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Agent-based Models as a Method to Analyse Privacy-friendly Business Models in an Assistant Ecosystem

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Abstract: Various projects and initiatives strive towards designing privacy friendly open platforms and ecosystems for digital products and services. However, besides mastering technical challenges, achieving economic viability and broad market success has so far proven to be difficult for these initiatives. Based on a publicly funded research project, this study focuses on the business model design for an open digital ecosystem for privacy friendly and trustworthy intelligent assistants. We present how the agent-based modelling technique can be employed to evaluate how business models perform in various constellations of an open digital ecosystem. Thus, our work relates to the strategic choice of suitable business models as an important success factor for privacy and security-relevant technologies.

Keywords: agent-based modelling; business models; smart assistants; ecosystem; diffusion

1 Introduction

Warnings of the dominance of big centralized platform players exploiting the data of their customers, primarily for advertising purposes, have been frequent [Th17] [Bu17] [ABR19] [SFP16]. While the creation of open, interoperable and privacy friendly platforms or ecosystems is part of numerous initiatives and research projects (a few European and German examples are RERUM [RE16], Big-IoT [Bi20], SmartOrchestra [Sm20], OpenIoT [Op20] and of course the new GAIA X initiative [Fe19]), the success of such initiatives is still questionable. At the end of 2019, the following 6 companies were among the 7 most valuable companies by market capitalization: Apple, Microsoft, Alphabet, Amazon, Facebook and Alibaba (the list is led by oil-giant Saudi Aramco) [Wi19]. That significant parts of these companies' business models rests on proprietary platforms indicates how powerful these platforms have become in the world economy.

Akin to the initiatives mentioned above, the research project ENTOURAGE, whose work forms the basis for this paper, aimed at building an open digital ecosystem for trustworthy and privacy friendly smart assistants [EN19]. To deliver on to their promises and support their user with context-sensitive and personalised assistance, smart assistants need to continuously gather as well as process significant amounts of contextual and personal information. If the

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data-collection and processing is performed on one single platform, or within a proprietary ecosystem controlled by one company, it can become an easy target for attackers [KGH16]. To address the various data privacy [MZH17] as well as security concerns arising when data is stored and handled on one platform, ENTOURAGE envisioned an open digital ecosystem without dominant participants and high privacy as well as security standards. Within this open digital ecosystem users can then combine smart assistants and data sources from vendors of their choice to achieve a trustworthy (secure and privacy friendly) assistance experience. How the project defines and implements privacy is detailed in its privacy and security reference architecture [ZHK19].

Most of the current open platform and ecosystem initiatives focus on technical aspects, developing open standards, powerful architectures and flexible interfaces [MK19]. In this respect, current open platform and ecosystem initiatives are similar to many initiatives in the areas of IT security, privacy enhancing technologies (PETs) and privacy friendly identity management. However, while it is certainly necessary to ensure the technical functioning of security and privacy friendly solutions, this is not sufficient for their broad adoption. Only with simultaneous consideration of non-technical aspects, a broad adoption can be achieved. This is what would be necessary to raise the actual level of privacy of the solutions in use [ZR12]. When setting up the project, the development of viable business models for the operation of the various ecosystem components was identified as a crucial non-technical determinant for the ecosystems' success [KGH16]. Since viable business models secure the required resources to develop the ecosystem further, attract the necessary amount of participants to create value, and are a fundamental ingredient to the success of innovations [Li11], [Ka15], the project dedicated significant efforts to the design of business models which find acceptance by potential ecosystem participants and users alike [MK19], [MZH19], [MZK19]. This was driven by various research and practice related challenges: As [Le12] point out, research on viable business models for open digital ecosystems is very scarce. Accordingly, with no or very little guidance from academia, practitioners would have to follow very costly and time-consuming trial and error approaches to identify the business models that would work in the context of open digital ecosystems. Besides, since digital ecosystems are very complex entities with many stakeholders whose goals are sometimes conflicting rather than aligned, practitioners must not only choose the business models suitable for their own business, but also be able to predict their value within various ecosystem constellations.

Unfortunately, testing the performance of various business models within an open digital ecosystem with several actors in the real world would exceed the resources of any research project. Hence, ENTOURAGE chose to explore how business models would perform within a digital ecosystem based on an agent-based simulation approach. In the following, this paper will focus on the simulation method that was used to analyse the general viability of the business model of the open assistant ecosystem. We do this, because the agent-based modelling approach employed in this study is very likely to be valuable for other privacy and security-relevant technologies facing similar challenges. Privacy-friendly identity

management ecosystems, for instance, are one noteworthy example for which our simulation approach might be valuable.

