Applications of Policy Based Agents in Wireless Body Sensor Mesh Networks for Patient Health Monitoring

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ABSTRACT
Considerable research interest in using wireless and mobile technologies in patient health monitoring exists, particularly in hospitals and nursing homes. For health monitoring, an intelligent agent based hierarchical architecture was presented in the authors’ previous work. The technique of monitoring and notifying the health of patients using an intelligent agent, to the concerned hospital personnel, was proposed. This paper presents the details of the functioning of four main intelligent agents, i.e., the nurse agent, the sensor agent, the database agent, and the ward boy agent, for intimating the health information to the concerned doctor in the hospital, based on certain policies relevant to the hospital. The policies worked based on the temperature parameter monitored by the nurse agent. This paper considers an example of the physiological parameter i.e., the body temperature monitoring, for policy based agent implementation. The implementation was carried out using JADE-LEAP agent development kit.

Keywords: Agents, Health Monitoring, JADE-LEAP, Patient Monitoring, Wireless Sensors Mesh Networks

INTRODUCTION
The cost of healthcare services has increased and this has been posing severe challenges for policy makers, healthcare providers, hospitals, insurance companies and patients. Under the circumstances, a major problem to be tackled, is taking care of the health care services of a large number of patients within easy reach.

DOI: 10.4018/jehmc.2011040103

This challenge can be met to a certain degree by deploying an appropriate patient monitoring system in hospitals. In this context, it is observed that there has been some progress related to patient monitoring using wearable devices using short-range communications.

This type of network is more specifically referred to as body area networks (BAN) (Chen, Gonzalez, Vasilakos, Cao, & Leung, 2010). An increasing number of patients start wearing such communicating devices, there is a need for a comprehensive patient monitoring solution.
using wireless sensor networks (WSNs) and the quality and reliability of patient monitoring can be improved by using wireless sensor based mesh networks (WSMN). In this case, the information on vital signs of a patient can then be transmitted to base stations by means of intelligent agents which would replicate the human nurses, and will be picked up by the appropriate healthcare professionals on their mobile device (Sankaranarayanan, 2008; Sankaranarayanan & Ganesan, 2009).

A hierarchical architecture for health monitoring using such intelligent agents has already been published by one of the authors of this paper (Sankaranarayanan, 2009a, 2009b). We present in this paper the details of the functioning of an intelligent ward boy agent for intimating the health information to the concerned doctor in the hospital, based on certain policies relevant to the hospital. The policies, in our case have been worked out based on the temperature parameter monitored by the nurse agent. We have considered just as an example, the physiological parameter of body temperature monitoring, for our policy based agent implementation. We have not focused on the performance of our architecture as this is not part of our research. Work has already been published in studying the performance of Agent Wireless Body Sensor Mesh Network using JADE-LEAP in Sun Spot sensor (Barnes, Ganesan, & Sankaranarayanan, 2009) and also on studying the performance of Wireless Body Sensor Mesh network in terms of Delay, Load, MAC delay, throughout under varying number of patients using OPNET Modeler 15.0 (Benjamin & Sankaranarayanan, 2010). The implementation has been carried out using JADE-LEAP (Bellifemine, Caire, Poggi, & Rimassa, 2003; Bellifemine, Caire, & Greenwood, 2007) agent development kit.

The remainder of paper is organised as follows. First, we briefly introduce the patient monitoring system and explore patient monitoring using wireless devices forming a mesh network. The next section talks about Intelligent Agent based Routing in Wireless Sensor based Mesh Network. Then we provide the details on the algorithm developed to make agents function based on certain policies relevant to the hospital, for patient monitoring and notification and also the implementation. Finally we give the results of the research study carried out using JADE-LEAP along with the conclusion and future work.

**PATIENT MONITORING USING WIRELESS SENSOR DEVICES**

Patient monitoring involves periodic transmission and reception of routine vital health parameters pertaining to a patient. One major issue in monitoring is how frequently monitoring (sampling) of vital signs should be done. Also, such vital health data may have to be compared with some previous target/threshold values to detect changes in values or patterns to come to some diagnostics. A good overview of some of the research work that have been conducted in this area has been given by Varshney (2006). Additionally, Chen, Gonzales, Vasilakos, Cao, and Leung (2010) have even gone a step further in using radio frequency identification (RFID), an important and emerging technology for patient monitoring to create a 2G wireless monitoring system for patient monitoring.

The most important advantage of the wireless type of system, is that the body sensors have no wires connected. On account of this, it is easier for the human patient to move around and interact with the near world. These days, the sensor devices are becoming more and more compact and reduced in size and are also cost effective due to improved technology. Using wireless sensor networks (WSNs) (Akyildiz & Wang, 2005; Mohammad & Imad, 2006; Stankovic, 2004), various physiological parameters like: body temperature, blood pressure, pulse, or oxygen level from the blood etc, can be collected. Recently it has started attracting attention towards the health industry for monitoring the health of the patient. Typically, a WSN consists of hundreds to thousands of tiny sensor nodes that communicate over wireless channels and perform distributed sensing and collaborative data processing. In the above
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