Detecting Vital Signs of CHF Patients with Wearable Sensors

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***Abstract*—Nowadays, chronic heart failure (CHF) affects an ever-growing segment of population, and it is among the major causes of hospitalization for elderly citizens. The actual out-of- hospital treatment model, based on periodic visits, has a low capability to detect signs of destabilization and leads to a high re-hospitalization rate. In this paper, a complete and integrated Information and Communication Technology system is described enabling the CHF patients to daily collect vital signs at home and automatically send them to the Hospital Information System, allowing the physicians to monitor their patients at distance and take timely actions in case of necessity. A minimum set of vital parameters has been identified, consisting of electrocardiogram, pulse, temperature, humidity, mems are measured through a pool of wireless, non-invasive biomedical sensors. Sensor data acquisition and signal processing are in charge of an additional device, the home gateway. All signals are processed upon acquisition in order to assert if both punctual values and extracted trends lay in a safety zone established by thresholds. Per-patient personalized thresholds, required measurements and transmission policy are allowed.**

***Index Terms*— Embedded Platform, ECG Module, Sensing Modules, GSM Module, Wi-Fi Module.**

I. INTRODUCTION

CHRONIC HEART failure (CHF) represents one of the most relevant chronic disease in all industrialized countries, affecting approximately 15 million people in Europe and more than 5 million in the U.S., with a prevalence ranging from 1% to 2% and an incidence of 3.6 million new cases each year in Europe and 550 000 cases in U.S. It is the leading cause of hospital admission particularly for older adults reaching a prevalence of 1.3%, 1.5%, and 8.4% in 55–64 years old, 65–74 years, and 75 years or older segments, respectively. Admission to hospital with heart failure has more than doubled in the last 20 years, and it is expected that CHF patients will double in 2030. Hospital admissions caused by CHF result in a large societal and economical issue, accounting for 2% of all hospitalizations. The CHF management accounts for 2% of the total healthcare expenditure and hospitalizations represent more than two thirds of such expenditure.

The current healthcare model is mostly in-hospital based and consists of periodic visits. Previous studies pointed out that in patients with a discharge diagnosis of heart failure, the probability of a readmission in the following 30 days is about 0.25, with the readmission rate that approaches 45% within 6 months.

It is acknowledged that changes in vital signs often precede symptom worsening and clinical destabilization: indeed, a daily monitoring of some biological parameters would ensure an early recognition of heart failure de-compensation signs, allowing appropriate and timely interventions, likely leading to a reduction in the number of re-hospitalizations. Due to lack of resources at medical facilities to support this kind of follow-up, the use of Information and Communication Technologies (ICT) has been identified by physicians and administrator as a possible valid support to overcome this limit. There is in literature some evidence that a multidisciplinary management program including a home-based follow- up strategy can improve outcome of heart failure patients, including a reduction in mortality, hospital readmissions, and lengths of hospital stays, and increase patient satisfaction.

This paper represents an extension of in which the same authors provide an overview of a flexible and high configurable platform for domestic vital signs acquisition and processing, integrated with the Hospital Information System (HIS).

This work has been developed within the Health at Home project (H@H) of the Ambient Assisted Living Program (AAL). It takes into account the recent AAL Roadmap guide-lines, the future challenges in telecare, and some recent studies conducted on AAL solutions.

The H@H platform aims at connecting in-hospital care of the acute syndrome with out-of-hospital follow-up by patient/ family caregiver, being directly integrated with the usual cardiology departmental HIS. Patients' signs, symptoms, and raised alarms can be received by healthcare providers, and aggravations can be quickly detected and acted upon. Thanks to the collection of vital parameters at home, the sensor data signal processing and the automatic data transmission to the medical center, a more frequent (usually daily) assessment of clinical status than in conventional practice is permitted.

In this paper we show a complete and integrated Information and Communication Technology system is described enabling the CHF patients to daily collect vital signs at home and automatically send them to the Hospital Information System, allowing the physicians to monitor their patients at distance and take timely actions in case of necessity.

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II. H@H TELECARE SYSTEM OVERVIEW

The H@H development Consortium is composed by industrial and research partners with qualified competences in sensing and data processing as well as very important healthcare providers (Hospitals Virgen del Rocio, Spain; Dom Koper Hospital in Slovenia and the research clinical center Fondazione Gabriele Monasteries in Italy). The system requirements come directly from the long experience in the CHF field of the involved physicians. The resulting platform takes into consideration both medical expectations, patients' features (elderly, with co morbidity and cognitive deficit), and the progressive nature of the disease. For these reasons, we propose an intuitive home monitoring system based on a configurable follow-up operating protocol (OP), integrated with the HIS of the cardiology department through a server software platform.

The complete H@H system has the client/server architecture The clients are typically located at patient's home and consist of a set of wireless sensors to measure the main vital signs and an additional device, the home gateway that centralizes all computation and communication resources. These domestic subsystems have in turn a client/server structure where sensors are the clients of the collection and transmission point represented by the home gateway. The server platform, installed at health service facilities, accepts data from gateways making them available in the HIS and finally allows the management of all patients' data since their enrolment.

