A Pragmatic Note on Knopflerfish-based Ambient Assisted Living (AAI) Systems Engineering

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ABSTRACT
The unprecedented adoption of pervasive computing, autonomic communication, mesh networking, and ubiquitous sensing technologies in sync up with a growing and gorgeous variety of highly miniaturized, multifaceted and smart devices, sensors, actuators, robots, displays, and controllers has set in a stimulating and sparkling stage for the fulfillment of the ambient intelligence (AmI) vision. That is, intelligence everywhere all the time is the ultimate vision for the evolving and enabling IT. IT infrastructures are increasingly virtualized and autonomic, IT systems and networks are becoming context-aware and cognitive through self-identification and environmental monitoring tags, stickers, sensors, system building-blocks such as services are fully process-centric, model-driven application components engineering is gaining more traction, etc. Interoperable and shared services and intelligent agents all collaboratively set to facilitate the realization of futuristic AmI applications. These have given the relevant and right confidence in the minds of many in order to establish and sustain a series of stunning smart environments such as smart homes, buildings, hospitals, hotels, stations, stadiums, etc. A bevy of real-time and real-world applications such as ambient assisted living (AAI), smart energy management, etc. are being explored, experimented, and espoused. The industry is abuzz with a growing array of robust and resilient AmI technologies, frameworks, middleware, etc. Natural interfaces for machine-to-machine (M2M) communication are fast emerging and evolving. Smart healthcare is the first mover to the technology-sponsored and splurged AmI space.

In this paper, A standards-based ambient healthcare system has been developed and tested. This is a great gift for the elderly, debilitated and disabled. Also, this system can substantially improve the living conditions of humans by leaps and bounds. Here our focus is to develop and sustain an ambient assisted living (AAI) system by using Open Services Gateway Initiative (OSGi), which is emerging as the most prominent and dominant service integration, composition and collaboration standard. There are several best-in-class implementations of the OSGi specification. This present implementation has carefully considered the pros and cons of them and finally zeroed down on Knopflerfish and derived the system architecture using a peer-to-peer approach. Furthermore it also developed a decentralized network of services and devices.

General Terms
Dynamic Device Discovery (DDD), orchestration, Service oriented architecture, Wireless Sensor Networks (WSN).

Keywords
Knopflerfish, Ambient Assisted Living, smart home

1. INTRODUCTION
There have been several circumstances under which humans have succumbed to the forces of nature like the perennial process of ageing. It has left people crippled from doing their daily chores at ease, which once they did it with the supple limbs. This trend, which is more pervasive in advanced countries, has led to the emergence of challenging research topics such as smart healthcare, ambient assisted living, tele-care, etc. in association with the promising and potential information, communication, sensing, vision, perception, decision-making and actuation technologies. More broadly there are institutional and international project initiatives on establishing smart homes, buildings, hospitals, hotels, etc. Context-awareness is the key differentiator for creating and sustaining smart environments [1-5]. With the emergence of competent technologies and proven methodologies, researchers as well as practitioners are passionately working on intelligent systems, networks, and environments. Considering the market potentials on next-generation healthcare systems, professionals are focusing on Ambient Assisted Living (AAL) [6-11]. The initial and foremost objective of AAL was to improve the living standards of aged debilitated and disabled people. AAL is being recognized as the most sought-after application for smart homes. Presently AAL is being made use of in several fields like medical automation, patient monitoring, e-nursing etc.

1.1 WSN Technologies
The maturity and stability of AAL is provided by a string of massively produced, highly miniaturized, networkable, and smart sensors, controllers, robots and actuators. These can find and form ad hoc networks (termed as smart sensor networks (SSNs)) within themselves using the pioneering mesh networking. This network formation goes a long way in precisely and concisely understanding the environmental and the needs (informational as well as physical) of users in that environment. The understanding gained through a community of sensors helps the centralized system to formulate the needed services via scores of actuators to be unobtrusively supplied to the users [12,13] in real time. The sensors and their networks are capable of constantly monitoring the physical environment to understand all sorts of happenings. That is, any kind of event / state change such as people movement / gesture / change in temperature, voice / noise level, incoming in that place, the arrival of device or people into the environment gets noticed and acted upon immediately and insightfully. There are energy-aware, wireless, lean and privacy-preserving communication

protocols enabling smart sensor networks. Sensor / actuator networks lay a solid and stimulating foundation for the success of AAL system engineering and management.

