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The communication module - gateway implementation

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ABBREVIATIONS AND ACRONYMS

ABBREVIATION	DESCRIPTION
AC	Alternating Current
ADC	Analogue to Digital Converter
AES	Advanced Encryption Standard
AODV	Ad hoc On-Demand Distance Vector
ASIC	Application-specific Integrated Circuit
BCM	Bridge Completion Module
CAN	Controller area network
CPU	Central Processing Unit
FMCW	Frequency Modulated Continuous Wave
FPGA	Field Programmable Gate Array
GPRS	General Packet Radio Service
GPS	Global Positioning System
HTTP	Hypertext transfer Protocol
HW	Hardware
HWMP	Hybrid Wireless Mesh Protocol
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
IR	Infrared
LAN	Local Area Network
LNA	Low Noise Amplifier
LSN	Local Sensor Network
LOS	Line-of-Sight
LPS	Local Positioning System
LPS	Local Positioning System
MAC	Medium Access Control
MEMS	Microelectromechanical Systems
MODBUS	A serial communications protocol
NTP	Network Time Protocol
PCCDN	Post Crisis Needs Assessment Tool in regards to Construction Damage and related Needs
PLL	Phase Locked Loop
RECONASS	Reconstruction and Recovery Planning: Rapid and Continuously Updated Construction Damage, and Related Needs ASSessment
RF	Radio Frequency

ABBREVIATION	DESCRIPTION
RF	Radio Frequency
RFD	Reduced-function device
RS485	Serial interface standard in which data is sent in a differential pair
SRAM	Static random-access memory
SRD	Short range device
SSID	Service Set Identifier
SSL	Secure Socket layer
SW	Software
TCP	Transmission Control Protocol
USB	Universal Serial Bus
VCO	Voltage Controlled Oscillator
VLAN	Virtual Local Area Network
WAN	Wide Area Network
WDS	Wireless distribution system
WEP	Wired Equivalent Privacy
WLAN	Wireless Local Area Network
WPA	Wi-Fi Protected Access
WSN	Wireless Sensor Network
xDSL	Symmetric digital subscriber line
ZC	ZigBee Coordinator
ZED	ZigBee End Device
ZR	ZigBee Router

GLOSSARY OF TERMS

Accelerometer	A sensor that measures the specific force (i.e. acceleration).
Accuracy	Deviation of a measured value to a reference value.
Agent	Agent is considered of a software module responsible to perform a set of predefined/pre-programmed actions
Anchor	Any sensor node with known reference position that communicates with other nodes to give them reference location data.
Communication Gateway Module	In this work the Communication gateway Module refers to the overall communication means utilised to exchange information from the sensors and LPS to the assessment tool (PCCDN).
Coordinator or base station	Connected to a certain number of LPS sensor nodes, coordinates positioning signals, calculation of position of each node relative to anchor, interface to the rest of the monitoring system.
Data hub	Data hubs will be used to locally collect all data from the different sensors (acceleration, strain, temperature, position), then transfer this data to the gateway.
Functional Requirement (FR)	An FR is a statement of an action or expectation of what the system will take or do. It is measured by concrete means like data values, decision making logic and algorithms.
Gateway	The communication's module central unit where sensor collected data is aggregated, formatted, classified, validated and finally transmitted to the PCCDN tool for further processing and subsequently overall structural and non-structural assessment. Furthermore, the underlying sensor network is monitored and managed through the RECONASS gateway in a way that ensures the network is operating efficiently mainly in terms of availability, reliability and power consumption.
LAN	Local Area Network – LAN access specifies the various interfaces between the gateway and the data-hubs and the communication means deployed between the data-hubs and the sensors.
LSN	Local Sensor Network – LSN access specifies the interfaces and the network deployed between the wireless/wired sensor nodes and the data hubs.
Magnitude	Size of an earthquake measured on the open ended scale of moment magnitude, sometimes called Richter magnitude.
Non-structural Components	All items in a building other than the building structural system and its foundation. Included are all architectural elements such as cladding, glazing, ceiling systems and interior partitions that are permanently attached to the building; all mechanical and electrical equipment such as fire sprinkler systems, water and sewer piping, HVAC (Heating, Ventilating and Air Conditioning) systems and electrical distribution and lighting systems that are permanently attached to the building. For the purposes of this deliverable non-structural components do not include building contents.
Precision	The repeatability of a distance or position measurement in an unchanged scenario.
Resolution	The ability of the LPS to separate targets (i.e. tags) in close proximity.
Structural Components	Building components that are part of the intended gravity, seismic, blast/impact or fire forces resisting system, or that provide measurable resistance to these forces.
System Architecture	A system architecture or systems architecture is the conceptual model that defines the structure, behaviour, and more views of a system. An architecture description is a formal description and representation of a system, organized in a way that supports reasoning about the structures and behaviours of the system. A system architecture can comprise system components, the externally visible properties of those components, the relationships (e.g. the behaviour) between them. It can provide a plan from which products can be procured, and systems developed, that will work together to implement the overall system.

