FCMS - Full Duplex Communication Mesh System

A bit of philosophy by way of introduction

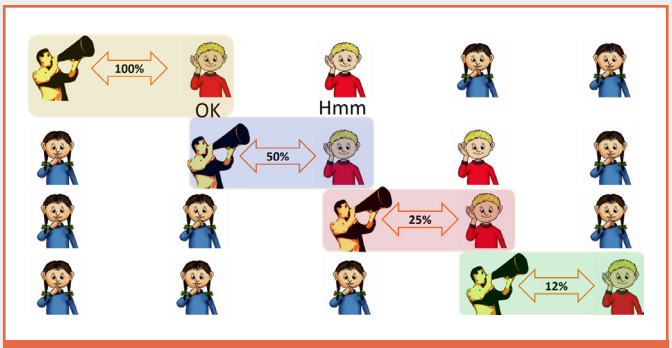
Cables are known to provide high data rates, and robust communication with either electrical or optical data transmission. They must however be planned and installed from the start, since any subsequent installation usually entails enormous expense. Wireless data transmission, on the other hand, provides maximum flexibility, but has limited availability as a frequency range cannot be used twice, and has weaker robustness and security. Outside the world of professionally managed frequency ranges, communication in the so-called license-free ISM frequency bands is only possible through a strict set of rules. Transmission power and duration define the possible data transmission.

In Europe, the permissible transmission powers in the ISM bands are set much lower than in the USA or the Far East. This is not always a disadvantage, as the range is lower and thus the availability of the transmission channel at neighboring locations is more likely. The consequence, however, is that one needs very different concepts for adequate data transmission depending on the application. So-called Low Power Wide Area Networks (LPWANs based on LoRa® or Sigfox®) enable wireless communication over long distances, but only with low bandwidth/data rates. These data rates are not sufficient for more complex applications, and stable communication can only be achieved by generous overlapping of the coverage areas.

Decision makers need to make a thorough list of the requirements for a technology selection at the beginning of a development to avoid a bad investment in time and money. LPWANs with a data bandwidth of a few kBit/s are always sufficient for metering tasks because these are not time critical. However, if the tasks become more complex or it is difficult to foresee what the future applications will require in terms of data throughput, planning should allow more flexibility for long-term investments. Initial product costs usually only represent a small part of the project lifetime cost including installation, maintenance/licensing costs or replacement.

Full duplex communication to solve the bandwidth reduction problem

As the demands on data rates increase, the achievable transmission distances become smaller due to the reduced sensitivity of the receivers. This is generally countered by installing several amplifiers in the signal chain to achieve the required communication distance. Since wireless spectrum is a shared medium, only one transmitter may be active at a time, which means that each amplifier in the chain of transmission links halves the available bandwidth. When the first transmitter sends, all the others must listen. If the data packet is amplified for the first time, logically the original transmitter must also stop its communication because the channel is occupied by the amplification. This means that the bandwidth is halved for the first time. Further halving of the bandwidth occurs with each successive amplification. In the example below with 3 amplifiers only 12.5% of the original bandwidth is available.



Halving the bandwidth by amplification in a shared communication medium

Well-known MESH systems such as ZigBee and Z-Wave are used for control applications and struggle with this difficulty. To solve this problem in communication, we need a solution whereby the amplifiers do not interfere with each other. In a traditional hardware installation, one could add a cable to transmit additional information in parallel. The equivalent in wireless communication is to transmit additional data over a different frequency. Typical devices for wireless communication are only equipped with one transceiver and share the transmission channel because they can only receive or transmit. If however an additional transceiver is added, it could receive data in one channel and transmit in another at the same time. This is called full duplex communication.

Street lighting infrastructure, poles and cables are omnipresent assets typically owned by municipalities or other public owners. Extending the functionality from simply switching on and off or dimming a street light to a ubiquitous network, under public control and ownership, gives municipalities the opportunity to improve the safety, attractiveness and quality of life of the city.

