System concept

The DLC-2000 concept implements a power line communication infrastructure to connect the servers of a utility company with field level equipment at the customers' premises. In accordance with the overall project goals, the primary usage of this infrastructure is remote meter reading and remote control. Besides that, the communication platform is open to various kinds of add-on services. Schematic architecture of the communication network is illustrated in Figure 1.

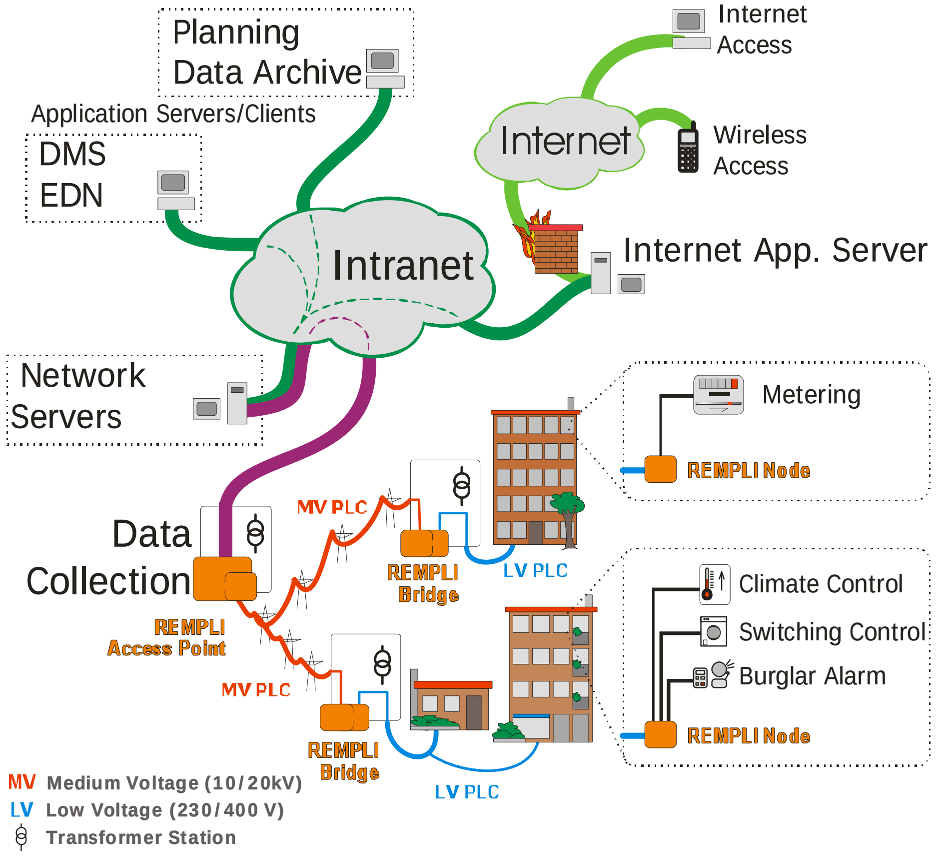

Figure 1: System Overview

As shown in Figure 1, the DLC-2000 communication infrastructure consists of

- low-voltage segments (blue lines), which cover electricity meters and groups of energy consumers (for example, a segment can span across one staircase of apartments within a living block, or cover a single production branch);
- medium-voltage segments (red lines) between the primary and secondary transformer stations;
- TCP/IP or IEC 60870 based segments (thick purple lines) between the primary transformer stations and the Application server(s);
- TCP/IP communication (green lines) between the Application Servers and their clients. The interfaces provided by the Application Servers could be available only within the Private Network or also by Internet clients (e.g., SCADA server/client communication).

All Field Devices within a DLC-2000 installation are connected to a cascaded power line network. The power line network consists of one or multiple Low-Voltage and one Mid-Voltage segment. Communication at both levels is Master/Slave-based. Low- and Mid-Voltage segments are coupled by the DLC-200 Bridge which is installed at the secondary transformer station, between two parts of the cascade. The link, established by a Bridge, is transparent for the information flow: requests are simply forwarded from the upper part of the cascade into the lower one, responses are passed back.