The home gateway receives sensors data via point-to- point Bluetooth connections initiated by the sensing modules. Upon received, it processes all data to detect dangerous alterations and then forwards them to the hospital server through ADSL or mobile Broadband, to be further analyzed and flowed into the HIS. In case of an alarm situation, caregivers or relatives are contacted via SMS (i.e., reporting the abnormal values that lead to the alarm), and all pending data are sent to the server.

The gateway normally operates connected to the power line, but the internal battery ensures about 5 h of autonomy in case of power failure. The peculiar features of the target patients require the design of an intuitive and simple home gateway user interface.

This is able to display reminder messages, guide animations and sounds when a planned activity time is reached according to the OP. Patient can read the last measured values and the status of sensor battery charge. Green, yellow, and red background colors are used for information, warning, and error messages, respectively. To simplify the use of the gateway, a five-key membrane keypad is provided (i.e., Yes, No, Alarm sending, and Up/Down scroll buttons).

The server platform is based on the web services paradigm for data reception and presentation and also for the interaction with the cardiology department HIS and the patient's information management. The user interface allows the clinicians to interact with the system, also in mobility, using the web browser.

The availability of multiple communication paths ensures a good adaptability of the system in overall operating areas and improves the fault tolerance. As the coverage of GSM is close to 99%, the system reaches a very high degree of connectivity.

Furthermore, the gateway is able to exploit the GSM network to send SMSs to the physicians, patient's relatives, and caregivers in case of alert situation.

Authentication, integrity, and confidentiality of the communication are guaranteed by the HTTPS protocol. The use of international standard for data communication, ANSI HL7-RIM Clinical Document Architecture v2 and XML, improves the interoperability of the system as well as the integration with existing HIS. All numeric and waveform observations use SNOME CT or LOINC standards codes.

The proposed system is conceived to allow a better assessment of vital signs identified by clinicians as the most significant in CHF through one or few daily measurements, being in contrast to those systems that offer a continuous monitoring for limited period. It does not introduce any remarkable overhead with respect to regular activities of the medical staff. Indeed all signs are flowed as row data into the patient's electronic health record, and, thanks to the provided automatic signal processing capability, clinicians and caregivers are timely informed in case of alarm detection. Moreover, H@H minimizes the impact on the patient. The wireless biomedical sensors avoid connection-cable encumbrance. The number of sensing modules is minimized, and the signal quality is not excessively dependent on transducer positioning. The domestic gateway reminds the scheduled activities, provides a graphical assisted procedure that shows how to use the sensors, and acquires data without requiring any preventive action to the user.

III. H@H SENSOR DEVICES

In general, biomedical sensors address the wearability/ portability, non-invasively, wireless communication, and battery duration concerns in order to be easily used autonomously by the patients at home. Moreover, the system minimizes the number of devices and sensors/electrodes to be positioned on the patient's body (e.g., three recording sites electrocardiogram (ECG) instead of a more complex 12-lead ECG is adopted to limit the effects of electrodes misplacement. The measurement experience consists of wearing/using the sensors periodically, once or twice a day, only for the duration of the acquisition without any long-period application of the sensors as in different solutions.

According to the analysis carried out by the clinicians, interesting vital parameters to monitor in a CHF patient are ECG, pulse, humidity, temperature and memes.

To achieve an asset for the implementation and to increase scalability of the system, the sensing modules have been clustered into two possible configurations: basic and advanced. Basic partitioning is intended as the minimum set of requirements to ensure a complete and useful telecare system in CHF. As advanced, we refer to additional features in order to widen the kind of CHF patients to be possibly enrolled into the telemonitoring and to cope with other chronic diseases (i.e., chronic obstructive pulmonary disease, diabetes). Since the basic configuration provides to the HIS the needed data set for accurate CHF telemonitoring.

The latter is based on a new multi-channel front-end IC developed for cardiac sensor interfacing. The overall set of devices, where the sensors positioning and the limited impact on the patient are also visible.

The modules implement the Service Discovery Protocol and the Serial Port Profile (SPP) to discover and wirelessly communicate with the access point collection service, which is identified in the home gateway, with optional link-level security (128 bit encryption). Each sensor acts as initiator of connections according to the following rules:

1) If it knows the default remote peer address (DRPA), it begins the page procedure to establish a point-to-point connection (GAP Connectable Mode enabled), sends all data, and closes the connection;
2) if no DRPA exists, the module initiates the inquiry procedure for 10.24 s to discover remote peers in range (Gdme General Discoverable Mode enabled) offering the SPP collection service (i.e., gateways)
3) all peers identified in step 2 are sequentially asked for the authentication PIN
4) the device that matches the PIN receives data from the sensor, and in case of successful transmission, it becomes the new DRPA;
5) if in the above step 1 the page procedure fails, steps 2 to 4 are performed to identify the new DRPA.