On the other side, service oriented architecture (SOA) is fast emerging and evolving to fulfill the long-standing requirement of seamless and spontaneous connectivity and integration among diverse, distributed and decentralized devices. With its runaway success in the enterprise space, SOA is to traverse through the vast and varied devices space to facilitate device coordination, composition, and collaboration to create and craft powerful and people-centric services and applications. Service oriented device architecture (SODA) is the unifying architectural style for the furiously growing embedded domain. There are several service-centric standards such as uPnP, Jini, Web services, OSGi, DPWS etc. Here this make use of OSGi considering its maturity and stability. Any standard OSGi-compliant framework comprises a variety of enabling resources, toolsets and platform such as versatile service middleware, a repository of services, and a management platform.

1.2 Service Orchestration

Services are composable through orchestration and choreography. Here it is preferred orchestration-kind of composition. For creating usable and sustainable people-centric services, there is a need for an orchestration engine to discover, connect, leverage, and regulate scores of distributed services. In an orchestra, there are a group of instruments and a big sequence of musical notes for each. Without a central body, it is almost impossible to find the correct notes by each musician. Hence this has a composer to orchestrates the concert. The same logic is being applied here which has several devices (like the musical instruments) and several services (like the musical notes). The centralized and core orchestration engine takes care of services interactions in order to produce competent and compact service-enabled device ensembles.

1.3 Development Tools

Knopflerfsh is an open source OSGi framework comprising all the OSGi-specified modules. It provides a very easy-to-use GUI that helps to deploy any bundle in the OSGi container. The bundles are created using Eclipse IDE, which consists of default OSGi plug-in creation module.

2. BASIS

The implementation explained below is to help people who are ill and resting at home. Any typical home in an advanced nation has a number of consumer electronics, kitchen utensils, machines, media players, medical instruments, computers, communicators, sensors, etc. It is getting complicated for these people to configure and operate these gadgets and gizmos effectively due to multiplicity and heterogeneity. In short, manually setting and handling all these systems are very tough for those debilitated people. Thereby automation is a boon and will prove to be an excellent way to handle the needs of the blind, aged and crippled. They being unable to do even small household chores without help, can feel secure with such facilities. Moreover it is very difficult to cater their individual needs by care givers and thus will prove to be a great supplement for them to reduce their burden.

This will also serve to be a great relief for the normal people who work. In today's highly competitive and ambitious society, workplace has become a battlefield, so people who return from work are already in a high pressure state. Thus daily chores tend to increase their state of tension. Prolonged and continued sessions like this prove the gradual deterioration of health of people ultimately leading high blood pressure, hypertension, and a variety of heart diseases and to the extent of brain damage in many cases.

3. SCENARIO

Let us consider a scenario where a person lives in a house. He spends most of his time in the living room and the bedroom. The TV is present in the living room and the music system is present in the bedroom. The living room being the place where most of his friends visit is where the Air conditioner (AC) is installed. The bedroom being a cooler place where he sleeps is where the Fan is installed so that the breeze circulates through the room and makes the place comfortable to sleep. Lights are installed in both the rooms and have separate controllers. The main door is installed with a mechanical lock. Speakers are installed in both the rooms. The living room has a couch and the bedroom has a chair and a bed.

The person likes to watch TV while he is sitting in the couch in the living room and he likes to listen to music while he is sitting in the chair in the bedroom. Unfortunately for him, he has to go through a series of works before he can enjoy it. Starting from entry, he has to unlock the door manually with his key and then get inside the room, switch on the lights, switch on the AC, switch on the TV, switch on the speakers and only then he can sit down to watch it. Moreover whenever he feels the room is very cold, he has to manually monitor the AC and when he feels the sound is too loud he has to manually reduce the speaker volume.

