Communications solutions for smart substations

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Current DSO architecture

1. Metering Headend
   - Scada/DMS
   - Enterprise servers

2. One or several WAN for connecting NAN and HV grid equipment to control centers
   - Usually consists of core IP network and backhaul networks

3. Networks for accessing meters (Neighborhood Area Networks), Distributed Energy Resources, Grid devices, field forces (Field Area Networks) etc.
Communications requirements to/from substations are changing.

Quality of service (reliability, security, criticality)

- Low bandwidth
- Medium bandwidth
- High bandwidth
- Not deployed in Distribution today

- Substation to substation com.
- Microgrid automation
- Teleprotection for transformer/line protection
- Grid monitoring & control for MV & LV
- Distribution Automation
- Cyber security monitoring
- Access control & Video surveillance
- DER monitoring inc. EV charging station
- Communications for Virtual Power Plant (DER control)
- PMU visualization
- Communications with Mobile Work Force
- Condition monitoring
- Smart Metering (data concentrator to central)
- Teleprotection for Distributed Generation Protection

Latency time:
- 10 ms
- 50 ms
- 100 ms
- 500 ms
- 1 s
- 5 s
- 10 s
- > 1 mn

Note: does not include communications within the substations
The grid transformation triggers questions about communications

STRATEGY

› What are the business requirements and the utility most likely smart grid roadmap (different possible scenarios)?
› What are the future data requirements (latency, security, QoS, bandwidth)? How much data treatment will be done in a distributed way (vs. traditional centralized approach)?
› Do my smart grid pilot project prepare well for scalable ICT deployment

TECHNOLOGY

› Which communications solutions are the best (technically and financially) for each SG application?
› How to chose between private networks and public infrastructure solutions?
› Which ICT standards are relevant for utilities?
› How to guarantee information security / privacy?

OPERATIONS

› How to minimize risk exposure and optimize operations during ICT migration periods?
› Which organization should be put in place?
› Which tools are necessary (Network Management Systems etc.)?
› Which skills should be kept in-house / outsourced?

Communications Technology choice is one important issue ... but not the only one
Communications design requires a holistic approach...
Based on a transformation project methodology

**Explore**
- Project specification
- Team mobilization and logistic
- Information gathering
- Start with Business

**ASSESSMENT & analysis**
- Understand Network situation
- Express Communications Requirements
- Select evolution topics

**Develop and DESIGN**
- Develop and Design Evolution solutions
- Address the impact on Operations

**IMPLEMENTATION**
- Evolution Implementation
- Evolution Implementation Support

Implementation phase can also be followed-up by regular performance reviews and improvement plans
How to Design Smart Grid Communications Networks?

- Critical task: the design of the target architecture
- Not only one answer - solutions will be different for each utility.

Main SGC networks design issues

- How to design the overall (physical) architecture?
- How to choose the SGC lower layers protocols (physical to transport)?
- How to choose the SGC application layers protocols?
- Should utilities adopt only standards or continue to work with some proprietary protocols?
- Should utilities retain specific solutions for teleprotection requirements?
- Should utility invest in private infrastructure or use public infrastructure?
Choosing the right protocols

- Main trends:
  - Move to standard IP and Web Services
  - Harmonization of CIM and IEC 61850
  - Harmonization of IEC 62056-XX (DLMS/COSEM) data model and IEC 61850/CIM
  - Development of **Cyber-security** around IEC 62351
  - Standard protocols for lower layers

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**SGC stack (modified from Smart Grid Coordination Group)**

<table>
<thead>
<tr>
<th>Application Layers</th>
<th>Transport &amp; Network Layers</th>
<th>MAC &amp; Physical Layers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Web Services/EXI, HTTPS/CoAP</td>
<td>802.1x / EAP-TLS based Access Control Solution</td>
<td>IEEE 802.15.4 MAC</td>
</tr>
<tr>
<td>SNMP, IPfix, DNS, NTP, SSH,...</td>
<td>IPv6 / IPv4</td>
<td>IEEE 802.15.4 2.4GHz DSUSS</td>
</tr>
<tr>
<td>IEC 61968 CIM ANSI C12.19/C12.22 DLMS COSEM</td>
<td></td>
<td>IEEE 802.15.4 enhancements</td>
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<tr>
<td>IEC 61850</td>
<td></td>
<td>IEEE 802.15.4 MAC (including FHSS)</td>
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<tr>
<td>IEC 60870</td>
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<td>IEEE P1901.2 MAC</td>
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<td>IEEE 1588</td>
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<td>IEEE P1901.2 PHY</td>
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<td>DNP</td>
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<td>IEEE 802.11 Wi-Fi</td>
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<td>ENS0090</td>
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<td>IEEE 802.3 Ethernet</td>
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<tr>
<td>MODBUS</td>
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<td>ETSI 102 887-1</td>
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<tr>
<td></td>
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<td>IETF RFC 5072</td>
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<td>IETF RFC 5121</td>
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</table>

