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Techno-Economic Analysis of Smart Home Hub and Integration Service

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Techno-Economic Analysis of Smart Home Hub and Integration Service

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Abstract— From the perspective of an access network operator, the smart home is an interesting opportunity. Operators have established customer relationships with their existing mobile and fixed broadband offering and view the smart home as an opportunity to create value-added services. Interoperability of smart home devices enables the full potential of smart homes as users are willing to use a single application for all their home control needs. Automation rules are one of the core benefits of smart home and requires interoperability between the devices. Interoperability and the single application as a control method can be achieved with a smart home hub and an integration service. One possible strategy for operators is to provide such hub and service.

To provide a smart home hub and an integration service, operators have to choose how to partner with the hub manufacturers. The paper identifies three alternative ways for the partnership using Value Network Configuration method. To compare those three alternatives, called value network configurations, a techno-economic model is created, focusing especially on costs. Three value network configurations are compared with the model using example input data and a single value network configuration is recommended based on the economic results such as net present value, internal rate of return and payback period in combination with sensitivity analysis. The article also introduces a simple approach for modeling the effect of development time when comparing the value network configurations. With the used input data, the results of the techno-economic model indicate that the operator should choose a value network configuration in which the operator deploys their application but utilizes the hub manufacturer's backend.

Keywords—Smart Home, Value Network Configuration, Techno-Economic Model

I. INTRODUCTION

For network operators, IoT becoming more common represents a huge potential, but also includes risks. For example [1] predicts that the total value of the IoT market will be 11.1 trillion dollars by the year 2025. However, they also predict that connectivity will only represent 5% of the total IoT revenues by 2025. To capitalize on a bigger share of the total IoT markets, network operators are looking to expand their offering beyond connectivity.

Many operators are studying the smart home segment as they are looking for ways to utilize their existing customer relationships and offer smart home devices and services on top of their current broadband offerings. One of the possible

strategies for operators is to offer a smart home hub and a related integration service. The research questions of this study are how should operators partner with solution providers to offer a smart home hub and an integration service, and what are the costs involved in developing and providing a smart home hub and an integration service. The questions are analyzed from the perspective of an access network operator.

In smart homes, a problem related to networking technologies exists. Many homes already have Wi-Fi, but Wi-Fi has relatively high-power consumption [2]. High power consumption means that Wi-Fi is not very practical for battery-powered use cases. However, Wi-Fi is still required in most homes for use cases requiring high throughput, such as media and entertainment. Other networking technologies have emerged to offer a solution with lower power consumption, with the cost of lower throughput. Zigbee, Z-Wave and Bluetooth Low Energy offer the low power consumption required [2]. In the year 2020, it is still not clear if any of the technologies will have a dominant role.

Smart home hubs typically support multiple networking technologies, and, in this study, a smart home hub supports those four aforementioned technologies. Smart home hubs have a varying amount of local processing capabilities, but also require a web-based integration service. An additional benefit of a smart home hub is that it enables users to control all their devices from a single application.

[3] studied the actor roles in indoor wireless coverage, but they didn't focus especially on smart homes and they only present a single option, that network operators should drive for.

In this study, the Value Network Configuration (VNC) method is used to identify three different combinations of roles, called value network configurations, an operator can take in the value network of the smart home. Those value network configurations are compared to each other with a techno-economic model, especially focusing on the modeling of the costs. Combining the VNC analysis with the techno-economic modeling, it is possible to recommend a one of the value network configurations for a network operator.

II. VALUE NETWORK CONFIGURATIONS

The Value Network Configuration method as described by [4] is used in this study. Value Network Configurations consist of technical components, roles and actors. Also, both the technical interfaces between the components and the business interfaces between the actors are presented. Value Network Configurations are used to visualize and create an understanding of how value is created in networks involving multiple actors and what are the possible combinations of roles that an actor can have. VNC method has been used in other studies as well. For example [4] uses the method to describe different configurations in wireless local area access, [5] analyzes industrial 5G with the method, and [6] presents VNCs related to eSIM. The aforementioned [3] uses the method to show an operator driven VNC for both LPWAN and LPWAN.

