Dependability Evaluation of WBAN-based Home Healthcare Systems using Stochastic Activity Networks

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***Abstract*—Wireless Body Area Networks (WBANs) have emerged as a great technological alternative for medical applications that require continuous monitoring of vital signs in patients with diseases of low progression and long duration. One of the most challenging problems in this kind of applications is related to preserve dependability attributes (reliability and availability), since a failure in the system might cause false alarms, alterations in medical diagnosis and, in a worst case, dead of patient. The absence of methodologies for evaluating and predicting correct system operation during design stage is common when developing this kind of devices. In this paper a Stochastic Activity Network (SAN) methodology is proposed, in order to assess dependability of a wireless equipment aimed to support vital signs monitoring for patients who meet the conditions for home healthcare. In SAN models the failures associated to hardware and wireless protocol communication were considered, for the purpose of estimating availability and reliability for typical operational scenarios. The results obtained allow system designers to identify dependability bottlenecks on which concentrate to reduce risks and threats to this fundamental system property.**

Keywords: *WBAN, Dependability, Reliability, Availability and Stochastic Activity Networks*

I. Introduction

The particular characteristics of Wireless Body Area Networks (WBANs) have consolidated this technology as a great alternative for improving life conditions of chronic disease patients, by providing support for continuous and remote monitoring of physiological variables without limiting their normal activities. WBANs are based on small, low power sensors located in or on the human body, that have the capability to collect, store, process, and transmit medical information that can be used to trigger first aid assistance, and to detect emergency situations [1]. Despite these advantages, there are still several system attributes that represent a challenge in WBANs, namely those related to dependability. Issues such as node failure, body shadowing, environmental interference, fault network propagation, quality of hardware and software design [2], need to be further developed in order to guarantee dependable nodes for medical applications. According to Avizienis et al. [3], reliability, safety, integrity, availability and maintainability are five attributes that gathered together describe dependability, defined as the ability to avoid more frequent and more severe system failures. All attributes associated with dependability are important in a general evaluation of any system. However, this research was focused on reliability and availability modeling and assessment, considering the requirements of medical devices used in home healthcare scenarios, where it is necessary to have trustworthy and reliable equipment, i.e. capable to finish the task entrusted, without experiencing a failure (reliability), and available to provide a correct service when it is required (availability). Despite the importance of evaluating this attributes during design stage, there are few papers that deal with the evaluation of dependability of WBAN related to sensor nodes hardware, communication protocol, and the effectiveness of use of the techniques proposed to overcome the threats to availability and reliability.

Designing dependable systems is not an easy task, partly due to the great difficulty to evaluate the effectiveness of different design options, taking into account the complexity and high cost of implementing prototypes to evaluate reliability and availability with high accuracy. Several methods like *fault rate models*, *reliability graphs*, *fault trees*, *Markov chains* and *Petri Nets* have been used to evaluate dependability of computing and communication systems [4]. However, they suffer from the fact that the system to be modeled must be described at the state level, and the number of states that must be considered can be huge [5]. Stochastic Activity Networks (SANs) are a modeling formalism widely used to assess performance, dependability and performability in complex computation systems, with an acceptable accuracy [6]. SANs are Petri nets extensions based on directed graphs, that provide the necessary tools to specify high-level atomic

models, reducing the complexity to specify thousand of states and their interaction, using graphics primitives. Taking advantage of the benefits of SANs, in this research they were used to assess the attributes of reliability and availability of a wireless sensor nodes aimed to support physiological signs monitoring in home healthcare scenarios.

The rest of the article is divided as follows: section II presents an overview of related work on identification of reliability and availability threats in WBANs, as well as the techniques commonly used to evaluate these dependability attributes. Section III includes a detailed description of the wireless sensor node architecture. Section IV contains the description of the SAN model of the sensor node. Section V shows the experimental results of the reliability and availability evaluation. Finally, section VI presents conclusions and future research.

