A Digital Ecosystem for Co-Creating Business with People

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***Abstract*— In recent years, we have seen the rise of Web 2.0, in which users become co-creators and software turns into services. During the last two years, we have also witnessed the phenomenal success of Apple's App Store for which people produce the applications and can also create business of them. While the technologies and business services related to these phenomena have been studied separately, we suggest that the underlying digital ecosystem that ties them together has not been made explicit. In this paper, we provide a conceptual model of a digital ecosystem for understanding how companies can co-create business with people. To construct such a model, we use multiple case study approach and explore two cases: an ecosystem around smart phone application market App Store and an ecosystem around bioinformatics service registry BioCatalogue. Our results suggest that the required technical solutions and business services are now available. However, to make business flourish, the orchestration of the overall ecosystem is also essential and needs to be taken care of.**

***Index Terms*—bioinformatics, business ecosystem, case study, co-creation, digital ecosystem, e-commerce, smart phone, Web 2.0, web services**

I. Introduction

A. Background and motivation

Since the bursting of the dot-com bubble in 2001, we have seen the rise of a new Web: Web 2.0. According to O'Reilly, there are no clear boundaries or definitions for this new Web, but instead, it is a set of principles and practices that ties everything together [1]. Some of the important characteristics for Web 2.0 are that services have replaced old-style packaged software and users are not mere end-users but trusted co-creators and sources of innovation. What are the technological and social conditions that have enabled these developments?

The possibility of creating business is an important motivating factor for many people. In the field of smart phone applications, we have witnessed extraordinary developments during the last two years. According to Apple, more than 350,000 applications, innovated and created by individuals and small companies, have already been downloaded 10 billion times from the App Store [2]. By any means, this is a phenomenal number of downloads reached only two and a half years after the launch. What are the factors that have enabled such unparalleled development?

In its entirety, Web 2.0 is an emerging and vivid ecosystem, and recent developments have provided tools and means for individual users to become service and application providers and also to create business from them. Even though there has been much discussion about Web 2.0 and many of the technologies associated with it, these themes have mostly been researched individually. Furthermore, less work has been done to understand these technological developments in the context of users and companies co-creating business together and to illustrate the digital business ecosystems that they form. We attempt to address some of these shortcomings in this paper.

Another important motivation for our work comes from the field of bioinformatics. In bioinformatics, computationally intensive techniques, such as data

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mining, are used to analyze biological data in order to increase our understanding of complex biological systems. Service business in bioinformatics has much potential for growth, and so far, Web 2.0 technologies have not been widely utilized. By mapping the concepts and business models from the Web 2.0 world to the field of bioinformatics, we hope to raise some new ideas regarding how these concepts can be applied.

B. Research questions

We are particularly interested in the new role of users (i.e., people) in the Web 2.0 co-creation ecosystem and the identification of the digital elements, the digital ecosystem, which make it functional. More specifically, we are interested in two specific aspects:

1. Seeing users as co-creators instead of mere end-users
2. Looking at how business is or could be boosted in the ecosystem

This leads to the formulation of our research questions:

1. What are the key actors and elements in a digital service and application co-creation ecosystem?
2. How do these actors boost user-driven service and application innovation and business?

The importance of studying co-creation phenomena in the context of e-commerce has also been acknowledged by others (for a thorough review, see Zwass [3]). Zwass also presents an initial taxonomic framework to contextualize research efforts in the area of co-creation. In his taxonomy, our research falls into the category of autonomous co-creation, in which "individuals or consumer communities produce marketable value in voluntary activities conducted independently of any established organization, although they may be using platforms provided by such organizations" [3]. To further define the scope of our research, we will specifically analyze the co-creation of *digital* services and applications. Furthermore, we will focus on digital elements related to making business, such as payment systems, and elements related to collaborating with other users and companies.

In our earlier research, we have studied some of these developments separately for Web 2.0 service ecosystem [4] and smart phone application market [5]. In this study, we aim at drawing more generic conclusions and explanations about the phenomenon by studying and comparing the two selected cases head-to-head.

