Aalto University
School of Science
Degree program in Computer Science and Engineering

Mahya Ilaghi Hosseini

Secured Personal Data Storage Platform for Private Clouds

Master's Thesis

Espoo, November 7, 2014

Supervisor: Axel Küpper, Technical University of Berlin
Toumas Aura, Aalto Univerity

Instructor: Gökhan Coskun

Aalto University
School of Science

Aalto University School of Science Degree Programme in Computer Science and Engineering	ABSTRACT OF THE MASTER'S THESIS

Author: Mahya Ilaghi Hosseini		
Title: Secured Personal Data Storage Platform for Private Clouds		
Number of pages:54	Date:07.11.2014	Language: English
Professorship: Data Communications Software	Code: T-110	
Supervisor: Axel Küpper, Toumas Aura		
Advisor: Gökhan Coskun		

Abstract:
Generated data by users is increasing daily and maintaining the personal data storage hardware is costly. Cloud data storage are getting popular for their user friendly and cost effective features. On the other hand, user privacy violation is an obstacle for adoption of cloud storage. Therefore, the recent growing interest in both public cloud and private storage services, shows the demand for solutions that are focusing on privacy awareness of users. Increasing the security and privacy related issues in cloud storages indicate a demand for an action to improve the security of data storage and increase privacy awareness. In this thesis, a novel trust level based solution for cloud data storage is introduced. This solution emphasizes in utilizing hybrid cloud technologies. This solution provides a simple user interface based on colors and it gives the possibility of selecting the storing places very easily and efficiently. Furthermore, to have a detail requirements of our solution a survey study based on questionnaire is administered and a proof of concept prototype is developed.

Keywords: Cloud data storage, hybrid cloud, secure storage

Contents

1 Introduction

"We have more things on disk, more photos, more items stored than we'll ever have to allocate time for."

—Jeff Davidson

Cloud computing as a shared pool of configurable computing resources with the capability of storing data and perform the computation remotely was a long vision of computing. Growing data and increasing popularity of cloud computing is a motivation to use data storages for personal and institutional data backups in the cloud. By having the data storages in the cloud infrastructures, users can be relieved from limitation of local data storage. Beside storage functionality, the cloud data storages focus on file sharing and synchronization as well. Generally speaking, cloud data storages have significant benefits, they bring ubiquitous data access (anytime from anywhere with any device) and sharing capabilities without the need of self-managing replication and data backups.

In spite of all the advantages delivered by cloud data storage, several challenges are arising for storing sensitive data without compromising user's privacy. The fact that users have no physical possession of their outsourced data and it is stored and processed remotely is hindering the adoption of cloud based data storages. Relying on a corporation to have access to all your personal data is a major concern for many end users. Thus, cloud data storages magnify an essential concern over data security and privacy. Several studies ranked security and privacy as a major area of attention for cloud adoption [24]. Due to privacy leakage and security exploit of major vendors, the end-users prefer local storage for sensitive data over cloud storage [26].

However, there are alternatives for stashing individuals' data which provide higher level of privacy than public cloud storages together with giving the advantages of using cloud. Using private cloud storage solutions combine the storages of data in local networked drive and having the full control over data with file sharing and synchronization facility. In personal cloud data storage the data store on local servers with the capability of online sharing and remote accessing. On the other hand, other personal solutions like Networked Attached Storage (NAS) devices are gaining popularity for data storages. However, natural disaster risks (flood, fire, being stolen, etc) and the effort of network storage setup are remained as a failure for this category of resources.

In addition to rising demand of personal data storage, the proliferation of online social networks is another issue to think about. Rapid growth of sharing and storing contents in online social networks become major points of concern for security and privacy issues. The centralized

nature of online social networks and service provider ownership of data brings the limitations for users. Thus, it becomes a potential motivation for developing a decentralized network for online social networking. Decentralized social network is a distributed information management platform, such as a network of trusted servers or peer-to-peer systems for social networking. On the other hand, implementation of the personal data storage is one of the key enablers of moving from centralized to decentralized online social network [16].

1.1 Thesis Objectives and Motivations

As mentioned here, the personal cloud data storages have received considerable attention from individuals who concerns about the security and privacy of their data. According to studies e.g. [26] customers are willing to pay for services that support strongest security and privacy mechanisms to protect the collection and dissemination of their personal and sensitive data (e.g., financial data, health records, etc.). On the other hand, users are also attract to usability, convenience and cost features of public clouds, the noticeable popularity of Dropbox as market leader of public cloud storage shows this interest [17].

The idea behind this research is to give the opportunity to individual users to take advantages of public cloud data storages meanwhile they also have their secure private storages. This research proposed a novel solution that combines storage drives from popular public storages providers with user personal local drives. Using the introduced solution allows users to decide where to store their data based on their personal trust levels and their data sensitivity levels. By assigning colors to storage user can control and manage stashing data in different storages easily. In general, this research introduces a trust-level based data storage solution which can changes today's behavior of users of data storages. The introduced solution enables user-friendly data management based on assigned trust-levels to storage solutions in a distributed data storage environment and the classified trust-level of the data to be stored.

Accordingly, this solution facilitates drawbacks of data storage solutions, such as considering of trustworthy in data storage processes and lack of security and trust, meanwhile it lets users to store less sensitive data in public cloud storage easily. In particular, the objective of the introduced solution in this research study is to enable data storage based on assigned trust levels to different storage solutions.

1.2 Research Question

The questions that this research intends to answers include

1. What are the current demands of cloud storage users?
2. How to design a system to facilitate usage of hybrid cloud storage based on the answer to question one?

1.3 Contribution

The next solution, the private cloud option, is a costly solution. The data that is being generated by users is increasing daily, and maintaining the personal data storage hardware cost a lot. The variety in sensitivity of data requires the different storage solutions, for example, there might be a need to a highly trusted place to store sensitive data such as financial data, health records, but storing video records of public events in an organization requires less concern. Therefore, our solution which is based on hybrid cloud, hybrid cloud is one of the four deployment model of cloud computing that is a combination of private and public cloud, will give the capabilities of both storages to the users.

The goal of our solution is to provide a secure platform for storage of data in different storages (by providing encryption mechanisms) meanwhile it helps users to have more control and awareness over their data location. This platform focus on simplifying the process of storing data in different location and it provides a good balanced between privacy awareness and usability with more affordable solution than only using private clouds or other personal solutions.

Uniqueness of our trust level based solution consists of easy to use storages of data in distributed environment.

1.4 Thesis Outline

The rest of the thesis is organized as follows. A brief introduction to background technologies of the work is presented in chapter 2. Chapter three reviews the state of art literature and researches of the relevant field. In chapter 4 research methodologies, details of the administration of a survey study and analysis of its results are gathered together. Chapter 5 is about development of a prototype as a proof of the thesis concept. After that, chapter 6 evaluates the results of development phase and compares them by the requirements of our introduced protocol. Finally, this thesis concludes with a summary of what is done and the future works. If readers are interested in business issues of this research work, in appendix 2 a market analysis of a product based on this thesis is provided. This Innovation and Entrepreneurship (I&E) thesis is written as a part of final master thesis. The purpose of this thesis is to gain an understanding of the market potentials for a proof of concept solution that is developed for this master thesis.

2 Background

"A people without the knowledge of their past history, origin and culture is like a tree without roots."

—Marcus Garvey

This chapter intends to review the most related technical background knowledge to the thesis. In the first section, a review to cloud computing technology is presented. The next section discusses cloud storage technology. Section 2.3 talks about the benefits that cloud storages bring to users. Finally, this chapter concludes with an investigation about privacy, security and trust notions.

2.1 Cloud Computing

Cloud computing has been defined by multiple experts, among them a definition by the National Institute of Standards and Technology (NIST) got popular. NIST defines cloud computing as

> "Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model is composed of five essential characteristics, three service models, and four deployment models." [48]

According to NIST [48], these five essential characteristics (i) are on-demand self-service, (ii) broad network access, (iii) resource pooling, (iv) rapid elasticity, (v)measured services. For detail description of these characteristics check the NIST definition article [48]. Three service models consist of Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). SaaS is the capability that enables consumers to use the provider's applications running on a cloud infrastructure. PaaS is the capability that enables consumers to deploy onto the cloud infrastructure consumer-created or other applications created by using supported libraries, services and tools of providers. IaaS is the capacity that enables consumers to provision most of the fundamental computing resources where consumers can run and deploy

software, operating systems and application. Furthermore, the deployment models are private cloud, community cloud, public cloud and hybrid cloud. Private cloud is when the cloud infrastructure administered by a single organization whereas the public cloud is where the cloud infrastructure provisioned for public usage. Hybrid cloud is a combination of this two clouds and community is somewhere between private and public one according to its specifications and exclusive usage.

2.2 Cloud Storage Definition

As one of the cloud computing services, cloud storage services have received considerable attention recently between individual users, organizations and researchers. In literatures, a clear standard definition for cloud storage is not provided. Among them, we referred to two definitions of cloud storage one by Fraunhofer Institute [25] as follows:

> "Basically, a cloud storage system can be considered to be a network of distributed data centers which typically uses cloud computing technologies like virtualization, and offers some kind of interface for storing data. To increase the availability of the data, it may be redundantly stored at different locations. In general, all of this is not visible to the user. "

and the other by [5] :

> "Cloud storage is a specific sub-offering within IaaS of cloud computing and it promise high data availability, and reduced infrastructure costs by storing data with remote third-party providers. "

These cloud storage services consists of two types, basic services and advanced services [25]. In basic cloud storage services are not directly accessed by users but they are incorporated into specific software using application programming interfaces (API). As such, Amazon S3 [1], Rackspace5[2] and Nirvanix6 [3].

Advanced cloud storage services provide interfaces for customers to utilize the basic cloud storage. These interfaces consist of client or web applications that simplify the storage of data in cloud infrastructure for customers. Some of advanced service also provides a simplified version of their API to enable the integration of their service's capabilities into third-party software. Some popular examples of this type are, Dropbox [4], Google Drive, Mozy[5].

[1] http://aws.amazon.com/s3
[2] http://www.rackspace.com/
[3] https://www.nirvanix.com/
[4] http://www.mozy.com
[5] http://www.mozy.com

2.3 Cloud Storage Technologies

According to cloud computing service models, cloud storages can be categorized into two service models:

- Cloud storage as a Service: this services are mostly provided by cloud service providers [10]. For example, Google and Microsoft.
- Cloud storage as an Infrastructure: this services are mostly provided by cloud Infrastructure providers [61]. For instances, IBM and Oracle.

From cloud computing deployment models, the cloud storage deployment models consist of three types [62]:

- Private Cloud Storage
- Public Cloud Storage
- Hybrid Cloud which is a combination of above two strategies

In the following these three models are described.

2.3.1 Private Cloud Storage Service

Private Cloud storage is where the enterprise data and cloud resources are situated inside a private cloud infrastructure within an individual organization and it usually behind the protection of firewalls. It is also called internal cloud storage. Since, most of the efforts such as management, maintenance, data center space, network, connectivity and power management are handled inside the enterprise architecture, having private cloud storage usually is more expensive than public cloud storage services. However, the main motivation to use private cloud storage is customers' concerns toward potential security risk and privacy of their data. Private cloud storage considers the security and privacy requirements while offering major features of the cloud storages namely scalability, reliability, rapid deployment. Examples of private cloud storages are, ownCloud, Seagate [6], My cloud [7].

2.3.2 Public Cloud Storage Service

Public cloud storages are the most popular types of storages among the individual customers as they reduce the complexity and expenses of storing data. For example, Dropbox has over 300 million users by may 2014 [18] . Public cloud storages are provided as a cloud computing services with minimum control of user over infrastructures.

[6] http://www.seagate.com
[7] http://www.wdc.com/en/

In public storage data is stored outside the enterprise data center, usually consumers provided by limited free storages and for having more it is possible to purchase more capacity based on pay-as-you-go principle of cloud computing, that is what makes cloud computing more economic friendly. Although, storing data in public cloud storages restrict control over data, deployment of public cloud is much faster and has more scalability and accessibility than private cloud storages. Figure 2-1 shows an overview of public cloud storage architecture.