In this study, three VNCs providing smart home hubs as-a-service are constructed from the perspective of an access network operator. The business roles and their related technical components are presented in table I. The definition for each technical component can be found in the Appendix.

The actors in the value network are a user, an operator, an IoT device manufacturer and a solution provider. Operator term is used to refer to an access network operator, and from the perspective of the analysis, it is irrelevant whatever the operator is offering mobile-only, fixed-only or both types of connections, as long as those are targeted for use as home broadband. IoT device manufacturer refers to a company making the end-device eq. a smart light. The solution provider term refers to the hub provider.

TABLE I. BUSINESS ROLES

Role	Description	Related components
Usage (IoT device)	IoT device either senses or acts.	IoT device
Indoor networking	Creates the needed networks between itself and the devices.	Hub
App provisioning	Developing and provisioning the mobile application.	Mobile application
Usage (smartphone)	Used as a mean to interact with the application.	Smartphone
Integration service	Enables interoperability of devices from different device manufacturers.	Integration server
Account operation	Meditating the access to the backend service.	Authentication, authorization and accounting (AAA)
Data analysis	Creating insights based on data produced by IoT devices.	Data storage
Operations support	Different support processes related to network and services.	Business and operations support system (BSS/OSS)
IoT device service	Provides a backend service for the manufacturer's own devices.	Device manufacturers application server
Network operation	Enabling wide area networks.	Access and core network

A. VNC 1 - Operator driven

In the Operator Driven VNC (see fig. 1), the operator is providing the hub, the mobile application and the backend consisting of the AAA, the integration server and the data storage. The operator is also responsible for operating the access and core network, as well as operations support with the BSS/OSS. The big role for the operator enables big revenues. However, in this VNC, the operator has to work with device manufacturers to create the necessary integrations and thus requiring a lot of work from the operator before entering the market and also having a lot to maintain.

