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Diversity & Interoperability: Wireless Technologies in Ambient Assisted Living

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Abstract—**Ambient Assisted Living (AAL) demands the seamless integration of a range of technologies such that the particular needs of the elderly may be met. Given the heterogeneity of the elderly population, in their needs and circumstances amongst others, this is a significant challenge. In essence, it demands that a disparate suite of technologies be deployed, integrated, managed and interacted with in a seamless and intuitive fashion. In this paper, how this heterogeneity may be managed is discussed. In particular, the use of ontologies and middleware are proposed as potential solutions to this heterogeneity problem.**

I. Introduction

Ambient Assisted Living (AAL) has been conceived in response to changing demographics in countries predominantly in the first world. The net effect of this demographic shift is that the number of elderly will exceed those who are actively working to an excessive degree. This will have significant implications in the social, health and economic spheres amongst others. The objective of AAL is to harness a range of Information and Communication Technologies (ICTs) and apply them such that the elderly can live independently for longer than would otherwise be the case. The urgent need for AAL has been acknowledged in the EU through the establishment of the AAL Association and the incorporation of AAL into the FP7 programme of research and development. Heterogeneity is characteristic of many subpopulations and the elderly are no different. They differ in their needs, both from an individual and environmental perspective. Moreover, the elderly will not accept what they perceive as intrusive technologies. And it is in addressing these twin issues of heterogeneity (a source of complexity in its own right) and intrusiveness, that wireless and embedded sensor technologies have a significant role to fulfil, enabling real world deployments of AAL.

A key feature of AAL is the passive monitoring of individuals such that deviations from normal behaviours can be identified and interventions arranged where necessary. Fundamental to this is a network of wireless sensors of various capabilities. A simple example is the standard Passive InfraRed (PIR) sensor that enables motion detection. These can be augmented with a range of contact sensors for doors and windows, and as well as other typologies of sensor, for example, pressure sensors. Though identifying primitive actions, deductions about common behaviours can be made quite easily. Combinations of sensors can be deployed according to the needs of the elderly person in question. However, the environment itself, ranging from apartments to cottages to rambling old houses, makes the adaptation of wired connections impractical as their cost will be prohibitive due to the installation effort. Thus, a wireless communications facility is essential to the practical realisation of AAL. Fortunately, many sensors are coming on the market that support a range of standardised wireless technologies, for example, Zigbee and Bluetooth. However, the issue of integration and interoperability remains.

In this paper, a popular mote platform that illustrates the heterogeneity in sensor components is described. The potential of ontologies for managing this diversity is then discussed. Finally, the question of harnessing middleware as a software solution for realising a suite of diverse services is considered.

II. Sensor Platforms

Since the term ”mote” was coined by researchers in the Berkeley NEST (now WEBS [2]) it has become well understood that these devices have great potential to play a key role in next generation cost effective and proactive AAL solutions. While the envisaged domain continues to evolve and vary somewhat depending on application specifics it is now widely accepted that these systems will consist of large numbers of heterogeneous, autonomous, processing, communicating and sensing platforms. Stemming from this there are now numerous platforms available to the researcher and a number of comprehensive attempts have been made to classify the functionalities of these solutions, notably [5], [6] and [7].

As the technology evolves further there are a number of key factors likely to influence the development of these hardware platforms. The WSN middleware component is becoming increasingly important driven by the ever growing requirement to increase deployment scales and to determine how intelligence is distributed in the network. A divergence in philosophies regarding node design can already be witnessed here, where in some cases the focus has been placed on implementations capable of supporting increased intelligence at node level, for instance the Sun SPOT mote [3]. At the opposite end of the spectrum some designers have taken a more centralised, data acquisition based approach, utilizing nodes with reduced functionality but with attendant ultra low power consumption e.g. the Spec mote [4]. Clearly there is no one solution likely to satisfy every users requirements therefore a worthwhile goal of any platform designer is to provide easily interoperable, expandable, reusable and robust solutions in a manner that may or may not be intelligent, seamless or context-aware. An

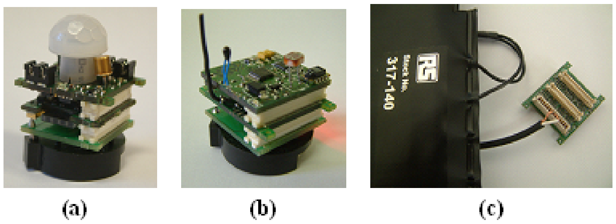

Fig. 1. The Modular Tyndall Mote with (a) 25mm BEM Standard Sensor Layer. (b) The Multisensor Layer (c) 25mm Generic Sensor Interface Layer connected to a pressure mat.

