Smarter Home middleware between SDPVnext and Apple Homekit

Bachelor Thesis

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by

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Author's declaration

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Stuttgart, August 30 2015

_____ Andreas Rau

Abstract

Background:

Concept:

Conclusion:

keywords: Smart environment, evaluation

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1 Introduction

1.1 Topic and Motivation

The term IoT is around for more than two decades. The concept of a smart device beeing connected to the internet was realized by four students of the Carnegie Mellon University by modifying a coke vending machine to be able to report it's inventory and temperature in 1982 (Martellaro, 1990). Several companies have started their IoT approaches among them Microsoft's "At work" and Novell's "Nest".

The concept of IoT became popular in 2002 when Paolo Magrassi introduced MIT's RFID and internet of things technology to the industrial and business world (Magrassi, 2001). The idea of identifying and connecting every device possible to control and manage them over a centralized computer has driven IoT to todays understanding of smart devices (Magrassi, 2002).

Smart Home is one application of IoT. Beeing able to monitor and control the mechanical, electrical and electronic systems independent of your location offers new oppurtunities in terms of security and economization.

As of 2014 smart home arrived at the average user by using the possibilities of smart phones to control your smart devices at home (McLaughlin, 2014).

A lot of movement in the IoT and Smart Home sector is going on right now. Smart Home is a great opertunity for startups to develop innovating products that "push the boundaries of smart" (“In The U.S. Smart Home Market, Don't Rule Out China,” 2015). Established companies like Samsung and Google seek their dominance by acquireing these startups and integrate them into their own product line (“In The U.S. Smart Home Market, Don't Rule Out China,” 2015).

presentation of the problem Current systems may have problems with connectivity or setup time and frequency ("Why Is My Smart Home So Fucking Dumb?" 2015). However another big issue is cross compatibility when it comes to connect **all** of your home. It seems that hardly any company or vendor makes the approach to be able to connect or controll devices of the competitors in a suitable way. This is the part where this thesis turns up the heat. The content of this thesis deals with smart home solutions and their cross compatibility. First of all basic definitions are clarified then theory is build up to emerge in a middleware solution which connects multiple vendors smart home solutions.

1.2 Limitations

In the course of this bachelor thesis the middleware solution is limited to the guidlines of given systems. In other words the systems that have to be connected by a middleware are economically chosen by IBM. On one hand there is IBM SDPvNext which suits more or less a user management role for devices that are registered in the IoT Foundation which stores devices and their configurations in a database Mielke (2015). At the time this paper is published SDPvNext will be integrated in the IoT Foundation Platform and be extended by an authentication layer (PatriziaGufler, 2015).

On the other hand there is Apple HomeKit, a relativly new approach on Smart Home. Where Apple is relying on local databases for device information storage as well as waterproof communication encryption with multiple security layers McLaughlin (2014) evaluated amongst other systems on the market in clause *Measurements*. IBM SDPvNext is a more basic approach Mielke (2015). This thesis will not cover explicit code explanations on the given solution nor specific programming lan-

guage explanations, more describing the idea and the technique used to solve the given problem. However the code can be easily reproduced with the given explanations of what is done and some basic programming skills.

Futher the psychological significance of a home is not considered in this paper. Never the less the state as well as changes of a home has a strong influence on behaviour, emotions and overall mental health *Raising young refugees' voices in Europe and beyond* (2008).

1.3 Goals

The goal of this thesis is to define measurements for a suitable smart home environment in the eyes of the user. Cross compatibility of vendors and devices as well as minimalism in the amount of extra hardware is valued. Further current systems are rated and two concepts of a middleware connecting multiple natively non connectable systems are developped and rated for further realization. The better solution is implemented and also rated.

Due to the given constraints an implementation of the scheme is not needfull to call this thesis successfull.

1.4 Tasks

The following tasks are written down in an artistic way which suits the creator of TEX Donald E. Knuth and its favour of describing programming as an artform (Knuth, 1998). At first terminology is declared to provide a consistend base for further argumentation. By specifying Smart Home measurements the solution gets its outlines. Thirdly a weighted overview of the functionality of every involved system and technology is given to provide the colors that will fill in the outlines. Last a solution is drawn with the technologies discussed earlier.

2 Theory

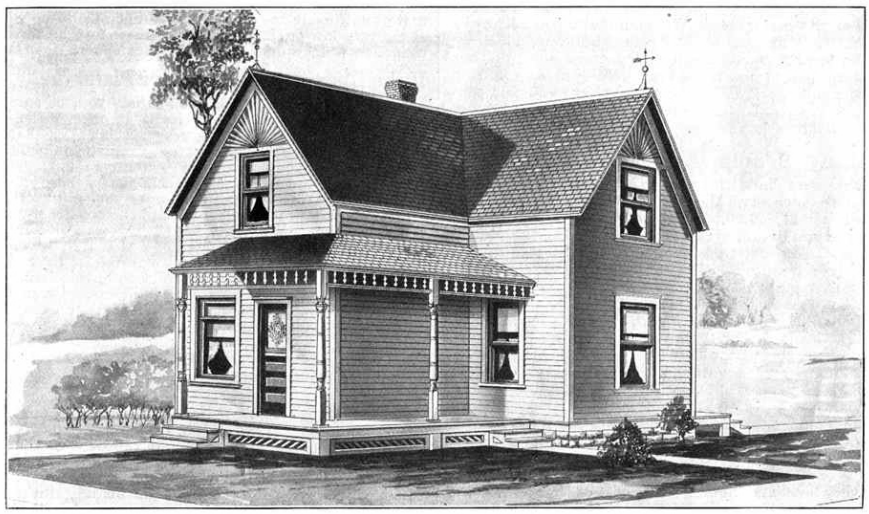
2.1 Smart Home

There is a neccissity to provide a sweeping substantiated knowledgebase in order to develop smart home middleware. Hence basic terms like *home* have to be defined which later build up the basis for justification on decision taking in the development process.

2.1.1 What is a home?

The general definition of a home *the place where a person (or family) lives (*Webster's New World College Dictionary*, n.d.)* is not sufficient enough for the domain of smarter home. Due to this fact information on the term *home* is collected and used to create a suitable definition.

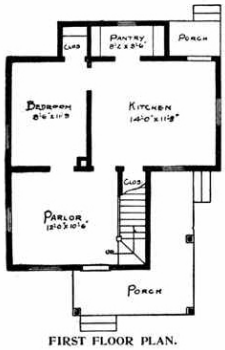
The famous citation of Louis Sullivan *form follows function* further used as *Sullivans rule*, originally altered from papers of nature obversation where Horatio Greenough came to the conclusion that form only changes if function changes (Sullivan, 1930) also applies to buildings such as homes. The following figure shows a plan of a house where every room has its specific functions assigned to it:



MODERN HOME No. 115

With Wood Foundation, Not Excavated.

On the opposite page we illustrate a few of the materials we specify on this, our $725.00 house.



