Vrije Universiteit Amsterdam

Universiteit van Amsterdam

Master Thesis

Is SOLID ready for Low-Resource Environments?
Tackling Data Privacy Issues in Sub Saharan Africa

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A thesis submitted in fulfillment of the requirements for
the joint UvA-VU Master of Science degree in Computer Science

August 23, 2021

"We need diversity of thought in the world to face the new challenges."
Tim Berners-Lee

Abstract

Context. Over the years, many initiatives have been undertaken to develop IT solutions for low-resource environments, in countries in the Global South. To meet the challenges of these environments, new and innovative approaches are needed. In this thesis, Solid (Social Linked-Data) – a new attention-gathering technology – will be examined whether it is ready to be used in low-resource environments. Solid is a technological solution, created by Sir Tim Berners-Lee with the goal to enhance data protection, improve user autonomy and give users on the Web full control over their personal data.

Goal. This study explores the current state of Solid in relation to the challenges of IT development in low-resource environments. I aim to assess whether Solid is ready to be used in these environments, looking at potential use-cases.

Method. As the number of studies on Solid is still limited, an exploratory research approach is taken. Data is collected through Web articles, Solid forums, interviews, a survey, and various meetings with experts and users. Meanwhile, lab experiments (laptop, mobile, Raspberry Pi) were carried out to examine the functionalities of Solid in soft- and hardware.

Results. This study shows the current limitations of Solid with respect to low-resource environments and gives recommendations, how it can be adapted to serve users in various contexts or regions of low-resource environments, for example urban and rural regions.

Conclusions. From the results we can argue that Solid needs to be adapted to become fully useful for users and applications in urban / rural areas in low-resource environments. There are two promising approaches suggested for further research that could help the adoption and increase of use-cases in low-resource environments: (i) a mobile approach, which caters for the widespread use of mobile technologies in rural regions and (ii) an offline approach, which tackles problems such as unstable internet connections. With these and other suggestions, this study aims to inform the Web developers community to innovate IT beyond high-tech environments, and to create a deeper understanding of the requirements for Solid in low-resource environments.

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1.   Introduction

Since the onset of the 21st century, the Web's seemingly endless capabilities for innovations have led to the emergence of many new innovative businesses. One of the most interesting opportunities offered by the Web is the abundance of data, in particular, personal user data. Many tech firms have recognized the business value of personal and behavioral data. This data can be used in many ways. For instance, to let users know that their favorite shaving cream is currently available at a discount, or to inform a car insurance company that – based on one of their customers Instagram pictures – a customer likes to do donuts in the snow.

   Whereas some of the user data is used for improvement of service or products only, the major chunk of user data is what Shoshana Zuboff dubbed *behavioral surplus*. This is the transformation of collected user data analysed with artificial intelligence and transformed into a marketable product sold to advertisers and other interested customers (1). The business value of personal data has drastically increased over the past few years. Tech companies try their best to get their hands on it and in a business landscape this is dubbed by Zuboff as *surveillance capitalism.*

   This type of business, which places the control of user data into private hands, is now considered a new form of user exploitation. How this exploitation can lead astray became clear in 2014, when data of 87 million Facebook users was handed over to political consulting firm Cambridge Analytica, which was later used to support the presidential campaign of Donald Trump in 2016 (2).

   In addition to companies misusing data, the enormous job of sustaining fault-tolerant computer security to prevent hackers from stealing personal data is another pressing challenge. Through the years there have been a multitude of data breaches, for example at Target in 2013 (3). Hackers were able to get inside Target's systems via a third-party contractor. The software eventually got into Target's in-store point-of-sale systems. Consequently, this allowed the program to capture and sent all credit card information of paying customers. The hackers stole 40 million credit card numbers, which damaged Target's reputation and cost more than USD 100 million in lawsuits.

   Given the growing business interest in personal data by tech companies, and given threats to the autonomy of citizens, which this type of business can entail, many national governments have established, or are in the process of establishing, policies and legislations in order to protect user privacy. These legislations should restrain companies from misusing personal data. One of the examples is EU's General Data Protection Regulation, also known as GDPR[1]. In addition, technological initiatives such as Solid could offer a helping hand to these legislations.

   Still, in many countries, especially in less technologically developed countries, there may be a lack of legislation, which is an open invitation for exploitation.

   In the past centuries, countries in the Global South have often been colonized or have suffered from imperialistic domination in various forms. Natural and human resources have often been exploited. Now that digital resources are increasing in value it is highly probable that these resources will be exploited as well.

   For example, Facebook has planned to give users in Sub-Saharan Africa free internet

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[1]`https://gdpr-info.eu/` [Accessed: 7/10/2021]

with their *Free Basics initiative*[1]. However, the catch was that users were only able to use a certain amount of websites, including Facebook, in this limited form of internet. People were questioning what would happen to their data and the project failed to come into fruition.

Another project started by one of the tech giants, is Project Loon, initiated by Google LLC. The main goal of this project was to provide wireless internet access to rural areas by launching helium balloons in the stratosphere that work in coordination with each other and with a ground antenna. However, recently the project closed, because they couldn't find a way to reduce costs[2]. On the contrary, if this project would have succeeded, Google would have a powerful position to capitalize on this network.

In this thesis, I will consider the context of low-resource environments and its users. This term refers to the environments in third-world countries that lack resources that civilians of Western countries may view as a commonplace. Some characteristics are unstable internet connections, zero electricity, scarce income, inadequate infrastructure and more. In addition, there is no quick access to pieces of hardware used e.g. in hospitals[3].

Consequently, Sir Tim Berners-Lee, known as the inventor of the World Wide Web, is concerned about online privacy[4]. In 2009, Au Yeung et al. have suggested a decentralized way of online social networking by using technologies such as linked data, semantic web ontologies, open single-signon identity systems, and access control (4). This idea has come to life in a new project called Solid; a decentralized platform for social web applications (5).

1.1   Solid: Bringing the ownership back to the user

When using an application, most likely we have to fill in personal data in some way. This has led to our personal data being scattered in different companies' databases. Next to that, behavioral data is collected too, without having control over how the data is used. Sir Tim Berners-Lee has shared his concerns over the evolution of the World Wide Web regarding the issues around online privacy and the harvest-and-hoard model of big tech companies[5]. Therefore, he took the matter in his own hands and led a project at the Massachusetts Institute of Technology (MIT) that became Solid. The goal of Solid is to restore the control of people's personal data.

The name Solid is derived from Social Linked Data, as it utilizes linked data technologies (e.g. RDF and LDP) in a social context. According to Bizer, Heath and Berners-Lee,"the term 'Linked Data' refers to a set of best practices for publishing and connecting structured data on the Web" (6). The project is build using existing W3C standards and protocols.

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[1]`https://www.theguardian.com/world/2016/aug/01/facebook-free-basics-internet-africa-mark-zuckerberg` [Accessed: 7/12/2021]

[2]`https://www.nytimes.com/2021/01/21/technology/loon-google-balloons.html` [Accessesd: 8/7/2021]

[3]`https://ewh.org/blog-posts/what-does-low-resource-environment-actually-mean/` `[Accessed:7/12/2021]`

[4]https://www.cnet.com/tech/services-and-software/tim-berners-lee-deeply-concerned-about-online-privacy/ [Accessed: 8/7/2021

[5]`https://www.nytimes.com/2021/01/10/technology/tim-berners-lee-privacy-internet.html` [Accessed: 8/7/2021]

Figure 1.1: Simple explanation of Solid[1]

Figure 1.1 shows the Solid ecosystem simplified. One important aspect of Solid is that it allows people to store their personal data securely in personal online data stores, referred to as Pods (5). With their Pod, a user can login to Solid applications. First, the application asks for permission to certain types of data, the user chooses which data he would allow the application to use, and the user data generated by the application will be stored on the user's Pod. Accordingly, when data is changed in the Pod, every application used by the user will see the changes when the user logs in again. For instance, normally when moving houses you would have to change your residency information on all shopping platforms, but with Solid, every shopping platform would retrieve the same data from your Pod, thus only having to change your information once.

Pods are hosted on a Solid server, which a user can host locally. This should give the user full control over their online identity or personal data. However, currently that is not attractive yet to the general consumer, because some developer experience is needed to set up the server. Therefore, a user can also use a so-called Pod Provider, such as *inrupt.net*. These Pod Providers allow users to create a Pod on the provider's public server, so that users don't have to go through the process of setting up a server.

After some breakthroughs, Berners-Lee decided to write a letter to the Web community for support on the Solid Project. In addition, Berners-Lee created Inrupt [2] and launched the Solid Community. Inrupt is the first company trying to commercialize Solid. An interesting project that is currently done by Inrupt is a collaboration with Flanders to integrate Solid in the government of Flanders and get every citizen a Solid Pod [3]. This could push the popularity and adoption of Solid and shows that there is interest in Solid. However, a blind spot for the Solid community are low-resource environment users. The technology should be accessible to as many people as possible in order for it to support

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[2]`https://www.inrupt.com/one-small-step-for-the-web` [Accessed: 7/10/2021]

[3]`https://inrupt.com/flanders-solid` [Accessed: 7/12/2021]

the Sustainable Development Goals[1] of the United Nations, from which the number one priority is *end to poverty*. The adoption of the project is still in a relatively early state, but it has been receiving positive attention. More research must be done on Solid and applications must be made to bring more support and use-cases to the Solid platform.

1.2 Low-resource environments

Poverty is a huge problem in the world. Figure 1.2 shows the Gross National Income per capita taken from the classifications of the World Bank in 2015. Low- and low-middle-income countries are mainly in Africa and Asia. There has been a rise in information technology projects in low-resource countries, but there is still a big gap between the Global South and Western countries (7).

Figure 1.2: Source: https://www.jkgeography.com/global-patterns-of-economic-development.html
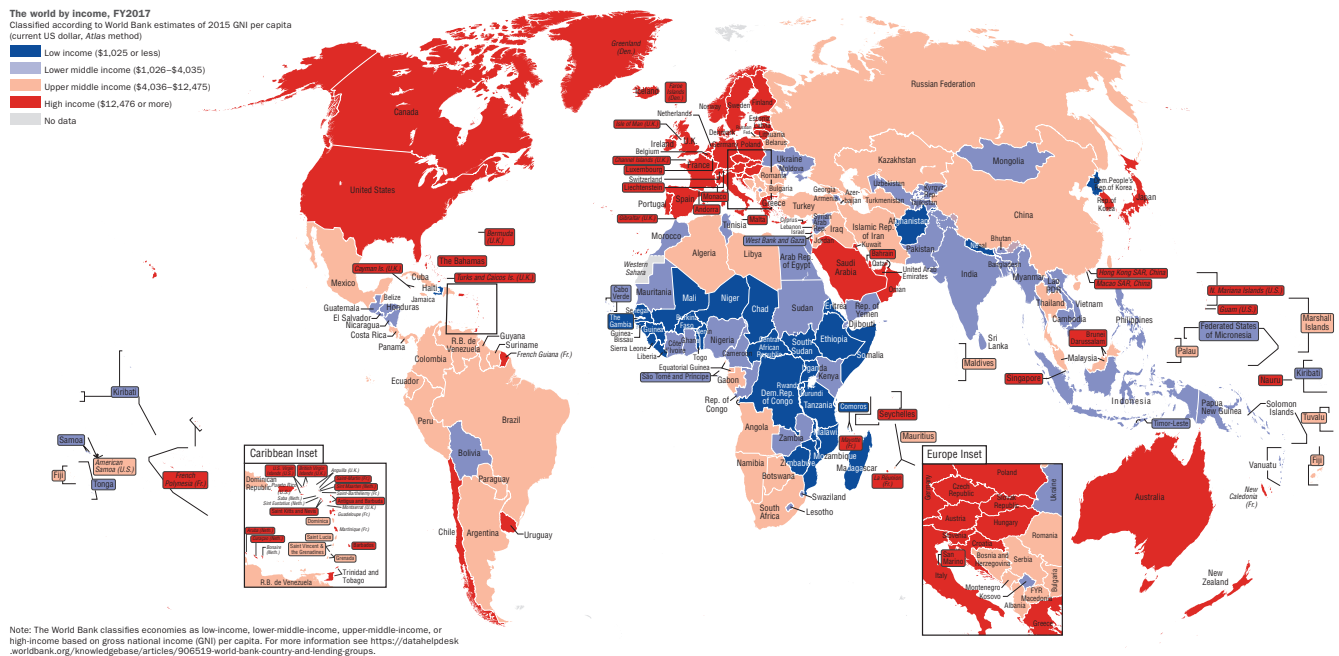
Building IT solutions in low-resource environments come with its challenges. Firstly, it should be clarified in what type of low-resource environment the solution will be used. Urban areas require a different approach than rural areas as different challenges arise. The challenges can mostly be divided into two types of challenges. Social challenges – such as dealing with corrupt governments, low motivation to work and depending on developing nations for hardware and cloud solutions – are more commonly seen in more developed areas in low-resource environments. There are some social challenges that happen in rural areas as well, for instance thieving, local languages and illiteracy. Technical challenges –

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[1] https://sdgs.un.org/goals [Accessed: 7/12/2021]

such as unstable internet connections, electricity outages and the impact of the environment on hardware – are encountered more often in rural areas in low-resource environments.

1.3 The objective: is Solid useful in low-resource environments?

The goal of this study is to assess the current condition of Solid and whether it is ready to be used in low-resource environments. One of the arguments is that the combination of Solid in low-resource environments has not been researched yet. Additionally, following the Solid Protocol documentation [1], the creators orient themselves using the Ethical Web Principles [2]. One of these principles is "The web is for all people". Therefore, it is important to analyze how Solid can become available for all people, especially within low-resource environments that may struggle with low bandwidth networks, unstable connections, electricity issues and low specification equipment. Next to that, it would be helpful to find problems where Solid can be used as a solution, as the community is looking for an application that will boost Solid to the mainstream[3].

Early on in the process, it was clear that developers are active on the forum, and I saw that the developer experience has some rough edges, therefore this was also taken into account in the research questions. See Table 1.1 for the research questions of this thesis.

Table 1.1: Research questions of this thesis

ID	Research Question
1	Is Solid applicable in low-resource environments?
2	What can be done to increase the accessibility of Solid in low-resource environments?

1.4 Approach

To answer the research questions, an exploratory research approach was adopted. Solid has not yet been researched in low-resource environments so it was necessary to find appropriate data elsewhere. The studied data is mostly qualitative and was gathered through brainstorm sessions, conversations and interviews with professionals, and surveys.

Evaluating the approach will be a challenge as this project is rather experimentally oriented. But the intention of the project is clear; to collect insight to inform the Solid project. This includes creating recommendations that are useful for the community of developers and for those who work to build applications for low-resource environments. Moreover, it draws attention to a "blind spot" of Solid: lacking a focus on low-resource environments.

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[1] `https://solidproject.org/TR/protocol` [Accessed: 7/13/2021]

[2] urlhttps://www.w3.org/2001/tag/doc/ethical-web-principles/ [Accessed: 7/13/2021]

[3] `https://forum.solidproject.org/t/looking-for-the-killer-app-for-solid/3782` [Accessed: 7/13/2021]

Table 1.2: Methods per chapter

Chapter	Method	Elaboration
The current state of Solid	Research	Find more information about Solid and the community
	Interview	Three interviews were held
	Survey	A survey was created and shared in the Solid community
Challenges and possibilities in low-resource environments	Research	Find more information about low-resource environments
	Interview	Three interviews were held
Experimenting with Solid	Lab experiments	Existing Solid applications were examined and three devices were experimented with: PC, mobile and Raspberry Pi
	Application development	A Hello World application was created

Throughout this thesis, I have been closely working together with Teodora Serbănescu and Anna Bon. Teodora Serbănescu is a master student that is doing a thesis on Solid as well. The data gathering as well as discovering Solid was often done in collaboration with Serbănescu. Anna Bon is the supervisor of this thesis and also a researcher from the Web Alliance for Regreening Africa (W4RA)[1]. This research group has done a multitude of projects in the field of ICT for Development (ICT4D). Within the ICT4D research group, different projects are done to encourage and assist communities in third-world countries. Every week a meeting was held with the three of us to talk through new findings and progressions.

During the research a lab journal was retained as a log to collect and maintain actions and experiments executed in the project. Meeting notes and other data are stored in the Appendix. In addition, an article is written on the W4RA (Web alliance for Regreening in Africa) web-blog[2] (see Figure 5.1 in the Appendix), to gather more attention from different platforms.

1.4.1   Data gathering strategy

In order to answer the research questions, information about both Solid and low-resource environments was gathered, which are divided in the chapters shown in Table 1.4. In addition, lab experiments were done. All information is examined and combined in the discussion. Lastly, in the conclusion the research questions are answered.

1.4.1.1   Solid community

Firstly, in the chapter *"The current state of Solid"*, Solid is explored from the perspective of the Solid community. To begin with, the development process and popularity of Solid

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[1] `https://w4ra.org/publications/` [Accessed: 7/13/2021]
[2] `https://w4ra.org/2021/03/22/solid-for-low-resource-environments/` [Accessed: 7/13/2021]

are investigated by analyzing the activity within the Solid community. Thereafter, three interviews and a survey have been conducted. The first interviewee is *Vincent Tunru* (see Appendix 5.9), a front-end engineer at Inrupt who works on the developer tools and libraries of Solid. More information about the company Inrupt is added in the next chapter. Secondly, *Noel de Martin* was interviewed (see Appendix 5.10), a Software developer that is interested in Solid and creates Solid Applications in his spare time. Having created 2 fully working Solid applications, the experience de Martin has is valuable for this thesis. Thirdly, *Arne Hassel* – a senior front-end engineer at Inrupt – has been interviewed (see Appendix 5.11). Hassel has a specialty in working with Linked-data and JavaScript from earlier projects, which he combines at Inrupt. To point out, Tunru and Hassel both share their personal experiences and are not talking as representatives of Inrupt. Lastly, a survey has been created using Google Forms and was available from 5/5/2021 to 7/5/2021. To attract Solid users and developers to the survey, the following platforms were used: the Solid Forum[1], Gitter[2] and Reddit[3]. When we first started investigating Solid, we recognized that the forum was quite active. Therefore first an introduction was created (see Appendix 5.2) and afterwards together with Serbănescu a post was written about the thesis projects (see Appendix 5.4). After the survey went offline, *fourteen responses* were collected (see Appendix 5.12).

1.4.1.2 People in low resource environments

Next in order is the chapter *"Challenges and possibilities in low-resource environments"*. In this chapter, low-resource environments were explored to be able to analyze the possibilities of Solid in these environments. Likewise as to the first chapter, the data was gathered by conducting three interviews.

The first interviewee was *Victor de Boer* (see Appendix 5.5); a professor at the Free University of Amsterdam specialized in semantic Web, digital humanities and ICT4D. Furthermore, de Boer is part of the W4RA community with personal experience in developing technologies for low-resource environments.

Francis Saa-Dittoh, the second interviewee (see Appendix 5.6), is a PhD candidate at the Free University of Amsterdam as well as an Information Technology Associate at UNOPS. Furthermore, Dittoh, van Aart and de Boer have written a paper about voice-based marketing for agricultural products in rural Northern Ghana (8). His expertise in creating technologies for low-resource environments, along with his personal experiences living in Ghana, is the motivation for interviewing him.

Lastly, *Joshua Opoku Agyemang Otoo* was interviewed (see Appendix 5.13). Opoku Agyemang Otoo is the president of the Ghana IoT Network Hub; a community of developers in Ghana working together on IoT solutions. Also, he is the Co-founder and CEO of Pesonet LLC, an African-based technology consultancy company.

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[1]`https://forum.solidproject.org/t/solid-survey-for-master-projects/4280`   [Accessed: 5/05/2021]

[2]`https://gitter.im/solid/chat/archives/2021/05/06` [Accessed: 5/06/2021]

[3]`https://www.reddit.com/r/SOLID/comments/n675jd/survey_on_solid_for_master_projects/` [Accessed: 5/06/2021]

1.4.1.3 Lab experiments

During the gathering of data, I did some technical experiments with Solid with the goal to familiarize myself, but more importantly, to analyze which hardware can be used in combination with Solid to get insight into Solid's possibilities. I did a few lab experiments, looked at Solid applications, installed Solid locally, examined different devices (PC, mobile and Raspberry Pi), and built a Hello World application. This is shared in Chapter *"Experimenting with Solid"*.

2.   The current state of Solid

Over the years there has been an evolution on the Web (9). In Web 1.0, the main characteristic was that it allowed static publications to be done. The main focus was on reading data. In the evolution of Web 2.0, writing data became more important, which resulted in a rise in social media platforms and an increase in businesses that benefited from it. Currently, we are going through the evolution of the Web 3.0. There has been an increasing amount of written data and in Web 3.0 the focus is on managing and structuring this amount of unstructured data, so that this data can be transformed into information and knowledge by computers. Solid might help doing that.

As part of gathering information for this chapter, three interviews were done, shown in Table 2. The interviewees are referred to as Developer ID.

Table 2.1: Interviewees from the Solid community

ID	Interviewee	Role	Appx
1	Vincent Tunru	Front-end engineer at Inrupt	5.9
2	Noel de Martin	Solid community member developing Solid applications voluntarily	5.10
3	Arne Hassel	Senior front-end engineer at Inrupt	5.11

2.1   The Solid Protocol

Solid is an open source project and the creation started at MIT. The first paper that extensively described Solid was published in 2016 (5). Solid is a decentralized platform for the social Web, based on RDF and other Semantic Web technologies. The main purpose is that it provides data independence and data management mechanisms to provide data privacy. Figure 2.1 shows the Solid Architecture presented in this paper, to give an overview of the components within Solid.

