Contribution toward interoperability of wireless sensor networks based on IEEE1451 in environmental monitoring applications

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I. Introduction

In last decade, Wireless Sensor Networks (WSNs) are becoming very attractive in many pervasive computing environments and they constitute a key technology to use in environmental monitoring applications, health care, industrial environments, surveillance, home automation and so on. WSN consists in a collection of tiny sensor nodes to deploy in a specific area, monitoring diverse physical phenomenons and it includes wireless communication capabilities in a short range using a distributed or hierarchical architecture. Usually, one of the nodes actuates as the coordinator and the others nodes use a transmission scheme with multi-hop routing to send the information to the coordinator. Often, the coordinator node acts as gateway to connect the WSN with external networks. In the future, thousands of pervasive devices will be operating in our daily life. They can generate a large amount of information; their management on a global scale can be too difficult for humans if a methodology is not introduced to reach the WSN interoperability. In this context, we propose three interoperability levels to introduce in present and future WSN deployments with smart sensors.

II. WSN Interoperability

Interoperability can be defined as the ability of nodes to communicate and exchange data effectively among multiple heterogeneous networks [1]. An interoperable node in WSN context can be modeled by compliance levels based on global standards. Interoperability is oriented toward the solution of practical problems of communication with heterogeneous devices and it can be modeled using three stages: technical, syntactic and semantic interoperability as shown in Figure 1.

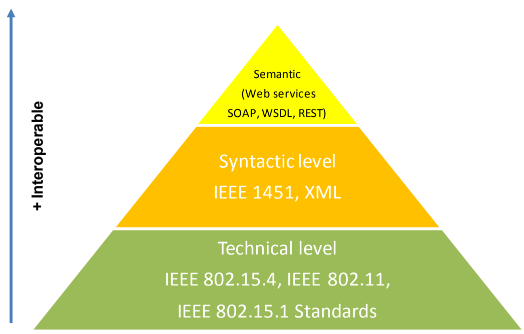

Figure 1. Levels of interoperability to introduce in a WSN

Technical level focus on transparent network connectivity among sensor nodes, including the establishment of the communications in physical layer level (PHY) and Medium Access layer level (MAC). For example in WSN we can use IEEE802.15.4 (ZigBee, 6loWPAN, WirelessHART), IEEE 802.1 (Bluetooth), IEEE 802.15.4a (UWB and CSS), IEEE 802.15.4f (active RFID), IEEE 802.15.4-TG6 (BAN), and IEEE 802.11 (Wi-Fi). The second level is namely syntactic interoperability and it involves standardized formats to send metadata and control commands by employing global standards in network and application layers. In this case, it is necessary a common structure to exchange messages between the sensor nodes and the coordinator node in both directions. At this level, the interoperability can be enhanced using open standardization. This is freely and publicly available for all communities, with neutral vendor and agreed to by a formal consensus process. An example of syntactic interoperability with smart sensors is the IEEE1451 standard [2] to be included in wired or wireless sensor networks. The third stage of interoperability is semantic level, which is responsible to give meaning to the information embedded in each syntactic structure. Semantic Web transactions allow transparent communication among different entities, for example node sensors, coordinator node, and clients to share the information without ambiguity over heterogeneous networks. In this level, sensor networks pursue an effective communication to communicate among them using the World Wide Web Consortium (W3C) languages and Internet Engineering Task Force (IETF) standards, with a concise and common syntax to perform metadata queries that return the information over multiple crossing sensor networks. Semantic Web interoperability in conjunction with SOA architectures and web services that can be introduced with IEEE 1451 smart sensor and WSN in ZigBee and 6loWPAN networks.

III. IEEE 1451 standardization

IEEE 1451 is a family of high level standards organized around a set of common architectures and protocols to permit the interoperability of smart sensors. The main objective of IEEE 1451 is the adoption of manufacturer independent common communication protocol to be used in wired or wireless sensor networks, for example, in WSN, IEEE 1451.5 can be used with Wi-Fi, Bluetooth, IEEE 802.15.4, ZigBee and 6loWPAN [3]. Fig 2 shows the IEEE 1451 smart sensor model in a WSN. An IEEE 1451 sensor node is modeled as Wireless Transducer Interface Module (WTIM).

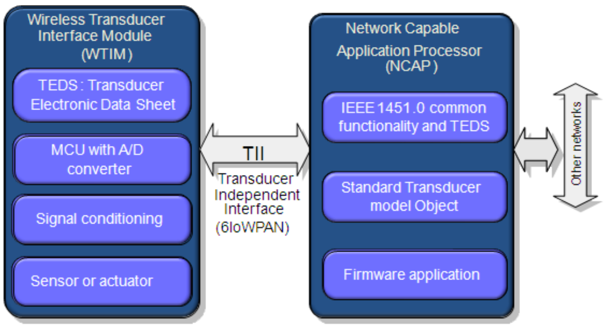

Figure 2. IEEE 1451 Smart sensor model

The WTIM node architecture includes channels to sense the physical variables, a signal conditioning submodule, ADC conversion submodule, and finally an important element so-called Transducer Electronic DataSheet (TEDS), embedded in a non volatile memory. TEDS contains metadata information to calibrate each sensing channel, configure a radio sub-specification interface, as well as additional identification information of WTIM to use in auto-calibration and auto-configuration tasks [4]. Additionally, IEEE 1451 defines the Network Capable Application Processor (NCAP) that actuates as sink or coordinator node in a WSN.

