ETSI TR 103 394 V1.1.1 (2018-01)

TECHNICAL REPORT

Smart Body Area Networks (SmartBAN);
System Description

Reference

DTR/SmartBAN-008

Keywords

MAC, routing support

ETSI

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Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° 7803/88

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Foreword

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

Modal verbs terminology

In the present document "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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1 Scope

The present document describes the system description of Smart BAN.

SmartBAN addresses the five major features below:

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

2) SmartBAN Data representation and transfer, service and application; Standardized interfaces, APIs and infrastructure for heterogeneity and interoperability management.

3) SmartBAN Measurements and Modelling of SmartBAN RF environment.

4) Low complexity MAC and routing for SmartBAN.

5) Enhanced, ultra-low power PHY for SmartBAN.

The following technologies are also to be defined:

- smart control;
- network management;
- implant communications;
- security; and
- privacy mechanisms.

SmartBAN takes a comprehensive view of BAN from lower layer (e.g. physical layer and MAC layer) to higher layer system aspects and end-to-end (e.g. heterogeneity management and semantic interoperability and monitoring and control). End-to-end connectivity (e.g. SmartBAN to Medical Centre or SmartBAN to SmartBAN) is illustrated by figure 1.

Figure 1: Scope of SmartBAN

SmartBAN facilitates the efficient use of multiple radio technologies. This will be handled in all the layers including semantic interoperabilities and a BAN coordinator will be introduced for that purpose (figure 2). This coordinator will also provide mandatory functionality related to routing and interactions with other application domains that includes e.g. SmartM2M, automotive, smart home environments.

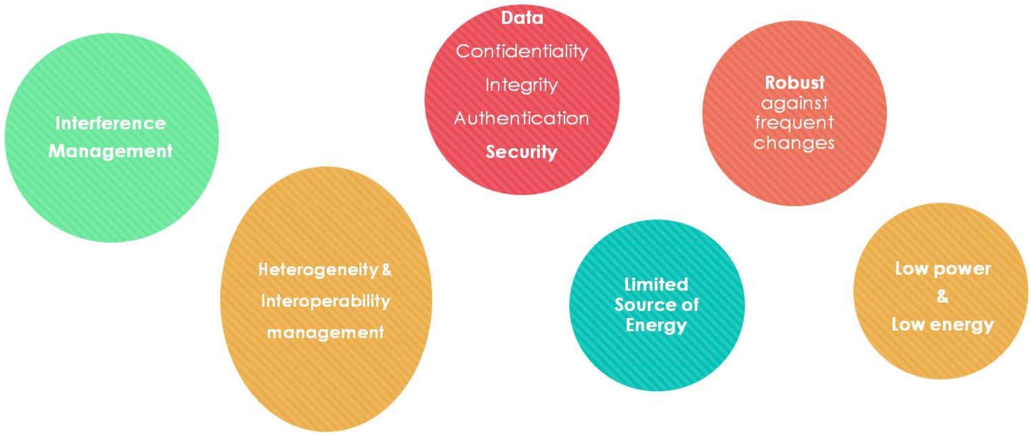

Figure 2: Summary of the SmartBAN environment main constraints

Figure 3 provides a an example of a possible future multi-radio (e.g. narrowband 2,4 GHz and UWB). The controller may be e.g. a handset or other device while other, simpler devices (e.g. smart watch or wristband) may serve as a relay/bridge within the BAN offering enhanced performance/robustness (e.g. relay around hidden devices) as well as opening the door for optimized SmartBAN solutions with enhanced connectivity (multi-radio).