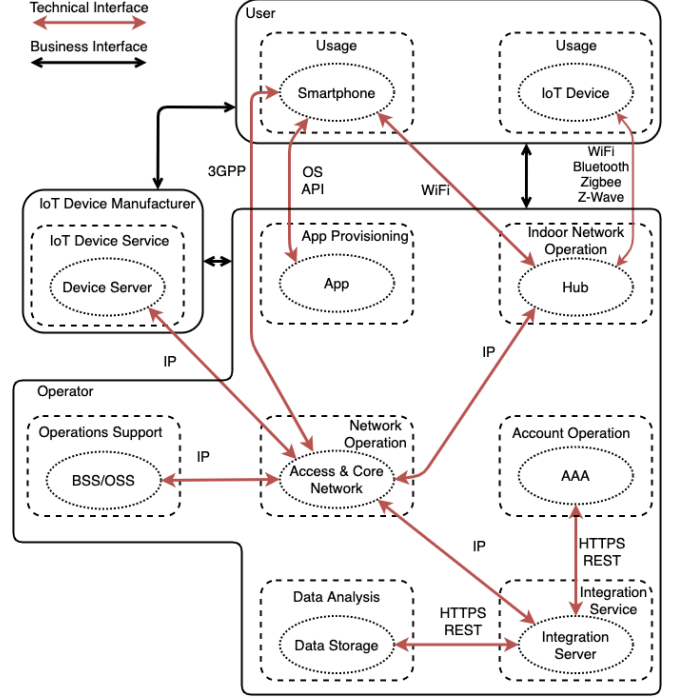


Fig. 1. Value network configuration 1 – Operator Driven

B. VNC 2 - Backend Sharing

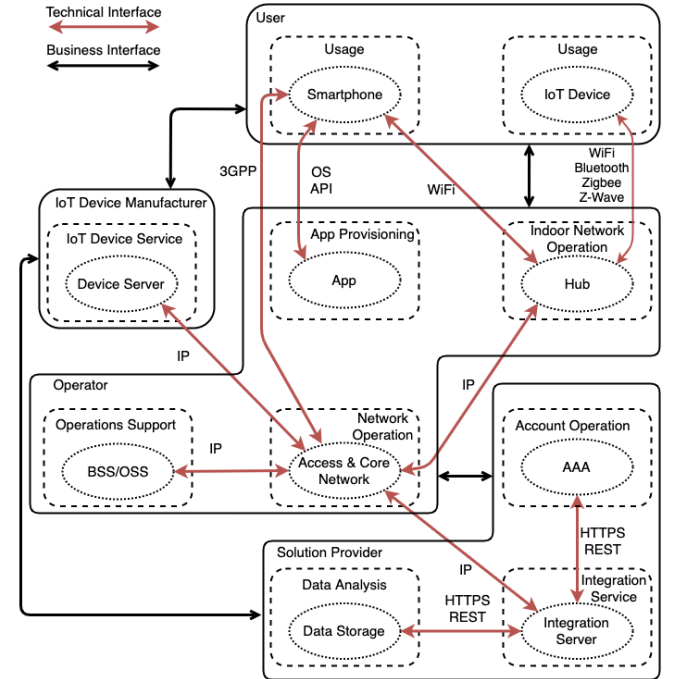


Fig. 2. Value network configuration 2 – Backend Sharing

C. VNC 3 - Sales and Billing Channel

Fig. 3. Value network configuration 3 – Sales and Billing Channel

III. TECHNO-ECONOMIC MODELING

Techno-economic modeling is a method for analyzing costs and revenues associated with technical service. The method is comprehensively introduced in [10]. [10] argues that in techno-economic modeling, the costs involved are modeled using bottom-up strategy based on forecasted demand and the values used are modeled top-down from existing products and services. For the revenue modeling, [10] argues that the main inputs are the number of customers and tariffs charged. The output of techno-economic modeling are economic results such as NPV, IRR and payback period. Techno-economic modeling should always be completed with sensitivity analysis.

A. Cost Model Structure

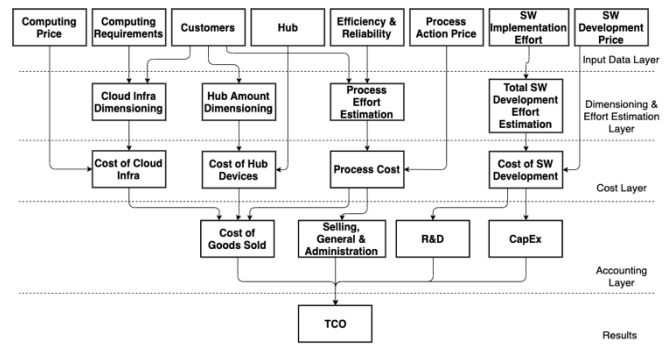


Fig. 4. Cost Model Structure

Cost modeling is done with a bottom-up approach and the model consists of layers as presented in figure 4. The information flow is from the input layer to the dimensioning and effort estimation layer, to the cost layer, to the accounting layer and finally to results.

B. Input Data Layer

The input parameters of the model are given on the input data layer. The definitions and exact values used can be found from the appendix table V. All input parameters are also categorized with the categories shown in figure 4. For the purpose of this study, the values used are example data and does not represent any real operator or their values.

C. Dimensioning and Effort Estimation Layer and Cost Layer

Dimensioning and effort estimation layer are divided into four separate parts: cloud infrastructure, hubs, processes and SW development. On the dimensioning and effort estimation layer, the required effort and needs are calculated, based on the input data layer values. For example, the number of hubs required yearly is calculated based on the number of yearly customers, churn rate and the average lifetime of a hub, as shown in figure 5.

On the cost layer, the needs and requirements calculated at the dimensioning and effort estimation layer are turned into money. For example, the number of hubs required yearly is multiplied with a price of a single hub in order to estimate what is the total cost of hubs yearly.

The cloud infra, needed to run the backend consisting of AAA, integration server and data storage, is modeled by dimensioning the total need of RAM and storage on the dimensioning and effort estimation layer, and multiplying those with their respective pricing on cost layer (see figure 6).