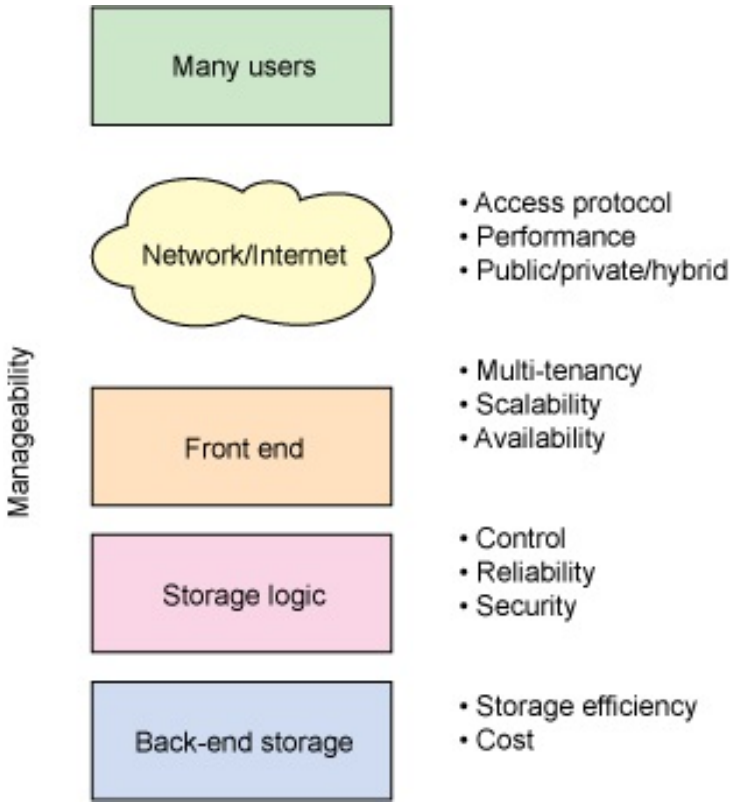

Figure 2.1: An overview of a public cloud storage architecture [30]

2.3.3 Hybrid Cloud Storage Service

Hybrid cloud storages integrate private and public cloud, in order to utilize benefits of both public and private storages. Hybrid cloud customizes rules and policies to have availability and security in cloud infrastructure. Storage assign to different internal and external clouds according to enterprise preferences. This solution helps to have balance between managing

data growth and purchase of external storage. For instance, StorSimple [8] and TwinStrata [9] are example of hybrid cloud storages. Figure 2-2 illustrates three cloud models.

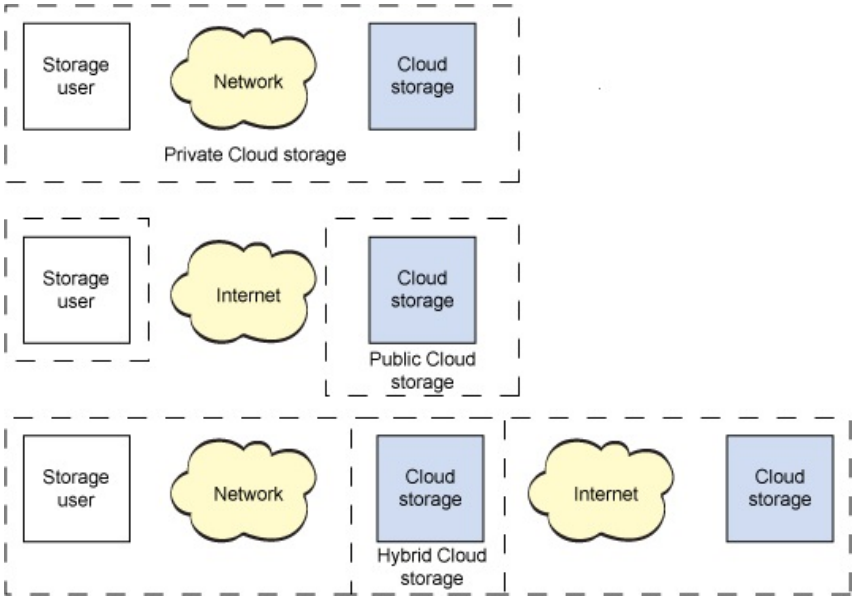

Figure 2.2: Three cloud computing models[30]

2.4 Benefits of Cloud Storage Services

Cloud storage has multiple benefits for individual and enterprise. These benefits include on-demand storage capacities accessible from various devices, backup facilities and data replication and synchronization to access to the latest version of documents in any devices. Four main benefits of cloud storage consist of copy, backup, synchronization of devices and file sharing [25].

2.5 Privacy, Security and Trust

Privacy, security and trust are complex concepts because there are no unified definitions for them but these issues are fundamentally matters of values, interests and power [21, 51]. Each fields of science defines these terms differently, reviewing academic literature on trust, privacy and security requires investigation in law, philosophy, sociology, political science, and psychology [21].

[8] http://www.microsoft.com/en-us/server-cloud/products/storsimple/explore.aspx
[9] http://www.twinstrata.com/

In computer technologies notions of trust, security and privacy are angles of a triangle that motivate users to go for on new technologies [46]. In the following subsection a brief explanation of each notion is presented.

2.5.1 Privacy

The definition of privacy as one on the fundamental human rights is changing over social progression but the primary focus of privacy has been to the personal data [34]. In commercial, organization, government personal data interpreted differently. The current European Union (EU) definition of personal data is that

> "Personal data shall mean any information relating to an identified or identifiable natural person ('data subject'); an identifiable person is one who can be identified, directly or indirectly, in particular by reference to an identification number or to one or more factors specific to his physical, physiological, mental, economic, cultural or social identity." [46]

Although the interpretation of what is considered to be sensitive data may vary depending upon authority, some personal data are considered more sensitive than others [46]. The data sensitivity highly depending on region and some of the personal data have sensitive nature. For example in Europe data that refers to information on religion or race, health, sexual orientation, political opinions, sexual orientation, data relating to offences or criminal convictions are categorized as sensitive data and in the US social security and driver license numbers, personal financial information and medical records are considered as sensitive data [46]. In the most cases, sensitive information which is part of personal data needs extra privacy protection.

2.5.2 Security

ISO 27001, information security management standardization [28], defines security as follows:

> "Preservation of confidentiality, integrity and availability of information; in addition, other properties such as authenticity, accountability, non-repudiation and reliability can also be involved."

According to this definition, security is an essential requirement to satisfy users' privacy. In general, when some organization responsible for personal information or confidential data, they are also responsible to have reasonable security level to protect data[46]. Moreover, ensuring security consists of mechanisms such as risk assessment, information security program,

administrative and technical aspects of security and putting safeguards [46]. Security and privacy are different, in that privacy relates to mechanisms of protecting personal data and information, individual rights but security is about protecting all forms of information and data [46].

2.5.3 Trust

As mentioned earlier, there is no universally accepted scholarly definition of trust [51], in this study [51] authors gathered several contemporary, cross-disciplinary collection of scholarly studies of trust and provide a definition of trust as follows:

> "Trust is a psychological state comprising the intention to accept vulnerability based upon positive expectations of the intentions or behavior of another. "[51]

Trust, in general, is an important factor in many social interactions [22]. Comparing trust with security, trust is a broader notion than security. Trust including two categories, hard trust (security-oriented) and soft trust (non-security oriented trust)[51]. The security oriented trust relates to encryption, security in transactions, confidentiality and authenticity, the soft trusts relates to human psychology, brand loyalty, and user- friendliness [51]. Reputation is an example of soft trust that is a very important component of trust in digital world, [41]. For example, in famous organizations such as Google and Dropbox good reputation in the one of the most valuable asset of them and their images are highly related with social trust and they will damage more if some breaching of trust or privacy happened to them. Even small security or privacy breach that publish in mass media immediately, for example failure reports in mass media such as these in references [39, 20] can cause trust loss. In general, comparing the relation between security and trust, security mechanisms can be key elements in to create consumers' trust [51].

3 Related Work

"The knowledge of all things is possible"

—Leonardo da Vinci

This chapter reviews literatures that are related to this thesis work. In this thesis, first the user experience toward the introduced model is surveyed, and second by the result from survey questionnaire implements the introduced solution that enable user-friendly data handling based on assign trust-levels to storage solutions in a distributed data storage environment and the classified trust-level of the data to be stored. According to thesis goal the literature review of this thesis is divided to four main parts.

First part includes literatures that related to study of trust in cloud computing and surviving user experiences, toward adoption of cloud computing in general, and more specifically cloud data storage. In the second part, the related literatures that intended to design privacy aware models and develop prototype to enable users to have better experience of using cloud storages. The third part, discusses articles related to enhancing method for increasing trust and the last parts, are studies that investigate the limitations and security and privacy issues of current cloud storage solutions and proposed models to overcome the limitations. A detail review of these articles is provided in the rest of this section.

3.1 Survey on Trust in Cloud

This part reviews the literatures that surveyed user experiences and behavior in trusting cloud computing services in general. This reviewing is done because in the main part of this thesis we plan to ask from user to figure out users' concerns and demands toward a cloud storage service. Therefore, in the rest of this part related articles of this kind are summarized.

In the article, "Do I Trust Google?" [32] authors intended to explore individual users' perspectives of cloud computing, especially issues regarding tendencies in trust evaluation of cloud services. This study focuses on end-users perspectives since they mentioned there were many literatures focused on adoption of cloud by enterprises and organizations not the end users. This article realized how end-users think about cloud computing and how they form their trust or distrust to cloud services and service providers. By analyzing their results they explored factors that affect formation of trust in cloud services.

According to this paper, three reasons motivate user to trust cloud services, first their needs, second popularity and reputation of cloud providers and third the commercial aspect of cloud

services. They also noticed the fact that end-users are aware of issues related to data security and privacy on the Web.

The next article "Home is safer than the cloud " [27] also mentioned the lack of researches in cloud adoption from end-users's point of views. This article investigated users' attitudes, especially on cloud consumer's privacy attitudes, beliefs and expectations for cloud storage and also examined user's awareness of contractual terms and conditions. The authors of emphasized the differences between the requirements of individual and organization in using the cloud storage. The results of this paper first shows that although users do not concern in issues such as guaranteed deletion of data, country of storage and storage outsourcing, they hesitate to user cloud storages.

Findings of this paper consist of first users prefer to use local storages for storing of sensitive data over cloud storage and they have a tendency to pay for services that have robust security and better privacy. Finally, they figured out that cultural differences influences in user behavior in cloud storages usage, for example their attitudes to store sensitive data in public cloud storages is varied in different countries.

The third article of this kind "To trust or not to trust? " [6] examined models of explanation of trust in cloud services from user experience in dynamical and experiential perspectives. The authors claimed that their study overcome the shortcomings of other studies by performing a holistic survey to examine user experience, emotions and trust in cloud technology. They tried to answer why it is important for IT and cloud computing, what influences trust in cloud computing and how can trust cause usage and acceptance of cloud services. They suggested a unified model for cloud trust in this paper and administered a survey questionnaire to find out "What influences the user's (dis)trust in cloud and cloud (dis)usage?" as their research objects they use Dropbox and ownCloud.

Beside these three relevant studies in this part, there are several other studies, that their results are useful to this thesis, such as [8] that examine the principles on evaluating user behavior trust, and provide a theoretical foundation about users' trust in cloud computing, or in [33]the authors introduced four main elements to affect users' trust in cloud computing which are security, privacy, accountability and auditability.

3.2 Design Models for Privacy Improvements

In this section, the related solutions in designing privacy aware models and developing solutions that provided better experience of cloud storages in terms privacy are reviewed. These categories have a wide range of related articles, a summary of the more related one is presented in the following of this section.

Among these introduced solutions, NubiSave [55] has similarity with this thesis work in combing different cloud storages but in broader perspectives. NubiSave designed to be an optimal cloud storage system with a user-friendly storage controller implementation. According to this paper, there are available solutions to protect access and encrypted and replicated needs but the practical limitation causes the lack of adoption of using cloud storage. NubiSave provided a novel cloud storage management system that combines storages resources from multiple providers. NubiSave development covered the entire lifecycle of development of storage

service and it is also validated to be an optimal solution.

Other solutions such as [37], proposed other novel solutions for privacy-aware distributed storage. In Uno, authors proposed a middleware to cloud storages which separated storing of physical and Meta data. To have a better privacy, in this model the physical data is stored in users local machines and only the Meta data stores on commercial cloud services.