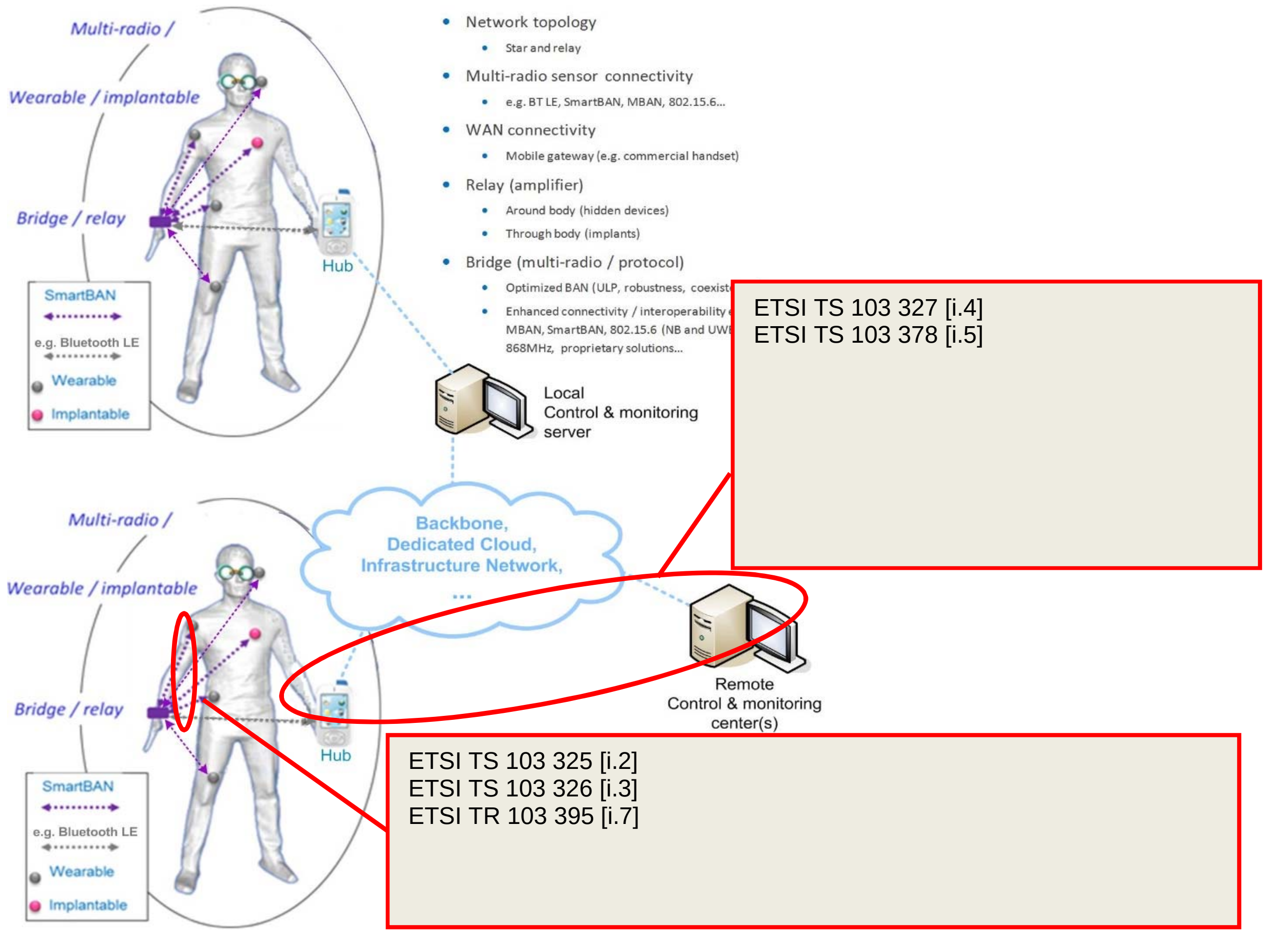

Figure 3: Future SmartBAN

2 References

2.1 Normative references

Normative references are not applicable in the present document.

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 referenced 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] IEEE Std. 802.15.6™-2012: "IEEE Standard for Local and metropolitan area networks - Part 15.6: Wireless Body Area Networks".

[i.2] ETSI TS 103 325 (V1.1.1) (04-2015): "Smart Body Area Network (SmartBAN);Low Complexity Medium Access Control (MAC) for SmartBAN".

[i.3] ETSI TS 103 326 (V1.1.1) (04-2015): "Smart Body Area Network (SmartBAN);Enhanced Ultra-Low Power Physical Layer".

[i.4] ETSI TS 103 327: "Smart Body Area Networks (SmartBAN); Service and application standardized enablers and interfaces, APIs and infrastructure for interoperability management".

[i.5] ETSI TS 103 378 (V1.1.1) (12-2015): "Smart Body Area Networks (SmartBAN) Unified data representation formats, semantic and open data model".

[i.6] ETSI TS 103 378 (V1.2.1): "Smart Body Area Networks (SmartBAN) Unified data representation formats, semantic and open data model".

[i.7] ETSI TR 103 395: "Smart Body Area Network (SmartBan); Measurements and modelling of SmartBAN Radio Frequency (RF) environment".

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:

*	Mathematical multiplication of the term immediately preceding the symbol and the term
D	Delay
$\oplus$	eXclusive OR (XOR)

3.3 Abbreviations

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

BAN	Body Area Network
BCH Code	Bose- Chaudhuri- Hocquenghem Code
BTLE	BlueTooth Low Energy
Dch	Data Channel
ECG	ElectroCardioGram
FCS	Frame Check Sequence
FEC	Forward Error Correction
IoT	Internet of Things
ISM	Industrial, Scientific and Medical
MAC	Medium Access Control
O&M	Observations and Measurements
OntoSensor	OntoSensor sensor ontology
OWL DL	Web Ontology Language Description Logic
OWL	Web Ontology Language
PHY	Physical Layer
PSDU	Physical Layer Service Data Unit
QoS	Quality of Service
RF	Radio Frequency
SensorML	Sensor Model Language
SSN	Semantic Sensor Network
SWSSN	Web-based Semantic Sensor
UWB	Ultra Wide Band
WSN	Wireless Sensor Network
WSSN	Wireless Semantic Sensor Network

4 Introduction and Background

Modern medical and health monitoring equipment are moving towards the trend of wireless connectivity between the data collection or control centre and the medical devices or sensors. Therefore, the need for a standardized communication interface and protocol between the actors are required. This network of actors performing some medical monitoring or functions is called a Smart Body Area Network (SmartBAN).