The bottom-level of the communication infrastructure is comprised of GAMA DLC-200 Meters, DLC-200 Modems or DLC-200 Nodes, each coupled with a PLC interface. These devices are usually installed at the consumer site, e.g., inside an apartment, and - in case of DLC-200 Modem or DLC-200 Node - have a number of metering inputs (such as S0, for electrical energy meters). DLC-200 Nodes are also equipped with digital outputs that allow switching off and on electrical/heat/gas/water supply for a particular consumer, upon commands from the utility company.

At the top-level of the infrastructure is the DLC-2000 Private Network (typically TCP/IP-based), where Application Servers of utility companies are connected to. Every Application Server performs a certain dedicated function, such as metering, billing or SCADA. All Application Servers access Field Devices in the PLC network via DLC-200 Access Point – a device which interconnects TCP/IP and PLC-based segments and, optionally, implements a number of additional services in the power line typically; a low voltage segment usually consists of one or several DLC-200 Bridges and a high number of DLC-200 Field Devices. The medium voltage segment consists of one or several DLC-200 Access Points and several DLC-200 Bridges.

The following subsections will describe the different system components in detail.

General architecture

The principal architecture of a Field Device - Access Point communication is illustrated in Figure 2. This structure can be logically divided into three major subsystems: the Access Point Application, the Field Device Application and the Power line Communication System.

Metering and control devices, located at the bottom, are capable of communicating using a certain protocol, such as IEC 1107 and M-Bus (for metering) or IEC 870-5-104 (for SCADA)[1]. Application Servers (not shown in Figure 2) are connected to the DLC-2000 Private Network segment. While performing their dedicated tasks, Application Servers expect to communicate with the underlying metering/control hardware using the aforementioned protocols, as if the devices have been connected directly.

The DLC-2000 communication system therefore is based on the idea of *tunneling particular metering/SCADA protocols over the power line network*.

At the Field Device side physical connection to individual metering and control devices is provided by drivers. Every driver is dedicated to a particular combination of hardware interface / communication protocol. A single driver can handle several pieces of homogenous equipment (shown for the case of S0 meter in Figure 2).

If necessary, a driver can also perform certain processing of metering data (for instance, store it in a log directly at the node; re-calculate raw measurement data into valid physical units; etc.). Often, drivers also attempt to reduce the amount of data transmitted over communication network (for example, compress metering data). This, of course, requires support from the driver at the opposite side – the Access Point side. Also in some cases, due to legal limitations related to certification of the system, drivers are not allowed to modify application data (or even complete protocol PDUs), transferred over the communication system.

Some data, such as that coming from an S0 interface (pulse input from meters), cannot be transferred over the PLC directly. It has to be translated into a full-fledged communication protocol, understood by metering software on the other side of the DLC-2000 system (e.g., IEC 1107). This is performed by means of a protocol translator, which is tightly integrated with the driver.

[1] The DLC-2000 system also includes a transparent driver that can tunnel unrestricted protocols such as TCP/IP connections. Nevertheless this driver is limited to point-to-point connection and is not highly optimized.