II. Related Works

Threats to dependability are a major challenge in WBANs for medical scenarios, considering the characteristics of this kind of applications, that collect, store, and transmit patient's vital and extremely confidential information. In this way, the evaluation of reliability and availability are fundamental non-functional requirements to be considered during design stage in order to guarantee the effective insertion of WBAN in home healthcare monitoring scenarios. In this sense, the authors in [2] have identified the potential causes of failure on a WBAN. Issues like unreliable hardware, limited or power loss, environmental interference, and network failure are addressed. They propose several schemes aimed to increase the dependability (related to reliability, availability and security attributes), being the inclusion of redundant nodes the recommended solution. However, this option implies an increase in cost while reducing the ergonomics and mobility of the user. In the same work, reliability assessment in the design stage is not addressed by the authors. In [7], the authors propose a methodology for reliability assessment on a wireless sensor node, based on an automatic generation of fault trees, when permanent faults occur on network devices. This proposal supports any topology, different levels of redundancy, network reconfigurations, criticality of devices, and arbitrary failure conditions, allowing to optimize in design stage parameters that could affect reliability and availability requirements. It was tested in typical industrial scenarios, and the results obtained show that is possible to identify dependability bottlenecks. Another approach to evaluate reliability is reported in [8], where the authors besides identifying threats to reliability and availability of Wireless Sensor Networks (WSNs), also propose a flexible framework for dependability evaluation and analysis using Stochastic Activity Networks (SAN). The classification of potential hazards and risks is performed using a Failure Mode and Effect Analysis (FMEA) for a WBAN in order to obtain the failure model of a single sensor node. It is noteworthy the use of external libraries in the SAN model, that allows to modify the failure behaviour at execution time according to network dynamics. However, the results lack of schemes or means that increase the values of reliability and availability. SAN formalism has been used to evaluate reliability and availability in different areas. The authors in [9] evaluate the failure probability of systems implemented on SRAM-FPGA technology. The results obtained with the SAN model allow to predict the probability of failures according to the maximum number of faults that can be injected, and the input signal probability of data signals. SAN modeling was also used to estimate the reliability of a Controller Area Network (CAN)-based system [10], whose results allow to quantify the reliability achievable by highly-reliable CAN-based systems that rely on a replicated bus topology. The authors were able to compare the reliability attainable by a replicated CAN bus with the one what would be achieved by a simplex CAN bus, and a replicated CAN star. In [11] the authors assess the operational reliability of an aircraft before and during a fly mission, using a SAN constructed from a meta-model that describes, at a high level, the behaviour of the mission. The SAN model considers real operation conditions after component failures in order to support aircraft maintenance planning. The results provide the schedule of repairs taking into account some optimization criteria: cost, remaining useful life and operational risks, according to reliability values after several missions.

III. WBAN Node Description

The system called *HealTICa* is composed of a couple of wireless sensor nodes located on the patient's body, in order to acquire physiological variables of interest such as heart beat rate, oxygen saturation, body temperature, blood sugar levels, as well as the electrocardiographic (ECG) signal. These variables are wirelessly transmitted to a sink node, in this case a smartphone, that features a dongle that integrates wireless transceiver and serial communication circuits, also allowing to store and visualize medical variables, while providing the functionality of triggering alerts in emergency situations, originated by algorithms that analyse medical information, or requested by the user using the panic button provided in the mobile application. Figure 1 shows the system architecture, highlighting the *HealTICa node* (ECG-PPG sensor node), responsible of acquiring, processing and transmitting the referred variables, except the blood sugar level, which is collected by another wireless glucometer. The HealTICa node is formed by an analog front-end for ECG signal acquisition, an infrared (IR) sensor for measuring the patient's body temperature, and a pulse oximeter sensor that calculates heart beat rate and oxygen saturation (SpO_2) values from a photoplethysmogram (PPG) sensor. All sensors are orchestrated by a low energy consumption microcontroller, responsible of executing data acquisition and processing algorithms, as well as communicating to the transceiver, that is configured according to the standard for low-rate wireless Personal Area Networks (PAN), IEEE 802.15.4 with beacon enabled. The PAN is formed by a coordinator, in this case a smartphone (equipped with an IEEE

