

A Taxonomy and Ontology for Digital Platforms

Thomas Derave¹[0000-0003-1547-8333], Frederik Gailly^{1,2}[0000-0003-0481-9745], Tiago Prince Sales³ [0000-0002-5385-5761], Geert Poels^{1,2}[0000-0001-9247-6150]

¹Department of Business Informatics and Operations Management, Ghent University,
Tweakerkenstraat 2, 9000 Ghent, Belgium

²CVAMO core lab Flanders Make, Faculty of Economics and Business Administration, Ghent University,
Tweakerkenstraat 2, 9000, Ghent, Belgium

³Services and Cybersecurity, Faculty of Electrical Engineering, Mathematics and Computer Science, University
of Twente, Enschede, The Netherlands

{thomas.derave, frederik.gailly, geert.poels}@UGent.be,
t.princesales@utwente.nl

1 Introduction

The platform economy encompasses a growing number of digitally enabled activities in business, politics, and social interaction, facilitated by different types of digital platforms (Kenney and Zysman, 2016). Platform economy is defined very broadly and overlaps with other phenomena; ‘collaborative economy’, ‘gig economy’, ‘on-demand economy’, ‘collaborative commons’, ‘peer-to-peer economy’, ‘access economy’, ‘the mesh’..., with ‘sharing economy’ as the most popular one (Ranjbari, Morales-Alonso and Carrasco-Gallego, 2018). In the platform economy, a wide range of services are exchanged by both human and organisational actors, in sectors such as travel, car rental, finance, staffing, information, music and video streaming, that were previously provided uniquely by firms (Puschmann and Alt, 2016; Görög, 2018). As a new economic phenomenon, the success of the platform economy is mostly due to the underlying digital platforms, such as Airbnb, eBay, Etsy, Ticketswap, Tinder and Uber.

In line with the different terms used for ‘platform economy’, different terms are also used for the facilitating digital platform, including ‘sharing economy platform’, ‘digital marketplace’, ‘on-demand platform’, ‘multi-sided platform’, and others. Currently, these umbrella concepts are getting a lot of attention in both academic and professional communities, but without consensus on what they comprise (Hagiu and Wright, 2015; Cheng, 2016; Codagnone and Martens, 2016; Oh and Moon, 2016; P. C. Evans and Gawer, 2016; Acquier, Daudigeos and Pinkse, 2017; Görög, 2018; Nguyen and Llosa, 2018; Sutherland and Jarrahi, 2018; Trabucchi and Buganza, 2019; Sanchez-Cartas and Leon, 2019). Generally, these platform types have a lot in common, but also have substantial differences in the functionalities that are offered. As a consequence, every platform type supports different business models and offers different functionalities. To add to this

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confusion, existing digital platforms strive to be under the big tent of the ‘sharing economy’, because of the positive symbolic value of sharing (Frenken and Schor, 2017).

This lack of agreement makes it difficult for scholars to determine the impact that digital platforms of different types have on the economy as well as on the society at large. It is difficult to compare different studies and their results since each of them conceptualises the markets and their platforms differently (Ertz, Durif and Arcand, 2016). Clearer definitions of digital platform types can improve communication, guide future research, and produce useful contributions and recommendations for practitioners who are keen on learning more about the opportunities that digitalization brings for fostering the platform economy (Ertz et al., 2016; Wieringa, 2019).

Furthermore, academic research on the functionalities of different digital platform types is scarce. Sutherland and Jarrahi (2018) observe “that perspectives on technology are currently lacking in the research on the sharing economy” as “few research works have been done from the perspective of information technologies” (Yin et al., 2018). During our study, we found out that there is a clear lack of knowledge regarding the requirements and design of the different types of digital platforms. Therefore, it is not known whether existing SaaS tools for developing digital platforms, like open-source Sharetribe Go (Sharetribe, 2022) for digital marketplaces, support the functionalities expected of other platform types too. Providing an overview of the various distinctions in the digital platform types is not only important from an academic perspective but also for regulators and policy-makers, as a ‘one size fits all’ policy and regulatory approach is inappropriate (Codagnone, Biagi and Abadie, 2016).

This paper contributes to filling these research gaps by creating two artefacts. First, we contribute to solving the lack of shared conceptualization of different types of digital platform by developing a taxonomy for digital platforms. The taxonomy is defined based on the identification of digital

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platform properties which allow distinguishing between different digital platform types. This digital platform taxonomy facilitates and improves the classification of digital platforms and enables researchers to study the relationships among these different types of platforms (Nickerson, Varshney and Muntermann, 2013).

Second, the lack of knowledge concerning the functionalities of different digital platform types is tackled by proposing a Digital Platform Ontology (DPO). While the taxonomy of digital platforms identifies the properties that allow distinguishing different types of digital platforms, the ontology describes the functionality that is expected of each of these digital platform types. The DPO consists of a core that describes the functionalities common to all digital platforms and additional modules that can be combined to describe the functionalities of individual digital platforms depending on their classification using the taxonomy. The DPO thus formalises both the general functionalities of any digital platform and the specific functionalities that depend on the type of digital platform. This modular composition provides for a flexible ontology structure that allows making new combinations or, if needed, adding additional modules whenever a new platform type arises. As a result, the DPO can accommodate the evolution of the platform economy and combine existing and emerging platform variations to model new digital platform types. Summarising, the DPO is envisioned as a common language that all platform economy stakeholders (including software engineers, entrepreneurs, managers, economists, governments and social scientists) can use to facilitate future research and foster the further development of the platform economy.

The paper is structured as follows: In section 2 we describe our methodology. In section 3 we review different digital platform properties that have been proposed in the literature to distinguish between digital platform types. In section 4 we present our taxonomy. In section 5 we present our ontology. In section 6 we demonstrate how to combine the ontology modules into platform-

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specific ontologies using Airbnb and Uber Eats as examples. In section 7 we discuss the evaluation of the ontology. In section 8 we further discuss the implications of our results and outline our current and future research. Finally, in section 9, we conclude by stating the novel contribution of this paper.

2 Methodology

This paper presents two interrelated artefacts that were developed using the Design Science Research (DSR) process. For developing the taxonomy, we followed the method of Nickerson, Varshney and Muntermann (2013), which is explained in sub-section 2.1. For developing the DPO, we combined the ontology engineering methods of Falbo (2014) and Ruy et al. (2017), which is presented in sub-section 2.2. Finally, in sub-section 2.3, we motivate our choice of tool for developing the DPO, which is OntoUML (Guizzardi, 2005; Guizzardi et al., 2021), and the reference ontologies we use as a foundation for constructing the DPO.

2.1 Taxonomy development method

Figure 1 shows the process we followed for creating the digital platform taxonomy. This process is guided by the taxonomy development method of Nickerson, Varshney and Muntermann (2013).

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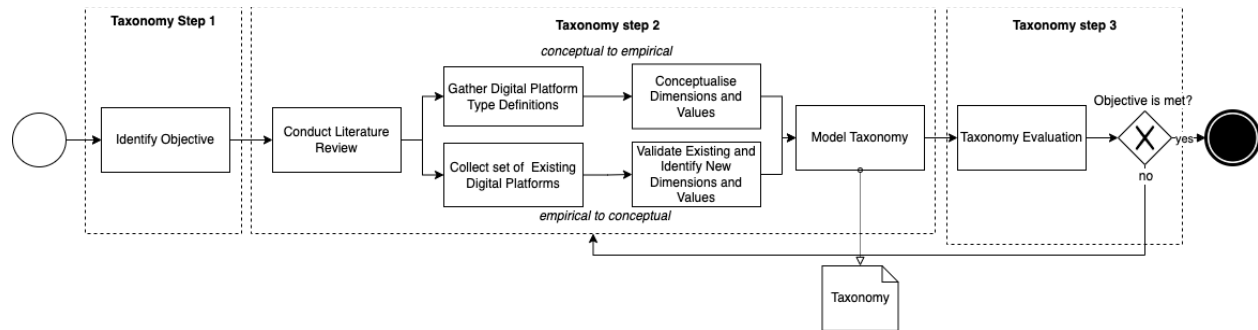


Figure 1: Taxonomy engineering method

The process distinguishes three main steps:

1. Identify the objective: The taxonomy should differentiate between the main digital platform types in our research scope. To define this scope, we construct a working definition for a digital platform based on a synthesis of definitions found in the literature.
2. Taxonomy development: The taxonomy development step is done in an iterative manner for which we alternately use the ‘conceptual to empirical’ and ‘empirical to conceptual’ approach, starting in the first iteration with the former.
 - For the ‘conceptual to empirical’ approach, we gather digital platform type definitions in line with our working definition. This is done by a literature search of secondary sources (literature reviews) on digital platforms and their types. As these literature reviews include a large variety of digital platform types and often also contradictory definitions for these types, we use convenience sampling (Etikan, 2016) to identify the platform types that, based on their definitions, are the most used and widely accepted by the academic community. We next compare these definitions to conceptualise the digital platform properties that allow differentiating between the different platform types. A digital platform property (e.g., one-sided market) is conceptualised as a value

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- taken on scale that is used as a dimension to classify digital platforms (e.g., one as value of the market sides dimension).
- For the ‘empirical to conceptual’ approach, we collect a set of existing digital platforms described in the primary sources of the literature reviews found using the ‘conceptual to empirical’ approach. This way, the digital platforms in this set can be directly linked to their types. As these primary sources document a very large number of digital platforms, we compose the set using a purposive sampling method called maximum variation sampling (Etikan, 2016). Using maximum variation sampling, a rather small but diverse enough sample can be selected that covers all types discussed in the selected literature reviews. The properties that were conceptualised in the ‘conceptual to empirical’ approach, can now be validated using the composed sample of existing digital platforms. Following Trabucchi and Buganza (2019), the emergent taxonomy is thus compared systematically with empirical evidence of the existence of instances of the identified digital platform types. If needed, a new iteration is started to add new properties (i.e., when we find in our sample existing digital platforms that cannot be characterised by the currently conceptualised properties).
3. Evaluation: Only when the taxonomy satisfies our objective of being able to differentiate between the digital platform types within the scope of our working definition, the taxonomy development process is terminated. To reach our objective, we verify that every digital platform type collected in step two has a unique combination of empirically validated properties (i.e., at least one existing digital platform with those properties is found), implying that the taxonomy allows to define a set of unique and inter-related digital platform types that all have real-life instances.

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2.2 Ontology engineering method

Our second design artefact is the Digital Platform Ontology (DPO), which is based on our taxonomy and built by combining the methods of Ruy et al. (2017) and Falbo (2014).

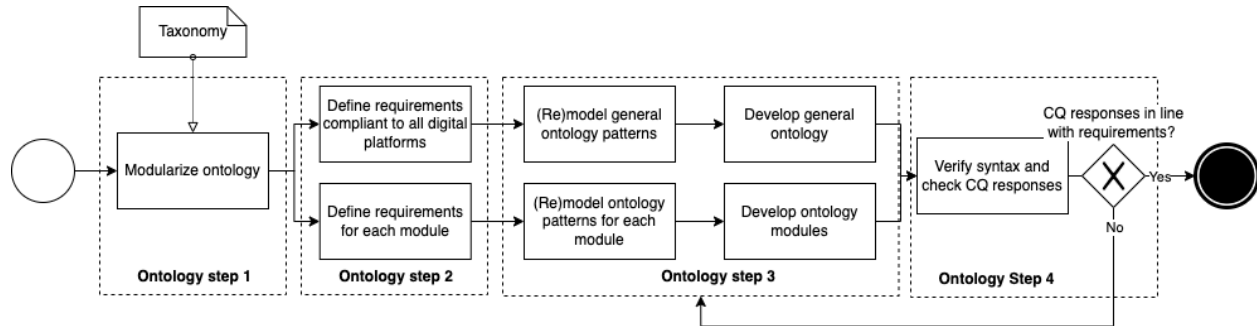


Figure 2: Ontology engineering method

Four steps are distinguished in the ontology engineering process (Figure 2):

1. The first step is to segment our domain of interest into subdomains that can be modelled independently, as designing ontologies in a modular manner achieves more efficient ontology management and change handling (Ensan and Du, 2013). Since we started building the ontology after creating the taxonomy, we modularize the DPO based on the digital platform properties as defined in the taxonomy.
2. The second step is to define ontology requirements. First, using the working definition that guided taxonomy development, we define the requirements related to the functionality provided by any digital platform, independent of its taxonomic classification. Second, specific requirements for each ontology module are defined based on both the literature and our sample used in the taxonomy development. For the combination of ontology modules that apply to an individual digital platform, these requirements define what functionality is expected for the digital platform to be defined as an instance of a certain digital platform type.