If he wants to enter the bedroom and listen to music, he has to switch off all the appliances in the living room, switch on the fan, switch on bedroom lights, switch on the music system, switch on the bedroom speakers and only then can he sit down to listen to it. Still he has to monitor the speakers manually. And when he gets up, he has to switch off all these and only then he can go to sleep peacefully. Considering that person being injured or old or crippled, all these series of actions cause his him much discomfort than the joy.

4. IMPLEMENTATION

Now this house has been equipped with a series of sensors. This includes a temperature sensors in both the rooms, Pressure sensors in the couch of the living room and the chair of the bedroom and motion sensor in the rooms. This empower each device with an RF transceiver, hence it has transceivers for two speakers, fan, AC, TV and music system. The front door lock is also installed with a transceiver and a small computing device kept somewhere in the house. The sensors can be installed as motes so that they are also connected by RF transceivers.

4.1 Discovering Devices

The first objective of our implementation is to make the setup flexible. Flexibility means to perform required tasks with the available devices easily. Here flexibility is achieved through the process called Dynamic Device Discovery (DDD). The small computing device present in the house consists of the middleware or the gateway through which all the devices and sensors are integrated. DDD is achieved as whenever the device is started, it searches through all the ports for familiar and non-familiar devices (as shown in Figure 1). Once it finds devices, it prompts them to register their service. Then it provides the required service for the familiar devices and installs plug-ins for the non-familiar ones. When there is a breakdown in a device, it gives an error message. At this point, the control can be turned to manual state and the particular device problem can be sorted out and then the system can be restarted. Now it recognizes the device again if ready else counts it unready if not.

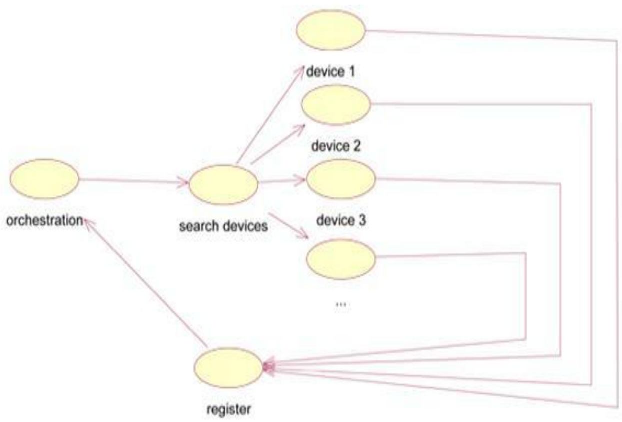

Fig 1: Device Discovery and Registration

4.2 Service Integration

The smart phone of the person is installed with an application to receive inputs from the orchestration middleware.

In the middleware the orchestration logic has been installed. Every device connects with the orchestration service and then invokes the other services that it requires. The communications between them can be done as usual. i.e., either it uses TCP/IP and create separate server sockets for the participating devices and connector clients, or a better method would be to use the javax.microedition.connection.io class which is compatible with Knopflerfish. The connection.io class comes with the CLDC/CDC package for mobile development.

The bundles are virtually connected as shown in Figure 2. Except the lights, all the other services are connected to the orchestration with the speakers and AC alone having individual connections with it. The living room sensor is virtually connected to the orchestration, lights, AC, and TV. The TV is in turn connected to the speakers. The door is connected to the orchestration and with the lights. The bedroom sensor is connected to the lights, fan and music system. The music system is in turn connected to the bedroom speakers. The temperature sensor is in direct connection with the orchestration and has no interactions with others. The orchestration module is now connected with the user application in the mobile device.

In this scenario that we have considered, there are separate speakers and temperature sensors in each room. Installing separate services for these will make the implementation more complex and redundant. Hence the logic is one but the device that is to be activated is controlled by the room's pressure sensors in the couch and the chair. Hence when the bedroom sensor receives input, the living room speakers and temperature sensor is already de-activated.