BAN uses small sensing devices and will need to meet the following technical requirements.

1) Very high energy efficiency:
BAN sensing nodes needs to be small and have batteries capable of providing sufficient power without charging.

2) Co-existence between other BANs or systems:
One of the possible channels for BAN is the Industrial, Scientific, and Medical (ISM) band which is used by wireless LANs and other systems. Additionally, BANs are moving with each other as the BAN users are moving. BAN is required to co-exist with other systems and neighbouring BANs.

3) Optimum control of QoS:
The sensing data has various transmission rates, allowable delay and allowable packets error rate. BAN should facilitate the transfer of these various sensing data with optimum QoS. Additionally, for medical care, minimizing the latency of emergency signals is also important.

4) Timely Access mechanism:
Node needs to connect to an intended hub within a short time.

In the present document, the system level description of SmartBAN is given. It also contains possible use cases for SmartBANs.

5 Comparisons with Other Related Standards

Table 1

Parameter		**SmartBAN concept**	**BTLE**	**IEEE 802.15.6™ [i.1]**
General system specs	System Architecture	Hub + smart relay coordination	One hub	One hub
	Networking communication interoperability (SmartBAN and non-SmartBAN nodes)	Yes	No	No
	Smart relay	Yes	No	No
PHY/MAC	FEC (forward error correction)	Yes	No	Yes
	Initial set up time	Fast	Less fast	Less fast
	Spread spectrum hopping	No	Yes	Yes (in limited cases)
	Channel reassignment	Yes	No	Multiple channel
	Very low latency emerging messaging	Very fast (timeslot)	No	Medium (superframe)
	Reutilization of scheduled unused time slots (efficiency parameter)	Yes	No	No
	Energy consumption/efficiency	Low (e.g. long sleep times)	Low	Medium
	Network complexity	Star concept + multi hub relay (planned)	Star concept	Star concept + relay
Smarts	Semantic approach, semantic interoperability, heterogeneity management, IoT compliance	Yes	No	No
	Additional semantic and data analytic enablers (e.g. semantic discovery, reasoning/rules)	Yes	No	No
	Automatic node discovery (e.g. semantic discovery of nodes, composition)	Yes	Partially	No
	Coexistence management by coordinator	High	Low	Low

6 Use Cases

6.0 Introduction

A number of use cases have been identified as potential scenarios for SmartBAN in this clause. These use cases serve as examples of scenarios from which the requirements are derived.

6.1 Safety Monitoring

Table 2

<table>
<tr><td>Category</td><td>Healthcare</td><td>Elderly care</td><td></td><td></td><td></td></tr>
<tr><td>Situations</td><td>Home</td><td>Outdoors</td><td></td><td></td><td></td></tr>
<tr><td colspan="6">Example of Use case</td></tr>
<tr><td colspan="6">Attaching patch-type sensors on an elderly adult body, an alert signal and his/her pulse data are transmitted to the data server when he/she feels physically sick. These data and signal are also reported to care workers immediately.</td></tr>
<tr><td colspan="2">Necessity of accurate time stamping on the sensor data</td><td>Yes</td><td></td><td></td><td></td></tr>
</table>

Sensors	Sampling rate/ quantization	Bit rate	Communication distance	# of Nodes	Real time/ Non real time
pulse wave or ECG	10 - 16 bit, 64 Hz - 1 kHz	640 bps - 16 kbps	up to 1,5 m	1	Real time
Accelerometer (body motion, posture)	10 - 16 bit, 64 Hz - 1 kHz	640 bps - 16 kbps	up to 1,5 m	1	Real time

6.2 Fall Monitoring

Table 3

Category	Healthcare	Elderly care	Fitness		
Situations	Home	Outdoors			
Example of Use case					
Attaching patch-type sensors on an elderly adult body, an alert signal is transmitted to the data server when detecting his/her falling. This signal is in parallel transmitted to care workers immediately.					
Necessity of accurate time stamping on the sensor data		Yes			
Sensors	**Sampling rate/ quantization**	**Bit rate**	**Communication distance**	**# of Nodes**	**Real time/ Non real time**
Accelerometer/gyroscopic all-in-one sensor (multiple number of sensors are attached on a body)	10 - 16 bit, 500 Hz - 1 kHz	5 kbps - 16 kbps	up to 1,5 m	1 to 3	Real time, Near real time