C. Structure of the paper

The remainder of the paper is organized as follows. In Section II, Relevant Research, we review the existing literature around co-creation and digital ecosystems. In Section III, Methods, we describe the research methods and data that were used for this work. Section IV, Results, presents the results of the work, including the use cases, the conceptual model, and the case study. Finally, Section V, Discussion, ends this paper with a summary of enabling digital elements and technologies, contributions and limitations of this study, and concluding remarks and suggestions for future work.

II. Relevant research

A. New actors in value co-creation and innovation processes

The classic manufacturer-centric and linear model of innovation that has prevailed for most of the past century [6] has shown its limits in describing accurately how innovations actually unfold. On one hand, the model assumes that innovation starts (mostly) from insights created from a firm's research and development unit. Innovative ideas are then developed into a product (offering), marketed, and further on "diffused" to end users [7]. From a business management point of view, a main concern has been to keep the process strictly controlled between the boundaries of the firm (closed) and assert it as the realm and monopoly of experts. This view places considerable limits on understanding who actually is involved in innovation and new business creation processes and to what extent [8]. In recent decades, research in diverse fields, such as science and technology studies [9], innovation management [10], marketing [11], design and information systems [12], and media studies [13] have shed light on new understandings of innovation as a distributed, non-linear, and dynamic process. It has also become increasingly clear that these processes involve changes at different stages (not only in technology) and that there are more active roles for stakeholders, like for example users, suppliers, or customers, who previously have been assumed to embody mainly reactive roles [9, 10].

For example, from the management studies perspective, there has been a shift away from linear models of value creation towards new co-production and co-creation models. Already in the early 90's, Norman and Ramirez argued that value creation in business cannot be understood as a chain in which value is added to things, but that value creation can be seen rather as constellations that articulate complete systems in which many actors, besides companies, play a role [14]. Building on some of these arguments, Prahalad and Rmashwamy have actively argued for a model of value co-creation in which customers participate actively in creating value [11] alongside firms and corporations. Amongst the reasons for this shift, Prahalad and Rmashwamy outlined how, for example, customers and consumers, thanks to new information and communication technologies, infrastructures, and social media, are now in a position to make more informed decisions, how they possess a global view on matters, and how they are actively networking with others. In doing so, a variety of new actors are able to experiment with and develop new products and service ideas.

Similar arguments have been made in innovation studies where new paradigms such as Open Innovation (OI) [15] have been proposed. In general terms, OI describes an emerging distributed mode of innovation that focuses more on how companies can profit and gain competitive advantage by managing the information flow more efficiently, regardless of its source. The argument

goes that in a world where knowledge is widely distributed, successful companies cannot rely only on their own research, but instead should constantly search and incorporate by buying or licensing processes or inventions from other companies. Furthermore, research by Von Hippel and his collaborators have empirically demonstrated how users, under certain conditions, are not mere consumers or customers, but also actually a significant source of innovation [8, 10].

All of these insights have important implications for understanding the roles of different actors in digital ecosystems, especially of those smaller actors who are in a position to play active roles as co-developers and, to some extent, as initiators of the development process and possible business partners. A new understanding of the variety of actors that are in a position of valued co-creators and sources of innovation not only points out users' ability to innovate by themselves, but also draws our attention to new forms of collective organization and collaborative practices that make possible collective and distributed innovation [16] that should be taken into account in digital ecosystem research.

B. Digital ecosystems

Briscoe and Wilde define the digital ecosystem to be "the digital counterparts of biological ecosystems, exploiting the self-organising properties of biological ecosystems, which are considered to be robust, self-organising and scalable architectures that can automatically solve complex, dynamic problems" [17]. This definition emphasizes the problem-solving and architectural view. We view it more as a technical layer of the overall digital business ecosystem (DBE) as defined by Nachira et al. [18]. Nachira et al. define the DBE as the "socio-economic development catalyzed by ICTs," emphasizing "the co-evolution between the business ecosystem and its partial digital representation: the digital ecosystem." In their view, there are two separate layers in the DBE: the digital ecosystem and the business ecosystem.