TOLLGATE SECTION

IV. Arm Processor

This generation introduced the Thumb 16-bit instruction set providing improved code density compared to previous designs. The most widely used ARM7 designs implement the ARMv4T architecture, but some implement ARMv3 or ARMv5TEJ. All these designs use aVon Neumann architecture, thus the few versions comprising a cache do not separate data and instruction caches.

Some ARM7 cores are obsolete. One historically significant model, the ARM7DI is notable for having introduced JTAG based on-chip debugging; the preceding ARM6 cores did not support it. The "D" represented a JTAG TAP for debugging; the "I" denoted an Icebreaker debug module supporting hardware breakpoints and watch points, and letting the system be stalled for debugging. Subsequent cores included and enhanced this support.

It is a versatile processor designed for mobile devices and other low power electronics. This processor architecture is capable of up to 130 MIPS on a typical 0.13 µm process. The ARM7TDMI processor core implements ARM architecture v4T.

The processor supports both 32-bit and 16-bit instructions via the ARM and Thumb instruction sets. ARM licenses the processor to various semiconductor companies, which design full chips based on the ARM processor architecture. The ARM7 family comprises the ARM7TDMI, ARM7TDMI-S, ARM720T, and ARM7EJ-S processors. The ARM7TDMI core is the industry's most widely used 32-bit embedded RISC microprocessor result. Optimized for cost and power-sensitive applications, the ARM7TDMI result provides the low energy consumption, small size, and high performance needed in compact, embedded applications[1,2]. The ARM7TDMI core uses a three-stage pipeline to increment the flow of instructions to the processor. This allows various simultaneous operations to take place and extended operation of the processing and memory systems. As the processor is having a more speed it is easy to make the communication between the RF module and the Image acquisition module

ARM is a family of instruction set architectures for computer processors based on a reduced instruction set computing (RISC) architecture developed by British company ARM Holdings.

A RISC-based computer design approach means ARM processors require significantly fewer transistors than typical processors in average computers. This approach reduces costs, heat and power use. These are desirable traits for light, portable, battery-powered devices—including smart phones, laptops, tablet and notepad computers), and other embedded systems. A simpler design facilitates more efficient multi-core CPUs and higher core counts at lower cost, providing higher processing power and improved energy efficiency for servers and supercomputers.

Performing modes:

The ARM7TDMI core has seven modes of operation:

1) User mode is the general program execution state

2) Interrupt (IRQ) mode is used for general purpose interrupt handling

3) Supervisor mode is a protected mode for the performing system

4) Abort mode is entered after an instruction pre fetch abort

The interrupt settings of ARM support the DHLS to response to the interrupt coming from the server department.

8 to 40 kB of on-chip static RAM and 32 to 512 kB of on-chip flash program memory.128 bit wide interface/accelerator enables high speed 60 MHz operation.

- In-System/In-Application Programming (ISP/IAP) via on-chip boot-loader software .Single flash sector or full chip erase in 400 ms and programming of 256 bytes in 1ms.
- Embedded ICE RT and Embedded Trace interfaces offer real-time debugging with theon-chip RealMonitor software and high speed tracing of instruction execution.
- USB 2.0 Full Speed compliant Device Controller with 2 kB of endpoint RAM. In addition, the LPC2146/8 provides 8 kB of on-chip RAM accessible to USB by DMA.
- One or two (LPC2141/2 vs. LPC2144/6/8) 10-bit A/D converters provide a total of 6/14analog inputs, with conversion times as low as 2.44 us per channel.
- Single 10-bit D/A converter provides variable analog output.
- Two 32-bit timers/external event counters (with four capture and four compare channels each), PWM unit (six outputs) and watchdog.
- Low power real-time clock with independent power and dedicated 32 kHz clock input.

V. ECG Module

The ECG module is a new sensing device, developed ad hoc in the H@H project. Specifically, the module provides electrocardiographic, pulse oximetry, and plethysmographic measurements by means of proper sensors and electrodes placed on patient's body, implementing non-invasive techniques. It is hosted in a robust and small size ABS case (92 × 150 × 28 mm, 200 g) powered by an integrated rechargeable 3.7 V and 1700 mAh Li-Ion battery able to ensure 18 h of continuous operability (i.e., more than 3 months of acquisitions considering 5 min track twice a day).

The module uses an ECG patient trunk cable with four lead wires: RA, LA, LL, and RL (neutral) to provide the electrocardiographic signal. The sensor for pulse oximetry and plethysmographic measurements is a classical finger clip reader type to be applied at patient's first finger. In accordance with the physicians, the Einthoven's 3 leads ECG configuration is considered sufficient for our purposes (e.g., detection of heart rate (HR) and rhythm) and not excessively dependent on the transducer positioning. All such signals are conditioned, digitalized and then packetized, and finally transmitted via Bluetooth protocol. The ECG device outputs digitalized waveforms of two standard limb leads, the oxygen saturation in the blood, the plethysmographic waveform, and the battery level.