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3. In the third step we model the requirements defined in step 2. For that, we use the OntoUML language (Guizzardi, 2005; Guizzardi et al., 2021), as recommended by Falbo (2014), and ontology patterns, as proposed by Ruy et al. (2017). An ontology pattern is a recurring modelling problem that arises in ontology development and presents a well-proven solution for the problem. Conforming to Ruy et al. (2017), we searched for reference ontologies that we can use to extract these patterns from. Our motivation for choosing OntoUML to represent the DPO and choice of reference ontologies for extracting ontology patterns, will be further discussed in subsection 2.3.
4. The fourth step is the evaluation of the ontology. First, we verify the syntactic correctness of the ontology representation using the OntoUML plugin for Visual Paradigm¹. Second, we validate the correct application of the ontology patterns using the method of (Bezerra, Freitas and Santana, 2013), which entails defining Competency Questions (CQs). These CQs are queries that the ontology must be capable of answering in order to be considered adequate for conceptualising the domain it was intended for. In our case, this means that the answers to the CQs should be in line with the predefined requirements. To test this, ontology users are asked to answer the CQ's using the developed ontology (modules). As long as the responses to the CQs are not in line with the requirements, the ontology patterns are remodelled to make sure our ontology captures the knowledge as required.

2.3 Representation and ontological foundation of the digital platform ontology

We designed the DPO using OntoUML, an ontologically well-founded version of UML for creating class diagrams as conceptual models (Guizzardi, 2005; Guizzardi et al., 2021). OntoUML

¹ <https://purl.org/krdb-core/ontouml-plugin>

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reflects the ontological distinctions put forth by the Unified Foundational Ontology (UFO) (Guizzardi et al., 2022) so that modellers can leverage more expressive and clearly defined constructs to represent their domains of interest. Simply put, OntoUML offers a set of stereotypes² for classes and associations and semantically-motivated rules on how to combine them, all of which has been tailored for ontology-driven conceptual modelling (ODCM). It has been shown that adopting ontology-driven conceptual modelling allows one to create semantically stronger conceptual models, leading to better representations of the systems to be (Verdonck, Gailly and de Cesare, 2020), without any significant difference in effort for the modeller (Verdonck et al., 2019). This advantage holds particularly when having to model the more challenging and advanced facets of a certain domain or scenario, of which there are plenty in the digital platform domain.

Three particular features of OntoUML motivate its choice as language for representing the DPO. First, OntoUML recognises the existence of different types of classes. OntoUML distinguishes, for instance, between rigid and anti-rigid classes (Guizzardi et al., 2021). Rigid classes are those that classify their instances necessarily, like Person or Dog. This means that there is no way in which people and dogs can change, while maintaining their identities, such that they will cease to be people and dogs respectively. It is essential for a person to be a person and for a dog to be a dog. In contrast, anti-rigid classes only contingently classify their instances. Typical examples include the classes Student and Adult. People become students when enrolled in an education institution and are considered adults as soon as they turn 18 years old. This feature is important for representing the DPO as digital platform users are agents (i.e., persons or organizations) that take a particular role when using the platform and these roles can change (e.g., a consumer becoming a

² In a valid OntoUML model, every class should be decorated with exactly one of its stereotypes, while an association may occur without one.

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provider or even prosumer) while the person or organization taking the role is still the same person or organization.

A second noteworthy feature of OntoUML is its support for modelling both objects³ (Guizzardi et al., 2021) and events (Almeida, Falbo and Guizzardi, 2019), such as an organisation and a service delivery, respectively. The language provides patterns to model objects and their parts, how objects participate, are created by, and are terminated by events, as well as how events compose and depend on each other. These finer-grained distinctions speed-up the ontological analysis process, as they give us a foundational layer of concepts to start modelling from. As the digital platform functionality is described by the DPO, for instance as platform-supported actions, representing the DPO requires modelling events, which is thus supported by OntoUML.

Third, OntoUML supports multi-level modelling (Fonseca et al., 2022). This means it can not only account for first-order classes, that is, classes whose instances are particular entities, but also for classes that have other classes as instances, dubbed high-order classes. To exemplify, consider the entities "John Doe", "Guest", and "User Role". John Doe is an individual, and therefore, cannot have instances. John Doe is, however, an instance of Guest, a first-order class. Just as Guest is an instance of User Role, a high-order class (or more precisely, a second-order class). As representing the DPO requires multi-level modelling (e.g., modelling types of platform-supported actions), this feature was another reason of choosing OntoUML as language to use for representing the DPO.

To develop the models that represent the DPO and its modules, we use the OntoUML plugin for Visual Paradigm (Fonseca et al., 2021), a reference tool for OntoUML modelling. The plugin not

³ Here, we use the term "object" in the very general sense of things that persist in time while undergoing qualitative change, such as people, cars, organisations, marriages, capabilities, and so on. In the ontology literature, these are often referred to as endurants (Guizzardi et al., 2022) and continuants (Otte, Beverley and Ruttenberg, 2021).

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only supports the creation of OntoUML models; it can automatically verify if they comply with the syntactic constraints of the language. The plugin uses colours to indicate the ontological nature of the individuals that instantiate each class: objects are represented in pink, reified relationships are represented in green, aspects of individuals are represented in blue, events are represented in yellow, and high-order types are represented in purple.

In step 3 of the ontology engineering process (Figure 2), ontology patterns from reference ontologies are used to model the requirements defined in step 2. Inherent in the use of OntoUML is the Unified Foundational Ontology (UFO) which has been purposefully designed as an ontological foundation for conceptual modelling. For representing general (i.e., not domain-specific) modelling situations, we therefore employ Foundational Ontology Patterns (FOPs) from OntoUML/UFO. We also use as reference ontology UFO-S, a core ontology for services that provides a clear account of service-related concepts (Nardi et al., 2015), such as service offering, service negotiation, service agreement, and service delivery. As digital platforms provide a service to their users, we consider the platform economy as part of the service economy. Therefore, we use Domain-Related Ontology Patterns (DROPs) from UFO-S to represent service domain-specific modelling situations.

We illustrate the use of UFO FOPs in Figure 3. Example general modelling situations represented by FOPs are the following: An object can participate in an event (i.e., Participation FOP); an object (red) can be the subkind of another object (i.e., Kind-Subkind FOP); a relator (green) has the ability to connect two or more objects (i.e., Relator FOP); each class can be instantiated (i.e., Instantiation FOP); and a kind can characterise a mode (i.e., characterization FOP). Note that none of these modelling situations is specific to the service domain.

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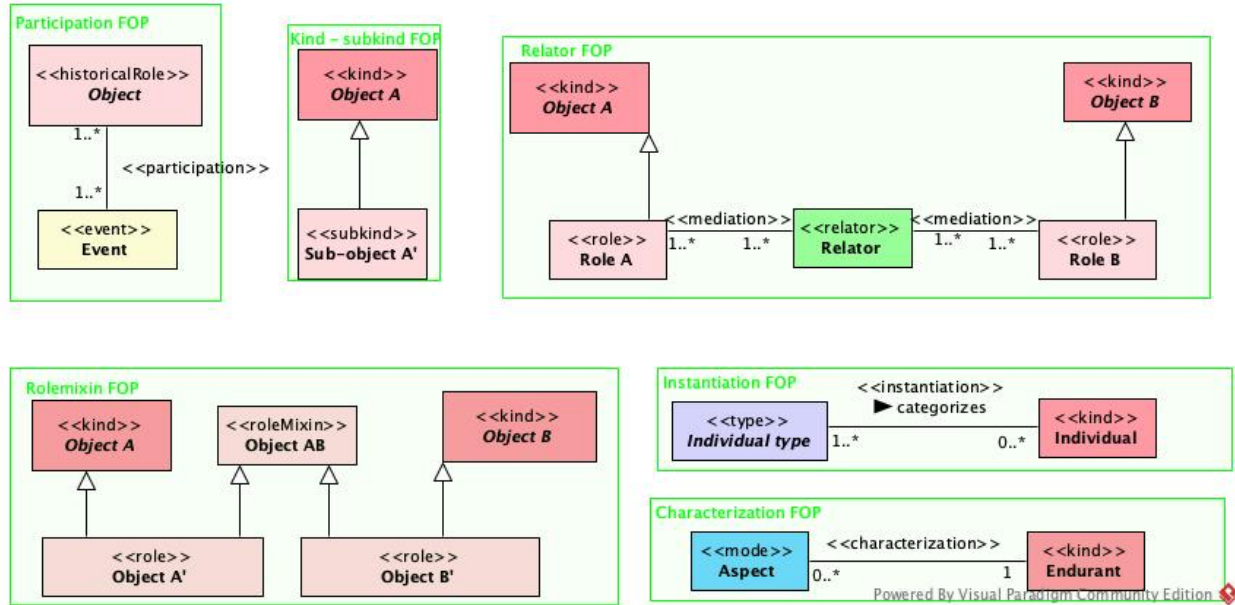


Figure 3: Foundational Ontology Patterns (FOPs)

Specific service domain semantics is captured by UFO-S DROPs in figure 4. A service offering is a social construct, which is represented as a relator that connects a service provider and a target customer community (i.e., Service Offering DROP). This service offering can result in the establishment of another relator called service agreement (i.e., Service Agreement DROP). Eventually, this agreement can lead to a service delivery, which can include both actions by the customer and provider (i.e., Service Delivery DROP).

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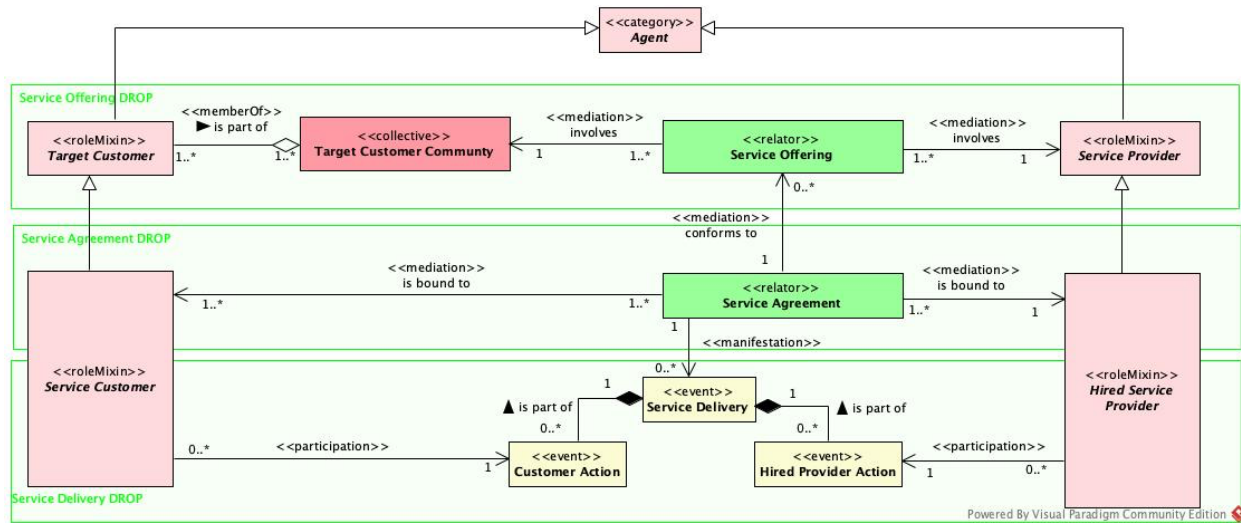


Figure 4: Domain-Related Ontology Patterns (DROPS) of UFO-S

3 Digital Platforms

Due to the dispersal of research across several fields, there is a miscellany of perspectives concerning digital platforms and the different ways to classify them into types. For instance, the terms ‘digital platform’, ‘sharing economy platform’ and ‘digital marketplace’ are used interchangeably and may refer to the algorithm or the technology enabling the platform (Sutherland and Jarrahi, 2018), the company owning the platform software (Oh and Moon, 2016) the business model underlying the use of the platform (Remane et al., 2016; Täuscher and Laudien, 2018), or the intermediary service provided through the use of the platform (Wu, 2017; Apte and Davis, 2019). This conceptual confusion hinders communication amongst researchers and the sharing of research ideas and results across different fields (Wieringa, 2019). We review in this section different digital platform properties that have been proposed in the literature to distinguish between digital platform types, acknowledging that these definitions are dispersed and originate in different research streams.