The digital ecosystem is the technical infrastructure used to connect to the services and information over the Internet and to enable the networked transactions. Information and communication technologies (ICT) have a central role in enabling service transactions and co-creation between different parties [19, 20]. In the forthcoming sections, we will explore the various digital elements and analyze the set of tools, technologies, and services that have enabled the development of DBEs in which companies can co-create business with people.

The business ecosystem refers to the ecosystem of companies, goods, and services. The business ecosystem concept was originally developed by Moore when he suggested "that a company should be viewed not as a member of a single industry but as part of a business ecosystem that crosses a variety of industries" [21]. Furthermore, in his book, Moore recognized individuals, in addition to organizations, as the "interacting organisms" of the business world [22]. In this study, we will specifically explore how individual developers and the small businesses that they have formed interact with the enterprises in the DBE.

For clarification, we do not view users as digital species of the digital ecosystem, but instead as having an important, emerging new role in the overall business ecosystem, as was argued in the previous section. In the remainder of this paper, we will use the terms "digital business ecosystem", "DBE", and "ecosystem" interchangeably to refer to the whole ecosystem. We will use the term "digital ecosystem" when we want to emphasize the digital part of it and "business ecosystem" to highlight the business aspect.

III. METHODS

In our study, we used the multiple case study approach and studied two cases. Yin suggests that several sources of evidence should be used for a case study [23]. In our study, we utilized two sources: document sources, such as Web sites and white papers, and participant observation. Mann and Stewart note that including participant observation in studying online communities and computer-mediated communication is seen to be a key way forward [24]. They also note that data that give insight to online groups is increasingly available. For these reasons, we chose participant observations as one tool in our case study.

To achieve generality, we chose to use two cases from two different domains where co-creation business ecosystems are emerging. Our first domain is the smart phone applications market and the case is the ecosystem that has emerged around Apple's application store, App Store. The second domain chosen is bioinformatics and the case is the ecosystem around the life science Web service registry, BioCatalogue [25]. We used the Web sites of the market places as the sources of information for our case study [26, 27].

In our case study, we used the inductive approach to see which themes are emerging from the data as we progressed with the cases [23]. To develop an initial proposition, we used use case modeling and developed two draft use cases—one for the producer and one for the consumer in the ecosystem. We then refined these use cases several times as we progressed with the case study. Based on the use cases, we then derived a conceptual model to illustrate the ecosystem.

In order to document the use cases, we will follow the guidelines presented by Cockburn [28]. According to Cockburn, use cases can be written with different levels of detail, depending on the usage. In our work, we will draw on use case modeling to describe two usage scenarios similar to business work processes. For this reason, we have chosen to use a strategic and less detailed level for describing the use cases, as Cockburn suggests. For the same reason, in analyzing the use cases, we will only describe the main success scenarios and leave failure conditions to be explored in future work. In order to clearly identify each actor and each step of the use cases, we decided to use a tabular format to describe the use cases. This also allows us to refer to the actors and each step of the use cases in the conceptual model. To

illustrate the conceptual model, we chose to continue developing our earlier approach and sketched an informal graphical model to visualize the main actors and their interactions [4, 5].

IV. Results

This section will introduce the results of the work. First, we present use cases to identify the different actors of the ecosystem and the interactions between them. Second, we derive a conceptual model from the use cases, collecting and illustrating our understanding of the digital business ecosystem in which companies can co-create business with people. Third, we provide a cross-reference table to show how the results were derived from the case study.

A. Use cases

Cockburn defines use case as "the statement of the goal the primary actor has toward the system's declared responsibilities" [28]. As specified in setting the research questions, in our study, we will explore ecosystems around producer-consumer networks where part of the users, individuals, or researchers, are also the producers of the ecosystem. To cover the goals of both sides of the ecosystem, we decided to have two use cases: one for the producer and one for the consumer.

The primary actor for the producer use case is the user in the role of developer, and the goal of the use case is to develop and publish a new service or application in the market place (see Table I).