The full documentation of Solid can be found here: *https://solidproject.org/TR/protocol*

User's Pod   A user's Pod is a personal online data store stored on a Solid server, in Figure 2.1 called Identity Profile Server. When a Pod is created, the user can add personal data to it, which is saved to a RDF profile document. An example is shown in Figure 2.2. Within the ecosystem of Solid, users can control their profile using a WebID, which is a HTTP URI that leads to their RDF profile document. The profile document contains all the linked-data of a user. In addition, users can control who can see what data; the idea is that users are able to give companies access to their data, but also revoke access.

It is also possible to connect two Pods with each other, for example by adding another Pod as a friend using the FOAF (Friend of a Friend) ontology.

Identity Profile Server   The Identity Profile Server – also called a Solid server – keeps track of its Pods, and allows client applications to identify a user and access resources from their Pod. It makes use of RESTful operations for data modifications, which can be used by Solid applications to modify data.
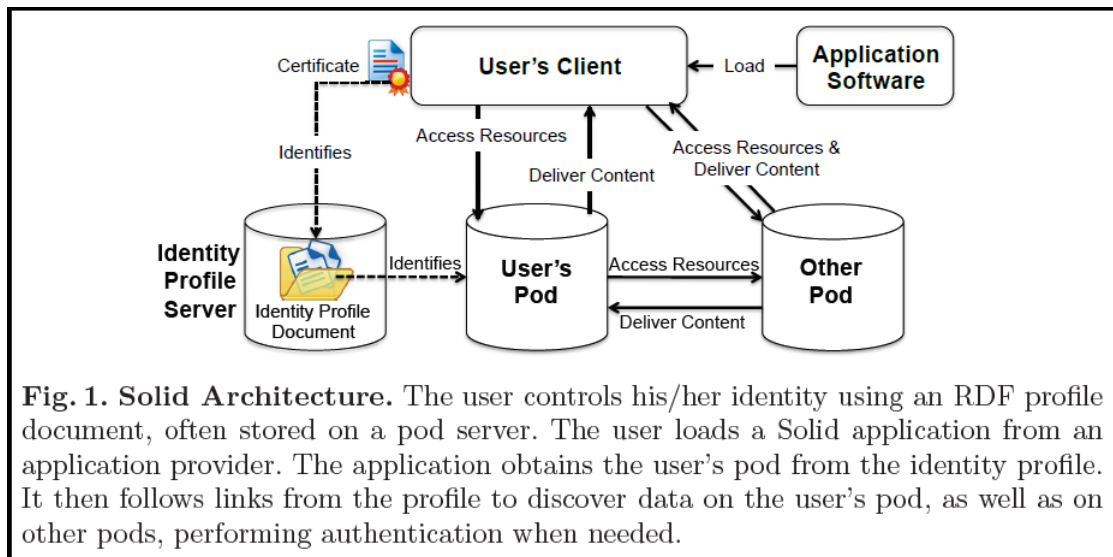
Fig. 1. Solid Architecture. The user controls his/her identity using an RDF profile document, often stored on a pod server. The user loads a Solid application from an application provider. The application obtains the user's pod from the identity profile. It then follows links from the profile to discover data on the user's pod, as well as on other pods, performing authentication when needed.

Figure 2.1: Image from "Solid: A Platform for Decentralized Social Applications Based on Linked Data", by A. Sambra, E. Mansour, S. Hawke, M. Zereba, N. Greco, A. Ghanem, D. Zagidulin, A. Aboulnaga and T. Berners-Lee. Page 4, 2016.

Figure 2.2: Identity Profile Document example

User's Client   A User's Client, which can be referred to as a Solid application, is a client-side Web or mobile application that can access Pods by authenticating with the Solid server. In the Identity Profile Document in Figure 2.2, there is one property called *n0:trustedApp*. This property is important because it indicates whether a Solid application has Append, Read or Write access. When a user uses a Solid application, it asks for permission to do certain operations like reading and writing data. This gives the user more control over what happens to their data. In Chapter 4 we go over some example applications.

2.2   Quantitative activity data in the community

Solid has a community of developers and other enthusiasts spread over various communication platforms. Social activity on these platforms is tracked to get a grasp of the popularity of Solid. Table 2.2 shows metrics taken from various social platforms, including the official Solid forum[1], Gitter[2] and Reddit[3]. The Solid forum and Gitter share the highest daily interaction. We could argue that there are more developers active in the community than Solid users, because Gitter is more developer oriented and many questions asked on the forum are implementation questions. In the interview with Developer 2, he also shared that he experiences seeing more developers instead of real users active in the Solid community, although there is a small amount of data to support that.

Platform	Description	Metrics
Solid Project Forum	The main forum of Solid. The data is collected on the about page of the website.	*Posts:* 16.0k (all), 35 (last 30d) *First post:* Oct 13, 2018 *Users:* 1.4k *Likes:* 11.1k *Active users (time):* 27 (last 24h), 44 (last 7d), 85 (last 30d)
Gitter	An instant messaging chat room service. The data is measured by going through the archives page and adding up all messages of each day.	*Created:* Aug 15, 2016 *User:* 1915 *Messages:* 54825 (all), 30.4 (avg 24h)
Reddit	A website with a network of communities. The data is collected via *subredditstats.com*, a web-page that allows users to find statistics of all public reddit pages.	*Created:* Mar 14,2018 *Subscribers:* 1810 *Posts per day:* 1 *Comments per day:* 1

Table 2.2: Collected activity metrics on different communication platforms [Collected on 7/22/2021]

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[1]`https://forum.solidproject.org/` [Collected on 7/22/2021]
[2]`https://gitter.im/solid` [Collected on 7/22/2021]
[3]`https://www.reddit.com/r/SOLID` [Collected on 7/22/2021]

Github data   The Solid codebase is available on Github[1]; a Git repository hosting service where developers collaborate on code. At present, the Solid Github page contains 109 repositories excluding forks, mirrors and archived repositories. From these, 5 are updated the day of accessing the page and 25 are updated last month. This collection excludes personal projects or code from Solid businesses such as Inrupt and Digita. Nevertheless, it is an enormous collection of repositories. We could debate that these open source repositories are hard to manage looking at Table 2.3. Within the 5 most popular Solid repositories (based on their amount of stars), 3 have over a hundred issues. In the *Solid* repository, more than half of the 131 issues are created in 2016. Similarly, more than half of the issues of the *node-solid-server* repository are created before 2020. Whether these issues are general questions, fixed issues that need to be deleted, or real issues is unclear, but it seems an extensive workload for the open source community. Coelho and Valente have researched failed open source projects to analyze why they fail (10). Subsequently, they saw that failed open source projects have an non-negligible amount of opened issues and pull requests. Therefore, tackling this issue might be urgent for the Solid community.

Name	Stars	Issues
solid	7972	131
node-solid-server	1610	252
solid-spec	1111	70
userguide	376	2
specification	242	133

Table 2.3: The amount of issues of the top 5 Solid repositories (rated on amount of stars) [Collected on 7/24/2021]

2.3   Solid's developer community

As Solid is an open source project, one of the main issues is that most developments are done by volunteers, which can lead to misjudgements and a disorganized environment, because of the reliance on volunteers that work part-time on Solid. However, there is a Solid Team[2] that manages the Solid project. Also, a monthly conference is held called Solid World led by the Solid Team, that captures and shares the latest improvements and projects in the Solid ecosystem. In addition, there is a W3C community[3] that manages the specifications of Solid.

2.3.1   Commercialization: Solid as a Service

One of Solid's dominant problems is not having a value chain. Most work was done by either volunteers or professors relying on funds. However, there have been some companies that try to tackle this problem by commercializing Solid. With projects being done by commercial companies, both the popularity of Solid and the quality of Solid propelled. The two main commercial Solid companies are Inrupt and Digita.

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[1] `https://github.com/solid` [Accessed: 7/23/2021]
[2] `https://solidproject.org/team` [Accessed: 06/05/2021]
[3] `https://www.w3.org/community/solid/` [Accessed: 06/05/2021]

Inrupt A substantial step forward was the establishment of the company Inrupt, founded by Tim Berners-Lee and John Bruce with their first release in 2020. The founders realized that as an open source project, there is a lack in financial resources. Therefore, the company was created to help companies implement Solid and as a consequence, push the popularity of the Solid project further. One of their products is an Enterprise Solid Server. In a recent interview[1], Berners-Lee spoke about the workings between Inrupt and the government of Flanders. The goal is to use Solid to give citizens their own pods.

Developer 1 and 3 both shared their views on Solid and their experience at Inrupt as well. When Developer 1 started working at Inrupt 3 years ago, it was very experimental, but it has improved a lot since then. One current matter is that working together with governmental organizations can take a lot of time, especially when working through all regulations. There could be more people with expertise working on other functionalities, but there has to be a consensus and some agreements on these regulations. However, there have also been great contributions from the community such as MediaKraken[2] by Developer 2.

Moreover, Developer 1 mentions that a lot of functionalities work within Solid, but they could be substantially improved. To improve the functionalities, clear answers should be given to some important questions: "How do I model my data and how do I change my data model? How do I optimize the amount of data I'm sending? How do I manage the performance of my application?" Inrupt is looking at these questions, but they are not the highest priority.

Digita Digita[3] is a Brussels-Flemish startup that provides Solid for enterprises as well. It has been founded in 2018 and has contributed to various Solid initiatives in The Netherlands and Belgium. For instance, one project is done together with VITO, a Flemish research organisation that focuses on cleantech and sustainable development. This project – the WeAre project – is an eHealth ecosystem based on the Solid ecosystem.

2.3.2   Shortcomings of Solid

The interviewees and survey applicants are concerned with some aspects of Solid. In the interviews, one often mentioned issue is the unclear user interface of Pod providers. There are a lot of functionalities included in the interface that make it buggy and unattractive to use. From Developer 2's experience, too many features can lead to confusion and a decrease in ease-of-use.

We gave an example of a marketplace application where products from a user's pod can be shared and shown in a list, but Developer 1 mentioned that it is still one of the many challenges from Solid. As a client application you would want to store as little data as possible and the question is how to gather data from different pods efficiently.

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[1]https://www.tijd.be/app/carousel1/tim-berners-lee-de-bedenker-van-het-internet-we-kunnen-het-wereldwijde-web-nog-fiksen/10309722.html [Accessed: 06/07/2021]

[2]`https://github.com/NoelDeMartin/media-kraken` [Accessed: 06/07/2021]

[3]`https://www.digita.ai/` [Accessed: 06/07/2021]

2.4 Adoption of Solid as an innovation

During the interviews and surveys, another purpose was to examine the adoption of Solid. The survey participants first discovered Solid through the web, either because of media articles, blogs, social platforms, or by a random occurrence. The amount of years people have known Solid ranges from 1 to 5 spread quite uniformly. From these people 12 of the 13 have experimented with Solid. From Developer 3's experience – over his three years of development on Solid – there has been some adoption, but mostly by developers or privacy advocates instead of real users.

One thing that isn't available yet is mobile compatibility of running the Solid server on both Android and iOS devices, which could increase adoption. There are no apps yet, and there is no way to host a Pod on a mobile device as of now. We will further discuss mobile possibilities in Section 2.6 of this chapter and in following chapters.

An idea mentioned by Developer 3 is to increase the general popularity of Solid could be to focus on giving value to end users. Applications don't have to be Solid applications, but could have an option to use Solid so that people can familiarize themselves with it. Moreover, Developer 2 suggests that more applications should be created for users instead of developers. When new users come into the Solid ecosystem, they could get kind of lost.

Developer 3 shared his opinion on what is essential for Solid to be implemented over the world, which is the idea of a fully functional ecosystem. There should be an ecosystem where there are end-users, developers and service providers that work together in a manner that brings food to the table for the various participants. End-users need something valuable, and service provides and developers should get something in return. In order for Solid to become successful, it should have a system like that. Moreover, developers and service providers are motivated to get involved because of the possible value creation that they will get out of it. The commercialization of Solid is an important step towards maturing this ecosystem.

2.4.1 Attracting developers

Developer 1 suggests that when a bigger audience is created, it is more attractive for developers to join in. But to increase the audience, there has to be a focus on building more things that feel complete. For developers, working in the current ecosystem isn't great. To attract more developers, Developer 3 has two theories. The first one stems from developers often being described as lazy, so Solid can make their work easier and faster. The second theory is that Solid solves unique problems in a full package. It solves online identity, authorization and storage in an unique combination which developers hopefully find attractive.

Lastly, within the forum of Solid, many discussions have been held about possible use-cases to increase the adoption. The main issue is that there are many Solid applications, but none that has been the *unicorn* of Solid.

2.5 The developer experience

Learning a new technology as a developer can be challenging. During the interviews and survey, some questions were asked regarding the experience of developing a Solid

application, from which the main points are shared. Figure 2.3 shows how participants of the survey rate different aspects of the developer experience. The top graph shows that on average the easiness of developing a Solid application is low. The easiness of setting up a Solid server seems a bit more distributed, but gravitates towards a low easiness as well. In the last graph, the current documentation of Solid is rated, from which the mode is 2. Although it is a small group of participants, the graphs suggest that there is opportunity for improvement.
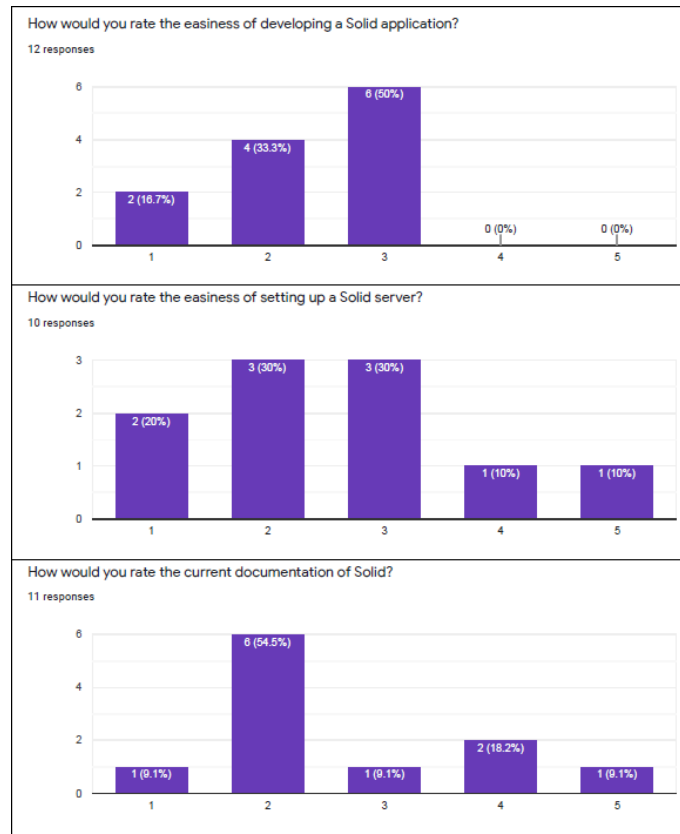
Figure 2.3: Graphs taken from Survey

Moreover, Developer 2 also shared some suggestions. For instance, the documentation of Solid could be improved, by using e.g. a Documentation Driven Development approach. The Solid specification provides a lot of information, but Developer 2 suggests that it should be clearer. An easy to use tool stack could be helpful too, as well as success stories that get seen by other developers. He also mentions that from his experience the most focus lays on features and not the developer experience. For example, there is a list of Solid apps online, but some of them don't work. There lacks a responsibility for that. Therefore, Developer 2 suggests having one person that is in control of the documentation full-time, which would help with the developer experience.

Another topic shared by Developer 3 is the different data structure used in Solid. As Solid is based on linked-data technologies, it uses graph data structures. Working with graphs instead of tree structures could be a change that developers need to get adjust

to. Nonetheless, it allows for a lot of functionalities that are not achievable using tree structures. Lastly, Developer 3 shares that there is more work to be done on introducing these technologies and getting all tools and libraries to a state where it is a piece of cake to work with any Solid related app.

2.6 Solid for low-resource environments

In the interviews and survey, there was a section of questions about the challenges that could arise with Solid in low-resource environments. Next chapter is a comprehensive examination of challenges in low-resource environments from its citizens. However, the perspective from the Solid community is interesting to examine as well.

Developer 3 mentions that the focus at Inrupt is to get new features in place and to provide tools that are directed at developers in general, not particularly low or high resources. Some of the functionalities are more directed towards high-end browsers and devices. As for Inrupt, their customers have mostly been enterprises in Western countries. He also experienced that most applications do not require a lot of battery power; they have not seen heavy GUIs or games. In addition, the introduction of HTTP2 might solve problems or introduce new challenges on low-end devices.

One idea that was mentioned many times was an offline approach towards Solid. Then a connection isn't always needed. Developer 2 is working on an offline-first approach towards Solid, which could be beneficial in low-resource environments. There have also been discussions around a mobile approach towards Solid. If users could have their Pods on mobile phones, more people could use the platform, which we'll explore further in the next chapter.

In addition, when we introduced the project on the Solid forum we got some responses as well (see Appendix 5.4). Developer 1 shared that the Solid Protocol makes a lot of HTTP requests. Thus, when there is an unreliable connection, it might be difficult to keep track of these requests, and a less chatty server might be more admirable. Another response was to include local community members in the discussions around Solid. For instance, for deriving ontologies and terms from a local community. People from different cultures should join discussions to create more accurate ontologies and vocabularies to describe the data of different domains.

2.7 Chapter Summary

In this chapter, we explored the current progression of the Solid project. Solid is moving into a commercial direction to help build a sustainable ecosystem to improve the adoption as well as the quality of Solid. With that, the current status of the companies Inrupt and Digita have been discussed. However, there are still many challenges, for example the amount of issues in the Solid repositories, improving the developer experience, and adoption of Solid. Suggestions have been given for these challenges. Lastly, ideas regarding Solid in low-resource environments have been shared from the Solid community. In the next chapter, the challenges and possibilities of Solid in low-resource environments will be discussed.

3. Challenges and possibilities in low-resource environments

This chapter will be a deep-dive into low-resource environments with the goal to understand its challenges and possibilities. Similarly to last chapter, three interviews were held along with a lecture given at the VU. The interviewees are referred to as Interviewee ID, as shown in Table 3.

Table 3.1: Interviewees from, or with experience in, low-resource environments

ID	Interviewee	Role	Appx
1	Victor de Boer	A Dutch professor at the Free University of Amsterdam specialized in semantic web, digital humanities and ICT4D. Also part of the W4RA research team.	5.5
2	Francis Saa-Dittoh	A Ghanaian PhD candidate at the Free University at Amsterdam as well as an Information Technology Associate at UNOPS	5.6
3	Joshua Opoku Agyemang Otoo	A Ghanaian president of the Ghana IoT Network Hub	5.13

The rest of the chapter is divided into the three main topics of the interviews: *the characteristics of low-resource environments*, *potential fields of use*, and *views on growing adoption.*

3.1 Characteristics of low-resource environments

There isn't a clear-cut definition of low-resource environments, but it can be identified by comparison. A low-resource environment lacks social and technological elements perceived in Western societies as commonplace. Some elements of low-resource environments are e.g. low levels of literacy, poor infrastructures and limited purchasing power (7).

One of the first remarks in the interviews was the depth of low-resource environments. Every area of a low-resource environment can not be put under one umbrella; areas within a low-resource environment can differ substantially. From the interview with Interviewees 2 and 3, a diagram (see Figure 3.1) is designed that gives a rough estimation of the different areas within low-resource environments and is used to support the oncoming sections. When building a solution with supporting a low-resource environment as the main goal, it is important for researchers and developers to determine the area in which the solution will be build. This will become more obvious in the following sections.

3.1.1 Technological observations

The main use of communication is the GSM phone, because there is a GSM network available almost everywhere, contrary to the internet. While the rise in internet usage in Africa went from 4.7% in 2009 to 24.4% in 2018[1], it is modest compared to Europe

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[1] https://www.statista.com/chart/17322/global-internet-access/ [Accessed: 7/22/2021]
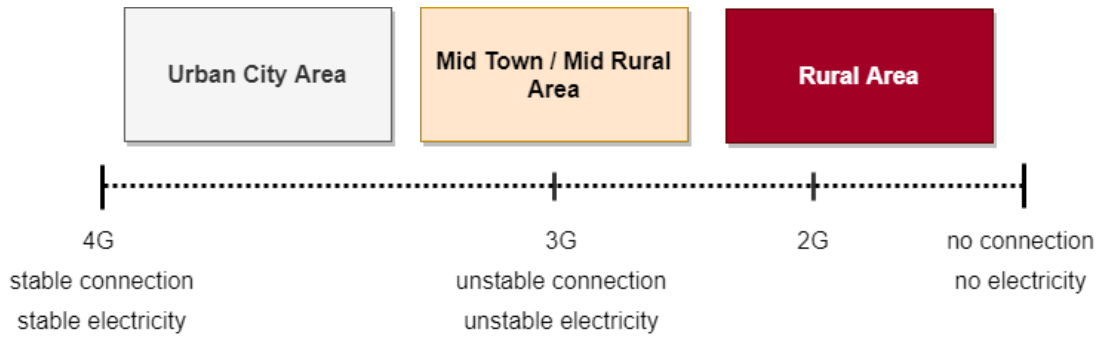
Figure 3.1: Estimation of different areas in low-resource environments

and the Americas. The Web 2.0 brought about a new economy to the world and an abundance of people are still unable to take advantage of it (7, 11). Aside from that, the use of desktops is lower than mobile phone usage; 7.7% of the households in Africa own a computer (2019)[1]. Therefore it is more reasonable to develop solutions for the mobile market, such as the voice-based marketing system created by Interviewee 2 (8). Figure 3.1 shows an estimation of several technological differences between areas in low-resource environments. Moving horizontally to the left shows an increase in options, but a decrease in potential users. With no connection or electricity whatsoever, it would be difficult to implement solutions that depend for instance on sharing data. However, a solution for unstable connections could be to let the software wait for an internet connection when sending data.