Within the ENTOURAGE project, the simulations were complemented by workshops and surveys with end-users, experts, as well as practitioners. These workshops helped to study important business model related aspects like user preferences, willingness to pay for secure and privacy friendly assistants [MZH17], and general preferences towards different business models [MZK19].

The paper is structured as follows: A brief overview of the related literature in chapter two substantiates the choice of our method. Then, in chapter three, the paper focuses on the agent-based modelling approach for ENTOURAGE and presents first experiences with the method. Ultimately, chapter four concludes the main insights generated by the agent-based simulation.

2 Related Work and Suitability of the method

The selection of the agent-based modelling approach used in this paper is substantiated by comparing and weighing the basic advantages of simulations against their disadvantages. Furthermore, our choice to perform an agent-based modelling approach is supported by research in comparable fields that shows how agent-based models can be applied. Following [Bö10], applying simulations as a method gives researchers the opportunity to investigate complex system structures that are not subject to the limitations of analytical methods. Moreover, processes as well as resources can be modelled with system-relevant restrictions and problem-relevant key parameters can be represented as well as observed at simulation runtime. As the simulation can be run several times, flexible sensitivity analysis of solutions are possible. Further, simulations also make it possible to observe complex system behaviour step by step in their temporal development and through clear, graphic representation. Besides, as [DF16] point out, simulations are also possible with less empirical data compared to a classical quantitative observational analysis of a specific market. Against this background, simulations allow researchers to create assessments of potential future developments as well.

Despite the numerous advantages mentioned above, agent-based simulations have also limits that need to be discussed. In terms of disadvantages, [Bö10] mentions that simulations typically have no standard benchmarking criteria, do not recognize an optimum and do not have clear abort criteria. Additionally, [SK16] point out that the data and the model and parameter assumptions of such simulations are decisive for the results, so that the calibration of simulation models is often challenging. Researchers can mitigate the methodological deficits of simulations through a variety of strategies: For one, researchers can make the simulation assumptions transparent. Then, researchers can engage experienced simulation experts to assess and improve their model. Further, researchers can also combine and complement their chosen simulation method with other suitable research methods.

In our study, we chose agent-based modelling as the particular simulation method. Simplified, the agent-based modelling method is a special form of discrete simulation that can act as a kind of virtual lab for experimental (socio-)economic research [DK10], [EA96]. The goal of an agent-based simulation is the reproduction of a real multi-agent system in a virtual environmental simulation. The simulation consists of different components and captures the co-interaction of these components. Further, the agent-based modelling method can provide insights into distributed, interactive connections and developments between many independent decision makers (agents). As such, the agent-based modelling approach allows researchers to perform analyses albeit limited empirical data availability [TCS14]. Typically, agent-based models consist of three elements: (1) the agents, with particular attributes and behaviours; (2) the agent relationships and methods of interaction; and (3) the agents' environment, which describes where the agents "live" and with which of the other agents they interact [MN14]. Recently, agent-based modelling has been applied in information systems research as well, for example to analyse digital business models for individual businesses [ZGJ14], service platforms [TBT19], platform diffusion [SB19], and incentive structures in blockchain-based applications [HT19]. In the context of privacy, the agent-based approach has been applied to model privacy concerns and behaviour depending on privacy-settings in social media [TCS14], [Ba11]. This list reveals the popularity and versatility of the agent-based modelling approach, which can be employed in different contexts. Nonetheless, while the agent-based modelling (ABM) approach has been applied to investigate a variety of IS related topics, we could not identify any work that employed it particularly to evaluate business models for privacy-friendly ecosystems.

3 Proposing ABM as a Method

From an economic perspective, an ecosystem is a network of market participants that are in interdependent service relationships. Thus, the ecosystem contains a multitude of networked actors with different competencies, therewith serving different stages of the value chain. The relationships amongst ecosystem participants are generally based on the cooperation principle. Yet, whenever several companies occupy similar value creation stages or companies have similar competences and offer them in the ecosystem, the cooperative relationships between ecosystem participants can take a competitive character.

An open ecosystem consists of diverse stakeholders with different economic interests. Whether it can sustain on the market depends on many factors such as the business models it supports, the distribution of costs and benefits amongst stakeholders, the number of end users and the share of actively participating companies. Since real-world market-testing of the full ecosystem exceeds the resources of any project, a simulation-approach was chosen for the evaluation of suitable business models. Building upon the related work discussed in the previous chapter, our agent-based model included a simplified set of ecosystem participants (i.e., agents): These were "end users" , "smart assistants" , "smart device manufacturers" and the digital ecosystem "ENTOURAGE" itself.