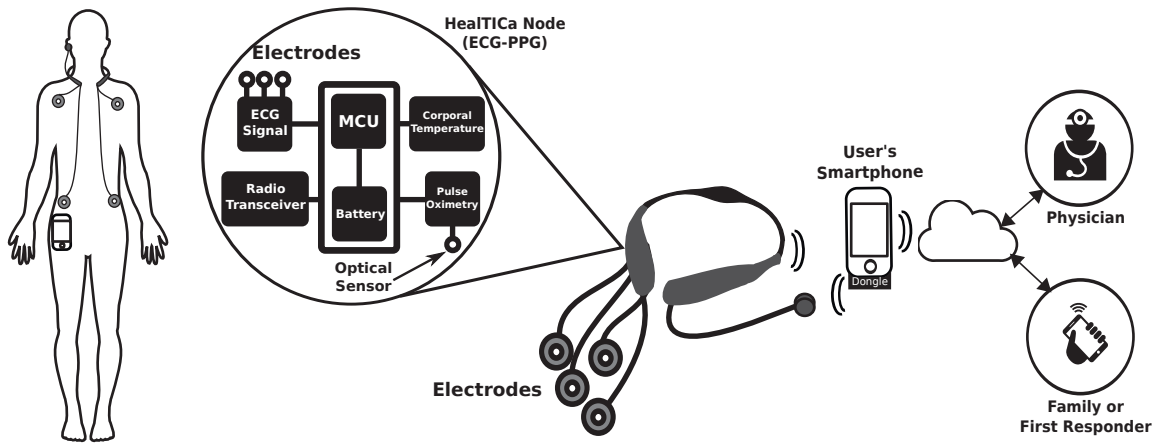

Fig. 1. Architecture and hardware block diagram of the HealTICa system

802.15.4 dongle), that is in charge of managing the whole network. The IEEE 802.15.4 MAC protocol is used in beacon enabled mode for saving energy [12]. The CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) algorithm is used in this protocol for channel access. Reliability of WBAN is affected by issues associated to this algorithm as reported in [13], [14] and [15]. A common solution to these issues consists in adjusting the standard parameters related to the maximum number of retransmissions (*macMaxFrameRetries*), and the number of backoff stages (*macMaxCSMABackoffs*) as it is intended in this work.

IV. Reliability and Availability Evaluation

In order to evaluate the reliability and availability of the HealTICa system, the Stochastic Activity Network modeling formalism is used. SAN is a probabilistic extension of Petri nets, and together with reduced base model construction techniques, has the potential to avoid the state space explosion for dependability evaluation of parallel and distributed complex systems [6]. The HealTICa system SAN model was created using the framework Möbius [16], which is an extensible dependability, security, and performance modeling environment for large-scale discrete-event systems. It provides multiple modeling formalisms and solution techniques, facilitating the representation of each part of a system, and providing different solution methods that allow the estimation of the system behaviour. Möbius offers the typical SAN graphical elements that allow to create high level models that are close to the actual stochastic behaviour of this kind of systems with a reduced number of states compared to those ones requiered for an analytic solution. SAN models include input gates, output gates, places, activities and arcs. Places, graphically represented by circles, can be seen as a state of the modeled system. Each place of a SAN contains a certain number of tokens, which represent the marking of that place.