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A first dimension to distinguish platform types is the number of market sides. A market is a place where agents can gather to facilitate the economic exchange of goods and services (Kenton, 2020). In case the platform users cannot be classified into roles that have different interests in the service offering (e.g., as distinct groups of content creators and consumers, or providers and customers), the platform operates in a *one-sided* market and is defined as a one-sided platform (Filistrucchi, Geradin, Van Damme and Affeldt, 2014). Examples are the dating platforms Tinder and Grindr and the communication platform WhatsApp. Unfortunately, for *Multi-Sided* (MS) markets there is not a clear and widely accepted definition (Sanchez-Cartas and Leon, 2019). The term was first used by Nobel price winners Rochet and Tirole (2001) and defined as a market including at least two distinct but interdependent sides to have direct and clearly identified interactions with each other creating cross-side network effects. A cross-side network effect is created when the increase in value of the platform to the users of one side of the market is associated with an increase in the number of participating users on another side (Hagiu, 2018). Because of such an effect, MS markets typically face the chicken-and-egg problem (D. S. Evans, 2005), having difficulties to find users of one side without having users of another side. It is gradually becoming acknowledged that MS markets pose specific challenges to market regulation and innovation policy as this strategy has strong indirect network effects that can lead to dominant market power and monopolies (Katharina Hoelck, 2016). Because of the complexity of the definition of Rochet and Tirole (2001), a more convenient and also popular definition of (Hagiu and Wright, 2015) is regularly used in academic research: “A MS market enables direct interactions between multiple sides with each side affiliated with the market”. A MS platform is a digital platform operating in a MS market, and obviously includes the two-sided platform as a subtype.

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A second driver for classifying digital platforms is the user affiliation to the platform. A multi-sided *transactional* market is characterised by the presence and observability of direct transactions between the users. This can give rise to usage externalities such as a one or two-way tariff depending on the pricing structure. Even when only one market side is charged, the market can still be defined as multi-sided (Filistrucchi et al., 2014). When these transactions are facilitated by a digital platform, the platform is called a (multi-sided) transaction platform by P. C. Evans and Gawer (2016). In case users of one side make an investment of financial resources that benefits users of another market side, the platform is an *investment* platform, as defined by P. C. Evans and Gawer (2016). This type includes online stockbrokers (e.g., Degiro, Keytrade) that intermediate financial instruments between stock exchanges and investors.

Besides the type of user affiliation, the digital platform type also depends on the participation role the users can have. When users are considered as peers, meaning equal participants, also called prosumers alternating in their role as producer and consumer (Ritter and Schanz, 2019), the platform operates in a Peer-to-Peer (P2P) market. How we define this equality amongst participants is further explained in our ontology, and this shows how our ontology can help to find and communicate generally accepted definitions. The P2P requirement marks the difference between a MS transactional platform and a *digital marketplace*. As defined by Täuscher and Laudien (2018), a digital marketplace needs to fulfil four conditions. The first condition, “connects independent actors from a demand and supply side and these individual actors can participate on both sides” (Täuscher and Laudien, 2018, p.320), implies that a digital marketplace needs to be MS and P2P. The second, third and fourth conditions, respectively “these actors enter direct interactions with each other to initiate and realise commercial transactions”, “the marketplace platform provides an institutional and regulatory frame for transactions” and “the marketplace does

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not substantially produce or trade products or services itself' (Täuscher and Laudien, 2018, p.320), indicate that a digital marketplace needs to allow transactions between users of different sides. Hence, MS platforms without clear transactions between users (e.g., YouTube) or intermediating non-P2P markets (e.g., Amazon) are not considered digital marketplaces. If the P2P condition exists for an investment platform, it is defined by Haas et al. (2014) as a *crowdfunding platform*, based on the P2P lending principles of Burtch, Ghose and Wattal (2013). An example is Kickstarter, helping projects to life by connecting creative people with their community (Kickstarter, 2020).

The definition of a *P2P sharing and collaborative consumption platform* by Chasin et al. (2018) on the other hand has four conditions. The first condition "individuals can assume the role of a peer-provider on the platform" (Chasin, von Hoffen, Cramer and Matzner, 2018, p. 300) translates to a P2P participation. The second and third conditions, respectively "peer-providers can offer physical resources on the platform" and "access to a resource is granted temporarily" (Chasin, von Hoffen, Cramer and Matzner, 2018, p. 300) can be linked to the user-oriented offering definition of (Ritter and Schanz, 2019), which states that an offering can be placed on a continuous scale between product-oriented and result-oriented. Product-oriented offerings are geared towards sales of products, while in result-oriented offerings the provider is selling a result or competence, by offering a mix of services. In the middle of this continuum are the user-oriented offerings consisting of product leasing, renting, sharing and pooling (Tukker, 2004), which is in line with condition two and three by Chasin et al. (2018). The fourth condition, "Peer-consumers can search for resources offered by peer-providers" (Chasin et al., 2018, p. 300), means a decentralised market following the frameworks of (Sutherland and Jarrahi, 2018; Acquier et al., 2019). In a decentralised market, the platform exercises little control for exchanges beyond matchmaking. The

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provider sets the price and the customer can search for a provider based on the set price. In a centralised market, on the other hand, the platform provides access to a centralised resource pool and has a strong influence on the interactions between users by determining matches and setting dynamic and time-related prices. To conclude, the P2P sharing and collaborative consumption platform type includes platforms where customers can search and rent physical resources (in combination with other services) from their peers. This type includes platforms such as Airbnb for home renting, BlaBlaCar for carpooling, and Sharedesk to book a working spot.

The basic concept of an *on-demand platform*, as defined by Mamonova (2018), is “immediate and effective access to a product and service” with Uber as the main example. Uber is clearly operating in a centralised market, also known as a matchmaker (Hafermalz et al., 2016), where the platform company acts as a brokering service offering and facilitating transactions between providers and customers. Secondly, an on-demand platform is part of the (immediate) access economy described by Gobble (2017) as “offering customers access to a product and service where and when the customer needs it, and this can be straight away”.

A *second-hand P2P platform* as mentioned by Acquier et al. (2017, p. 8) is a decentralised, product-oriented digital marketplace, as it facilitates the searching and sales of used products between peers. An example is Carousell, a platform to resell used goods.

The definition most used for ‘*sharing economy*’ is the one by Frenken and Schor (2017): “Consumers granting each other temporary access to under-utilized physical assets (idle capacity), possibly for money” (Frenken and Schor, 2017, p. 4). A typical example of a platform operating in the sharing economy is Couchsurfing, where private persons rent out temporarily vacant accommodation (under-utilised physical good) to other private persons (C2C) for an agreed upon number of days (temporary access). It includes the six affordances of sharing economy by

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Sutherland and Jarrahi (2018) (i.e., generating flexibility, matchmaking, extending reach, transaction management, trust, and facilitating collectivity). In this paper we consider a sharing economy platform by Frenken and Schor (2017) as a platform where all transactions operate in the sharing economy. This is equal to the already discussed *P2P sharing and collaborative consumption platform* of Chasin et al. (2018), but with under-utilised products offered and consumed by private persons (i.e., C2C instead of P2P).

4 Taxonomy

First, we need to set our scope with a working definition of digital platform. By combining the definitions of Evans and Gawer (2016), Kenney and Zysman (2016), Wu (2017), Apte and Davis (2019), and Sanchez-Cartas and Leon (2019), we constructed the following definition:

‘A digital platform is a service, enabled by software, that is offered to intermediate the interactions between agents’

We purposefully include abstract terms in our definition, such as ‘intermediate’, ‘agent’ and ‘interactions’, so we could make the scope clear yet comprehensive. We will refine these abstract terms when developing the DPO as the purpose of creating an ontology is exactly to help defining and communicating definitions, requirements, relations and constraints. In view of our working definition, interactions intermediated by a platform can solely consist of information transfer (e.g., WhatsApp, Tinder) but also the transaction of products (e.g. eBay), the provision of services (e.g. Airbnb), and making investments (e.g. Kickstarter) are within scope.

The taxonomy captures differences between digital platforms according to their types. Its development started with iterating the ‘conceptual to empirical’ approach, after which we ended up with six literature reviews (Codagnone and Martens, 2016; Görög, 2018; Nguyen and Llosa,

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2018; Ranjbari et al., 2018; Sutherland and Jarrahi, 2018; Sanchez-Cartas and Leon, 2019). Out of these reviews and their primary sources, we collected 11 digital platform types, as shown in table 1.

Table 1: Digital platform types

Digital Platform Type	Source
One-sided platform	(Filistrucchi, Geradin, Van Damme and Affeldt, 2014)
Two-sided platform	(Hagiu and Wright, 2015)
Multi-sided platform	(Hagiu and Wright, 2015)
Transaction platform	(Acquier et al., 2017)
Investment platform	(Evans and Gawer, 2016)
Crowdfunding platform	(Haas, Blohm and Leimeister, 2014)
Digital marketplace	(Täuscher and Laudien, 2018)
Peer-to-peer (P2P) sharing and collaborative consumption platform	(Chasin, von Hoffen, Cramer and Matzner, 2018)
Sharing economy platform	(Frenken and Schor, 2017)
On-demand platform	(Mamonova, 2018)
Second-hand P2P platform	(Acquier et al., 2017)

We compared the definitions of these platform types and conceptualised their properties. Based on the maximum variation sampling method of Etikan (2016), we then collected in our iterations of the ‘empirical to conceptual’ approach, instances of all digital platform types.⁴ For each instance, information was gathered based on sources such as the official website, blogs, and industry magazines, following the approach of Trabucchi and Buganza (2019). The properties for the identified types were validated and, if needed, adjusted based on the information of the real instances selected for these types. The final taxonomy resulting from this iterative application of

⁴The full sample of existing digital platforms with an overview of their values can be found on <http://model-a-platform.com/sample-of-existing-digital-platforms/>

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the ‘conceptual to empirical’ and ‘empirical to conceptual’ approaches, identifies the properties presented in table 2.

A distinction is made between inclusive properties that can have more than one value for the classification dimension that is considered and exclusive properties that can have only one value for such dimension. An example of an inclusive property is a user affiliation that is both registration and non-transaction. In table 2, the combinations of values that are possible for a classification dimension are visually positioned on top (or under) each other. For instance, a user affiliation that is both non-transaction and investment was not a property of any digital platform within the scope of investigation. A one-sided market is an example of an exclusive property as market sides cannot have another value if it is one-sided. In table 2, values for dimensions that exclude each other are visually positioned next to each other. For instance, a product-oriented offering cannot be result-oriented or user-oriented. Finally, table 2 also indicates by means of the vertical positioning of grey cells when properties make other properties irrelevant. For instance, a product-oriented offering makes immediate access and under-utilized irrelevant. As another example, if user affiliation is non-transactional, then participation cannot be C2C. Hence, a top-down reading of the table reveals which properties a digital platform can have and which properties do not exist within the scope of digital platforms investigated.

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Table 2: Digital platform properties

Dimension	Values			
<i>Market sides</i>	One-sided	Multi-sided		
<i>User Affiliation</i>	Registration			
	Non-transaction	Transaction		
		Investment		
<i>Centralization</i>	Decentralized			
	Centralized			
<i>Participation</i>	P2P			Non-P2P
	C2C			
<i>Offering orientation</i>		Product	Result	User
<i>Immediate access</i>				True False
<i>Under-utilized</i>				True False

In total, the taxonomic schema identifies seven dimensions that can take different values based on which digital platforms can be classified into types:

- Market sides (Hagiú and Wright, 2015) is the number of different groups of platform users that are enabled to interact with each other.
- User affiliation (Sanchez-Cartas and Leon, 2019) refers to different ways that users can be connected to the platform. The user affiliation is always registration but can be combined with other values. What is not shown in table 2 is that transactions are only between users of different sides, while investments require that users can engage in transactions. User affiliation is inclusive as users can connect to the platform in multiple ways.
- Centralization (Sutherland and Jarrahi, 2018; Acquier, Carbone and Massé, 2019) refers to the way that users of different market sides can connect to each other. This can be via a search by the users of one side (i.e., decentralized matching of users) or via an automated matching of users of different sides by the platform software (i.e., centralized matching of

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users). Centralization is an inclusive property as some platforms support both ways of matching platform users. For instance, Uber Eats allows users to search themselves for a restaurant and meal but then matches the customer to an available deliverer.

- Participation (Ehikioya, 2018; Täuscher and Laudien, 2018) indicates whether the user interactions are intermediated by the platform are Business-to-Business (B2B), Business-to-Consumer (B2C), Consumer-to-Consumer (C2C) or Peer-to-Peer (P2P). As our investigation showed that B2C and B2B are not distinguishing two types of digital platform, they are excluded from the taxonomy. While C2C is only applicable for transactional platforms, P2P holds when platform participants are considered as ‘equals’, hence by definition this value can also hold for one-sided platforms. C2C is a specialisation of P2P when users of at least two sides are only allowed to be private persons. Participation is an inclusive dimension as a single platform can target different kinds of users.
- The offering orientation (Ritter and Schanz, 2019) differentiates between product selling, result-oriented services or user-oriented offerings including leasing, renting, sharing and pooling of a product. The choice of offering orientation is only applicable for transactional platforms.
- Immediate access and under-utilized capacity are only relevant for user-oriented offerings. A digital platform offers immediate access (Andersson, Hjalmarsson and Avital, 2013; Gobble, 2017) if the offering can be delivered immediately following ordering.
- Finally, under-utilized (Frenken and Schor, 2017) indicates excess capacity of the personally used offered product.