6.3 Stress Monitoring

Table 4

Category	Healthcare				
Situations	Home	Outdoors	Office		
Example of Use case					
Logging daily physical and emotional stress and use the data for health management.					
Necessity of accurate time stamping on the sensor data		Yes			
Sensors	**Sampling rate/ quantization**	**Bit rate**	**Communication distance**	**# of Nodes**	**Real time/ Non real time**
pulse wave or ECG	10 - 16 bit, 64 Hz - 1 kHz	640 bps - 16 kbps	up to 1,5 m	1	Non real time

6.4 Sleep Monitoring

Table 5

Category	Healthcare	Medical			
Situations	Home	Hospital			
Example of Use case					
Checking asleep conditions and use the data for people's need for better sleep. The data is utilized for insomnia treatment.					
Necessity of accurate time stamping on the sensor data		Yes			
Sensors	**Sampling rate/ quantization**	**Bit rate**	**Communication distance**	**# of Nodes**	**Real time/ Non real time**
Pulse wave or ECG	10 - 16 bit, 64 Hz - 1 kHz	640 bps - 16 kbps	up to 1,5 m	1	Non real time
Accelerometer (body motion, posture)	10 - 16 bit, 64 Hz - 1 kHz	640 bps - 16 kbps	up to 1,5 m	1	Non real time

6.5 Blood Pressure Fluctuation Monitoring

Table 6

Category	Medical				
Situations	Home	Hospital			
Example of Use case					
Monitoring blood pressure fluctuation. It is assisted in diagnosis of high blood-pressure.					
Necessity of accurate time stamping on the sensor data		Yes			
Sensors	**Sampling rate/ quantization**	**Bit rate**	**Communication distance**	**# of Nodes**	**Real time/ Non real time**
ECG	10 - 16 bit, 64 Hz - 1 kHz	640 bps - 16 kbps	up to 1,5 m	1	Real time
Pulse	10 - 16 bit, 64 Hz - 1 kHz	640 bps - 16 kbps	up to 1,5 m	1	Real time

6.6 Abnormal Cardiac Rhythm Monitoring

Table 7

Category	Medical				
Situations	Home	Outdoors	Office	Hospital	
Example of Use case					
Attaching a long time (24 hour) applicable sensor on a person who has heart disease, arrhythmia is detected.					
Necessity of accurate time stamping on the sensor data		Yes			
Sensors	**Sampling rate /quantization**	**Bit rate**	**Communication distance**	**# of Nodes**	**Real time/ Non real time**
ECG	10 - 16 bit, 64 Hz - 1 kHz	640 bps - 16 kbps	up to 1,5 m	1	Real time
Pulse	10 - 16 bit, 64 Hz - 1 kHz	640 bps - 16 kbps	up to 1,5 m	1	Real time
Accelerometer /gyroscopic sensor	10 - 16 bit, 64 Hz - 1 kHz	640 bps - 16 kbps	up to 1,5 m	1	Real time

6.7 Apnea Monitoring

Table 8

Category	Medical				
Situations	Home	Hospital			
Example of Use case					
Attaching patch-type sensors on a person with a sleep problem, it is detected a symptom of apnea and treated.					
Necessity of accurate time stamping on the sensor data		Yes/No			
Sensors	**Sampling rate/ quantization**	**Bit rate**	**Communication distance**	**# of Nodes**	**Real time/ Non real time**
ECG	10 - 16 bit, 64 Hz - 1 kHz	640 bps - 16 kbps	up to 1,5 m	1	Non real time
Accelerometer/ gyroscopic sensor	10 - 16 bit, 64 Hz - 1 kHz	640 bps - 16 kbps	up to 1,5 m	1	Non real time

6.8 Sports Monitoring

Table 9

Situations	Outdoors				
Example of Use case					
Measuring amount of activity and estimating calories burned up during sports. Checking pitching form and avoid dropping into a bad habit.					
Necessity of accurate time stamping on the sensor data		Yes			
Sensors	**Sampling rate/ aquantization**	**Bit rate**	**Communication distance**	**# of Nodes**	**Real time/ Non real time**
pulse wave or ECG	10 - 16 bit, 64 Hz - 1 kHz	640 bps - 16 kbps	up to 1,5 m	1	Real time
Accelerator (body motion, posture)	10 - 16 bit, 64 Hz - 1 kHz	640 bps - 16 kbps	up to 1,5 m	1 to 6	Real time

7 Overview of PHY/MAC

7.1 System Parameters

The technical requirements for SmartBAN PHY parameters are listed as below.

Table 10

Parameter	SmartBAN Requirements
Coexistence/robustness	Good (low interference to other systems, high tolerance to interference)
Data rates	Nominally 1 kbps to 100 kbps (vital sign monitoring), up to 1 Mbps
Transmission rate (PHY)	Up to 1 Mbps
Network topology	Star network+ optionally relay and mesh are envisioned
Power consumption (node)	To be defined
Channel reassignment	Yes
FEC	BCH (127,113,t=2), repetitions (2,4)
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	< 2 m inside single BAN
Latency	10 ms (real-time, high priority transmissions), approx. 100 ms regular traffic
Security/privacy	3-level: 1) unsecured; 2) authentication; 3) authentication and encryption, To be defined.