Figure 2 shows the atomic SAN model of the HealTICa node hardware. In this model each place represents the status of hardware components. Places related to sensors are

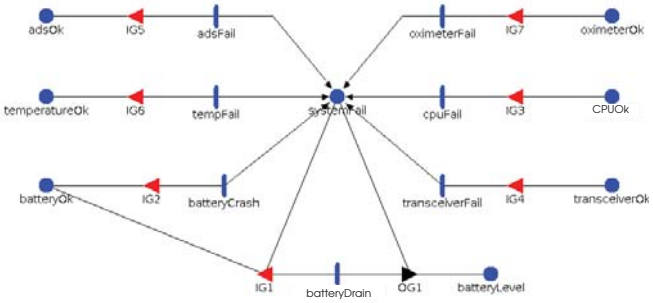

Fig. 2. Atomic SAN model for the HealTICa node hardware

adsOk (ECG signal sensor), *temperatureOk* (corporal temperature sensor), and *oximeterOk* (pulse oximeter sensor). There are also places related to the status of the microcontroller (*CPUOk*), communication transceiver (*transceiverOk*), and battery (*batteryOk*). If any of these places have only one token, this means that there have been no failures in those components. Evolution in time of the SAN model is governed by activities, input gates (IG) and output gates (OG). Activities (transitions in Petri net terminology) represent actions of the modeled system that could take some specified amount of time to complete. There are two types: timed and instantaneous activities. Timed activities have durations that affect the performance of the modeled system. Instantaneous activities represent actions that complete immediately when enabled in the system. In the HealTICa system SAN model presented in Figure 2, there are seven activities, graphically represented by thick vertical lines, associated with failures in each component of the node. Activation time follows an exponential distribution, which is associated with failure rates of hardware components reported by manufacturers. The *adsFail* activity represents the time between fails in the ECG sensor following an exponential distribution. This likewise occurs with the remaining *transceiverFail* (communication transceiver), *tempFail* (corporal temperature sensor),

TABLE I
ENABLING PREDICATES IN THE HEALTICA NODE HARDWARE SAN MODEL

Input gate	Enabling predicate	Input function
IG1	(systemFail->Mark()==0)&& (batteryOk->Mark()==1)	;
IG2	batteryOk->Mark()==1	batteryOk->Mark()=0;
IG3	(*CPUOk* ->Mark()==1) && (systemFail->Mark()==0)	*CPUOk* ->Mark()=0;
IG4	(transceiverOk->Mark()==1)&& (systemFail->Mark()==0)	transceiverOk->Mark()=0;
IG5	(adsOk->Mark()==1)&& (systemFail->Mark()==0)	adsOk->Mark()=0;
IG6	(temperatureOk->Mark()==1)&& (systemFail->Mark()==0)	temperatureOk->Mark()=0;
IG7	(oximeterOk->Mark()==1)&& (systemFail->Mark()==0)	oximeterOk->Mark()=0;

batteryCrash (Li-Ion battery), *oximeterFail* (pulse oximeter sensor), and *cpuFail* (microcontroller) activities. Activation of activities depends on boolean enabling predicates of input gates. An input gate is graphically represented in a SAN model by a triangle. If an input gate enabling predicate is true, its associated activity is activated, initiating its corresponding time distribution function. At the time an activity is completed, the input function of the corresponding input gate updates the marking of the network. In the HealTICa node SAN mode presented in Figure 2, when an activity is completed, one token is located in the *systemFail* place. If there is a token in this place, it represents a general fail of the system. The *systemFail* place is considered in the reward function for reliability and availability assessment. The marking of the network can be also updated by the output function of an output gate. Output gates, as input gates, are also graphically represented by triangles in a SAN model. When an activity terminates, the output function of the corresponding output gate updates the marking of the network. Table I presents the enabling predicates and input functions for each input gate of the HealTICa node SAN model illustrated in Figure 2. Meanwhile, Table II presents the output function for the output gate *OG1*. In both tables, the *Mark()* function returns the number of tokens of the corresponding place. The output function in *OG1* changes the marking of the *batteryLevel* place, reducing the number of tokens, according to the energy consumption per hour (*batteryDrain* activity) of the HealTICa node represented by the variable *TotalBatteryDrain*. When the level is less than 50 *mAh* (threshold from where there is a high probability of electronic components failure) a token is located in the *systemFail* place . The output function in Table II is compared with the marking in the *batteryLevel* place. If *batteryLevel* place is less than 50 *mAh*, the *systemFail* place receives a token indicating a failure in the system. This also occurs if a token is located in the *batteryCrash* place, that represents a critical battery failure.