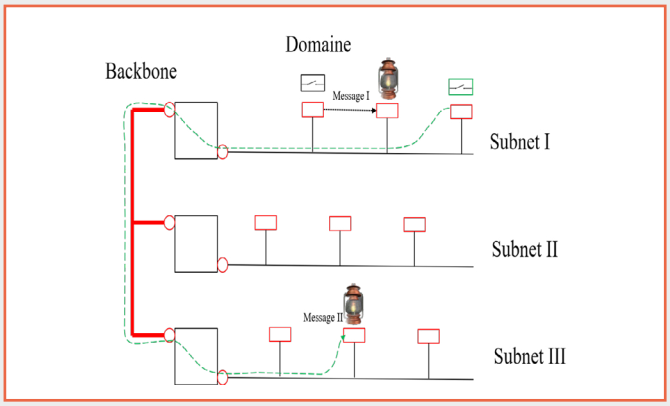
Network communication management

Widely differing requirements have led to the development of various communication protocols. Lean protocols carry hardly any overhead, are quick and efficient but are only tailored to a limited area of application. Others, such as the IP protocol, are designed so universally that there are virtually no restrictions but bring a high overhead. The LON protocol, which was developed in the 1990's provides a suitable combination of efficiency (not much overhead), universal applicability, routability and various services. Everything that is necessary is available and is also covered by an EN / ANSI standard, so that it is open and available to anyone. When comparing the IP and LON protocols, there are many welcome similarities, but certain non-vital features have been left out for the sake of efficiency.

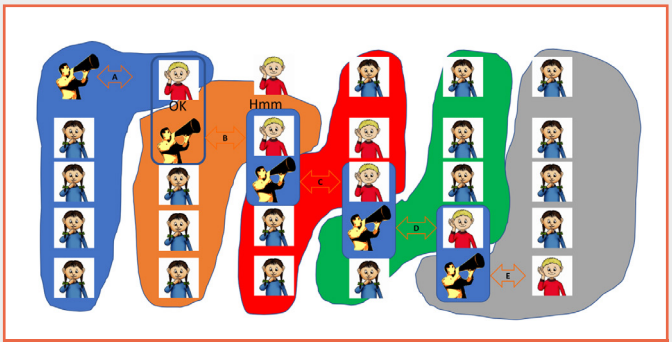
The following vital features are available with the LON® protocol:

- Subdivision into Domain, Subnet, Node-ID
- Services: Uni cast, Group cast, Broad cast
- Unacknowledge / Acknowledge
- Routability
- Different transmission speeds and transmission media
- Payload 1 .... 31 byte
- Interoperable through optional standardised definitions of the payload and device profiles
- Standardised according to ANSI CTA 709.1 (709.n) and EN 14908-1 (14908-n)
- A general tool base for commissioning

The LON protocol allows structures to be built that can transmit and filter/route data very efficiently, so that only those network segments are loaded in which communication is happening. In the following picture we find two messages. The message (I) which only exists in the same segment because it is filtered out by the router as well as the message (II) from the 1st subnet via the router (I) into the backbone and then via the router (III) into subnet 3 to reach its destination.



If we now bring together both ideas of **full duplex data transmission** and a **suitable protocol** that allows structuring, the result is a new technical solution that goes far beyond what is available today in the field of wireless communication. Considering the LON specification and its limitations, it is theoretically possible to build networks in a domain with 255 subnets and 127 controllers per subnet.



Structuring of data transmission through router frequency ranges

When factoring in reserves for communication availability we find that up to 100 subnets in a row with 15 to 30 controllers per subnet are feasible without problems. This assumption would result in interconnected network islands of 1500 to 3000 controllers. The first confirmed measurements in field tests proved that stable communication with net 100 kBit/s can be achieved via 80 hops/repeaters and the latency between sending the information and reaching the destination via 80 routers is only approx. 300 ms.