7.2 PHY/MAC Layer Structure

Figure 4 shows the PHY and MAC layer structure. A MAC frame consists of MAC header, MAC body and FCS. In PHY layer, the MAC frame is fragmented into 1 143 bit sequences and each sequence is encoded by (127,113) BCH code and these BCH codewords form a PSDU having the length of L_{PSDU}. Adding a 16 bit preamble and a 37 bit PHY header to the PSDU, a PHY frame is generated.

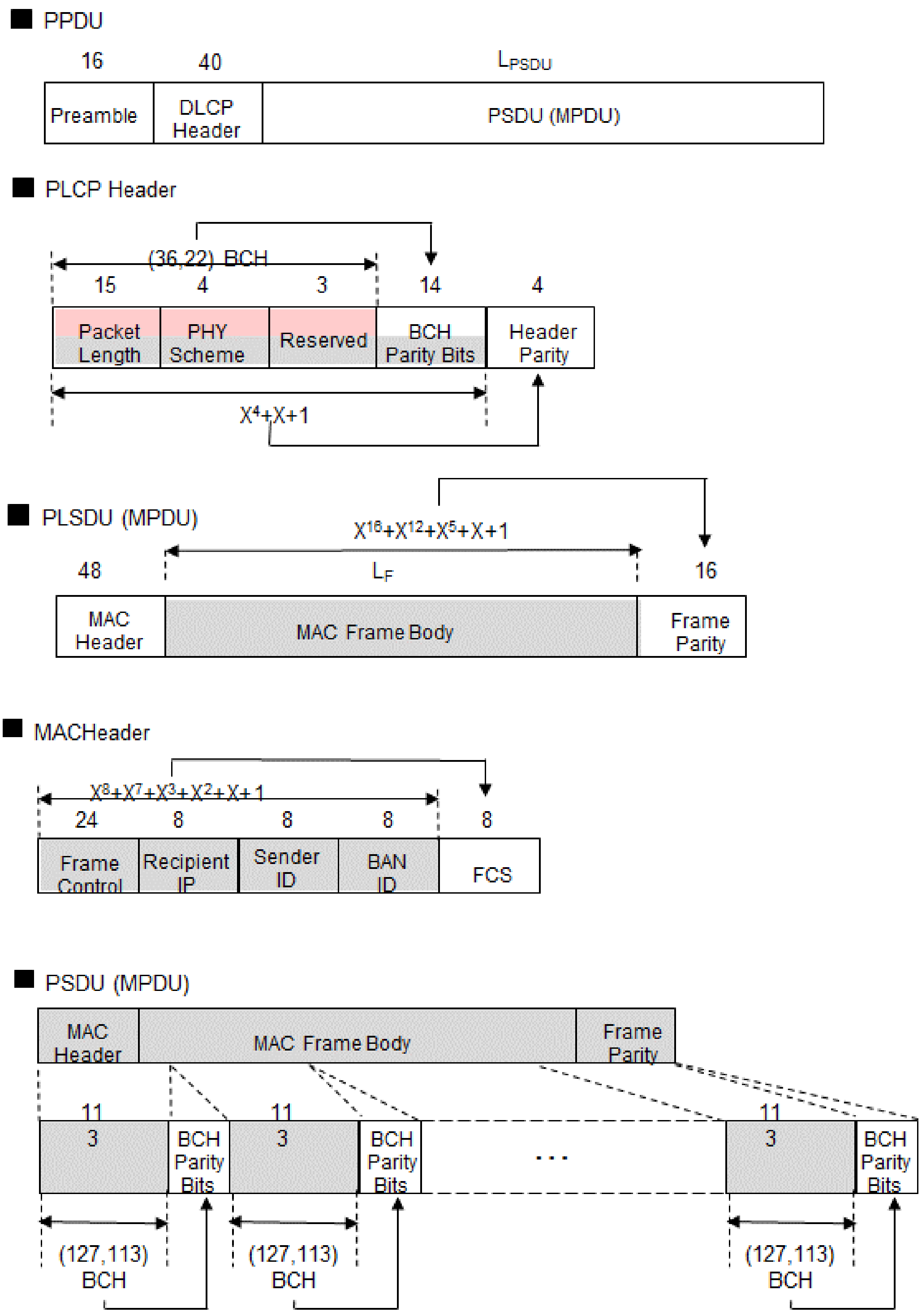

Figure 4: PHY/MAC Layer Structure

7.3 Example of PHY/MAC Parameters

A typical examples of PHY/MAC parameters are listed below.