Sensor node or tag	Small locatable device to be embedded at crucial points such as beams and columns in the structure. Certain external nodes will be provided with access to GPS.
Strain gauge	A strain gauge is a device used to measure strain on an object.
Technical Specification	Specification (often abbreviated as spec) may refer to an explicit set of requirements to be satisfied by a material, design, product, or service.
User Requirement (UR)	A UR is a statement of what users need to accomplish. It is a mid-level requirement describing specific operations for a user (e.g., a business user, system administrator, or the system itself). They are usually written in the user's language and define what the user expects from the end product.
Wi-Fi	The Wi-Fi Alliance, the organization that owns the Wi-Fi (registered trademark) term specifically defines Wi-Fi as any 'wireless local area network (WLAN) products that are based on the IEEE 802.11 standards.'
Wireless Sensor Network (WSN)	Spatially distributed autonomous devices (nodes) using sensors to cooperatively monitor physical (such as, acceleration, strain) or environmental conditions

EXECUTIVE SUMMARY

The RECONASS Communication Module and Gateway Implementation report describes the relevant prototype that has been developed within the RECONASS Project for delivering all types of communication from the sensors up to the disaster management tool (PCCDN tool), the latter being the graphical user interface (GUI) that a user operates for monitoring a given constructed facility (be it a critical or a conventional one). The prototype covers a) communication between the sensors and the wireless sensor nodes, b) communication between the wireless sensor nodes and the data hubs (data aggregation points), c) communication between the wired sensors and the data hubs, d) communication between the data hubs and the communication gateway, the latter being the central communication node of the overall monitoring system and e) communication between the communication gateway and the PCCDN tool, the latter enabling depiction of the sensor related information and relevant structural and non-structural assessments into a graphical user interface that uses a building information model (i.e. building design).

The present document serves as an accompanied report of the Communication Module and Gateway Implementation prototype aiming to explain in detail the hardware and software integrated and developed respectively to support a wide set of specifications in regards to real-time sensor monitoring, interoperable communications for the creation of Local and Wide area Networks, security mechanisms to support data exchange from the sensor level up to the PCCDN tool, redundancy and resilience of the monitoring system in every-day use and during and after disastrous events such as earthquake, explosion and fire.

The report is structured as follows:

- In section 2, the overall Communication Module and Gateway Implementation architecture is presented including brief descriptions of the communication nodes, networks, communication interfaces and functional capabilities supported of the prototype as a whole as well as of its distinct components.
- In section 3, a detailed description is provided on the sensors' layer, that includes communications of the sensors nodes (temperature, strain, acceleration and positioning tags) with the data hubs, the latter constituting the first level data aggregation nodes where monitoring data and measurements are stored, processed and forwarded following a cluster approach for segmenting the various monitoring areas of the building of interest.
- In section 4, a detailed description of the software, hardware, network interfaces and functionalities supported by the data hubs is presented.
- In section 5, the Communication Gateway is presented from a hardware and software point of view. The Gateway is considered as the central communication point of the entire monitoring system that is responsible primarily to aggregate all building's monitoring information (including measurements and communication nodes). The Gateway locally stores all raw data and subsequently performs complex management of such information by filtering the data, controlling and remotely configuring the entirety of sensor nodes of the monitoring system and finally transforming the captured sensor data into a unified format that supports communication with the disaster management tool over OGW SWE sensor enabled services. For the Gateway-PCCDN tool communication dedicated tunnels are created to maintain high data security and a set of services are initialised to govern such information routing over heterogeneous wide area network interfaces (e.g. Wi-Fi, LTE, UMTS, etc.). Noteworthy the software implementation and the hardware integration have been realised in such a manner to satisfy stringent redundancy and resilience requirements (such network of power failures) that are of outmost importance when a disaster occurs.
- In section 6, the Gateway Dashboard is presented which is the graphical user interface developed within the RECONASS project for supporting monitoring and configuration of the central gateway component. The dashboard allows the user (system operator) to visualise the gateway's performance in real-time, to monitor data exchange and to re-configure the gateway en operation.

As a conclusion the RECONASS Communication Module and Gateway Implementation has achieved compliance with a wide set of requirements (extracted from extensive user consultation and technical specifications creation) so as to effectively support a monitoring system for buildings (critical or conventional ones) in terms of real-time data capture, storage and processing over heterogeneous local and wide area networks enhanced by increased security mechanisms to ensure data integrity and user/node authentication and authorisation whilst preserving resilience and redundancy in unfortunate events during which the structure's capacity is under stress.