IV. 6loWPAN with IEEE 1451 interoperability

IPv6 can be used in personal area networks with embedded smart sensor nodes over IEEE 802.15.4 introducing the 6LoWPAN adaptation layer. 6LoWPAN uses a set of standards defined by the IETF that enables a very compact implementation of IPv6 over WTIM and NCAP nodes. Fig 3 shows a 6loWPAN network compliant the IEEE 1451 standard using UDP protocol transport.

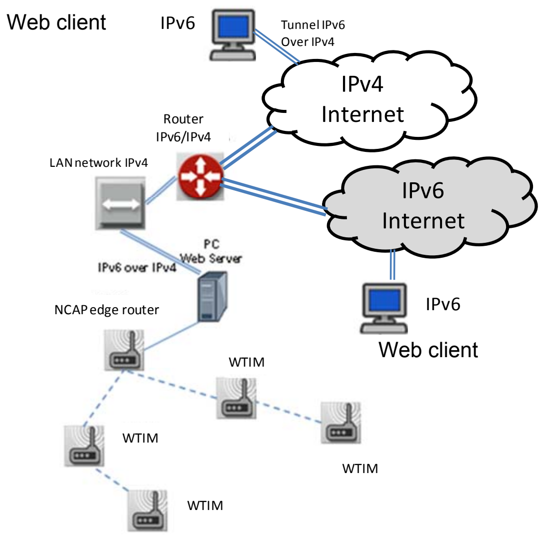

Figure 3. 6loWPAN network compliant the IEEE 1451 standard

Web clients, in an IPv6 cloud or IPv4 cloud, can connect to the IEEE 1451 6lowPAN sensor network. The IPv6 web client uses the IEEE 1451 commands embedded in data frame structures and using tunneling IPv6 over IPv4 to arrive to the sensor network. In our approach, each WTIM sensor node employs small UDP packets to send environmental information to the NCAP, which is connected to Internet. The web clients are able to send IEEE 1451 commands opening an UDP socket to communicate with the NCAP edge router and it can communicate to the collection of WTIMs using the common commands IEEE 1451.0. UDP datagram structure compliant with the 6loWPAN and IEEE 1451 is shown in Table 1. Physical layer includes: PHY and MAC IEEE 802.15.4, payload and frame control sequence. The IEEE 802.15.4 payload contains the small 6loWPAN UDP packet. It is composed of these main parts: 6loWPAN header (3 bytes), hop limit (1 byte), UDP header (3 bytes) and the payload (106 bytes). At present, the 6LoWPAN format allows a very heavy compression from IPv6 using HC1 header to indicate IPv6 over IEEE 802.15.4, and HC2 to compress UDP header, reducing the full packet IPv6 structure to the small compressed 6loWPAN UDP packet. In our WSN, the IEEE 1451.0 commands are encapsulated in 6loWPAN UDP payload [5]. Finally, a compact TEDS structure based on compression with reduced data types was included in a non volatile WTIM node memory.

IEEE802.15.4 physical and MAC layer		
PHY/MAC [10 B]	Payload [113 B]	MAC - FCS [4 B]

6loWPAN UDP packet			
6loWPAN Header[3 B]	Hop limit [1 B]	UDP [3 B]	Payload [106 B]

6loWPAN Header			Hop limit	UDP header		Payload
Disp [1 B]	HC1 [1 B]	HC2 [1 B]	Hop limit [1 B]	Source & Dest. [1 B]	UDP Check [1 B]	IEEE 1451

Payload (IEEE 1451.0 commands)				
Dest. Transd. Channel [2B]	Command Class [1 B]	Command Function [1 B]	Length Offset [2 B]	Command Read/write [100 B]

Table 1. 6loWPAN UDP frame structure using IEEE 1451.0

Our proposal TEDS model decreases the overall memory used in each WTIM node. In this case, the memory size reduction in Meta-TEDS was of 25% and the memory size reduction in physical TEDS (PHY-TEDS) was of 48%. This option can be exploited in small RFID tag or nodes that use energy harvesting methods and operate with limited memory.

V. Contributions

A 6loWPAN network compliant with IEEE1451 has been modeled in a real environment. Each WTIM node includes IEEE1451.0 standard commands and IEEE1451.5 TEDS. A new format of PHY TEDS to include in 6loWPAN has been proposed for future inclusion in the standard IEEE1451.5. WSN deployments with IEEE1451.5 explore the capabilities of interoperability with smart sensor nodes in 6loWPAN networks.

VI. Acknowledgments

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VII. References

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[2] EEE 1451.5 Standard for a Smart Transducer Interface for Sensors and Actuators Wireless Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats. IEEE Instrumentation and Measurement Society. ISBN: 978-0-7381-5599-9.

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