5 Digital Platform Ontology

In subsection 5.1 we focus on the general ontology that describes the functionality of any digital platform while the ontology modules in subsection 5.2 describe the functionality of each individual digital platform type in relation to the properties identified by the taxonomy.

5.1 General Digital Platform Ontology

First, we define the requirements derived from the definition of digital platform that we formulated for taxonomy development, as presented in section 4. After, we develop the general ontology that addresses these requirements.

5.1.1 Competency Questions

From the definition of digital platform given in section 4, we derive four requirements that we formulate as the following CQs:

1. What is a digital platform (i.e., what is the *service* offered)?
2. Who is involved in a digital platform and in what role are they involved (i.e., who are the *agents* that benefit from the service offered)?
3. What is the platform *software* and how does it enable the service offered (i.e., what makes the platform *digital*)?
4. What are *platform-intermediated interactions* (i.e., what is the service offered used for by the agents)?

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5.1.2 Ontology Description

Based on these requirements we created the general ontology, which is displayed here for the sake of clarity in three parts by the OntoUML models shown in figures 5, 6 and 7. The choice of FOPs of figure 3 and DROPs of figure 4 for modelling the general ontology is summarized in table 3.

Table 3: FOPs and DROPs

Applied FOP/DROP	Figure	Source
Service Offering DROP	5	UFO-S (Nardi et al., 2015)
Service Agreement DROP	5	
Kind-Subkind FOP	5, 7	UFO (Guizzardi, 2005)
Participation FOP	5, 6, 7	UFO (Almeida, Falbo and Guizzardi, 2019)
Participational FOP	7	
Instantiation FOP	6	UFO (Fonseca, Guizzardi et al., 2022)

Figure 5 models digital platform user actions and thus addresses the requirements formulated by the first two competency questions (i.e., req 1 and req 2), and partially also the requirement formulated by the third competency question (i.e., req 3). A *Digital Platform* is a service offering made by a *Platform Company* to a *Target Platform User Community* (req 1). This community is a collection of *Target Platform Users* (req 2). Only when a *Target Platform User* is bound to a *User Affiliation Agreement* with the *Platform Company*, the target platform user becomes an actual *Platform User* (req 2). Besides *User Actions*, the *Platform Software* also enables *Platform Company Actions* (i.e., actions performed by employees of the platform company) and *Platform Software Actions* (i.e., without user or employee intervention) (req 3). *Offline Actions* by platform users are not enabled by the software but might be required for service delivery (e.g., showing a customer around in the rented accommodation by the host of Airbnb).

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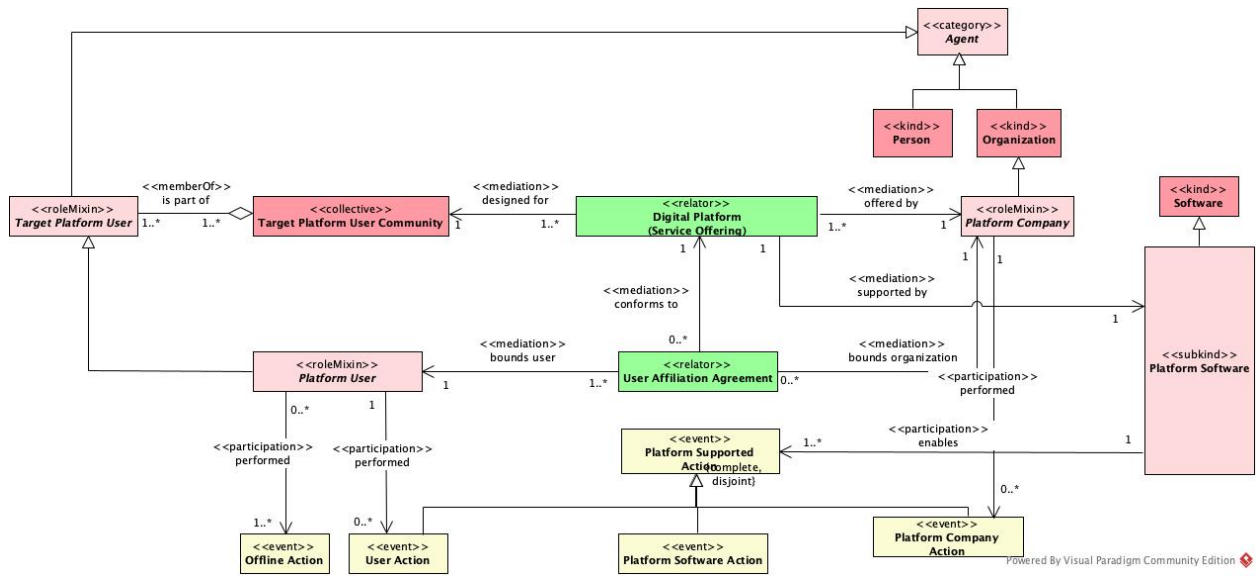


Figure 5: General ontology: User Actions

Figure 6 models user roles and thus further addresses req 2. Figure 6 shows that a *Platform Company* defines *User Roles* that allow users to conduct certain actions (req 2), meaning that platform users having a certain role assigned to them are allowed to perform actions that for other roles may be prohibited (e.g., create new accommodation offering for homeowners, book accommodation for customers). By participating in a *User Affiliation Action*, a *Platform Visitor* becomes a *Platform User* and is bound to the *User Affiliation Agreement* that determines which actions can be performed, including actions that change the *User Role Assignment*. By participating in such *User Role Action*, the user can change their *User Role Assignment*.

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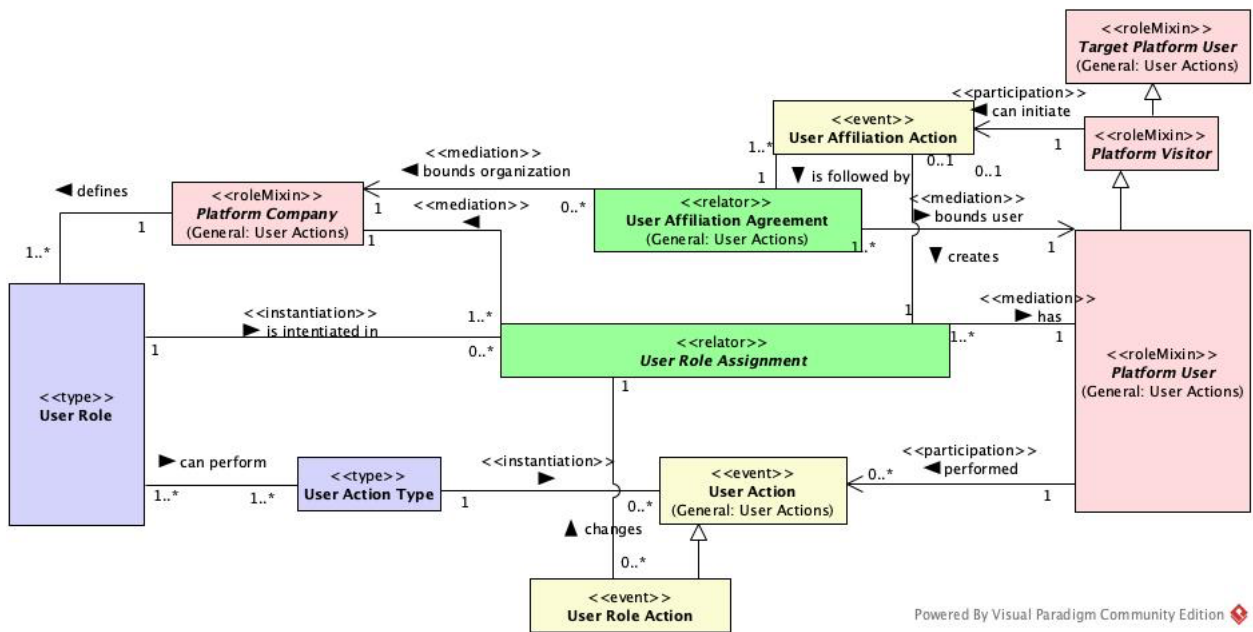


Figure 6: General ontology: User roles

Finally, figure 7 models platform-intermediated interactions and hence addresses the fourth competency question (req 4). Figure 7 shows that for a digital platform there need to be at least two types of user actions with instantiations supported by the software: *Digital Content Creation* (e.g., sending a message or file, creating an offering) and *Digital Content Consumption* (e.g., receiving a message or file, accepting the offering). When both creation and consumption of the same digital content are performed by two different users (i.e., the *Content Creator* and the *Content Consumer*), we talk about a *Platform-Supported Communication*. The service offered by a digital platform is thus to support interactions between platform users, which requires two-way communication between different users (e.g., sending, receiving, replying, receiving) (req 4).

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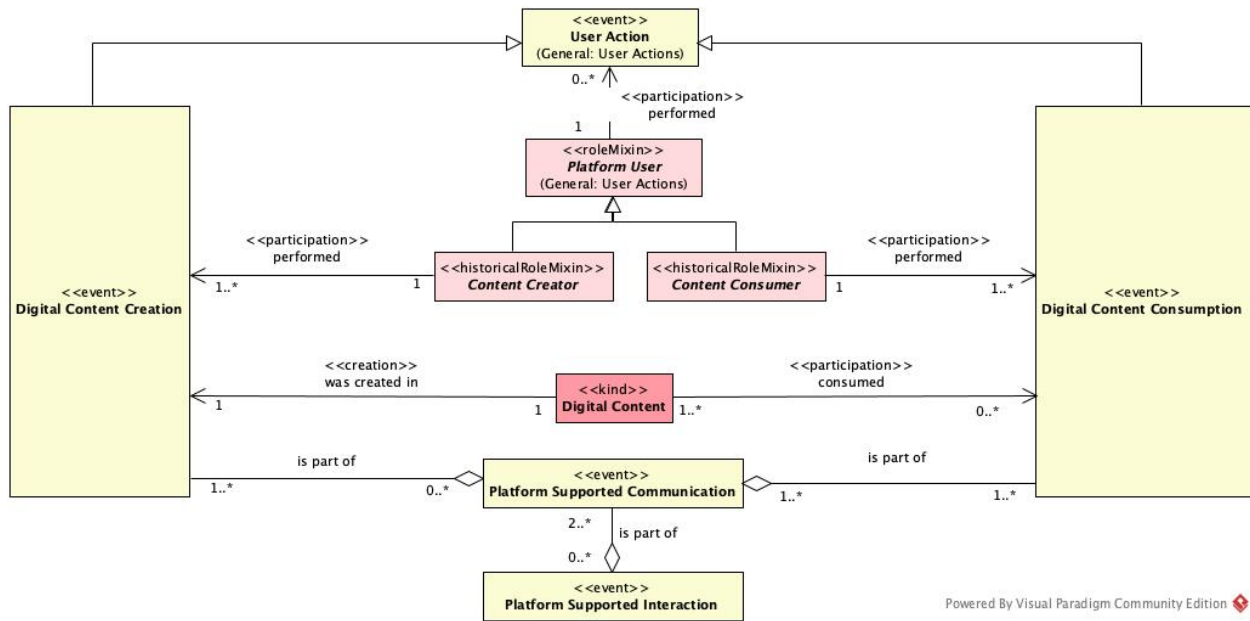


Figure 7: General ontology: Interactions

5.2 Ontology Modules

As mentioned before, there is a conceptual confusion of the different types of digital platform, with important ramifications for their expected functionality. To give the reader a clear understanding of the digital platform types that can be distinguished based on the digital platform properties identified in the taxonomy, we created a taxonomic view of the ontology (Figure 8). All the properties included in table 2 are thus used to classify existing digital platforms and assign them to types. For example, without checking the offering orientation and under-utilization of the product it is not possible to know if rentmydress.com is a sharing economy platform by Frenken and Schor (2017) or a second-hand P2P platform by Acquier et al. (2017).