In [29] authors presented a privacy as a services solution which contains a set of security protocols to provide privacy for users of cloud computing. Moreover, in this article [63] they proposed techniques to have a privacy aware computing in hybrid cloud systems. The last in this category, is [35] which introduced a new approach for privacy aware system that focused on both users and the data providers.

3.3 Design Models for Trust Improvements

In this section, the related articles in studying trust models in cloud computing and cloud storage are reviewed. This article [3] reviewed shortcomings and concerns of users' toward cloud computing and they proposed a model to increase trust. They summarized seven concerns, such as data location, investigation, data segregation, availability, privileged user access, backup and recovery regulatory compliance and long term viability; and their solution elaborated on these issues. For example, in data location concern their hypothesized trust model, suggested providing ability to investigate users' data on providers' datacenter.

This article [33] reviewed the key issues and challenges in achieving a trusted cloud platform and introduced a trust cloud framework that focused on accountability in cloud computing through technical and policy-based approaches. In the [53] authors highlighted the benefits and drawbacks of using cloud that could satisfy users and according to these a new trust model had been introduced that works between clouds provide and cloud users. This model works in three turns, in first turns user must be satisfied with reputation of cloud providers, second turn when users have the knowledge about service level agreement and third turn is when first two are satisfied then users can trust the cloud provider. This trust model is based on the fact that clouds providers must have a good previous experience to achieve user trust.

This articles [11] proposed and developed a more specific trust model. In their proposed model they offer a reliable files exchanging and their focused in private cloud. In their model, trust is calculated according to several metrics, and they also evaluated their result to prove the effectiveness of their proposal. This study [54] also attempted to investigate the issues of trust in cloud computing and highlighted the important elements and reviewed the available trust models. Finally in [15] authors proposed a model based on real life trust that focused on privacy issues on cloud services but more on online social networks. There are more studies of this category that proposed model for cloud systems in general such as [19], [7], [36], [4], [40].

3.4 Design Models for Security Improvements

The last category of this section consists of studies that focused on security problems of cloud storages and provided methods to mitigate these issues. The majority of studies in this part

discussed about cryptographic mechanisms to provide secure data storage solutions.

Lockbox [57]introduced a method for protecting privacy and ensuring security in cloud storage environments that relayed on encryption methods.

In [64] a role-based encryption method had been presented, this method employed for organizations that want to store sensitive data. It has been tailored to be used in hybrid cloud. The solution in this article [31] is a cryptographic technique for public cloud. This article [47] investigated the existing cryptographic techniques in cloud storages. Moreover, other studies [60],[42] consist of literature focused on efficient cryptography mechanisms in cloud infrastructure and storages. Beside, cryptographic methods, there are several studies that presented methods for data integrity for example, in [49], [50], [56], [59],[13].

4 Research Strategy

"I don't understand a thing about this world: about people, and why they do the things they do. The more I find out, the more I uncover, the more I know, the less I understand."

—Craig Silvey, Jasper Jones

The main goal of this thesis is to introduce a solution that enables user-friendly data handling based on assigned trust levels to storage solutions in a distributed data storage environment and classified trust levels of data. While we have this conceptual solution in mind, for extracting the detail requirements our system, we identified that understanding user behaviour and preferences is essential step for this thesis. Therefore, a survey study was employed and the collected data and its analysis is summarized in this chapter.

4.1 Objective

The main goal of having survey is to find out the behavior of the users in the context of data storage and how they use public cloud storage. In addition, find out what are data classification schema from user perspective. In general, this survey intend to find out answers to the main following questions:

- How many categories users would prefer to divide their data storages?
- What are the sensitivity levels of data for users?
- What are users opinion about our conceptual (proposal) system for trust level based data storage?
- What are the criteria that people use to categorize their data?

4.2 Survey Design

According to [1] "the survey is a non-experimental design that uses a series of written and verbal prompts/ items to quantify the personal opinions, beliefs, and ideas from a group of respondents. The survey instrument (typically questionnaire or interview schedule) translates unobservable content (e.g., beliefs) into numerical or other empirical referents into order to observe patterns across a group of respondents."

Surveys have a wide variety of purposes and they can be conducted in many ways – over

the telephone, by mail, email, online or in person. Among these types of surveys, this survey was based on questionnaires that were conducted online. The rationale behind this choice to collect data over online questionnaire was that this method allows to obtain a large amount of data from a relatively large group of people within a reasonable time period and without great expense [52]. Therefore, the online survey via questionnaire truly met the requirements to perform this study.

This survey was designed and developed mainly by following the standard approach by Salant and Dillman [52] p.11. The design of questionnaire was based on simplicity principle in order to have adequate responses and questions were reviewed by three supervisors, from both academic and industry area.

There are two different types of questions that are used to conduct a survey, which are closed-ended questions and open-ended questions [1] p. 213. Closed-ended have explicit response categories and the open-ended give a chance to respondents to express their opinion in their own words. In order to have a balance between these two types, the questions of this survey are a combination of both types. The first also called a structured or fixed response question and the second is called non-structured or open question.

For this survey to work, the survey was posted online by use of Google online survey tools. The survey pretested among a group of 7 colleagues. After that, the survey posted in variety of forums to capture the opinions from both experts and normal users. The survey posted online in popular social networks. in order to reach more experts, the topic related forums on LinkedIn, Twitter and related IRC channels were chosen, such as Cloud Security Alliance, Cloud Computing, Security and Privacy groups and ownCloud. Finally, the survey was posted to several Facebook pages. In addition, the invitations to participate also send by email to group of employees of the Deutsche Telekom and the Technical University of Berlin.

The survey was conducted in mid September to beginning of October 2014 and received over 150 responses. The response chart in Figure 4-1 shows a summary of results based on time and numbers.

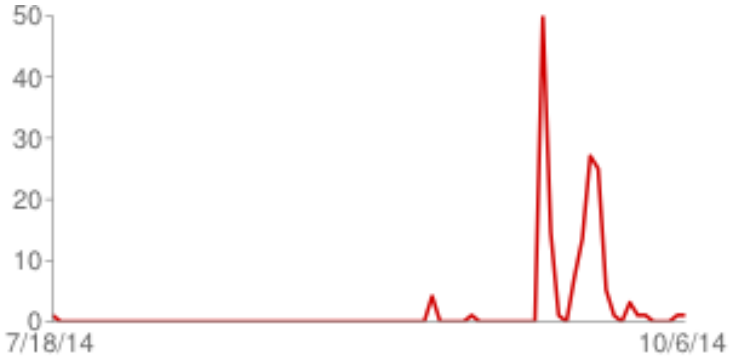

Figure 4.1: The response chart based on time and numbers

4.3 Respondents

As the aim of the survey was to find out users behaviors and opinions, the target respondents were normal Internet users and users who need to manage their digital data. On the other hand, to have more accurate results, the survey is also distributed among cloud technology professionals. Since, the target audiences were the Internet users, posting the questionnaire online were in the direction of finding the right respondents.

As mentioned earlier, the target respondents were chosen by posting the online survey in different social networks. As it is shown in the chart of Figure 4-1 the survey distribution, there are two peak points. It is because of two distribution phases, first one was targeted experts by distributing the survey over related cloud technology forums and second more focused on normal users by distribution over Facebook.

4.4 Questionnaire Design

This section explains the rationale behind each question of the questionnaire and how the answers will help to reach the goal of this survey study.

The questionnaire which is called, "Individuals data sensitivity level user experience", begins with an introduction about the objective and short background. Then in the following, there are 17 questions, the questionnaire can be found in Appendix 4.

4.4.1 Questions About Respondent Knowledge and Usage Level

These seventeen questions are based on four main parts. The first part of questions (questions 1-4) aimed at understanding the respondent knowledge level of cloud data storage, the usage patterns, the popular cloud storage and the willingness of users to pay to extra storage. These questions are important because: first, in general users with different levels of knowledge may have different understanding of the cloud storage technology. Second, the willingness of people to pay and the popular cloud storage are also very important since the analysis of the results of these questions is affected the requirements and design process of our solution. The questions are as follows:

1. What is your knowledge level about cloud storage services (like, Dropbox, icloud) Check all that apply.
   - 1. I have no Idea what it is
   - 2. I heard about it, but not used it at all (please go to question 2)
   - 3. I know it and use them, (please continue from question 3)
2. If not, could you specify why? Check all that apply.
   - I do not need extra storage
   - They are not trustworthy

- Other:

3. Which of this public cloud storage you are using? Mark only one oval per row. Yes No
   - GoogleDrive
   - Dropbox
   - iCloud
   - OneDrive
   - Box
   - Others
4. Have you ever paid for additional online storage in any of these? Check all that apply.
   - Yes
   - No

4.4.2 Questions About User Awareness

The second part aimed at understanding users perceived about their personal data, their concern level about different types of data, user awareness about private cloud services and getting the general impression users on public cloud services. These part is consist of question 5 to 9, question 5 and 7 are followed by an open-end question to have more explanation. Question 8 asked respondents to explain their reasons that intend to evaluate the privacy level concern and awareness. Moreover, these questions are considered to be placed in this part because they prepared respondents' minds for the next and main part of survey.

The questions are as follows:

5. Do you store the below information in the cloud storage, if not could you specify why not? Mark only one oval per row. Yes No
   - Financial data and banking document
   - Governmental (ID numbers, ..)
   - Health Document
   - Personal Images
   - Personal Video
   - Backup of your hard drive
6. Why not, please specify your reason for each?
7. Do you use any private (cloud) storage service? Mark only one oval per row. Yes No
   - Network Attached Storage (NAS)
   - Wuala
   - ownCloud
   - other

8. If you checked "other option" in previous question, could you specify which service?
9. What is your general feeling about public cloud storage? Check all that apply.
   - I feel completely safe to use public services and send personal data to them
   - I think public services show concerns to my data, but there is a small risk that my data is modified by third parties
   - Public storage does not have good reputation at all

4.4.3 Questions About Data Classification Preferences

The main part of this survey is the questions related directly to our target service. This part consists of question 10 to 14. As mentioned earlier, to find out the detail requirements for our services it is essential to figure out what is the behavior of users in categorization and organization of their data. This part aimed to understanding what are the criteria for classification of data, the numbers of categories they would like to divide their data according to their sensitivity toward data and the users preferences to store data in different storage (e.g. a combination of public and private storage). Answers to these questions are essential road map to design the details of proposal service model.

The questions are as follows:

10. How do you prefer to categorize and organize your digital files? Check all that apply.
    - Based on content (Holiday, ..)
    - Based on data type, e.g audio, video,..
    - Based on date, e.g September 2010
    - Based on relative importance
    - Based on frequency of use
    - Based on average file size (in megabytes or gigabytes)
    - Other:
11. Do you store your data in different places based on your categorization? for example different drives of hard disk, different hard disks, ... Mark only one oval.
    - Yes
    - No
12. If you want to classify your personal data, to how many groups you would like to divide it? [according to its sensibility]?
    - Personal data e.g. financial data, health, banking, government ID numbers, images, video
    - Check all that apply.
    - Two groups

- Three groups
- Four groups
- Other:

13. Could you give a name to each group?
14. According to your defined sensitivity groups, where would you like to store your data? Check all that apply.
    - store all groups on my local device
    - A combination of my local hard drive and one public storage
    - A combination of my local hard drive and more than one public storage
    - Store all in public clouds
    - Other:

4.4.4 Questions About User Feedback

The last part, question 15 and 16 intends to realize users' opinions about the proposal solution model of this research for trust level based data storage among a combination of public and private cloud data storage. Understanding the fact that users prefer to use such system and their opinions about it usefulness is important steps for development of this system. Finally, the last one is a single question, this question try to figure out the relation between general interest of users in technology and the way they treat their data.

The questions are as follows:

15. What is your opinion about a platform with facility for combining and managing your storage from multiple providers? Check all that apply.
    - It won't be useful
    - It could be useful
    - It meets my need exactly
16. Could you specify your reason?
17. What do you feel about new information technologies in general? Check all that apply.
    - Among my peers I am usually the first to try out new information technologies
    - If I heard about a new information technology, I would look for way to experiment it
    - I hesitate to try out new information technologies
    - I strongly avoid to try new information technologies

4.5 Survey Results Analysis

This section presents the results of data collection from questionnaires together with a detail analysis. The results are based on 153 responses that fully completing the questionnaires.

