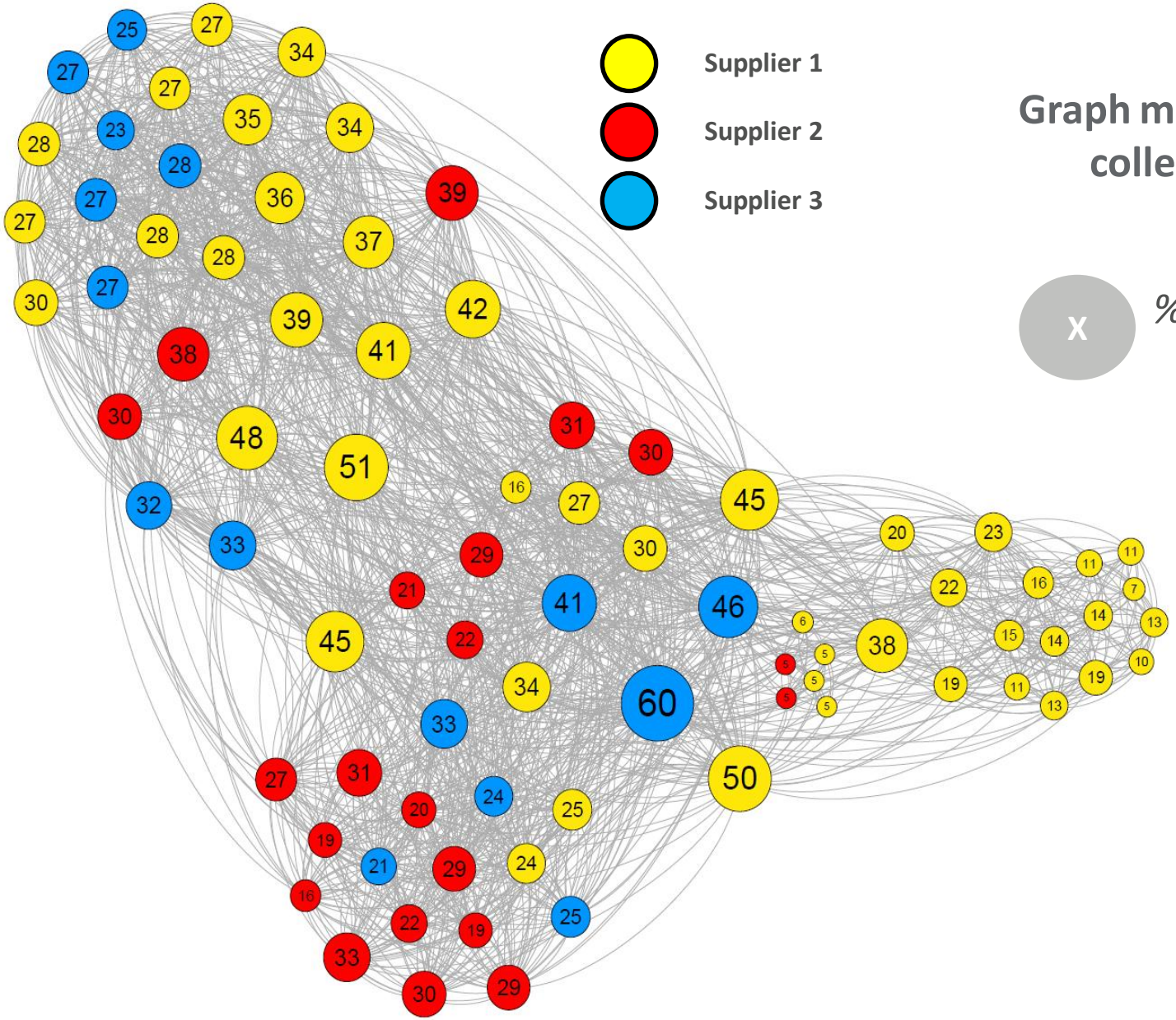
6LoWPAN Layer : Services

- Zoom on… The routing protocol (LOADng)
  - The case where DC and meters are in the same POS is a particular case
  - Protocol smartness is distributed among the network