3.1.1.1 Lack of hardware resources

Another observation shared by Interviewee 3 is that developers in low-resource areas depend on developing countries for hardware components and manufacturing. Creating an Internet of Things (IoT) solution demands hardware like circuit boards, cables, casing and other IoT components. Sometimes, advanced solutions are required, such as self-designed products that demand custom hardware. Especially then, the expenses to manufacture parts of a product in for example China, and ship it over to Ghana, could become too much. Likewise, approaches that require online services – for instance cloud storage, cloud computing and artificial intelligence – often depend on solutions build by the Big Tech. There are practically no local data-centers.

3.1.1.2 Environment

Every continent has their own environments and different approaches are needed when building solutions for them. In Sub-Saharan Africa, extreme heat and drought are legitimate occurrences and developers should be aware that electronics should be able to withstand that. For instance by having sufficient cooling to prevent overheating a device.

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[1]`https://www.statista.com/statistics/748549/africa-households-with-computer` [Accessed: 7/22/2021]

3.1.2 Social observations

On a social level, there are a number of observations shared by the interviewees.

3.1.2.1 Language and literacy

Africa contains various languages. From more popular languages such as French and English, to more rural languages such as Swahili and Amharic. Depending on the area the language differs. Urban city areas are more inclined to have citizens that have picked up a popular language, and languages within rural areas could differ extraordinary. Besides that, illiteracy is a considerable problem too. Based on data collected in 2019[1], around 34.7% of all people above 15 years old in Sub-Saharan Africa are illiterate.

3.1.2.2 Governments

Another aspect is governmental trust. From Interviewee 1's experience, governmental trust in some African countries is low compared to first-world countries. One survey[2] done in South Africa in 2018 showed that citizens generally have a low level of trust in police and public services in South Africa. By offloading some of the trust to technologies, the reliance on the government could decrease because the technology takes its place. However, the government could misuse it. Therefore the technology should be developed in a way that the possibility of misuse is minimized. In addition, governments lack knowledge about approaching IT issues. Interviewee 3 explained that the government doesn't address about problems such as cyber security and data privacy. Other unions such as the European Union have established the General Data Protection Regulation to assert data protection and privacy.

Moreover, Interviewee 3 shared that it can be a huge challenge for organisations to build a solution when state approval is required, especially with a corrupt government.

3.1.2.3 Project development

From Interviewee 3's experience, the work ethics are low and there's a need for a push from communities to motivate people. In addition, solving a problem and involving users and clients in the development process of a project turns out to be a great challenge. Developers often just start somewhere without regularly communicating with clients, which can cause issues later on when a project has to be redone. Therefore there is a lack of experience in a project's development cycle and type of methodologies that can help when creating a product, such as Agile software development[3].

3.1.2.4 Social media

Interviewee 2 experiences a high social media usage in Africa. Platforms like Facebook and WhatsApp have high usage numbers, but people are also becoming more aware of the

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[1] `https://www.statista.com/statistics/262886/illiteracy-rates-by-world-regions/` [Accessed: 7/17/2021]

[2] `https://afrobarometer.org/publications/south-africa-summary-results-2018` [Accessed: 7/17/2021]

[3] `https://en.wikipedia.org/wiki/Agile_software_development` [Accessed: 7/19/2021]

privacy issues of these platforms. One example is when WhatsApp continuously reminded people to accept their new terms and conditions, which led to mistrust and an explosive increase in downloads of other apps such as Telegram and Signal[1]. People recognize targeted and personalized advertisement, which makes them eager to use applications that focus more on their privacy.

3.1.2.5 Theft and damages

Finally, Interviewee 3 also shared the issue of theft. This certainly is a problem in any area, but in an area without regular patrolling and insufficient housing security, it will become simpler to commit burglary. Hardware used to e.g. measure the health of crops that are on the field could be destroyed or stolen rather easily.

3.2 Potential fields of use

After having questioned the interviewees about their experience in, and observations of, low-resource environments, the interviewees were asked how Solid could play a role in low-resource environments. Both the rural areas and urban city areas are described separately, as they have different issues.

3.2.1 Mid Town / Mid Rural Areas & Rural Areas

The biggest challenge of implementing Solid in rural areas is the web-based design of the Solid Protocol. Having an unstable internet connection can be a problem. One idea mentioned by Interviewee 1 is based on a master thesis from one of his students (12), in which the student explores machine to machine communication between geographically distributed devices. With regard to Solid, if a Solid server could be deployed at a location or in a vehicle, people could now and then connect to it when available and update their data. In order to do that, an offline-first approach is needed. This would allow users to only update their data when the connection to the server is available. A more outrageous idea is a vehicle that gathers all data of the users in an area and drives back to where a server runs. Moreover, a distributed approach where data is replicated over multiple servers could bring new possibilities as well.

The backbone of Africa has been agriculture for years and there is a subtle increase in the inclusion of technologies and data. In order to keep up with developing countries, developers are looking into how to make data on African farms practical. One example is from Oliveira-Jr et al., who have created an IoT sensing platform for small-scale farmers (13). Adding Solid to these projects could be irrelevant as some functionalities, such as digital identity, might not be beneficial in agriculture systems.

For the areas without electricity, solar panels could be used because of the amount of sun being there.

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[1]https://mynewsghana.net/reminders-on-rise-as-whatsapp-update-deadline-looms/ [Accessed: 7/19/2021]

3.2.2 Urban City Areas

Urban city areas introduce more possibilities and as Solid is based on web technologies, we are more inclined to focus on urban city areas in Africa.

Firstly, Interviewee 2 shared a governmental proof-of-concept idea. Currently, every time information is required for governmental applications, such as car licenses and passports, a citizen repeatedly has to share the information because there is no central database. All data is segmented over different institutions. With Solid, citizens' information could be stored in one place: in their own pod. We've talked about Inrupt working with the government of Flanders to implement Solid, which is a matching approach. In addition, it is similar to DigiD[1], an identity management platform by the Dutch government that allows citizens to login to different institutions with their identity.

Another idea shared by Interviewee 1, is about a local marketplace where people can login with their pod and share the products they would like to sell. Consumers and farmers could create a connection and see for instance their contact info to buy their products.

The next section will include a presentation given at the Free University of Amsterdam as well as a proof-of-concept idea for Solid.

3.2.2.1 *Use-case:* Monitoring Animal Health and Status

Within the Free University of Amsterdam, I gave a presentation together with Serbãnescu (see Appendix 5.3) about the Solid project to students of the ICT4D in the Field course[2]. In this course, students collaborate on IT projects, aimed at developing countries. It was especially interesting since it is an international course with students from low-resource countries as well. The presentation included a brief explanation of Solid, but more importantly how it can be used in the students' projects. The goal was to find possible use-cases and to discuss, together with the student groups, whether Solid would be a viable solution for their projects.

For the presentation, a proof-of-concept idea was created based on one of the projects, which is shown on Slide 4. The use case was named *Monitoring Animal Health and Status* and was based on Cowtribe[3]; an innovative company that improves animal health service delivery along with other projects in Ghana. After the presentation, we joined break-out rooms and discussed the possibilities of Solid within their projects.

One of the encountered issues when deciding to implement Solid in a project is the lack of human expertise. When doing a development project, there will be a limited amount of resources in a team. Someone can be excellent in one type of skill and taking advantage of that is a practical decision. Learning a new skill takes time, which is scarce. And as development projects can have tight budgets, it can become an inconvenience to add Solid to the project. Therefore, it is important that Solid is easy to implement and use. We also encountered projects that didn't necessarily need some of the functionalities Solid provides, such as having a digital identity.

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[1] `https://en.wikipedia.org/wiki/DigiD` [Accessed: 7/20/2021]

[2] `https://studiegids.vu.nl/en/Master/2020-2021/computer-science-joint-degree/XM_0008` [Accessed: 6/18/2021]

[3] `https://www.cowtribe.com/story/` [Accessed: 06/02/2021]

3.3 Views on growing adoption of Solid in low-resource environments

Growing the adoption of Solid in low-resource environments could be beneficial to both its citizens and the platform itself. In this section, different ways to increase the adoption of Solid are explored.

3.3.1 Mobile Pods

With the high mobile usage in Ghana being way above desktop usage, it would make more sense to look for a mobile approach towards using Solid, with a focus on Android, as that is commonplace compared to iOS or other. The ability to manage and store a Pod in an application on a mobile phone could increase the accessibility and usability of Solid drastically looking at the amount of mobile users. When creating this functionality, developers should consider the type of mobile phones used in low-resource environments and analyze their specifications.

3.3.2 Multilingual

Solid is mostly documented in English, and so are Pod Providers such as Solid Community and Inrupt, which cuts the population of Ghana in about a half. Thus, adding multilingual support could increase adoption of other language speakers as well, which is an interesting point to look at in the future.

3.3.3 Collaboration

Interviewee 2 also mentions the rise in innovative apps created by local developers for the African market. Just like Interviewee 3, he has experience with tech hubs and programming groups in Africa. He says it will be easier to adopt a new technology when people recommend it, inspire you and when there is a community behind it that will support you. Explaining the multitude of functionalities Solid provides could demonstrate to developers that it might be easier to use Solid than to implement some of the functionalities themselves (for instance authentication, data storage and a digital identity).

In 2021, Nvidia collaborated with Ada Labs Africa and AICE in East Africa on a number of data science and AI projects to help train new AI and data engineers. These collaborations can push a new generation of students and Solid could do the same to start a new movement of Solid developers in Africa[1].

3.3.4 Resource usage

Interviewee 1 shared that it would be interesting to research the resources required to run solid Solid (such as electricity use, computational power, size, and web connectivity). This could be helpful information when creating Solid solutions for low-resource environments and when trying to increase the sustainability of Solid.

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[1]`https://techbuild.africa/ada-labs-africa-nvidia-artificial-intelligence/` [Accessed: 06/05/2021]

3.4 Chapter Summary

Low-resource environments are complex, but in this chapter we have unraveled some of the complexities. There are varying areas within low-resource environments with their own challenges. For example, city areas struggle with social issues, whereas technological issues more often crop up in rural areas. Afterwards, we looked at different fields of use, for instance within the government, and why adding Solid to a development project might be difficult. At the end, different ways to increase the adoption of Solid in low-resource environments have been shared. In a nutshell, these are a mobile approach, multilingual documentation, increasing the collaborations with third-world nations and looking at resource usage of Solid.

4. Experimenting with Solid

During the research, I have explored and experimented with Solid to understand the technical possibilities and limitations of Solid. Three different hardware devices have been taken into account. PC, mobile, and Raspberry Pi are examined to see their usefulness and whether it is possible to use these devices in Solid's current state. First Solid Applications created by the community are explored. Then the Solid packages used in the lab experiments are described. Afterwards, the experiments on the different devices are discussed. And lastly, a Solid application is described that I created in the experimentation progress.

4.1 Solid Client Applications

On the website of Solid[1], there is a multitude of applications that rely on Solid, each with different functionalities. These applications are added to a list on the main website of Solid for others to use and experiment with. There are certainly more Solid applications, but as this is the main website of Solid, it is logical to examine these. I selected the applications based on two criteria; the application has to be ready to use, and the selection should be diverse.

Some interesting examinations are described in Table 4.1. When comparing the interface used at Inrupt and the Solid Community server with the interfaces at the Solid applications OHMYPOD! and Inox, you can see substantial differences in the design. Figure 4.1 shows the Inrupt and Inox interface. The Inox interface is visually pleasing compared to the Inrupt interface. Another interesting point is that when new data is stored in the pod, often the data is stored at the root level of the Pod storage. Sometimes even without a clear name (random generated code). In the future this could lead to a long confusing list of data.

One of the applications is a Hello World[2] application that is minimal in functionality and doesn't work well. Also, it has no instructions whatsoever. Having a better Hello World application could attract more developers as it is a popular term for a program that explains the basic syntax of programming languages.

4.2 Solid Packages

In this section, packages of Solid are described that used in the experimentation process.

4.2.1 node-solid-server

The Node Solid Server lets users run a Solid server on their file system using Node.js; a cross-platform Javascript runtime environment[3]. It includes millions of packages to be used, e.g. packages to run a http-server. The node-solid-server repository is open-source

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[1]`https://solidproject.org/apps` [Accessed: 5/15/2021]

[2]`https://en.wikipedia.org/wiki/"Hello,_World!"_program` [Accessed: 5/16/2021]

[3]`https://nodejs.dev/learn` [Accessed: 5/17/2021]

Table 4.1: Different Solid client applications

Name	Goal	Other observations
Notepod	Take notes which are stored in the user's pod.	There is a caching issue when the session is expired. Also, a .ttl file is stored in the users POD, but it has a random generated name and is added to the root folder. Therefore when a user has thousands of files, it will be difficult to find a certain file.
Media Kraken	Keep a media collection.	Movies can be imported from IMDB. Soukai models and relationships are used to represent the data model.
Solid Chess	Connect people to play chess.	It is a decentralized way of playing chess. All data of the game is stored on the users' pods.
Plume	A blogging platform to create blogs.	It is deployed on top of a Pod, which is different from the other applications.
Hello World	To show the basics of a Solid application.	It is very minimal.
OHMYPOD!	To let people manage their pods.	It is possible to see your profile, friends and files in a nicely looking interface.
Inox	Allows people to track their data between different pods.	The interface is pleasant and inviting, compared to the POD interface.

on Github[1]. One of the things to take into consideration is the need for an SSL certificate, because the Solid server requires SSL certificates to create a secure connection. Therefore, a test server is used in the experiments that allows self-assigned certificates.

4.2.2 solid-client-authn-js

Solid JavaScript Authentication is a library that allows developers to manage the authentication required to access a Pod on a Solid server. This would be useful in a Solid client application to connect to a Pod.

There was an issue where one folder was not being generated on Windows. After coming into contact with the forum, we created a new issue on Github, which got solved[2].

4.3 Experimenting on devices

Three devices have been experimented with: PC, Mobile and a Raspberry Pi to see whether Solid can be used on these devices. See Section 4.3.1 for the information about the used devices.

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[1]`https://github.com/solid/node-solid-server` [Accessed: 5/17/2021]
[2]`https://github.com/inrupt/solid-client-authn-js/issues/1223` [Accessed: 5/17/2021]
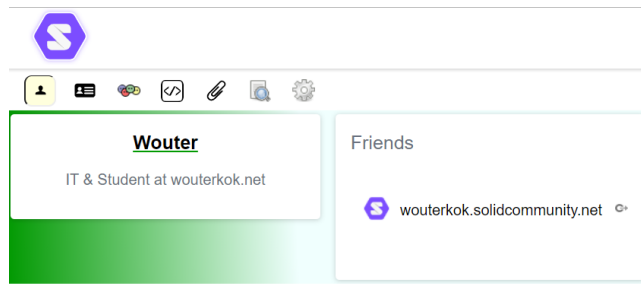
(a) Inrupt interface
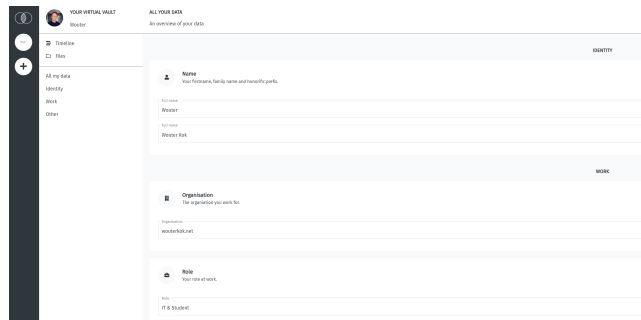
(b) Inox interface

Figure 4.1: Comparison of the Inrupt Pod card interface and the Inox Solid application interface

4.3.1 Development environment

- **Laptop: Dell XPS 15 9560**

  - *OS Name:* Windows 10 Home

  - *Version:* 10.0.19043 Build 19043

  - *Processor:* Intel(R) Core(TM) i7-7700HQ CPU @ 2.80GHz, 2801 Mhz, 4 Core(s), 8 Logical Processor(s)

  - *Editor for Web:* Sublime Text

  - *Editor for Mobile:* Android Studio

- **Mobile: Samsung S8+**

  - *OS Name:* Android 8.0

  - *Processor Cores:* 8

- **Raspberry Pi 4 Model B / 4GB**

  - *SD Card:* SanDisk Ultra Micro SDHC 32GB - UHS1 & A1

  - *OS Name:* Rasbian GNU/Linux 10 buster lite

4.3.2 Pod on PC

The process of experimenting on PC was straightforward as the documentation is focused on development on computers.

Firstly the node-solid-server was installed and examined. The first problem was an issue with authentication, which was caused by using incorrect certificates. After looking at the documentation on Github, it showed that a development area could be set up by using the solid-test server and by generating self-made certificates. That solved the issue and a server could be ran and a Pod account could be created. Windows Subsystem for Linux with Ubuntu 18.04 LS was used to run the server, because there were some issues running the solid-test server on Windows. In addition, using a Pod created on a local running Solid server, it was possible to login to client applications, for example Notepod in Table 4.1. It is also possible to run a client application like Notepod locally and login with a Pod. As experimenting on PC was quite clear-cut, this section ends here. In Section 4.4, a Solid application which I created on PC is shared.

4.3.3 Pod on Mobile

As most people in third-world countries use mobile phones, we can not ignore the possibilities that mobile phones might bring with Solid. Most websites are mobile friendly, so a user could create a Pod on one of the public servers' websites like Inrupt and use that Pod to login to a Solid Application like Media Kraken. However, in environments with unstable internet connections, an online pod is inconvenient. One possibility that was shared during the interviews was running a Solid server on a mobile device. If an offline-first approach would be developed, it would be even more attractive to have a mobile Pod, as internet isn't necessarily needed then.

In this experiment we started off by trying to run the Node Solid Server on a mobile phone. Running Node.js on a mobile phone is already an issue. However, there are options that can run node on mobile phones. One package[1] found browsing the internet combines the Cordova framework and Node.js, which was used in this experiment.

The tests were done on a Samsung S8+ model SM-G955F. This experiment was a bad experience. After fixing most errors, the main issue was encountered; the different file system of an Android phone, which is not compatible with the current Solid server. When trying to write something to the Android device, there was an error that didn't allow write operations, because the security of the Android file system is strict on writing operations. Reading operations however, are more effortless. In addition, setting up the environment with all the correct versions is a hustle. One older or newer version could already break a program that is dependent on having correct versions. For this experiment a Github repository is created with an extensive overview of what is done, how to deal with common errors, and which error is currently encountered. The repository can be found here:

`https://github.com/wkokgit/Node-Solid-Server-on-mobile-using-Cordova`.

To be able to make this work, more research and experimentation has to be done on how to make a Solid server compatible with both the Android and iOS file-systems. It took a

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[1]`https://github.com/JaneaSystems/nodejs-mobile-cordova`

Figure 4.2: Raspberry pi set-up

while to do this experiment and as this thesis isn't solely focused on mobile devices, the experiment has stopped here.

4.3.4 Pod on Raspberry Pi

Another device that was experimented on is the Raspberry Pi[1]. This is a small single-board computer and relatively low-priced compared to laptops and desktops, which makes it attractive to use in low-resource environments. Moreover, it already has been used for several IoT projects and for the improvement of education (14, 15).

In Figure 4.2 the setup of the Raspberry Pi can be seen. A Raspberry Pi 4 Model B / 4GB is used together with a SanDisk Ultra Micro SDHC 32GB - UHS1 & A1 to store the data on. To flash the SD card with a version of Rasbpian, balenaEtcher is used. A lite version of Rasbian GNU/Linux 10 (buster) was used to keep the data usage small and keep the device fast. In addition, a combination of Putty, to connect to the Raspberry Pi console via SSH, and Samba, to connect to the file-system, was used.

The node-solid-server can be used as a single-user server, but also a multi-user server. At first the single-user server was tested, but when trying to login in the server using a connection between a laptop and the Raspberry Pi there was another problem: an account could not be created using the laptop. For this problem an issue was created in the Github repository[2], advised by Developer 1.

An attempt to solve the issue was to use a full OS instead of a lite OS and experiment on the Raspberry Pi itself instead of a connection between a laptop and a Raspberry Pi. Unfortunately, the sd-card or the sd-card reader got corrupted and the experiment could not be continued.

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[1]`https://www.raspberrypi.org/` [Accessed: 5/20/2021]
[2]`https://github.com/solid/node-solid-server/issues/1600` [Accessed: 5/26/2021]

However, there have been some discussions on the forum about running Solid on a Raspberry Pi[1] and someone was able to run a Solid server correctly on a Raspberry Pi. More research is needed to further explore the technical side and potential use-cases it creates.

4.4 Building a "Hello World" application for Solid

As part of experimenting with Solid applications, an application was created to further explore Solid's capabilities. The interviews and survey have shown that developing a Solid application can be difficult. This sparked the idea to create an application that shows the basic functionalities of Solid and extra information that will help developers kick-start their journey with Solid. *Hello World* is a term often used in the programming community to explain a basic functionality. There already exists a Hello World type of application for Solid[2], but it lacks functionalities, explanations and doesn't work well. However, this application was used as groundwork for the new Hello Solid application.

The Solid application is hosted on Github at the following address:
`https://wkokgit.github.io/hellosolid/`.
The code repository can be found at the following address:
`https://github.com/wkokgit/hellosolid`.

4.4.1 Objective

The goal of this application is to support new developers that want to quickly learn more about Solid. In addition, it is meant for developers that want to see how you can perform the core tasks of Solid, such as accessing, adding and updating data in a POD. First, functional requirements were created.

4.4.2 Functional Requirements

This section describes the functional requirements of this application. The functional requirements marked with a asterisk were already provided by the existing Hello World application.