The atomic model of the HealTICa system dedicated to

TABLE II
OUTPUT GATE IN THE HEALTICA NODE HARDWARE SAN MODEL

Gate	Output function

OG1	batteryLevel->Mark()=batteryLevel->Mark()-totalBatteryDrain;
	if (batteryLevel->Mark()<50){
	systemFail->Mark()=1;
	}

the wireless protocol communication is based on the standard IEEE 802.15.4 configured with the default parameters for the number of *backoff* stages (*MaxCSMABackoffs* = 4), and the maximum number of retransmissions when the ACK is not successfully received (*MaxFrameRetries* = 3), as it is modeled by the output function of the output gate *OG3*, and shown in Table IV. This model considers the CSMA/CA algorithm related to frame drops due to congestion. If the channel is busy, represented by the *chBusy* place in Figure 3, the Contention Window (*CW*) (number of *backoff* periods during which the channel must be sensed idle before accessing the channel) is re-initialized to $CW = 2$ i.e. the Clear Channel Assessment (CCA) is made twice, and the Number of Backoffs (*NB*) that represents the number of times the CSMA/CA algorithm was required to *backoff* while attempting to access the channel is incremented. If the maximum number of *backoffs* (*macMaxCSMABackoffs* = 4) is reached, the algorithm reports a failure, and a token is located in the *discardPacket* place, as it is shown in the *OG4* output function in Table IV. Otherwise, it goes back to the CCA. If the channel is sensed as idle, *CW* is decremented. The CCA is repeated if $CW \neq 0$. This ensures performing two CCA operations to prevent potential collisions of acknowledgement frames. If the channel is again sensed as idle, the node attempts to transmit until the number of *MaxFrameRetries* = 3 is reached, when the packet is dropped. The atomic model of the HealTICa system wireless communication protocol presented in Figure 3 considers a transmission rate represented by the *txPacket* activity. This activity fires if the *idleRadio* and *transceiverOk* places have at least one token. When a failure in the transceiver occurs, the token in the *transceiverOk* place is removed. The *waitACK* and *chBusy* places receive a token according to the probability of transition of the *txPacket*. Meanwhile, *txStatus* and *chStatus* activities correspond to a delay associated to the ACK before the process of retransmission, and the period of *backoff* in the CSMA/CA algorithm, respectively [17]. These cases in the activities represent the probability of failure in the Clear Channel Assessment (CCA), and the probability of successfull ACK reception. It is considered that a failure in the system occurs if the number of tokens in *discardPacket* place is greater than 40 data frames per hour. In this case, a token is located in the *systemFail* place. This value represents the maximum number of tolerable discarded packets in order to successfully reconstruct the ECG signal by the application installed in the smartphone. The output functions of output gates *OG3* and *OG4*, described in Table IV, check that the number of retransmisions *MaxFrameRetries* (number of tokens