On-field performances

Example of G3 connectivity and reachability



Supplier 1

Supplier 2

Supplier 3

Graph made from Neighbors tables collected on a real network

x *% of meters with which a PLC communication is possible*

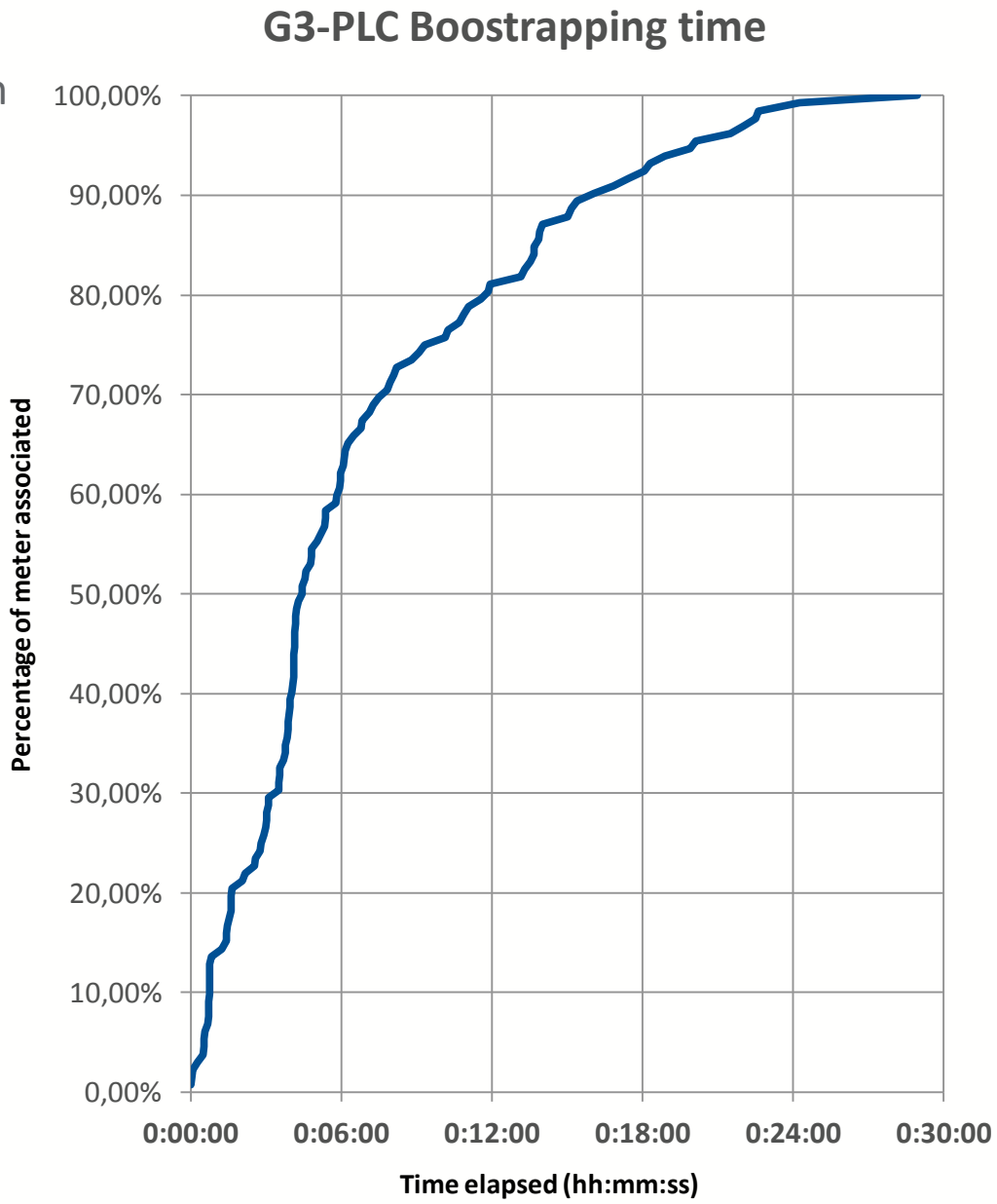
G3-PLC Bootstrapping Time

► At start, a G3 node knows nothing. It has to find an already bootstrapped neighbour (aka LBA) to help it convey information with the DC:

- **Pre-Shared Key** (PSK) to ensure device authentication,
- **Group Master Key** (GMK) to ensure secured transactions in the cluster
- **Short Address** to reduce the size of each address

In a second step, **DC can send IPv6 Prefix** and context (optional) to compress IPv6 Global Addresses

Number of meters in the cluster	**133**
Max number of hops	**5**
Environment	**Lab**
Interoperability	**4 different meter & 3 different G3 chips**
Specs	**G3 Specs (apr-15)**



Performance in the field : Choice of the cluster

ERDF has more than 45 000 G3-PLC meters installed now in various environments (rural, urban, deep urban).

- We could have chosen a cluster which works well but results would have been biased.
- We could have shown the average performance figures, but that would been of limited interest since the environment and cluster size varies greatly.

We choose to focus on the **toughest cluster** we have as of today:

- the one equipped with the largest number of meters,
- in a deep urban environment.

Frequency Band.....CENELEC-A

Location.....Ile de Nantes, city of Nantes, West of France

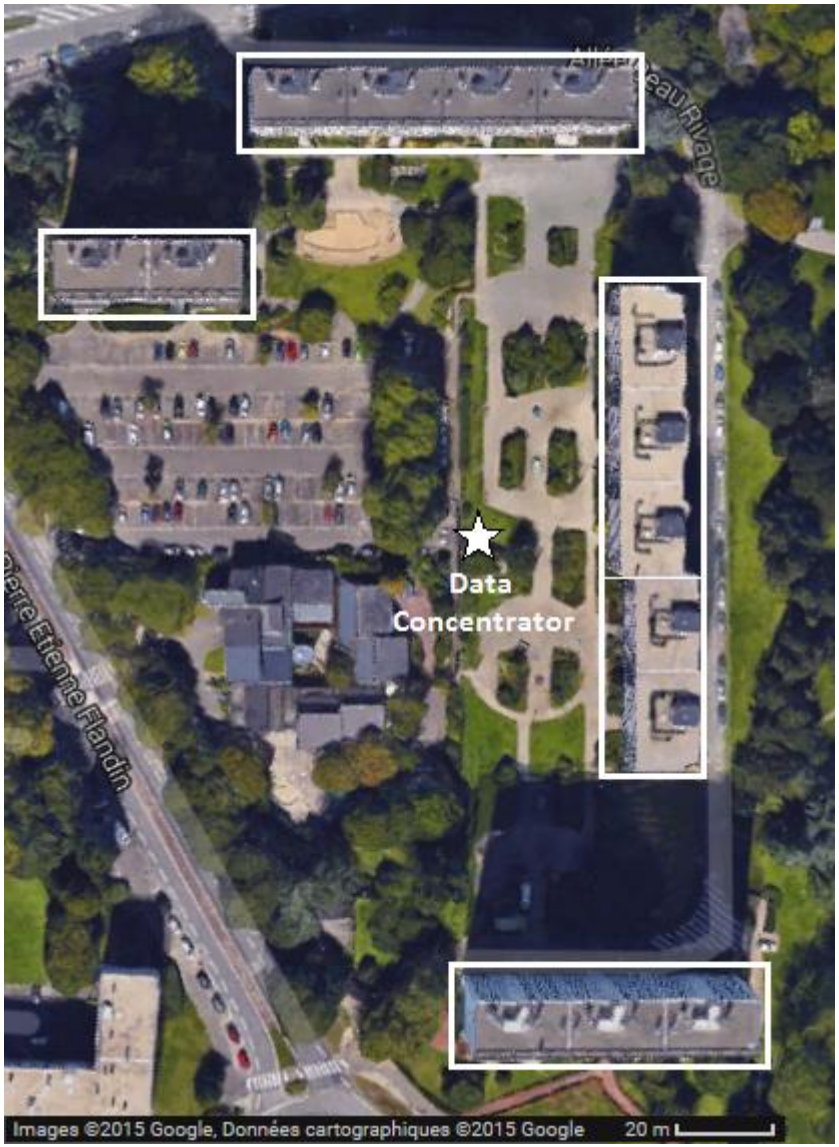
Number of meters : .....463 meters installed in high rise buildings up to 16 stories (social housing)