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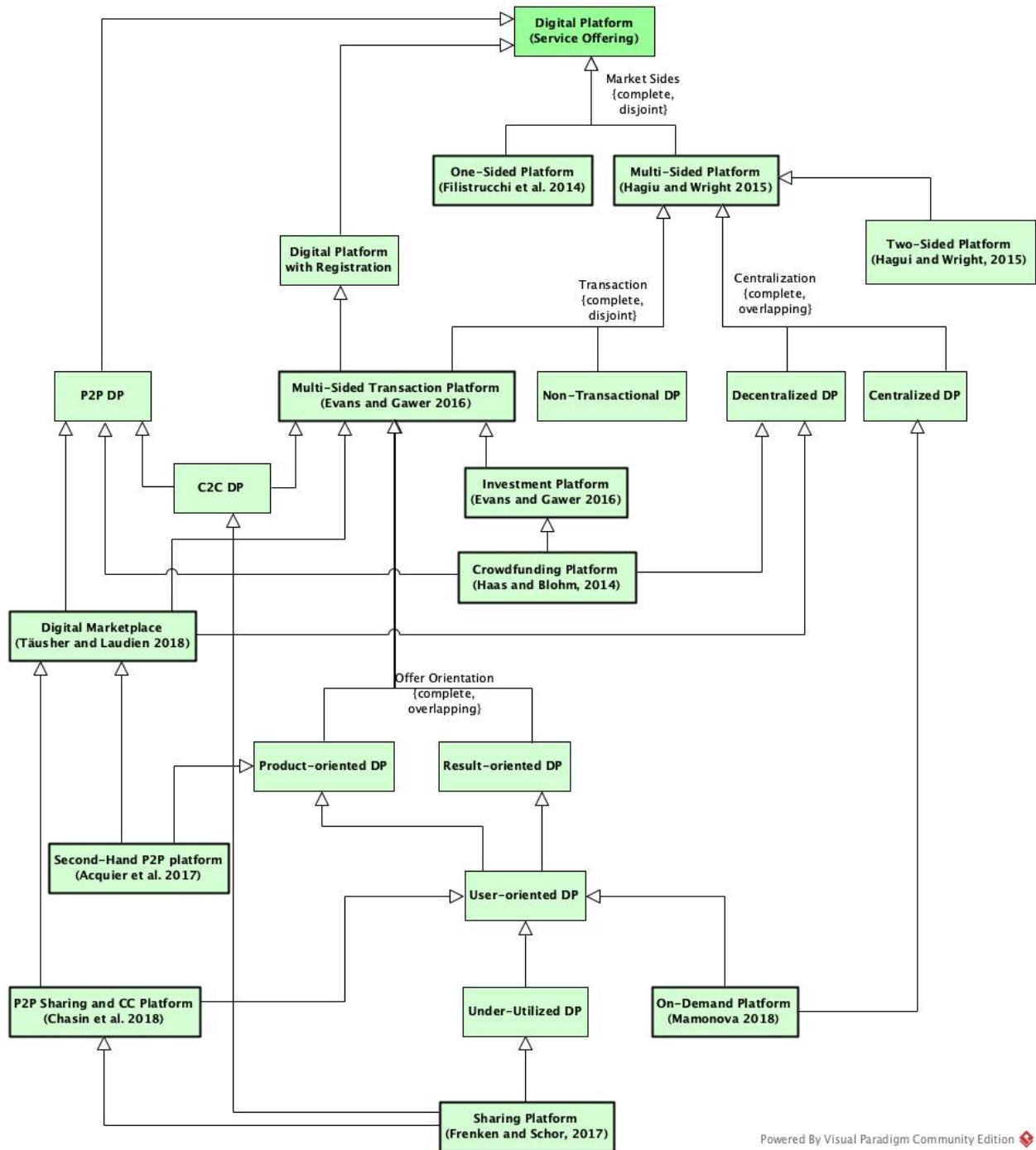


Figure 8: Taxonomic view of the ontology

Guided by figure 8, we now extend our general ontology with ontology modules capable of modelling each digital platform type. Based on our taxonomy (table 2), studying the set of existing digital platforms and the conducted literature review we define requirements, formulated as CQs,

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for each property. These requirements are subsequently used to develop the ontology modules. The modular organisation allows the ontology to be applied to both existing digital platforms and new digital platform ideas by combining the relevant ontology modules like building blocks. For the sake of simplicity, we do not show in the figures for the ontology modules the UFO or UFO-S stereotypes of the modelled concepts and annotations that indicate the application of FOPs and DROPs (unlike we did for the figures showing the general ontology). All UFO classes, relationships and their stereotypes can be found online in the Visual Paradigm files⁵, together with a complete explanation how the taxonomy, existing digital platforms and literature review have influenced the design of the ontology modules.

In what follows, we present per property identified by the taxonomy the corresponding ontology module, and we organize the modules by the dimensions of table 2.

5.2.1 Market Sides

Most businesses are operating in a ‘traditional’ market and only support the interaction between the company and the customer. These businesses only benefit from direct network effects without enabling interactions between their customers (Filistrucchi et al., 2014). A digital platform, on the other hand, enables interactions between the customers of the service offering (i.e., the platform users). This creates a market which also favours indirect network effects.

In case the platform users cannot be classified into types that have different interests in the service offering (e.g., as distinct groups of providers and consumers), the platform operates in a one-sided

⁵ https://github.com/tdrave/Digital_Platform_Ontology

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market and is defined as a one-sided platform (Filistrucchi et al., 2014). Such users affiliate to a one-sided platform by registration.

The ontology module for a one-sided market is given in figure 9 and addresses the following CQs:

- What is a one-sided platform?
- How many communities does a one-sided platform target?
- What kind of one-sided platform user affiliations are there?

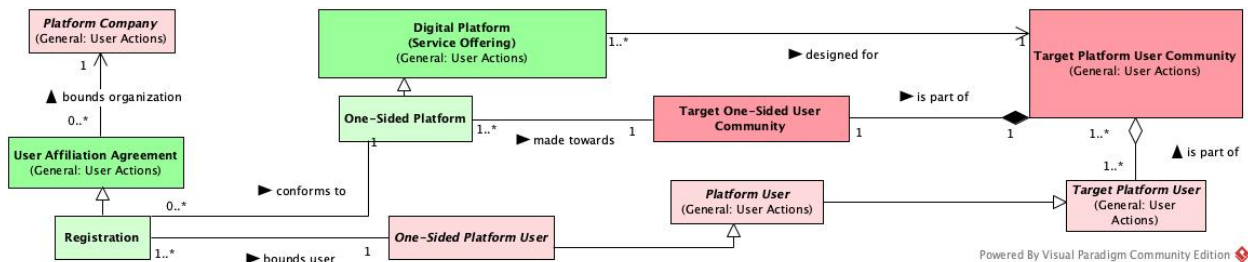


Figure 9: One-sided market ontology module

A Multi-Sided (MS) platform is a digital platform operating in a MS market, and enables the interactions between the users of distinct groups (e.g., providers and consumers). Users of each side need to be affiliated with the market by registration, transaction(s) and/or investment(s). These affiliations will be further explained in the next subsection.

The ontology module for multi-sided market is given in figure 10. It addresses the following CQs:

- What is a MS platform and how many user roles can it have?
- How many sides does a MS platform target?
- What kind of MS user affiliations are there?
- What is a MS platform supported interaction?

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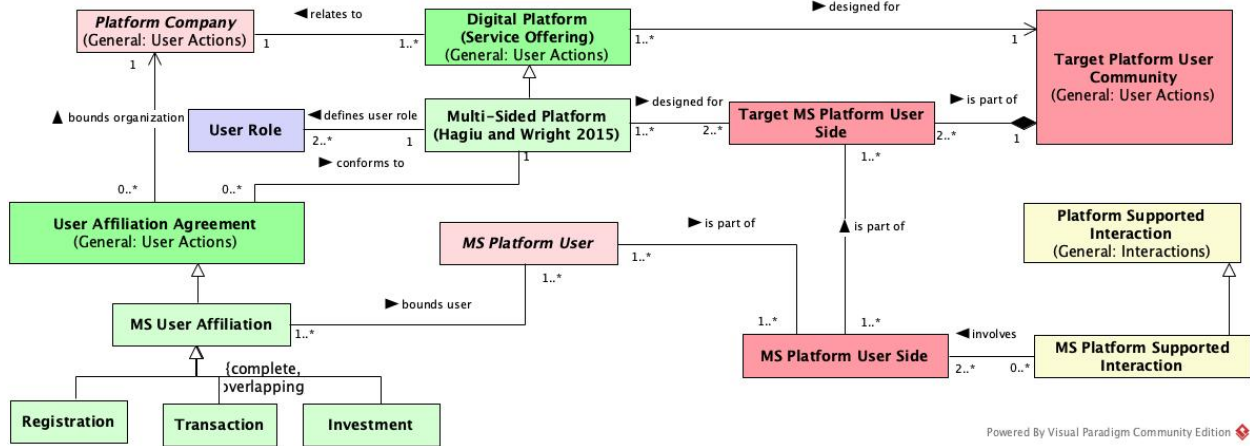


Figure 10: Multi-sided market ontology module

This module can easily be modified to a two-sided market, by replacing the cardinality constraints at *Target MS Platform User Side* and *MS Platform User Side* from 2..* to 2.

5.2.2 User Affiliation

We define a user affiliation as a registration when a platform visitor needs to provide personal information to become a user, which is also the case when a user registers via a social media login button. During the registration, the user agrees to the user affiliation agreement of the digital platform. After the registration, the user is allowed to engage in certain actions (e.g., book accommodation on Airbnb, find a match on Tinder).

The ontology module registration is given in figure 11 for the following CQs to address:

- By which event can a user become a registered platform user?
- What is a registration and how is it related to the registration action and registered platform user?
- What is collected by the registration action?

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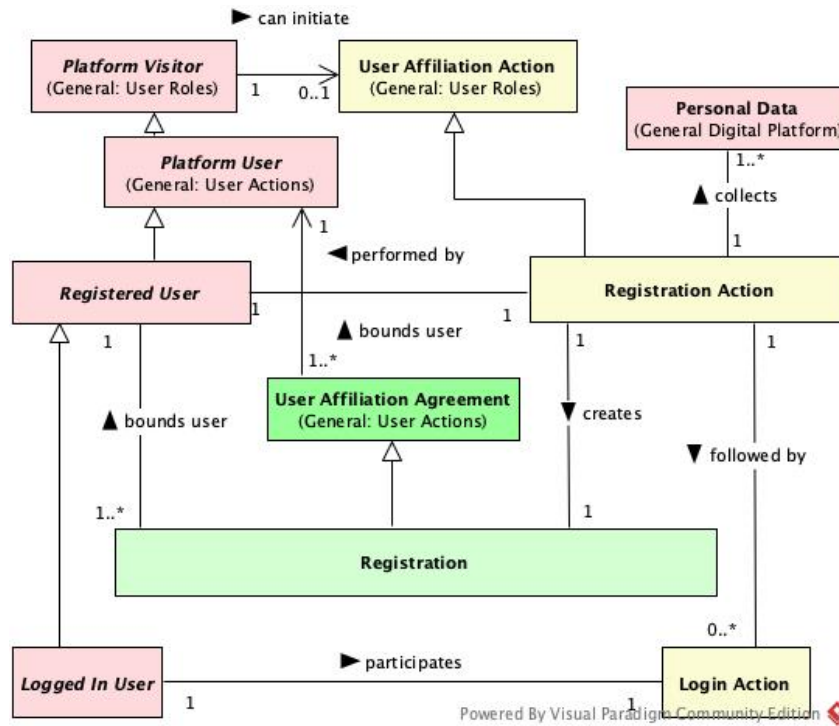


Figure 11: Registration ontology module

Note that in the Registration ontology module we distinguish the *Registration*, modelled as a relator (in green) that defines the service agreement between the user and the platform company, from the *Registration Action*, modelled as an event (in yellow) that allows a user to register (e.g., by filling in the registration form which is made available by the platform software).

An affiliation by transaction can involve the transfer of a tangible product (e.g., bag on O My Bag), the right to a service (e.g., a ticket on TicketSwap), the service itself (e.g., teaching on Preply), a financial investment (e.g., crowdfunding on Kickstarter), or a combination of these (e.g., meal delivery on Uber Eats) (Täuscher and Laudien, 2018).

The ontology module for transaction is given in figure 12, addressing the following CQs:

- What is an offering on the platform?
- How does a offering on the platform come onto existence?

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- Who is involved in a platform offering and how?
- What is a platform Transaction and how is it related to the platform offering?
- What is a delivery and how is it related to the platform transaction?

