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**Smart Body Area Networks (SmartBAN)
Unified data representation formats,
semantic and open data model**

Reference

DTS/SmartBAN-009

Keywords

health, information model, interoperability, ontology, security, semantic

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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Smart Body Area Network (SmartBAN).

Modal verbs terminology

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1 Scope

The present document specifies and formalizes SmartBAN unified data representation formats (including in particular sensor/actuator/relay/coordinator/Hub descriptions and sensed/measured data), semantic open data model and corresponding ontology.

The present document is applicable to a BAN and/or a Smart BAN comprising wearable sensors/actuators devices, a relay/coordinator device and a Hub. The relay/Coordinator and the Hub functionalities may be handled by a single device or by two distinct devices.

The present document does not yet address the specification and the formalization of the SmartBAN service ontology and associated enablers. This will be addressed in the future release of the present document.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

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The following referenced documents are necessary for the application of the present document.

[1] ETSI TS 103 325 (V1.1.1) (04-2015): "Smart Body Area Network (SmartBAN); Low Complexity Medium Access Control (MAC) for SmartBAN".

[2] ETSI TS 103 326 (V1.1.1) (04-2015): "Smart Body Area Network (SmartBan); Enhanced Ultra-Low Power Physical Layer".

[3] R. Hodgson, P. Keller, J. Hodges, J. Spivak: "QUDT - Quantities, Units, Dimensions and Data Types Ontologies", 2013.

NOTE: Available at http://www.qudt.org/.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] S. Movassaghi, M. Abolhasan, J. Lipman, D. Smith and A. Jamalipour: "Wireless Body Area Networks: A Survey", In IEEE Communications Surveys & Tutorials, issue 99, pp. 1-29, January 2014.

[i.2] J. Y. Khan and M. R. Yuce: "Wireless Body Area Network (WBAN) for Medical Applications", New Developments in Biomedical Engineering, Domenico Campolo (Ed.), 2010, ISBN: 978-953-7619-57-2.

[i.3] A. B. M. Moniruzzaman, S. A. Hossain: "NoSQL Database: New Era of Databases for Big data Analytics - Classification, Characteristics and Comparison," International Journal of Database Theory and Application, Vol. 6, August 2013.

[i.4] I. döt Net, C. Evans, O. Ben-Kiki: "YAML Ain't Markup Language", 2011.

NOTE: Available at http://www.yaml.org/about.html.

[i.5] ECMA - 404 (10-2013): "The JSON Data Interchange Format".

NOTE: Available at http://json.org/.

[i.6] Apache Avro™ 1.7.7 Documentation.

NOTE 1: Available at http://avro.apache.org/docs/current/.

NOTE 2: Apache Avro™ is an example of a suitable product freely available. This information is given for the convenience of users of the present document and does not constitute an endorsement by ETSI of this product.

[i.7] IEEE 802.15.6 standard tutorial.

NOTE: Available at https://mentor.ieee.org/802.15/dcn/11/15-11-0826-02-0006-ieee-802-15-6-tutorial.ppt.

[i.8] J. Ison, M.Kalas: "EDAM: an ontology of bioinformatics operations, types of data and identifiers, topics and formats", 2013.

NOTE: Available at http://bioportal.bioontology.org/ontologies/EDAM.

[i.9] Location owl ontology.

NOTE: Available at http://dbpedia.org/ontology/location.

[i.10] M. Smethurst, R. Styles, T. Scott: "The Places ontology", 2007.

NOTE: Available at https://github.com/mmmmmrob/Places-Ontology/blob/master/schema.rdf.xml.

[i.11] I. Horrocks, P. F. Patel-Schneider, H. Boley, S. Tabet, B. Grosof and M. Dean: "SWRL: A Semantic Web Rule Language Combining OWL and RuleML", W3C Recommendation, May 2004.

[i.12] D. P. Swain, K. S. Abernathy, C. S. Smith, S. J. Lee, S. A. Bunn: "Target heart rates for the development of cardio respiratory fitness", Med Sci Sports Exerc., 26(1):112-116, PMID:8133731, 1994.

[i.13] S. Cox: "Observations and measurements-xml implementation" OGC document, 2011.

NOTE: Available at http://www.opengeospatial.org/standards/om.

[i.14] ISO 19156: "Geographic information -- Observations and measurements".