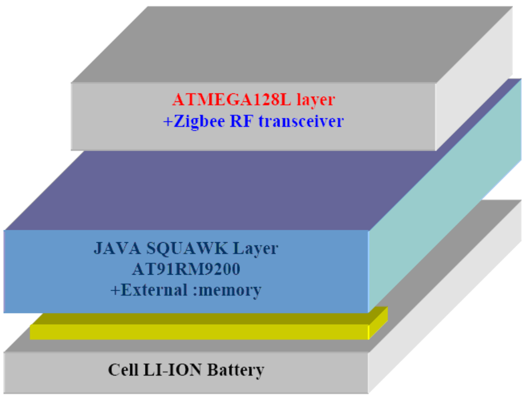

Fig. 2. Agent Ready System Block diagram

example of a platform that adopts this approach is the Tyndall Modular Mote WSN prototyping system.

A. The Modular Tyndall Mote WSN prototyping system

The Tyndall prototyping system is a highly modular approach to design negating the need to replace the mote infrastructure should a change in wireless technology, sensing capabilities or power supply be required [8]. The platform implementation consists of a variable number of layers that are stacked on top of each other in order to satisfy application requirements. There are a number of benefits in adopting this modular approach to node design namely the platform is far more interoperable with a diverse range of wireless technologies. This plug-in and play feature enables the background functionality of the network to be retained and the need for sensor recalibration to be removed should a change in wireless technology be required [9]. To date upwards of 40 system layers have been developed including over 25 modular sensor layers some of which are shown in figure 1. Additional intelligence can be added to the platform by means of a Smart Pervasive System Layer the block diagram for which is illustrated in figure 2. This layer comprises a powerful Java compatible processing platform supporting a SQUAWK virtual machine enabling the deployment of certain Java-based agent frameworks, for example, Agent Factory Micro Edition (AFME) [13].

III. Wireless Technologies

The great advances made in the last few years in wireless sensor networking are manifested with the large diversity of the wireless protocols employed. While Bluetooth dominates short-range communication among mobile phones, Zigbee-based networks found their space in sensor-based applications for industrial and residential contexts. The main difference between the two protocols lies on the greater energy-efficiency and larger scale of Zigbee-based networks versus Bluetooth. A particular scenario of interest, which is attracting great interest both from academia and industry, is the built environment. As an illustration, two typical scenarios of Zigbee-based networks and their utilization are now considered.

A. Case scenarios: Building Auditing systems

Recent development on Zigbee-based sensor networks resulted in the development of interesting applications of building auditing systems. Auditing a building include not only the static physical parameters of the building itself but include all dynamic events happening within premises such as how the building is used by occupants. Interesting applications include energy reduction techniques, carbon foot printing and ambient assisted living. In this context, the system consists of wireless sensors strategically positioned both inside and outside a structure, to monitor important performance parameters over a certain time period. From this, the system reports on the environmental characteristics of the building, including luminosity, thermal, acoustic, CO2 and humidity levels and occupants activity. This data are available for several parts of the structure and its surroundinga, for example, the roof, internal and external walls and windows. Important requirements are that the system should operate seamlessly during everyday life of occupants so as to provide precise sensorial data in relation to occupant habits and behaviours. In the case of empowering energy saving techniques the output of the system is to generate an accurate profile of the structure and energy saving prediction to possibly guide an energy efficient installation plan. In the case of ambient assisted living, the sensor-based building auditing system can effectively be used to unobtrusively monitor occupants behaviours throughout their day activities. Based on this data collection, intelligent algorithms can learn habits and routines of occupants so that deviations from day/night routines may be captured to make informed decisions concerning what actions to take.