FR-1* Create a POD via an external link
> The user should be able to create a POD via one of the POD providers. Therefore a link to the "Get a Pod" page of Solid[3] can be used.

FR-2* Login with a Pod
> The user should be able to login with a POD .

FR-3 View user profile
> The following variables should be shown on the user's profile:

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[1]`https://forum.solidproject.org/t/business-opportunities-using-solid-pod-servers-without-using-advertis` 1301 [Accessed: 5/26/2021]

[2]`https://github.com/melvincarvalho/helloworld` [Accessed: 5/27/2021]

[3]`https://solidproject.org//users/get-a-pod` [Accessed: 5/27/2021]

- webID
- name
- mail
- role
- country
- friend list

FR-4* Log out of the application
> The user should be able to log out.

FR-5 Update the user name
> The user should be able to update their user name.

FR-6 Update the user role
> The user should be able to update their role. This is a VCard property.

FR-7 Add new data to the pod
> The user should be able to add new data to a pod. An example could be a new VCard property[1] e.g. country-name.

4.4.3   Implementation Details

There are multiple ways to create this application, but also when it comes to accessing data from a person's POD; multiple libraries can be used to modify the data. Consequently, because there are many ways the data can be modified. All data operations are both written using LDflex and rdflib.js, so that the developers have extra examples to look at. More similar libraries could be added in the future. *To change between LDflex and rdflib.js, edit the scripts section of the HTML file.*

LDflex – a domain-specific language – is used for querying Linked Data on the web. The creators are Ruben Verborgh and Ruben Taelman, but Verborgh additionally created one library configured for use within the Solid ecosystem.

rdflib.js – originally created as a Python library to work with RDF – has a similar focus. However, it offers more support for other file formats like Turtle and N3. It has extra functionalities that weren't used in this application.

In developing this application, a better user experience was encountered when using LDflex, as it seems more straightforward. In addition, the functions written in the Hello Solid application take less lines of code using LDflex. However, this is based on a month of coding, without complicated and intrinsic problems to be solved. Both libraries have adequate documentation.

In addition, as this is an application that tries to explain the basic functionalities of Solid, they should be elaborated extensively. Therefore, explanations will be added on the

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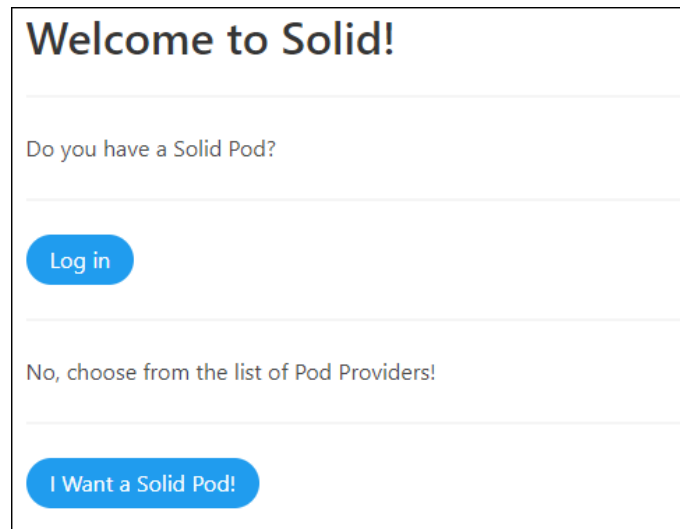[1]`https://www.w3.org/2006/vcard/ns#` [Accessed: 5/27/2021]

Figure 4.3: The user interface of the forked Hello World application

web-page and useful websites will be added that offer more information. Also, the code is commented.

All used libraries are shown below:

solid-auth-client[1]
Used to login and logout with a user's Pod in the client application

rdflib.js[2]
Used to read/write RDF/XML data

solid-query-ldflex[3]
Used to read/write RDF/XML data

jquery.js[4]
Used to help coding in JavaScript

For the full code-base, go to: `https://github.com/wkokgit/hellosolid`.

4.4.3.1   User Interface

Firstly, Figure 4.3 shows the beginning state of the interface. It was minimal, lacking many of the functionalities mentioned in the functional requirements. In this interface, the CSS framework Bulma[5] was adopted to help making the design process easier and faster. Figure 4.4 shows the new interface, which also uses Bulma. The goal was to make the user interface attractive to use.

Now we will go further by explaining all functional requirements one by one.

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[1]`https://github.com/solid/solid-auth-client` [Accessed: 5/29/2021]
[2]`https://github.com/linkeddata/rdflib.js/` [Accessed: 5/29/2021]
[3]`https://github.com/solid/query-ldflex/` [Accessed: 5/29/2021]
[4]`https://jquery.com/` [Accessed: 5/29/2021]
[5]`https://bulma.io/` [Accessed: 5/30/2021]
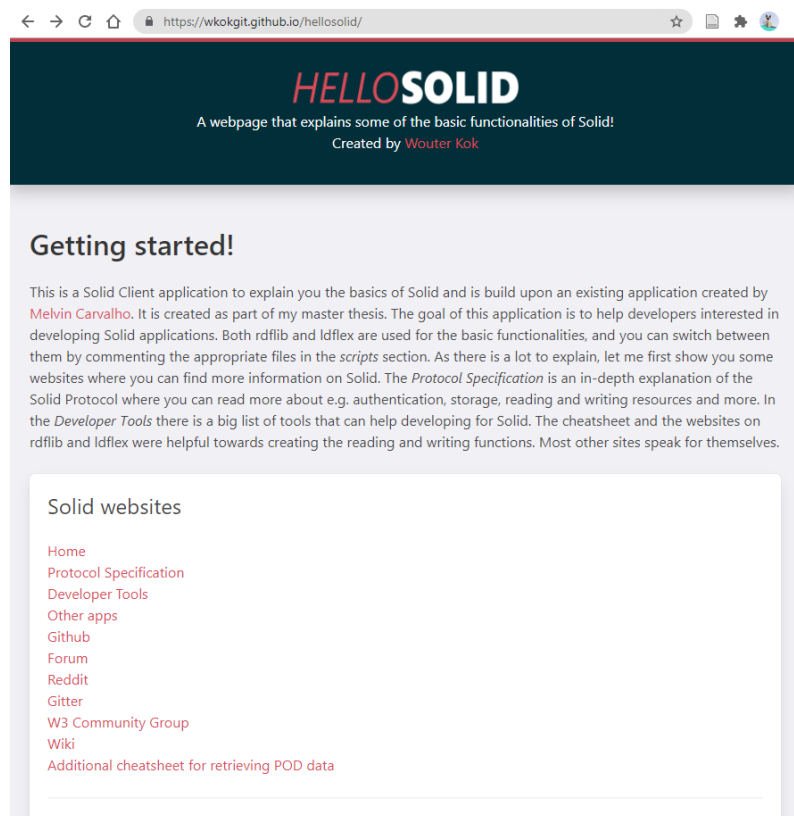
Figure 4.4: The new user interface of the Hello Solid application

Figure 4.5: Login section of the application

4.4.3.2   FR-1 Create a POD via an external link

This functional requirement is easily achieved. Shown in Figure 4.5, a button is created that opens a new window to the *Get a Pod* site of Solid. The user can create a Pod using that link and afterwards login to the application.

4.4.3.3   FR-2 Login with a Pod

In Figure 4.5, there is a button at the bottom that allows the user to login. When the button is clicked, the Solid authentication will be executed by launching a pop-up that manages the authentication. After the user fills in their webID and presses *Log in*, the log-in should go successfully so that a session is started.

When a user has logged in, the display of login section is set to *not visible*, and a new section is set to visible which shows the rest of the functions below.

4.4.3.4   FR-3 View user profile

After logging in, the user profile is loaded, shown on Figure 4.7. The profile demonstrates how data could be accessed in the Pod. As a developer, it is recommended to check the code for more explanations.

4.4.3.5   FR-4 Log out of the application

With the log out button in Figure 4.7 at the bottom, the logout function from the Solid authentication library is fired and stops the user session.
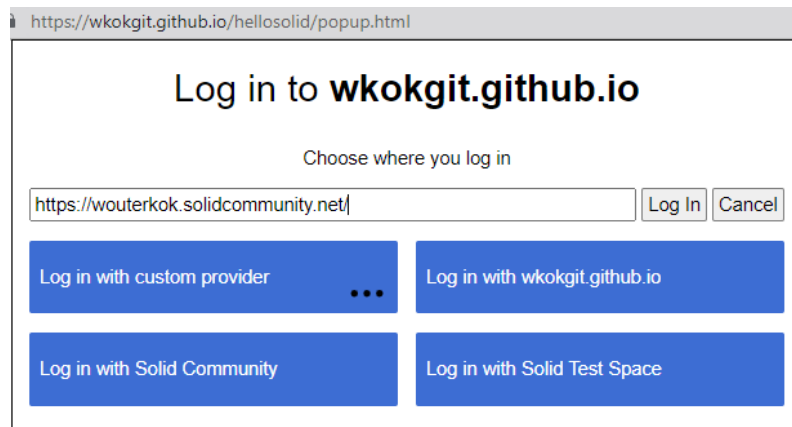
Figure 4.6: Pop-up after pressing login button
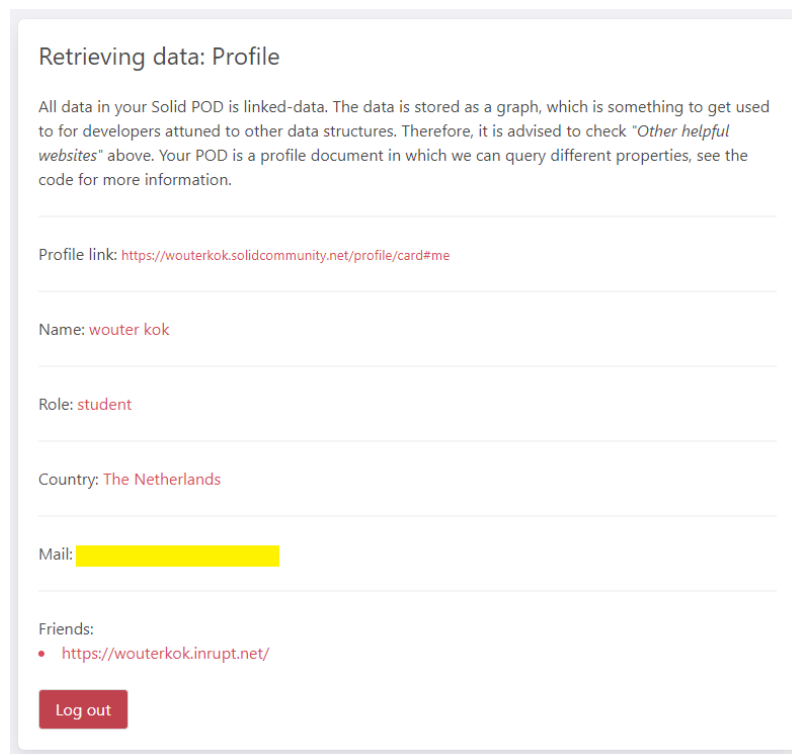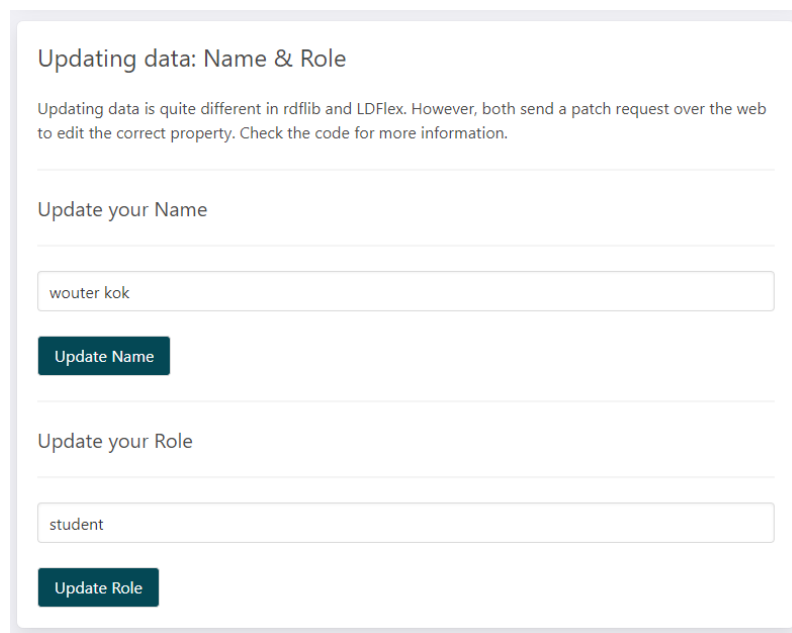
Figure 4.7: Profile section of the application

Figure 4.8: Update section of the application

4.4.3.6 FR-5 Update the user name

As there is a connection to the user's Pod, it will be possible the update the user's data. However, the user should allow the application to modify its data first. Figure 4.8 shows where the name can be updated. See the code for more information.

4.4.3.7 FR-6 Update the user role
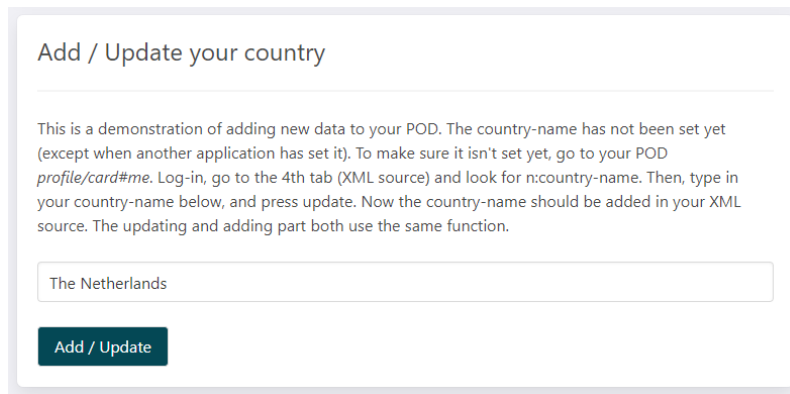
Figure 4.8 shows where the role can be updated as well, which is a similar process to FR-5.

4.4.3.8 FR-7 Add new data to the Pod

Finally, Figure 4.9 shows where new data can be added to the Pod. Normally, when a user creates a Pod at one of the Pod Providers, there is no country property in someones Pod. This function will add that property to a pod. There are more advanced types of data where a data model is needed, but this is a small example of how to add data to a Pod.

4.5 Chapter Summary

In this chapter, we have shared lab experiments on Solid. At the start, multiple existing Solid applications have been assessed to get familiar with how a Solid application works. Through the experiments, we saw that Solid on mobile and Raspberry Pi need more work, especially Solid on mobile. Using Solid on a computer is the most straightforward. Lastly, Hello Solid, an application I created as part of the experimentation process is explained. This application is intended to help beginning developers on their journey of using, under-

Figure 4.9: Add section of the application

standing and building Solid applications themselves. In the next chapter, the learnings of the past three chapters will be discussed.

5.   Discussion and Conclusion

In the past chapters information has been gathered from (i) the Solid community, (ii) the low-resource environment community and (iii) lab experiments. This information is evaluated and explored in this chapter to uncover new information and to challenge the research questions of this thesis.

5.1   Deficient usability of Solid

The ease of use of Solid turns out to be low indicated by the results of the interviews and the survey. According to the Cambridge Dictionary, the meaning of *usability* is "the fact of something being easy to use, or the degree to which it is easy to use"(16). I have experienced through the lab experiments that multiple aspects in the Solid ecosystem can be difficult to use.

Adding Solid to a project takes time. At first, developers have to learn more about Solid and its graph-like data structures. And if there already is a database and authentication system created, migrating the system to a Solid ecosystem is plausibly a considerable amount of work. There are companies that could help with this process, but the only two companies as of writing this thesis are Inrupt and Digita.

ICT4D projects are often executed by NGO's and universities that depend on a certain budget and the skills of a research team. There might not be enough budget to first learn Solid, as it requires quite some knowledge about semantic web technologies.

Therefore, it is important that the usability of Solid is high and that it is easy to use for new developers and users. The following points are suggestions for improving the usability.

Setting up a Solid server   When a user wants to set up a Solid server, first it should be cloned from Github, then the user has to configure the server, and afterwards run it. In the configuration, one problem is creating a certificate to create secure connections. All these steps are difficult for non-developers. One solution to increase the easiness of setting up a Solid server in a household, could be an application that can be installed on your computer, which helps the user step-by-step through the process of configuring a Solid server. Furthermore, another idea could be an IoT device that connects to the user's internet, which the user can set-up via a web-browser, similarly to how routers can be set-up through apps and a browser. Instead of the Enterprise Solid Server of Inrupt, this could be the Household Solid Server.

The Pod Browser of Pod Providers   The interviews and survey in Chapter 2 showed that there is a dissatisfaction from developers towards the user interface of the Pod Browser. The interface is buggy and unattractive to use. Next to that, the amount of features create a confusing environment. However, Solid applications such as OHMYPOD! and Inox let users browse their Pod data as well in a clearer interface. It might be unusual for a user to create a Pod at a Pod Provider and to manage their Pod using a different Solid application. This only makes the process more confusing. The user has to give access to all their data when they use a Solid application to manage their Pod, which makes this option less attractive.

My suggestion is to examine and update the current user interface of the Pod Browser.

Documentation   The current Solid documentation received a low score on ease-of-use in the survey and was discused during the interview with Noel de Martin. The Solid Protocol specification is quite technical and can be overwhelming to new developers. There should be discussions about creating a user-friendly documentation with examples and figures. I have created a Hello Solid application to serve as a sort of user manual for developers when learning about Solid. I have no supporting evidence that this will be beneficial to the community, but we will find that out in the future.

5.2   Challenges of Solid in low-resource environments

Whether Solid is ready to be adopted in low-resource environments, depends which part of a low-resource environment is focused on. We have determined that city areas in low-resource environments are quite developed already. With a stable internet and electricity connection, working with Solid should be similar between low-resource environments and high resource environments. Moreover, in the interviews with the Solid community it appears that Solid does not use a great deal of electricity. However, the majority of the population in low-resource environments from rural areas would be left out. For instance, rural areas have unstable internet and electricity connections. From both the interviews and lab experiments, a suitable solution for rural areas in low-resource environments in the current Solid ecosystem has not been encountered.

Research low-resource environment technologies   When developed countries improve technologies, for example creating faster CPUs and GPUs, more possibilities and opportunities arise. However, if developing countries can't keep up with the technological improvements, they also can't utilize these new possibilities. It is important to analyze and research what type of technologies are used in low-resource environments with their specifications, so that Solid developers know which minimum specifications Solid should support. Different devices such as smartphones, laptops or tablets in low-resource environments should be analyzed.

Another aspect could be which browser versions are used and whether they support new technologies, such as HTTP/2 and HTTP/3.

Language differences   The world has an enormous amount of languages and it will be a challenge to translate Solid in all these languages. Especially in rural areas of Africa, where languages such as Swahili and Amharic are spoken.

Low purchasing power   As of now, Solid is a free to use platform. When the user-base increases, it is unclear if it stays that way. When creating a business model for Solid, the local circumstances of citizens in developing countries should be taken into account as they have low purchasing power.

5.3   Broadening the target audience of Solid

Africans are becoming more aware of data privacy issues and Solid could play a helpful role towards bringing control to the users' data. In this section, some suggestions are given to broaden the target audience of Solid.

Collaborations   Through the interviews, we have learned about the usefulness of collaborations between Western companies and people in low-resource environments. To spread Solid over the world, it is necessary to involve many different cultures and people to provide a solution that is helpful for many. I would suggest the Solid Team to collaborate with schools and universities in developing nations by giving guest lectures or to initiate IT projects using Solid.

Cultural differences   It would be beneficial to look at cultural differences when creating representation of ontologies and vocabularies for the Semantic web, as Solid is based on these technologies. Different cultures could have different meanings for different things, but also how they relate to certain things. As for Solid, looking into solutions such as multilingual documentation, could be a promising effort.

The unicorn Solid application   On the Solid forum, there have been many discussions about what would be the *unicorn* Solid application: the Solid application that will boost the adoption of Solid exceedingly. Currently, there are many applications, but not one that has gathered mainstream attention. It is important that these conversations keep being held and that developers try to experiment with creating new Solid applications.

Mobile approach   We've learned about the popularity of mobile phones in low-resource environments. A mobile Solid server could be helpful when working in a local environment with unstable internet connections, or if people don't want to rely on a Pod provider. There are some challenges however.

- How can a Solid server be run on mobile devices when the protocol is written using Web Standards?

- How can Solid be adapted to make use of the storage of Android and iOS devices?

- How can data be backed-up in case a phone breaks down?

- How can the pop-up that is used for the authentication between a Pod and a Solid application be changed to make it work on mobile?

Offline-first approach   From the past chapters we've also encountered the idea of an offline-first approach. This would create new possibilities, because users would be able to store information locally when no internet is available. Then, when internet would be available, the information could be updated on an online server. This approach would create many opportunities. Local solutions would not have to depend on an internet connection anymore. Also, having Solid Client applications that work offline could give users an offline environment to work in, which updates when internet is available.

5.4 Decentralized vs Centralized

To use Solid as a governmental solution to handle citizen data in low-resource environments was suggested multiple times. In Belgium, Inrupt is putting this use-case to practice with the government of Flanders to enable every citizen to have a Solid Pod. But isn't this solution contradicting the goal of Solid being a decentralized platform? Are citizens of Flanders allowed to host their own Pods? In addition, there should be clear decision-making as to whether this Pod is solely used in governmental context or also in different contexts. If the user is allowed to use the Pod on any application and logins to e.g. a right-wing news website, the information could be beneficial to governmental parties. Similarly, data such as behavioral sensory data from smartphones and smartwatches could be used in civil cases.