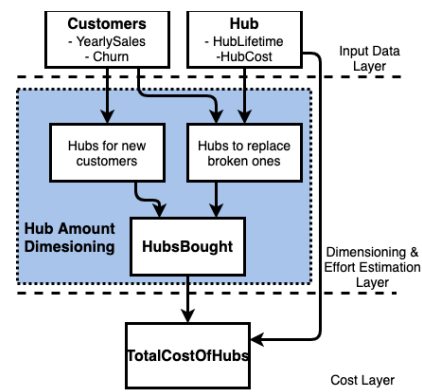


Fig. 5. Hub amount dimensioning and cost

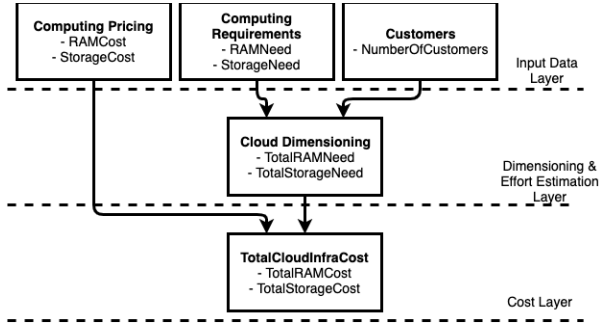


Fig. 6. Cloud infra dimensioning and cost

There are multiple processes involved in providing the service. The processes are modeled as shown in figure 7, and the modeled processes are delivery, sales, monitoring, billing, fault repair, customer service and marketing. Also, an administration cost is modeled based on administration multiplier.

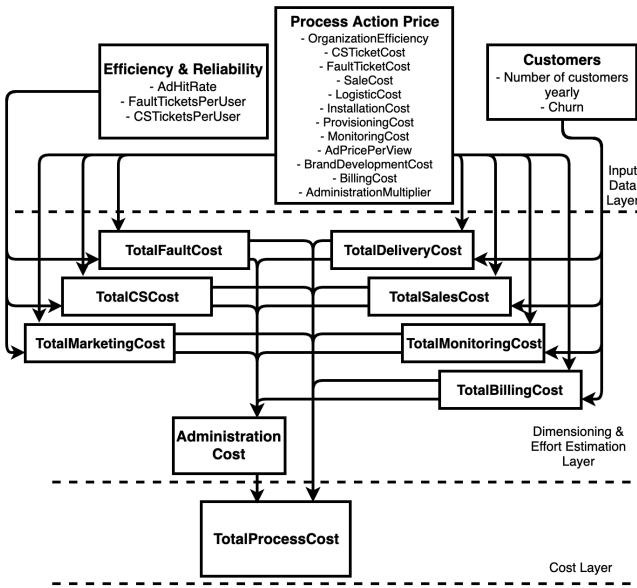


Fig. 7. Process dimensioning and cost

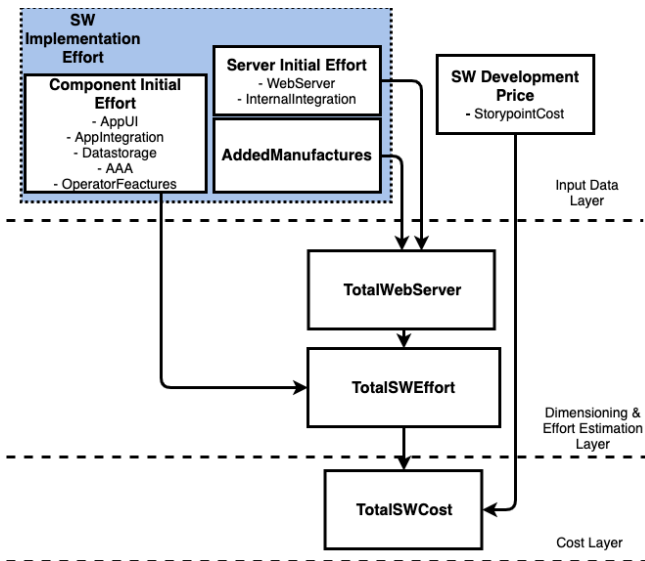


Fig. 8. Software development effort estimation and cost

Developing and maintaining the service includes software development. The development effort is modelled as Scrum storypoints, as shown in figure 8.

D. Accounting Layer

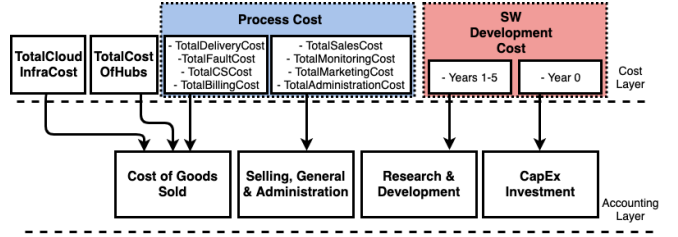


Fig. 9. Accounting of the costs

On the accounting layer, the costs identified on the cost layer are categorized based on the accounting terms (see figure 9).