Market activities are driven by the movement process of the end-user agents that can be triggered by direct contact with other agents or environmental influences. The ENTOURAGE agent serves as a kind of control center for the realization of the overall ecosystem, through which smart device manufacturers and smart assistant providers are connected with the end users and provide their products and services. Smart assistant agents and smart device manufacturers offer various services and products to end users that are compatible with the ENTOURAGE ecosystem. The services and products are offered via a subscription plan or purchase within the respective area of influence. The agent-based model was implemented using the software-package NetLogo[4]. The model's user interface is shown in Figure 1.

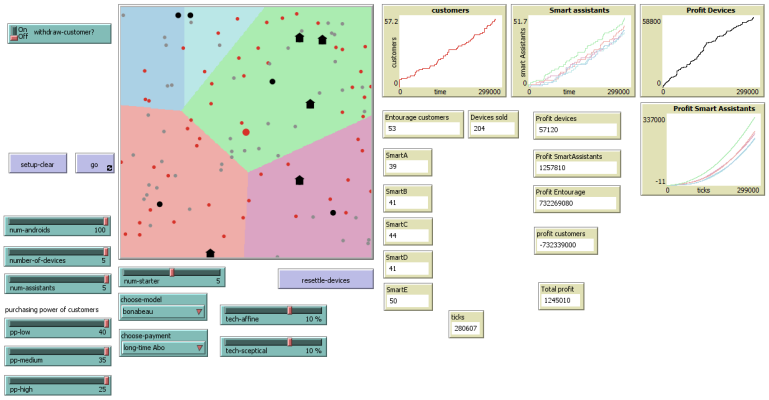


Fig. 1: User interface

The visualization in the center of the user interface (see Figure 2) shows a visualization with end users as small dots, smart assistants as large black dots, and manufacturers of smart devices as black houses. ENTOURAGE is represented as a large red dot in the center of the area. The colored Voronoi partitions[5] represent the sphere of market influence of the smart assistants.

The flowchart shown in Figure 3 describes the ongoing processes of the model. After the model initialization, the movement process starts randomly moving the end users in the area. End users that have an ENTOURAGE subscription are shown as red dots and end users without an ENTOURAGE subscription are shown as grey dots.

The distribution of ENTOURAGE happens via word-of-mouth marketing when a non-subscriber meets an ENTOURAGE customer or the central ENTOURAGE instance. This principle corresponds to the spread of a virus infection. We implemented the following diffusion models that can be chosen via the user interface:

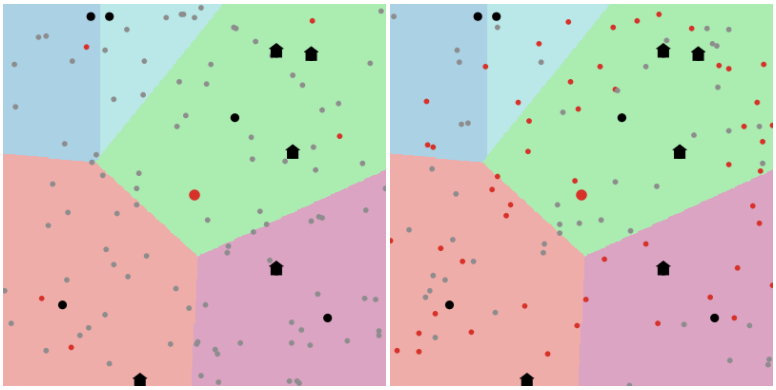
- Bass diffusion model [Ba69]

[4] `https://ccl.northwestern.edu/netlogo`

[5] Voronoi partition: A polygon with one generating point from which every point in the polygon is closer to than to any other generating point of other polygons.

- Bonabeau diffusion model [Bo02]
- Sigmoid function

We chose the Bass diffusion model because it is a commonly used and well-established model in the literature to estimate technology diffusion. Furthermore, we implemented the newer, ABM-related Bonabeau diffusion model and a simple sigmoid function.



(a) Initial situation (0 ticks) (b) Advanced simulation progress (280.607 ticks)

Fig. 2: Visualization of the model

If the non-subscriber becomes an ENTOURAGE customer, the grey dot turns red and the new subscriber distributes ENTOURAGE itself, which accelerates the growth of the customer base (see Figure 2). The distribution of smart assistants is based on the corresponding Voronoi partitions wherein the end users become customers with a defined probability at every step of the movement process. The size of the Voronoi partitions thereby represents the market power of the corresponding smart assistant. The distribution of smart devices works in a similar way, but in contrary to smart assistants, a distribution requires direct contact of the end user with the smart device manufacturers.