FIRST FLOOR PLAN.

The arrangement of this house is as follows:

FIRST FLOOR.

Parlor - - - 12 feet by 10 feet 6 inches
Bedroom - 8 feet 6 inches by 11 feet 9 inches
Kitchen - - - 14 feet by 11 feet 9 inches
Pantry - - 8 feet 2 inches by 3 feet 6 inches

SECOND FLOOR.

Front Bedroom, 8 feet 3 inches by 10 feet 6 inches
Rear Bedroom, 8 feet 6 inches by 11 feet 9 inches
Large Attic - - 14 feet by 11 feet 9 inches
All bedrooms have roomy closets.

Size: Width, 24 feet; length, 28 feet, exclusive of porch

SECOND FLOOR PLAN.

Figure 1: social functions for rooms

Since the function of a home is in general a place to live and the question of life is a little to complicated to clarify in this paper, more general abstractions are defined to meet the daily approaches on living. The National Institute of Schooling started an approach on naming the functions of a home:

- Protective
- Economic
- Religious
- Educative
- Social
- Affectional
- Status-giving

(**homeFunctionality**)

These functions are the root for further more complex and current *daily needs* like .

Religious, Educative, Affectional and Status-Giving functions are not considered as neccessary for a good smart home implementation and therefor not applied later. Further a home is a geographical location like a city or suburb and used as a permanent or semi-permanent residence, whereas transistory accomodations (hospital, prison, college, etc) are not considered as home but in the scope of smart home.

2.1.2 Smart Home Use Cases

Smart Home Use Cases are pretty much bound to the Services that are run. So in the following table some Services are provided as Use Cases:

Table 1: Homekit Accessory Profiles

Services	**Characteristics**
Garage door openers	Power state
Lights	Lock state
Door Locks	Target state
Thermostats	Brightness
IP camera controls	Model number
Switches	Current temperature
Custom	Custom

These services represent actions that can be performed with the help of smart home devices. A more general way of describing use cases for smart home is done by naming the functions it has to serve in order to accomplish the given actions.

2.1.3 Definitions: Smart Home - IoT

To get an inside view smart home and suitable IoT definitions are shown below:

- **Smart Home** "Smart Home is the topic for technical procedures inside of houseings that are supposed to improve indoor environment and living quality, security and efficient energy using remotely controlled devices."
- **IoT** "the Internet of Things (IoT) refers to identifiable objects and their virtual representation in an Internet-like structure." (Ashton, 1999)
- **IoT** "moving small packets of data to a large set of nodes, so as to integrate and automate everything from home appliances to entire factories." (Raji, n.d.)

- **IoT** “the term commonly is used to signify advanced connectivity devices, systems and services that go beyond machine-to-machine communications, and covers a variety of protocols, domains and applications.” (“Internet of Things - Techcrunch,” 2015)

Smart Home, general things to keep in mind The following list is an aggregation of the previous definitions:

- improvement of indoor environment and living quality
- improvement of security
- improvement of energy efficiency
- devices are remotely controlled
- devices are identifiable objects and have a virtual representation
- actions are automated

2.1.4 *Feature-ism*

Computing power hasn't increased much since 2010, a more stagnating trend is visible. Companies like Intel are improving power consumption instead of computing power because there is a physical end, namely the size of transistors can't get any smaller. The idea is to scale in width rather than heigth, which means more cores instead of more power (Chacos, 2013).

So we have come to the point that the everyday user is used to the fact that computing power won't increase drastically anymore (Chacos, 2013).

To keep the users buying and attracted to new hardware tricks have to be played. Samsung and many others know the path of feature-ism to keep the users attracted to their devices. Every year all new features that

"revolutionize" the user experience are thrown into the market and cause technological entanglement (Machine, 2012). New feature are always "cool" to show them to your friends, but longterm thoughts suffer. Users are "often enticed by the lure of interesting and exotic technologies that look like fun, but in the end, they don't serve us very well for what we want to achieve."(Machine, 2012) John Martellario, a writer for the MacObserver mag, states that: "there is only a proper, considered subset of all the available technologies out there that are required to get any specific job done." (Machine, 2012) With that idea in mind and combined with the Sullivans rule minimalism in technology is what makes it usefull and good.

Later on measurements are also taken on futureproof-ness because its aimable and neccessary to create a worthwhile user experience (Machine, 2012).

2.1.5 Mapping of Smart Home and basic home functions

There is little information about valuation methods for IT systems in the internet that cover topics like usability for the user and extensability as well as futerproof-ness, but dozens of financial valueing methods. Due to this fact the definitions of smart home are aggregated and mapped to the basic functions of a home in order to provide usecases for a propper valuation.

2.1.6 Final Measurements

These smart home functions have to be mappable to basic home functions. Due to the fact that device functions do not change when replaced by smart home devices, the amount of set up and carry on work should be as low as possible: *minimalism.* Moreover *Where function does not change, form does not change (***SullivansRule** *)*, implies that the absence of

Table 2: Mapping of Smart Home services to basic home functions

Smart Home	**home functions**
Indoor environments	Economic and Social
Living quality	Social
Security	Protective
Energy efficiency	Economic
Remotely controlled	Protective and Economic
Identifyable devices	Protective and Economic
Automation	Protective and Economic

minimalism namely extra hardware is negatively valued. A switch is still a switch and shouldn't need to be connected to extra hardware in order to work. Smart Home devices are costly and therefor should be future-proof and not fall into the garbage whenever a new version hits the market.

For economic reasons costs of requiered hardware, installation and maintenance have to be considered. Due to the fact that IBM doesn't provide homegateway hardware, costs have to be roughly evaluated from current systems on the market not considering the purchase price. Overall costs are mapped to two different categories. First a familiy with two children, secondly a single household and later on given by costs per person. In the case of the family the costs are distributed to the parents without charging the kids.
The following list shows all measurements that are considered in this thesis:

- security
- smart home functions
    1. feature-ism
- cross compatibility

1. sullivans rule / minimalism
2. futureproofness

- costs
- other

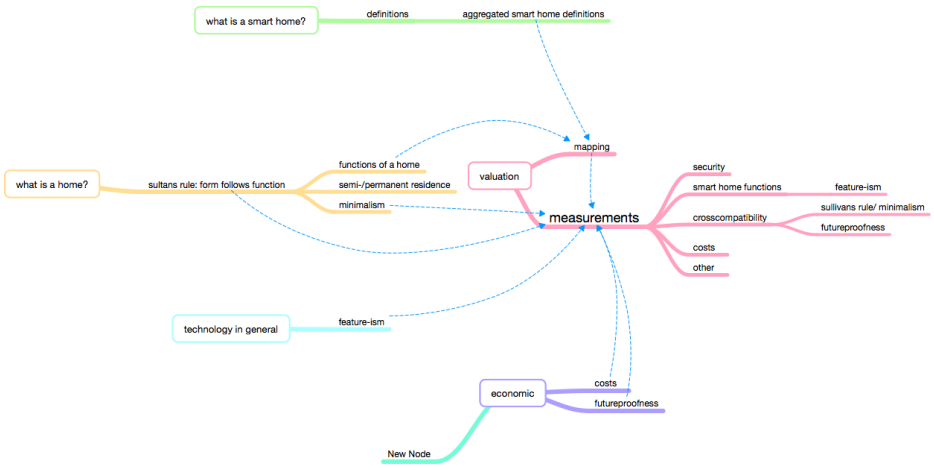


Figure 2: Overview of Smart Home measurements

2.2 Current Systems

In the scope of this thesis more familiar and emerging smart home solutions in the sheer flood of vendors are discussed. Therfor the selection of vendors for a basic analysis are the following:

2.2.1 Apple Homekit

Overview Apple builds up its functionality on two radio systems: WiFi and Bluetooth Low Energy. Where all HomeKit enabled devices connect directly to an iDevice there is also a possibility of connecting a HomeBridge which serves more radio and cable systems in order to connect more decent devices. Since version 2.0 HomekIt comes with the possibility of using the Apple TV as a tunnel to the internet. All iDevices that are registered to the same Apple ID can communicate to each other for a home automation interaction. Further approaches do not rely any more on the Apple TV. Third party HomeBridges are enabled to take communication over the internet. The iCloud itself will serves as a switchboard where iDevices can communicate to all HomeKit enabled ones. Currently there are no news on a car connection or further approaches into smart cars.

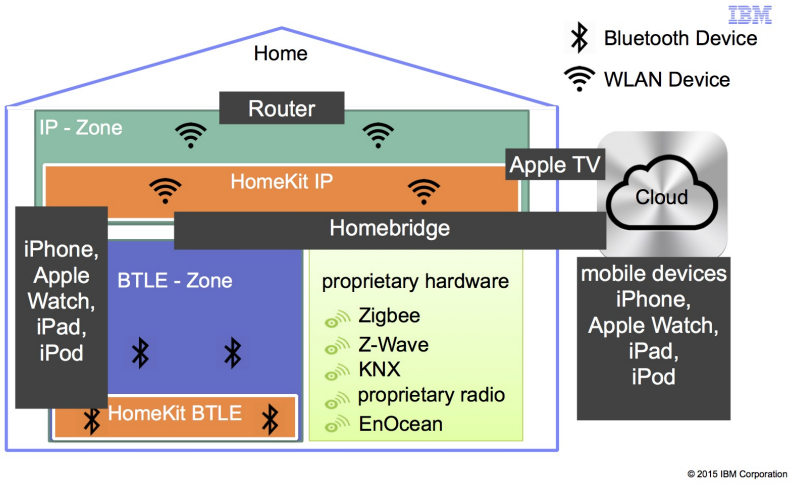


Figure 3: Overview of the functionality of Apples HomeKit

2.2.2 Samsung Smart Home

Overview Samsung Smart home solution provides connectivity between all connected devices at home with a single app that can be accessed from smart phones, tablets, tvs and watches. Further information about Samsungs Smart Home solution is rare but three key features are explained below:

Device Control Device Control allows the user to interact with several home devices. Moreover voice control is implemented and enables the possibility to use special phrases like "I am leaving" to trigger predefined actionsets like turning of the ligths, the air condition and start the cleaning robots (Pochanke, 2014).

Smart Customer Service The Smart Customer Service notifies the user whenever a smart device needs to be cleaned or repaired (Pochanke, 2014).

Home View Home View is considered as a sort of home surveillance system featuring connected cameras to monitor everything happening at home (Pochanke, 2014).

It shoould be mentioned that at the current state only devices out of Samsungs own productline are supported for smart Home purposes. Never the less Samsung claims third party support witch the aid of its Smart Home Protocol (Pochanke, 2014).

2.2.3 SmartThings

Overview SmartThings started as a kickstarer project and was acquired by Samsung in 2014. The idea behind it is a combination of a hub and an app. The hub provides the interconnectability to other devices and aggregates communication for the app. In other words the app can talk to devices from multiple vendors. This is made possible by supporting additional radios compared to HomeKit and Samsung Smart Home namely Zigbee and Z-wave. A big downside is the absence of voice control. Only with more or less elaborate workarounds it is possible to control your devices with your voice ("SmartThings: Security Issue," 2012).

2.2.4 Google Smart Home

Overview In 2014 Google acquired the Smart Home specialist Nest with its productline consisting of a thermostat (Nest Thermostat) and a smoke sensor (Nest Protect) (“Nest: Erstmals neue Smart-Home-Geräte seit Übernahme durch Google,” 2015). After nearly one and a half year of silence in googels smart home sector Nest revealed the Nest Cam, a 1080p smart home connected camera. for additional $ 10 per month the user acquires the ability to review video material of the last 10 days as well as getting notifications from nest whenever suspicious activity is detected.

Brillo "Brillo extends the Android platform to all your connected devices, so they are easy to set up and work seamlessly with each other and your smartphone"(“Google Developers - Brillo,” 2015). With Brillo comes Weave which serves a consistent api for device communication. An instant communicaiton with Android is guaranteed by the developers at google (“Google Brillo und Weave: Ein Android fürs Internet der Dinge,” 2015). The bedrock of Brillo is a downscaled version of Android supposed to run on systems with low hardware specks like smart home devices (“Google Brillo und Weave: Ein Android fürs Internet der Dinge,” 2015).

2.3 Battle for Standards

2.3.1 HomeGateway Solution

Insteon, Lutron and many others compeeting in the HomeKit market aren't developing dedicated devices to connect to Apples Smart Home solution. The common answere is a bridge wich serves as an allocator for connecting existing smart home devices. Where Elgato is the pioneer with it's EVE series on dedicated devices.

2.3.2 Radios

Where the market in the industry is ruled by radio systems like zigbee and z-wave, the smart home segment is more common radio systems frinedly by using widely spread technology like WiFi and Bluetooth Low Energy.

2.3.3 Cross Compatibility

It doesn't matter how good every single solution on smart home is on it self. For many users the usage and the installation of multiple vendors solutions is difficult. So cross compatibility is desirable. Approaches on this topic are mearly solved with bridges that are able to connect more devices to an existing platform than it actually supports.

2.3.4 Fog underneath the Cloud

These bridges have to have more logic components than end devices in order to prefilter information and handle communication over different radios. An innofficial term for that kind of technology is the fog. The fog itself stands for logical pre computatiion before pushing information to

the cloud.

2.3.5 Market Dominance

The market domincance is at the moment not important because there is no standard in smart home communication. When thinnking back to the early ages of the internet a top dog like http and ip where only possible by defining standards.

2.3.6 User VS Company

It remains the question if the user drives the development of new smart home technology or the companys do.