Table I.
Producer Use Case: Develop And Deploy A New Service Or Application

Design scope	Ecosystem
Goal level	Strategic
Primary actor	Developer (user in the role of developer)
Trigger	User gets a business idea for a new service or application
Success condition	Service or application is developed, deployed, and published in the Market Place

Actor	*Interest*
Developer	Develop a new service or application and create business from it
Ad-service	Provide advertisement service
Market Place	Provide Market Place for offering services or applications
Payment Service Provider	Provide payment service
Cloud Computing Provider	Provide computing resources as a service
Collaborative Development Environment	Provide hosting and tools for open-source software projects

Step	*Action*
D1	Download: Developer downloads the software development kit (SDK) from the Development Center. To access the resources, Developer might need to first register with the Development Center.
D2	Develop and test: Developer develops application using the SDK and other tools provided. Typically, SDK contains also tools for testing the application.
D3	Get support: During the development work, Developer might need help and support in his work. Support might include fixes to bugs that users have encountered. He might get it from the official support forums in the Development Center or from the unofficial community-hosted resources in the Collaborative Development Environment.
D4	Register as publisher: Developer needs to register as a publisher and accept the terms and conditions before he can submit a service or application to be published in the Market Place.
D5	Submit: Developer submits his service or application to be published in the Market Place. This step might involve deploying the service in Cloud Computing Environment.
D6	Review and publish: Typically, Market Place reviews all services and applications before accepting them for publishing.
D7	Advertise: Developer might advertise his service or application using an ad service.
D8	Ad-hoc distribution: In addition to using the Market Place, Developer might deliver services and applications directly to other users using his own server, e-mail, or other means of transfer.

Ext.	*Branching Action*
D2a	Re-use: Developer might re-use existing source code from Collaborative Development Environment.
D2b	Mash-up: Developer might use mash-up approach to combine content from existing services.
D2c	Integrate: Developer might need to integrate his service with Payment Service Provider, Cloud Computing Provider, and Ad Service.
D3a	Contribute: In addition to getting help from others, developer might contribute back by submitting bug fixes and participating in forum discussions in Collaborative Development Environment.

The primary actor for the consumer use case is the user in the role of end-user, and the goal of the use case is to find and use service or application (see Table II).

Table II.
Consumer Use Case: Find And Use Service Or Application

Design scope	Ecosystem
Goal level	Strategic
Primary actor	User (user in the role of end-user)
Success condition	User gets the requested service or application. Service or application is paid for. All parties involved get their share of the payment.

Actor	*Interest*
User	Find and use service or application
Developer	Get payment from the usage of the service or application that Developer had developed
Market Place	Provide a Market Place for services or applications
Payment service Provider	Provide payment mechanism

Cloud computing Provider	Provide computing resources as a service
Content Provider	Provide content for services and applications
Ad Service Provider	Advertise the service or application. Provide ads for services and applications.

Step	*Action*
U1	Find: User finds the service or application from the Market Place or through an Ad Service Provider. User might need to register with the Market Place before accessing services or applications.
U2	Pay: User pays for the service or application (optional). There might be free services or applications available as well.
U3	Process payment: Market Place processes payment using a Payment Service Provider and tracks the payment so that revenue sharing can later be done according to the agreements between different parties.
U4	Procure service: Service is procured from Cloud Computing Environment or application is provided from download location.
U5	Use: User uses the service or application downloaded from the Market Place.
U6	Vote and comment: User can rate services or applications by giving stars and also post comments about them.

Ext.	*Branching action*
U4a	Fetch content: Some of the content for the service or application might be fetched from a Content Provider.
U4b	Fetch ads: User might make some additional revenue by including advertisement in his service or application from an Ad Service Provider.

In the use case tables, we have followed the structure suggested by Cockburn, and we refer the reader to his book for a more in-depth explanation of use case modeling [28]. The sections of the use case tables are (from top to bottom):

1. Basic information, including the name, design scope, goal level, and primary actor
2. Stakeholders and their interests
3. Possible triggers and success condition
4. Description of the main success scenario with each step followed
5. Possible extensions for the steps in the main success scenario

In our problem setting, we specified two aspects to be studied in the ecosystem: seeing users as co-creators instead of mere end-users and looking at how business is or could be boosted in the ecosystem. To address the first aspect, the user is the primary actor in both use cases. In addressing the second aspect, creating business is the main interest for most of the parties on the producer side of our use cases. As we can see from the use case table, several actors are present in both cases. In the next section, we will present a conceptual model that visually ties together these two use case and the actors in the ecosystem.