E. Revenue modeling, financial assumptions and sensitivity analysis

The revenue modeling is done for each year by multiplying the estimated number of users, with monthly average revenue per user (ARPU) and with 12 (months). Also, revenue sharing is assumed, where the operator has 100% of the revenue in VNC 1, 80% in VNC 2 and 20% in VNC 3. The financial assumptions used are the discount rate of 10% and the tax rate of 20%. A sensitivity analysis was also included using a best case – worst-case method with values $\pm 50\%$ to the original input data parameter.

As the software development effort is modeled using Scrum storypoints, it is possible to compare the efforts for each VNC. Time-to-market scales according to development team size and development rate. However, outsourcing or recruiting developers is not always feasible. To simulate that more realistic setting, the development team size and development rate were fixed, and development time was calculated. The free cash flows were delayed according to development time for each VNC and new economic results were calculated.

IV. RESULTS

This section presents the results of the study. Section A presents the results of the VNC analysis and section B presents the results of the techno-economic modeling. Section C links the results of the VNC analysis and the results of the techno-economic modeling.

A. VNC Results

This study identified three different value networks for providing smart home hub and integration service from the perspective of a network operator. The VNCs identified in the VNC method are compared on multiple attributes in Table II. The comparison is done using a high-medium-low scale and colors are used to represent the goodness of the attribute value from the perspective of the operator.

VNC 1 enables the biggest revenues but requires a lot of co-operation with the device manufacturer and high effort before market entry. VNC 2 maintains operator branding and enables medium revenues with medium effort. In VNC 3, there is only a low effort required, but also the revenues for the operator are the low.

TABLE II. VNC METHOD ATTRIBUTE VALUES

Attribute	VNC 1	VNC 2	VNC 3
Operator Revenue Share	High	Medium	Low
Co-operation with end-device manufacturers	High	Low	Low
Effort before market entry	High	Medium	Low
Operator control on the pricing model	High	Medium	Low
Operator look-and-feel	High	High	Low
Dependence on the solution provider	Low	High	High
Solution provider switching difficulty	Low	High	Low

B. Economic Results from Techno-Economic Modeling

The cost modeling results are that the bigger the role for the operator, the higher the costs (see fig 10). The economic results of the techno-economic modeling are presented in fig. 11 and table III. For a 5-year project time, VNC 1 has the highest net present value (NPV), but VNC 2 has the highest internal rate of return (IRR) and the shortest discounted payback period. This suggests that the operator should choose either VNC 1 or VNC 2.

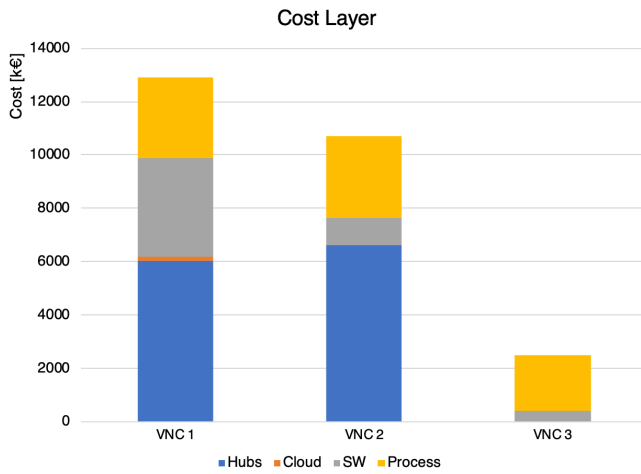


Fig. 10. Hub amount dimensioning and cost

TABLE III. VNC METHOD ATTRIBUTE VALUES

Result	VNC 1	VNC 2	VNC 3
NPV (5 years)	1 440 k€	1147 k€	343 k€
Discounted Payback Period	3.69 years	3.29 years	3.65 years
IRR (5 years)	27%	39%	32%