IV. Ontologies in WSNs

Essential to supporting and adapting to the diversity of services as well as heterogeneous hardware employed in AAL systems is the adoption of the SensorML [10] standard to describe sensor's data, as well as standard ontology languages to describe events. Standard encodings and associated metadata annotations are important to increase system's interoperability and also provide a consistent view of the underlying information, for instance, to be used to relate new and past observations and thus leverage on previously acquired skills to serve the needs of the user despite changes in the smart home environment.

SensorML provides a specialization of XML that is specifically oriented in describing sensors and sensors' data, and which also includes the instructions for deriving higher-level information from observations. Processes described in SensorML are discoverable and executable. All processes define their inputs, outputs, parameters, and methods, as well as providing relevant metadata. SensorML is valuable for the way it builds on common data definitions that are used throughout the OGC Sensor Web Enablement (SWE) framework, and in the associated standardization of related Web Services, such as the OGC Sensor Observation Services (SOS), Sensor Planning Services (SPS), and Sensor Alert Services (SAS).

Ontology-based representations are very important to enrich the low-level description of devices and services with high-level, application-specific concepts. For instance, two devices/services with the same input/output signatures could be used for very different objectives in the same system. The AAL system should not only be aware of the existence of a passive infrared sensor in a room at a given coordinate but also that the sensor is actually detecting the user entering into the kitchen, in order to enable a chain of inferences about the user's likely future activities.

Based on Description Logic, ontology languages such as the Ontology Web Language (OWL) used within the SemanticWeb initiative can be used to define complex concepts and relationships among them, as well as specific factual information. Both the ability of SensorML XML encoding to support semantic extensions through references to external ontologies or through RDF annotations (see Figure 3) and the partial modelling of SensorML concepts in standard ontologies may be harnessed to create a correspondence between low-level and high-level concepts (e.g. [11] [12] in order to improve the modularity of future AAL solutions and thus ease their portability across heterogeneous deployments by creating a common repository of services and resources.

V. THE MIDDLEWARE SOLUTION

Current middleware offerings for sensor networks tend to encompass systems that can aid application development to any system between the application and the operating system of the sensor. While this broad definition includes many solutions, there are a number of common goals:

- to facilitate application development;
- to provide the capability of deploying a sensor network with little in depth knowledge of WSNs.

The SIXTH Middleware, currently being tested in our laboratory, is in keeping with the existing goals of WSN middleware but also provides additional capabilities not currently present: modularity, flexibility, reusability, openness, extensibility, universality and multiple abstractions.

One of the primary goals of SIXTH is to create reusable components capable of intelligent and autonomic behaviour which can be brought together to form the application. The SIXTH middleware is therefore the collection of components along with their integration. On a marco level this means that the application uses the middleware components and each component may be part of many applications. Given the uniqueness of the sensor devices, it is important that many applications can coexist on the same sensor infrastructure and this is achieved through the use of multiple agents.

SIXTH is built using the Open Services Gateway initiative (OSGi), which allows us the select combination of various bundles of functionality to produce a coherent application. At its most basic form, the middleware could produce a WSN application by reusing existing components and grouping them together to achieve the desired operation. A more customisable solution allows some or all components to be configured to produce the desired functionality. Finally new modules can be written to deliver application specific functionality not currently supported in SIXTH. In every case, it is desired to achieve the highest level of reusability of hardware and software components to minimise development time.

VI. CONCLUSION

Though the objectives of AAL are laudable, nevertheless, there are still a number of challenges that must be addressed before it can becomes a viable solution. In this paper, AAL has been considered in light of the diversity of its constituent sensor components. Managing this heterogeneity is a prerequisite to the success of AAL. The use of lightweight middleware architectures offer one viable solution to managing this problem.

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```
<swe:DataRecord definition="urn:ogc:def:property:OGC:atmosphericConditions">
    <swe:field swe-om:Quantity rdf:about="#AirTemperature" name="AirTemperature">
        <swe:Quantity definition = "urn:ugc:def:property:OGC:AirTemperature">
            <swe:uom code="Cel" swe-om:hasUomIdentifier
              rdf:about="http://sweet.jpl.nasa.gov/ontology/units.owl#degreeC"/>
            <swe:value swe-om:hasDoubleValue rdf:datatype="&xsd;double"> 35.1</swe:value>
        </swe:Quantity>
    </swe:field>
</swe:DataRecord>
```


Fig. 3. Sample sensor data in XML + RDF

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