B. Conceptual model

By using the different actors that were identified in the use case analysis and by collecting all of the interactions between them, we have built a conceptual model of the ecosystem, illustrated in Fig. 1. Next, we will describe the model in more detail.

The model is built around the Market Place located in the middle that connects the two use cases with each other. The lower part of the figure illustrates the producer use case (green) and the upper part illustrates the consumer use case (red). The blue lines and elements illustrate the interlinking parts that are typically controlled by companies.

Each actor of the use cases is illustrated with its own symbol in the figure. For human actors, we used a human-shaped symbol, and for digital actors, forming the digital ecosystem, we used computer and server symbols. The name of each actor is written under the symbol corresponding to the actor names in the use cases. Each step of the use case is illustrated with an arrow symbol and numbered respectively. The optional steps are illustrated with a lighter line.

As there are several providers of basic services behind the market place, such as payment and computing resources, which are needed for procuring the complete service, there needs to be some solution for orchestrating the choreography between them. We think that this orchestration should be provided by the Market Place or by using some technical solution. In the conceptual model, we call this orchestration and choreography, and illustrated it using a spinning wheel that acts as a higher-level coordinating entity taking care of the communication between these basic services. This and other enabling elements of the digital ecosystem will be elaborated further in the discussion section.

C. Case study

As defined in the methods section, we used the inductive case study approach to develop our use cases and the conceptual model. We selected two ecosystems for the case study that are briefly described and motivated next.

For the first case, we chose Apple's App Store ecosystem around the smart phone application market. App Store was chosen for the study because it is arguably the most successful business co-creation ecosystem that has emerged so far. Currently (as of January 24, 2011), App Store has more than 350,000 applications available, and there have been more than 10 billion downloads since its launch in July 2008 [2].

For the second case, we chose the ecosystem around the life science Web service registry, BioCatalogue. Bioinformatics is a rapidly developing field that has many possibilities for growth in the Web 2.0 world, and thus serves as an interesting subject for a review. Furthermore, being a science field, it is different enough from the other case that represents the consumer service domain and thus should be useful, considering the generality of the model. In addition, creating business and charging for the services, another specific context chosen

