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WIDE
Decentralized and Wireless Control of Large-Scale Systems

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→**PU**	Public
PP	Restricted to other programme participants (including the Commission Services)
RE	Restricted to a group specified by the consortium (including the Commission Services)
CO	Confidential, only for members of the consortium (including the Commission Services)

Executive summary
This report defines requirements for industrial wireless standards based on the technical and experimental developments of the project.

Contents

1. Introduction

The ongoing standardization efforts on industrial wireless are focusing on monitoring applications, since the inherent unreliability of wireless links raises safety concerns. Commonly, monitoring and control applications are classified into usage classes:

Safety	Class 0 : Emergency action	*(always critical)*
Control	Class 1: Closed loop regulatory control	*(often critical)*
	Class 2: Closed loop supervisory control	*(usually non-critical)*
	Class 3: Open loop control	*(human in the loop)*
Monitoring	Class 4: Flagging *Short-term operational consequence* *(e.g., event-based maintenance)*	
	Class 5: Logging & downloading/uploading *No immediate operational consequence* *(e.g., history collection, SOE, preventive maintenance)*	

Importance of message timeliness increases

The applications targeted under the WIDE concept are primarily class 2, but also class 1 is relevant.

However, it is important to note, that this traditional view is solely defining latency as the criterion for suitability of a networking solution for a specific usage class. This is true for wired networks, where the network itself is static and once installed, it's latency is constant and loss rate is almost zero.

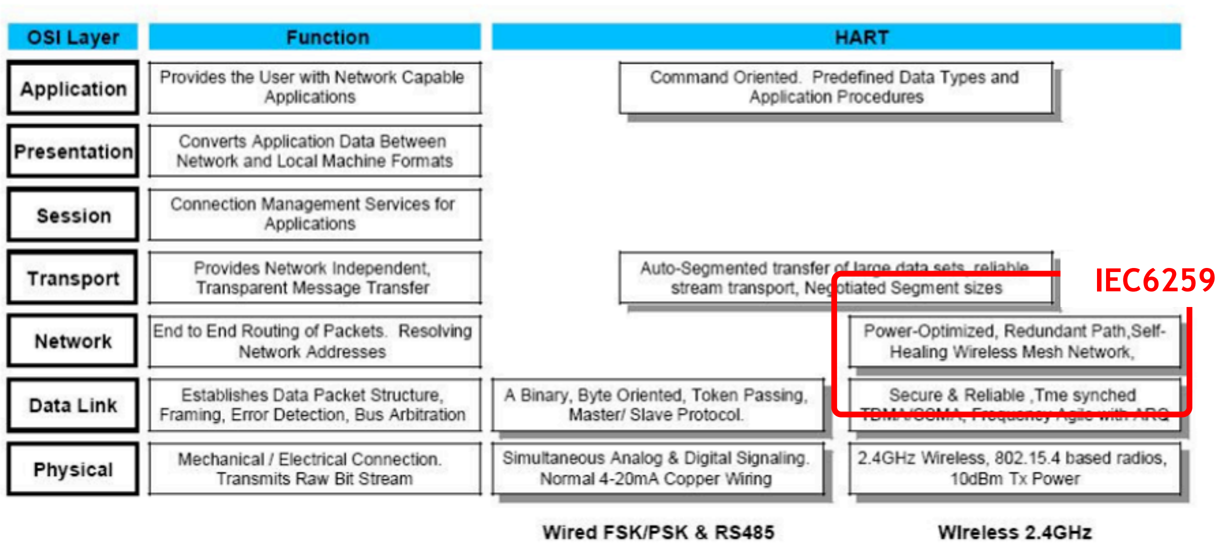
For wireless networks, the scope of this usage class definition will need to be extended to cover latencies and loss rates and also non-static networks. As we have shown in WP2 and WP4, both loss rates and latencies influence the performance of a closed-loop control loop, and it is non-trivial to trade the two quantities against each other. When energy considerations are taken into account, the complexity in engineering high-performance solutions that work reliably over extended periods of time increases even further.

2. Current status of Standardization

There are various standardization approaches, primarily in the building automation market (ZigBee, 6loWPAN, EnOcean, Z-Wave) some of them claiming “industrial” as a field of application, too. Among the vendors of industrial control equipment, however, only two families of standards are supported with products available in the market: WirelessHART / IEC62591 and ISA 100.