Data Concentrator 1

Transformer .....9 feeders

Security.....activated

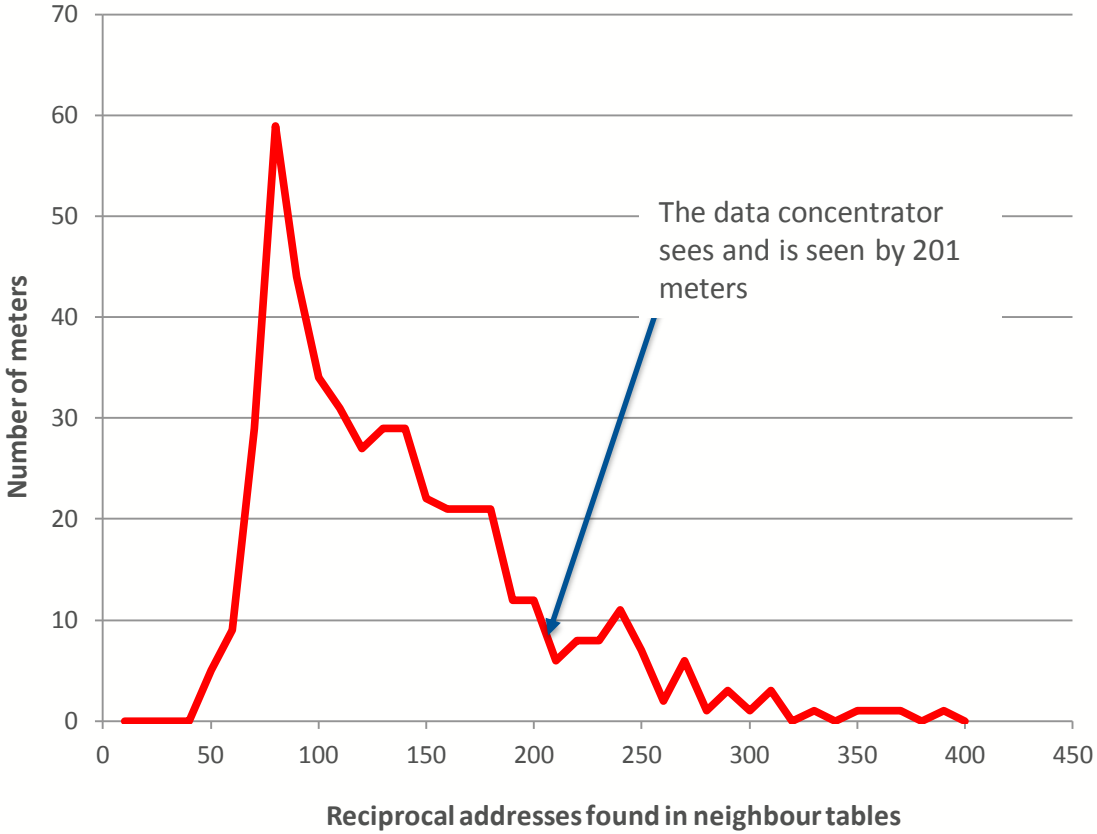
Environment .....extremely challenging with a very large number of neighbours (meters in the same hearing collision domain) that share the same media.



Characteristics - Neighbour distribution

Each G3 node stores information on PHY characteristics to communicate with this neighbour :

- Modulation and tone map (carriers) to use when sending packet to the neighbour,
- Link quality of the last received packet from the neighbour,
- Phase difference with the neighbour.