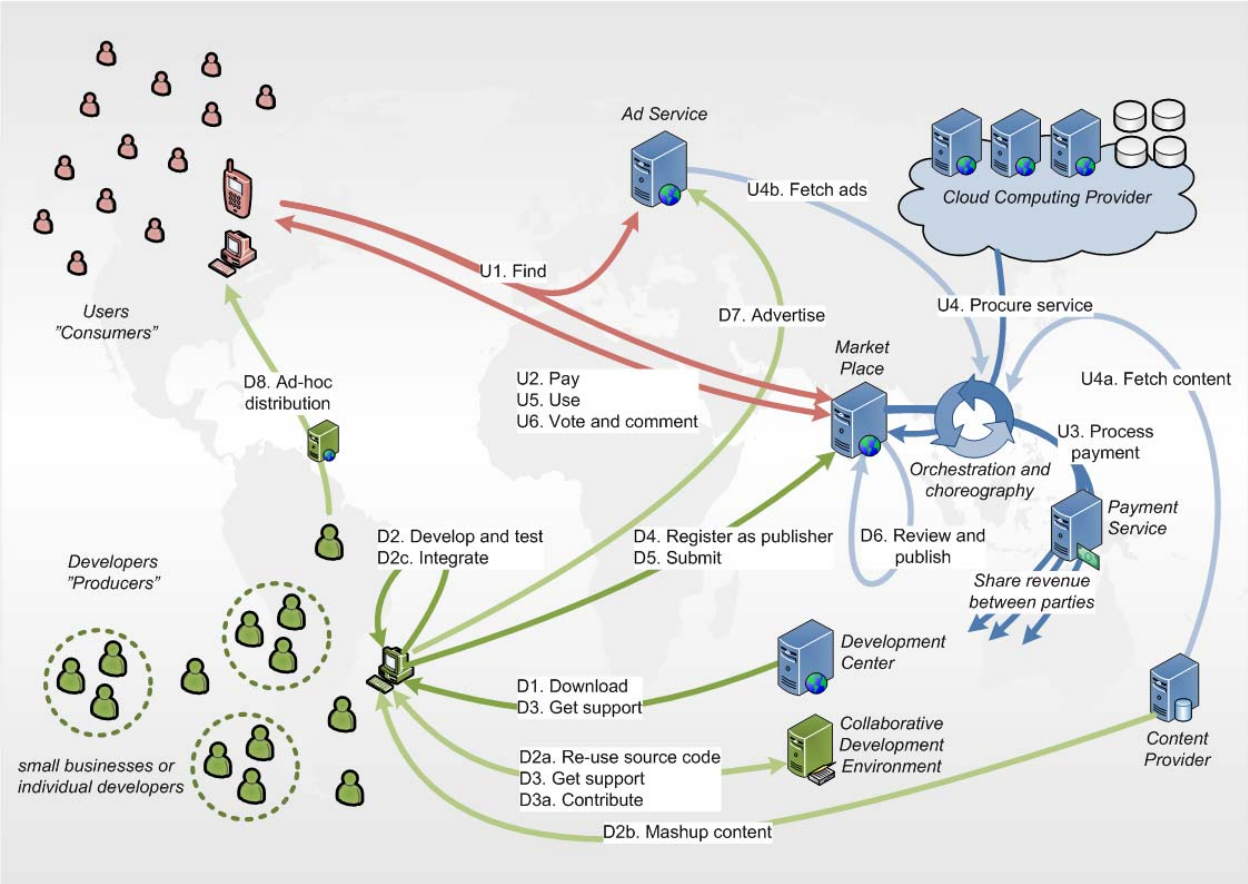

Figure 1. Digital Ecosystem for co-creating business with people

for the work, is natural in bioinformatics. BioCatalogue currently has (as of January 19, 2011) 1,739 life science Web services available, 139 service providers, and 466 users [27].

In our analysis, we iteratively checked every step of our use cases against both cases and refined steps, if necessary. The findings of this analysis are shown in Table III (for the producer use case) and Table IV (for the consumer use case). These tables serve as cross-reference tables between the use case steps and how they were derived from the two cases.

V. Discussion

In this paper, we applied the multiple case study approach and presented a conceptual model of an ecosystem where users and companies can co-create business together. In the following discussion, we will summarize the enabling digital elements and technologies that were found in the case study. We will then list the contributions and limitations of this study and finally provide some concluding remarks and propose areas for future research.

A. Enabling digital elements and technologies

In analyzing the cases, we identified various essential elements in the digital ecosystem and other developments that would be necessary or that support business co-creation. We will discuss these next in more detail.

Simple and lightweight development technologies: Service development and composition need to be made easier to encourage more and more users to be involved in the service development. Apple has managed this really well by providing a simple and stable API that provides a solid base that users can innovate and build upon.

Standards for service integration: It is important that there exist some standards that make re-using, combining, and interfacing with other services easier. One solution to this is Web services that are defined by the World Wide Web Consortium (W3C) as “a software system designed to support interoperable machine-to-machine interaction over a network." [33]. There are also some more lightweight solutions available such as REST API (representational state transfer) that are typically supported. BioCatalogue supports both of these standards for the services in their registry.

Tools for sharing and collaborating with others: In order for a community to work together, there must be mechanisms and tools for sharing and collaborating with each other. Today, there are several open-source software licenses available, and several collaborative development environments, such as Sourceforge and Github, have emerged. Even when people decide to keep their source code proprietary, which is typically the case for smart phone applications, communities play an important role in providing discussion boards, documentation, and other support for the developers.