Table 11

Parameter	SmartBAN Requirements	Example values
Dch Structure	Beacon interval [ms]	100,00
	Beacon length [ms]	0,45
	Scheduled period length [ms]	80,00
	Control/Management period length [ms]	10,00
	Inactive period length [ms]	9,55
Dch Beacon	Beacon data size [bits]	224
	PHY symbol rate [kbps]	500
	PHY mod [bit/sym]	1
	PHY data rate [kbps]	1
Scheduled Access period	Uplink period ratio [%]	90
	Uplink period length [ms]	72
	Uplink period length/Beacon interval [%]	72
	PHY symbol rate [kbps]	1 000
	PHY mod [bit/sym]	1
	FEC rate	0,89
	PHY data rate [kbps]	890
	Transmittable data bits during uplink period [bits]	64 080

8 Interoperability and Heterogeneity Management

8.0 Introduction

BANs are made of a growing number of small sensing devices and are used in multiple use cases for which data procurement, collection, monitoring and control are mandatory. Generally domain dedicated, those devices are provided by an increasing number of manufacturers, which leads to interoperability problems (e.g. heterogeneous interfaces and/or grounding, heterogeneous descriptions, profiles, models, etc.). Interoperability management is thus a SmartBAN key requirement and should be handled. Furthermore, data provided by these BANs are very heterogeneous because they are coming from sensing/actuating nodes with various abilities (e.g. different sensing ranges, formats, coding schemes, etc.). This entails managing data level heterogeneity. Therefore, data heterogeneity management is another SmartBAN key requirement that should also be handled.

For handling BAN interoperability management, the design of a BAN-dedicated open and extensible framework, provided with standardized APIs, for generic interactions with BAN devices (or nodes) and corresponding data/information, becomes mandatory. This kind of open middleware/framework will enable vertical interoperability within a given application domain, such as e.g. well-being, m-health, tele-health, safety/emergency, entertainment, etc. It will also ease the cross domain interworking of in particular devices, which represents a first step towards the horizontal management of BAN multiple vertical application domains. Finally, the SmartBAN open framework should also be provided with interworking components (entities, APIs or gateways) for allowing interactions with non SmartBAN enabled environments. Interoperability of multiple and new BAN technologies not only implies a generic interconnection between BANs components (sensors, actuators, relays, concentrators and hubs) but also a shared and mutual understanding of BAN devices and environment description, as well as of exchanged data format (syntactic and structural interoperability among frameworks). This is manageable through the use of a common and standardized metadata description format. All the aforementioned issues will be handled within ETSI TS 103 327 [i.4].

For handling data heterogeneity, the solution consists of the formalization and the specification of a shared semantic for SmartBANs, expressed within a common open data model and provided with the associated ontology. This open data model and ontology will provide the required generic description for BAN entities and corresponding data (including monitoring and control ones). This data model, should be in particular designed for handling any kind of BAN devices and measured data (which is still not the case of existing WSNs data models). The SmartBAN data model should also be sufficiently semantically rich for e.g. allowing similarity detection and conflict resolution. But this semantic enrichment of the SmartBAN data model should not be done at the expense of the mandatory low complexity constraint of SmartBANs (i.e. right balance should be found between semantic richness and complexity). This then made also compulsory the design of a modular data model and ontology for SmartBANs. Furthermore, if SmartBAN automated monitoring and control functionalities want to be enabled, as well as if the design of new SmartBAN services and applications wants to be eased, service level data model should be addressed and added to the SmartBAN open data model and associated ontology.

The SmartBAN service ontology will in particular brings BAN devices and associated services discovery and composition functionalities, as well as their reusability at application level. It will also ease the BAN measuring data fusion.

Finally, if the SmartBAN service level semantic data model is designed by addressing semantic interoperability, then it will also provide a solution for SmartBAN application interoperability and will guarantee common expectations for BAN Devices/data accesses. All the aforementioned issues will be handled within ETSI TS 103 378 [i.5], except the SmartBAN service level data model and ontology specification and formalization that will be covered in a revision to be published as V.1.2.1 [i.6].

Figure 5 summarizes SmartBAN interoperability/heterogeneity management constraints. However, the following reminder should be made: BAN interoperability and heterogeneity management have to be handled by taking into account the other strong constraints already pointed out in the present documents (see clause 5 of ETSI TS 103 378 [i.5]) and in particular low complexity, ultra-low power and dynamicity (e.g. node mobility, topology changes).