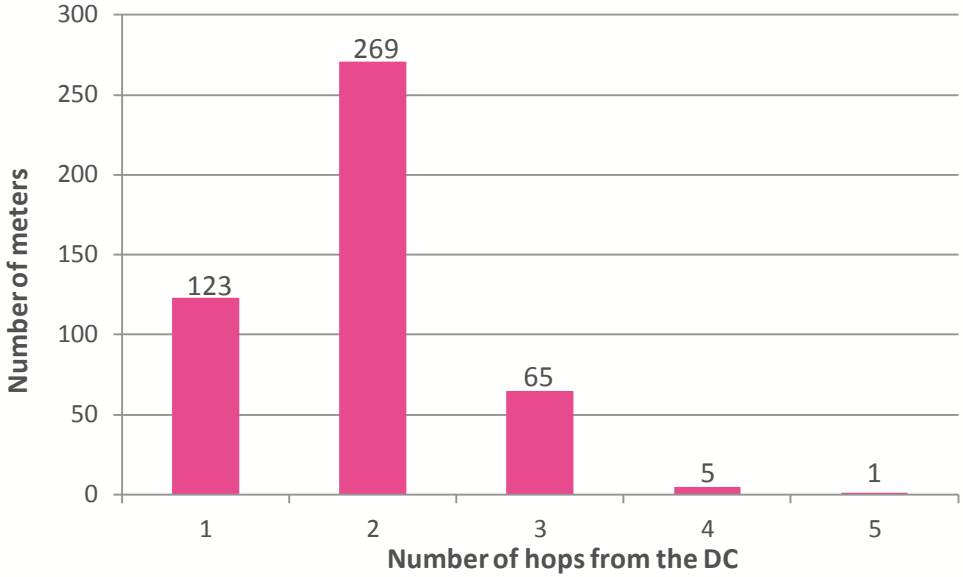


Number of meters in the cluster	**463**
Max number of hops	**5**
Environment	**Ile de Nantes – deep urban**
Specs	**G3 Specs (apr-15)**

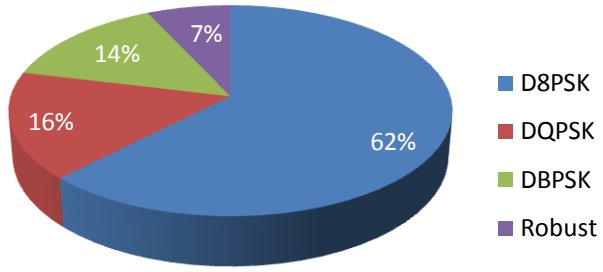
Routes topology / Number of hops

The number of hops varies with the metric used.

The results shown here is done with the default metric provided with the G3-PLC specifications



Number of meters in the cluster	**463**
Max number of hops	**5**
Environment	**Ile de Nantes – deep urban**
Specs	**G3 Specs (apr-15)**