One could argue whether or not users have full control over their data when it is being administered by governmental institutions. Especially in developing nations where corruption exists. How will citizens be informed about how their data is being stored and used?

Another important consideration is the possibility of a monopoly of Inrupt. If Inrupt is hosting everyone's Pods, then it would be one central location that provides Pods.

5.5 Uncertain business model

Many people seem to be used to the advertising business model where companies offer a service for free that has advertisements from other companies. Platforms such as Facebook, Youtube, Reddit and Twitch have a business model aimed at advertising products and can be used for free. The question for the Solid Team is how to determine an appropriate income generating business model and to find out to what extend users would be content to pay for privacy. There are some examples of software that help contain privacy, such as AdBlocker, and Blur and DeleteMe from Abine [1], and some virus scanners have options that help prevent leaking your data, such as Virtual Private Networks, password managers and network traffic scanners. Some of these solutions cost money and people are willing to pay for that.

Currently, Pod Providers such as Inrupt and Solid Community are free to use. But when the amount of users increases, who is going to pay for server maintenance and data storage? How will data be backed-up?

The business model will influence who uses the platform too, especially for citizens in low-resource environments that have low purchasing power.

There are many open questions and I suggest the Solid Team to carefully look at them.

5.6 Conclusion

At the start of this thesis, the research questions (see Figure 1.1) are reported and elaborated on. Now, the conclusion is described by means of answering the research questions.

In First World countries, it is common to have a computer, stable electricity and stable connections in most households. On the other hand, in low-resource environments, this

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[1] `https://www.abine.com/index.html` [Accessed: 8/03/2021]

is unusual. Through the interviews, an estimation has been made to categorize different areas in low-resource environments, which are: city areas, mid city / mid rural areas and rural areas. The findings indicate that city areas usually have stable connections, stable electricity and more computers, compared to rural areas. Therefore it can be concluded that city areas in low-resource environments are ready to use Solid, because Solid is build upon web technologies that depend on these circumstances.

The experiments and interviews made clear that Solid is in an early phase. Many of the main functionalities of Solid are still under development and being improved. In rural areas most people use GSM phones or mobile phones and the internet connections are unstable. Due to the lack of proper infrastructure, and Solid's absence of support for the technologies used in these areas, it is difficult to use Solid in these environments. On top of that, Solid is mostly written in English, and in rural areas, many uncommon languages are spoken. With this information we conclude that Solid is not yet applicable in low-resource environments, which answers the first research question: *Is Solid applicable in low-resource environments?*

The second research question is: *What can be done to increase the accessibility of Solid in low-resource environments?* To increase the accessibility of Solid in low-resource environments, three technological solutions have been suggested: (i) Multilingual support, (ii) Mobile Solid server support and (iii) Offline-first support. Furthermore, I have two recommendations. Firstly, I recommend the Solid Team to update the interface of the Pod Browser to make it more user-friendly and attractive for new users. Secondly, I recommend to involve a bigger variety of cultures and people from low-resource environments through collaborations when designing these Solid solutions. This will lead to solutions that are more accessible for more people and pushes Solid to be more in line with the Sustainable Development Goals of the United Nations.

I hope the information provided in this exploratory study is insightful for the Solid community and inspires other developers and researchers to thoroughly research the Solid project to build upon, support, or challenge the findings of this thesis.

Appendix

Innovative student project: "Solid for users in low-resource environments"

This entry was posted in Information and Communication Technologies | Networked approaches | Sustainable ICT | Uncategorized | User-centred design | Web Science | World Wide Semantic Web | and tagged Fair ecosystems on March 22, 2021 by Wouter Kok.

Ownership of data and data privacy have become an extremely important issue, nowadays. Users are becoming aware of the need to control their personal data, and not letting it be manipulated and used by anyone on the Web. A new initiative, in this respect is Solid.

Solid (derived from "Social Linked Data") is a new Open Source Web technology that enables users to be in control of their own identity data, independently from for example, the big social media platforms. Users do this by creating their own decentralized data store, also called a "Pod", and keeping track of how their personal data is being used, and by whom.

The purpose and rationale of the Solid project [2] is to put the full control of personal data into the hands of the user. Currently user data is explored by platforms and social media providers to generate profit, in return for "free access" to social media and other services. This business model is referred to as Surveillance Capitalism [1]. When you are an active user of social media (as we are all nowadays) you know that your personal data is scattered all over the web, and you have limited or no control over who is using it, and for which purpose. A technological solution to this serious problem is Solid.

The Solid project is an initiative by Sir Tim Berners-Lee — the inventor of the World Wide Web and of the Web of Data [3]. Again, Tim Berners-Lee reached out to the community of web users by requesting them to start building Solid-based applications. These applications allow users to log-in with their Solid Pod, and control which data will be used by that application. Of course the project is in a start-up phase and there is a need for more applications to test Solid and to gather new ideas.

Two Computer Science students, Wouter Kok and Theodora Serbănescu have taken the Solid challenge in relation to the W4RA program. Wouter and Teodora are doing their master research projects on the usefulness and adaptation of Solid to the benefit of people in low-resource environments. By doing this they want to gather experience how this could be done in very resource-constrained context. This will surely bring up new ideas and potential new applications. The Solid has core values: Interoperability, Self-determination, Equal access, Sourcing, Public Value, Connecting. This team, obviously adheres to these principles and values.

Tim Berners-Lee meets Mathieu Ouedraogo, president of Réseau MARP from Burkina Faso. The importance of Solid for low resource environments, as there are many in West Africa, should not be underestimated.

Yet, still too often, in technological innovation, the Global South is overlooked. It will be interesting to research and collaborate with local communities, for example in rural regions of West Africa, where we have good contacts, to find what challenges and barriers hamper the uptake of Solid in local digital services.

If you have any ideas for our project or want to share something with us, you can reach us below!

Wouter Kok: w.j.kok@student.vu.nl

Theodora Serbănescu: t.serbanescu@student.vu.nl

[1] Zuboff, S., Möllers, N., Wood, D. M., & Lyon, D. (2019). Surveillance Capitalism: An Interview with Shoshana Zuboff. Surveillance & Society, 17(1/2), 257-266.

[2] Mansour, E., Sambra, A. V., Hawke, S., Zereba, M., Capadisli, S., Ghanem, A., ... & Berners-Lee, T. (2016, April). A demonstration of the solid platform for social web applications. In Proceedings of the 25th International Conference Companion on World Wide Web (pp. 223-226).

[3] Berners-Lee, T., Chen, Y., Chilton, L., Connolly, D., Dhanaraj, R., Hollenbach, J., ... & Sheets, D. (2006, November). Tabulator: Exploring and analyzing linked data on the semantic web. In Proceedings of the 3rd international semantic web user interaction workshop (Vol. 2006, p. 159).

Solid for users in low-resource environments

Computer Science students Wouter Kok and Theodora Serbănescu, have taken the Solid challenge and are making an adaptation of Solid to serve people in low-resource environments, such as rural West Africa.

Figure 5.1: An article written for the W4RA web-blog (see: https://w4ra.org/2021/03/22/solid-for-low-resource-environments/)

10 DAYS LATER

wkokgit   13d

Hi everyone. I'm Wouter, a Master Computer Science student at the Free University of Amsterdam. I'm | Mar 10, 2021 3:34 pm |
following the track Software Engineering & Green IT and am in the second year.

For my master project I have contacted a researched at my university that is specialized in ICT for
Development. After some brainstorming we came with the idea to do research about Solid, as we we're
very interested in the capabilities of Solid and what it stands for. Also, we heard about the call from Tim
for a need of new deployments of applications and testing in diverse contexts. Therefore we came with
the idea to evaluate how Solid can be applied in low-resource environments (like in third-world
countries), with possible barriers and possible new ideas. Another student I'm brainstorming with is also
doing a master project around the topic.
We are thinking about the possibilities of creating a proof-of-concept, an application, possible tests in
the field and more, but currently we are mostly in a design/planning/experimental phase.

For this reason I wanted to say hi. This forum seems like a great welcoming place to ask questions and
I might ask some in the future!
If you have any ideas in mind or suggestions about my master project, don't hesitate to let me know!
Thanks for reading and I look forward to talking to everyone.

4 ♥   𝒮   •••   ↩ Reply

Figure 5.2: Solid Project Forum introduction post

Figure 5.3: Presentation given at the ICT4D in the Field course at the Vrije Universiteit Amsterdam

SOLID

- Sir Tim Berners-Lee
- Return control to the user
- Secure data storage on so called Pods

POD
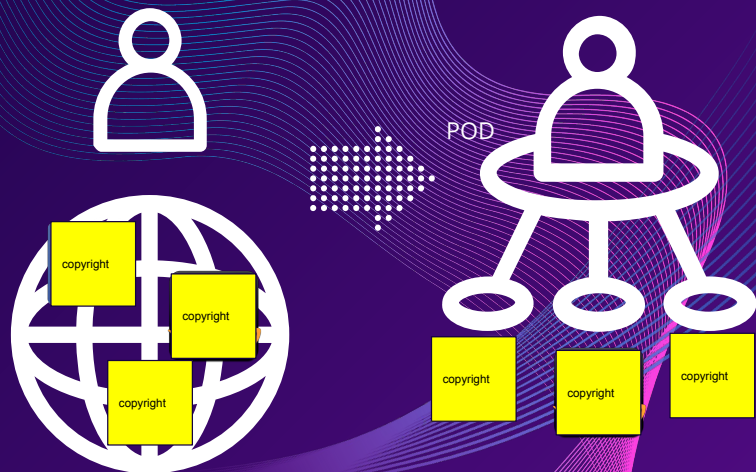
The goal of this research

To see what the possibilities of Solid are in low-resource
environments

- experimenting
- interviewing
- surveying

Wouter: Use case 1 - Monitoring Animal Health and Status
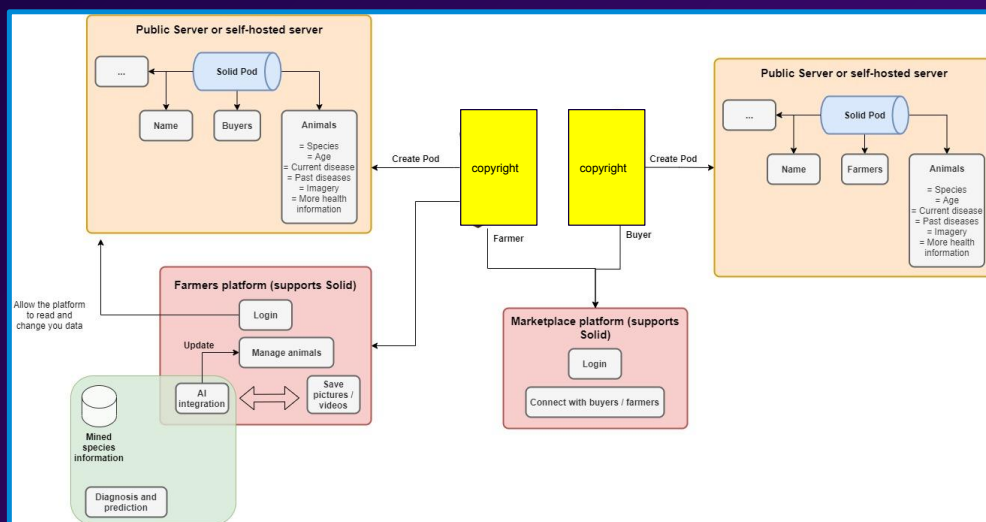
Teodora: Use case 2 - Telecenter Kampung Kuah AI Tutor

CONNECT WITH US

Do you have any questions or input?

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Solid in low-resource environments. (master projects)

wkokgit 22h

Hi forum!

I recently joined and wanted to share some things me and a fellow student are working on.
Me and @teodora are both Computer Science Master students at the Vrije Universiteit Amsterdam.
I am following the track Software Engineering & Green IT and Teodora is following the track Parallel computing.

For our master project, we were brainstorming together with our supervisor for potential research topics. Then we came up with the idea to do 2 master projects on Solid, as there was a call for more ideas and use cases and we are very interested in the project. Specifically, (since our supervisor is specialized in the research area of ICT for Development) we want to do research on the possibilities of Solid in low-resource environments like in Third-world countries.
The protocol documentation of Solid also states that the Ethical Web Principles are used for orientation, which we will try to support even further. The Global South is often forgotten and doesn't have most resources and support to make use of new ideas created in first world countries and therefore the gap in between seems to increase by that.

The goal of this research is to include the Global South by researching how Solid can be taken advantage of there. This is done by coming up with new ideas and possibilities, possible barriers, designing a proof-of-concept, creating of a Solid app and deployment in a real world environment. In African countries like Nigeria and Burkina Faso, most people use mobile phones so adapting to these technologies will become a challenge.

One example project our supervisor is working on, is a project in Mali to connect farmers to potential buyers of their seeds. These countries are less up-to-date about data laws etc, and this data can be misused by others because it is personal data. Using Solid might provide a solution to this problem. But this is just one example to give some more food for thought.

It would be nice to start a general thread here with possible ideas, feedback or thoughts about this project. All comments, both negative and positive, are welcome!
Thanks for reading.

3 ♥   🔗   ✏   ⋯   ↩ Reply

created	last reply	2	30	2	5		
22h	19h	replies	views	users	likes		⌄

Mar 15

1 / 3
Mar 16

19h ago

Vincent 22h

Very cool! I'm not sure what's appropriate and feasible for a Master project in your tracks, but one thing that comes to mind for me is that the Solid protocol is quite chatty, i.e. makes many HTTP requests. I'm not too attuned with the Global South, unfortunately, but I've heard that they're mostly reliant on mobile data there, which makes this less than ideal.

So some things that might be worth looking into, depending on your interests and expertise, might be how to model data so as to minimise the number of requests, or maybe to minimise the payload of each request, or even just to determine which of those is more appropriate. Other approaches might look at how an offline-first approach would work in Solid and what challenges would arise there.

Anyway, just some thoughts that, even if they're not entirely what you're looking for, might at least inspire some other ideas 🙂

1 ❤   🔗   ⋯   ↩ Reply

wkokgit 19h

Thanks for the answer Vincent!

We have seen the amount of HTTP requests which we agree on is quite high, but maybe not of interest to us. An offline-first approach is also something we've been talking about because internet connections aren't always steady in some places. Even electricity isn't sometimes steady, so analyzing how power outages can be handled best could be interesting as well.

Some other ideas we've been thinking about:

- some sort of raspberry pi infrastructure for setting up the server
- the possibilities of managing your data through text messages
- a buyer / seller platform to help farmers and others sell their product easily by connecting them with buyers
- increasing usability because for technical illiterate people it might be hard to understand

1 ♥   🔗   ✏   ⋯   ↩ Reply

51

Figure 5.4: Solid Project Forum post about the thesis project

wkokgit   7d

Thanks for the answer Vincent!

We have seen the amount of HTTP requests which we agree on is quite high, but maybe not of interest to us. An offline-first approach is also something we've been talking about because internet connections aren't always steady in some places. Even electricity isn't sometimes steady, so analyzing how power outages can be handled best could be interesting as well.

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- the possibilities of managing your data through text messages
- a buyer / seller platform to help farmers and others sell their product easily by connecting them with buyers
- increasing usability because for technical illiterate people it might be hard to understand

2 ❤   🔗   •••   ↩ Reply

teodora   3d

Hi everyone! My name is Teodora, I am working with **@wkokgit** on this project.

Hi **@Vincent** , thank you for sharing your thoughts on this and for pointing that out! I think in our case it's important to keep an eye on it and see if we can improve it. I might come back to you with some questions on this, if you think you could help. Do you have any pointers to give right now?

1 Reply ⌄   3 ❤   🔗   •••   ↩ Reply

jeffz   3d

Great project! In addition to the kind of technical questions that **@Vincent** mentions, there are, of course, a number of cultural and social questions when people from one social context prepare tools for people from another social context. My off-the-top-of-my-head thoughts below may or may not apply to your particular projects, but I think need consideration in the long run.

In the best case, software projects will be designed, developed, and implemented by or in collaboration with people from the communities where the software will be deployed. A person from the community brings knowledge of the needs software can fulfill and of the best practices for ensuring the software is understandable by and likely to be adopted by the community.

In terms of Solid, this means that the aim is to spread Solid, not by giving it to recipients, but by co-creating it with partners.

One aspect of that is finding out how the strengths of Solid translate into something relevant to the local community. What do privacy, decentralization, control over data mean in local community terms? What community values does Solid provide?

Another aspect : the ontologies and terms should be derived from the local community. This is both a question of language and of categorization. A local community member might have very different ideas of what the basic entities and relationships are than a software developer in a distant land or from a different cultural context in the same land. So making an ontology locally relevant is more than adding some language qualifiers to properties and a translation of labels.

5 ❤   🔗   •••   ↩ Reply

Vincent   ↪ T teodora   2d

Happy to answer questions if I can (and since you're at the VU, if you'd prefer Dutch that works for me too), though I suggested them part because I don't know that there are answers yet 🙂 Not sure what other pointers to give without specific questions though, sorry.

1 ❤   🔗   •••   ↩ Reply

Introduction

Meeting attendees: Victor de Boer, Anna Bon, Wouter Kok, Teodora Serbănescu

0:11 Victor introduces himself. He does research into linked data domain technologies, using semantic web technologies and knowledge representation principles in various domains. Mostly in cultural heritage and digital humanities domains. (Some Solid work there).
He is also busy in the ICT4D domain like Anna Bon. Analyzing how linked-data and semantic web work in low-resource environments.

Different projects

1:29 Victor: Another student did a project where he used Sparql queries using Raspberry pies, but using sms to send the queries. He send the paper, it is this one:
http://www.victordeboer.com/wp-content/uploads/2016/04/valkering2016ekaw.pdf
http://www.victordeboer.com/msc-project-low-bandwith-semantic-web/

4:25 Victor: Also a project around voice services, which is this one:
http://few.vu.nl/~vbr240/publications/swj2013_deboer_dialogue.pdf

5:15 Victor talking about a project he did with Christophe Guéret to downscale linked-data solutions. That is taking the semantic web and lowering the hardware on which it is deployed, which is alike what we are doing. He made a system in which people could exchange information using the semantic web protocols. Here is the project:

https://worldwidesemanticweb.wordpress.com/projects/semanticxo/
(see also this video https://vimeo.com/36500596)

7:36 Anna explains about an earlier idea of Raspberry pies and asks for ideas for a proof-of-concept.

8:20 Victor talks about a local use case for a school where you would have a downloaded version of Wikipedia and update that using local information exchange (could also be local farmers). And every month a car driving by could update it. Which is the Wifi Donkey idea which Victor send by mail.

More specific ideas for Solid

10:24 Anna asks about a more specific use case where Solid could be better utilized.

10:37 Victor talks about utilizing the Semantic web technologies so that all your data can be stored in one knowledge graph. One idea is to have a local marketplace where people can link to with their pod and for example the radio could advertise that. Then you could pick which information you want to share and which not. So, you could share your products but not the price.

14:00 Victor talks about research questions:

- How can we make this work in a low-resource environment?
- What kind of connectivity is needed?
- Alternative forms of communication?
- Including mobile phones in some way. (how about an app that lets you store a pod on your phone?)

Evaluate using realistic case studies

15:00 Victor talks about doing a study on resource information of Solid, power, electricity, web connectivity, towards ICT4D use cases. After he goes through the Semantic Web in a SMS paper.

23:20 Teodora asks about benchmarks and devices people use because Anna and Victor have more knowledge on that. Specifically, what type of device they use is helpful and bandwidth etc.

24:20 Victor: People generally use mobile phones. So, you could see how you could do semantic sharing using mobile phones. (now that I think of it, I did not see a lot about testing solid on mobile phones). You could assume that they have basic smartphones. There are specific smartphones that are made for the African market. The average farmer does not have a computer laying around. There are more and more people with smartphones.

Conference in September

28:00 Victor talks about a semantics conference in September in Amsterdam with industry and scientists (around 50-50). One of the workshops includes Solid. Would be interesting to present our work there: https://2021-eu.semantics.cc/

https://docs.google.com/document/d/e/2PACX-1vRP-H7pmfzX8ovwKNppcTtP5VaSF3M1GWbxXUYG1ueo6chHAZuAY82iQpyqqrH_CyRQdlQdA4CZbmXS/pub

Figure 5.5: Notes of a meeting with Victor de Boer on 4-7-2021

Next meeting

32:30 Victor wants to meet up again at the start of May because he is so interested in the project.

Other questions

33:40 Wouter asks about the goal of Solid to strive against the misuse of data and if there is a lot of personal data in Africa or not.

33:52 Victor: In one way, Africa is just like the rest of the world. There are people that use social media like Facebook. So they have some of the same challenges we have. A specific one is the CARPA project: http://www.victordeboer.com/wp-content/uploads/2021/04/digdivhumpaper.pdf

This project makes it possible to report on malpractices for example in the mining industry, so if the working circumstances are bad, you can report this in an application. (in a way sharing information, with some personal information, need to be careful with privacy information)

Here we are dealing with low-governance situations, so you cannot really trust the government. In the Netherlands, the base trust is quite high (trusting the government), but in these countries it is low like in Congo. If you have technologies like Solid or Blockchain, *you offload some of the trust to technologies*. (very interesting)

A question being asked in the ICT4D course is "Why is it different in Africa." And one of the reasons is that the technological infrastructure is different, but another one might be the governments and trusting the government is different. So the term here is low-governance situations which is typical in developing countries.

42:35 Wouter asks a question about how the ontologies could differ in low-resource environments.

43:00 Victor: That would be interesting and I'm looking for a PhD position in that direction. The current questions are: How do we develop knowledge representations or ontologies that are culturally aware. Gives an example of how there was a misunderstanding with classification between a project in The Netherlands and Suriname.

