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# Wireless Biomonitor for Ambient Assisted Living

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***Abstract*—The 1990s has been the era of the personal computer and the mobile phone with the resulting large-scale integration of IT and communications providing vast processing power and accessibility to information and people. The next decade will see the emergence of intelligent sensors and their widespread deployment throughout our environment, dramatically improving the quality of our daily lives in terms of our health, security, comfort and entertainment. Wireless sensor networks (WSNs) will enable point-of-care-diagnostics and provide the data input to e-health management systems that will allow significant enhancement of health care programmes. They will also support the evolution of wearable medical devices aimed at improving the fitness and general well-being of the individual. This paper discusses the development, design characterization and test of a miniaturised wireless, wearable blood pressure and ECG monitor developed at the Tyndall National Institute for medical applications. This wireless platform is incorporated with the Data Management System (DMS) architecture which aims to optimise accurate data delivery within a WSN medical environment. Good data management infrastructures within a medical environment help improve productivity levels for medical practitioners, and can improve patient diagnosis.**

***Keywords: Biomonitor, Wearable Wireless Sensor Network, Data Management System (DMS), Ambient Assisted Living.***

## I. INTRODUCTION

Ireland's Tyndall National Institute sees the necessity of utilizing Wireless Sensor Network (WSN) technologies in the aArea of Ambient Assisted Living (AAL), and developing scenarios in the health arena. This paper presents the development in hardware and software of a WSN based wearable biomonitor. It is wirelessly enabled to measure ECG, blood pressure and pulse rate. The low power consumption, ISM band transceiver based mote is integrated with the hardware conditioning circuitry required for the wearable biomonitor. This system is integrated with a software architecture called DMS (Data Management System) which provides a context aware service within a WSN medical environment. The DMS collects real-time patient data using a software agent platform on top of a WSN node. The advantage of agent technologies stem from their ability to be proactive, adaptability to changing environments, and their efficient bandwidth usage.

## II. RESEARCH MOTIVATION

Research has been conducted in a number of related areas including contextual retrieval of medical data [1] and agent based medical environments [2], both of which highlight the role that agents can play in a medical environment. Analysis into the cause of errors within a medical environment over the period 1998-2005 [3], found that lack of sufficient technological aids caused basic administration tasks to bewere jeopardised. One solution to alleviate some of these issues is the collaboration between medical staff and the latest technologies incorporating software agents [4] which can assist medical practitioners during diagnosis. Thus wireless sensor networks will enable point-of-care-diagnostics and provide the data input to e-health management systems that will allow significant enhancement of community-based, primary health care programmes. Such technologies can be termed medical eGadgets [5]. As wireless sensor systems become miniaturised and are deployed as wearable systems, the development of the required Data Management System (DMS) needs to address issues such as mobile computing and database constraints [6], [7] which are applicable to the "Pervasive Computing" paradigm as the attributes of software agents make them ideal for handling external stimuli such as patient sensor data where the quality of such data is critical and needs to be addressed by constrained resource environments.

## III. BIOMONITOR HARDWARE

The heart of the patient monitoring hardware system is the Tyndall25 mote [8], see Figure 1.

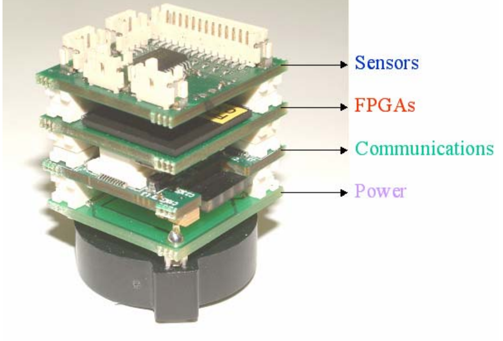

Figure 1. Tyndall 25mm Wireless Sensor network modular platform

The Tyndall25 hardware platform is a 25mm x 25mm stackable developmental platform designed to be modular in nature and to be suitable for a variety of WSN applications. Layers can be combined in an innovative and robust plug and play fashion and include communications (a selection of ISM band 2.4 GHz transceivers), processing (a low power consumption 8 bit microcontroller with 128kB of program memory) and a variety of sensing interconnect, sensor layers and power supply layers. This provides application specific solutions for WSN systems. An embedded antenna is integrated into the system to enable the 25mm form factor. The power layer may include a number of energy supply/harvesting methods i.e. vibration, electromagnetic fields, solar cells or piezo-electric power generating mechanisms.