Integrating ECG functionalities in a novel single device reduces the number of sensing devices in the final system and also enables to acquire synchronized ECG plethysmogram traces. This allows a larger and more specific amount of information for advanced analysis and multi-sensor data fusion (e.g., the Pulse Transit Time estimation).

As reported the ECG module is realized assembling its building blocks on a single printed circuit board. All communications within the board take place under the coordination of a dedicated firmware running on the MSP430F2418 Ultra-Low Power Mixed Signal Controller, responsible for mixing raw data before passing them to the Bluetooth interface. The core of the ECG block is an ad-hoc developed application-specific integrated circuit (ASIC), very compact and high configurable, able to integrate the ECG functionality into portable and wearable devices. The technical specifications of the chip, called CARDIC, while a detailed description of the chip architecture and performance is provided.

The ECG module also hosts the Chip Ox OEM by Envitec for pulsioximetry measuring, being fully configurable, highly dimension-contained and with low power consumption, the device gives also HR digital data and a digitalized plethysmographic waveform (PPG). The range of measure is from 45% to 100%, with an accuracy of 1.5%–2% for oxygen saturation and 0–255 LSB at 100 Hz, with accuracy > 6 ppm/LSB for plethysmography. It consumes up to 25 mA at 3.3 Volt of power supply, and it communicates over an UART-TTL with a baud rate of 9600. Its dimensions are 31 × 14 × 5 mm.

ASIC CARDIAC TECHNICAL SPECIFICATION

Function	Schedule
Multi-channel ECG block features	8 input differential ECG channels fully configurable + configurable gain and offset per channel +pace maker detector + RL and Shield driver to reduce 50 Hz noise
Multi-parameter channels	Body temperature channel, blood pressure channel, general purpose auxiliary channel
ADC section	Resolution: 12 bit @83 KS/s, INL: ±1 LSB typ, DNL: 0.75 LSB max, conversion time: 14.1µs
Interface	Serial, 1.3 MHz, pin 3.3V/5V compliant
Power	5V/ 20 mA (max), 10 mA (typ) consumption
Technology/package	CMOS/TQFP128 14 x 14 x1.4 mm

ECG signal is, obviously, one of the most significant and reliable sources of information for CHF patients monitoring. Expert cardiologists within the project have considered that special attention should be given to four signs of heart deterioration:

- Abnormal heart frequency, above 120 or under 50 beats per minutes
- Emergence of atrial fibrillation (AFIB) episodes
- QRS complex of more than 120 ms with complete left bundle branch block morphology
- Signs of myocardial ischemia

Early detection of these symptoms is decisive in the prevention of cardiac threats. Home monitoring, such as the one developed in this project, allow the physicians to periodically check the ECG of the patients without unnecessary visits neither to the patient's home nor to the clinic. However, this can still be improved. Making a prior study of the ECG at the patient's house makes it possible to repeat those measures that obtained unexpected results and to raise early alarms for the physicians to check certain patient's ECG sooner. At this project, the ECG analysis is separated in two parts. The first one extracts basic features for HR calculation or respiration analysis. The second part uses the extracted information to evaluate the presence of AFIB episodes.

1) Basic Feature Extraction: The starting point for any ECG analysis is feature extraction, particularly the QRS complex detection that is nearly always the reference point within the ECG signal. A first derivative-based algorithm combined with a rule-based system is used for the QRS complex detection. Fig. 9 shows the main points of the ECG and the steps of the processing algorithm. The signal is filtered using an optimum Kaiser Filter band pass 85th-order symmetric FIR in order to keep just the central frequencies (8 to 30 Hz) where the QRS complex information lays.

Comparing the averaged signal against a threshold creates a set of windows that allow recognizing the R peaks in the filtered signal (maximum positive within the window).

The R peak has still to pass through a rule-based system that evaluates whether the detected QRS is a valid QRS complex or not basing on the distance in time between consecutive peaks: i.e., if two peaks are closer than the refractory period of the myocardium (200 ms), one of them is discarded. Then, the T-wave discrimination is performed, being stricter about those peaks situated 200–360 ms later than an accepted R peak. The rule system is also used to check for possible missed peaks when the current RR interval is 1.5 times the previous RR interval. In addition, a 50 Hz notch filter is applied to the signal. This filtering does not affect the detection, but it improves the legibility of the track for further medical review. Fig. 10(a) and (b) show the raw and filtered signal. There is also a cubic spline data interpolation algorithm that extracts the envelope of the R peaks as an indication of the respiratory activity. Maximum, minimum, and average HRs along the track are calculated (RR interval) and analyzed using a 30 s window that is shifted along the time axis on 5 s length steps. The VSIPL library linear FIR function was used to implement the Kaiser filtering, and additional IIR filtering and cubic spline interpolation functions have been developed based on the basic functions of the library.