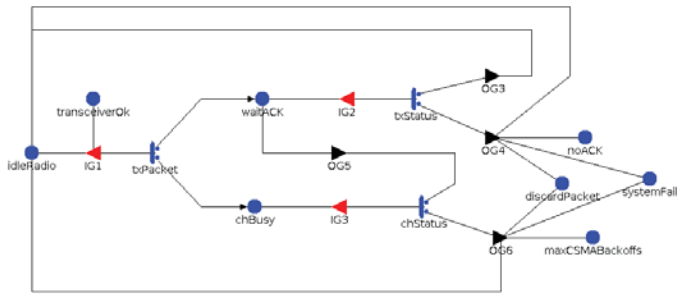

Fig. 3. Atomic SAN model for the HealTICa node wireless communication protocol

TABLE III
INPUT GATES DESCRIPTION FOR THE HEALTICA NODE WIRELESS COMMUNICATION SAN MODEL

Input gate	Enabling predicate	Input function
IG1	(transceiverOk->Mark()==1)&& (idleRadio->Mark()==1)&& (systemFail->Mark()==0)	idleRadio->Mark()=0;
IG2	(waitACK->Mark()==1)&& (systemFail->Mark()==0)	waitACK->Mark()=0;
IG3	(chBusy->Mark()==1)&& (systemFail->Mark()==0)	chBusy->Mark()=0;

in the *noACK* place) is less than 3, and the number of *macMaxCSMABackoffs*, that are represented by the number of tokens in the *macMaxCSMABackoffs* place, is less than 4. The *noACK* and *macMAxBackoff* places are incremented according to the evolution in time of the model. If the marking reaches the limit, the output gates *OG3* and *OG4* increment the number of tokens in the *discardPacket* place.

Atomic models can be replicated and joined together to form a complete, or composed, model, allowing to share global variables. The HealTICa system SAN composed model is formed by the atomic models presented in Figure 2 (sensor node hardware) and Figure 3 (wireless communication protocol), and it is not illustrated here for the sake of space.

TABLE IV
OUTPUT FUNCTIONS IN THE HEALTICA NODE WIRELESS COMMUNICATION SAN MODEL

Gate	Output function
OG1	waitACK->Mark()=1; maxCSMABackoffs->Mark()=0;
OG2	idleRadio->Mark()=1; noACK->Mark()=0;

OG3	noACK->Mark()++;
	waitACK->Mark()=1;
	if(noACK->Mark()>3){
	discardPacket->Mark()++;
	}

OG4	chBusy->Mark()=1;
	maxCSMABackoffs->Mark()++;
	if(maxCSMABackoffs->Mark()>4){
	discardPacket->Mark()++;
	}

V. EXPERIMENTAL SETUP AND RESULTS

Different scenarios were considered in order to test the HealTICa system SAN model, representing typical situations under which it can operate. These experiments aim to identify the impact of different factors on the HealTICa system reliability and availability attributes, according to each scenario. The HealTICa system SAN model was depicted and simulated to estimate its reliability and availability using the Möbius software tool [16], running on a Laptop with an Intel Core i5-3337U processor (1,80GHZ, 3MB cache), 4 GB RAM memory, and Ubuntu Linux 14.04 as operating system. Table V shows the constant global variables of the HealTICa system SAN composed model. ECG, oximeter and corporal temperature sensors failure rates are taken from datasheets published by manufacturers. Data trasmission rate (*txRate*) was established in 900 frames per hour, according to the number of data frames required to reconstruct and analyze the ECG signal.

TABLE V
CONSTANT GLOBAL VARIABLES IN THE HEALTICA SYSTEM SAN MODEL

Variable name	Value	Description
adsFailRate	$2{,}6\times10^{-10}$	ECG sensor failure rate
oximeterFailRate	$3{,}4\times10^{-6}$	Oximeter sensor failure rate
tempFailRate	$1{,}8\times10^{-6}$	Corporal temperature sensor failure rate
txRate	900	Data transmission rate (frames per hour)

The experimental setup and results for five different scenarios intended for HealTICa system SAN model reliability evaluation are presented as follows:

- *relCommTypical scenario*: This scenario is composed by typical values of congestion in the 2,4GHz band, in which IEEE 802.15.4 works. This band is shared with Wi-Fi, bluetooth, cordless phones and many other devices, making the sensor node susceptible to interferences generated by the mentioned technologies. This scenario recreates a current home environment where the HealTICa system can be deployed. The values of the variables associated with ACK reception (*receiveACKProb*) and channel congestion (*chBusyProb*) were consequently configured as shown in Table VI. Figure 4 shows an exponential decreasing of the reliability, associated to the loss of data frames. Although the impact is negligible for less than 100 hours, it is important to take into account these values in order to schedule preventive maintenance when the reliability values are close to 95%, that is after 900 hours of operation. For this scenario, the computation time for solving the HealTIC system SAN model was 1064 seconds, with a SAN state space of 7564 states.