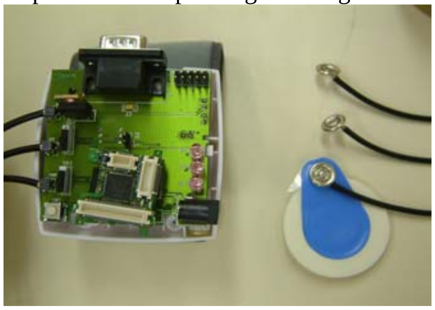

Figure 2. Wireless Patient Module with miniaturised Tyndall mote

The wireless biomonitor platform is compriseds ofan ECG and pressure sensors, their required sensor interfaces, and the Tyndall mote described above. The Tyndall25 mote provides the wireless communications mechanism for the system. This is a proprietary low power consumption protocol [9] utilising Nordic Semiconductors [10] "shockburst" transmission mechanism, where data is compressed and transmitted in short bursts to reduce overall power consumption of the node. The 8-bit microcontroller implements all communications protocols for data transmission, acquires sensor data utilising its 10-bit Analog to Digital converter and controls the overall behaviour of the system e.g. auto inflating pressure cuffs for pulse monitoring.

The sensor interface layer may be connected to three ECG patches, one Blood pressure and one Pulse rate sensor. The pressure sensor hardware was designed to fit into the inflatable cuff from an off-the shelf Blood pressure/Pulse rate sensor, the Balance KH8095, while the ECG patches are connected to the sensor layer via miniaturized coaxial cable and connectors. Figure 2 shows the patient module.

### A. *Blood pressure & pulse rate monitor*

The pressure sensor circuitry was implemented in the motherboard of the system to enable the inflatable cuff to be operated. This was designed to house a commercially available surface mount piezo resistive strain gauge, utilising a 5K bridge to measure differential pressure measurements (relative to atmospheric). To ensure highly accurate measurements irrespective of battery voltage, the bridge is driven by a constant current source. In a typical blood pressure measurement, we have a pressure of approximately 120mmHg (16Kpa or 2.32psi) so typical output voltages of 4mV need to be measured. Furthermore the blood pressure monitor (BPM) units were calibrated, as in Figure 3, showing typical bridge output of ~ 6mV, agreeing with the above calculation. The BPM sensor output conditioning circuitry, to enable ADC measurement is illustrated in figure 4.

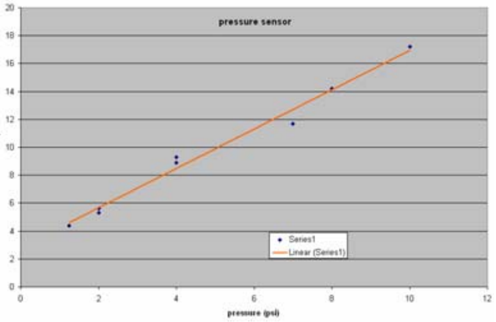

Figure 3. Pressure transducer calibration, bridge output voltage vs. pressure.

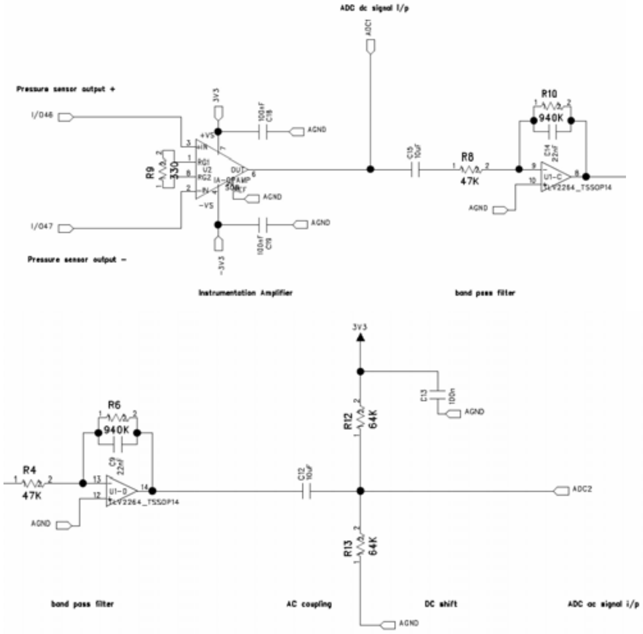

Figure 4. Blood pressure & pulse rate monitor conditioning circuitry.

The pressure transducer output was further signal conditioned in the sensor interface layer, by amplification (*150) with an instrumentation amplifier This o/p was then fed into one of the Atmel micro-controller in-built 10 bit ADC’s, to yield a DC pressure reading of systolic or diastolic blood pressure, using microcontroller controlled inflation of the wrist cuff on the patient. Finally a cascaded band pass filter was enabled, with a pass band of 1 – 4 Hz, for pulse rate measurement. This coincides with the typical pulse rate of ~ 1Hz. The AC pulse output after amplification, band pass filtering, AC coupling & DC shifting was fed into another of the micro-controller ADC inputs, to determine pulse rate.