NOTE: Available at http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=32574.

[i.15] OGC® Sensor Web Enablement.

NOTE: Available at http://www.opengeospatial.org/ogc/markets-technologies/swe.

[i.16] OGC® Sensor Model Language (SensorML).

NOTE: Available at http://www.ogcnetwork.net/SensorML.

[i.17] R. Bendadouche, C. Roussey, G. De Sousa, J. Chanet and K. Mean Hou: "Extension of the Semantic Sensor Network Ontology for Wireless Sensor Networks: The Stimulus-WSNnode-Communication Pattern," In Proceedings of the 11th International Semantic Web Conference, Boston, USA, November 2012.

[i.18] M. Compton, C. Henson, L. Lefort and H. Neuhaus: "A survey of the semantic specification of sensors," In Proceedings of the 2nd International Workshop on Semantic Sensor Networks, Washington DC., USA, October 2009.

[i.19] D.J. Russomanno, C. Kothari and O. Thomas: "Building a Sensor Ontology: A Practical Approach Leveraging ISO and OGC Models," In Proceedings of 2005 International Conference on Artificial Intelligence, pp. 637-643, Las Vegas, NV USA, 2005.

[i.20] ISO 19115-1:2014: "Geographic information -- Metadata -- Part 1: Fundamentals".

NOTE: Available at http://www.iso.org/iso/catalogue_detail.htm?csnumber=53798.

[i.21] W3C Semantic Sensor Network Incubator Group.

NOTE: Available at http://www.w3.org/2005/Incubator/ssn/.

[i.22] S. Nicolić, V. Penca, M. Segedinac and Z. Konjović: "Semantic Web Based Architecture for managing hardware heterogeneity in Wireless Sensor Network", International Journal of Computer Science Issues, Vol. 8, Issue 4, No 2, July 2011.

[i.23] CEN Technical Commitee 251 on health informatics - published standards.

NOTE: Available at http://standards.cen.eu/dyn/www/f?p=204:32:0::::FSP_ORG_ID,FSP_LANG_ID:6232,25&cs=1FFF281A84075B985DD039F95A2CAB820.

[i.24] CEN/ISO 13606 standard on semantic interoperability in the electronic health record communication.

NOTE: Available at http://www.en13606.org/the-ceniso-en13606-standard

[i.25] ISO/IEEE 11073 standards: "Health informatics -- Personal health device communication".

NOTE: Available at http://www.iso.org/iso/home/search.htm?qt=11073&published=on&active-tab=standards&sort-by=rel.

[i.26] Bluetooth® Core Specification 4.2 document.

NOTE 1: Available at https://www.bluetooth.org/DocMan/handlers/DownloadDoc.ashx?doc_id=286439.

NOTE 2: Bluetooth® is an example of a suitable product available commercially. This information is given for the convenience of users of the present document and does not constitute an endorsement by ETSI of this product.

[i.27] Recommendation ITU-T H.810: "Interoperability design guidelines for personal health systems".

NOTE: Available at http://www.itu.int/rec/T-REC-H.810-201312-S/en.

[i.28] ASTM - Committee E31 on Healthcare Informatics.

NOTE: Available at http://www.astm.org/COMMIT/E31_Fact_Sheet_2015.pdf.

[i.29] ASTM E1238-97: "Standard Specification for Transferring Clinical Observations Between Independent Computer Systems".

NOTE: Available at http://www.astm.org/Standards/E1238.htm.

[i.30] ASTM E1394-97: "Standard Specification for Transferring Information Between Clinical Instruments and Computer Systems".

NOTE: Available at http://www.astm.org/Standards/E1394.htm.

[i.31] ASTM E1467-94 (2000): "Standard Specification for Transferring Digital Neurophysiological Data Between Independent Computer Systems".

NOTE: Available at http://www.astm.org/Standards/E1467.htm.

[i.32] ASTM E2369: "Standard Specification for Continuity of Care Record (CCR)".

NOTE: Available at http://www.astm.org/Standards/E2369.htm

[i.33] ASTM E1384: "Standard Practice for Content and Structure of the Electronic Health Record (EHR)".

NOTE: Available at http://www.astm.org/Standards/E1384.htm

[i.34] S. Tartir, I. Arpinar and A. Sheth: "Ontological Evaluation and Validation", Theory and Applications of Ontology: Computer Applications, Springer, pp. 115-130, 2010.