All described forms of interactions with the end users are summarized under "business contact" (see Figure 3). At every step of the movement process, any subscription of the corresponding end users is cancelled by a given probability.

We implemented the cash flow between stakeholders and their profit in the model. The calculated profits have to be interpreted in relation to the other stakeholders and thus serve as an indicator of how well a business model performs. The cash flow was implemented dimensionless, since the framework conditions of the model do not allow any explicit conclusions regarding revenues and profits.

The influencing factors for the profit of the respective stakeholders is illustrated in Figure 4.

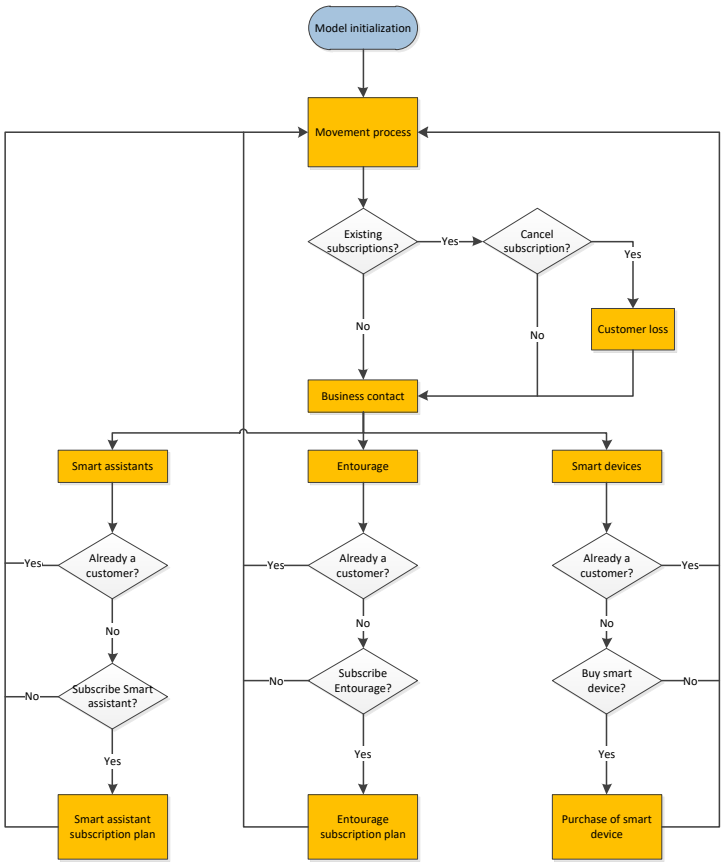


Fig. 3: Flowchart of the model

So far, three business models for ENTOURAGE have been implemented: An ad-financed business model without subscription fees for end users (potentially less privacy-friendly), a subscription model with a short contract commitment and higher subscription fees in comparison for end users and a subscription model with long contract commitment and lower subscription fees in comparison. In this first prototype of the model we did not include the possibility of different business models inside a group of stakeholders (i.e. different smart device manufacturers following different business models).

In all business models the cash flow between the other stakeholders is the same: Smart assistant providers and smart devices manufacturers pay a license/usage fee for the ENTOURAGE implementation. Furthermore, operational costs are incurred as fixed and variable costs depending on the number of users.