Cumulative DCF

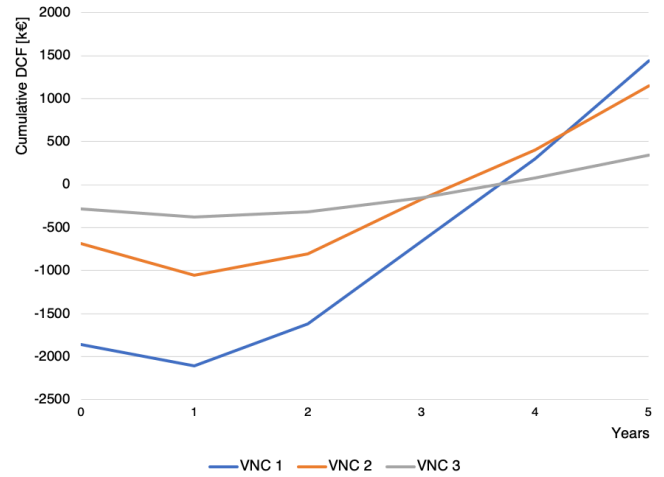


Fig. 11. Cumulative Distributed Cash Flows (DCF)

By fixing the development team size and development rate, it is possible to compare the time-to-market more realistically. With cash flows delayed according to time-to-market, new techno-economic results are achieved (see table IV). With these delayed cash flows and the same 5-year project time, VNC 2 has the highest NPV, the shortest discounted payback period and the highest IRR. This suggests that an operator should choose VNC 2.

TABLE IV. VNC METHOD ATTRIBUTE VALUES

Result	VNC 1	VNC 2	VNC 3
Time-to-market	1.64 years	0.6 years	0.24 years
NPV (5 years)	-274 k€	662 k€	273 k€
Discounted Payback Period	5.33 years	3.90 years	3.90 years
IRR (5 years)	4%	30%	32%

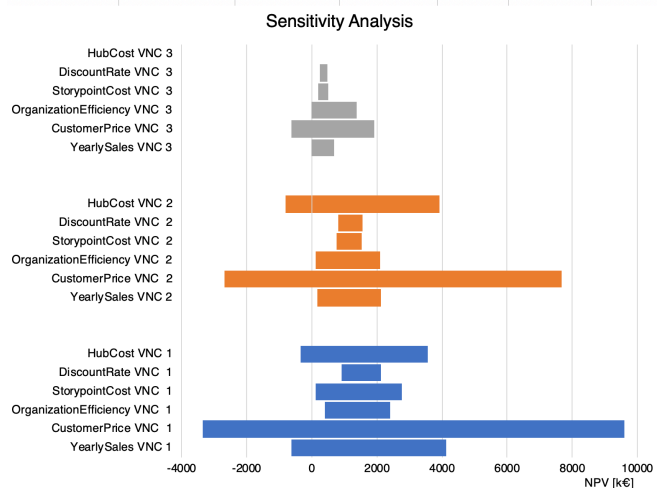


Fig. 12. Sensitivity Analysis

The sensitivity analysis results (see fig 12.) show that the parameter with the highest effect on NPV is the price of the service for the customer. Also, it can be seen that VNC 1 has the highest total uncertainty. This also suggests that VNC 2 should be chosen instead of VNC 1.

C. Linking the VNC method and Techno-Economic Modeling

This study identified three different value network configurations and compared the configurations using techno-economic modeling. Both, value network configurations and techno-economic modeling was done from the perspective of a network operator. With the given input data, the techno-economic results suggest that VNC 2 should be chosen by the operator.

Used input data values are example data and do not represent any real operator. Any operator looking to provide a smart home hub and an integration service as a subscription could replicate this analysis with their input data values for the techno-economic modeling. The model outputs economic results and based on those results, a suggested VNC can be obtained. The VNC represents the configuration that is the most profitable for the operator. This suggestion can be used as input for the operator's strategic decision making.

V. FUTURE RESEARCH

As the techno-economic modeling was highly focused on costs, more detailed revenue modeling could be used to improve the results. Also, considering additional revenue models besides monthly subscription could provide interesting results. The sensitivity analysis was done using a simple best case – worst-case analysis and more complex method such as what-if analysis and Monte Carlo-simulation could be used to highlight the sensitivities even more.