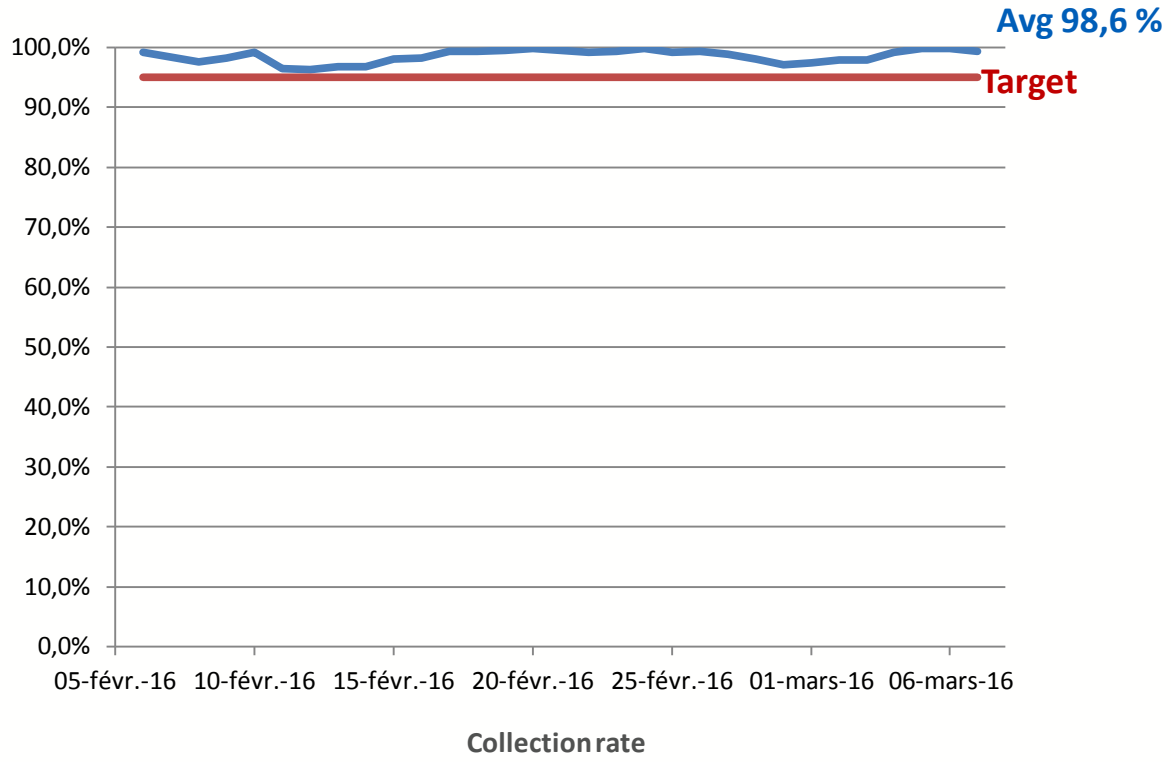


Modulations chosen by data packets

PLC performance : Collection rate

Everyday the DC collects the meters.

Data includes power registers and error status.



Number of meters in the cluster	**463**
Max number of hops	**5**
Environment	**Ile de Nantes – deep urban**
Specs	**G3 Specs (apr-15)**

Ping Round Trip Time for nodes one-hop away from the DC

min	average	max
180 ms	190 ms	500 ms