- *relCommNoisy scenario*: The configuration of this experiment is similar to the previous one, adding

high interference, which is represented by a high probability of packet loss and low probability of channel access. Hence, the values of variables associated to congestion (*chBusyProb*) and packet loss probability (*receiveACKProb*) are shown in Table VI. This behaviour was experimentally verified when the nodes operate in environments with more than ten Wi-Fi hotspots. It is observed in Figure 4 that the drop on reliability associated to noisy environments is pronounced, reaching 90% of reliability after 1000 hours of system operation. These results suggest the implementation of techniques for reducing the packet loss such as changing the default parameters *MaxFrameRetries* and *macMaxCSMABackoffs*. For this scenario, computation time for solving the HealTICa system SAN model was 321 seconds, with a SAN state space of 182796 states.

- *relMCULow* and *RelMCUTypical scenarios*: Third and fourth scenarios contemplate different failure rates for commercial micro-controllers (*mcuFailRate*), as shown in Table VI. MCU is a key component of the sensor node, because its failure represents a severe system error. Manufacturers of MCUs offer a wide variety of devices according to the application requirements. Typical values of general purpose microcontrollers provided in manufacturers datasheets were used in these scenarios. From the experimental results is possible to identify MCU failure as the main issue that concerns reliability. Figure 4 shows a pronounced decrease in reliability after 500 hours of system operation when using MCU with short Mean Time Before Failure (MTBF) values (*relMCULow* scenario). This means six months of usage, with the system working eight hours a day. On the other hand, MCUs with large MTBF values (*relMCUTypical* scenario) yields to a very important reliability improvement, reaching 93% of reliability after 1000 hours of operation, as can be seen in Figure 4. In the *relMCULow* scenario, the computation time for solving the HealTICa system SAN model was 1055 seconds, while for *RelMCUTypical* scenario was 1108 seconds. For both scenarios the number of SAN states was 7564.

- *relBatteryTypical scenario*: This scenario consists of varying the value of reliability for commercial batteries, usually indicated in hours of operation. According to [18], batteries of Li-Ion have an average cycle of life of 40000 hours. The graph associated to this experiment in Figure 4 presents a smooth decline in reliability, reaching values greater than 92% after 1000 hours of system operation. In this sense it is important to consider battery preventive maintenance for life cycles near to 1000 hours. For purposes of evaluating a most severe scenario, a battery with a life cycle of 20000 hours were considered. The results are not shown in Figure 4 because its time response is very close to the scenario with a low reliable MCU (*relMCULow*), i.e. reliability values are lower than 90% after 850 hours of operation. Hence, reliable batteries are a major requirement to take into account in this kind of applications. The computation time of the HealTICa system SAN model for this scenario was 1059 seconds, with 7564 SAN states.

TABLE VI
VALUES OF EXPERIMENTAL SETUP FOR RELIABILITY EVALUATION IN DIFFERENT SCENARIOS

Experimental scenario	Variable	Value
relCommTypical	receiveACKProb	0,95
	chBusyProb	0,05
relCommNoisy	receiveACKProb	0,85
	chBusyProb	0,15
relMCUTypical	mcuFailRate	1×10^{-8}
relMCULow	mcuFailRate	1×10^{-6}
relBatteryTypical	batteryFailRate	1/40000