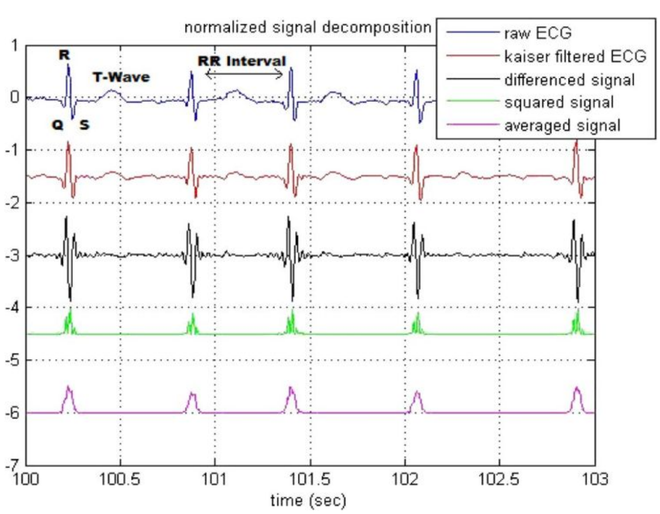
2) Abnormal Heart Frequency: At the basic configuration, heart frequency is calculated using a 30 s window shifted along the time axis on 5 s length steps. For each step, the number of beats within the window is counted, and that value is extrapolated to a 60 s window to the beats per minute value. Maximum, minimum, and average HRs along the track are calculated. If these values go higher or lower than the limits established by the physicians, an alarm is raised.

3) AFIB: AFIB is one of the most common arrhythmias, particularly between elder people. It is the cause of approximately one third of hospitalizations for cardiac rhythm disturbances. An estimated 2.3 million people in North America and 4.5 million people in the European Union suffer fromAFIB, and with the aging of the population, the number of Patients suffering from this condition are definitively going to increase. AFIB is a heart condition where the activation in the atria is fully irregular or chaotic. This might be caused by an irregular focal triggering mechanism involving automatic cells or multiple reentrant wavelets that randomly excite tissue that has previously just been activated by the same or another wavelet. Irregular atrial activity is reflected in the ECG as the absence of P waves before the QRS complex and fluctuating waveforms in the baseline. Organized ventricle activity allows QRS complex to maintain its usual shape, but with irregular rates so RR interval will show sharp variations.

Many of them are based on RR interval variability and its statistics: in the authors compare the standard density histogram of the RR interval length (RR) and RR difference (ΔRR) with previously compiled standard density histograms segments during They compare the histograms of the normalized ΔRR for both AFIB and non-AFIB episodes and demonstrate that they can be approximated by Laplace and Gaussian distributions fed with RR intervals statistics is used.

Another common approach is to separate the atrial activity from the ventricular activity in order to analyze the atrial behavior. It is necessary to take into account that atrial and ventricular activity occurs in the same frequencies and sometimes, as during AFIB, at the same time. There are multiple documented methods to do this. Some are based on detecting and subtracting the QRS complex. Others are based on representing the ECG signal in a distributed way (principal component analysis (PCA), wavelets, etc.) that allows the atrial activity to be separated. presents a solution based on PCA (Karhunen-Lòeve Transform). After calculating first 12 coefficients of KLT of the V1 lead, it concludes that coefficients 1–2 contain ventricular information, 3–8 contain atrial activity information, and 9–12 contain noise. reconstructs the atrial activity using components 3–8 and after makes a study in frequency of that activity presents a similar solution based on wavelets. Atrial activity is mainly contained in 4–9 Hz frequencies and can be isolated using certain coefficients of the stationary wavelet transform (SWT). Other authors mix classic RR interval analysis with additional indicators to decrease the number of false positives detected with the previous methods.

It also includes a hysteresis counter to determine the beginning of an episode only if several consecutive sets of parameters have been classified as AFIB. It uses Markov process modeling to analyze RR interval regularity. P wave detection considers P wave location (PR interval variation) and morphology.



ECG main points and signal processing for QRS detection

VI. Pulse Module

BP is the pressure exerted by circulating blood upon the walls of blood vessels. During each heartbeat, BP varies between a maximum (systolic) and a minimum (diastolic) level. In this segment of population, the abnormality of punctual values of BP and its variability in a short period are the main manifestations of cardiac instability. For these reasons, more measurements per day are suggested. The systolic and diastolic punctual values provided by the sensor are analyzed to find under or over threshold situations, and the general trends of both parameters are verified looking for suspicious variability. The complexity in terms of memory and computation is linear with the number of values considered. An example of observation of BP, one month long, along with the safety thresholds. It is possible to observe an under threshold and an over threshold situation, respectively, for the diastolic and systolic parameters.

Pulse Oximeter

In its most common (transmissive) application mode, a sensor is placed on a thin part of the patient's body, usually a fingertip or earlobe, or in the case of an infant, across a foot. Light of two wavelengths is passed through the patient to a photo detector. The changing absorbance at each of the wavelengths is measured, allowing determination of the absorbances due to the pulsing arterial blood alone, excluding venous blood, skin, bone, muscle, fat, and (in most cases) nail polish.