Due to TMR (Tone Map Request) exchange

Size : 64 bytes
Evaluated over 100 Ping

Field Sum-up

environment

harsh

- 6 buildings with 16 stories
- **463 meters**
- 1 single DC for **9 feeders**

performance

Very satisfactory

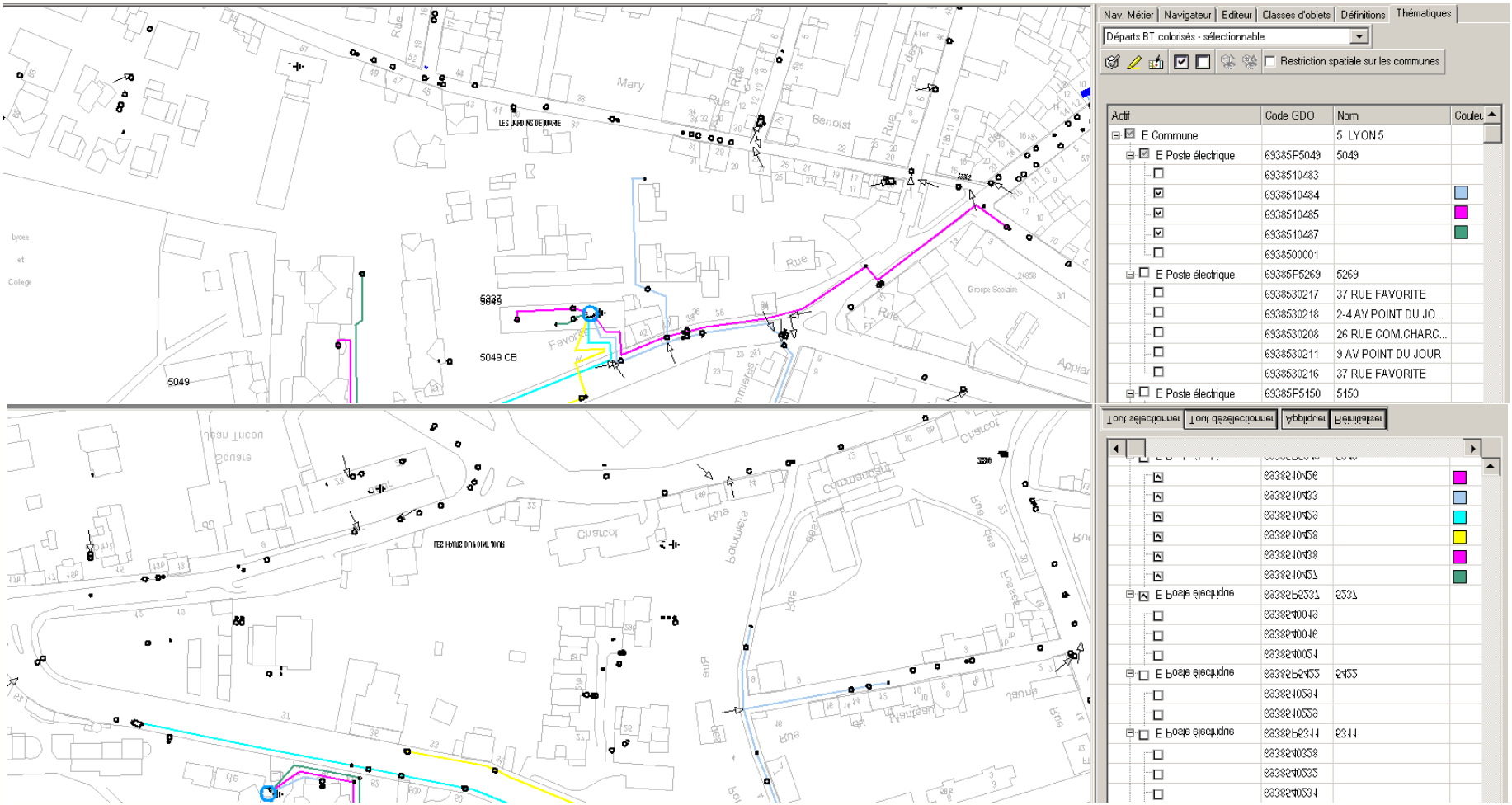
- collect rate target reached
- Meters reached in 4 hops or less
- Highest modulation scheme (D8PSK) represents +60% of the modulation used
- Less than an hour to collect