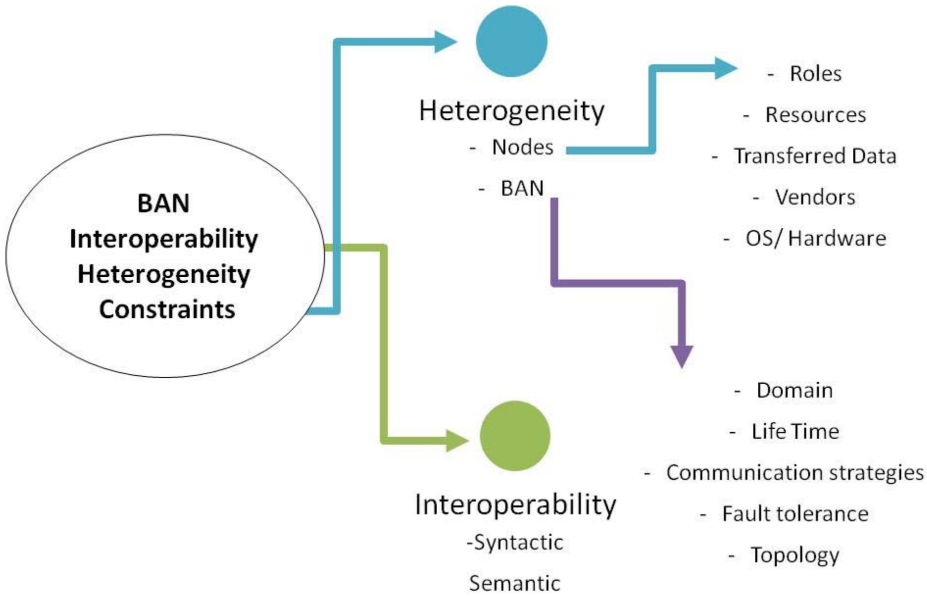

Figure 5: SmartBAN interoperability/heterogeneity management constraints

8.1 Heterogeneity management

As already introduced in clause 8.0, SmartBAN data are very heterogeneous and this entails managing data level heterogeneity. For handling this heterogeneity, the SmartBAN retained solution consists of the formalization and the specification of BAN dedicated shared semantic, expressed within a common semantic open data model and provided with the associated ontology. In order to take into account the BAN low complexity strong requirement, the SmartBAN semantic data model should be designed as a modular model where some classes could be implemented in the sensor/actuator nodes depending on its resource's availability, and some other could be implemented and processed in more capable nodes like e.g. the hub. For that reason, its ontology is divided into three main parts [i.5]: BAN, Nodes (i.e. hub, relays, sensors, and actuators), and Process (Process and Measurement). The SmartBAN semantic open data model and ontology is fully described in ETSI TS 103 378 [i.5]. Table 12 compares, in a non-exhaustive way, the SmartBAN ontology with mostly used WSN ontologies.

Table 12: Non-exhaustive comparison of SmartBAN ontology and mostly used WSN ontologies

	SmartBAN ontology (*non exhaustive list*)	**SensorML/ O&M**	**OntoSensor**	**SSN**	**WSSN**	**SWSSN**
Semantic Annotation	Semantic Language	-	OWL DL	OWL DL	OWL DL	OWL DL
	Semantic Rules	-	-	-	-	-
WSN/WBAN Service Model	Yes	-	-	-	-	-
WSN/WBAN	Location/Topology/Application Domain	Yes	-	-	-	-
	Contact	Yes	Yes	-	-	-
Sensor/Nodes	Physical	Yes	Yes	Yes	-	Yes
	Link/Geo-location	Yes	Yes	Yes	Yes	Yes
	Identity & Manufacturing	Yes	Yes	Yes	Yes	Yes
	Memory Components	-	Yes	Yes	Yes	Yes
	Energy Source	-	-	-		Yes
	State	-	-	-	Yes	-
	Interfaces	Yes		-	-	-
	Trust Level	-	-	-	-	-
Observation	Inputs/Outputs	Yes	Yes	Yes	Yes	Yes
	Feature of Interest	Yes	Yes	Yes	Yes	Yes
	Accuracy	Yes	Yes	Yes	Yes	-
	Frequency	Yes	Yes	Yes	Yes	-
	Response Model	Yes	Yes	Yes	Yes	Yes
	Unit of Measurement	Yes	Yes	-	-	Yes
	Communication Process		-	-	-	Yes
Data	Data Type	Yes	-	-	-	Yes
	Acquisition Policy	-	Yes	Yes	Yes	Yes
	Data Quality	-	-	-		-
	Data State	-	-	-	Yes	-
Others	Routing/Fault Management	-	-	-		-
	Validity	Yes	Yes	-	Yes	-
	Legal/Security	Yes	Yes	-	Yes	-
	Compression	-	-	-	-	-

8.2 Interoperability management

As already introduced in clause 8.0, an important issue to be considered for SmartBANs is their heterogeneity in terms of node models and profiles, data gathered (e.g. sensing ranges, formats, coding schemes and metadata), communication protocols and/or grounding, and applications. Within the same BAN, each node, which could also be coming from different manufacturers, could offer different processing functionalities and could require different resources depending, in particular, on its role (node, actuator or sink). This leads to interoperability problems. For managing this interoperability, the SmartBAN retained solution consists of the design and the specification of a BAN-dedicated open and extensible framework, provided with standardized APIs, for generic interactions with BANs' devices (or Nodes) and for generic sharing and management of corresponding data/information. The design choices that have been retained for this SmartBAN open framework (see ETSI TS 103 327 [i.4]) is to rely on a distributed multi agent based IoT architecture. The SmartBAN open and extensible framework and corresponding generic APIs are fully described in ETSI TS 103 327 [i.4]. Its High Level Architecture is summarized in figure 6.