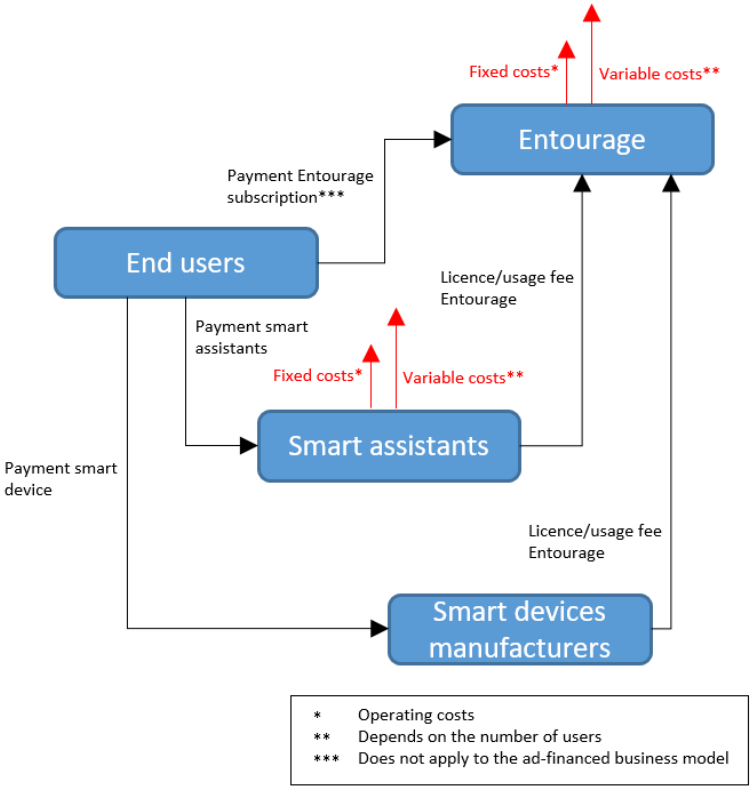


Fig. 4: Visualized cash flows

In order to be able to control the interdependencies of stakeholders, all parameters of the model can be easily modified via the user interface shown in Figure 1 or via the source code. The behaviour of the end-user agents can be fine-tuned in this way: The end users are divided into three groups, of which the ratio can be modified, with low, medium and high purchasing power affecting the likelihood of purchases. Furthermore, the model differentiates between regular, interested and skeptical users regarding ENTOURAGE as well. Regular users are moving purely random, whereas interested users are more likely to follow, and skeptical users are more likely to move away from ENTOURAGE customers in their immediate vicinity. Further parameters that strongly impact the simulation process are the number of end users, the initial number of ENTOURAGE customers, the number of smart device manufacturers and the number of smart assistant providers.

At first, simulations indicated strong differences regarding profits and customer base of individual stakeholders. Thus, the simulations indicated the challenge of a well-balanced business model, since a market situation in which a gap in profit between stakeholders is

too large inevitably leads to the failure of the business model in the long term. However, first simulation results showed that a decentralized, open ecosystem as envisioned in ENTOURAGE can basically be simulated and underlying business models are viable when well-adjusted. Our results indicate that a privacy-friendly open ecosystem as described in section 1 can be viable on the market. However, aspects of privacy and security need to be integrated into the model for further investigation. This includes both, the added value for end users and the privacy preferences of other stakeholders regarding the use and utilization of user data.

4 Conclusion

As consumers as well as the general public grow increasingly aware of privacy and security issues related to digital products and services they connect to, various initiatives and research projects strive towards designing and implementing trustworthy and privacy friendly digital offerings, platforms and ecosystems. However, designing privacy friendly digital offers poses various novel challenges that need to be addressed. Based on a real project sponsored by the Germany Ministry of Economy and Energy, this study focused on the challenge of designing an open digital ecosystem for privacy friendly and trustworthy intelligent assistants while still ensuring the attractiveness and economic viability of the construct. In this regard, this study presents how the agent-based modelling technique can be employed to evaluate how business models perform in various constellations of an open digital ecosystem. Thus, this study relates to the strategic choice of suitable business models as an important success factor for all technologies, including privacy and security-relevant technologies.

Typically, a company's or a business network's chances to survive and thrive in the market depends on various individual but also interdependent factors. Business models, distribution of costs and benefits amongst stakeholders, the number of end users and the share of actively participating companies are only a few of such success-critical factors that influence each other. Beyond the complicated interactions between various determinants for success, companies who want to successfully join an open digital ecosystem also need to fine-tune their strategic decisions in accordance with the constraints and dynamics of the ecosystem and its participants.

Against the background that a real-world market-testing of the full ecosystem exceeds the resources of any company or project, this paper shows how an agent-based simulation-approach can be used to evaluate the suitability of business models in the context of privacy friendly digital ecosystems. Our first modelling approach as presented in this paper is focused on the business models as such and their economic viability – not on the privacy aspects of these business models and their influence. Although the model is still a rudimentary early prototype (this is why we did not present quantitative results at this stage), it is extendable to investigate a variety of success relevant factors other than business models. Further, the model is also modifiable with regard to the agents, their goals and relationships of these entities. This way, this paper presents a viable model which supports both researchers and

practitioners to foresee how success-relevant factors interact with each other and behave in various ecosystem conditions. In future evolutions further factors can be added and for example enable sensitivity analysis can be performed.

As privacy-friendly digital services, platforms and ecosystems gradually gain traction, researchers' and practitioners' demand for suitable simulation and probably more sophisticated ABM models is also very likely to increase. Hence, we invite fellow researchers to build upon our model to develop a more extended and refined version of it.

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