The “power layer” is stimulated using 2*AA 1.5V batteries used to drive the motor and power the regulated interface circuitry. Furthermore provision for miniaturised coax jacks for ECG patch measurements was created. Similarly the conditioning circuitry is added to the stackable sensor interface layer, enabling amplification of the small ECG signal (<< 0.5mV) & band pass filtering in the 0.5 – 100Hz band, this schematic is illustrated in Figure5.

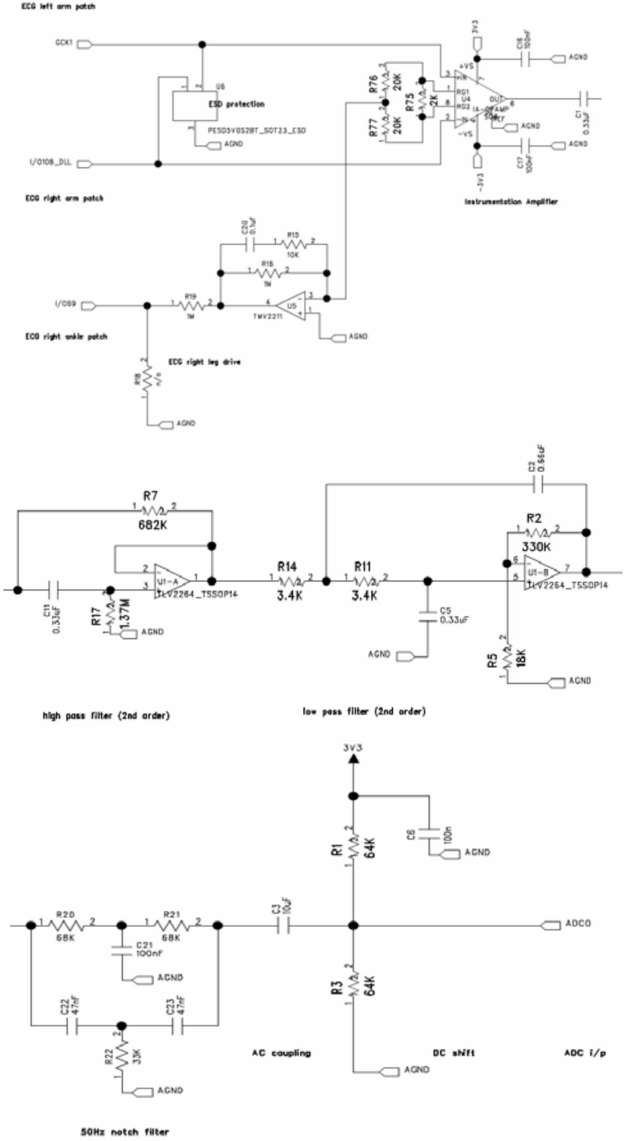

Figure 5. ECG sensor conditioning circuitry

Circuitry to compensate for potential 50Hz mains common mode noise was implemented using a right leg drive loop circuit. This resulted in three patches being attached to the patient; on the right ankle, also on the left & right shoulders. The ECG signal following suitable amplification with an Instrumentation AMP, filtering, AC coupling and DC shift, was read by a 10bit micro-controller Analog to Digital Convertor (ADC), after an overall gain of ~ 483.

Achieving good signal quality was found to be a challenge. The ECG waveform shape is a function of the filtering applied and sampling rate adopted. However the P, QRS and T waveforms were clearly visible (cf. Figure 6) when the patient is at rest and inactive during the measurements.

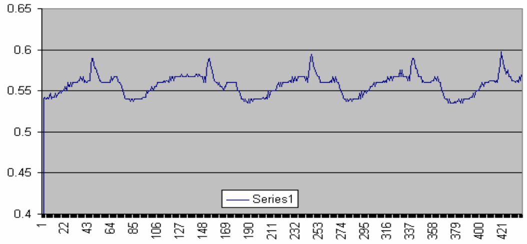

Figure 6. ECG signal measured for ISM band RF transmission

## IV. DMS

The primary role of the DMS is to provide mobile medical practitioners with accurate data delivery within a WPSN. This will improve productivity levels for medical practitioners by working to deliver relevant and accurate data on time every time. Pervasive medical environments require intelligent management of patient data [11]. Agent platforms provide the necessary characteristics in developing architectural solutions for context and situation aware applications. The software agents work in three logical layers: data collection; data correlation and data presentation. The agents within each layer operate according to the DMS rules and context aware parameters. This ensures that greater attention is given to high priority data sets, and that critical data is given the appropriate amount of system resources.