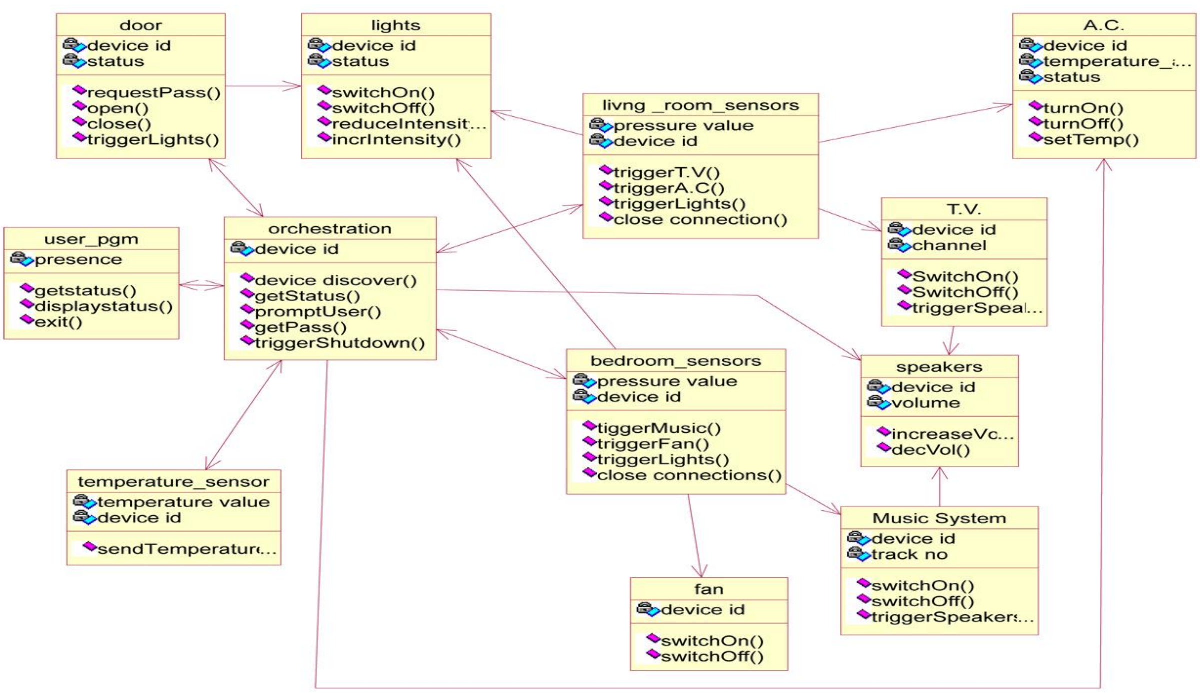

Fig 2: Service Integration and Interaction

4.3 Shutdown

One more important aspect of this implementation is the concept of triggered shutdown (Figure 3). In this scenario when the user wants to shut down the whole service cluster, it is enough that the user shuts down the corresponding application alone. As the user does that, the orchestration triggers certain packets to shut down which in turn triggers other packets to shut down. In the end, all the services are shut down with just one closure by the user. Then the devices can be controlled manually. It is important to note that the devices are not shut down but merely their ambient services are. The devices remain in the same state as left by the user and the user can still continue to use them manually.

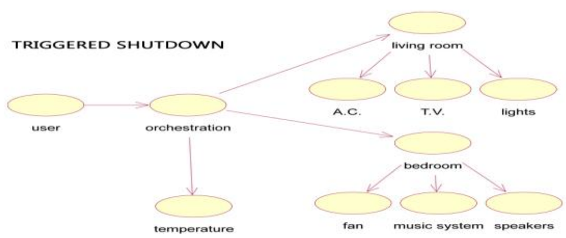

Fig 3: shutdown mechanism for manual override

5. WORKING MODEL

When the person is found to be near the door outside the house, the middleware recognizes it and triggers the door service. The door service requests for the password to the user through the orchestration and using the user application. As soon as the user types in the correct password, the door service activates the lights which get switched on and the door opens. Now as the user enters the room, the sensors of the living room remain in the active state and a menu appears in the screen of the device as shown in Figure 4 giving options for viewing temperature, controlling AC and controlling speakers.