2.1 WirelessHART & IEC62591

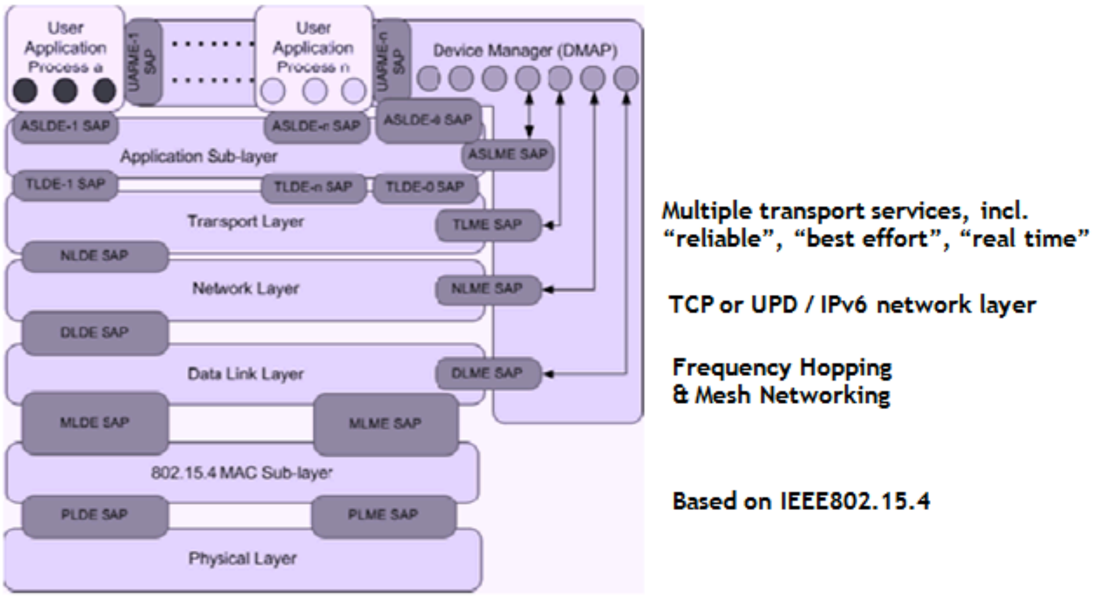
WirelessHART is based on the IEEE802.15.4 radio standard. Time-synchronization is added to the physical layer as basis for a TDMA datalink layer. A network layer is defined comprising the basic mechanisms for building and maintaining a wireless mesh network allowing the network nodes to “sleep” most of the time, thus enabling low-power operation so that nodes can operate on batteries for many years or use power-harvesting for battery-less operation. In addition, WirelessHART defines the upper layers of the protocol stack using commands and transport mechanisms inherited from the conventional HART-protocol, which is based on wired networks.



The definition of a comprehensive protocol stack spanning all 7 layers of the OSI model simplifies integration of WirelessHART into existing control environments where HART messaging is used. At the same time, this limits the applicability of the standard and especially SCADA systems cannot easily interface with a WirelessHART network.
The standard IEC62591 adopted the lower layers of WirelessHART, thus addressing a wider range of applications using almost the same transmission technology.
In the context of WIDE, it is important to note, that WirelessHART / IEC62591 are not specifying network management in detail. The methods for managing, e.g. messages to exchange for management purposes, are defined, but no rules related to network topology are given.

2.2 ISA 100

ISA 100 is also based on the IEEE802.15.4 radio standard, just as WirelessHART, and follows similar principles related to wireless transmission, namely channel hopping, TDMA and mesh networking. The scope of ISA 100, is significantly wider then WirelessHART: Various transport services are envisaged, including latency-controlled transmission with latencies as low as 100 ms. Consequently, ISA 100 is defining itself as a “family of standards" and is planning to also address control applications in usage classes 1 and 2. The current status of standardization, however, is only supporting non-critical monitoring applications (usage class 5) and the details of latency-control are subject of ongoing discussions within the standardization committee. In addition, the impact of latency and loss as well as network re-organization on control applications are not yet considered by the standardization committee.



Honeywell product OneWireless is based on ISO 100 standard. Team of Honewyell editors participated in the preparation of ISO 100.11a standard, which is now in the IEC PAS stage. Honeywell team covered the areas of System Management, Provisioning, Network Layer, Application Layer and Security, with input into overall system aspects. This activity was not supported by WIDE funding.

3. New requirements to industrial wireless standards

As can be seen from the current status of industry standards, the market for wireless sensing & control applications is still in its infancies and standardization itself has not made the step beyond pure monitoring applications. Therefore, new requirements derived from the WIDE project are essential and advanced requirements to allow for a stepwise approach to standardization.

The goal of such standardization efforts shall be a wireless communication network guaranteeing pre-defined communication service levels defined by their latency and loss characteristics. Advanced control algorithms, as developed by WIDE, shall be able to provide reliable control as long as the service level is fulfilled.

3.1 Essential requirements

Defined latency and loss models are essential for control to work. The important step towards standardization of the wireless technology is to translate this requirement into rules for managing network topology. As elaborated in deliverable D2.4 of the WIDE project, latency and loss are primarily determined by network topology and link budget. Therefore, one option would be fixed rules for network topologies and for the minimum allowable link budget safety margins. A more flexible approach would only identify latency and loss classes and leave it to the product developers to come up with appropriate network management methodologies.

Network formation and re-organization is far more complex and latency as well as losses are much more difficult to determine. Therefore, an operational mode suppressing all network re-organization after initial network formation is required.

3.2 Time stamping

As elaborated in deliverable D4.2 of the WIDE project, the impact of time-varying latency, out-of-sequence data and lost data on control performance can be significantly reduced by using network-aware Kalman filtering technology, incorporated in the control loop in a similar way as a Smith predictor for delay compensation. As the latency of data delivery in multiple-hops network with reconfigurable network topology is varying, the solution proposed requires the individual data items to be time stamped at the source of the data item so that the actual latency can be recovered on the receiving side.
The time stamping information can be also used for advanced routing algorithms. From control performance point of view, the packets with the latest data should be communicated with highest priority.

3.3 Advanced requirements

Expanding the application space beyond simple wire-replacement results in advanced requirements allowing for flexible network formation and re-organization during runtime. Controlling latency and loss during network (re-)formation implies, that network advertisements be sent in predefined maximum intervals to allow restricting the maximum time it takes for a searching node to find a suitable parent node to join. For very low latency classes, it will be required to limit the number of network channels used, to simplify and thus accelerate network search. A slow network re-formation scenario, where secondary paths are re-configured while the primary link is still active, will be needed for very low latency class networks.

Network join after successful search is not expected to be subject to major changes, but prioritization of related messages will be required.