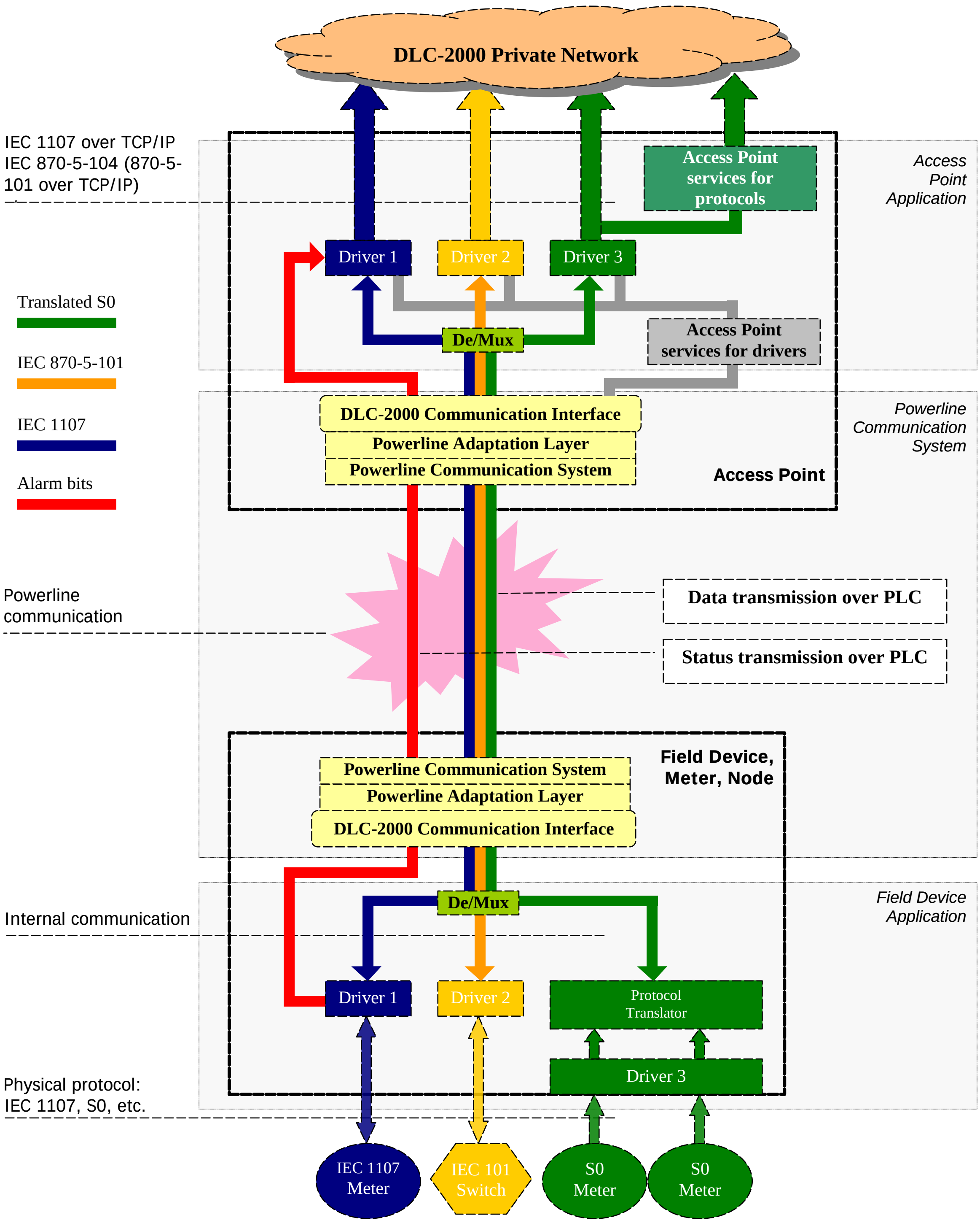

Figure 2: DLC-2000 communication architecture

At the Access Point side drivers perform a different function: they convert a metering/SCADA protocol, received from the Node, into its TCP/IP-based equivalent. This can be either simple tunneling or conversion from one standard into another (for instance, IEC 870-5-101 has to be converted into IEC 870-5-104). All deviations from standard, implemented at the Field Device side driver to reduce traffic over the communication network, are undone here: above the Access Point (just like below the Field Device), each tunneled protocol is fully standard-compliant.

The Power line Communication System is a set of hardware and software components that implement data transmission over a single-segment (Medium Voltage or Low Voltage) or dual-segment (Medium- and Low-Voltage) power line networks. Internally the Power line Communication System comprises a number of layers (transport, network and physical). It handles packet-oriented driver-to-driver communication. Most of this communication is carried out using PDUs (Protocol Data Units) of the respective metering/SCADA protocol, typically in a master/slave way: a request is issued by an Access Point side driver and responded by a Field Device side driver. Apart from data communication, the PLC system, used within DLC-2000, also offers another technique: fast status transmission. This allows for fast signaling (sending several bits, always in direction from Field Device to the Access Point), and can be optionally used for internal driver-to-driver communication.

The dynamic topology and changing transmission parameters of the power-line require features typical for ad-hoc networking. The single frequency network technology developed within the project meets these requirements and allows a broadcast to every node even for the very first transmission without any topology or routing information. Reliability requirements of the system are met by the capability to manage and automatically use redundant networks based on a time-division multiple access mechanism. To generate system-wide consistent time slots for multiple master access, a precise time synchronization (with accuracy below 1 ms) is implemented, which can also be used for the time stamping of (application) events. An also newly designed transport layer provides the QoS mapping and is used for the DLC-200 Bridge / DLC-200 Access Point routing as well as for the handling of the redundancy inside the network.