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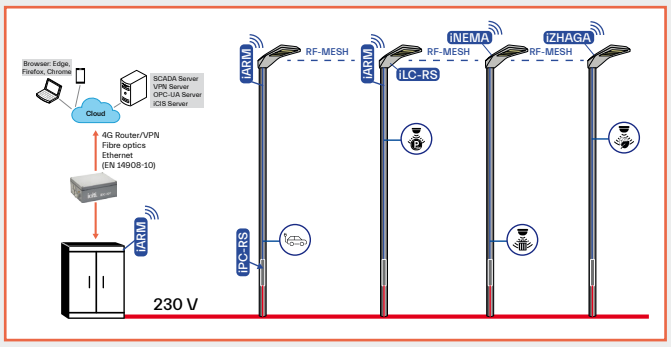
The measured latency of the data transmission length depends, among other things, on the channel occupancy, and must be determined in later field tests with different payload lengths and according to Wifi activity in order to obtain a basis for reserves that must be included in when dimensioning the networks.

Overall, these results provide a significant improvement to the network size limitation of 70 to 100 controllers of competing technologies. The combination of LON's typical multi-master capability and the event-driven behaviour results in further advantages with regard to the organisation of the network.

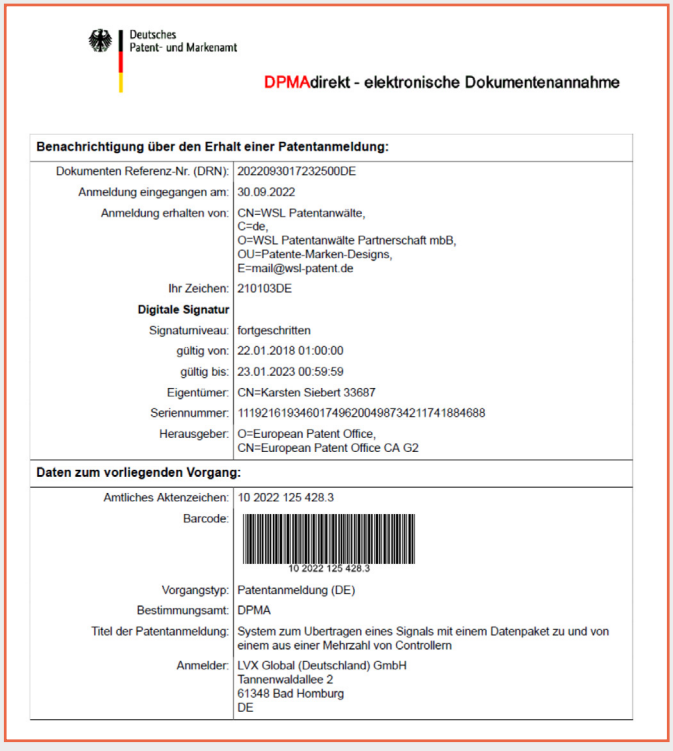
CDMA (Collision Detection Multiple Access), with LON's preferentially implemented event-driven behaviour, ensures low network utilisation. Thus, due to the full duplex capability in each subnet, costly synchronisation via TDMA (Time Division Multiple Access) as well as the waste of time slots can be avoided. The formation of a communication infrastructure via the backbone must be carried out using full duplex capability, but simple participants such as (sensors/actuators) without full duplex capability can be connected/integrated into the respective subnet at any time. As a result, it is still possible to use very energy-efficient devices that are only equipped with one transceiver and need only be upgraded by expanding the protocol stack.

If we return to the topic of simple mesh systems, it is now understandable that the goal is to position as few amplifiers as possible in the transmission channel so that the bandwidth remains as large as possible. Thus, the transmission power and the sensitivity determine the communication distance. In an open space (line of sight) the communication distance is about five times greater than in the built environment. If you reach 1 km in an open space, it is about 200 m in the city. Many causes are responsible for this, such as signal attenuation, interference or the overlapping of products with higher transmission power, such as Wifi-based communication networks.

The idea of combining full duplex transmitter/receiver and protocol structuring means that a much higher number of amplifiers can be used in the transmit/receive chain, as only the latency is affected, but the bandwidth remains stable. A distance of typically 100 m and, if necessary, down to 30 m is no problem, as long as the latency/time delay in the installation remains below one second. If absolute synchronicity is needed, this can be achieved via the GPS time and the data could be enhanced by adding an execution time stamp.



The idea of combining full duplex capability and protocol structuring has been registered via the following patent:



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