4.5.1 Respondent Knowledge and Usage Level

In the first question that examined the knowledge level of cloud storage services the results are as follows: I have no idea what it is (1%), I heard about it, but not used it at all (11%), and I know it and use them (85%). The summary of results is shown in Figure 4-2. These results show that administration of the survey was in a correct way to reach the appropriate target audience. 99% of the participants had the knowledge about cloud storage; therefore, their opinions are valid inputs for the survey.

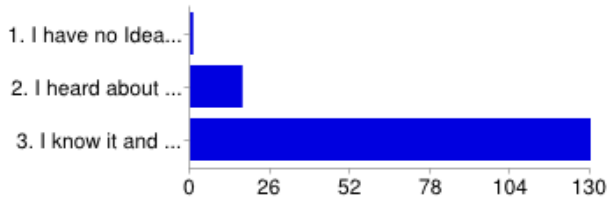

Figure 4.2: Result of knowledge level about cloud storage service

The second and third questions were connected to the first one. The second questions asked from 11% of respondents, who had the knowledge of cloud storage but are not use it, the reason behind not using them. The results are as follows: 7 respondents checked that they do not need extra storage, 11 responses which mention the reason that cloud storage are not trustworthy. This results shows that among who are not using cloud storages 60% have concern about trustworthy, which strengthening the requirements of our proposed systems. The rest of responses are 38 % of users who have low consumptions of data storage.

The third question asked the 85 % of respondents who use these services to find out the most popular cloud data storage. The summary of results depicted in Figure 4-3. These comparison is based on top five popular cloud storage [14, 12] GoogleDrive, Dropbox, iCloud, Box. As it shows in the chart in Figure 4-3 Dropbox with 127 (83 %) responses and Google Drive with 106 (69%) are the top two popular storage among the others. These results are considered for the development phase of our proposed solution.

Answers to the fourth question shows that only 12 percentages of users paid for online storage in general and 86 percentages never paid for additional online storage in any case. This result declares that a combination of the storage in order to use the free capacity of each storage service would be an ideal solution for users who have no desire for extra expenses.

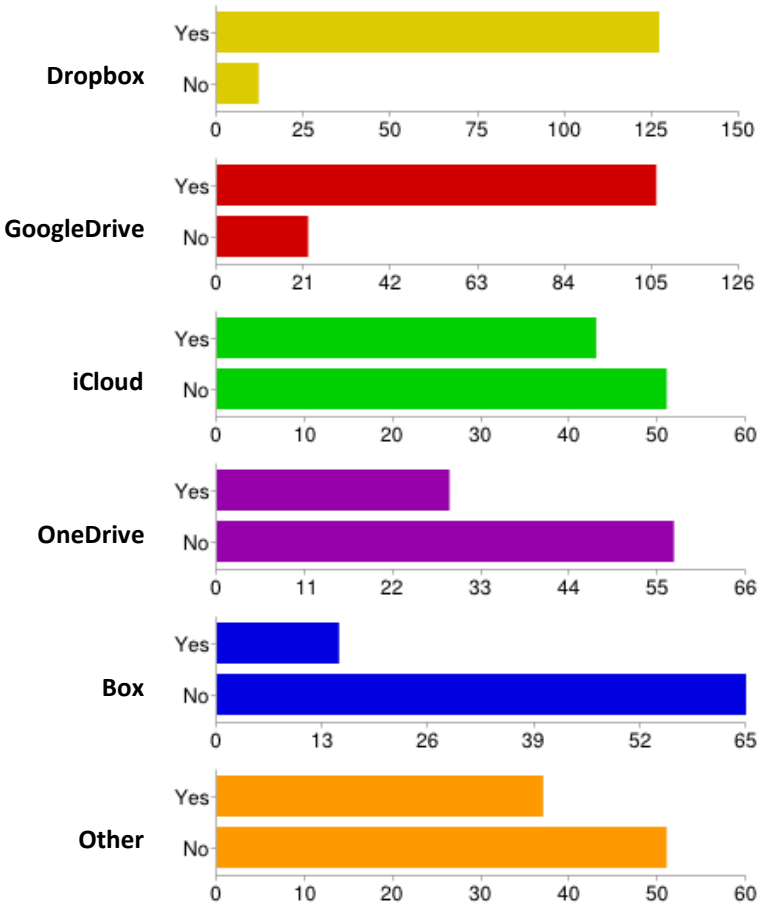

Figure 4.3: Top five popular cloud storages' usages

4.5.2 User Awareness

In this part, in question 5 the respondents decided for 5 categories of data to store in cloud storage or not. The results are as follows: users have the least interest to store financial data and banking document in the cloud with 20 % tendencies, the rest are listed respectively from least to most interest. Health document 24 %, governmental 29%, storing of backs of from local drivers 35 %, personal videos 59 % and personal images 78 %. The summary of the results from this question is provided in Figure 4-4. The differences in the results shows that users are very concern about storing different types data and this in the rationale behind our proposed solution to make this process of storing different categories of data to desire locations faster and easier. It also makes clear that sensitivity levels of data types are various among users and our trust level based storage solution would be fit into these needs of users.

Furthermore, questions 6 asked users to specify their reasons of avoiding data storage in public cloud. There were 82 responses to this question, and these keywords, security, privacy, safety and trust were repeated over 90 % of the answers. It is also worth to mention that

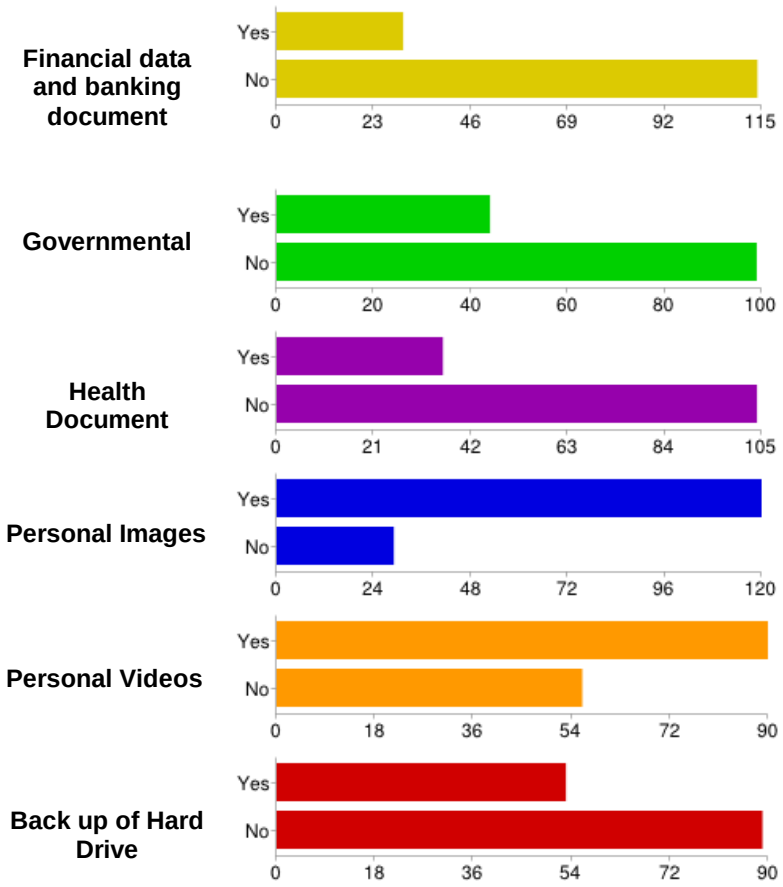

Figure 4.4: Tendencies to store different categories of data in public cloud storage

in reviewing the responses to this question, there were several replays that users said they do not have any digital documents that relates to government, health or financial which is because of the different digital lifestyle between countries. In conclusion, according to these facts, privacy and security are major concerns of respondents who avoid public clouds for specifics files which was conforming to our assumption and finding of related studies.

The next questions (number 7-8) provided interesting results; the numbers of users who are familiar and using local storage or private cloud solution are calculated. Among these solutions, there most popular ones were listed in the questionnaire, Network Attach Storage (NAS), Wuala and Owncloud. The results are listed here, 20% of the respondents uses NAS, 13 % use ownCloud, and 2% use Wuala and 4% use other private solutions. These other solutions which are mentioned in the next open-end question by users are, Evernote, Tresorit, their own server and IntelCloud inhouse SSD base solution.

In the next question users' general feelings about public storage was examined. The results are as follows and summary of them is in Figure 4-5:

- I feel completely safe to use public services and send personal data to them, 10 %
- I think public services show concerns to my data, but there is a small risk that my data is

modified by third parties, 63 %

- Public storage does not have good reputation at all, 29%

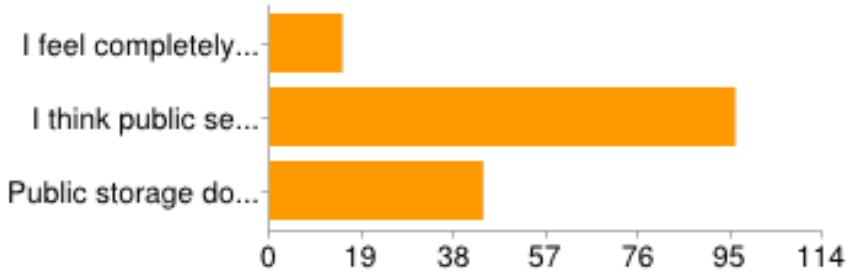

Figure 4.5: Users' general feelings about public storage

In general, these results were according to our expectation and assumption, since around 40% of the respondents also uses private solutions, our proposed solution will be helpful by providing hybrid cloud computing as a feature to our introduced solution to the users.

4.5.3 Data Classification Preferences

This part consists of 5 questions, from 10-14. Question 10 asked about users' preferences in categorization of their digital data. The results are as follows:

- 74 % of respondents were categorized their data based on content (e.g holidays, business, homework),
- 48% based on data type (e.g audio, video, documents,
- 41 % based on data,
- 15% based on relative importance,
- 15 % based on frequency of use,
- 1 % based on average file size and
- 7% of respondents chose other criteria.

Figure 4-6 depicted these results.

After realizing how respondents classified their data, their willingness in storing these categories in various places was the subject of the next question. 75 percentages of respondents have positive opinions about storing their digital files in several places and 24 % were negative Figure 4-7 shows a pie chart of this result.

Question 12 and 13 asked the respondents their behavior to distinguish their data sensitivity. Question 12 examined the numbers of groups that users prefer and the results was

- 18% chose 2 groups

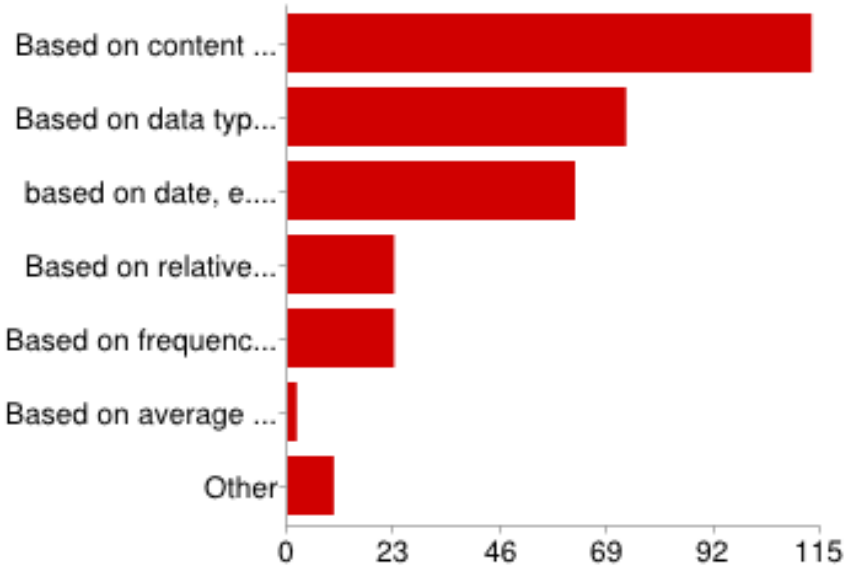

Figure 4.6: Data categorization

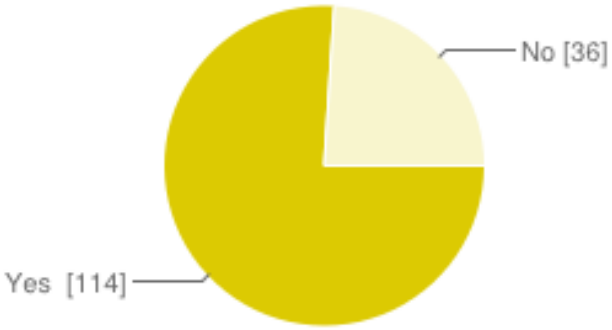

Figure 4.7: Pie chart of users willingness to save files in different places

- 28% three groups
- 37% four groups
- 16% prefers other numbers

Figure 4-8 shows that the largest group is 37 % that chose to have four levels to store their data. In order to validate the results of question 12, in question 13 asked users to specify their chosen group by given a name to each group. There were 99 responses to this open-ended question. Among them 65 responses mentioned names for their three or four desired categories. Although, 37 % of respondents chose to have four groups, only 16 respondents gave names to their favorites four categories and 49 respondents gave names to their three different levels.