[i.35] N. Guarino, C. Welty: "An overview of OntoClean", Handbook On ontologies, Springer, Chapter 8, 2009.

[i.36] V. Cross and A. Pal: "OntoCAT: An Ontology Consumer Analysis Tool and Its Use on Product Services Categorization Standards", Computer Science and Systems Analysis, Miami University.

[i.37] A. Lozano-Tello, A. Gomez-Perez: "ONTOMETRIC: A method to choose the appropriate Ontology", Journal of Database Management, 2 (15) pp. 1-18, 2004.

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

example 1: text used to clarify abstract rules by applying them literally

3.2 Symbols

For the purposes of the present document, the following symbols apply:

s	second
bps	bit per second
bpm	beats per minute

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

ANP	Alert Notification Profile
ASTM	American Standards for Testing and Materials
BAN	Body Area Network
CCR	Continuity of Care Record
CCU	Central Control Unit
CEN	European Committee for Standardisation
CESN	Coastal Environmental Sensor Networks
CRS	Coordinate Reference Systems
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DL	Description Logic
ECG	Electrocardiogram
EDAM	Embrace Data and Methods
EEG	Electroencephalogram
EHR	Electronic Health Record
GAP	Generic Access Profile
GATT	Generic Attribute Profile
GPS	Global Positioning System
GW	Gateway
HID	Human Interface Device
HL7	Health Industry Level 7
HOGP	HID Over GATT Profile

HR	Heart Rate
IC-ISM	Intelligence Community Information Security Marking
ICT	Information and Communications Technology
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
ISM	Industrial, Scientific and Medical
JSON	JavaScript Object Notation
KB	Knowledge Base
LAN	Local Area Network
LE	Low Energy
LSDIS	Large Scale Distributed Information Systems
MAC	Media Access Control
MBAN	Medical Body Area Network
MIPS	Microprocessor without Interlocked Pipeline Stages
MMI	Marine Metadata Interoperability
NoSQL	Not only SQL
NT	Node Type
O&M	Observations & Measurements
OGC	Open Geospatial Consortium
OpenGIS	Open Geospatial Consortium
OSI	Open Systems Interconnection
OUI	Organizationally Unique Identifier
OWL	Web Ontology Language
OWL DL	Web Ontology Language Description Logic
PDA	Personal Digital Assistant
PER	Packet Error Rate
PHD	Personal Health Device
PHY	Physical layer
RAM	Random Access Memory
ROM	Read-Only Memory
RTLS	Real Time Location Services
SDO	Sleep Domain Ontology
SEEK	Science Environment for Ecological Knowledge
SensorML	Sensor Model Language
SIG	Special Interest Group
SPARQL	SPARQL Query Language
SPP	Scan Parameters Profile
SQL	Structured Query Language
SSN	Semantic Sensor Network
SUMO	Suggested Upper Merged Ontology
SWAMO	Sensor Web for Autonomous Mission Operations
SWE	Sensor Web Enablement
TBD	To Be Defined
TC	Technical Committee
TTL	Time to Live
UML	Unified Modeling Language
US	United States
UUID	Universally Unique IDentifier
UWB	Ultra Wide Band
W3C	World Wide Web Consortium
WBAN	Wireless Body Area Network
WBANID	Wireless Body Area Network Identifier
WSN	Wireless Sensor Network
WSNs	Wireless Sensor Networks
WSSN	Wireless Semantic Sensor Network
XML	Extensible Markup Language
YAML	Yet Another Markup Language

4 Introduction

The present document gives the high level description of a unified data format providing one of the building blocks for heterogeneity management in Smart BANs. The present document will in particular define a unified description model with an extensible semantic metadata for Smart BAN entities related data as well as for monitoring and control information. The corresponding metadata management and indexing framework will also be investigated.

5 Ambit and induced constraints

The scope of clause 5 of the present document is to briefly investigate the initial TC SmartBAN use case requirements in order to point out their impact on ETSI TS 103 378 specifications and designs. The initial additional requirements induced by ETSI TS 103 378 scenario will also be listed.