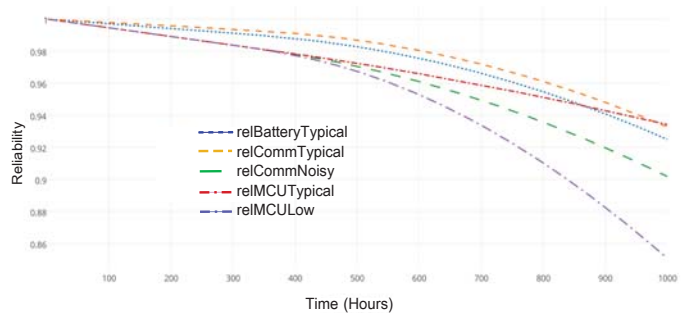

Fig. 4. HealTICa reliability node for different scenarios

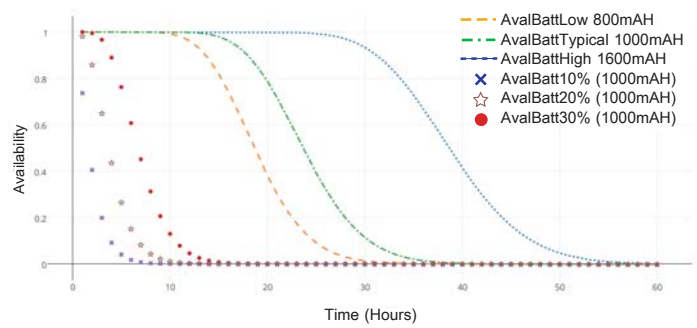

Fig. 5. HealTICa node availability for different battery capacities and percentages of charge

Finally, two sets of scenarios were created to evaluate the HealTICa system SAN model availability. By means of these experiments it is possible to estimate the system autonomy, and the minimum percentage of battery charge required to guarantee two hours of continuous operation, which is a medical

requirement for the system. In the first set, for exploring system autonomy, three different values of charge for commercial batteries were considered: 800 *mAh* (*availBattLow*), 1000 *mAh* (*availBattTypical*), and 1600 *mAh* (*availBattHigh*). According to Figure 5, although the battery with larger charge produces longer availability, it is necessary to consider its cost and size that could affect system viability and ergonomics. In the second set, for determining the minimum battery charge required to guarantee two hours of continuous operation, a 1000 *mAh* battery was considered. Three experiments were performed with charges of 10% (*avalBatt10%*), 20% (*avalBatt20%*), and 30% (*avalBatt30%*) of full capacity. Figure 5 shows that is necessary to have at least 30% of full capacity when using a 1000 mAh battery to guarantee two hours of continuous operation. In these scenarios the average computation time for solving the HealTICa system SAN model was 750 seconds, and the number of SAN states was 54208.

VI. Conclusions and Future Work

In this study, the availability and reliability of a wireless sensor node for medical applications called HealTICa was evaluated using the formalism named Stochastic Activity Networks. The results obtained from high level atomic models provide information about hardware quality, power supply and environment conditions necessary to ensure proper system operation, evaluated in terms of system dependability, specifically in its availability and reliability attributes. The direct relationship between the battery charge and the availability of the system was verified under different operational scenarios. During the design stage it is necessary to consider not only the battery capacity in *mAh* but also the battery reliability in life cycles to guarantee system availability. Low reliability microcontrollers turn themselves as a system reliability bottleneck. In terms of communication protocol, it was evidenced the interference issue in the IEEE 802.15.4 2,4 GHz band because it is shared with countless devices in typical operational scenarios. WBANs represent a serious alternative for developing home healthcare devices. This work presented an approach to evaluate the dependability (in term of its availability and reliability attributes) of a WBAN-based home healtcare system during the design stage, in order to early detect risks and threats in different operational scenarios.

For future work is being considered to design a reliable hardware and software architecture for home healthcare applications in order to have highly dependable systems, adding more attributes as maintainability, safety, confidentiality and integrity. This architecture will be modeled with the SAN formalism in order to avoid space state explosion, and to evaluate its effectiveness prior to system prototyping.

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