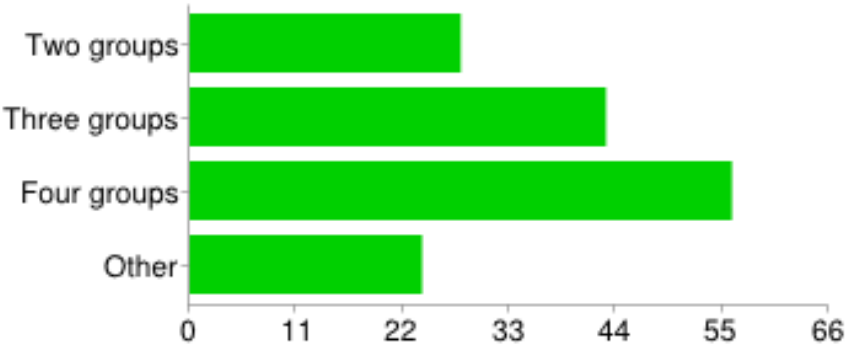

Figure 4.8: Number of groups users prefer to have for their categorized data

Analyzing these 16 respondents declared that majority of these four categories had overlapped, for example by looking at these samples responses, 'private, photos, music, formal stuff 'and this 'important, less important, not important, removable ', in these samples the four categories are not clear enough. But the responses to three categories were more logical than four. Table 1 shows some sample answers to question 13. From these results, we can ratiocinate that respondents who chose three groups were more accurate in responding in these question.

Everyone take it	Kind of private	For my eyes only
Must haves	Nice to haves	Good to haves
Private	Cloud friendly	Too large for cloud
Finance	Pictures	Children
Personal	For friends	Public
Private	Wwork	Shares

Table 4.1: Sample answers for naming the data categories

Finally, the last question in this part aimed to understanding where users' preference location is to store their defined sensitivity levels of data. The results to this question are as follows:

- Store all groups on my local device 31%
- A combination of my local hard drive and a public storage (e.g. my hard drive and one cloud storage) 33%
- A combination of my local hard drive and more public storages (e.g. my hard drive and two different cloud storage) 25%
- Store all in public clouds 4 %
- Other 10%

These results are gathered in Figure 4-9.

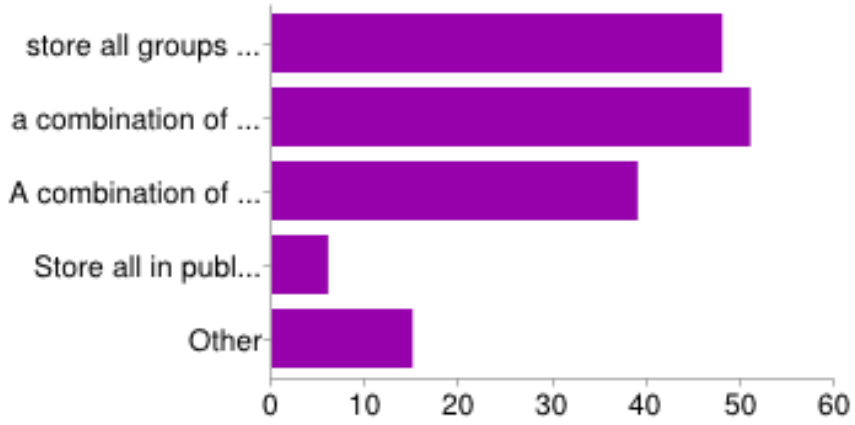

Figure 4.9: Where to store categorized data

4.5.4 Users' Feedback

In this part introduced solution of this research study has been pre-evaluated by collecting opinions of the respondents about the idea behind the proposal service. One of the elementary design principles of the proposed model is the combination of storage from multiple providers, which is questioned here. Only 20 % of respondents marked that this services will not be a useful services, 67 % marked that it could be useful and the rest of respondents answered that this services could meet their exact needs, Figure 4-10 shows these results.

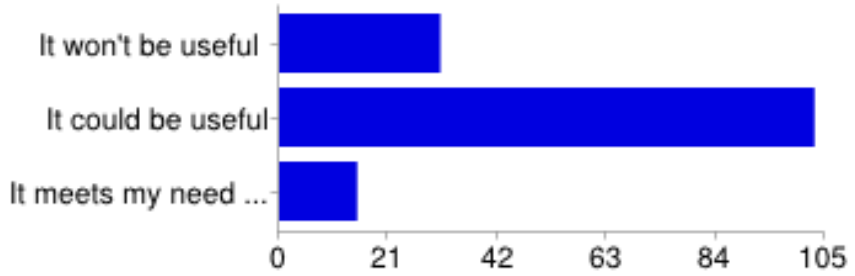

Figure 4.10: Users opinion about the idea behind the proposal service of this research study

In the next question, asking respondents to specify their reasons behind their opinion of usefulness of such a system. 68 responses wrote more details about their opinion, for instance, the reason for not using such a system mainly were: unable to trust an unknown providers, single point of failure and avoiding tiresome management, etc. In addition, the main reason to show interest in this feature were: better overview and organization, saving time and efforts, increase effectiveness.

In general, having over 80% positive reactions to having a platform with the combination of multiple provider was another motivation and supporting for our proposed services. The questionnaire end up with a departed questions, which also important since it shows us the

interested of our target groups to experience new technologies. As the result shows,

- 29 % are highly interested in trying new technologies,
- 67 % are looking to ways to experiment new things,
- 14% are less interested for new information technologies
- 2 % are avoiding new technologies

This results also very important since it shows the validity of our evaluation of the target respondents. For sure, people with enthusiasm toward new technologies are the right target toward having the opinion for design system.

4.6 Chapter Conclusion

This chapter discussed details of survey administration to find out the exact requirements for our introduced solutions. After analyzing the results, the main answers to main questions were highlighted. Users would prefer to divide their data storages to four different levels. Dropbox and Google Drive and iCloud are considered the top three public cloud storages to mount as external storages for our solution.

5 Prototype Development

"knowing is not enough,we must apply
willing is not enough,we must do.."

—Johann Wolfgang von Goethe

This chapter is set out in details the development of a prototype for our introduced solution for trust level based cloud storage. The software development process of the prototype, requirements specification, design principles and fine detail of implementation are gathered in this chapter.

5.1 Objective

The aim of this chapter is to develop a prototype system based on a method for trust level-based data storage. According to the basic concept of our study, a survey questionnaire was administered and the results were presented in the previous chapter. After having the basic requirements of our intended system, the details requirements had been gotten from the results and analysis of the survey study.

For the ease of use, in the rest of this chapter, this prototype is called Color Drive.

5.2 Requirements

The requirement of Color Drive consists of two main parts, the basic requirement that introduced in the starting point of the project and the complementary requirements that gathered from survey study.

5.2.1 Basic Requirements

As described above, the main goal of Color Drive is to provide the functionality to have trust-level based data storages and access. In addition to this, there are several basic requirements that this prototype need to fulfill. These basic requirements were mainly retrieved from task description of this thesis study. A list of these requirements is in the following:

1. Security and confidentiality:The ability to store, exchange and share data in a secure way
2. Privacy-level awareness technique to data storage
3. Support of multiple users
4. Support of user groups (data sharing)
5. Provide the feature to have multiple level of trust
6. Enable user to set up the trust-level of storage location
7. Easy to use and intuitive user interface
8. Capability to implement in resource constrained devices (e.g. Raspberry Pi) [1]

5.2.2 Complementary Requirements

Analyzing the survey results and users preferences leaded to have more details of the requirements, First of all, Color Drive needs to supports up to four levels of trust based. Second, for these levels besides users' own premises additional storages have been chosen by their popularity ranks.

5.2.3 Basic Functional Principle

According to our requirements list, Color Drive performs data storage based on users 'classification of data and the assigned trust levels of each group of data. In order to have an intuitive user interface and easy to use system the trust level storage locations are specified by specific colors. An example interpretation of colors is explained here; however, this explanation is according to each user's preference and can be assigned completely differently to each user.

- Green: storage of data in own premises
- Yellow: storage of data in trusted locations
- Blue: storage of encrypted data in public cloud
- Red: storage of data in non-trusted locations

This assigning of colors to different storages needs to be done once by users. After that, users just need to selects the colors and users do not need to decide in which data storage location the data will be stored. As shown in Figure 5-1 Color Drive provides a multi-platform access management system and give the opportunity to users to configure and manage between these platforms. Once the users set these trust levels by assigning colors then uploading files is based on choosing colors, Figure 5-2 demonstrates the intuitive user interfaces where users needs to play only with colors instead of names. Figure 5-1 and 5-2 are example demonstrations of three levels and three colors.

[1] Raspberry Pi is a small single-board computer, http://www.raspberrypi.org/

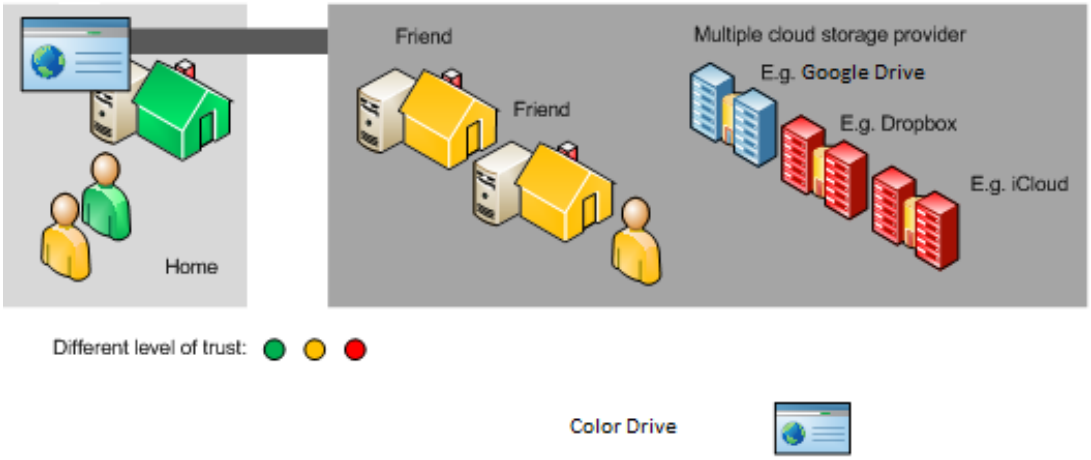

Figure 5.1: A overall visualization of the concept behind Color Drive prototype

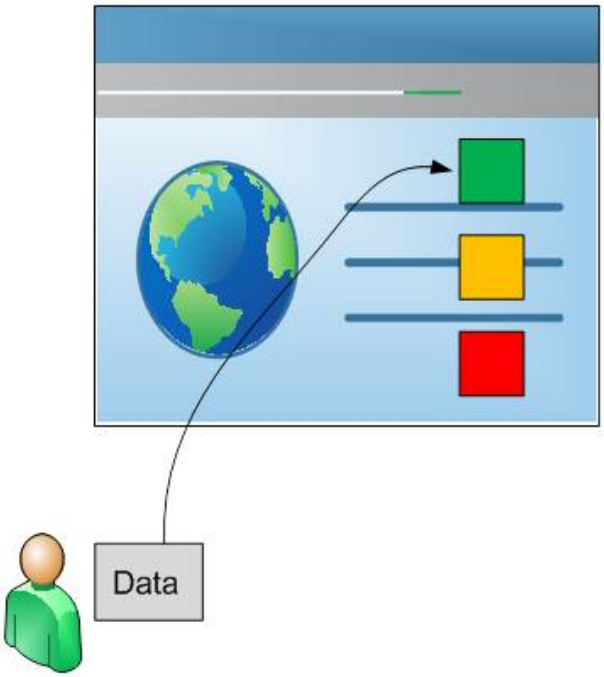

Figure 5.2: An intuitive user interfaces where users selects colors

5.3 Requirement Analysis

Considering the goal of this thesis work, developing our system from scratch is out of scope of this work. Therefore, we need to choose among open source on-premise cloud data storages

which are able to satisfy the basic requirements of the Color Drive. After precise reviewing of available solutions, ownCloud has been chosen. A minute detail of this comparison between available solutions is summarized in a table in appendix 3. According to that table, ownCloud [2] had been selected based on better reputation, availability and also the following reasons.