2.4 Technologies

2.4.1 HomeKit enabled

Lutron Electronics Lutron Electronics, a company born when electricity was rare and lightbulbs were generating that much heat that they were rather used to boil some eggs than to read a book at night. It's founder Joel Spira was a pioneer in dimmable lights, a technology former only known in theatre. Spira liked the idea of saving energy and money by dimming lights. 1959 he filled out his first patent of a dimmable switch which would fit into a wallplug, revolutionary at that time. Nowadays Lutron holds over 2,700 worldwide patents, one of them is a window shading technology ("Lutron History," 2015). In 2015 Lutron steps into the HomeKit Smart Home area by revealing new bridge which can be controlled over an iOS app as well as Siri and Apple Watch. All existing caseta and caseta wireless devices can be connected over the bridge.

Insteon Technologies Insteon Technologies is a home automation company which was founded by Joe Dada in 1992 and has coined the term Smart Home. In January 2015 Insteon announced a gateway (bridge) to allow an interconnection with Apple's HomeKit system.

Elgato Eve Elgato started with Eve it's HomeKit compatibility, where all devices are equipped with Bluetooth Low Energy to connect directly to an iDevice like the iPhone.

2.4.2 Non-HomeKit

Raspberry Pi There are multiple HomeKit Accessory Bridge implementations for the Raspberry Pi including HAP-Java, which relies on the

reverse engineering work of Alex Skalozub.

Belkin WeMo Belkin WeMo is a series of lights, switches and sensors that come with a dedicated app. Control takes place over WiFi where nearly every device is able to connect itself to the local network.

2.4.3 Radios

Belkin is more the home approach for an automation where zigbee and z-wave are more top dogs in the industry.

Zigbee Zigbee is a specification for low powered radio devices which are used for small data rates, perfect for home automation.

Z-wave Z-wave itself is pretty close to Zigbee.

Bluetooth

WiFi

2.5 HomeKit and SDPvNext

2.5.1 Apple HomeKit

Apple Homekit is an API developed by Apple. A common database stores all home information to provide consistency and is available to all Apps. Users can use Siri to interact with their home accessoiries. Homekit also provides remote access and uses end to end encryption between iDevices in order to maintain user privacy and security (McLaughlin, 2014).

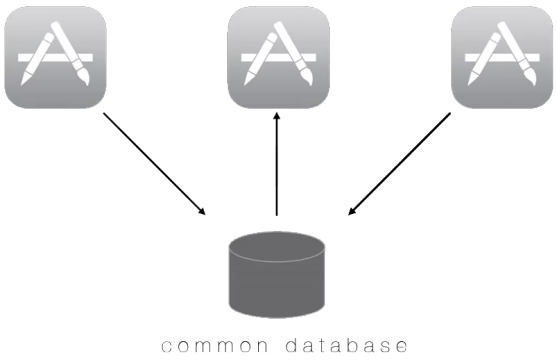


Figure 4: All of the home information is made available to all Apps by a common database provided by Homekit (McLaughlin, 2014)

The Home Manager is the entry point for all apps. With the help of the Home Manager changes to the database are made. Homes can be added or removed and will notify the user in case of changes (McLaughlin, 2014).

The organigram used by Homekit is build up by **Homes**. Homes create their own namespace and have to be named uniquely, contain Rooms and Accessoiries. Rooms have to be named uniquely in their Home domain. (McLaughlin, 2014)

An Accessory corresponds to a physical device and is assigned to a Room. Accessory Objects allow to access the device state (McLaughlin, 2014).

Services represent functionality of an Accessory and are like parameters you can interact with. Services may have a name because some Services are not ment to interact with a user(update firmware). Services are a collection of **Characteristics** like range or units, e.g. the power state of a lighbulb Service. (McLaughlin, 2014).

Characteristics can be of a fiew variety:

- read-only - e.g. the current temperature
- read-write - e.g. lightbulb power state
- write-only - e.g. identify accessorie

Homes, Rooms, Accessories, Services and Characteristics are recognized by Siri and can therefore be accessed without a direct interaction with an app, making the use of Homekit very comfortable. Services have Apple defined types, that can be accessed by natural language like synonyms or expression that do not exactly refere to the correct name provided to the Service making interaction experience more natural like. (McLaughlin, 2014).

The Accessory Browser is used to find any new Accessories available and is used to add them to a Home. When it is added to a Room it's time to name the Accessory and assign it to a Room (McLaughlin, 2014).

Initial setup workflow:

- Create a Home - User provides name

- Add Rooms to the Home - User provides names
- Add Accessories - Use an Accessory Browser - add Accessory to Home - User provides name - User chooses Room
- interact through application and/or Siri

A natural way of refering to Accessories in a Home is done by grouping. Apples Homekit enables the user to group Accessories in several ways, name them and provide access to Siri (McLaughlin, 2014).:

Zones are arbitrary, uniquely named groups of Rooms e.g. *upstairs*, where Rooms can be in any number of Zones and are recognized by Siri (McLaughlin, 2014).

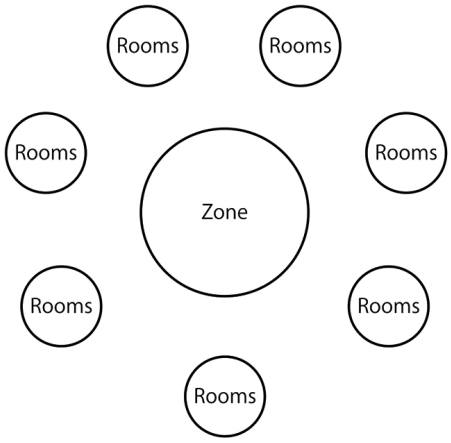


Figure 5: Zones (McLaughlin, 2014)

Service Groups are arbitrary, uniquely named groups of Services and are a convenient way to control Services across accessories e.g. *nightlights* (McLaughlin, 2014).

Actionsets Collection of actions that are executed together in an undefined order, e.g. *night* (McLaughlin, 2014).

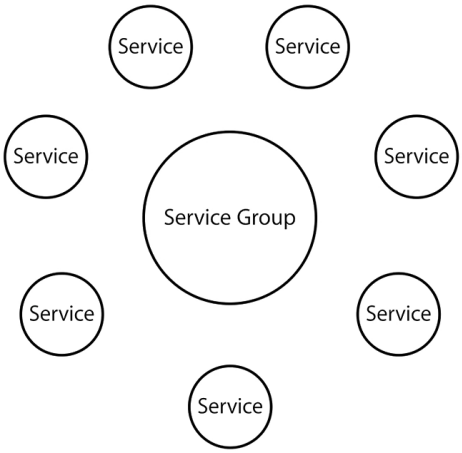


Figure 6: Service Groups (McLaughlin, 2014)

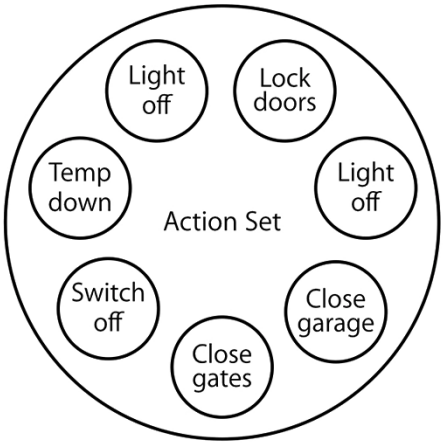


Figure 7: Actionsets (McLaughlin, 2014)

2.5.2 WWDC15

Security All communication between the Accessories and Apple HomeKit are end to end encrypted. Moreover Keys for encryption are changed after each session. Keys are not able to decrypt data from the past or the future. All data is encrypted using keys that are local on the device which ensures privacy of data. Further on administrative features for user management are added.