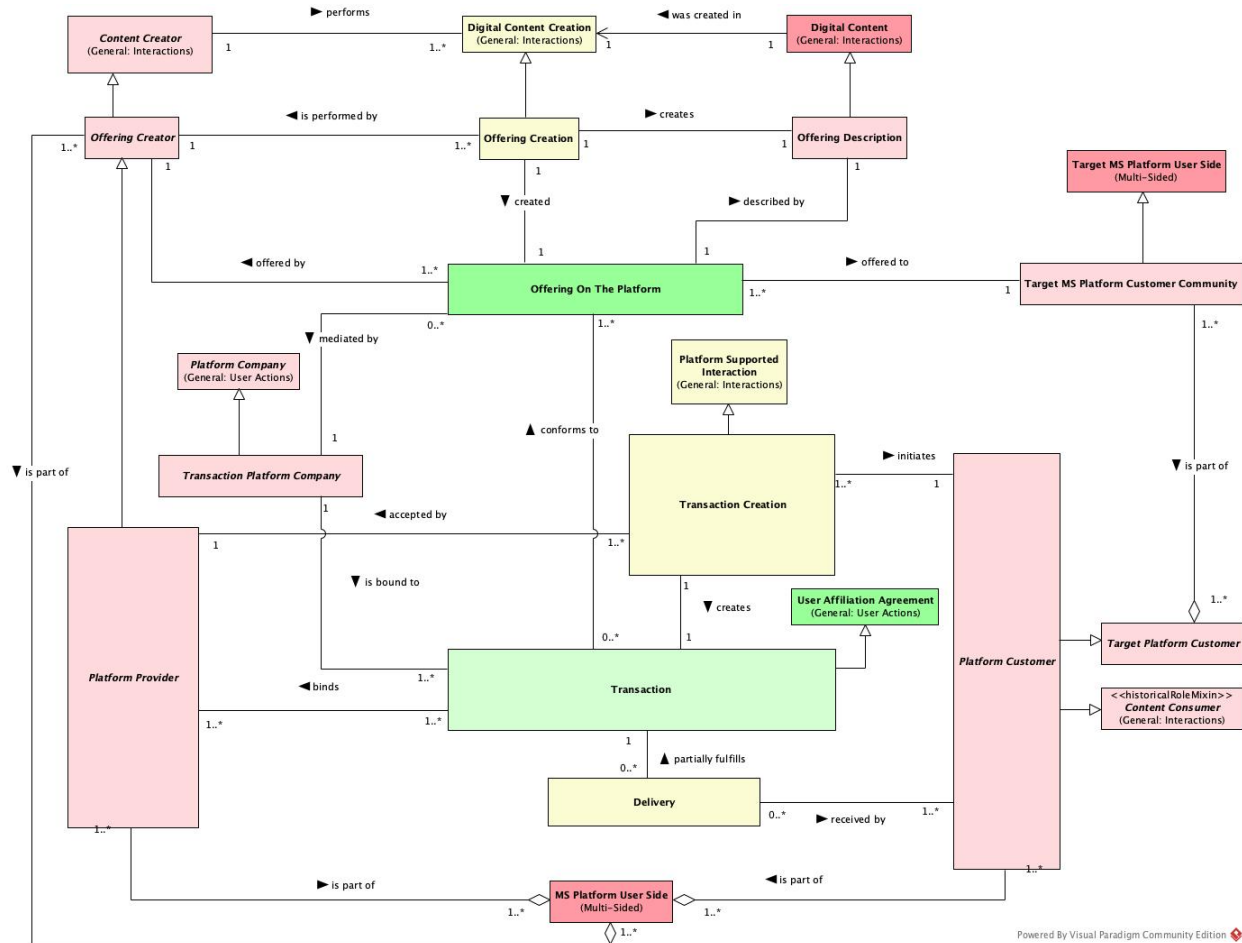


Figure 12: Transaction ontology module

Based on the financial intermediation theory, Haas et al. (2014) defined crowdfunding as the allocation between capital-seeking and capital-giving agents by a market-making mechanism. The intermediary provides certain functionalities and performs as electronic matching market to overcome information asymmetries and to minimize transaction costs.

The ontology module for investment is given in figure 13. It addresses the following CQs:

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- What is a platform investment, to who/what is it related and how?
- What is a future reimbursement commitment, to who/what is it related and how?
- This investment bounds a future reimbursement commitment from the capital-seeking agent towards the capital-given agent.

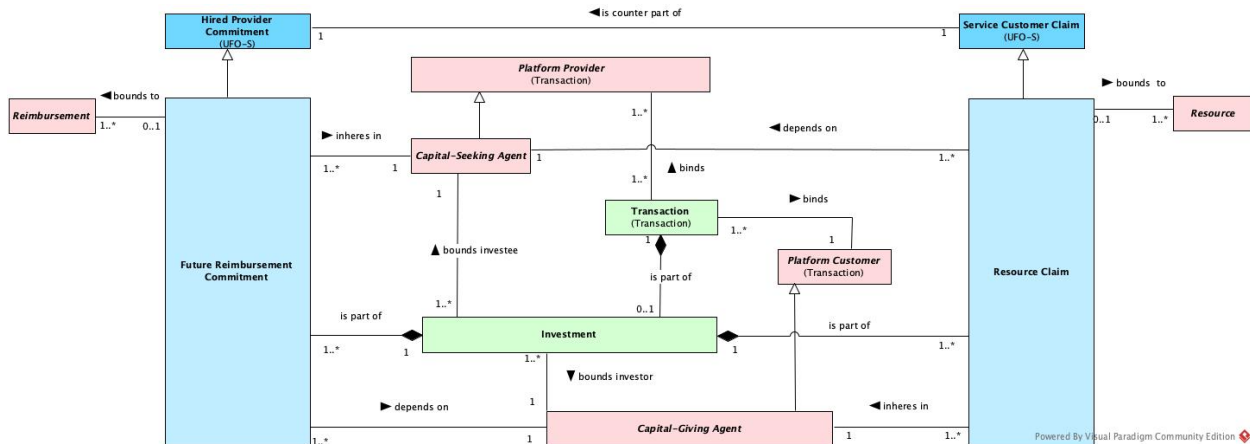


Figure 13: Investment ontology module

Conform our taxonomy, these user affiliation options are inclusive which allows a user to be connected to the platform in multiple ways. However, to model a one-sided platform only the ontology modules for registration can be used. All three user affiliation ontology modules can be combined for modelling a multi-sided platform.

5.2.3 Centralization

Two fundamental pools of offering allocation models emerge from the literature: A model of decentralized list-based offerings a certain user can choose from, and a model of centralized offerings automatically matched to a certain user by the platform software. Most digital platforms are on a continuum between centralized and decentralized, making the property inclusive.

A decentralized digital platform offers a simple list-based solution as the basic matching mechanism. Platform customers can choose themselves with which other users to interact by

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performing a search through the digital content. Platform customers can specify the desired characteristics of the requested resource (e.g., rental interval), and next the platform software queries the offerings, typically called the ‘listings’, and presents the customer an individual list of matches to choose from.

The ontology module for decentralized is given in figure 14 for the following CQs:

- What is an offering on a decentralized platform called?
- What are the actions a targeted decentralized customer can perform?
- What can a listing search result in?

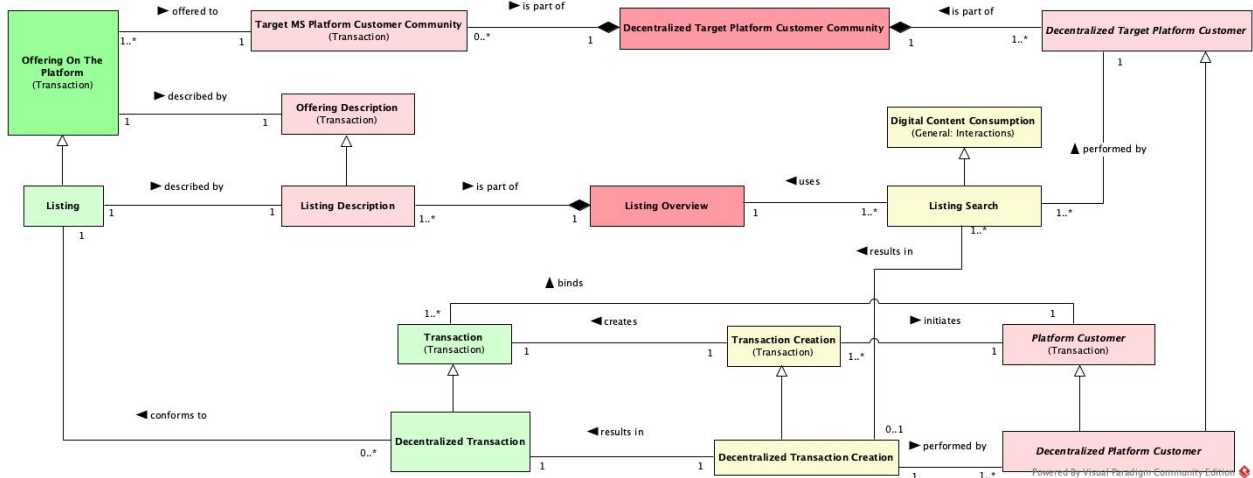


Figure 14: Decentralized MS platforms ontology

A centralized digital platform offers matching based on optimization procedures of supply (offers) and demand (customer requests). This way, a customer doesn’t need to scroll through the list of offerings for the final selection but can, for instance, directly navigate to the nearest vehicle of a car sharing provider. Examples of centralized platforms are Uber, matching drivers and customers, and Mechanical Turk, matching employers and employees.

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The ontology module for centralized is given in figure 15 for the following CQ:

- What is a centralized transaction creation, what does it include and who is involved?

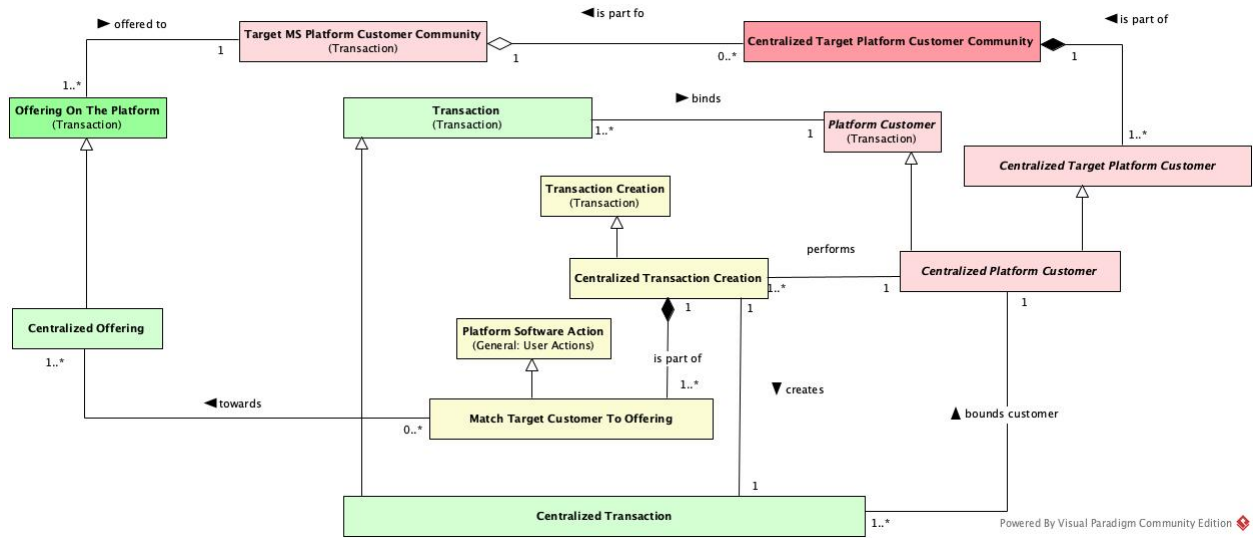


Figure 15: Centralized MS platform ontology

5.2.4 Participation

A transactional market has at least two sides, one creating the offering and another consuming the offering. It is possible that the kind of users allowed to operate at each side of the market is constrained by the platform company.

A *P2P* platform does not necessarily offer transactions, but intermediates in the interaction between its users as equal participants, also called prosumers alternating in their role as producer and consumer co-creating the value proposition (Ritter and Schanz, 2019). Based on our sample, we also state that for a platform to be *P2P*, the time and the cost for all peer users to be affiliated to the platform should be near zero by fully automating affiliation actions.

The ontology module for *P2P* is given in figure 16 for the following CQs:

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- What are peer users and what actions can they perform?
- What action is required to become a peer user?

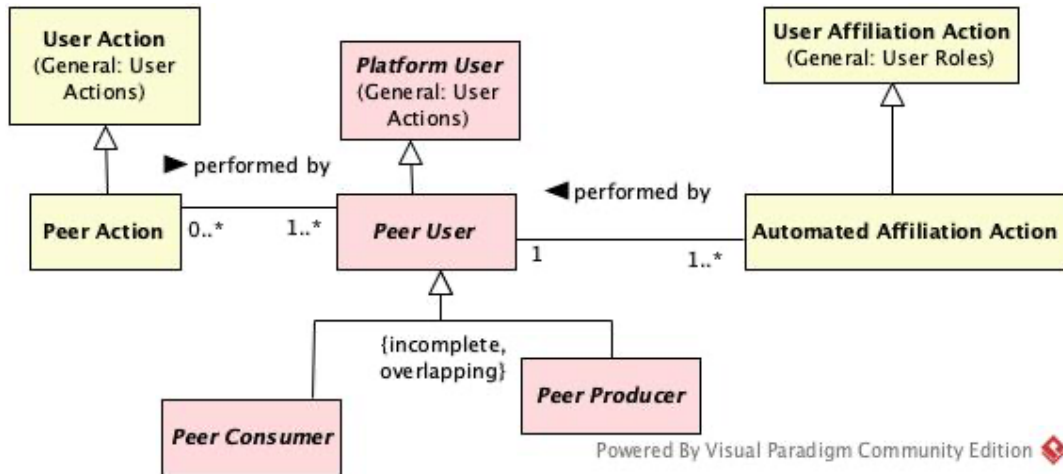


Figure 16: P2P ontology module

The ontology module C2C on the other hand is presented in figure 17 for the following CQ:

- What is a C2C transaction and what type of users are involved?