Besides Power line, the Access Point architecture allows for transmitting data over multiple communication systems (such as ISDN, GSM or plain old telephone system – POTS).

Example of a DLC-2000 Application

Figure 3 shows a typical DLC-2000 application, covering multy metering, street light control, network quality and data exchange to other utility services. Most beneficial: communication infrastructure is “free off” because of the existing power grid.

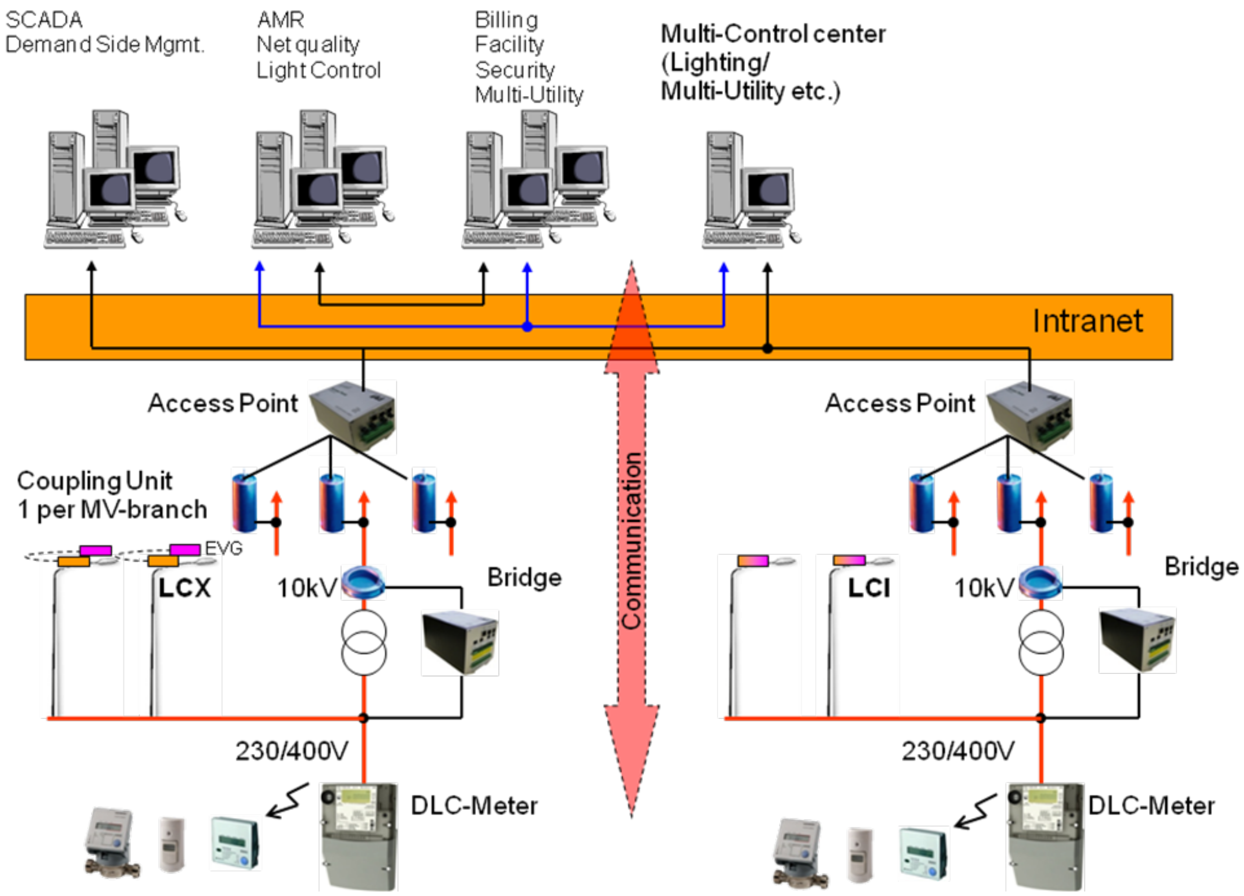

Figure 3: DLC-2000 Application Example