| | | ETSI 102 887-2 |
| | | IETF RFC 2464 |
| | | IETF RFC 5072 |
| | | IETF RFC 5121 |
| | | IEEE 802.16 WiMax |
Technologies currently deployed do not meet smart grid requirements

<table>
<thead>
<tr>
<th>Technology</th>
<th>Power Line Carrier (Low Voltage PLC)</th>
<th>RF Mesh (narrowband unlicensed)</th>
<th>GPRS</th>
<th>Long-Range Radio (licensed or unlicensed)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Current application</strong></td>
<td>Electricity smart metering Europe</td>
<td>Smart metering North America</td>
<td>Smart metering Europe (backhaul or direct)</td>
<td>Smart meter in particular water and gas</td>
</tr>
<tr>
<td><strong>Main advantages</strong></td>
<td>• Appropriate for long LV grids with many customers after secondary substation</td>
<td>• Utility private network for reasonable cost</td>
<td>• Existing offering available for voice and data services</td>
<td>• Licensed frequency bandwidth (ex: 169MHz Europe)</td>
</tr>
<tr>
<td></td>
<td>• Utility infrastructure</td>
<td>• Self-healing network</td>
<td>• No interference</td>
<td>• Private network with good penetration, low interference, easy to install (vs. mesh)</td>
</tr>
<tr>
<td></td>
<td>• Being standardized (reserved bands)</td>
<td>• Good scalability</td>
<td>• Ease of use</td>
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</tr>
<tr>
<td><strong>Main drawbacks</strong></td>
<td>• Only for electric meters (no gas) on long LV grids</td>
<td>• Unlicensed frequency bands (eg 900MHz), sensitive to interferences, restricted by regulation in Europe</td>
<td>• Not utility owned: no control of QoS / Opex</td>
<td>• Not much used by electric power companies</td>
</tr>
<tr>
<td></td>
<td>• 3 standards not all IP</td>
<td>• Takes long time to establish connection</td>
<td>• Limited network reach and data rate</td>
<td>• Low bandwidth, QoS</td>
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<td>• Technical robustness varies in different parts of the grid (signal attenuation &amp; distortion)</td>
<td>• Proprietary solutions</td>
<td>• Aging offering that may not be supported by Telco soon</td>
<td>• Not always standardized (except wireless M-bus)</td>
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<tr>
<td></td>
<td>• Sensitive to power availability</td>
<td>• Limited bandwidth &amp; QoS</td>
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<tr>
<td><strong>Long-term fit to smart grid</strong></td>
<td>Very low because of technical limitations</td>
<td>Low (although ongoing technology improvement)</td>
<td>No</td>
<td>Low</td>
</tr>
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</table>

Communications solutions (physical layers) already deployed for smart metering have not been designed for smart grid requirements.
new generation of wireless solutions hold good promises

› Wired solutions based on fiber can easily address all the requirements for connecting substations and homes but connecting all secondary substations would have a prohibitive cost

› The move of utilities (and other industries alike) to new generations of wireless solutions for communications with substations and other grid devices is inevitable:
  - Ubiquitous
  - Easy to deploy
  - Standards (3GPP)
  - Mass volume

Technology comparison

<table>
<thead>
<tr>
<th>Technology</th>
<th>Bandwidth/Latency</th>
<th>Cost/Time to deploy</th>
<th>Bandwidth</th>
<th>Coverage, interference</th>
<th>Bandwidth</th>
<th>Technology orphan</th>
<th>Significant bandwidth</th>
<th>Limited concurrent nodes</th>
<th>QoS for smart grid</th>
<th>High bandwidth</th>
<th>Latency/QoS/Security</th>
<th>Coverage/spectrum allocation</th>
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<tbody>
<tr>
<td>FIBRE</td>
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<td>LTE</td>
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LTE is well suited for substation communications