Maintain Existing Objects In order to guarantee uniqueness of Accessories, Apple has introduced a unique identifier (NSUUID) in iOS 9.

Predefinded Scenes are scenes that occure in a regular every day cycle. Apple has provided some standard scenes like:

- Get up
- Leave
- Return
- Go to bed

Moreover these predefined scenes can not be deleted but customized and are recognized by Siri. These scenes are managed actionsets, as known from iOS 8. Visual clues are information that are added by an Accessory Category.

Apple Watch Homekit is now available on watchOS2. All the home data is mirrored on Apple Watch. Homes can be viewed, Accessories can be controlled and scenes can be executed by hand or over Siri.

Event Triggers Scenes that are executed at specified times of the day are known from iOS8. Events respond to the state of an Accessory or location based events by using geofences. Furthermore Events can be triggered:

- Time-based
- Significant events like:
- Surise
- Sunset

Time based triggers can be used in a natural way. One way to use them is to specify a time-based trigger to fire after 6pm another to trigger on Sundays. Every trigger can be used in logical addition. To tie it all together every trigger has an associated scene which will be executed when the trigger is fired.

Remote Access alllows the user to control their Accessories even if they are not at home. In order to get access to that feature the user needs an Apple TV 3rd gen. Verification is done by using the same Apple ID on both devices. For users without an Apple TV remote access is managed with the *Homekit Accessory Protocol (HAP)* over iCloud. This means that you can controll your Accessories and get notifications without an Apple TV, no matter where you are. The HAP runs on a dedicated iCloud service in order to scale with good performance. The access to HAP over iCloud is free for developers.

Bluetooth Low Energy The distance to an Accessory is cruciul in order to control it over BTLE. Devices that are to far away from the user can not be controlled. A secure connection is possible in iOS9 by HAP secure tunneling provided by an intermediate device. The Accessory is connected over BTLE to the intermediate device which is then exposed as an Object over WiFi. The range extender will also be able to provide remote access to all connected BTLE Accessories that works with HomeKit. To ensure privacy the intermediate device can not see the content of the HAP protocoll.

Notifications BTLE Accesssories fully support notfications and metadata for custom characteristics. Notifications transported over different

channels are recognized by the iDevice featuring iOS9 as redundant.

Programmable Switches are used to map this event to a trigger and execute a scene. This feature is very powerfull and usefull to map an amount of actions to physical switches.

2.5.3 HAP - HomeKit Accessory Protocol

Transports There are two ways to connect Accessories to HomeKit, one is BTLE the other one is over IP.

Security is achieved by *Bi-directional authentication* and *Per-session* encryption.

Bi-directional authentication or Mutual authentication is a technology where both parties involved in authentication are aware of each other. This means that the server is authenticating itself to the user as well as the user is authenticating itself to the server. The term *Authentication* describes the process of confirming identities and is done by verfiying the validity of a client with a digital certificate.

SSL is a "cryptographic protocol designed to provide communication security over a computer network". The way that SSl works is by "authenticating the counterpart with whom they are communicating and to negotiate a symmetric key". "This session key is then used to encrypt data flowing between the parties". "An important property in this context is forward secrecy, so the short-term session key cannot be derived from the long-term asymmetric secret key". SSL is initialized in layer 5 (Session Layer) of the ISO/OSI model and has a handshake using an asymmetric cipher in order to establish cipher settings and shared key for that session.

Afterwards the presentation layer (ISO/OSI 6) is providing the encryption fo the data.

Network

2.5.4 Siri

HomeKit itself is app independent service running in the background like Siri. Siri is Apples own natural language interpreter which is able to answere questions and perform actions on spoken and wirtten user commands. Actions can be delegated to third party webservices like Wolfram Alpha or in the domain of this thesis actions can control smart devices. Apple has logically concatenated the HomeKit database with Siri to enable seamless interaction between both services.

2.5.5 iDevices

Apple TV The Apple TV serves as a tunnel to the outside world in order to access your smart home devices from everywhere internet is accessable.

iPhone The proprietary HomeKit service is running in the background of all iDevices and can be accessed and managed from all iDevices registered to the same Apple ID.

Apple Watch The Apple Watch serves as an external display for iPhones. Further more it is packed with a microphone as well as a speaker which makes the wach perfect for interacting with Siri and your home.

2.5.6 Bluemix

Bluemix is an upcoming webservice of IBM based on OpenStack software where users can create environments to test their code. Several languages are supported among them Java and NodeJS. Further there is a possibility to host an IoT environment called IoT Foundation. This service is backed up with a database and able to connect to IoT Foundation clients of your choice. The clients are devices which are able to connect them selves to the internet and build up an connection to the IoT Foundation - Smart Home devices. Because of the fact that the devices have to handle ip communication its standing to a reason that they mostly serve as home-gateways which are connected to more proprietary smart home devices.

2.5.7 IoT Foundation

The IoT Foundation is the cloud solution of IBM where configured home-gateways connect themselves to exchange information about connected devices.

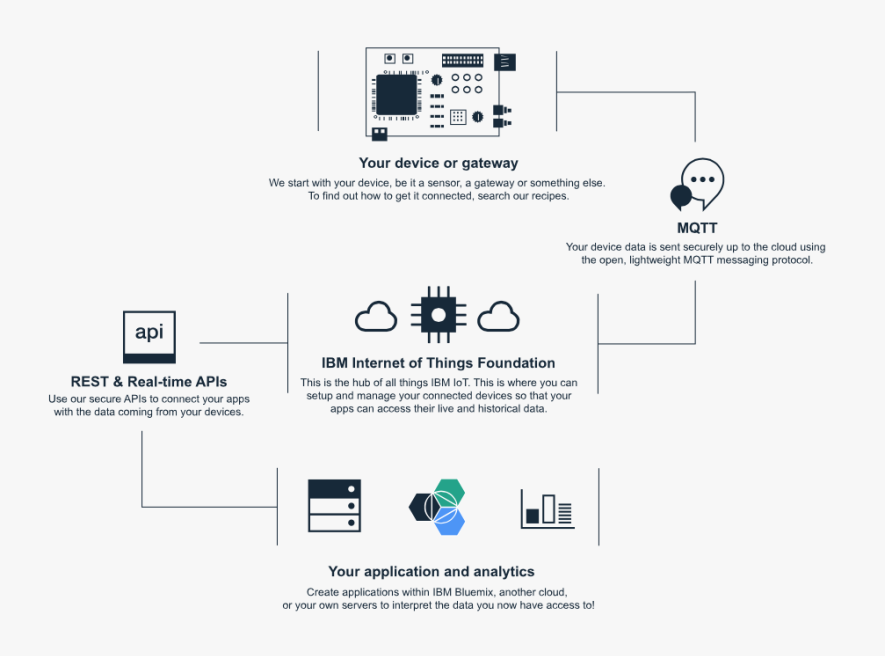


Figure 8: IoT Foundation Overview (“Understand things?” 2015)

2.5.8 SDPvNext Rest API

SDPvNext is the frontend and user management system for the IoT Foundation service. Currently beeing integrated into the IoT Foundation and extending its functionality by adding an authentication layer to it. SDPvNext is equipped with a Rest API which provides basic restcalls to get devices and their configurations.