- ownCloud is open source and free
- ownCloud provide Encryption features which help us to have a reasonable level of confidentiality
- ownCloud can be implemented in wide range of operating systems, such as Mac, Windows, Linux and Raspberry Pi. As mentioned in basic requirements, the ability to run in Raspberry Pi is also important.
- ownCloud support multiple users and user groups
- ownCloud community provides acceptable documentation and their forums and IRC channels are actively responding to developer's problems. And it is in actively development phase. They regularly provided new updates and new versions.
- According to [3] ownCloud has a highest popularity rank among others
- The ability to support the communication with other storages

In addition to this, a detail description of the ownCloud is provided in the following section.

5.3.1 owncloud Overview

ownCloud is a software system for file hosting, data storage and data synchronization. It provides the facility of storage as a service features for private cloud computing, in order words ownCloud provides the same facility as Dropbox, and enable access to data from any device but important difference being that it can be installed and operated in personal server without storage capacity limitations.

The ownCloud software package is parted into two related partition, ownCloud server software and client software. The ownCloud server mainly consists of PHP code which hosted by a web server. It mainly runs on Apache servers but it is possible to install it in other servers as well such as Microsoft Internet Information Server, Nginx, Lighttpd, Yaws, and Hiawatha. The database for installing metadata including access rights, shared files information (are SQLite, MySQL and PsotgreSQL which can be changed depend on installations size for smaller. As described before, ownCloud can be run in wide range of operating systems, various versions of Linux, Raspian, Windows, and Mac. In the ownCloud server software in addition to core features, a list of additional features can be added to it by installing internal and third party "Apps", for instance server side encryption, ability to mount external storage (storage from other providers) and file versioning. Developing third party Apps make it possible to extend the ownCloud functionalities and tailored it according to ones needs. The ownCloud software uses a Model-View-Controller (MVC) architecture with additional Hooks that enable providing

[2] owncloud.org
[3] alternativeto.net

further functionalities. [45, 38, 23]

On the other hand, the ownCloud client software has a web interface and several desktop and mobile clients to access to stored content. Moreover, it has a WebDAV interfaces to access file system for other standard-based tools. Figure 5-3 shows snapshot of ownCloud web interfaces.

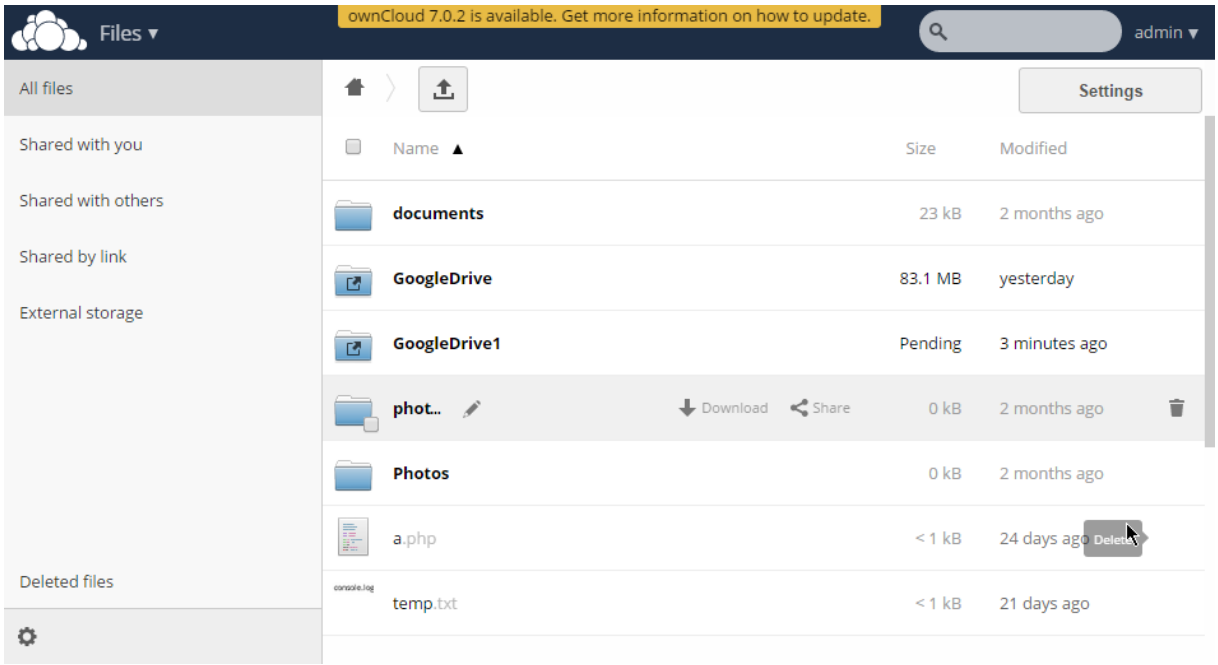

Figure 5.3: An example of ownCloud web Interface

5.4 Design

This section takes into consideration the requirements from previous section and identifies the specific design for the developing the prototype. In the design process the specifications of the Color Drive artifact is created in a way that the system could be able to fulfill all of its primary requirements and accomplish the thesis goal.

From the requirements it has been possible to find out two main features to be added to ownCloud to accomplish the mission. First the ability to assign colors to external storages and the ability to select security levels in the file uploading phase. These activity diagrams in the following figure 5-4 and 5-5 show the overall flow controls need to be implemented.

After examine the ownCloud architecture and structure in detail, the exact points for starting the development of Color Drive were recognized. Figure 5-6 shows the overall structure of the ownCloud file system. In order to add the two desired features, manipulating codes in two identified ownCloud internal applications is necessary, which are "Files" and “External Storage Support". Former is responsible for file and folder handling and latter performs mounting external storage to ownCloud file system. These applications are located in the "files" and ’files-external" folders in "apps" folder of ownCloud. Figure 5-7 and 5-8 show the layout of

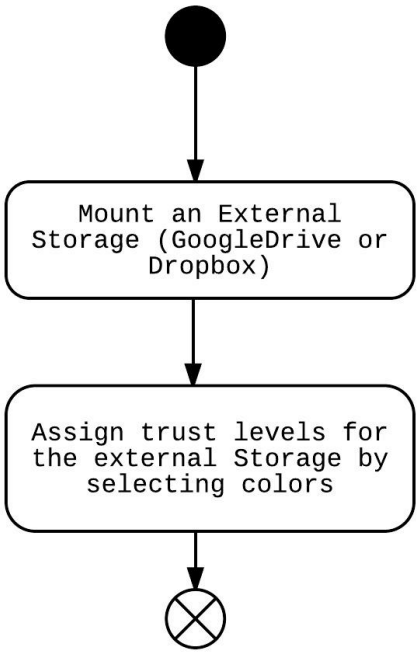

Figure 5.4: Activity diagram for assigning colors to external storages

ownCloud 'files' and 'files-external' apps.

5.5 Implementation

This section focus on how to implement the defined designed in the previous section. The prototype will be implemented as an extension of ownCloud, since the ownCloud is written in PhP, the rest of implementation is in PhP together with, Javascript, jQuery, Ajax, HTML CSS.

The environment specification for the implementation phase is summarized in the following Table 5-1. In the beginning the implementation was in ownCloud version 6 and it upgrade to the latest version at the time of writing that was 7.0.02. In the implementation phase ownCloud was hosted in a standard LAMP stack environment (Linux, Apache, MySQL, PhP) on Linux machine with Ubuntu 14.04 operating system with Apache webserver 2.2 and MySQL 5.6.

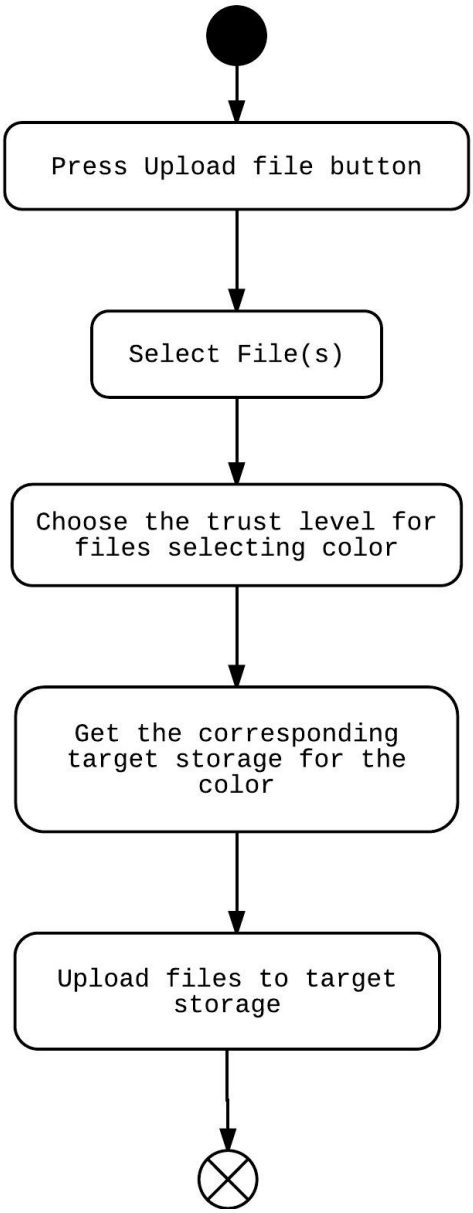

Figure 5.5: Activity diagram for selecting security levels in the file uploading phase

Operating System	Ubuntu 14.04
Web Server	Apache 2.2
Database Server	MySQL 5.1.61
ownCloud	Version 7

Table 5.1: The environment specification for Implementation phase

5.5.1 Implementation limitations

As it mentioned previously, the respondents chose to have four levels of trusts. In the other hand, Dropbox, Google Drive and iCloud, as top three popular public cloud storages were