Interviewers: Wouter Kok, Teodora Serbănescu

Interviewee: Francis Saa-Dittoh

Taken place at: 05/12/2021.

INTRO
-Permission for recording Yes
-Permission for name in thesis Yes

QUESTIONS

Do you have ideas of how to use Solid, or implement it in low resource environments?

There are sort of two levels in low resource environments. These levels are places, like urban cities in Africa, where there is some internet access, but not always reliable and stable. There is access to smartphones and other devices, but it is not that reliable and not always available. There is also a second level, where there is almost no access to internet, and no access to constant electricity. There is access to GSM phones and the GSM network.

So, it depends which level we are looking at.

We are aiming toward the urban city level.

At that level it is easier to implement stuff, but on the raw level it is more challenging, because you must figure out things that do not use internet. It is more difficult but more interesting.

Solid sounds a bit advanced so it might be difficult to implement it without internet, but it is up to you.

Right now, we are looking at having a local server. I do not know without any internet if it would be possible or helpful.

What do you think would be the benefits of using Solid in low resource environments?

For one thing, Africa is probably using more social media then any part of the world. Especially stuff like Facebook is used a lot. And so, the recent issues of privacy on Facebook and Whatsapp. People are getting more concerned with sharing their private information. And so, solutions that can help people here to be able to implement something where they have complete control of their information will actually be very attractive to people.

But the problem is the constant internet connection. So if my information is at a server in the Netherlands it would be very difficult. So a solution that could have the information on multiple servers, or replicated over multiple servers, and available in a kind of offline approach, might be interested to people in places like Ghana.

So multiple servers in an area that provide the same data you mean?

Yea but especially a means to access this information without having access to the WWW per se. That could be interesting. Or rather not having access constantly. We can think of a local solution that updates when it has a link to the internet, but still can be accessed online.

The other angle is that I think mobile usage in Ghana is way above desktop usage, especially in accessing social media. So it would probably be more of use as a mobile solution, compared to a web-based solution or a desktop solution.

Additionally, there are far more Android users than the other OS users.

Another angle we look at in our research is Speech technologies, because about half of the country is illiterate. And because of that Speech technologies is a bit important to deliver information in local languages then in text. So that would also be helpful. But it is difficult because most languages here are not resourced online. So you have to come up with more innovative ways to do this.

And most of Solid is in English

Yea so that would be the very first problem, so we already cut the population in about a half. That is another angle to look at.

We are also trying to find a proof-of-concept application that could be useful.

Maybe for example the governmental stuff, like car license and passports, all that requires personal information, I think they could also benefit from Solid. So, for example the reason why I go off and on is that I am at a vehicle licenser office, to update my driver license. And I have been here for hours simply because there is no information about me here, they must take all my details again. I think this could be a implementation for something like solid in that I have private access to my information. These companies take a long time because all the information is segmented, and every department has their own database. Something like that, also applying to school can also be interesting.

Do you know right now how this information is stored?

Figure 5.6: Notes of a meeting with Francis Dittoh on 5-12-2021

Yea at the moment, they have various agencies that handle these separately, and each agency has a separate database, like passport, vehicle license, schools. There are no api's that give access to this information anywhere to where it is centralized. There are also privacy issues with having a central storage, but with Solid this information belongs to the user and not to the government. And the user can verify that the governmental agency can access this data.

Also, most people don't trust the government that much, which is also a reason that Solid could be more helpful.

One more I can think about is that in most African countries, especially like Ghana, there are a lot of innovative apps created by local developers. We've realized a lot of software that do not really use the African market, so a lot of startups look at only the African market. These startups can probably also benefit from access to APIs that give them access to individual information, if the individual uses the app and approves to give the information. And so we can skip the process of creating databases hosted by big tech. If the users know they own the data, and the app requests the data, it will help the local app developers, especially when it is meant for Africans and not focused for everyone else.

One of the biggest problems we have here as startup entrepreneurs, is that we are in competition with big tech, although we are in third world countries, and it is difficult but this could possibly help, so that the data is stored here.

How do you get people to use Solid, it sounds like for you the main reason is privacy, is that right?

Yes, people are beginning to realize that their information really is not really that safe. Everyone receives ads and people realize that they are very targeted. Like ads popping up about things we are talking about. So, people become aware of their privacy and are ready to jump to solutions for their privacy safety. For example, when Whatsapp showed their privacy policy update and people needed to accept, there was a massive increase in the use of Telegram in Ghana. Now people are in between using Telegram and Whatsapp because of this privacy policy. So, I think people are already looking for solutions to have privacy and get rid of too many ads. That is an angle when people get to know Solid, they would be eager to use it.

We have a lot of tech hubs and programming groups, and most of these people are professionals and IT, and whatever trend they take, they have a lot of people that will follow. One of the things we learned from our research is that people especially in Africa are more inclined to use solutions they were apart of or they know their own people were apart of. So being involved in these groups will help adoption.

Solid is also created in the west, but at least with a good purpose I think.

The problem has more to do with technologies created by the big tech. There is a lot of use of open-source software here, so people do not mind software created by other companies or communities. They are only a bit skeptical by things created by the big tech. So, I think Solid would not be a problem for people to use.

Do you know any local developers involved in Solid or something privacy related?

Yea, I belong to a few groups. The two places I can think of… there is an internet society that deal with all things about internet, they would have knowledge about Solid and would be interested. There is also an IoT network that would probably be of interest. I can speak with the leaders of these two groups and see their response. Personally, I find it interesting so I would be glad to be apart.

Showing users' data as a Client application: A marketplace platform issue

wkokgit   2d

Introduction and idea
If you look at a sellers platform like Ebay, users can login and add products to sell. All user data is stored at Ebay. But I'm brainstorming about a simple marketplace platform on solid where users can show products they have and come into contact with buyers. This might for example be useful for low-resource environments where local farmers would like to sell their products and come in contact with buyers. And of course the other way around.

Storing data as a client
Most Solid Client platforms I've checked can edit your data on your pod, but what if you have a client that shares data from users. In the aforementioned case a user could add for example that they are selling bananas, not even a price or amount, to their pod. The client application then should be able to show the products of the users that have logged-in (in a list), and buyers should be able to see that list. Is it viable to save the users that have logged-in to gather this data? It won't be really efficient I think.

The main problem
How could the client application show information of different users? As far as I know Solid clients don't save any data related to users, not even who logged in once and therefore you can't gather your user data. Is there a way to do this in a privacy-respecting, efficient way? *If you would like to recreate Twitter, or Medium, most data is open and collecting this data out of all user pods might take super long too.*

Possible solutions

- saving pod uris or user data at the client side
- creating an account at the Client side with your Solid pod

Privacy issues
There are of course some issues with sharing this data to everyone in the world, therefore a solution is that the seller could be anonymized and and the buyer could first try to send a message to the seller to form a connection. In addition, saving the data of users at the client-side is also not really what we want.

Hope anyone can help or has a solution, which I might have overlooked :).

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⊘ Share   ▪ Bookmark   📁 Flag   ↩ Reply

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INTL   4/10/2021

Figure 5.7: Solid forum question about a marketplace application. Source: https://forum.solidproject.org/t/showing-users-data-as-a-client-application-a-marketplace-platform-issue/4206
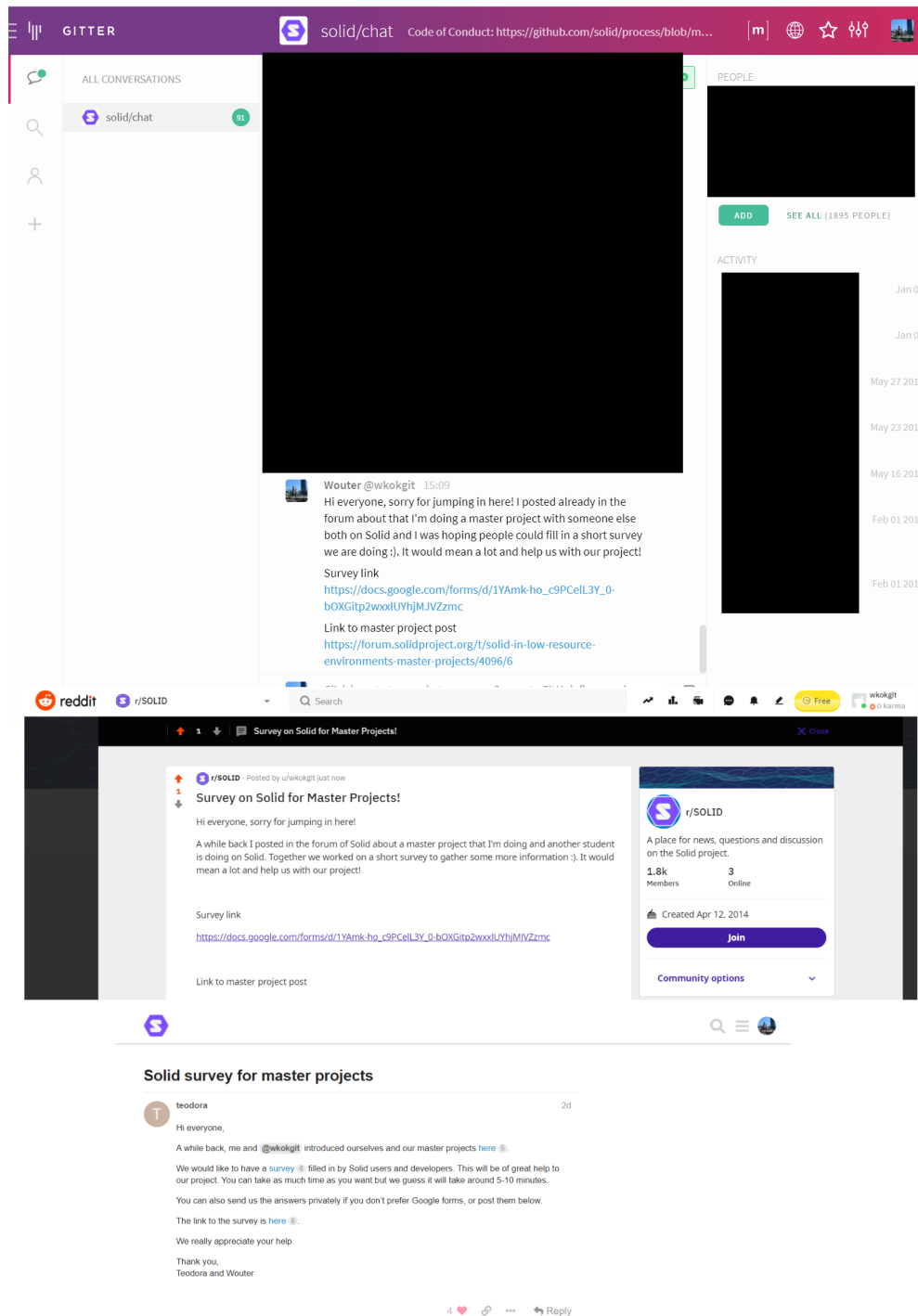
Figure 5.8: The survey is shared on Gitter, Reddit and the Solid Project Forum

Interviewers: Wouter Kok, Teodora Serbănescu

Interviewee: Vincent Tunru

Taken place at: 06/08/2021.

INTRO
-Permission for recording Yes
-Permission for name in thesis Yes

Everything Vincent says is personal and is not on behalf of Inrupt

QUESTIONS

First I would like to ask some basic questions

Could you tell us a little bit about what kind of work you do?
Working at Inrupt. Works on the developer tools, so if people want to work on a Solid application, they can use those libraries. I'm not too familiar with the Solid specifications. More on the concerns as an app developer, what do you need to do and what problems you run into.

Are you doing that full time?
Yes, 4 days a week.

Is there any overlap between work activities and activities in the Solid community?
Yes

Have you gotten paid for your work on Solid?
Yes

What attracted you towards helping in the Solid community?
Partly because it is my job. The job attracted me as well. Cares about giving people control of data more, but also the big picture effects, influence on democracy, wanting to put more power in the hands of individuals and that starts with data.

Did you know Solid from this work position, or did you already know it?
Did come across it earlier but did not know if I could add onto it with my skills. Friend of my joined Inrupt so then I applied as well.

Now I want to talk a bit about your survey answers.

In the survey you said that you have known Solid for 2-3 years, have you seen much progress over these years, regarding new users and the platform itself?
Yes and no, you always hope for more, but it has come a long way. Back when I started it was very experimental and there are still quite a few rough edges, like the interface of inrupt and solid community. But there have been some big contributors, like Noel de Martin who created Media Kraken. It is great to see the use-able and useful stuff that is coming out of the community.

You've given the easiness of developing a Solid application a 3 from 1-5, could you please expand upon that answer?
I am taking as bassline regular application development. Adding Solid to that is doable. There are some things that are not great, but they work. For example, if you have a connect to Solid button, and you login and refresh, you either sign out or get redirected to somewhere else. Also, how do I model my data. How do I change my data model? How do I optimize the amount of data I'm sending, the performance of my application basically.. To become a 5 those should have clear answers, but they are not close.

Do you know if people are working on improving these things, or do you think there is a need for more developers?
Mostly, there is Inrupt who have resources to invest time in it. But the priorities are not directly aimed at them, because there are other things that are really needed, so they have priority over things that work somewhat already. For example, when they need a government contract, which takes a lot of time with all the regulations. There could definitely be more people with expertise working on them, but one challenge is that you have to build consensus and have to convince people and that is a bottleneck, because there are only so many things people can be convinced over.
Not sure what the solution is, there could be more people to help, but there is also a need to have some to prioritize or align the priorities with the thing I needed as a developer.

We've seen from the survey and experimenting ourselves that it isn't easy developing for Solid, do you have ideas on how to attract more developers towards using Solid?
Part of it is building an audience. Building android and iphone applications is already more difficult, but there is a big audience there. When the ecosystem grows, for example Inrupt working with Flanders, if you build a Solid app, all these Flemish people no longer need their own accounts, you don't need to store data for them, you can do it on their pods.

Do you have any idea of how to increase the popularity of using Solid?

Figure 5.9: Notes of an interview with Vincent Tunru on 6-8-2021

One thing is focusing a bit more on building things that feel complete, for example the interface has a lot of stuff added and makes it buggy and not attractive to use. Also, for developers, if you have to work in an ecosystem like that it is not great.
What Inrupt is doing is getting a lot of people a Pod, which also attracts more developers to use the system. If you have to get people to use your app and get them to use Solid, that is a bigger challenge, then already having a pod.

In the survey you said that there are many communications with the server and that you were unsure about the reliability of connections in developing nations. We've talked with someone from a developing country and he agreed that connections are often unstable and in some places there is no internet connection at all. There are also other problems like no energy, data centers, language differences, and technical illiteracy. Have you guys thought about these type of problems as well, or are you more focused on developed countries?
For myself it is more of a, kind of aware of it and I have some experience with making apps offline-first. But that is more because it is useful everywhere. Main focus is stimulating Solid adoption in general. There are still a lot of challenges that apply to anyone, so we first try to focus on those. And hopefully there are none of them so we can focus on other challenges that come in low-resource environments.

Lastly I would like to ask some other questions relating to Solid
Do you know of some successful business cases that have been developed using Solid?
Depends on what we mean by successful. Flanders is the prime example of a successful application: the flemish government adopts it so I presume there will be a lot of people there using it and they are building things to work with Solid.
Quite a few companies have been funded and have started working on Solid products. Another good example is the NHS in the UK.

Do you have an idea of how to explain the usefulness of Solid to people in low-resource low-technical environments?
I don't think I would dare to say something about that. It's hard for me to put myself in their shoes. I'd have to talk to a lot of people in their situation first.

Sometimes you have things that you don't think you want but you actually want. Take for example Steve Jobs who created the smartphone. Nobody knew they wanted one before it existed.
To figure out what people want you need to observe what they are doing and what they are struggling with. Sometimes people don't know what they want because they get used to the pain points and they don't notice them anymore. If someone else from the outside looks at them, they may point out some improvements that can be made.

Do you have any other research ideas to improve Solid?
Research in general has never been my strong suit so I don't have any particular idea.

After discussing with other researchers and locals, we ruled out the main issue: an unstable connection. We are currently working on running a local server using a Raspberry Pi. Do you have any advice on that?
Look at the community server rather than the Node Solid Server. That's probably more stable, even though it's still experimental. Noel de Martin is experimenting with the offline first approach which might be useful in your situation.

You once pointed out how chatty Solid is, a large number of requests and responses can surely be affected by an unstable connection. Can you tell us how you observed this in your work and how does this affect you?
I work in the front-end. When writing a Solid app, I have to write data in three different places. First, I have to find out where to save it, then I have to read the file where I will save it, then I need to create my own file which I will link back from the other file and then to store more data there. So I have to write all those connections. Even with a good connection it can take a while.

Do you have an idea of how to improve this?
It's more of a philosophical discussion. On one side, you can have the server do more. Send a single request which deals with all the work. On the other side, there are people who think the server should be easy to implement, which means the client has to send many requests. Or you could have another server that is in front and does all those requests for you, but this is also not ideal. I can primarily see the problem, not so much solve it.

For our use case with the Solid application with a marketplace, if you log in to the marketplace you would like to see what products are there and who sells them. How can you have a list of data from different pods?

This is one of the many challenges that don't have a good answer yet. It's not that once having a Solid pod there should be no central service anymore. For example, the web was initially decentralized, then Google created an index with all the links to the other places. You could keep an index with all these products in a marketplace website.
But you could also look for more federated solutions. If your data is in the pod and you have your own listing there, then people can create a competing marketplace with the same data in there because it's in the pod. But you have to discover the pods first. Again, there is no good solution for this yet.

Even then, if you have 10000 products but when you load the page you have to grab those products from different pods, then the complexity increases.
Yes, you'd probably have a server that just caches all that, just like Google doesn't in real time visit all those websites.

Interviewers: Wouter Kok, Teodora Serbănescu

Interviewee: Noel de Martin

Taken place at: 06/14/2021.

INTRO
-Permission for recording Yes
-Permission for name in thesis Yes

QUESTIONS

First, I would like to ask some basic questions

Could you tell us a little bit about what kind of work you do?
Software developer (working on websites and apps) started working on Solid 2 years ago, but only on side-projects. My main job has nothing to do with Solid. One day each week I spend on Solid. Basically, my interest in Solid is doing applications, so not really the server-side. I've created 2 applications. In both I was interested in making it usable for people who are not familiar with Solid. I think one of the more difficult things for someone to get started, is to actually have a Pod. You need a pod but don't know how to create one, that can be an issue. So in my first application I always had an option to store data offline, so you could use Solid, or local storage.
The thing is, lately, I thought this was also a bit annoying for users. If you start doing it offline, then you have to log out and create an account and import your data. For this new application I'm doing now, I'm exploring a real offline first approach. Users don't have to choose if they want to use it offline, they can use it, and if they get internet connection, everything syncs with the server. This is what I'm working on now, it is not finished.
So after this I know the basics of Solid applications.

What attracted you towards helping in the Solid community?
Before I knew about Solid, I already had an idea that was similar. The idea was to use Dropbox or Google cloud, one of these things that already exists, and the idea was to make apps that allow you to choose where to store the data. When I found out about Solid, I saw that it was really close to the thing I was trying to do.
And I liked that it was backed by the W3C organization, so it was going to be a standard. It is solving something that is a real issue.

Where are you currently working and do you get paid for developing for Solid?
I do not get paid for developing for Solid. I work currently at Moodle for 4 days.

Now I want to talk a bit about your survey answers

In the survey you said that you have known Solid for 2 years, have you seen much progress over these years, regarding new users and the platform itself?
I have some doubts. In the last six months I've seen more people using it, but in the first year it was like nobody. We still need new users, because most are developers or privacy advocates.

I like the projects of Inrupt they are doing with governments. Also something challenging, the applications I've made, I don't know how many people are using them. With the nature of Solid, the data goes to the user's server. I could use tracking, but because it is a side-project and I don't like tracking, I really don't know how many people are using it.

Do you know if any of the people use tracking?
I don't think they are doing it, but also I do not know many Solid apps with many users. If you want more data for your research, you could ask people at inrupt if many people are using it. I also don't know how long it takes for technologies to get adopted.

Maybe you could also look at how many people attend Solid World. Normally it is around 100-200 people I think.

You've given the easiness of developing a Solid application a 2 from 1-5, could you please expand upon that answer?
Something I'm doing in my side projects is that I make my own libraries for almost everything. That's because my background is from an app developer. I used to work with laravel and vue, which are frameworks with a lot of developers that use them and are being improved a lot. But with Solid, there aren't many developers working on it, and the ones that do, they are more focused on features then developer experience.

Figure 5.10: Notes of an interview with Noel de Martin on 6-14-2021

If I was working on Solid, then I would do what I'm doing now, as a side-project. If I would do it more seriously, I would probably some of the libraries that already exist, but I think they are very rough right now.

Another issue in this aspect is that I think there isn't a core team working on Solid itself. There is inrupt, and they work on their inrupt libraries. These are evolving, but the Solid community team, for example the node-solid-server, which was the first server that supported the solid protocol, most of the people working there are volunteers. So they sort of do whatever they feel like is best. I think that is kind of an issue, because things don't evolve as well as they would.

If you use the node-solid-server, you know the user experience can be improved a lot. Everything is really old fashioned and not intuitive for most users. I think it is similar for users. The user experience in the browsers and in the tools is not too good, and I think the developer experience is the same.

I like about Solid is that it is a protocol and allows me to do my own libraries. Even if I am slow, I can continue improving because it is an open system.

I was wondering if there are also volunteers at Moodle that do a lot of work there and if that modifies the easiness of developing the application.

Moodle has a similar issue in this sense. The user experience can also improved a lot. It has too many features and it is not intuitive. If people are using Google classroom, they like it more because it only has 2 features and they like it a lot.