2.6 Constraints

HomeKit and SDPvNext HomeKit and SDPvNext are the systems to connect in the course of this bachelor thesis and have been chosen by my supervisor.

HomeKit Database Accessability The Homekit Database is only accessable through iDevices, which means that only apps executed on an iPhone, iPad and iPod are able to add new devices to the HomeKit db.

SDPvNext Rest API The given Rest API is limited to only read values in form of states out of the IoT Foundation. Thus restricting interaction with the platform to a unidirectional communication from SDPvNext to the iOS app. It is yet not stated whether adding or removing devices is possible through the rest API.

Apple MFI Due to the fact that Apple is restraining their HAP-Protocol and it's functionality as well as every documentation on it to ensure just MFI certified developers are able to access it, it's nearly impossible to get any information on this topic. Hence this bachelor thesis relies on reverse engineered work from a russian programmer Alex Skalozub.

General This thesis is beeing written from June 1st until Agust 31st 2015. Apple itself released only rare information about the functionality of HomeKit on June 8th. Further more during this period there were no user or professional reviews on HomeKit devices since they just hit the market on 28 of July. Any experiences are gathered through simulation of devices and may not be equivalent or differ to real ones.

2.7 Development Tools

2.7.1 Mac OSX

Xcode Xcode is the standard tool to develop apps for iOS devices.

Hardware IO Tools for Xcode 6 In oder to test the functionality of apps beeing developed Apple makes a good job in simulationg devices. Due to the unavailability of real HomeKit devices the use of simulated ones is mandatory. Apple provides Hardware IO Tools to guarante a testing environment which suits the real devices.

Homekit Accessory Simulator The Homekit Accessory Simulator is used to simulate Accessories and Bridges and acts just like real accessories. By default every Accessory has an Access Informationn Service containing basic information like the name, manufacturer, model and serial number. Bridges are a special type of Accessory that provide the functionality of a Hub, whereas Hubs provide access to Accessories that can't connect themselves directly to iOS. Every Accessory provided by a bridge is listed as seperate Accessory later in order to interact directly with it (McLaughlin, 2014).

2.8 Middleware

Goal The goal of this thesis is to implement a middleware which is capable of communicating with the IoT Foundation as well as the HomeKit database. Changes in either db's should be applied to the corresponding one by adding or removing devices from the databases (for additional information refer to constraints). Further the Apple Watch should be able to monitor and control the listed devices.

3 Concept of Smart Home Solution

3.1 Applying Measurements

The measurements defined in 2.1.4 are applied to Google, Apple and Samsung smart home solutions are compared against each other. SmartThings is a kickstarter project acquired by Samsung but acting on their own and therefor listed seperate.

3.1.1 Some words on trustworthiness

Trustworthiness in smart environments is relying on privacy and security. The Ubiquitous Computing Acceptance Model (UCAM) consists of the three mentioned parts and "explains (a) how privacy, security and trust are linked to one another; and (b) how trust is related with usage intention" (Oliver Sack, 2014). Where simple lightbulb controlls have nearly no security or privacy impacts, devices like doorlocks do. The first approach of most IoT and Smart Home novices is to control their light from any device which is regulary not considered to do so. Managing this first hurdle a new wave of home automation is beeing triggered. Two categories of devices are directly distinguishable:

- sensors
- actuators

Where sensors are used to measure or detect temperature, humidity, daylight or motion, actuators such as motors and switches have a higher risk to do significant damage. Therefor security is valued high amongst other measurements even though smart home solutions consisting only of sensors are possible.

3.1.2 Security

Apple Apple has reveiled its HomeKit Accessory Protocol (HAP) which is explained in 2.6.3. In summary Apple has invested quite some time in developing a fool proof information transport system between the suppported devices. The only downside is that devices need to have more calculation power to provide the HAP security, which leads to lag on non suiting hardware and therefor leads to more expensive devices. Elgato "tweaked the firmware and added additional on-chip memory to handle the heavy-duty encryption" (Rossignol, 2015) to suit Apples requirements. Further all device information is stored locally at home.

Apples security system is valued positive.

Google Google claims secure information transportation between devices both locally and through the cloud over Brillos weave. As well as availability for Android and iOS. No further information about technologies were found in the internet therefor valued neutral.

Samsung Samsung Smart Home solutions dropped 2014 in South Korea and The United States of America (Lohmann, 2014). Information on any security systems implemented by Samsung is hardly to find, maybe because there is none. David Lodge, who works for Pen Test Partners has disclosed some major security flaws in Samsungs Smart TVs (Mottl, 2015). voice data recorded over the Smart TV is send en clair to third party companies as well as facial recognition information on persons standing in front of the tv (Mottl, 2015).

Considering the fact that Samsungs Smart Home solution is sharing its data over the cloud and no adumbration on any security actions nore on it's official website or elsewhere are made, the educated assumption that there is no special security involved can be made.