Wireless Body Area Networks (WBANs) are made of a collection of low-power embedded devices, mainly sensors or actuators that are used for monitoring vital data of a human and its environment (but not limited to human). Those embedded devices are located in the vicinity or on or inside the body, and are mainly provided with short range communication technologies. BANs are short distance networks of maximum 6 m^3 that contain maximum 6 networks per m^2 and maximum 256 nodes per network [i.1]. These nodes may be mobile and the network topology may change frequently. The data rate of sensed data can actually vary from 75,9 kbps to 15,6 Mbps [i.1]. WBANs are not expected to be operated in licensed frequency bands. Hence, the frequency spectrum of operation will be in the unregulated frequency bands for industrial, scientific and medical (ISM) applications. If ISM and MBAN bands (US and European) with frequency between 2,3 GHz and 2,5 GHz are initially considered within TC SmartBAN, higher frequency bands (from 3,2 to 10,2 GHz) will also be considered for allowing the support of Real Time Location Services (RTLS). Finally, WBANs are characterized by strong constraints in terms of low power, low latency, low Packet Error Rate (PER), reliability, QoS, coexistence and security. The initial technical requirements retained by TC SmartBAN for WBAN parameters are listed in table 1.

Table 1

Parameter	Smart BAN Requirements
Coexistence/robustness	Good (low interference to other systems, high tolerance to interference)
Data rates (Sensor)	Nominally < 100 kbps/node (vital sign monitoring)
Transmission rate (PHY)	Up to 1 Mbps
Network topology	Star network
Power consumption (node)	TBD
QoS control	Priority based control and cross layer optimization. Emergency signal transmission supported.
Reliability	Robust to shadowing and multipath interference
Max. node capacity	up to 16 nodes (typically 8)
Range	< 1,5 m
Latency	< 125 ms (high sampling applications e.g. ECG, EEG.)
Security / privacy	TBD

The initial ambit envisioned by TC SmartBAN contributors is a BAN network organized around a Hub and mainly following a star topology. The Hub play the role of the BAN cluster head and also serves as an intermediary Gateway (GW) node allowing the interconnection of the BAN cluster with an healthcare local/remote monitoring and control centre. This node, with extended memory and processing capacity (e.g. a smart phone), should be responsible for all the heavy processing management and control operations of the SmartBAN. In case of a multi hope routing strategy, the BAN shall be provided with at least a bridge/relay functionality that could be handle by the SmartBAN's Hub or within a dedicated SmartBAN device. This relay/bridge device offers enhanced performance and robustness (e.g. relay around hidden devices), as well as optimized SmartBAN solutions with enhanced connectivity (multi-radio) and routing (multi-hop) capabilities. In some global healthcare architectures, the BAN's Hub role may sometimes be handled by a cluster-external intermediary node called Central Control Unit (CCU) [i.2]. Finally, BAN discovery functionality and interworking shall be handled and shall thus be taken into consideration for the specification of the SmartBAN semantic open data model. Figure 1 gives a simple example of the considered SmartBAN end-to-end architecture.