TABLE III. COMPARISON OF PRODUCER USE CASE

Step		Apple App Store	BioCatalogue
D1	Download	Registered Apple developers can download iOS SDK from iPhone Dev Center.	Developers can freely choose the tools they want to use. Open-source tools, such as Taverna [29], are freely available.
D2	Develop	Developers develop smart phone applications that are run in the mobile phone.	Developers develop bioinformatics services that consist of scripts and workflows that are run on computers.
D2a	Re-use	Smart phone applications typically don't re-use existing solutions that much.	Typically, workflows utilize and re-use ready-made tools (such as Emboss package) [30].
D2b	Mash-up	Smart phone applications might mash-up some data, such as weather and traffic information. Data is typically fetched online.	Bioinformatics services are about analyzing data, and typically, they build upon existing information (such as Ensembl [31]) that others have created and produced earlier. Data is typically integrated off-line.
D2c	Integrate	Developer needs to integrate his application with advertisement and payment service. Typically integration is easily provided through SDK and its API.	Currently, there are no ready-made solutions available for integrating with payment and other services and developers need to do it themselves.
D3	Get support	There are both company provided officials as well as community resources available for the developers.	There are mainly community-provided resources available.
D3a	Contribute	Developers typically don't share their source code but might actively engage in the discussions on the discussion boards. Developers also submit issues about bugs that they have discovered in the SDK.	Recently, Sourceforge-style collaboration environments and shared repositories such as MyExperiment [32] have been introduced that are specifically targeted for bioinformaticians. Developers mainly collaborate on the tool and data level and not so much on the service level.
D4	Register as publisher	Developer needs to pay for joining Apple Developer program in order to publish in the AppStore Market Place. Developers cannot sell their applications in any other Market Places.	After registering, Developer can publish his service in the catalogue. Developer can publish his service in other Market Places as well.
D5	Publish	Developer uses SDK to package and sign his application and can then submit it for review.	Developer needs to package his service using supported Web service standards (such as WSDL) before publishing it.
D6	Review	Apple reviews all applications before publishing them.	Developer can immediately publish his service. Biocatalogue has curators who annotate services so that users can more easily compare the quality of services.
D7	Advertise	Apple controls the mechanisms of how applications are promoted and advertised in the Market Place. Developers can use other advertisement channels and there exist 3rd partly listings for iPhone applications.	Developers can use bioinformatics service listings as well as general purpose ad services, such as Google ads, for promoting their service.
D8	Distribute ad-hoc	Developer can distribute his application to a maximum of 100 people.	Developers can freely distribute their services to their colleagues.

TABLE IV. COMPARISON OF CONSUMER USE CASE

Step		Apple App Store	BioCatalogue
U1	Find	iPhone users can browse the applications available in the App Store using their mobile phone or iTunes software in their PC.	Researchers can find Web services from BioCatalogue Web site.
U2	Pay	Many of the applications are free, but there are many commercial applications as well. Users can pay with credit card or by using a Paypal account.	Currently, most of the services are free, but there are some commercial services as well. Payment schemes and systems vary for every service.
U3	Process payment	Apple has integrated a payment system into the App Store.	There is no integrated payment system that producers could utilize.
U4	Procure	Phone downloads and automatically installs the stand-alone application which is then run on the mobile phone.	Service is typically run offline in remote servers managed by the providers. Users can access the results through Web service interface. There seems to be emerging services, such as CRdata.org, for providing computing resources from a cloud.
U4a	Fetch ads	Apple provides iAd service that can be used to include advertisement into mobile phone applications.	Because bioinformatics services are run offline and are not targeted for consumer market, online ad business is not that relevant.
U4b	Fetch content	Many smart phone applications fetch content from the external services over the Internet.	Typically, bioinformatics services contain large amounts of static data that is used in the analysis. This also requires substantial storage resources from the cloud computing environment.
U5	Use	User runs the application in his mobile phone.	User uses Web service interface to use the service.
U6	Vote	Users can give stars and comment on the applications in App Store.	Users can give stars and comment on the services available in BioCatalogue.