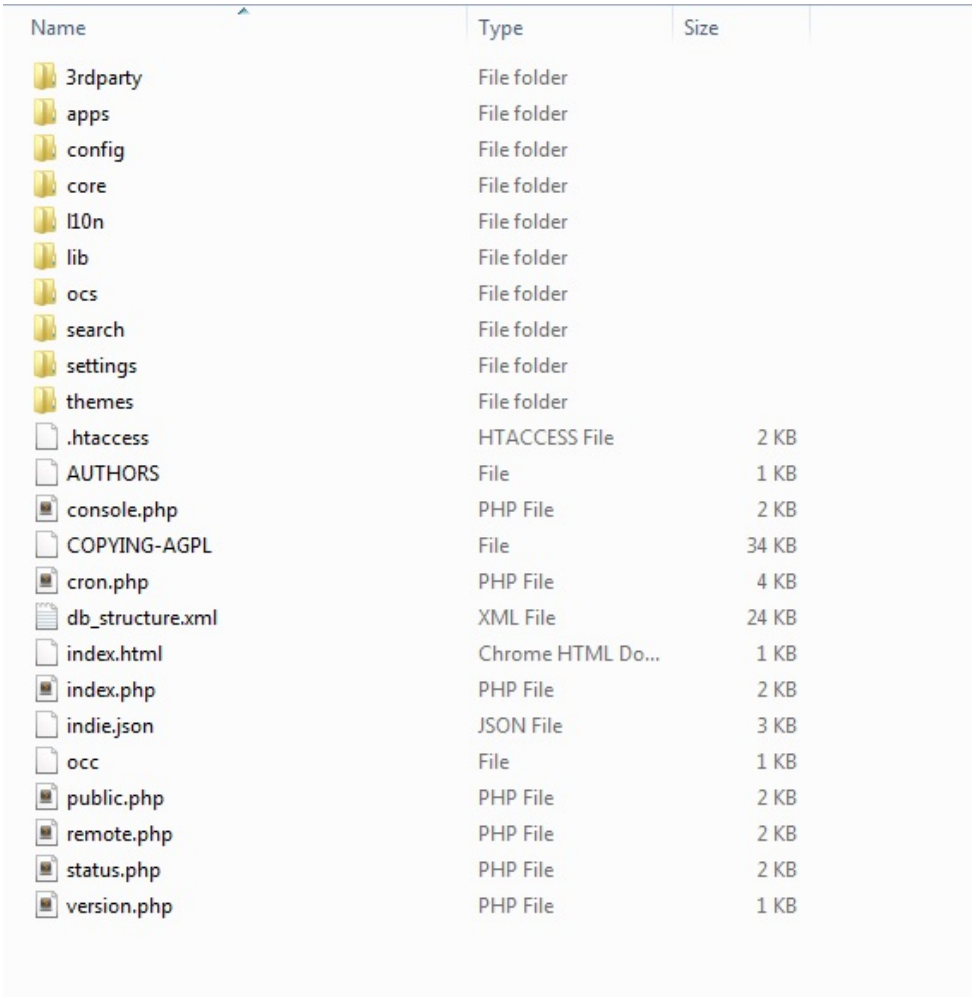

Figure 5.6: The overall structure of the ownCloud file system

selected to add to our solution. Each external storage have to be implemented separately since they have every cloud storage has its own specification. The implementation of adopting each of this public storage with our system requires considerable time and efforts. Due to our time limitation for this master thesis only Dropbox and Google Drive are adopted to be the Color Drive implementation.

5.5.2 Persisting of Users Configuration

One of an important issues to implementing our prototype is handling each user's configuration. ownCloud 7 provides a mechanism for saving configuration data. These data can be saved as global, app and user settings:

1. System values: The global configuration can be saved, read and modified in "config/config.php".

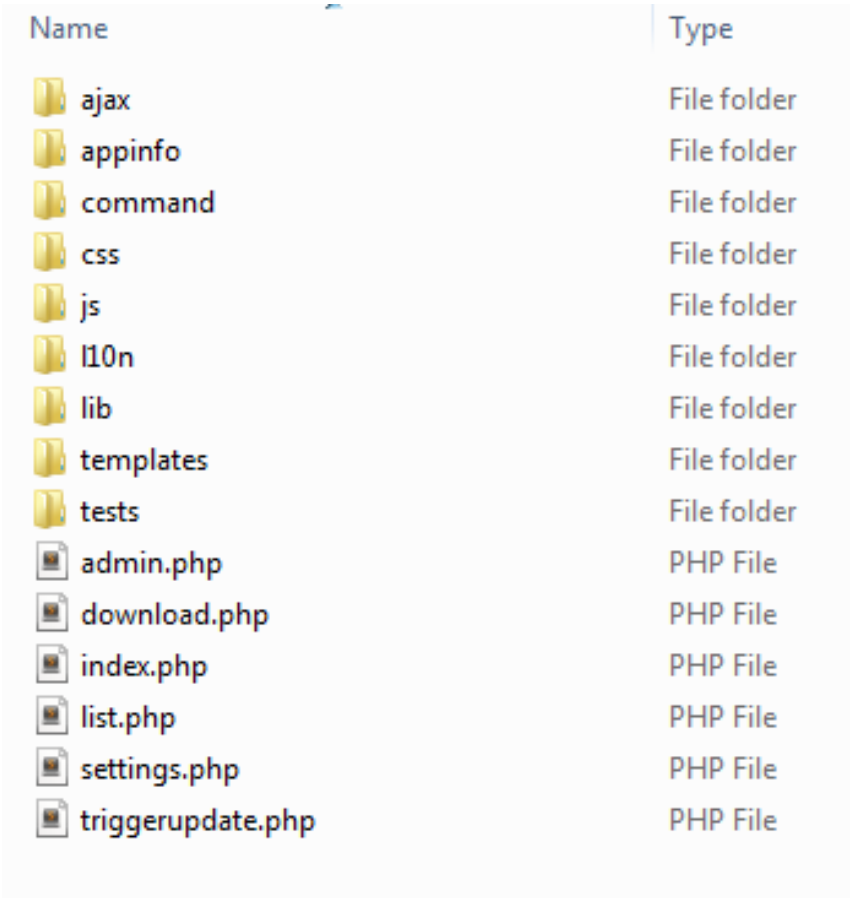

Figure 5.7: The layout of ownCloud 'files' application

2. App values: Application settings can be saved in the database as app values.
3. User values: User specific settings also are saved in the database.

The third type of configuration values are utilized to save trust level colors and its target external storage for each user specific settings. "ConfigService" is a utility class in ownCloud which handles getting and setting user values several times in our implementation.

5.5.3 Assigning Colors to Mounted External Storages

In this section the implementation of assigning a trust level color for mounted external storages to ownCloud is explained. To make the steps more clear the activity diagram from design section is expanded here in Figure 5-9.

In this section the implementation of assigning a trust level color for mounted external storages to ownCloud is explained. As mentioned earlier, the "External storage mount" is used for mounting and unmounting external storages. The target external storages for this implementation are Google Drive and DropBox. ownCloud itself is considered as one of the storage

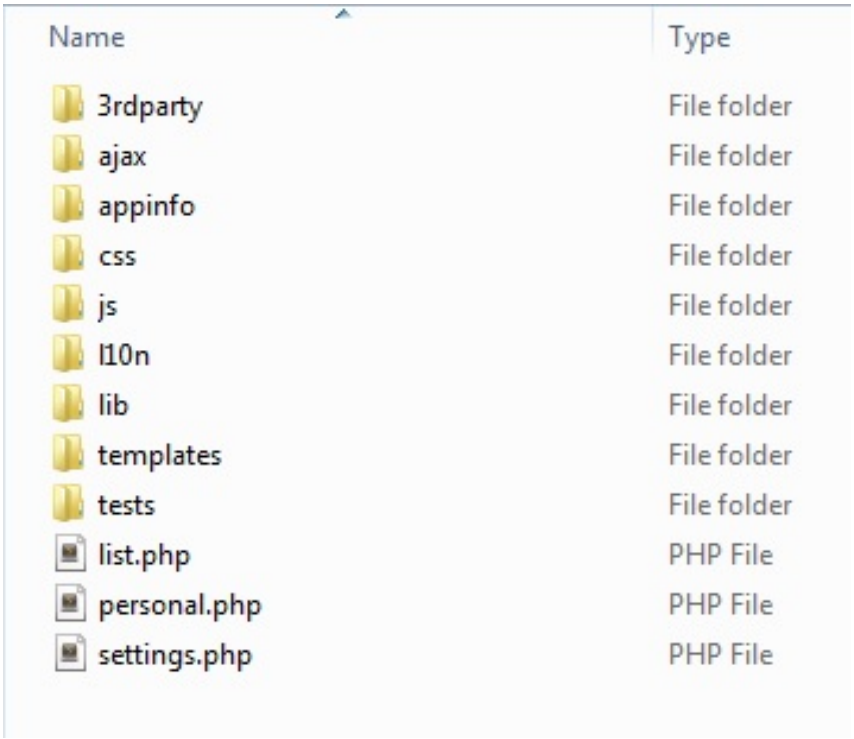

Figure 5.8: The layout of ownCloud 'files-external' application

which can get a color; whereas it is not shown in the list of external storages, in the first step it is required to add ownCloud in a list and enable to select a color for that. Although, in this implementation the highest trust level for ownCloud is required, since all other storage action is based on it, to show a complete proof of concept this ability to assigned the desire color to ownCloud is also added to Color Drive prototyping.

In the "template" folder consists of of setting file, "settings.php", which adds visual components for mounting external storages. This list is only for "externals" but because ownCloud is an internal storage, it is added as "Internal storage" title. The HTML code of this can be found in appendix 1-part 1.

The "js" folder contains settings.js which adds required event handler and functionality to setting.php template file. The logic for assigning a color to a drive is according to activity in figure 5-9 diagram. If a color is already selected for a storage it will be displayed in front of the storage and the drop-down for color selection is disabled. If there is no color selected for drive then drop-down is enabled. The corresponding script for this part is added to appendix part 2.

To be able to share and reuse the code for assigning, removing and checking trust level colors, "colorsConfigUtility.js" is developed. It interacts with "colorsConfig.php" through ajax calls and provides the required functionality. For example, if a selected color is already assigned to another drive an error message will be displayed to the user. The script code of "colorsConfigUtility.js" is as follow. The "colorsConfig.php" is attached in appendix part 3.

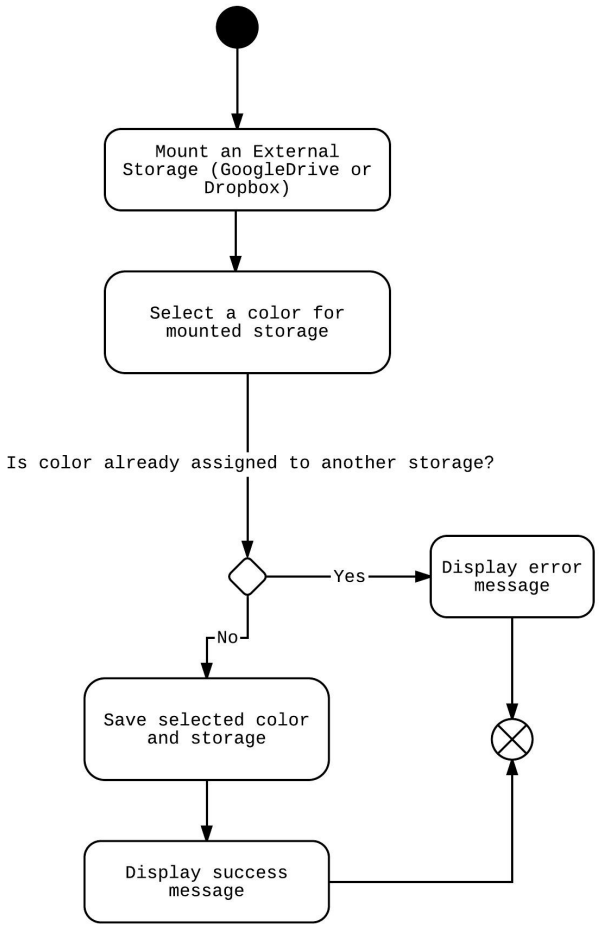

Figure 5.9: Detail activity diagram for assigning a trust level color for mounted external storages

Listing 5.1: "colorsConfigUtility.js"part one

```
<script>
 var colorsConfigUtility = {
     colorHandler: function(mountPoint, selectedColor) {
       $colors = $.ajax({
         url: this.getAjaxUrl('colorsConfig'),
         data: {
           mountPoint : mountPoint,
           selectedColor : selectedColor,
         }
       }).done(function(response) {
         if (response.data.exist) {
           OC.Notification.show(" " + selectedColor + " is already selected for
               another storage ("+ response.data.value +"). Select another color.")
               ;
           setTimeout(function() {
             OC.Notification.hide();
           }, 3000);
         } else {
           OC.Notification.show("Successfuly assigned " + selectedColor + " to " +
               mountPoint);
           setTimeout(function() {
             OC.Notification.hide();
           }, 2000);
         }
       });
     },
```

Listing 5.2: "colorsConfigUtility.js"part two

```
1       removeMountPointColor: function(mountPoint) {
2         $colors = $.ajax({
3           url: this.getAjaxUrl('colorsConfig'),
4           data: {
5             mountPointToRemove : mountPoint
6           }
7         }).done(function(response) {
8           OC.Notification.show("Successfuly removed " + mountPoint);
9           setTimeout(function() {
10            OC.Notification.hide();
11          }, 2000);
12        });
13      },
14
15      getAjaxUrl: function(action, params) {
16        var q = '';
17        if (params) {
18          q = '?' + OC.buildQueryString(params);
19        }
20        return OC.filePath('files_external', 'ajax', action + '.php') + q;
21      }
22    };
23  </script>
```

On removing an external drive, the assigned color also will be removed to be able to add that to another storage. This also is handled in "settings.js".