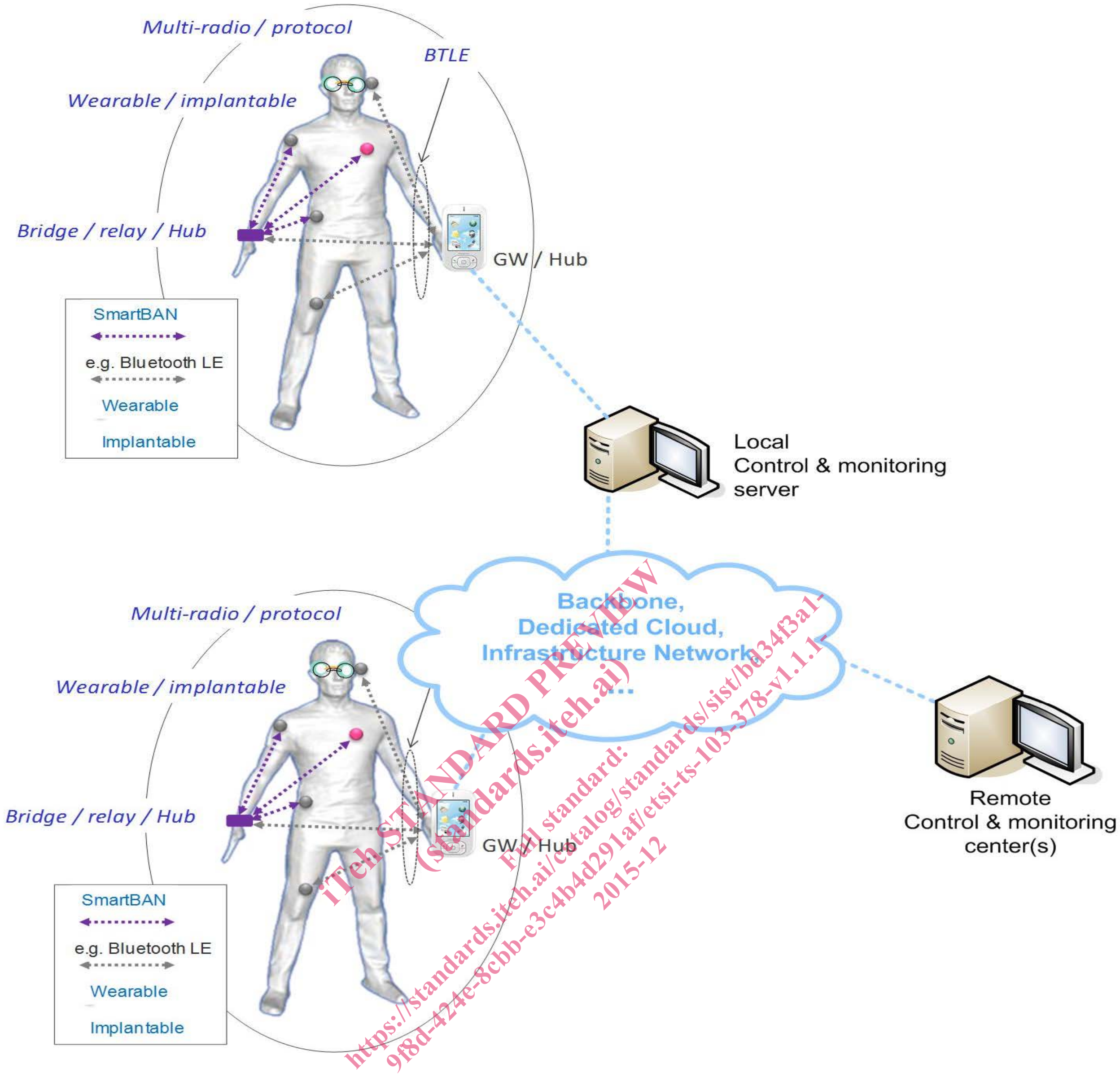

Figure 1: Example of considered SmartBAN end-to-end architecture

One main objective of the present document is the BAN heterogeneity management through the specification of a generic sensor and sensor data description and transfer format. This description format shall be as rich as possible to allow e.g. conflict resolution or similarity detection, but shall also be handled with low processing, low power and in quasi real time (e.g. latency < 125 ms and node addition or removal time < 3 s [i.1]). In that context, two scenarios shall a priori be envisioned:

- Or the proposed ontology is sufficiently light for allowing the sensor raw data pre-processing within the sensor itself,
- Or the pre-processing is deported to most powerful BAN's nodes. In that case, aforementioned nodes such as the BAN Hub or the BAN coordinator seem a priori good candidates for handling that pre-processing.

Furthermore, the ontology pre-processing and processing operations complexity strongly depend on the ontology format and storage format used (e.g. NoSQL [i.3] compared to SQL, or -YAML [i.4], JavaScript Object Notation [i.5], Extract Load Transfer strategies and Avro Schemas [i.6], etc. - compared to in particular XML, could significantly reduce the processing power required).

The aforementioned issues will be addressed in the present document.

6 SmartBAN open data model and ontology

6.1 SmartBAN information analysis

The objective of clause 6.1 of the present document is first to perform information analysis of the SmartBAN scenarios and to identify:

- the relevant related information sources, types, formats and owners;
- the information processing operations and functionality towards the SmartBAN related information.

Then, based on the analysis of existing information models already investigated in the SoA clause (see clause A.1 of the present document), the SmartBAN information meta-model (UML diagram) will be defined in clause 6.1 of the present document.