- Standardized and future-proofed technology
- Very low latency
- QoS, policy control, and priority handling
- Secure ecosystem
- Rapid deployment
- All IP packet core
- Self organizing network (plug and play)
- Scalable bandwidth
- Spectrum Flexibility
- Efficient Multicast / Broadcast
- Multi-antenna support (MIMO)

And rapidly falling cost...
The evolution of DSO communications networks

- **Legacy for electricity smart meters in Europe**: PLC, Micro wave, RF MESH, Long Range Radio, FIBER, Copper, Satellite (often for rural areas or back-up solution).

- **Legacy for smart meters in North America and Europe**: FIBER, Copper, SDH > IP/MPLS, Access NAN FAN.

- **High cost but FTTx can make sense for multiutilities (inc. TV etc.)**: Wide area network.

- **Ubiquitous wireless coverage for all devices**: Access NAN FAN, Power devices

*Other networks for grid control based on Tetra, DMR, etc.*
private vs. public: benefit from complementarities!

**Privately owned**
- Total control of communications (reliable, secure, sustainable)
- Higher Capex / lower Opex
- Often unlicensed frequency bands / difficulty to get a licensed band for private use (LTE ex.)
- Risk of vendor lock-in
- Risk of developing proprietary solutions (vs. standards)

**Shared commercial**
- Utilities can focus on core business (power)
- Deployment easy and fast
- Higher Opex / Lower Capex
- Typically “secured” licensed frequency bands
- Risk of carrier lock-in and issue with sustainability of carrier offering
- Control issue in case of emergency

- Tendency to fully control the grid monitoring infrastructure
- Different operations models as ICT becomes more complex and technology and services offering improves (SGaaS)
- Intermediate models (Private Virtual Network Operators)
USE CASE 1
Proof of concept in Australia

- Distribution Monitoring & Control & Work Force Management
- Successful PoC
- 15 Sites x 3 Sectors

“By using the same LTE technology as mobile carriers, we will benefit from economies of scale for chip, device and equipment pricing as 3G networks around the world migrate to LTE”

George Maltabarow
Ausgrid Managing Director
Press release published 23/11/2010
One homogeneous network for distribution

› Distribution Use-Cases

› Target for private wireless network:
  › 150 sites & 200 major zone substations
  › 12,000 smart monitoring devices
  › 3,000 mobile field computers
› Designed for 2 Million devices incl. smart meters
USE CASE 2
Stockholm Royal Seaport

IEC 61850 GOOSE protocol over IP using multi-vendor intelligent electronic devices (IEDs)
DEMONSTRATOR
GOOSE OVER IP – REMOTE INTERLOCKING

Grid simulation

Demonstrator
LATENCY performance of LTE opens new opportunities

LTE is theoretically suitable for substation-to-substation / Distribution Automation communications
Latency EVALUATION results

Latency evaluation showing round trip times (RTT) through two Operator LTE networks for different packet sizes.

Note: Standard network with no optimization for M2M traffic.

Planning for live trial in 2013
DISTRIBUTED FLISR Use case

› Distributed Fault Location Isolation & Service Restoration (FLISR)

› IEC 61850
  - Latency 20 - 100 ms
  fast – slow automation

› Sequence of events
  - Tree falls on Feeder 1
  - CB1 trips – Feeder 1 down
  - Reconfiguration decision made
  - ROS1 and ROS2 open
  - ROS3 and ROS4 close
  - Fault isolated between CB1 and ROS1

Communication required to all distributed devices

Source: [5]
Conclusion

› Substations are critical smart grid nodes
› Not one solution for all utilities
› Horizontal approach to communications
› Current smart metering solutions not enough for smart grid
› Benefits of new wireless technologies – even when strong latency constraints

Networks are the base to be complemented by connectivity management, service enablement and security solutions
Long term M2M view

› Networks for substation access as a first important brick to smart grid and Machine-to-Machine platform

› Value added services around energy efficiency, green energy etc.

› Subscription management, service exposure, service creation / composition, etc.

› Operations Support Systems for Networks performance management, network device connectivity management, provisioning, QoS management, etc.

› Heterogeneous networks (legacy, new) built for different applications