Smart Home Challenge Problem

1. Introduction

The Internet of Things (IoT) is a topic receiving an increasing amount of attention from industry and academia. One of the most prominent potential applications of IoT technology is the *Smart Home*, i.e., a home featuring a broad range of automated services to make it, e.g., more convenient, safer, or less costly to live in. Smart homes provide their inhabitants with many options for adapting the surrounding environment to his or her personal use, abilities, and needs. A variety of devices and services allow the user to perform a range of tasks including:

- Monitoring the energy consumption globally or for a specific electrical devices;
- Controlling electrical actuators (adjusting the brightness of lights, opening shutters according to the time of the day, etc);
- Collecting data from a range of sensors including temperature sensors, brightness sensors, presence sensors, microphones, etc, and looking for anomalies to, e.g., detect emergencies or optimization opportunities.

An important theme in the study of Smart Homes is **in-home support**: providing individuals who require nursing care, elderly people, or disabled people with the personalised and reliable care services they need in order to live maximally autonomously in their home environment, while giving them comfort and a sense of security despite their handicaps. This support is provided by a customized IoT, potentially requiring human interaction. The challenge is the design of (parts of) a suitable open and customizable software architecture that in concert with appropriate hardware provides this support.

2. Description

A Smart Home has to address a number of security, societal, legislative, economical and ecological challenges and constraints. This part sketches some ways in which the services in a Smart Home could address these challenges.

2.1. Safety and security.

As any other home, smart homes must provide a certain level of protection against unwanted physical access by burglars. But Smart Homes are also particularly vulnerable to cyber attacks and must offer effective protection against them. Security breaches or poor authentication mechanisms may allow hackers to take control of the system or steal personal information. However, compared to classical homes, smart homes can leverage sensors and devices to detect intrusions and respond by alerting, e.g., inhabitants, care givers, or the police, as appropriate. Note that this functionality could also be used to protect the home while the inhabitants are on vacation.

Other emergencies could be detected and dealt with in similar fashion. For instance, the mobility of the home inhabitant is often so compromised that they cannot get up after a fall; data collected from sensors, microphones, or cameras could be used to automatically detect the fall and request help accompanied by relevant information such as location of the fall and the person's vital signs. Similar responses could be initiated after certain medical emergencies such as heart attacks, strokes, or seizures.

Another important concern of Smart Homes is that the information collected is stored safely and securely and in a way that prevents the violation of any privacy or confidentiality rules to an acceptable degree. This concern is exacerbated by the fact that the software architecture of the Smart Home may, essentially, be that of a distributed system that allows some remote parties not only to connect, but also to collect data and exert a certain amount of control. Measures must therefore be taken to ensure that, e.g., proper authentication, encryption, monitoring, and data storage techniques are employed.

A related concern is that system reliability should be sufficiently high. In cases where critical functionality is lost (e.g., due to software bugs, broken hardware, power outages), adverse effects should be kept to an acceptable level and not, e.g., jeopardize the health, well-being, and assets of the inhabitants. The system should take, or at least support, mitigating or correcting measures as appropriate.

2.2. Accommodations to physical, medical, and mental restrictions of inhabitants.

A Smart Home should be able to adapt to the physical, medical, or mental restrictions of its inhabitants and to provide appropriate accommodations to them to ensure a safe and convenient living environment. Examples include voice controlled appliances (e.g., telephone, TV, coffee machine), height-adjustable cabinets, warning or auto-off functionality for stoves that have been left on, and warning or auto-lock functionality for doors that have been left open. Inhabitants with dementia or Alzheimers could be supported in the completion of certain tasks through suitable, automatically given cues and reminders provided by audio or video. Anomalous, potentially harmful behaviour such as leaving the home at an usual time or for an unusual duration could be detected. Moreover, violations of important rules specifying, e.g., a healthy diet or the proper timing and dosage of medication could be detected, and used to trigger appropriate action.

Finally, there is significant potential to leverage data mining or learning to allow the Smart Home to identify its inhabitants' habits, schedules, preferences, and changing physical or cognitive abilities. This information could be used to adapt the home to reduce costs without compromising comfort (by, e.g., keeping unused rooms at a lower temperature in Winter), to increase safety (by, e.g., facilitating the detection of unusual behaviour), or to support care givers (by, e.g., providing information supporting a diagnosis or indicating an improvement or deterioration of a medical condition).

2.3. Environment and economy.

Smart Homes should be energy efficient to meet local laws and regulations governing energy consumption, but also to reduce costs in general. The reduction of room temperature when inhabitants are sleeping is one example. Moreover, a smart home might also be able to leverage information about the behaviour of its inhabitants to, e.g., reduce the use of heating or air conditioning in rooms that are expected to be unused for a sufficiently long time. Remote temperature control would allow inhabitants to adjust the temperature while on vacation or during an unexpected trip. Automatic blinds could be used to help heat or cool the home while inhabitants are absent. If appropriate, certain appliances with high energy needs (such as washing machines, dryers, and dishwashers) might automatically schedule their operation to 'off-peak' times with lower electricity rates.

But, apart from reducing energy consumption, a Smart Home of the future is also likely to contribute to the production of energy. Solar panels and wind turbines might automatically charge batteries in the home or in the car. Warm water could be produced by a solar water heater. Information from local weather forecasts could be used to optimize energy storage capacity and cost savings given certain expected usage demands.

3. List of requirements

A list of requirements for the Smart Home challenge problem is provided below. The list is not exhaustive and it is not mandatory to satisfy all of the suggested requirements. Additional requirements can be defined as well. Each requirement below is numbered so it can be referred to easily.

ID	Category	Description
SH_01_010	Security	The Smart Home must support prevention and detection of unauthorized physical intrusion.
SH_01_020		The Smart Home must support prevention and detection of unauthorized computer intrusion.
SH_01_030		The Smart Home must provide an identification-based access control system.
SH_01_040		The Smart Home must call the police station in case of burglary or any other unauthorized intrusion.
SH_01_050		The Smart Home must be able to detect signs of fire and call the fire station in case of suspicion of fire.

SH_01_060		The Smart Home must be able to detect certain medical emergencies (e.g., accidents, falls) and call an ambulance.
SH_01_070		The Smart Home must allow physical access to emergency services (firemen, hospital service, etc.).
SH_02_010	Accommodation	The Smart Home must accommodate physical, medical, and mental conditions of the inhabitants.
SH_02_020		The Smart Home must accommodate specific preferences entered by the inhabitants.
SH_02_030		The Smart Home must learn from the behaviour of inhabitants.
SH_02_040		The Smart Home must assist inhabitants with certain everyday tasks.
SH_02_050		The Smart Home must be monitorable via a central interface located in the main room.
SH_02_060		The Smart Home must support the authorized connection of smart devices of the inhabitants.
SH_02_070		The Smart Home must have a bed that accommodates to the disability of the inhabitants.
SH_03_010	Economy	The Smart Home must be energy efficient.
SH_03_020		The Smart Home annual consumption should be less than local regulations.
SH_03_030		The Smart Home must support the production and efficient use of energy via solar panel, wind turbines, etc.