Reflectance pulse oximetry may be used as an alternative to transmissive pulse oximetery described above. This method does not require a thin section of the patient's body and is therefore well suited to more universal application such as the feet, forehead and chest, but it also has some limitations. Vasodilation and pooling of venous blood in the head due to compromised venous return to the heart, as occurs with congenital cyanotic heart disease patients, or in patients in the Trendelenburg position, can cause a combination of arterial and venous pulsations in the forehead region and lead to spurious SpO2 (Saturation of peripheral oxygen) results.

VII. Humidity sensor

Humidity is the amount of water vapor in the air. In daily language the term "humidity" is normally taken to mean relative humidity. Relative humidity is defined as the ratio of the partial pressure of water vapor in a parcel of air to the saturated vapor pressure of water vapor at a prescribed temperature. Humidity may also be expressed as absolute humidity and specific humidity. Relative humidity is an important metric used in forecasting weather. Humidity indicates the likelihood of precipitation, dew, or fog. High humidity makes people feel hotter outside in the summer because it reduces the effectiveness of sweating to cool the body by preventing the evaporation of perspiration from the skin.

Absolute humidity is the quantity of water in a particular volume of air. The most common units are grams per cubic meter, although any mass unit and any volume unit could be used.

Relative humidity is defined as the ratio of the partial pressure of water vapor in a gaseous mixture of air and water vapor to the saturated vapor pressure of water at a given temperature. Relative humidity is expressed as a percentage.

Specific humidity is the ratio of water vapor to air (including water vapor and dry air) in a particular volume. Measuring and regulating humidity. There are various devices used to measure and regulate humidity. A device used to measure humidity is called a psychrometer or hygrometer. A humidistat is used to regulate the humidity of a building with a de-humidifier. These can be analogous to a thermometer and thermostat for temperature control.

Humidity Sensor

Relative humidity can also be determined by locating the intersection of the wet- and dry-bulb temperatures on a psychometric chart.

VIII. Temperature Sensor

The LM35 is an integrated circuit sensor that can be used to measure temperature with an electrical output proportional to the temperature (in °C)

The LM35 - An Integrated Circuit Temperature Sensor

You can measure temperature more accurately than a using a thermistor. The sensor circuitry is sealed and not subject to oxidation, etc. The LM35 generates a higher output voltage than thermocouples and may not require that the output voltage be amplified.

Working of LM35:

It has an output voltage that is proportional to the Celsius temperature. The scale factor is .01V/°C the LM35 does not require any external calibration or trimming and maintains an accuracy of +/-0.4 °C at room temperature and +/- 0.8 °C over a range of 0 °C to +100 °C.

Another important characteristic of the LM35DZ is that it draws only 60 micro amps from its supply and possesses a low self-heating capability. The sensor self-heating causes less than 0.1 °C temperature rise in still air.

The LM35 comes in many different packages, including the following.

- TO-92 plastic transistor-like package,
- T0-46 metal can transistor-like package
- 8-lead surface mount SO-8 small outline package
- TO-202 package. (Shown in the picture above)

Temperature Sensor

IX. Mems

Accelerometers are acceleration sensors. An inertial mass suspended by springs is acted upon by acceleration forces that cause the mass to be deflected from its initial position. This deflection is converted to an electrical signal, which appears at the sensor output. The application of MEMS technology to accelerometers is a relatively new development.

MEMS use micro-machining fabrication to build electrical and mechanical systems at the micron scale — one-millionth of a meter. Using technology originally developed for the integrated circuit industry, MEMS is an attractive platform for medical devices because mechanical, sensing and computational functions can be placed on a single chip.

Mems sensor

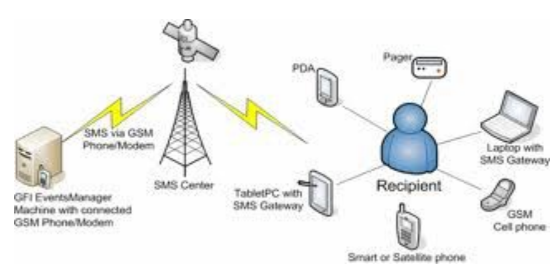
Electronic monitoring devices can be used to estimate compliance with medication regimens in patients with severe schizophrenic disorders, but there are methodological improvements that can be made to increase data recovery and compliance, and these are discussed.

The Medication Event Monitoring System, ([MEMS], Aprex Corp., Fremont, Calif.) is a medication bottle cap with a microprocessor that records the occurrence and time of each bottle opening. The MEMS has been used in a variety of populations with medical disorders. The only study we know of to date using an electronic medication monitor for patients with chronic mental illnesses (i.e., schizophrenia, schizoaffective disorder and severe mood disorders) was conducted in a population of veterans patients using a day hospital and intensive support.