Dealing with tiny devices in WBAN shall lead towards the design of a modular model where some classes should be implemented in the sensor/actuator nodes depending on its resource's availability, and some others should be implemented and processed in more capable nodes like e.g. the SmartBAN' Hub or coordinator. Basically, the SmartBAN open data model shall be divided into three main parts: WBAN (SmartBAN or BAN cluster in the TC SmartBAN context), Nodes (i.e. Hub, sensors, actuators, etc.), Process and Measurements. Figure 2 depicts the class diagram that shall be introduced for the WBAN/Smart BAN.

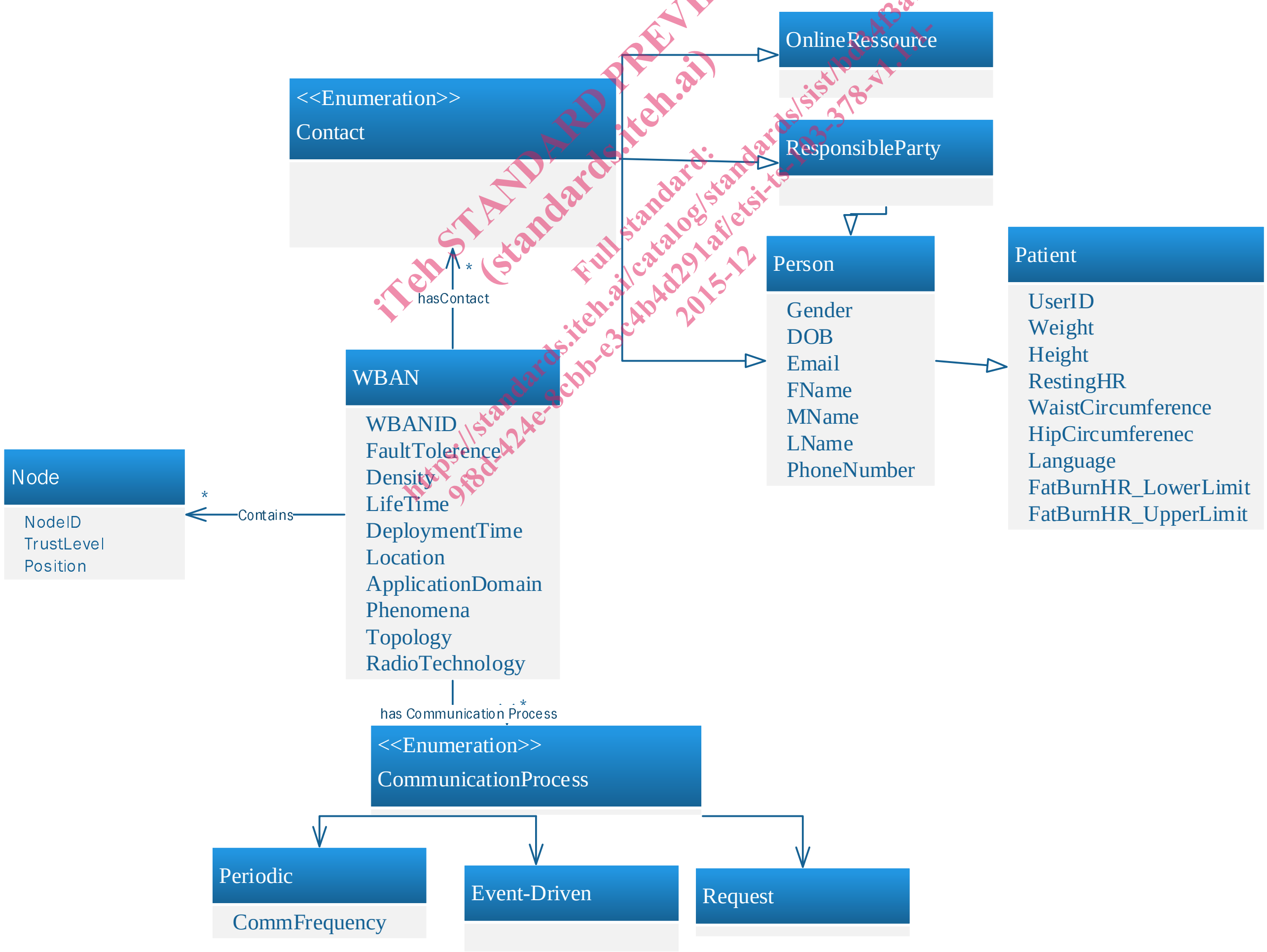

Figure 2: UML classes - TCSmartBAN_WBAN