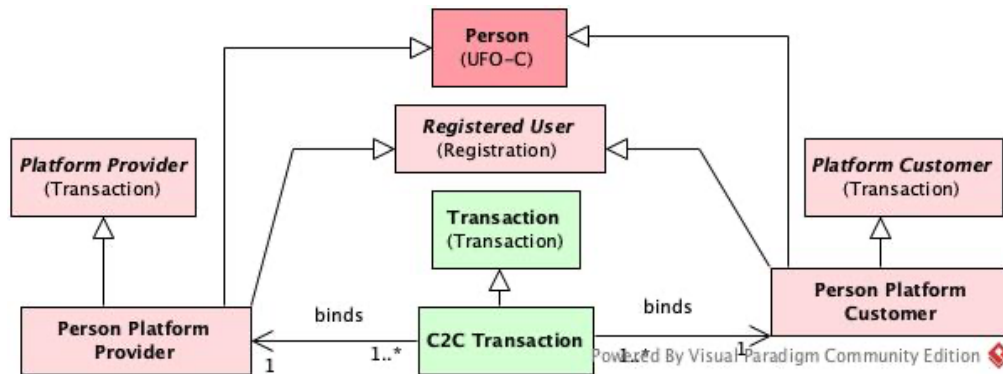


Figure 17: C2C ontology modules

5.2.5 Offering Orientation

Offerings can be placed on a continuous scale of product-oriented and result-oriented (Ritter and Schanz, 2019). *Product-oriented* offerings are geared towards sales of products, while for *result-oriented* offerings the provider is selling a result or competence, offering a mix of services and is

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equal to a service delivery as defined in UFO-S. An offering can be anywhere on this continuum, and the relevance of the product as a core component decreases as the offering gets closer to the result-oriented side. In the middle of this continuum are the *user-oriented* offerings consisting of product leasing, renting, sharing and pooling (Tukker, 2004).

The ontology modules for product, result and user-oriented offerings are presented jointly in figure 18 for the following CQs:

- What does a delivery of a product-oriented offering involve?
- What does a delivery of a result-oriented offering involve?
- What is a user-oriented delivery?

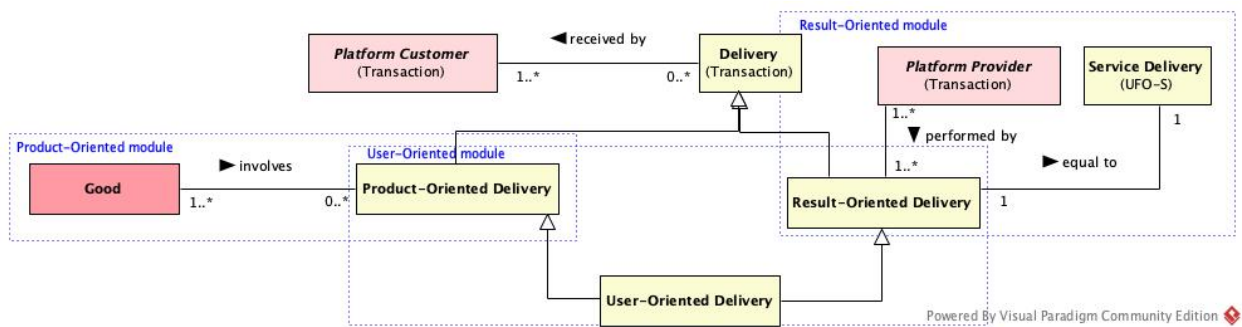


Figure 18: Product, result and user orientation ontology modules

5.2.6 Immediate Access

On-demand platforms like Uber and Deliveroo commit to an immediate access for the customer to the preferred service. The service is therefore characterized by a shortage of time between advertising, matching and actual delivery. In other words, an on-demand platform offers access to a service where and when the customer needs it, and this can be straight away.

The ontology module for immediate access is given in figure 19. It addresses the following CQs:

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- What can a customer expect after an immediate access transaction?
- What is the provider is committed to after an immediate access transaction?

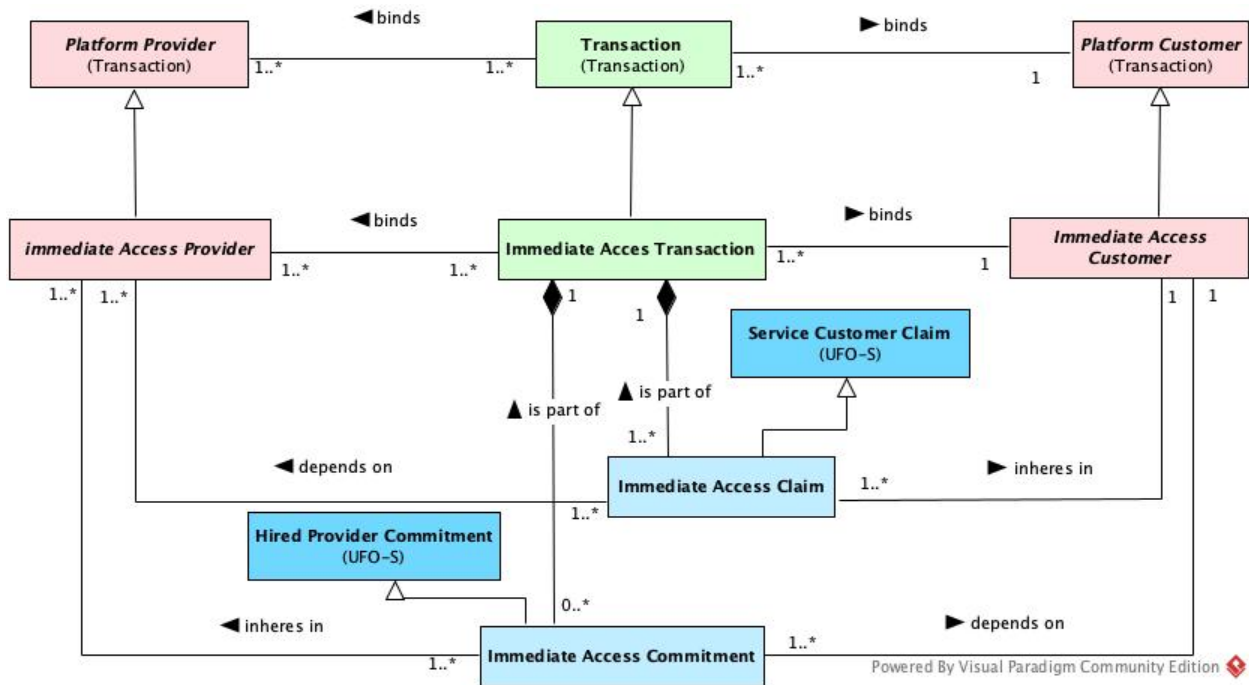


Figure 19: Immediate access ontology module

5.2.7 Under-utilization

The under-utilization of goods comes into existence when there is excess capacity, giving the offering creator an opportunity to lend out or rent out his own goods to potential customers. Excess capacity of a physical good is present when the owner does not consume the good all the time.

The ontology module for under-utilized is given in figure 20 for the following CQ:

- What is the difference between a good and an under-utilized good?

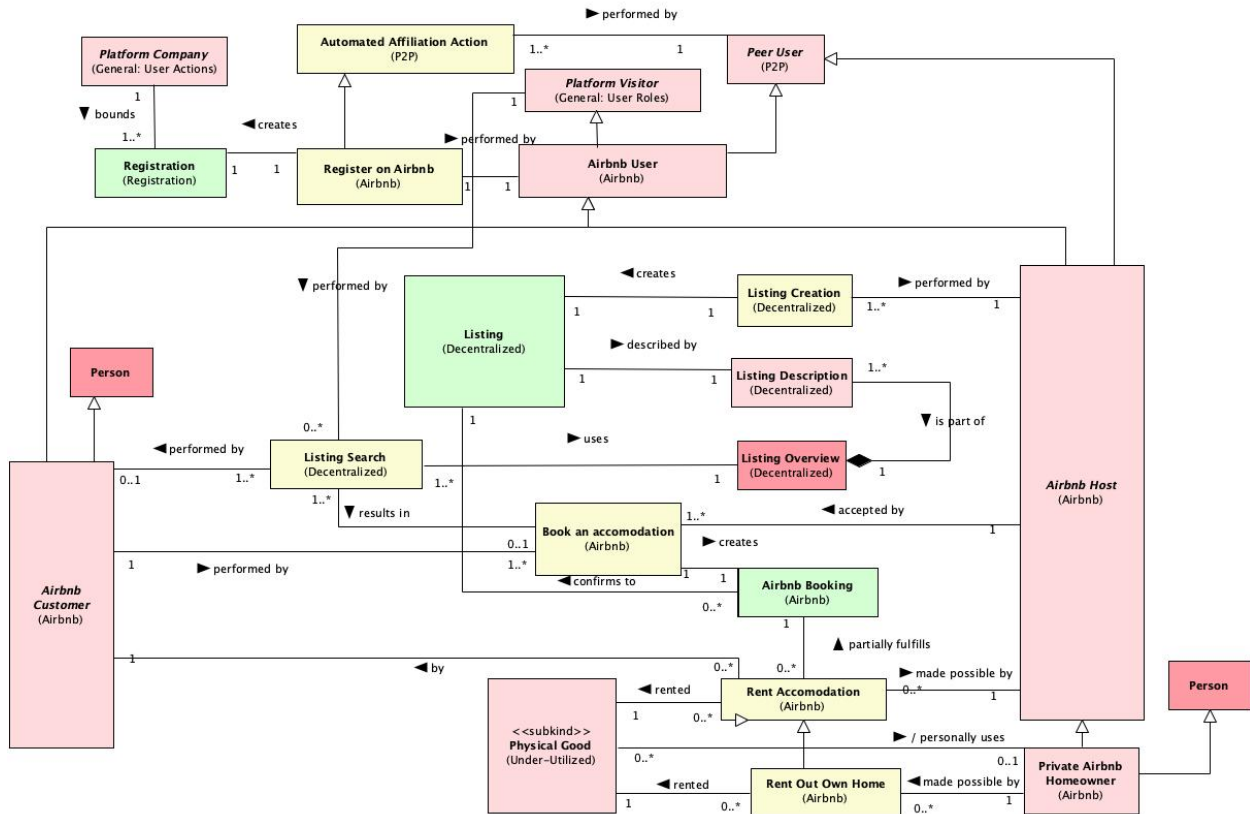
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6.1 Airbnb Ontology

As a first example we developed an ontology for Airbnb using the relevant ontology modules for a sharing platform as defined by (Frenken and Schor, 2017). This ontology clearly positions Airbnb as a sharing platform showing the functionality that is expected from this type of platform.

The ontology model in figure 21 shows that Airbnb platform visitors can search for listings but must register before becoming a user. An Airbnb user can then create listings, becoming a host. And a user can perform listing searches, after which the user can book an accommodation as a customer. This booking can then be followed up by both users meaning that the accommodation is used by the customer and made possible by the host. The platform software enables the interactions between customers and hosts (two-sided). Users are affiliated to the platform by registering and by the transactions with each other. The registration and transactions are instantly and fully automated, and an Airbnb user can be both a customer and a host (even for the same booking) making the Airbnb users peers. Platform visitors or Airbnb customers can search themselves through a listing overview (decentralized). The rental involves the temporary use of an accommodation (user-oriented). In case the accommodation is also personally used by the host as his own home (under-utilized), and both the host and renter are private persons (C2C), the offering is also considered as part of the sharing economy domain as defined by (Frenken and Schor, 2017).

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Powered By Visual Paradigm Community Edition

Figure 21: Platform-specific ontology of Airbnb

6.2 Uber Eats Ontology

A second example is an ontology model for the meal delivery company Uber Eats in figure 22, that intermediates in the interactions between three user roles (multi-sided): customer, restaurant and deliverer (also called rider according to the Uber Eats terminology). The platform combines the modules of both digital marketplace and on-demand platform. All users need to register (registration). As opposed to the customer and rider whose registration is fully automated (P2P) and can be considered as peers, the restaurant needs to pass some manual checks before using the platform (non-P2P). After registration, the restaurant can upload their menu and install the dashboard to create their listing. The customer can search through a listing overview (decentralized) what can eventually result in a meal order (transaction). After the order, the

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restaurant prepares the meal, and the rider is automatically matched to the meal order (centralized). In case the rider accepts the ride, he has the obligation to deliver the meal to the customer as soon as possible, creating both an immediate access commitment by the rider and an immediate access claim by the customer (immediate access). Nevertheless, the physical good (the meal) is not personally used by the rider nor the restaurant (under-utilization false). Consequently, Uber Eats cannot be classified as a sharing platform, following (Frenken and Schor, 2017).