In this sense with Solid it is similar. The difference is that Moodle already has 20 years and a lot of universities are using it. So it has a lot of real users already. People who contributed to the Moodle code have been working on it for a long time. I think that is the difference. I'm not sure if there are Solid users that use Solid for real.

The kind of projects I like, like Laravel and Vue (open-source frameworks), I think they work really well, because they have 1 person who is in charge of writing how things evolve, and these frameworks are opinionated. BDFL, is someone who dictates the technical direction of a project. I think in practice, having this figure is really good. If there is one person who decides what is the path to take, everyone would go in the same direction. I think one issue in Solid is that we don't really have one person. Technically you could say that it is Tim Berners Lee. But in reality he doesn't dictate what people should do. He is doing what he wants and he is open to speak with people, but he is not organizing what must be done. I think maybe that is one of the things that would be beneficial for Solid, but this is also dangerous, of course. With great power comes great responsibility.

Vincent also told us that one challenge of Solid was that the decision making process takes a lot because there are so many different layers that you have to talk about and this makes everything a lot more time consuming.

I think I have read somewhere that right now it is mainly looking for developers to contribute and not for users.
It depends who you ask. The apps I do are for real users, not for developers. It is true that I am slow at developing them. I guess everyone in the Solid system has different roles.

As a user, if I had to come into the Solid ecosystem I would be kind of lost. Other than my applications I don't know many applications for users. Liquid Chat is an example, a chat application made for Solid. Maybe also the one Vincent created, called Penny, but this is also more for the developers. So there is certainly a lack of applications for users right now.

We've seen from the survey and experimenting ourselves that it isn't easy developing for Solid, do you have ideas on *how to attract more developers towards using Solid*?
Keep in mind that this is the opinion of someone working on Solid as a side project. I would focus more on the Developer experience. For example, the tools I generally use as a developer that I enjoy a lot have great documentation. There is a term called DDD, Documentation Driven Development, developers spending a lot of time on documentation. I feel like this does not happen with the Solid apps that I use. There is a specification, but you cannot call it documentation because it is not as clear. And it is also not 100% stable. To bring more developers, you would first need to improve the developer experience with a tool stack that is easy to use. And secondly, you also need success stories, because many developers start working on something after they see something working. If you show them a React application and they like it, they will be interested in the technology.

Something that could also be improved in Solid is that there are a lot of advantages and possibilities in Solid that are not being taken advantage of. What you said in the beginning, when users go into the app and they can chose how to store their data, that's the most simple thing in Solid. There are a lot of things that you could do. For example, you could be using two applications and they can use the same data. Let's say you have a task manager and you want to have a second one. Then you can use both at the same time and they will work properly. You don't even have to migrate data. You can even have an application that is taking data from multiple pods. So there are a lot of possibilities in Solid but they are not being used yet. And I think that you could do some applications that are only possible with Solid, but since they don't exist yet, people are not aware of this. They see Solid only as a privacy respecting thing, but this is not all. It can also enable a very good (developer) experience.

There was also a Hello World application which I tried to use but I encountered some problems with it, so I thought about why isn't there a great application where everything is neatly explained, so I was trying to work on that. Do you think this might also help to bring more developers?
Yes, absolutely. There is a list with Solid apps, which you may have seen. And half of those apps don't work. I think the problem is not incompetence, it's not that someone doesn't want to do it or doesn't know. It's that nobody is responsible for that. If this was created

two years ago and was updated from time to time, there is no one who makes sure the page is working. The problem with the developer experience is that there is nobody dedicating their time to this. The people who do it are not dedicating all of their time on it, but only a fraction of it. I think if they would do this, it would help a lot.

We've talked with someone from a developing country and he agreed that connections are often unstable and in some places there is no internet connection at all. There are also other problems like no energy, data centers, language differences, and technical illiteracy. Have you guys thought about these type of problems as well, or are you more focused on developed countries?
The offline first approach that I am working on right now, I didn't think of it for developing countries. I just thought it would be a better solution for everyone. The thing is that these kinds of things might not be the case for everyone, because when someone is developing an application with Solid or when companies are adopting Solid it is for different reasons. For example, a reason for using Solid is that when you don't store data, you are not responsible. That depends a lot on the purpose that everyone has.
I already told you that Solid has a lot of possibilities. This means it's really flexible and you can also do "bad things". For example, the offline first thing I am doing is not directly related to Solid. You can do offline first with Solid, but you can also not do it. And the track thing with Solid, you can also track more than on Facebook, because the technology is really flexible.
To sum up and answer the question, personally, I am not doing that(focusing on developing countries). I am trying to build the best technology, but that is not my main focus.

Lastly I would like to ask some other questions relating to Solid
Do you know of some successful business cases that have been developed using Solid?
No, I don't. There are some companies(for example, Digita) that work on Solid mostly but I have not seen any products. One of the problems is that outside of the Solid ecosystem I don't see anyone talking about Solid. It takes time.

Do you have an idea of how to explain the usefulness of Solid to people in low-resource low-technical environments?
I think Solid is awesome, but these kinds of questions have nothing to do with technologies. It is a social discussion. If everyone would use Solid tomorrow, it would be awesome, but if it continues like this, I wouldn't recommend anyone to do it. I really think it has the potential because the technology is great, but it depends on how it is used.

Do you have any other research ideas to improve Solid?
From my side, only developer experience and success stories.

Interviewers: Wouter Kok, Teodora Serbănescu

Interviewee: Arne Hassel

Taken place at: 06/16/2021.

INTRO
-Permission for recording Yes
-Permission for name in thesis Yes

QUESTIONS

First I would like to ask some basic questions

Could you tell us a little bit about what kind of work you do?
I work at Inrupt as a Senior front-end engineer. So I use my knowledge as a specialist on JavaScript and sort of on Linked-data to create apps and to find solutions for problems that people have, usually in the form creating some app.
Right now I'm working at the Pod browser at Inrupt. My background is that I have a master in CS at the university of Oslo where I did focus on Javascript and Linked-data. My supervisor also works at Inrupt, so when he got asked to join, I was also asked and I enjoy working there.

What attracted you towards helping in the Solid community?
Ever since I kind of started to look at the Semantic web, I've seen a lot of possibilities and things that you could solve. I've always been interested in the Semantic web and combining that with my front-end specialty, so that was a very good chance. I had the project on the radar for 4 years, so it was a no brainer for me.

Can you remember when you started working at Inrupt?
August 2019

Now I want to talk a bit about your survey answers

In the two years working for Solid, have you seen much progress, regarding new users and the platform itself?
Depends how you look at it. There is a big change with Inrupt coming in at the stage with their commercial side of Solid and working with really big organizations to see how Solid can provide their needs. It is an important step in the development of Solid. Doing that we could work with more resources to pay people for the specifications for example.
In those terms I think the development of Solid has sped up in the soon to be 3 years. But working with specifications takes a long time. So for example some of the work with authorization and data reusability is still in the works, it kind of always been in the works, but it is really good to see the work the panel is doing on that.

You've given the easiness of developing a Solid application a 3 from 1-5, could you please expand upon that answer?
I think it has become much better with the production of the Inrupt Solid client, and of course the authentication packages. It is getting there, but in terms of introducing Solid to people that are mostly in the front-end world, it is still a big step to work with Solid. Mostly because it is working with graphs instead of tree structures, which I think for a lot of developers is a bit of a change and shift to handle data. That step is quite enriching for a lot of developers to get into. There are so many things you can do with graphs instead of tree structures and especially when you have linked data.
I still think we have a bit to go in terms of introducing these technologies and getting all tools and libraries to a state where it is a piece of cake to work with any Solid related app.

We've seen from the survey and experimenting ourselves that it isn't easy developing for Solid, do you have ideas on how to attract more developers towards using Solid?
That's a million-dollar question. I kind of have 2 theories, that derives from 1, that developers are quite lazy. So if you could make their work easier and faster and better than what they are currently doing. The challenge being there is that it is difficult to understand these graphs. But if we could serve those needs it could help with a lot of adoption.
Another way is that we are able to solve unique problems, it is not really unique but it solves having an online identity, authorization and storage. So I think the uniqueness is the combination of technologies that it brings, which I think a lot of developers will appreciate.
Another part is how well adapted this technology is. Hopefully we see this kind of network effect, where do get the killer apps that users find easy to use and onboards them to use Solid, and solves problems for them. Hopefully, this increases adoption and motivation for developers to learn it.

Do you have any idea of how to increase the popularity of using Solid?
It needs to solve a problem that end users have in a way that they give value, so that they appreciate it. For me, that application doesn't really need to say that it is a Solid app, but of course when users are onboarded, maybe as part of the onboarding process the service provider would tell the users that with this set-up you have the opportunity to use other apps with this kind of data and decide where you store the data. I hope these features would be important things for end-users to value. Right now I don't think that gives the people the most value. It is more accessibility, ease-of-use, to certain domains how easy it gets the job done.
The app needs to solve a problem to become popular.

Figure 5.11: Notes of an interview with Arne Hassel on 6-16-2021

One project that I worked a bit on as a volunteer was at a startup that looked at refugee camps. And they did not have a cloud solution to store something on the web, so Solid could be a possibility. In addition, they don't really have a digital identity, so this feature could also bring value to them.

For the question "What do you think the challenges will be implementing Solid over the world?" your answer was "Getting an ecosystem up that's stable and reliable enough for businesses and associations to develop services for", could you expand a bit more upon this answer?
It ties into what I usually refer to as the network effect. It is basically where you get the adoption of a system that you get enough people being invested in, creating solutions. For example solutions that they get paid for. Then we have to have end users that are willing to pay for those services. So I think it is essential for Solid to be able to create this ecosystem where you have end-users, developers, service providers and all of these kinds of people working together in a manner that brings food to the table for the various participants. Especially for service providers and developers. They need to build something that they get paid for. If Solid is going to be part of that, or rather if Solid is going to be a success I think part of that success is to be able to have that system. So that developers and service providers are moderated to get into because of the possible value creation that you get out of it.

We've talked with someone from a developing country and he agreed that connections are often unstable and in some places there is no internet connection at all. There are also other problems like no energy, data centers, language differences, and technical illiteracy. Have you guys thought about these type of problems as well, or are you more focused on developed countries?
The various tools we provide are directed at developers in general, not necessarily high-end or low-end terms of resources. But for example with the Pod Browser initially we are more directed towards high-end browsers and devices. Because to a certain degree we are carrying a lot of new functionalities and we want to get these features in place.
I'm very interested in what is going to chance in terms of the broadband connection when we get full adoption of HTTP2 and get some other alternatives and how we send packages. So I think right now we are mostly focused on high-end devices, but I think it is important to also focus on low-end devices.
Of course, another important thing is to have support for offline applications. A really good project there is by Noel de Martin. The idea is that you can use pods to store data or you can also use local storage, and in the latter case you can have it offline.
So there are discussions about this subject around the community but it is probably not as prioritized as it should be.
It is a very good principle, offline first. As with mobile first, having those limitations on the design and then enabling more features with progressive development. But of course, we have limited resources, budget and time. For Inrupt, our customers have mostly been enterprises in Western countries. And our main focus was on the customers.

We also tried a mobile first approach, but we encountered issues with Android. There were some problems with permissions when accessing the file system.
Reading is usually not a problem. It's when you want to write and get input from the user, that's when it gets complicated.

Lastly I would like to ask some other questions relating to Solid
Do you know of some successful business cases that have been developed using Solid? Last week we talked to Vincent and he mentioned the Flanders, with the Flemish government.
It depends on how you define success, of course. But yes, I would say that Flanders is a successful project. To some degree, I would also mention the French startup, Starting Blocks, that has this social app for designers and developers, basically entrepreneurs, where they can post projects, they can list and get jobs. Their scale might not be that big, but they are successful. Digita, the consultancy agency has had some success in their work, but I don't know the hands on experience, which projects they have developed successfully, but they are doing their work and contributing to the Solid community.

Do you have an idea of how to explain the usefulness of Solid to people in low-resource low-technical environments?
One thing is, obviously, that you don't have to store it on your device. So being able to store it on a Pod, in a server, somewhere else, means it won't have to take up space on your phone. Although, I don't think hardware space is a bg problem with low resource devices. I guess the problem is I don't know too much about what are low resource devices.

We can tell you what we've found out so far from our discussions with various teachers, professionals that conduct various researches there and people that live there. They are mostly relying on smartphones and usually not on computers. The problem is the internet connection.
In terms of the low bandwidth. A feature of Solid in that sense is that you are able to split the data quite easily. You don't have to download more than you need. You can decide the data model to have those features. Of course that introduces other challenges. The more you distribute data or decentralize data into multiple resources, the more resources you might have to download if you do want to use that data. It really depends on how you design the system. As I mentioned, being able to work offline and sync when you have a network connection is something that would be really valuable. It's not that highly prioritized by the community, but it is a very useful feature.
Most applications that we'll see are applications that do not require a lot of battery power. I don't know if we'll see many applications with a lot of GUI involved, like games, for example. Those are not necessarily implemented with Solid in mind. So the applications do not usually require a lot of power. But again, that depends on how they are implemented.
It is not prioritized right now but this is just a result of the current trends. In the future, it might be different.

We know that the people in developing countries are very data aware and they are noticing all the targeted ads so we thought they would really appreciate something like Solid which would be beneficial in that sense.
There is a big benefit from Solid, which is that you can easily take control of your data, which might be vital for people who live in countries with very strong governments or governments who try to limit exposure to certain information. Having something like Solid that doesn't require a real name policy and you can combine with other technologies, for example VPN. For those users it's a big

downside that we don't support encryption but there are people working on that so this will be solved in the future. One of the things that might be very important for users who live in low resource environments is being part of the discussion when we are discussing the ontologies and vocabularies to describe the data and domains that we want to describe. At least that I'm aware of, that is a very social thing and not necessarily constrained on technological or educational confidence, but being able to understand logics and logical relationships between
That being said, having people from all sides, so that when we talk about something we make sure how we communicate about those things are fair to all the users involved. I think that might be a challenge for those users from those communities in general, simply for historical reasons, they might not be the people with the most resources to influence that decision.

Do you have any other research ideas to improve Solid?
For your research, I suggest you take contact with the Health University of Oslo. They have many years of experience with low resource devices. I think they would be very useful to talk to.
I'm curious how the introduction of http2 might solve some problems or might even introduce some new challenges for low end devices, like whether there are more bytes sent over the network and if that works better with unstable connection or if it takes longer. I'm guessing that's not going to be your focus, but it's a thing that I'm curious about in general.

Figure 5.12: Survey answers and questions on the Solid community extracted at 7-5-2021

How did you learn about Solid?

14 responses

Through friends on the web

Some post on a blog, no sure

From one of my uni professors

Introduced to it through my employer

I guess it was LinkedIn

A friend told me about a media article.

Looking for distributed web annotation and found dokieli

It's been several years...I think I was into linked data first

Doing research for my graduation thesis.

https://medium.com/@timberners_lee/one-small-step-for-the-web-87f92217d085

From Tim

With Startin'blox cooperative

Recent articles (this year) about TBL

I think I saw an article about it on news.ycombinator.com at some point

How many years have you known Solid for?

14 responses
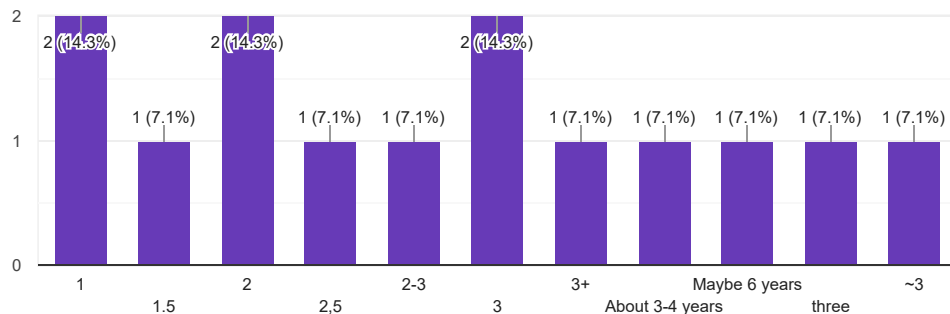
Have you experimented with/developed something using Solid?

14 responses

Yes — 12 (85.7%)
No — 2 (14.3%)
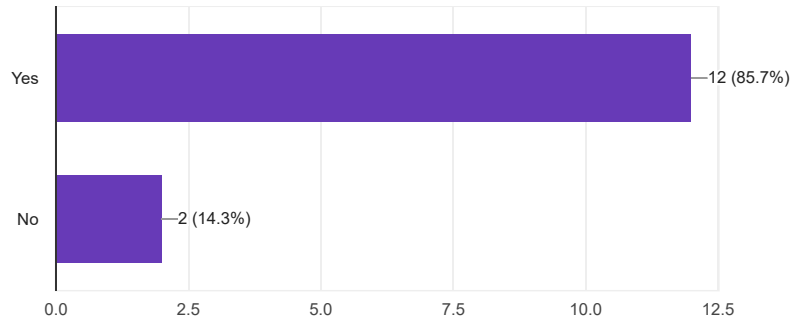
How would you rate the easiness of developing a Solid application?

13 responses

- 1: 2 (15.4%)
- 2: 5 (38.5%)
- 3: 6 (46.2%)
- 4: 0 (0%)
- 5: 0 (0%)
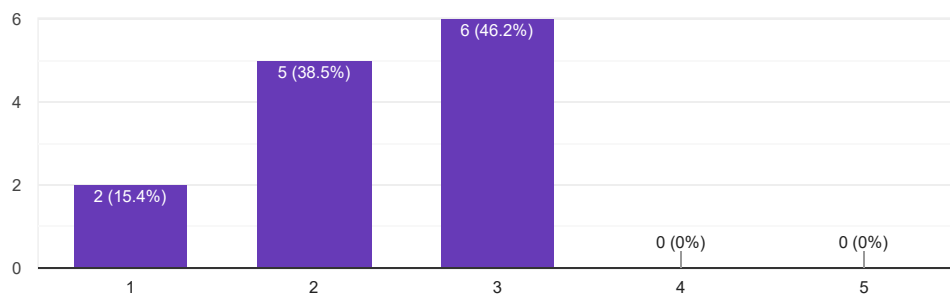
How would you rate the easiness of setting up a Solid server?

11 responses

- 1: 2 (18.2%)
- 2: 4 (36.4%)
- 3: 3 (27.3%)
- 4: 1 (9.1%)
- 5: 1 (9.1%)
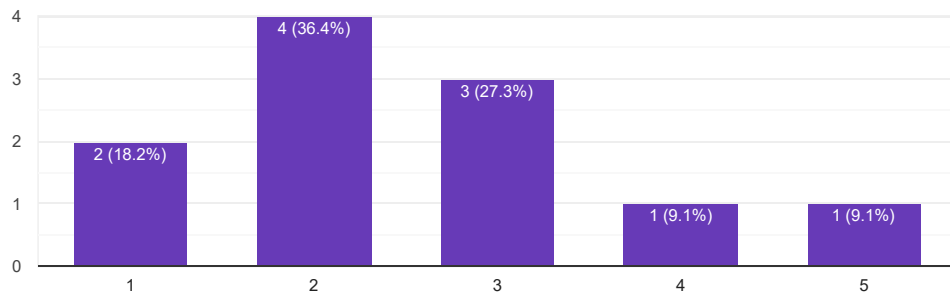
How would you rate the current documentation of Solid?

12 responses
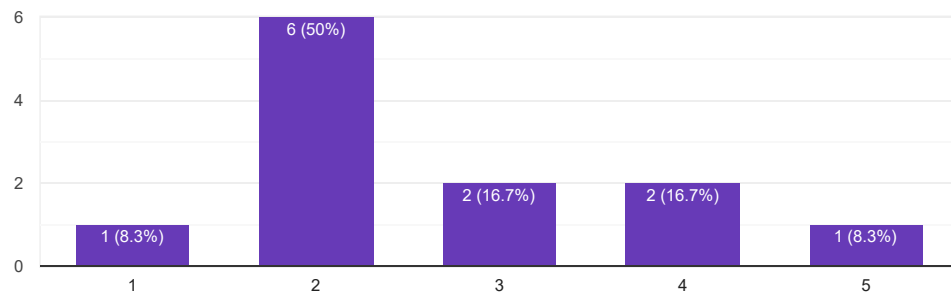
What do you think the challenges will be implementing Solid over the world?

14 responses

Getting an ecosystem up that's stable and reliable enough for businesses and associations to develop services for

Makind the average user understand a) the data model which is no longer 'installed app + file on disk' but 'some apo + some pod', and b) the identity and auth methods.

I think that two of the biggest bottlenecks for developers atm are:
* Finding, Defining and Adopting interoperable data schemas
* Using rdflib (documentation is lala)

Lack of tech, standards and economic incentives, UX

authentication, interoperability, coordination

Developing public awareness of the importance of data privacy and a sense of communal responsibility for the state of the Internet. Developing legal structures to support those.

Maintaining interoperability given remaining gaps in the spec

making applications interoperable

Either bringing new solid-aware interoperable applications to mainstream, or having currently mainstream applications become solid-aware and interoperable.

Improving the UX of the Solid Apps in the ecosystem and increase developer adoption of Solid as a "cool technology", instead of being used only by privacy enthusiasts.

Interoperability of applications and data

Solid is a project for an universal API. It makes people scared of a so huge ambition. Interoperability should be think first in context to build poc with the existing web. Moreover, Inrupt DO NOT help other actors in the world who build on solid. It's very dangerous for the community. How can we credible in France if we make promotion of Inrupt job and Inrupt ignore us ? A last thing : PODS is a very geek and individual conception of data souverainty. Data souverainty can be archieve at community level. What about CODS (collectif online data store) ? That's what we do in France with Virtual Assembly and Startin'blox. We believe in data cooperative or this kind of concept more or less. Some time I meet people who work on semantic web and who are closed to solid specification and they say "I'm not Solid because I don't have pod". We should onboard this guy too ! And Activity Pub community too ! !