X. GSM Module

A GSM modem is a wireless modem that works with a GSM wireless network. Global system for mobile communication (GSM) is a globally accepted standard for digital cellular communication. GSM is the name of a standardization group established in 1982 to create a common European mobile telephone standard that would formulate specifications for a pan-European mobile cellular radio system performing at 900 MHz

GSM provides recommendations, not recommendations. The GSM specifications define the functions and interface requirements in detail but do not address the hardware. The logic for this is to limit the designers as little as possible but still to make it possible for the operators to buy equipment from different suppliers. The GSM network is divided into three big systems: the switching system (SS), the base station system (BSS), and the operation and support system (OSS). The basic GSM network elements are shown in below figure



GSM Network Topology

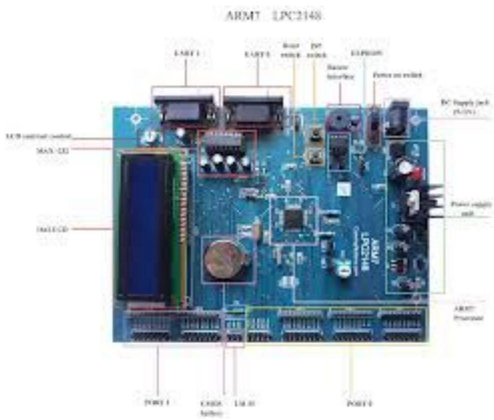
GSM modems support a continued set of AT commands. These continued AT commands are characterized in the GSM standards. With the extended AT commands, you can do things like:

- Reading, writing and deleting SMS messages.
- Sending SMS messages.
- Monitoring the signal strength.
- Monitoring the charging status and charge level of the battery.
- Reading, writing and searching phone book entries.

Sending the message:

To send the SMS message, type the following command:
AT+CMGS="+31638740161" <ENTER>

Replace the above phone number with your own cell phone number. The modem will acknowledge with:
> (Response from the modem)



You can now type the message text and send the message using the <CTRL>-<Z> key combination:
Hello World ! <CTRL-Z>

Here CTRL-Z is keyword for sending a sms through the mobile device. After some seconds the modem will respond with the message ID of the message, announcing that the message was sent correctly:
+CMGS: 62

XI. Wi-Fi

Wi-Fi, also spelled **Wifi** or **Wi-Fi**, is a local area wireless technology that allows an electronic device to exchange data or connect to the internet using 2.4 GHz UHF and 5 GHz SHF radio waves.

Wi-Fi Module

The name is a trademark name, and is a play on the audiophile term Hi-Fi. The Wi-Fi Alliance defines Wi-Fi as any "wireless local area network (WLAN) products. However, since most modern WLANs are based on these standards, the term "Wi-Fi" is used in general English as a synonym for "WLAN". Many devices can use Wi-Fi, e.g., personal computers, video-game consoles, smart phones, some digital cameras, tablet computers and digital audio players. These can connect to a network resource such as the Internet via a wireless network access point. Such an access point (or hotspot) has a range of about 20 meters (66 feet) indoors and a greater range outdoors.

Hotspot coverage can comprise an area as small as a single room with walls that block radio waves, or as large as many square kilometers achieved by using multiple overlapping access points.Wi-Fi can be less secure than wired connections (such as Ethernet) because an intruder does not need a physical connection. Web pages that use SSL are secure but unencrypted internet access can easily be detected by intruders. Because of this, Wi-Fi has adopted various encryption technologies. The early encryption WEP, proved easy to break. Higher quality protocols (WPA, WPA2) were added later. An optional feature added in 2007, called Wi-Fi Protected Setup (WPS), and had a serious flaw that allowed an attacker to recover the router's password. The Wi-Fi Alliance has since updated its test plan and certification program to ensure all newly certified devices resist attacks.

XII. Conclusion

This work presents the requirements and the realization in terms of sensing devices and sensor data signal processing of a complete and integrated ICT platform to improve the provisioning of healthcare services for CHF patients. The H@H system proposes an innovative home care model in order to support in integrated and coordinated fashion the whole process of the patient treatment, connecting in-hospital care with out-of-hospital follow up. With the remote monitoring, the medical staff can realize changes in the parameters of patients without frequently visiting them and consequently they can take concerned action to prevent possible aggravations. The benefits extend beyond the early detection of clinical exacerbation to optimizing specialized resources scheduling and to reduce unnecessary travels to hospital. The system definition was completely driven by the end-users resulting in a platform particularly effective and practical with respect to other telemonitoring. One of the main system novelties is represented by the home gateway which embeds, through the so-called OP, the medical prescription for any given patient. Moreover, it locally performs all the sensor signal processing and alarm detection. The OP is configurable according to the patient's needs and remotely updatable if required via the server platform. The basic sensors kit established by physicians includes two commercial devices for temperature and humidity and a new developed module for acquiring synchronized ECG and pulse. In this we can also send the readings through GSM for any number that can be the concerned doctor or any other family member.