Fig 4: Options available to the User in Device

5.1 Temperature Check

If the user tries to check the temperature, the orchestration receives input through the application and invokes the particular sensor of the room which is determined by the motion sensors of the rooms. This sensor sends information to the orchestration which in turn forwards it to the user. The user command and the reaction is given in Figure 5.

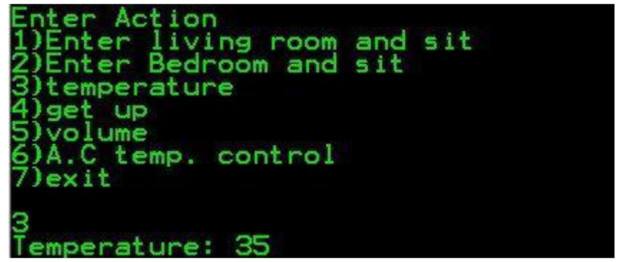

Fig 5: Temperature Monitoring

5.2 Room Controls

When the user sits in the couch, the following events take place. The TV is switched on and the TV in turn switches on the speakers. The lights are dimmed and the AC is switched on. Now the user can use the application to control the speaker volume and the air conditioner. When the user gets up from the couch, automatically the sensor receives this information and the TV is switched off which in turn switches the speakers off, The AC is reduced and the lights are brightened which enables him to walk through the room easily. The switch off sequence is illustrated in Figure 6.1 and the couch bundle in the knopflerfish is shown in Figure 6.3.

Fig 6.1: Exiting the Living Room Patterns

As he enters the bedroom, the motion sensors are alerted and the temperature sensor and speakers of the living room are dropped of control and those of the bedroom are taken into control. As the person sits down on the chair, the fan is switched on, the lights are dimmed and the music player is switched on (Figure 6.2). The music player in turn triggers the speakers of the bedroom and the setup plays the person's favorite tracks according to his playlist. Again when the user gets up from this chair, the music system and the speakers are turned off, the lights are turned up and the fan is off automatically (Figure 6.4). The chair bundle outputs are illustrated in Figure 6.6.

Fig 6.2: Events when person sits on the Bedroom Chair

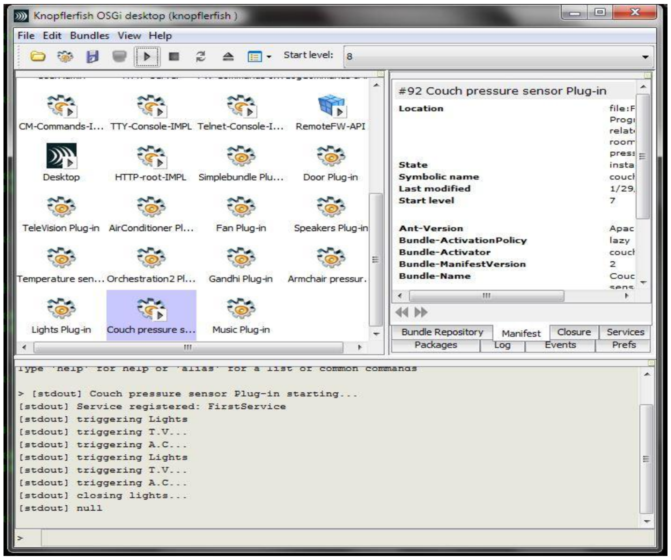

Fig 6.3: Living Room Couch Bundle

Fig 6.4: Events on getting up from the Chair

When the user exits the application, triggered shutdown of services take place due to which all the services are turned to manual (Figure 6.5). Thus from this point, the person can actively use it by himself. When the application is restarted, the services become ambient again. Moreover the temperature can be monitored by the user anytime needed in both the rooms due to the presence of separate sensors. Using this information, the AC temperature can be controlled in the living room. The orchestration bundle which is very responsible for the ambient to occur is shown in Figure 6.7. It displays what all packets have been called, how they have registered and how the packets are shutdown.