Cost-effective and scalable deployment of services: Lowering the barrier for service development and composition alone will not be enough. There must be an easy way to deploy the service and make it available for others. Recently, the introduction of cloud computing services, such as Amazon Elastic Compute Cloud (EC2) and Amazon Simple Storage Service (S3), has offered a comprehensive solution by providing an elastic computing infrastructure. In a cloud, capacity can be easily increased or decreased in minutes, and the payment model is more flexible and inexpensive, as only the actual capacity consumed is paid for. So far, cloud computing has not been utilized for mobile applications, but this might change in the future.

Basic e-commerce services: To create business from a service, many basic e-commerce services are needed. In recent years, several new services have been introduced in these areas. For services such as paying for goods and managing payment transactions, there are several providers available, such as Google Checkout or Yahoo! Paypal Checkout. For promoting the service, there are online advertisement services, such as Google Adwords and marketplaces, such as Yahoo and eBay. So far, these services have been mainly geared toward selling physical goods, but support for selling digital services and applications is added continuously.

Service orchestration and choreography: To produce a specific service for a customer, several related activities are typically required, such as payment processing and providing computing resources. Management of interactions between these sub-activities is essential and has to be solved somehow [34]. If the orchestration and choreography between basic services, such as payment and procuring computing resources, could be provided ready-made, this would further lower the barrier for users to create business from their services.

Market place: In addition to basic e-commerce services, it seems evident that setting up a vivid market place for the ecosystem is essential for its success. Nokia was the first company in the smart phone market, but it wasn't before Apple launched the App Store that the smart phone application business rocketed. Similarly, it seems that in bioinformatics, the App Store -style market place is missing. BioCatalogue is more of a registry for listing the services, rather than for doing business of them.

B. Contributions and limitations of this study

The main contribution of this paper was a concrete conceptual model for a Web 2.0 digital ecosystem where companies can co-create business with their users. Our objective was to illustrate the key actors in the digital ecosystem and the main interactions between them. By using easy-to-understand graphical symbols, we hope that this model will be understandable for experts as well as for people who are unfamiliar with all the technological aspects. Because there are very few graphical illustrations available for digital ecosystems for any domain, we hope that our model can also serve as a practical and concrete example of how digital ecosystems in general, and specifically for Web 2.0 concepts and phenomena, can be illustrated. The second contribution of this paper was summarizing the essential digital elements that support business co-creation and discussing how these developments have enabled the phenomenon.

We also recognize some limitations in our study. In this study, we did only qualitative analysis. As these ecosystems are already functional, there would be quantitative data available for analysis as well. Furthermore, we were able to conduct only a superficial analysis of the identified concepts and use cases. By analyzing each concept and use case in more detail, additional information about the ecosystem could be revealed, both at the level of technological enablers and of social and economic interactions. We will leave these to future work.

C. Concluding remarks

This work provided a concrete and practical conceptual model for a Web 2.0 digital ecosystem. We hope it clarified the concepts and phenomena associated with the ecosystem. We hope that our work inspires researchers in other domains to illustrate their concepts and ecosystems in a similar way. During the work, several areas for future research were identified. To make the ecosystems really functional, some orchestration and choreography are needed between the basic services, as was revealed in the case study. One topic for future research could be to present a concrete design and implementation of choreography for the provision of services utilizing cloud computing resources, including the management of payment transactions and automated revenue sharing between the service provider and the cloud computing provider. Another possible future research would be to extend the study of the field of bioinformatics and present a more thorough and detailed conceptual model for it. Because the field bears many resemblances to the standard software service ecosystem, many of the concepts from the software industry could be applied there as well. In this work, we studied the selected digital ecosystems at a rather general level. In our future work, we are planning to formally model the ecosystem and see if companies' and other actors' roles can be somehow quantified.

It seems that many of the concepts related to Web 2.0 and digital ecosystems still lack a clear understanding, and there are few examples and modeling practices to illustrate them. Furthermore, the role of users and user communities and how they relate to digital ecosystems research still need to be discussed and defined in more detail. We hope that our work has provided some progress in these areas and will inspire researchers to continue the work.

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