Still room for improvements to get to 100% or better performances

1. Fine-tuning the parameters (we use default values in all environments),
2. Increasing Data Concentrator requests rate,
3. Minor nits on standard interpretation will be cleared,
4. Searching for possible interferers on the grid.

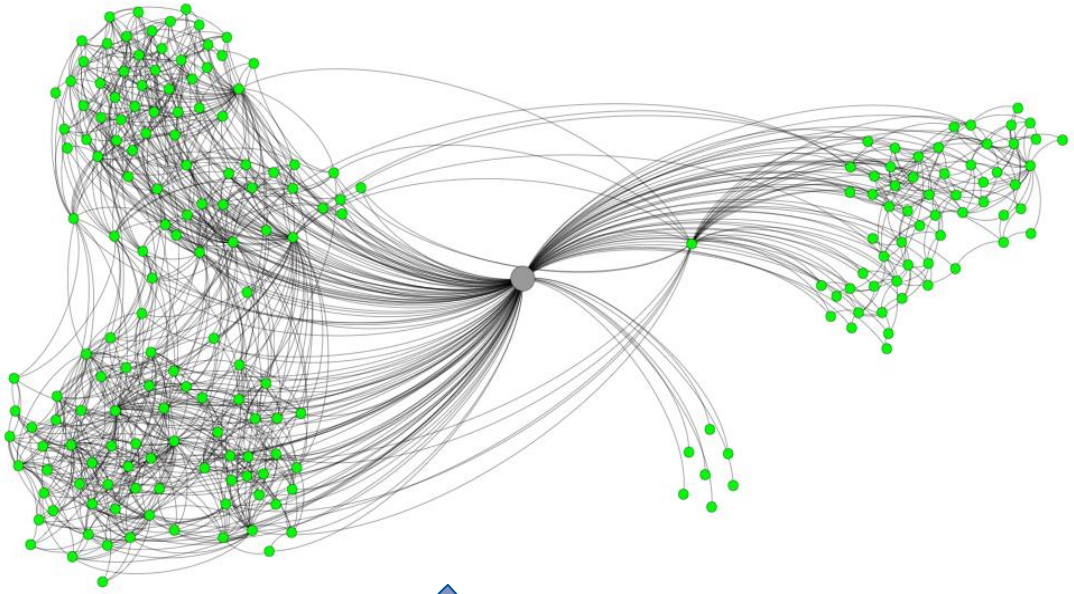
G3 Perspectives

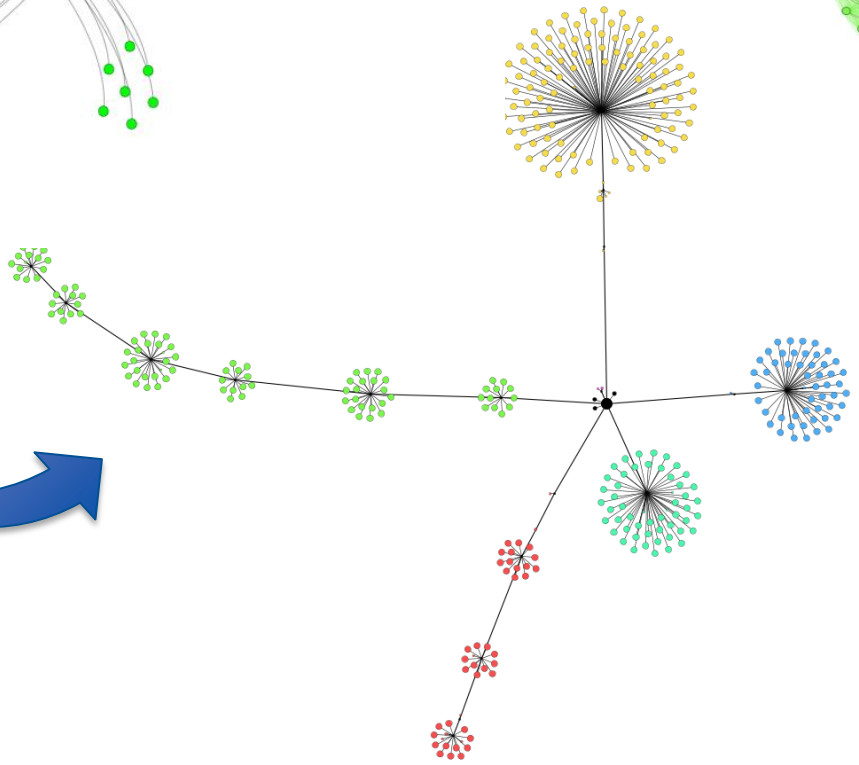
Building the grid cartography using G3 data

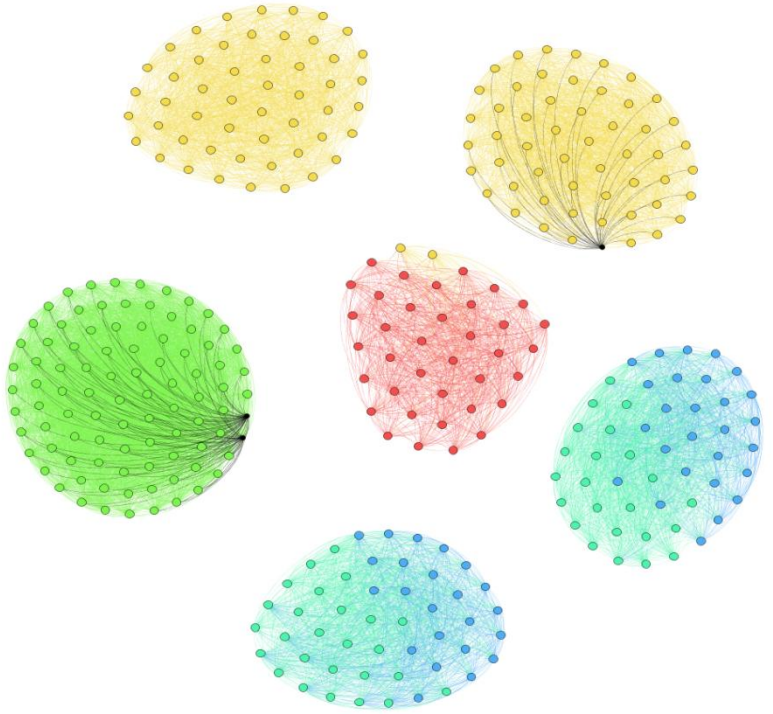


Linky data enable to rebuild the LV topology :
Identification of LV customers connection (substation, feeder, phase)

Reliability of the grid cartography







Community détection

Crossing with cartographic data

Thank You

Questions ?

More Infos ?

Cédric Chauvenet
cedric.chauvenet@erdf.fr