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APPENDIX

TABLE V. INPUT PARAMETERS

Item	Unit	Description	VNC 1	VNC 2	VNC 3
RamCost	€/GB	Price of RAM for the cloud backend	5	-	-
StorageCost	€/GB	Price of data storage for the cloud backend	0.1	-	-
RAMNeed	Gigabyte [GB]	The need of RAM per user	0.1	-	-
StorageNeed	Gigabyte [GB]	The need of storage per user	10	-	-
YearlySales	Piece [1]	The number of subscriptions sold yearly	10 000	10 000	10 000
Churn	Percentage [%]	The percentage of customers terminating the subscription during year	20	20	20
HubLifetime	Years	The average lifetime of hub device before it breaks down and needs to be replaced	3	3	3
HubCost	€	The price the operator has to pay for a single hub device	100	110	-
AdHitRate	Percentage [%]	The percentage of sold subscriptions per ads seen	1	1	1
FaultTicketsPerUser	Percentage [%]	Fault tickets created yearly per customer	1	1	1
CSTicketsPerUser	Percentage [%]	Customer support tickets created yearly per customer	5	5	5
FaultTicketCost	€	The average cost fault ticket	50	55	-
CSTicketCost	€	The average cost of customer support ticket	10	11	12
SaleCost	€	The average cost of sales per sold subscription. Includes sales personnel salaries, rents etc.	25	25	25
LogisticCost	€	The average cost of logistics per sold subscription	5	5	5
InstallationCost	€	The average of installation per sold subscription. Assumes that most customers are able to install devices themselves, but some are needed to visit	5	5	5
ProvisioningCost	€	The average cost of service provisioning per sold subscription	5	5	-
MonitoringCost	€	The average cost of service monitoring per sold subscription	5	5	-
AdPricePerView	€	The average price of ad viewed	0.01	0.01	0.01
BrandDevelopmentCost	€	One-time fee for planning needed changes to the brand to begin providing smart home hub & integration service	10 000	10 000	5000
BillingCost	€	Average cost of billing per customer per month	0.01	0.01	0.012
AdministrationMultiplier	Multiplier	Multiplier used to mode the overhead cost of administration	0.1	0.1	0.1
StorypointCost	€	Average cost for completing a single Scrum storypoint	250	250	250
Addedmanufactures (year 0)	Piece [1]	The number of manufactures supported in the initial launch of the service	10	10	10
Addedmanufactures (years 1-5)	Piece [1]	The number of manufactures added to service yearly after service launch	2	2	2
WebServer	Storypoints	The effort required basic functionality of the web server	700	-	-
InternalIntegration	Storypoints	The effort required for integrations to BSS/OSS	500	500	600
AppIntegration	Storypoints	The effort required for integrating the mobile application to the web server	500	500	-
AppUI	Storypoints	The effort required creating the mobile application user interface	700	700	-
DevelopmentMaintenanceRatio	Multiplier	The ratio of required maintenance compared to initial development	0.1	0.1	0.1
ManufacturerIntegration	Storypoints	The effort required for adding a support for a single manufacturer to the service	300	-	-
DataStorage	Storypoints	The effort required to set up data storage to the service	500	-	-
AAA	Storypoints	Authentication, Authorization and Accounting system development effort	500	-	-
OperatorFeatures	Storypoints	The effort required to develop operator specific features to the hub	1000	1000	1000

TABLE VI. TECHNICAL COMPONENTS

Technical Component	Description
IoT device	Physical object with wireless network, eq. s smart light bulb.
Hub	Central device connecting the IoT devices to the access network.
Mobile application	The application used to control the states of the devices.
Smartphone	The device used to run the application.
Integration server	The central web server used to host the service.
Authentication, authorization and accounting (AAA)	The component responsible of authenticating, assigning access rights to the resources and auditing the usage of the service.
Data storage	Stores the information about connected devices and their current and past states.
Business and operations support system (BSS/OSS)	The software supporting back-office activities such as service delivery, billing, and customer relationship management.
Device manufacturers application Server	The server used to host device manufacturers own service and related AAA and data storage.
Access and core network	The wide area access network, either fixed or wireless, and the core attached to it.