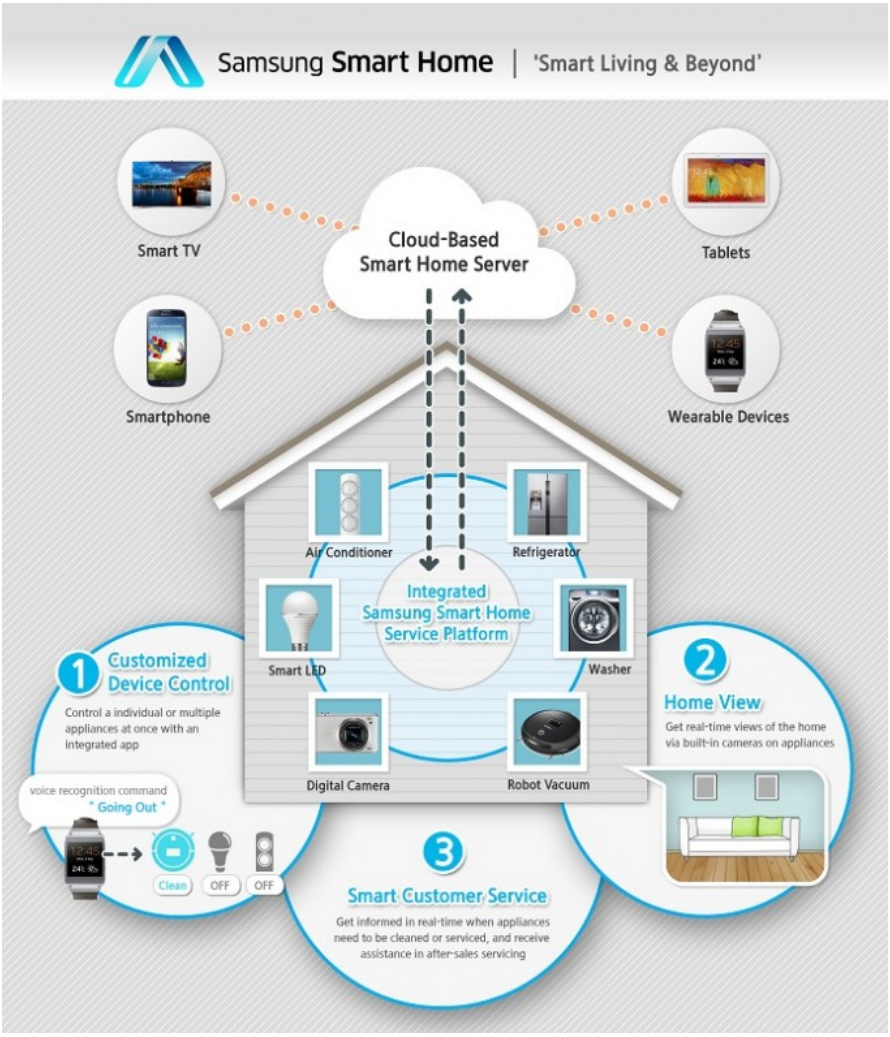


Figure 9: Overview of the functionality of Samsungs Smart Home

Samsungs security system is valued negative.

SmartThings Lately the SmartThings smart home solution experienced a vulnerability with its cloud communication. Data is in general pushed into the cloud and then send to the according app to notify the user about anything happening at his home. This communicaiton is encrypted using Secure Socket Lacer (SSL) standard. Validation of the cloud servers identity on the hub side is crucial for a secure communication, this is exactly where the failure happened. "This means that an attacker with privileged access to a user's home network (e.g. physical access) could have executed a "man-in-the-middle" attack that could have

decrypted the communications between the SmartThings Hub and the SmartThings Cloud." (“SmartThings: Make Your World Smarter,” 2015). This issue was fixed i a firmware update and further a third party security firm was hired to perform penetration tests on the system.Due to the fact that in general an SSL secured server communication is guaranteed and the security breach was fixed immediatly with non affirmed user exploits and the fact that smarttings will head off the cloud (“Smart Home: SmartThings wendet sich von der Cloud ab,” 2015). Further zigbee and z-wave are encrypted radios. Therefor smartThings is valued positive.

inter-resume With safety in mind Apple is way ahead of other systems like Samsung. Samsung lacking in security is thrown out of the competition at first. Smartthings uses in general secured communication but currently stores all data in the cloud (“Smart Home: SmartThings wendet sich von der Cloud ab,” 2015).

3.1.3 Smart home functions

Apple Apple build up a reliable security standard with the sideeffects of hardware claiming software. Hence at the time this thesis is written only few manufacturers have fullfilled Apples MFI programm and only a handfull of devices hit the market. But companies like Insteon are on the right track by providing bridges that connect all of their previously non homekit compatible hardware. Never the less basic functionalities like switches, lightbulbs and environment scanning devices as well as doorlocks did hit the market, fullfilling six out of seven smart home functions and therefor Apple is rated positive.

Google Google covers with it's Nest family consisting of a thermostat, webcam and a smoke sensor relatively small domain of smart home devices compared to Apple, Samsung and SmartThings. Besides the fact that Googles devices comply with five out of seven smart home functions, basic light, switch and doorlock compatibilities aren't fullfilled. Therefor Google gets a negative credit on smart home functions.

Samsung Samsung is connecting it's smart productline consisting of lightbulbs, vacuum cleaners, refridgerators, washers, doorlocks and smart tvs all together in it's smart home solution. This quite rich smart home environment complies with six out of seven smart home functions only lacking in indoor environment controlling. Therefor a positive rating.

SmartTings SmartThings has a wide variety of smart home devices solving nearly every problem you want to solve with your smart home solution as well as problems that didn't even exist before *feature-ism*. Therefor a positive rating.

3.1.4 Cross Compatibility

In this thesis cross compatibility pays special attention to extensibility of systems with third party products. Cross compatibility is valued combining the measurements of the sullivan rule and futureproofness.

Apple In the Apple domain all systems are working like a charm but when it comes to cross compatibility Apple is very puring. Elgato and Insteon are therefor developing a bridge solution to connect their Smart Home pallet of devices which are inherently not able to speak cupertinos language (“Future Proofing Your Smart Home for Apple HomeKit Compatibility,” 2015). Keeping this in mind cross compatibility can be extended to an nearly infinity amount as the bridges are providing connectivity to more proprietary radiso like zigbee and z-wave. Moreover the *sullivansRule* is fullfilled with the standard homekit devices beeing connected over already existing WiFi or Bluetooth Low Energy. When considering bridges which extend the HomeKit domain extra hradware is neccessary, but the benefits overweight the use of one extra hardware:

"Insteon’s offering makes all of their existing products compatible with HomeKit. This means you can already outfit your entire home, from outlets and plugs to thermostats and locks, with devices that will work with HomeKit. That’s something that not very many companies can offer" (“Future Proofing Your Smart Home for Apple HomeKit Compatibility,” 2015).

On the downside currently there is no possibility to connect non Insteon zigbee or Z-wave solutions (“Future Proofing Your Smart Home for Apple HomeKit Compatibility,” 2015).

all in all Apple HomeKit is valued positive.

Google Google drives its cross compatibility with the help of its own IoT operation system Brillo, but their considered system nest, consisting only of a thermostat, a smokesensor and a webcam is not sufficient enough for overall smart home purposes nor fullfilling the smart home functions defined earlier nor in any way crosscompatible, therefor considered negative.

Samsung Samsung has introduced its Smart Home Protocol (SHP) to enable the communication between different home appliances. Further it is intended to enable third party manufacturer to control their devices over the Samsung cloud. Future plans include Home-Energy, Secure Home Access, Healtcare und Eco Home Applications enabled (Pochanke, 2014). Due to the fact that no third party vendors were announced for over a year since Samsung dropped their Smart Home initiative the aibility of cross compatibility is valued less than already available products. Current Samsung smart home solutions are

Samsung is valued negative.