More approachable for .NET developers

Solving the chicken and egg problem: there's no reason to build a Solid-supporting app if nobody has a Pod, and nobody needs a Pod if there are no apps.

What do you think the challenges will be implementing Solid in developing nations or low-resource environments?

13 responses

Providing services that in no way exploit the users

Currently one needs to be very tech savvy to setup a pod and an webid. Done wrong, it does either not work or isn't safe.

The reliance on centralized infrastructure like dns and the general availability of the pod are issues that can only be improved by vertically scaling the infrastructure

Tech overhead (slow internet connections vs lots of requests needed to fetch resources).

Complicated user UX. English centric knowledge.

unambiguous specifications

Development of local ontologies relevant to the local community. Publicly funded and hosted spaces for those with no access to storage.

Slow and unreliable server response time, and solid spec not currently having any features for interoperability with offline sync other than etags, which don't handle conflict well
Need for both server access and web development skills

maybe offline first challenges

Having pod providers trusted by the people and by the government at the same time.

Having a culture in the community about making performant applications with best practices focused on accessibility.

Availability of digital records, connectivity.

Take care of not having only non tech groupies, groupies hurt credibility. The main lever I see is to focus on community logics. In France we have local collectif that help the local community with numeric empowerment tools (https://chatons.org/). I think the best strategy will be to invest few very local communities to make poc/experimentation to prove that digital emancipation of a local community is possible, desired and scalable. Local politics should be part of the party.

Apps have to communicate with the server a lot, which can be tricky if connections are slow or unstable. But I don't know if they are - I'm not familiar with infra in developing nations.

What do you think the opportunities will be, especially for developing nations, implementing Solid?

12 responses

More flexible data storage that can move with users and across borders

Many places have non- or poorly functioning institutions, and people have a single device. This can bring the needed environment for safe conputing.

The people and the government could own their data from the getgo, instead of industrial nations who have to claim it back.

Big players might not be as stablished or interested in competing.

simplifying thangs

The opportunity for people to be actively involved in the creation and management of their own content in a way that does not support the concentration of computing power in the hands of the few.

Going straight to federated data models, reducing reliance on centralised servers

the schools can sometimes be better and they may produce amazing developers

Centralizing identity and services on users (instead of on service providers) can speed up digitalization and inclusion, allowing societal maturity with speed and quality.

Given the nature of Solid, apps can potentially be extremely resilient and versatile. If that aspect of Solid is fully embraced, I think Solid Apps will have an inherent competitive advantage compared with other technologies.

Ability to provide common, interoperability data and applications as a baseline for more efficient and responsible data exchange with citizens.

Maybe they are even more annoyed than us, Westerners, by the domination of American firms? Is it that their use of digital technology is still unformatted? Or on the contrary is their use of the web only shaped by gafam?
I don't know..

Can you think of Solid applications that would be useful in developing nations?

12 responses

Perhaps a system that allows sharing of local insights, such as reviews on certain goods and services that can be speculative unless information about it is shared

Proof of citizenship, some kind of micro-banking, more trusted sources of info (market prices)

I think that Virtual Classroom tools that share knowledge through a decentralized knowledge graph could be useful, as well as all kinds of government tools that use the WebId as a common identifier for citizens instead of email or postal adresses

-/-

I think it is absolutely the wrong approach to ask this question of technical people in developed countries. The answer MUST come from those nations themselves.

Meeting personal/small business information management needs with self-sovereign data model allowing formal data sharing arrangements

apps where users pay the developer

Citizen identity with focus on health and basic social services.

Nothing comes to mind :/.

Cross-government citizen record management.

Digital emancipation could also be a lever of citizen animation for the return to local politics. Decentralization seems to become a necessity in countries to maintain the trust of citizens in the difficult context we know. Solid allow to think community information system scale.

Possibly

How can Solid be distributed over the entire world?

12 responses

Global actors could certainly be helpful, such as Google or MasterCard

Make a solid server and some basic bundled solid app trivial to install on sone platforms (android)

Through the collaboration of a lot of developers

perseverance in media coverage

By gaining local partners who are motivated to use Solid to solve local community needs.

Strengthening spec and tech base and getting to the point where backwards compatibility is maintained. At the moment there are already a number of obsolete apps

with a distributed content addressable swarm network like IPFS for storage

Massively spreading the word and applying pressure so that big service providers join and cascade the technology to all layers and industries.

Forgeting the idea of having a "single source of truth" for an app. For example, if I make an app it shouldn't be accessible at "my-cool-app.com", that should only be one of the distribution channels but the app should work on any medium: Mobile devices, browser, and even downloading the assets in a .zip file and running them locally. Solid Apps can potentially have a distribution as good as The Web, and without relying on network connectivity.

Something that's also not been explored a lot but is very interesting is local Solid PODs. For example, I could have a Solid POD that is "hosted" on my mobile device, and all apps could work offline by default.

By delivering applications that give people and organizations (private and public) new value.

Please, let's make sure that Solid is not Inrupt. We are raising an ecosystem in France and we feel abandoned. This weighs on our credibility. How can Solid spread healthily over the world if only Inrupt dominates the market? We need systemic solidarity and for the moment although we have asked inrupt for a minimal support in principle for the promotion of Solid in France, our requests have remained dead letters.

Don't know

Other things you want to share:

6 responses

-/-

Don't underestimate how immature solid still is

my ratings on ease of developing and setting up a server are years out of date by now

-

Thank you for doing this.

I understand that there are professional secrets at Inrupt but the ecosystem is not fed enough in concrete realization and in poc. In the absence of news, the credibility of the project is put at stake. Like a utopia that has been announced for years already and that people would have been tired of waiting for.

Share your webId (not necessary):

6 responses

https://megoth.inrupt.net/profile/card#me

https://testpro.solidweb.org/profile/card#me

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Not a Solid webid, but you can find about me on https://noeldemartin.com

https://justin.bingham.id/profile/#me

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Interviewers: Wouter Kok, Teodora Serbănescu

Interviewee: Joshua Opoku Agyemang Otoo

Taken place at: 07/07/2021.

INTRO
-Permission for recording Yes
-Permission for name in thesis Yes

QUESTIONS

Can you tell us about the IT groups and projects you are involved in?
I'm the president of the IoT Network Hub Africa, a tech community in West Africa. Also a Founder of Entrepreneurs Network Hub.

I tried Googling around. I think it is the future we are looking at. Personalization and customization for everybody. And I think here we are looking at Industrial revolution 5.0, where we currently are at 4.0 where we are looking at drawing boundaries between physical and biological worlds. As a result, driving by AI and IoT technologies. With industrial 5.0 we will see the peak of these technologies being embedded in everything in our society and world today. And when that happens, data will become commoditized, and not having control over your data can be a problem. So therefore Solid can be critical. Everything I do, there can be data collected so I also have a digital identity, but who owns that digital identity? It is very crucial and important. The world might not have seen that this is needed, but as Tim has stated there is a great reason to do this.
Even with the current experience we have with data consent and privacy, we having challenges as to how we define privacy today and how we define what data should be open and what should be considered close to the public. So if we have a project where the data is kept in a vault and we can allow companies to access and not access, I think it is a great project.
In the 4th industrial revolution we are going to be living in a whole digital transformation, especially in Africa, we are still catching up even though the gap is really big. But I believe in the next 20th years to come things are going to change and when this happens we have to redefine our data and the control over our data. Very interesting project to look into.

So you mentioned you are in the IoT tech hub in Africa, and we wanted to know when you are creating new applications, what are mostly the challenges in your area and maybe with some examples?
When it comes to our continent for building solutions, one of the most challenging thing is that even though we face most of the problems, we don't understand most of the problems ourselves. Before I discovered design thinking, usually we just sit in a corner, we imagine the solution and built it and give it to the client. The client might not like what we have build, so one of the challenging parts when building solutions in our environment is involving the people in your process. So if you have the human-centeredness, you build the solution for them, and not in a corner and give it to them to use. So I think it is one of the critical challenges because African problems are very wicked, so it is better to involve them in the process.
Secondly, depending on the application you are building, if it is more software based, it is more about connectivity when your solution uses constant internet. But that also depends on who you are targeting. For example urban areas, you don't have issues with connectivity. But targeting rural areas or deprived communities you have to deal with connectivity, but we don't have 3g in most of the rural areas and some 2 and some you don't have any connection at all. In the cities you get 4g, in the mid towns and mid rural you get 3g or worse.
For adoption it depends on the target group, if you don't evolve them in the process, adoption will be very low. One of the major challenges of IoT is connectivity, energy efficiency and environmental conditions to cross will be a challenge. Also depends on the application. Most of the rural areas might not have access to electricity, so to charge your batteries it will be difficult, however there is a lot of sunlight for solar solutions.
Electricity, connectivity and the way you solve that problem (involving people) are the three major challenges.

We are looking mostly at urban areas. And how do you try to solve these problems now?
I think Africa has a lot of deep-rooted problems so solving any of them is great to explore. From your perspective I will have to look at social challenges, one of them is work ethics, which is low. You could also look at corruption. If you are dealing with anything that requires state approval then that is a big problem.
Also theft, if your solutions uses physical things on the field, you should be content with theft.
In addition, challenges with resources, we don't have factories that develop hardware. We produce hardware through China right now. The cost of production can be high here. It is cheaper to develop elsewhere.
These are more social and some technical.

What are the most promising areas where IoT can be used, is it irrigation or is it other areas?
Africa is very green so we have the environment to grow anything. But the challenges we face over the past years has been our way of growing things. That comes from tradition. We don't use much data analytics or involve enough innovation in our processes.
In a world where we have a lot of challenges, from climate change to pest invasion, the world has changed since our forefathers' times. I think the future of Africa will be data on your farm or piece of land. Getting to understand your soil and seeds and environment etc, you can predict which crop can dry up the most, we can adapt. So I think adaptation in agriculture practices can help with data.
With Solid, imagine all farmers having personalized data that tells them what to do with minimal expenses. I think it is great, the backbone of Africa is Agriculture, it has been our number one pillar.

Figure 5.13: Notes of a meeting with Joshua Opoku Agyemang Otoo on 7-7-2021

On the other hand, you have to for example store all the data, and there are for now not many data centers to store this data. Given the investments for datacenters, isn't there a risk that the data will be captured by Chinese, American or European big tech.

Yea I think it is a game for our leaders to play. I don't think there are so many problems that we cannot fix them. The problem is the people that don't believe we can fix it. The best thing is to have some partners and it should be beneficial. So when China or America helps with infrastructure, they should have some value in return. You need to find ways to bring the value back. I think selling the data is not ideal, but there should be a way to make it beneficial for both parties. But our leaders mostly look for short gain to ease their pain and in the long run we will all lose as a continent. I think Africa is going through this now, but I thnk one day we will believe to fix it.

If you lose your data in this generation, I'm not sure what resources you will have left. Everything is data and you can lose it to a country.

We realized that what happens what we don't do something. We see that these obstacles, if we don't overcome them now, what we are waiting for in the future will be too much. That is the drive for building this community.

How do you see the side problem of cyber security?

It is one hot topic in the industries. In Ghana and Africa, one thing that the leadership hasn't seen is that in the digital age, the warfare works over the internet. So how can nations keep their personal data save from malwares and attacks. I think these are dangerous warfaces I think our leaders have no idea of, which is sad. Because the harm that can be caused by a cyber attack can precede any bomb. Unfortunately, much has not been done in our part of Africa. There are individuals and private organisations that are pushing this agenda in most of the countries in Africa. I don't know if because of how the we haven't been able to penetrate into the internet. So we haven't seen the need to make sure all these measures have been put into place. For me, I feel we need to risk kill our security system, from the military to police into the digital age, how they can apply their knowledge and skills to protect systems, not necessarily in the warfaces we see. And I think it's something going forward, our generation will have to look into it, because I feel there's been a shift in everything in society of moving to data. So we have social media, and there is the security of the physical structures that are moving through the decades as a cyber war and cyber security. So how do you also move ourselves into that space and make sure that we protect our state agencies, our state's infrastructures from outside attack, digitally? And these are things that I think most haven't been done in that space, which is very dangerous. So there's a lot of work to do.

So in the IoT Tech Rep, you probably sometimes pick a new technology that you want to use. So I wanted to know what your experiences are with using newer technologies, and what problems you often run into as a developer when using this new technologies.

So um, yes, you're right. So we use different, emergent technologies. And what we started first with was the IoT Internet of Things. We're trying to understand the IoT ecosystem. And then research we did, we noticed that it's a whole ecosystem. It's not just about the hardware. But they need to bring all this value chain in the ecosystem together. So in the IoT ecosystem, you need a developer who builds the app that controls the devices, so you need to develop AI in the ecosystem. You need a designer who designs the UI, your brand and everything of the app. You need many diverse engineers. You need an electronic engineer who can design your circuit boards and everything. And then frame wise as well. You also need the electrical engineers who can build your network electrically, so they'll be able to deploy a solution out there. So for instance, if you build a home automation system or smart home system, the electronic engineers will build the hardware but they can't install it in the homes, so they need the electrical engineers. So I think one of the challenges when we started was understanding the processes that go to build an IoT solution and deploying them to the field. And once that was understood, now, we needed to bring all these actors together. So bringing a developer on board, the engineer on board, etc. Even with security, you need cybersecurity experts who can tell the vulnerabilities and to sustain the building. So we needed to bring all these artists on board. And then through our activities, our program meetings, we take projects, every team will build their side, then the cybersecurity will come and test for vulnerability in the sustains, then we see the things that we didn't do, right, developers also go out there and integrate into the hardware. So the other day, all these actors will be coming on board to make it necessary for now, when it comes to technical glitches on learning new technology, the amount of the challenge has been the learning curve. If you learn in isolation, it becomes difficult. Because most times you need somebody to inspire you to learn something new. Unless you're someone who has built the habit of getting started to learn new things, then you can probably pick something and then land. But then coming together as a community picking something new, there's always somebody to help you when you need some assistance. So the challenges of suffering alone aren't there. when something doesn't work well there is a group of people who are ready to support you. And resources was challenging, because the ecosystem wasn't here in Ghana, in some parts of Africa. So we need to get the people who also want to go into real retelling of the components. So that when we need a particular sensor, or microcontroller, we know who to contact to get it. So it's been an interesting learning experience. But then I just noticed you can't work in this space alone. It can't be alone working in its space, you need to get partners collaborations on board in order to to build a solution. So there has been a learning experience. Recently, we had a partnership with Nvidia. So Nvidia in the US also came to Africa. last few months. Nvidia has now merged into GPU computing hardware so they have their chips out there. And then they also go into emerging markets. So they also come to Africa. So with Nvidia, we also started in machine learning and deep learning AI on the edge. So with nvidia had ways we can process AI without necessarily having access to the internet. So in rural areas, or places where there's no connectivity, be able to use edge computing, I think I heard you mentioned the Raspberry Pi. So but prior to can be used for edge computing, to run your AI models without connectivity. So we also explore that with Nvidia.

As such, we also dive into 3d printing, where we will understand the concept of 3d printing and how it works out. We design our casing for IoT devices after building the devices, we need to cover them. So we go to design casing for them, model them and then price them out. So we also exploit 3d printed things. One thing about these emerging technologies, they are very interesting. And their results. I always also like it feels magical, because it's something we haven't experienced before. So once you try something small and it works for you, the excitement alone drives you to want to find out more. So I think it has been so interesting.

One thing we haven't done much is the blockchain with blockchain technology, the thing that cryptocurrencies have taken a hype out of is most of the applications are always about money, money, money, money. But then I think IoT and blockchain have a great impact if

we can be able to protect the data that we collect from temporary, then as you're building your projects, I think blockchain or decentralizing data would be a way to also help secure it from attack and other other stuff. We have a community here in Ghana, already into blockchain, mostly the cryptocurrency. But then we will look into how Basically can build applications beyond just currency, but then how we can build practical solutions using the technology and how secure data is.

And we're looking forward to building more solutions by a combination of two or three of these technologies. The projects we've worked on include a smart home system. So we build a system that allows you to control your homes, with your phone, whereby, apart from control, he can also monitor your energy consumption and know the status of your appliances. So in Ghana, there have been frequent fire outbreaks, there have also been instances where a lot of people leave their homes on a rush because they're late work due to traffic, and they forgot to turn off their irons, their lights, the appliances, and this will be on the whole day causing mismanagement of energy in the home. So this whole thing says to help them utilize the energy in the house.

Then we also work on waste on council sanitation in Ghana Africa, also one of the challenges. The one thing we're looking to build is sensors that can be attached to the bins on the streets, usually the bins will be full, and nobody will pick them out. And the people will start dumping around, it's so before you realize it does turn into a very huge dumping site. So these are challenges that we thought of if we have a sensor that can collect data on the level of the bins, and whatever they are for the collectors can be notified. It also helped them to manage their collection routes and operations.

And COVID came to us and we built some innovations to help Ghana and Africa. And some of them include washing buckets that allow you to wash your hands without touching any surfaces. So you just put your hands under the sensor and the water flows. So this and many innovations we've been trying to do with all these technologies we've been exploring.

We are doing constant research on several of these topics, for example, in blockchain also for low resource environments and on IoT. So if we could be permanent partners with you. And we have students and staff members working on this research, and we could work with you and help and help each other and maybe publish together.

So I think it'd be something very interesting to work with you. So one thing or one major challenge as a community here is publications, we don't really take publication seriously at all. So most of the work we do, we do a great job, but nobody hears about it. So it's once in a while being fortunate for a media to pick up on innovation, and then it will go but I think we have to have the consciousness of making sure that whatever projects we do we read the comments and publish them, which is very, very important. The way we've been trained, we don't do much documentation and publication, or we just want to take their problem, their solution and fix it? Well, I think yes, we should be able to mind the two together. So as we build in, we try that process, then we'll be able to also publish something. So I would also really love to work with you on this and many other things going forward. Because one thing I keep mentioning, every place I found myself talking about is that in this revolution, the fourth industrial revolution, we can do with our collaboration, our partnership, it's not competition, but cooperation. So we need to come together and see how we can put our strengths together, to be able to build well sustainable communities and societies for ourselves. So yes, I really like it.

So you explained a lot of the new technologies you were using and also why you picked them, because they're mostly very interesting and you see value in them.
So linking this to Solid, do you have some tips for maybe the solid community on how to make solid more attractive to developers like you? Like, why do you want to use solid etc.

I think after this, I'm going to read a lot about Solid. I just did a Google search and I noticed it was also built on a decentralized network. So it's something great. So imagine how bad things are today, we have our personal data, stored in the same way, where everybody has control of their own data and decides who to share with or who not to share with. And after my research into it, we'll see how best we can start a community here, like a sub focus group that can explore more Solid, we can start building solutions.

For your projects, I think one of the things you might have to look at is what kinds of data you want to collect from the personalized data you want to collect? I believe there is data that is open data, that even though it might be in environments, you can't take the control away because it needs to be open to the public, then we need to also understand the definition for private data. The data one can have control of doesn't necessarily have to be a Biograph data, or any data around the individual without the environment.

I think one thing I also forgot to mention is the Data Protection Act. I don't know how, you know, now, every nation or continent is trying to put up a Data Protection Act. And Tim Lee wants to disrupt that. So there might be opposition depending on where such a solution will be deployed. But then yes, I think it's still in the early stages. And it's something that the world will need going forward.

So when it comes to your project, if you're looking at IoT Core, then that means that it would be great to have every user of your solution, having control over their data. But then one thing about the IoT solution is that even though you might have control over your data, the developer or the owner of the hardware business needs this data. I think as the developer you collect all this data, you process the data with your machine learning models, then you can help each customer have access to the process data. Refined data. So, for instance, if you're looking at a farm's data, you can collect data about moisture, pH level, weather, oxygen, and all around environments. So you got data in it's raw state but it doesn't make sense to the farmer. But then you are able to process data with machine learning. So I don't I don't know what kind of data you might look into collection and how you want to process it. So for your projects if you want IoT, you also need AI. IoT means we need 3d printing. So you might want to print some components. So if you use a 3d printing technology, you need to do the IoT too, as well. Then with AI, you need machine learning models able to analyze the data and make predictions and improve upon the performances.

So in a glance, I see these three, and then probably security will be a concern. So cybersecurity can protect your data, what protocols to use to secure the data transmission, and then your, your PI if your PI is going to be on site, the physical security and other data security to be very important. I don't know if I answered your claim, but these are the technologies I think will play a major role if you need to build your projects, as far as you want collecting data automatically without human intervention.

I think one field that might be of much concern is finance. If there is a way to build Solid applications in finance, where people are usually fearful to give their data, knowing that they will have control now. That would be very, very amazing.

Maybe it's a bit comparable with a bank. So I can keep my money at home, but I can also bring it to the bank where they have better places to store it and it's not stolen. But I have to trust the bank to keep it safe and not do something else with it. The same with your data. It's also related to the blockchain that you mentioned. RThe network owns the money or owns the data or owns the power of decision and not a central entity. But does this work? But I think it's very good to think about these things and maybe to try out simply to do a test. Maybe next year, do a test with your user group, on Solid, for example. Let people on it and see how they, how they manage and what their experiences are. That would be really great.

Can you think of an example of a project you worked on? That didn't have solid or didn't have this privatization of data, and would have really benefited from it.

So for other projects we've worked on, we've never used the decentralized system. So we've never used a blockchain in applications, that means we haven't used anything close to Solid. So in our solutions or projects, data are made accessible to everybody. And measures aren't controlled, don't have the data. So data is mostly centralized. So we are yet to explore. So we will explore Solid and blockchain technology going forward to see how best we can use either to move some existing projects into that architecture, or those innovations in the architecture.

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