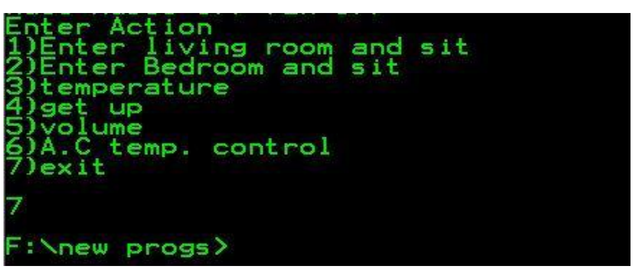

Fig 6.5: Exiting Application

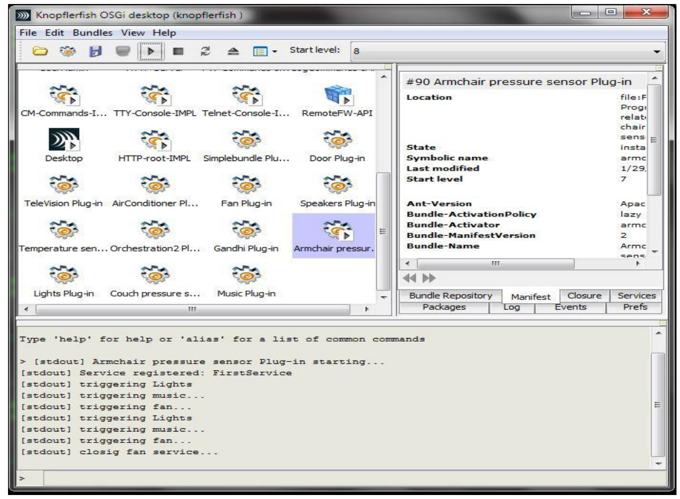

Fig 6.6: Events triggered by the Chair Pressure Sensor

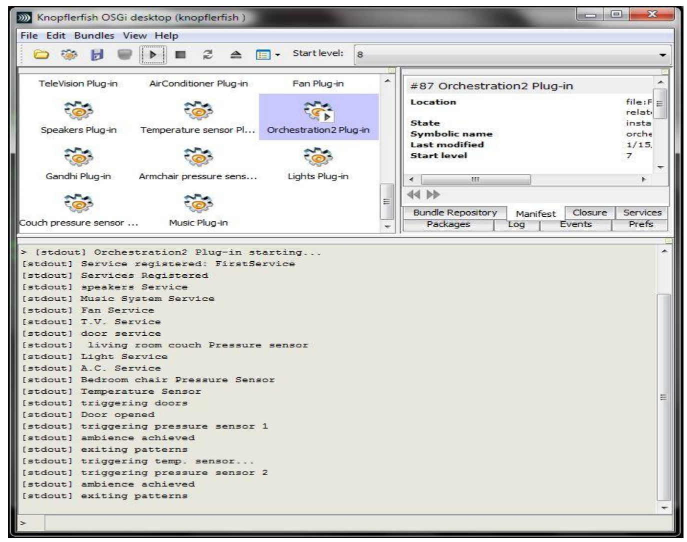

Fig 6.7: Orchestration Packet giving Details of All Actions

6. CONCLUSION

Thus it has a flexible ambient application which not only assists a given single situation but can handle many such situations without manual configuration for each scenario. This will help people accelerate their work and not worry about small manual adjustments to their daily activities.

There are several improvements which can be made to this structure. These services can be made available through the Web by a concept which is known as Device Profile Web Services (DPWS). Through DPWS, all the services can be accessed by the user anywhere outside the house through either his mobile or his computer. He can make the house pre-ready for him to enter.

In this kind of a situation when a device failure occurs, there is no way that the architecture is going to complete the processes leading to a failure notice to the user. This can be taken care of by an intelligent orchestration module. When the system detects a hardware failure, the orchestration can re-route the service to some other path of devices and prompt the user of the failure in the particular hardware. This will then become a fail-safe ambient architecture. Many such small inclusions and tweaks can make this system more versatile in exhibiting its use in the human life. There are several more technologies yet to come which can make human life simpler and more efficient.

7. ACKNOWLEDGMENTS

The author wants to thanks Rengarajan Amirtharajan Assistant Professor / ECE School of Electrical & Electronics Engineering SASTRA University for his valuable guidance and moral support.

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