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

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ERDF manages the distribution network in France

- Production
- Transport
- Distribution
- Supply
- Customers

**38,000 employees**

**3 Billions € of investments**

**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 is moving toward its digital transformation through the Linky project

**Remote Control through AMM**
- Linky
- Data concentrator
- Information System
- Remote metering and operations

**Local balance adjustment**
- Production / consumption
- Consumers
- Producers

**Reduce operational cost and delays on the grid**
- Diagnostics
- Self-Healing
- Operations

**Adjust investments efficiency on the grid**
- Meter reading system (Linky) and data management
- Risk management and predictive maintenance

ERDF is moving toward its digital transformation through the Linky project.
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 CONCENTRATOR TO THE CENTRAL IT SYSTEM

**DAILY COLLECTION RATE**

- **95%**

**35** MILLION of Smart Meters

**600,000** Data Concentrators

**€ 5 B**

- Billion of current Euros of investment by 2021

**10,000** jobs created in France

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

**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 interchangeable devices

- **Evolutif**: Ability to do software update to be future proof and resilient
Roll out strategy (2015-2021)

Past phases
Pilot deployment (2009-2011) and evaluation

Leopard pattern rollout

2017 (2nd semester)

2019 (2nd semester)


PREPARATION

MASS ROLLOUT

Million of Smart meters
8 M
3 M

35,000,000

Up to 8 million meters installed per year
G3 PLC
Why PLC ? (Power Line Communication)
The electric wire as a communication manner

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**

**Electric Signal**
France = 220V / 50Hz

**PLC Signal**
G3 = 1V / [35-90 kHz]
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 countries
- 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 additional 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

- **TCFM**
  - 175 Hz

- **Ripple Control**

- **Meters & More**
  - 78.5 kHz < f < 93.5 kHz

- **Linky S-FSK**
  - 63 kHz, 74 kHz

- **PRIME**
  - [42 kHz, 88 kHz]

- **G3-PLC CENELEC A**
  - [35 kHz, 90 kHz]

- **G3-PLC CENELEC B**
  - [98 kHz, 121 kHz]

- **G3-PLC ARIB**
  - [154 kHz, 403 kHz]

- **G3-PLC FCC**
  - [154 kHz, 487 kHz]

- **Homeplug 1, 2, AV, Green PHY**
  - [1.6 MHz, 30 MHz]

- **Panasonic HD PLC**
  - [1.6 MHz, 30 MHz]

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Presence of broadband PLC (typically starting around 1 MHz) applications: video streaming, in-home LAN,...
Internet relies on a **IP, standard architecture**, enabling to interconnect **machines, people or objects** to bring **services**

**G3 PLC fits into this paradigm 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

<table>
<thead>
<tr>
<th>Alliance/DSO</th>
<th>Utilities/Operators</th>
<th>Chip Manufacturer</th>
<th>Supplyers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>G3-PLC Alliance</strong></td>
<td><strong>ERDF, EDF</strong></td>
<td><strong>STI, Atmel, Renesas</strong></td>
<td><strong>Sagemcom, elster, itron, Nexans, Landis Gyr, Yitran, Panasonic</strong></td>
</tr>
<tr>
<td><strong>Prime Alliance</strong></td>
<td><strong>Iberdrola, GasNatural Fenosa</strong></td>
<td><strong>STI, Atmel, Texas Instruments, Renesas</strong></td>
<td><strong>Landis Gyr, Itron, Siemens</strong></td>
</tr>
<tr>
<td><strong>Meters and more OPEN TECHNOLOGIES</strong></td>
<td><strong>Enel, Endesa</strong></td>
<td><strong>STI, Atmel, Renesas</strong></td>
<td><strong>Landis Gyr, Siemens</strong></td>
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<td><strong>HomePlug® Powerline Alliance</strong></td>
<td><strong>Duke Energy, Edison</strong></td>
<td><strong>STI, Qualcomm Atheros, Broadcom</strong></td>
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*WG G.Hnem, WG P1901.2*
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

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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):

<table>
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<tr>
<th>Frequency Band</th>
<th>ROBO PHY D.R. (kbps)</th>
<th>DBPSK PHY D.R. (kbps)</th>
<th>DQPSK PHY D.R. (kbps)</th>
<th>D8PSK PHY D.R. (kbps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CENELEC A (36kHz to 91kHz)</td>
<td>4,5</td>
<td>14,6</td>
<td>29,3</td>
<td>43,9</td>
</tr>
<tr>
<td>FCC (150kHz to 487.5kHz)</td>
<td>21</td>
<td>62,3</td>
<td>124,5</td>
<td>186,9</td>
</tr>
</tbody>
</table>
G3 MAC Layer : Services

Zoom on...

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

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

The routing protocol enable to reach this meter by choosing the best path according to a given criterion (routing metric)

... a new route will be automatically created.

Meters in the DC neighbourhood

Routing Node

If the route breaks …
On-field performances
Example of G3 connectivity and reachability

Graph made from Neighbors tables collected on a real network

% of meters with which a PLC communication is possible
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.
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.

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**Frequency Band:** CENELEC-A

**Location:** Île 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.
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.

### Environment

- **Ile de Nantes – deep urban**

### Specs

- **G3 Specs (apr-15)**

### Metrics

<table>
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<th>Value</th>
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<td>463</td>
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<tr>
<td>Max number of hops</td>
<td>5</td>
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The data concentrator sees and is seen by 201 meters.
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.
Everyday the DC collects the meters. Data includes power registers and error status.

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<td>G3 Specs (apr-15)</td>
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Ping Round Trip Time for nodes one-hop away from the DC

- min: 180 ms
- average: 190 ms
- max: 500 ms

Size: 64 bytes

Due to TMR (Tone Map Request) exchange

Evaluated over 100 Ping

Avg 98.6%
Field Sum-up

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

- harsh

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 ?

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