SmartThings SmartTings was developed with wide range compatibility in mind. "Its open system works with a wider selection of gadgets, and developers keep adding compatibility to more devices on a regular basis" (Carey, 2015). The wide variety of SmartTings compatible devices which can be connected to the hub are in parts useless for the daily life and fall into the category of *feature-ism* therefor beeing valued negative. Devices always have to be connected to a hub which doesn't serve the measurement of minimalism, but to keep in mind they are cross compatible to many devices and therefor valued positive. All in all crosscompatibility is valued positive.

inter-resume Further a distinction must be made between smart home solutions like Apple which only provide software in form of services and protocolls for third party companies which then have to implement Apples standards in order to play their part, where Samsung and Google provide their own hardware. SmartThings on the other hand provides software in form of an app as well as a dedicated hub which allows third party systems to connect to. At the time this thesis is written, only Apple and SmartThings provide the aibility to connect devices that are not specifically intended to work with the system. Moreover of the two just Apple HomeKit is out of the box voice controlled. Further more "mature" vendors like Elgato and Insteon provide a hub which provide connectivity of their none homekit productline to control them over the Apple solution. Google with its thin productline loses the cross compatibility race and its non-compliance in the predefined smart home functions.

intermediate result

- Apple +4
- Google -2
- Samsung +0
- SmartThings +4

3.1.5 Cost

All of the compared systems require smart phones in order to send commands and read out sensor data from smart home devices. For the cost calculation these smart phones will not be added to the total costs. It is questionable whether or not smart watches should be considered for the total cost estimation. Due to the fact that they are not required to operate a smart home and just have a subset of functions compared to there big brother phones they are not considered in the computation of costs.

Apple Apple certified smart devices are in the range of 50 to 200 Dollar.

Google Nest device costs are in the range of 99 to 200 Dollar.

Samsung Samsung smart home solutions are pretty cost intensive because their line of devices are regular domestic appliances with a little logic in it to communicate to an app. Therefor cost ranges start at 150 up to multiple tousand Dollars.

SmartThings A smarttings hub costs 100 Dollar.

3.1.6 Extra

Extra points for minimalism are dispends if the smart home solution is providing voice control.

Apple Apple provides out of the box voice control with the help of its spech assistant siri (McLaughlin, 2014). this is a big step into seemless smart home controlling and fullfilling the minimalism criteria. Therefor an extra point for Apple.

Google Google as well provides voice control functionality and gets an extra point.

Samsung

Samsung as well provides voice control functionality and gets an extra point.

SmartTings SmartThings is nativel not supporting voice control, therefor zero extra points.

3.1.7 The Comparison

The points total are shown in the following table:

Table 3: Evaluation of smart home solutions

Services	**Apple**	**Google**	**Samsung**	**SmartThings**
Security	2	0	-1	1
Smart Home Functions	1	-1	-1	1
Cross Compatibility	1	-1	2	2
Costs	X	X	X	X
Extra	1	1	1	0
Overall	5	0	1	4

3.1.8 The Winner

Apple wins the competition hence the solution will be build upon homeKit.

3.2 The Concept

The basic idea of connecting SDPvNext and Apple HomeKit is to write a middleware which is running on a homegateway and providing a connection to SDPvNext as well as pushing the devices with HomeKit meta data into the local network in order to control them over iDevices and Siri. For clarification purposes a graphic of the idea is given:

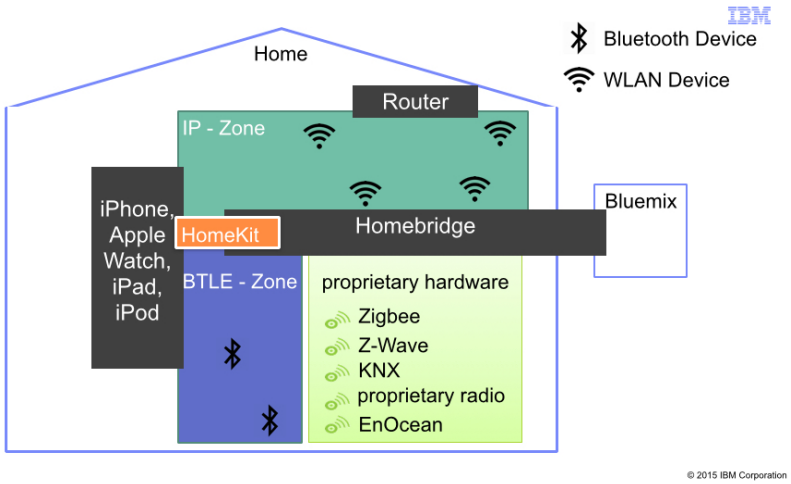


Figure 10: Concept idea

3.2.1 Possible Solutions

Revisiting the graphic of HomeKits functionality, there are two possible solutions for a interconnectivity to SDPvNext marked in blue:

On one hand a bridge equipped with extra software providing non HomeKit, SDPvNext provided devices the aibility to be managed by Apple. On the other hand an iOS app using the SDPvNext rest and homekit api to provide interconnectability between the two smart home solutions.

Bridge Solution

SDPvNext Rest API + iOS App

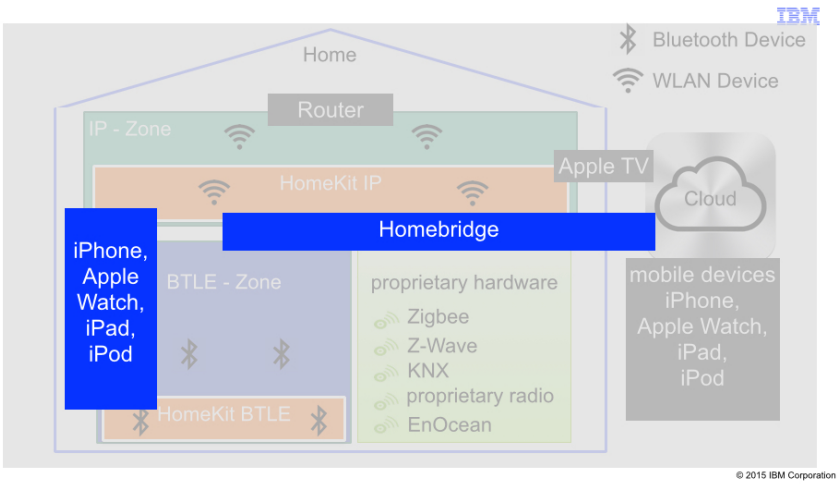


Figure 11: HomeKit middleware possibilities

3.2.2 Advantages and Disadvantages

3.2.3 Use Cases covered

3.2.4 Measurements

The measurements defined in 2.1.4 are applied to the solution in order to value the outcome. **Reliability of Manufactors**

Security

cross compatibility

setup

3.3 The Solution

3.3.1 Design

3.3.2 Implementation

3.3.3 Test

3.3.4 Future Work

4 Summary

4.1 Reflection

4.2 The Result

4.3 Future Work

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Appendix