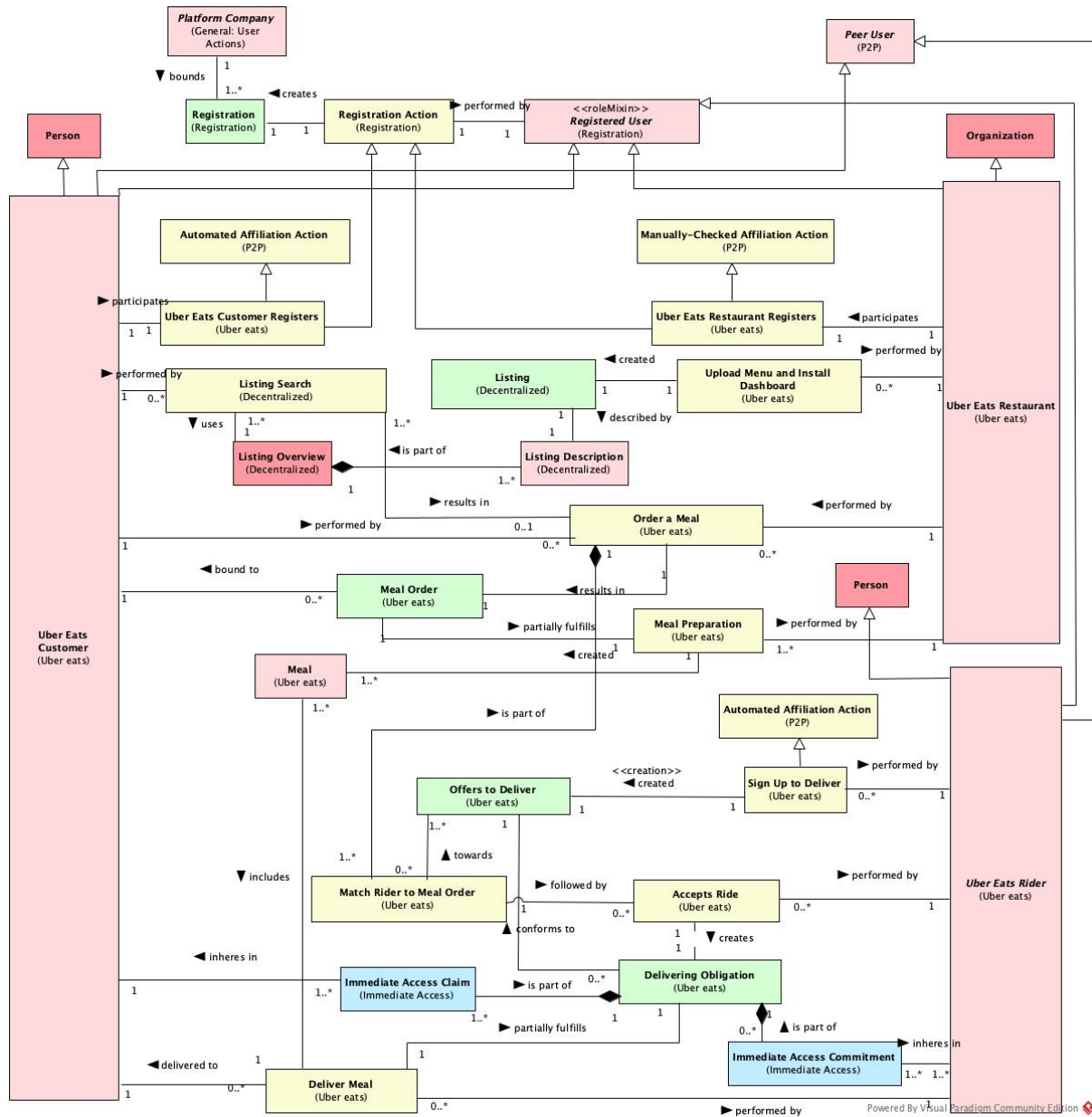


Figure 22: Platform-specific ontology of Uber Eats

7 Ontology evaluation

First, we verified that our model confirms to the OntoUML syntax using the OntoUML plugin for Visual Paradigm⁷ (Fonseca et al., 2022), which can automatically assess models and identify any syntactical transgressions.

Next, we performed an empirical ontology validation using the defined CQs as they constitute a requirements specification against which the ontology can be checked (Asunción, Mariano and Oscar, 2003). If the expected answer to a CQ, meaning the answer intended by the ontology requirement, is provided by a user when searching and interpreting the ontology model, then the requirement corresponding to the CQ can be considered as achieved.

We asked three ontology experts to answer the CQs based on their interpretation of the DPO. One expert is the author of the original UFO-S paper. Another expert has more than 10 published UFO/OntoUML papers. The third expert has 11 ontology papers of which 3 OntoUML/UFO papers and one UFO-S paper. In table 4 we show as an example, the answers of all three experts to the first CQ: ‘What is a digital platform?’. As can be seen, these answers approximate closely the working definition of digital platform we employed for our research.

Table 4: Responses to the CQ ‘What is a digital platform?’

Expert 1	A Digital Platform is a service offering relator (or relationship) of a specific type that connects the platform provider (the platform management that plays the role of service provider) and its software platform to its target community.
Expert 2	It is a service offering that relates a software platform to a predefined user roles and focuses on a target customer community.

⁷The OntoUML plugin is available on github via <https://github.com/OntoUML/ontouml-vp-plugin>

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Expert 3	I would define a digital platform as a service offering, where multiple users can enter different agreements with each other.
----------	-------------------------------------------------------------------------------------------------------------------------------

For each CQ, we compared the answers of the experts to the requirements that were formulated to be addressed by the ontology, and in case of differences, the relevant DROP application was remodelled. The full list of CQs, answers by the experts and changes to the model can be found online.⁸ The current version of the DPO can also be found online.⁹

8 Discussion

One of the main issues in ontology engineering is the knowledge acquisition bottleneck (Starr and Parente De Oliveira, 2013). This bottleneck is observed in the digital platform domain where the meaning of concepts can change very fast. This may create two problems. First, it may be the case that just after the ontology is ready to be deployed, the digital platform conceptualisation has already changed. Second, it is possible that the cost to update the ontology is prohibitively high given the fast development of the field. We postulate, however, that our ontology can accommodate changes well because of its modular structure, which is based on the taxonomic structure. Should new digital platform types emerge, then it needs to be investigated if they can be defined in terms of the taxonomic structure presented in the paper. If the present taxonomic structure allows defining new types, then the ontology doesn't need to change, as the new types can be modelled by a combination of existing ontology modules. In case of changes to the taxonomic structure, for instance, because of properties that are conceptualized as new values for

⁸ <http://model-a-platform.com/validation-of-the-ontology-using-cqs/>

⁹ https://github.com/tdrave/Digital_Platform_Ontology

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existing dimensions or even values on new dimensions, then we recommend to first define new ontology requirements for these new properties, and next develop new ontology modules following the approach set forth in this paper. We wish to emphasise that to keep control over the further development of the ontology, the alignment of taxonomy and ontology is key.

Despite this issue, we believe that the taxonomy and ontology created in this paper can already be important artefacts to grab and communicate the complexity and future direction of the digital platform domain. We noticed during this research, for instance, that different digital platform types are starting to merge, combining providers of different sorts on one platform for a single offering. A first example is the car service app Uber, that is further being developed to allow combining different types of providers and products into one transaction (Karanovic, 2019). When someone wants to have transportation from A to B, Uber is planning to propose a combination of Uber car, train, plane, bike and scooter renting services into one service to get the customers to their destination in the cheapest way possible. Another example is a travel platform as described by (Derave, 2019) and Radonjic-Simic, Richter and Pfistere (2019), where multiple assets, goods and services (including accommodation, car, activities, guide, and driver) by different providers can be combined as one offering on the platform. These combinations of platforms are also called mega-platforms (Radonjic-Simic et al., 2019), hybrid platforms (Acquier et al., 2019) or integrated platforms (P. C. Evans and Gawer, 2016), that provide the functionalities of different platform types. As shown by these examples, the taxonomy can help to analyse such evolutions by classifying digital platforms according to the distinctive properties of the platform types that are included, and our ontology can help to understand and communicate these distinctive properties.

In this paper, we modelled both the general functionality of a digital platform, independent of its type, and the functionality that differs depending on the type of digital platform. In follow-up

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research we already proposed an extension of the DPO for the digital marketplaces type, with modules to model functionality related to specific business model choices (Derave et al., 2021). We based ourselves on the business model framework of (Täuscher and Laudien, 2018) and the business model ontology of (Osterwalder, 2004), to expand our taxonomy (and ontology) with properties (and modules) like listing type, price discovery and calculation, payment system, revenue stream and source, conversation and review system. This partly solves the lack of research concerning the technological aspects of the development, implementation and operation of platforms (Sutherland and Jarrahi, 2018; Trabucchi, Muzellec and Ronteau, 2019).

Further, we also proposed a method where the DPO and its DPO business model extension (for digital marketplaces) is used as the foundation for the development of platform-specific ontologies (Derave et al., 2022b) as demonstrated in section 6. Platform-specific ontologies increase the knowledge of software design in the sharing and platform economy, which triggers the conception of alternatives for monopolistic companies like Airbnb and Uber, who are criticized for paying low wages, taking high commission fees and avoiding taxes (Kenney and Zysman, 2016).

Most recently, we proposed a method where a platform-specific ontology can drive Minimum Viable Platform (MVP) development (Derave et al., 2022a). A MVP is a minimum viable product of a digital platform, hence software with just enough features to be usable by early customers who can then provide feedback for future product development (Gracia, 2022). We are now developing several MVPs operating a variety of business models. A test case is set up with aspiring entrepreneurs who plan to develop a MVP of their platform idea starting from a self-constructed platform-specific ontology. A clear method for MVP development is important, because due to high costs of implementation, competitors with less diversification but superior technology are still capable of monopolizing a market. Lowering the barrier of digital platform development is

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therefore vital as this creates incentives to enter and isolate the influence of large competitors, increasing the differentiation of digital platforms. It is therefore in our opinion vital to facilitate the development of alternative and more socially responsible platforms.

In future research, we plan to further validate and expand our artefacts. First, we will further *validate* our taxonomy and ontology with domain experts. At this moment, we are in contact with a consultant firm with expertise in the agile development of digital platforms. This firm applies short iterations to gather the requirements from the client (i.e., the future platform company) and develop software in accordance with these requirements. We plan to validate if the application of our ontology is able to capture these requirements and test how it can help to elicit these requirements from the client more adequately.

Second, we will implement our ontology using the Web Ontology Language (OWL) (W3C OWL Working Group, 2012) by extending gUFO (Almeida et al., 2019), an implementation of UFO for the Semantic Web. This would allow us to create a knowledge graph with data about digital platforms instances, a resource that could be leveraged by both researchers and practitioners. This activity would have the side benefit of further validating our ontology, as the representation of more cases would stress-test the ontological commitments we made there.

Another avenue for further research is to *extend* the taxonomy and ontology. First, we plan to capture the possible influence of regulation, as a 'one size fits all' policy and regulatory approach is inappropriate (Codagnone et al., 2016). Applying DROPs of UFO-L, a core ontology that accounts for a comprehensive set of related legal notions, including rights and duties, no-rights and permissions, powers and liabilities, disabilities and immunities, as well as liberties (Griffo, Almeida, Guizzardi and Nardi, 2019) can be an aide in this matter.

9 Conclusion

In this paper we presented two artefacts. The first is a taxonomy for digital platforms that is based on a rigorous review of the literature and on empirical evidence that we gathered through a maximum variation sampling of existing digital platforms. The taxonomy identifies digital platform properties that express the possible variations between digital platforms depending on their type.

The second artefact is an ontology, called the Digital Platform Ontology (DPO), consisting of a general ontology, which describes the functionalities of any digital platform, and a set of ontology modules, which describe functionalities that apply only to certain types of digital platforms. We believe that the DPO can serve as a common language that all platform stakeholders can use, facilitating future research and development in this domain. The DPO also tackles the lack of knowledge concerning the functionalities that are expected of a digital platform depending on its type.

With these two artefacts we contribute to the conceptual clarification of the different types of digital platforms that can be observed and the functionality that is expected of each type of platform. We believe that this conceptual clarification can help to advance the state-of-the-art in the research on and application of the cross-disciplinary concept of digital platforms.

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