Working in a data rich environment, the DMS [12] is designed to contextually respond to the end-user's run-time needs. DMS is comprised of three layers, each of which executes on top of an agent platform. Their primary task is to handle and present data in the required format while ensuring that all context and situation derived data are taken into account. DMS consumes data from a number of input streams (e.g. PDA, patient module), and it correlates this data checking certain explicit relationships. This approach is vital in a context aware medical environment, as the DMS can inform the end-user if an event breaks one of the system rules. The core DMS agents operate in the following areas:

**Data Collection [Layer 1]:** Wireless patient modules (cf. Figure 7) and medical staff PDAs may transmit data to the DMS. Such data is received by the data collection layer. The frequency of data transmission from the patient module to the DMS is determined by the practitioner's requirement.

**Data Correlation [Layer 2]:** Multiple data records relating to the same real-world element may exist within the DMS. To ensure that vital information is not ignored, an explicit relationship between these data sets is defined giving the physician a complete overview of the patient's status.

**Data Presentation [Layer 3]:** Finally data presentation is determined by the context of the mobile environment in association with patient and medical staff profiles. This ensures that caregivers are not overloaded with information

## V. PATIENT MONITORING SYSTEM

Without going into detail, it is clear that a sophisticated ontology is required to fully model blood pressure, its regulation, and its interaction with other body functions. In our application, the wireless patient sensor node provides two measurements: the systolic pressure, i.e. specifically the maximum arterial pressure during contraction of the left ventricle of the heart, and the diastolic pressure, i.e. the minimum arterial pressure during relaxation and dilatation of the ventricles of the heart. These measurements are important indicators [13]. High systolic blood pressure appears to be a significant indicator for heart complications in all ages, but especially in older adults. High diastolic pressure appears to be a strong predictor of heart attack and stroke in young adults. The difference between systolic and diastolic readings (pulse pressure), although not usually considered, may be a predictor of heart problems in older adults.

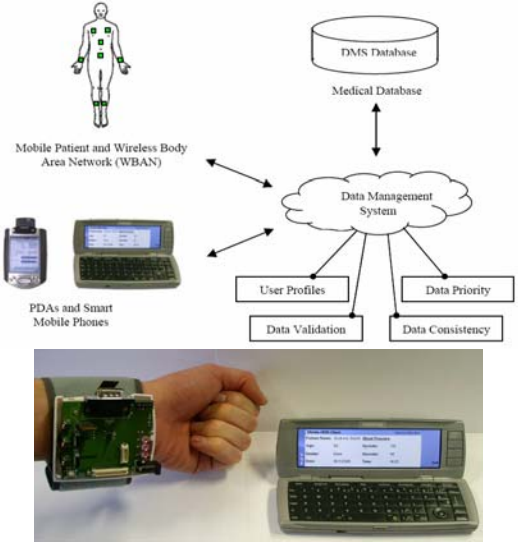

Figure 7: Tyndall Mote interacting with a Mobile Client (Nokia 9500).

Real-time patient readings are received from the wireless patient module and transmitted back to the DMS layer. Requests from practitioners may come from their PDAs. Static data, such as patient records, are stored in a medical database. Data communication is facilitated through agents over a Wi-Fi network. The three main external components are as follows: Tyndall 25mm cube (Patient module) which may be attached to a patient. Patient vital readings are returned to the DMS where automatic analysis may begin based on the patient's current and previous states. Generated results will be forwarded on to the physician's PDAs and/or PC, enabling medical staff to monitor their patient's state, and finally to a medical server which stores the archived data of the patients. This static information pool can play an important role when analysing a patient's current state. Relationships defined in the ontological model of the DMS layer between static (medical database) and dynamic (live sensor readings) patient records may indicate possible solutions to assist the medical staff during diagnosis.

## VI. CONCLUSIONS AND FUTURE WORK

Utilising the modular capabilities of the Tyndall miniaturised WSN development system, a biomonitor pressure, pulse and ECG monitor has been developed, to wirelessly provide patient biometric data to a health care provider in a non-intrusive non-invasive manner. An intelligent agent middleware (Jade) provides the context aware capabilities to function within a pervasive medical environment. Working alongside the agent platform is a rule-based system which triggers predefined actions based on a set of DMS rules.

Future developments of the DMS architecture will incorporate data consistency models to ensure all medical practitioners are viewing up-to-date data sources. Techniques for vValidation of communication and sensor readings techniques need to be developed to ensure that relevant and accurate data is transmitted within an ambient medical environment.

## VII. ACKNOWLEDGEMENTS

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