XIII. REFERENCES

[1] “SHAPE survey results to the general public,” in Proc. Annu. Congr. Eur.
Soc. Cardiol. Vienna, Vienna, Austria, Sep. 2003.
[2] F. Zannad, N. Agrinier, and F. Alla, “Heart failure burden and therapy,”
Europace, vol. 11, no. 5, pp. 1–9, Nov. 2009.
[3] V. Roger, A. S. Go, D. M. Lloyd-Jones, R. J. Adams, J. D. Berry, T. M. Brown, M. R. Carnethon, S. Dai, G. de Simone, E. S. Ford, C. S. Fox, H. J. Fullerton, C. Gillespie, K. J. Greenlund, S. M. Hailpern, J. A. Heit, P. M. Ho, V. J. Howard, B. M. Kissela, S. J. Kittner, D. T. Lackland, J. H. Lichtman, L. D. Lisbeth, D. M. Makuc, G. M. Marcus, A. Marelli, D. B. Matchar, M. M. McDermott, J. B. Meigs, C. S. Moy, D. Mozaffarian, M. E. Mussolino, G. Nichol, N. P. Paynter, W. D. Rosamond, P. D. Sorlie, R. S. Stafford, T. N. Turan, M. B. Turner, N. D. Wong, and J. Wylie-Rosett, “Heart disease and stroke statistics—2011 update: A report from the American Heart Association,” Circulation, vol. 123, no. 4, pp. 18–209, Feb. 2011.
[4] F. Alla, F. Zannad, and G. Filippatos, “Epidemiology of acute heart failure syndromes,” Heart Fail. Rev., vol. 12, no. 2, pp. 91–95, Jun. 2007.
[5] C. Berry, D. Murdoch, and J. McMurray, “Economics of chronic heart failure,” Eur. J. Heart Fail., vol. 3, no. 3, pp. 283–291, Jun. 2001.
[6] A. Bundkirchen and R. H. G. Schwinger, “Epidemiology and economic burden of chronic heart failure,” Eur. Heart J. Suppl., vol. 6, no. SD,
pp. 57–60, Aug. 2004.
[7] J. Ross, J. Chen, Z. Lin, H. Bueno, J. P. Curtis, P. S. Keenan, S. L.
Normand, G. Schreiner, J. A. Spertus, M. T. Vidán, Y. Wang, and H. M. Krumholz, “Recent national trends in readmission rates after heart failure hospitalization,” Circ., Heart Fail., vol. 3, no. 1, pp. 97–103, Jan. 2009.
[8] S. Stewart, “Financial aspects of heart failure programs of care,” Eur. J.
Heart Fail., vol. 7, no. 3, pp. 423–428, Mar. 2005.
[9] F. McAlister, S. Stewart, S. Ferrua, and J. J. McMurray, “Multidisciplinary strategies for the management of heart failure patients at high risk for admission: A systematic review of randomized trials,” J. Amer. Coll. Cardiol., vol. 44, no. 4, pp. 810–819, Aug. 2004.

[10] E. Seto, “Cost comparison between telemonitoring and usual care of
heart failure: A systematic review,” Telemed. J. E-Health, vol. 14, no. 7, pp. 679–686, Sep. 2008.
[11] C. Klersy, A. De Silvestri, G. Gabutti, F. Regoli, and A. Auricchio, “A
meta-analysis of remote monitoring of heart failure patients,” J. Amer. Coll. Cardiol., vol. 54, no. 18, pp. 1683–1694, Oct. 2009.
[12] S. C. Inglis, R. A. Clark, F. A. McAlister, J. Ball, C. Lewinter, D. Cullington, S. Stewart, and J. G. Cleland, “Structured telephone sup-
port or telemonitoring programmes for patients with chronic heart fail- ure,” Cochrane Lib., no. 8, p. CD 007 228, Jul.–Sep. 2010.
[13] S. Saponara, M. Donati, T. Bacchillone, L. Fanucci, I. Sanchez-Tato, C. Carmona, and P. Barba, “Remote monitoring of vital signs in patients
with chronic heart failure: Sensor devices and data analysis perspective,”
in Proc. IEEE Sens. Symp. Appl., 2012, pp. 1–6.
[14] G. van den Broek, F. Cavallo, and C. Wehrmann, Ambient Assisted Living
Roadmap. Amsterdam, The Netherlands: IOS Press, Mar. 2010.
[15] S. J. Devaraj and K. Ezra, “Current trends and future challenges in wire- less telemedicine system,” in Proc. IEEE ICECT , 2011, pp. 417–421.
[16] C. Fabbricatore, M. Zucker, S. Ziganki, and A. P. Karduck, “Towards an unified architecture for smart home and ambient assisted living solutions:
A focus on elderly people,” in Proc. IEEE DEST , Jun. 2011, pp. 305–311. [17] A. Jara, M. A. Zamora, and A. F. G. Skarmeta, “An architecture for ambient assisted living and health environments,” in Proc. Lecture Notes
Comput. Sci., 2009, vol. 5518, pp. 882–889.
[18] J. P. Riley and M. R. Cowie, “Telemonitoring in heart failure,” Heart
Educ. Heart, vol. 95, no. 23, pp. 1964–1968, Dec. 2009.
[19] T. Bacchillone, M. Donati, S. Saponara, and L. Fanucci, “A flexible home gateway system for telecare of patients affected by chronic heart failure,” in Proc. IEEE Int. Symp. Med. Inf. Commun. Technol., 2011, pp. 139–142.