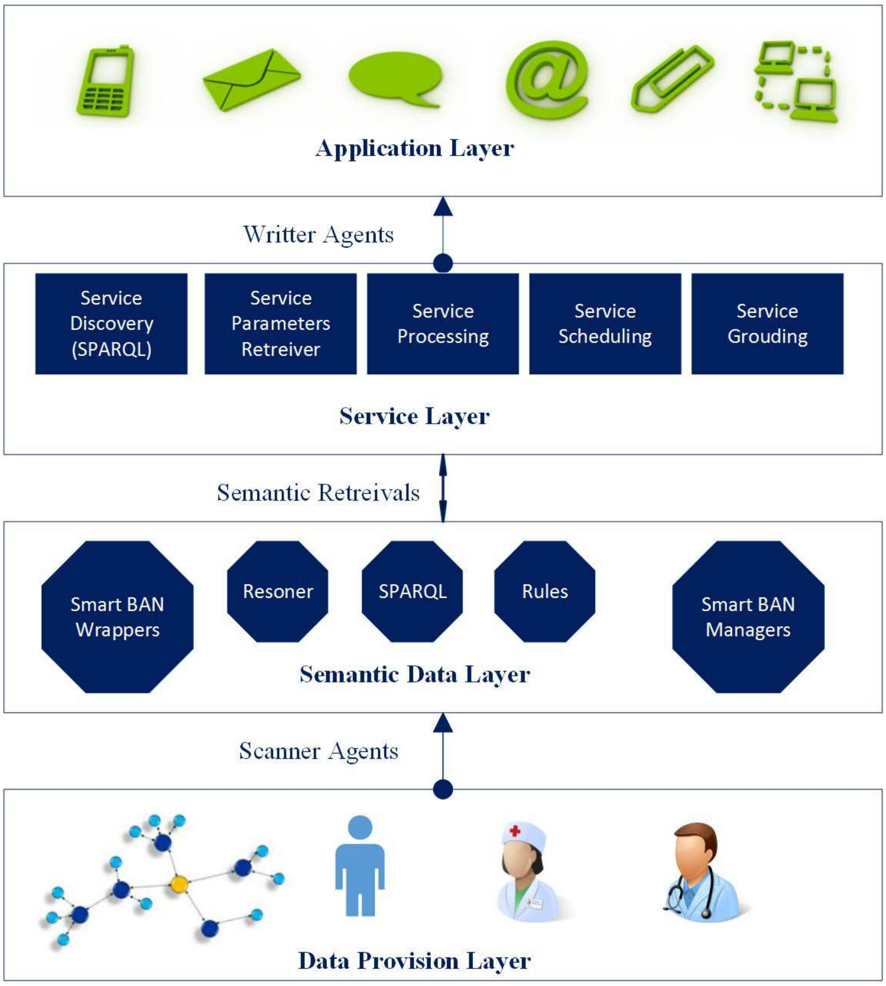

Figure 6: SmartBAN open framework High Level Architecture

As shown in figure 6, ETSI SmartBAN architecture comprises 4 layers: Data Provision, Semantic Data, Service and Application. Each of those layers provides a set of both agents and generic feature modules that offers a cohesive set of services. Figure 6 also shows that ETSI SmartBAN architecture model is fully relying on SmartBAN semantic data/service models and corresponding ontologies specified in ETSI TS 103 378 [i.5] and is also addressing semantic interoperability.

9 Radio Frequency (RF) measurement and modelling

The RF measurement and modelling specify the state-of-the-art and the future investigations on coexistence for allowing smart body area network (SmartBAN) devices to properly work and co-operate in the Industrial, Scientific and Medical (ISM) band. Interference appears to be one of the major threats as well as coexistence with other existing systems radiating in the same portion of the frequency spectrum. ETSI TR 103 395 [i.7] describes the experimental measurements and coexistence analysis done in Finland and Italy in order to specify the requirements for the SmartBAN compatible devices. In particular, a stochastic mathematical model of the interference based on real measurements in hospitals is proposed, as well as a complete simulator for proving the performance of SmartBAN devices, including physical and MAC layer.

Annex A: Throughput Requirements

A.1 Downlink Throughput Requirements

The downlink throughput requirements are for further study.

A.2 Uplink Throughput Requirements

The uplink throughput requirements is listed as follows:

Table A.1: Uplink Throughput Requirements

Application	Sampling Rate (kHz)	Data Rate (kbps)	Communication Distance (mm)
ECG	1	16	1 500
Temperature	0,001	0,1	1 500
Accelerometer	1	96	1 500
SpO2	1	16	1 500

History

Document history		
V1.1.1	January 2018	Publication