The "setting.php" template file includes all available options for adding external storages such as "Amazon S3 and compliant", "OpenStack Object Storage" and some more. The security level color should be available to select for Dropbox and Google Drive, so it can not be added to "setting.php" as a general option for all storage types.

In the "js" folder, there are two javascript files Dropbox.js and googledrive.js which handles mounting storages for Dropbox and google. The visual component (drop-down) is added in these files.

The logic for assigning a color to a new added external storage of type Dropbox and Google Drive is the same as ownCloud. All of these scripts can be found in appendix 1 part 4.

Figure 5-10 shows the web interface result of this implementation.

5.5.4 Select Trust levels When Uploading Files

In this section the implementation details for uploading files is presented, in this part also the activity diagram from design section is expanded to make the steps more clear Figure 5-11 shows this activity diagram.

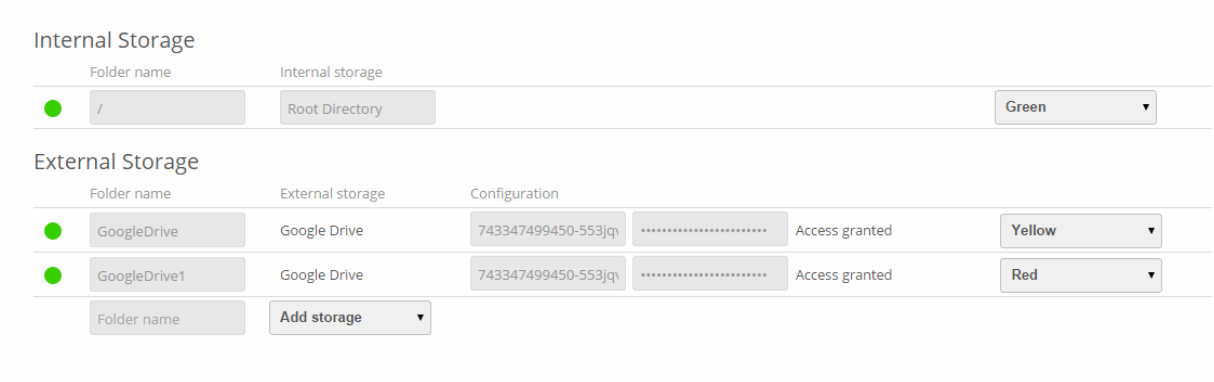

Figure 5.10: Screen-shot for assigning colors when mounting external storages

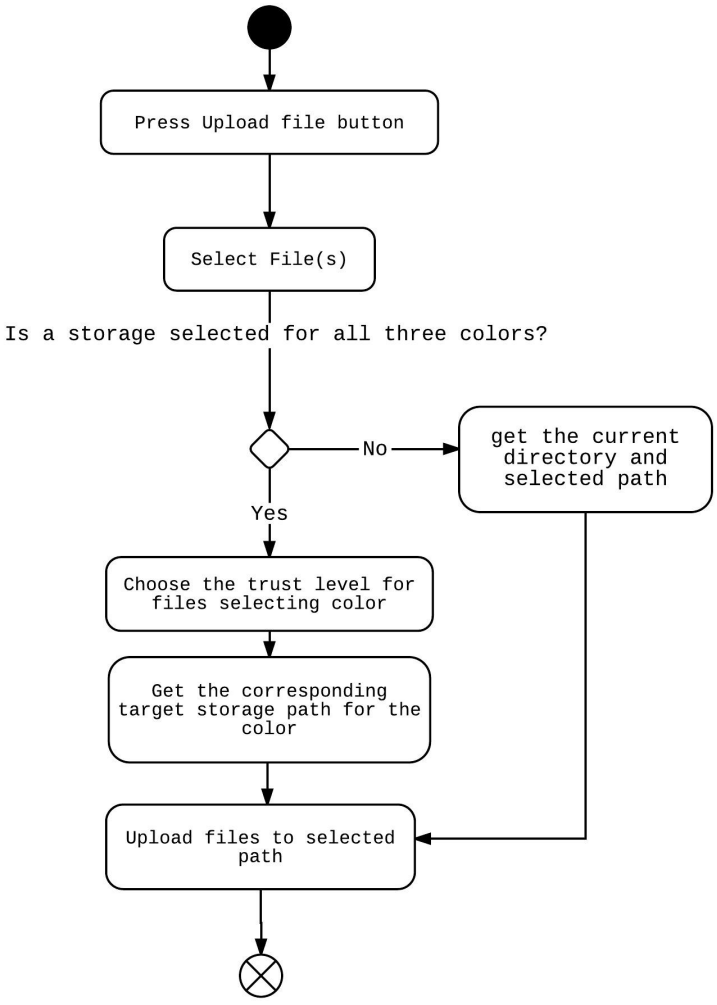

Figure 5.11: A detail activity diagram for selecting trust levels when uploading files

As in all ownCloud applications, template files contains views. The "list.php" is target file

for adding new visual components. Three new components are added to this file: "Settings" button, "Settings" dialog window which is displayed by pressing "Settings" button, and "Security Level" dialog window which is opened after selecting a file to upload. The following is code snippet for setting component, the code for others can be found in the appendix 1 part 5. Styling files also are located in css folder, the styling lines that are added to upload.css are also added in appendix 1.

Listing 5.3: Code for setting dialog

```
1
2  <div id="settings_dlg" title="Settings" style="display:none">
3    <p>Selected target storage for each security level</p>
4    <li id="green">
5      <label>Green Level</label>
6      <div class="to-right"><label id="green_drp" class="mount-point">Not Assigned</
         label></div>
7    </li>
8    <li id="yellow">
9      <label>Yellow Level</label>
10     <div class="to-right"><label id="yellow_drp" class="mount-point">Not Assigned</
         label></div>
11   </li>
12   <li id="red">
13     <label>Red Level</label>
14     <div class="to-right"><label id="red_drp" class="mount-point">Not Assigned</
         label></div>
15   </li>
16 </div>
```

After adding the visual components, the relevant classes that are involved in uploading files process to customize them according to our needs are figure out. The following the detail of implementation is described. All javascript files are placed in js folder, for uploading files "file-upload.js" interacts with 'blueimps' jQuery file upload library (jQuery File Upload Plugin 5.32.2) to provide file uploading functionality. It contains required methods and handlers for different actions for instance: adding files for upload, canceling uploading files, handling conflicts between files and Etc.

For adding new files there is an add method, it is needed to modify this function to display "Security Level dialog" before passing files for upload. To run ownCloud smoothly, first all colors are checked to have a corresponding external storage, if all colors have values then "Security Level dialog" will be displayed else the normal upload flow of ownCloud will be followed and uploaded files are added to current path.

To check all colors, an ajax call is made to config.php which is responsible for retrieving external storages assigned to each color. When all colors are set then the "Security Level dialog" will be displayed and selected color is kept. There is another method as "submit" method which submits all added files for uploading. The selected color is passed as one of the parameters in ajax request to the 'upload.php' file.

Another part of "file-upload.js" which runs right after the 'Files' application starts, is an ajax call which gets all colors and assigned values to be displayed on "Settings" dialog. The follow-

ing piece of JavaScript codes shows these calls.

Listing 5.4: ajax call to get all colors and assigned values to be displayed on "Settings" dialog

```
<script>
  // *** get selected color info to display
  $colors = $.ajax({
    url: getAjaxUrl('config'),
    data: {
    }
  }).done(function(response) {
    console.log(response.data);
    if (response.data.green !== "") {
      console.log(response.data.green);
      $('#green_drp').text((response.data.green == "/") ? "ownCloud" : response.data
          .green);
    }
    if (response.data.yellow !== "") {
      $('#yellow_drp').text((response.data.yellow == "/") ? "ownCloud" : response.
          data.yellow);
    }
    if (response.data.red !== "") {
      $('#red_drp').text((response.data.red == "/") ? "ownCloud" : response.data.red
          );
    }

    $('#settings_dlg').dialog({
                autoResize: false,
                autoOpen: false,
                position: 'center',
                draggable: true,
                minWidth: 500,
                buttons: {
                  "Close": function() {
                    $(this).dialog("close");
                  }
              }
     });
  });

  function getAjaxUrl(action, params) {
    return OCA.Files.Files.getAjaxUrl(action, params);
  };

  $('#settings_btn').click(function() {
      $('#settings_dlg').dialog('open');
  });
</script>
```

To clarify more "upload.php" and "config.php" are reviewed here. "upload.php" handles uploading files on server side. It receives selected color for each file (if any) and then gets corresponding external storage path for that and uses that path to upload files. As mentioned before, "ConfigService" is an inner class in "upload.php" and helps to retrieve assigned external storage path to each color. The “class ConfigService” can be find out in the following PHP code.

Listing 5.5: class ConfigService hadeling configuration per user

```php
<?php
  class ConfigService {

      private $config;
      private $appName;

      public function __construct(IConfig $config, $appName){
          $this->config = $config;
          $this->appName = $appName;
      }

      public function getUserValue($userId, $key) {
          return $this->config->getUserValue($userId, $this->appName, $key);
      }
      public function setUserValue($userId, $key, $value) {
          $this->config->setUserValue($userId, $this->appName, $key, $value);
      }
  }
?>
```

For handling user configuration we add config.php. The "config.php" file is an added file in ajax directory. It contains the required functionality for checking whether all colors are set and getting values for each color. The rest of the code for this part is attached in appendix part 6.

The following screen-shots in figure 5-12 and 5-13 shows the web interface for setting button and uploading files.

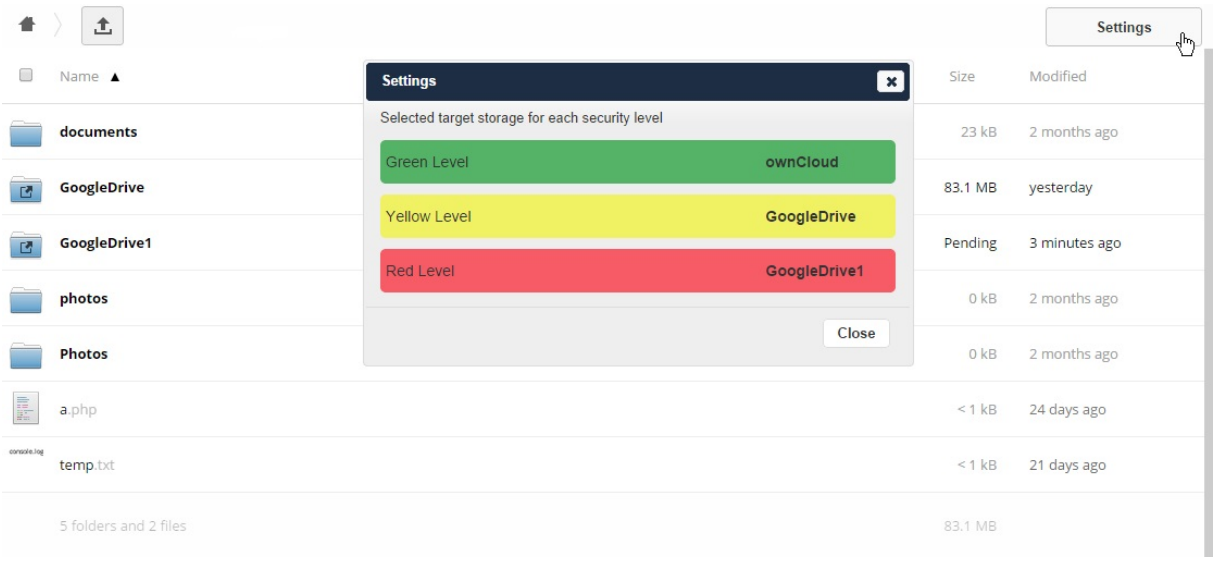

Figure 5.12: Setting button to display user configurations

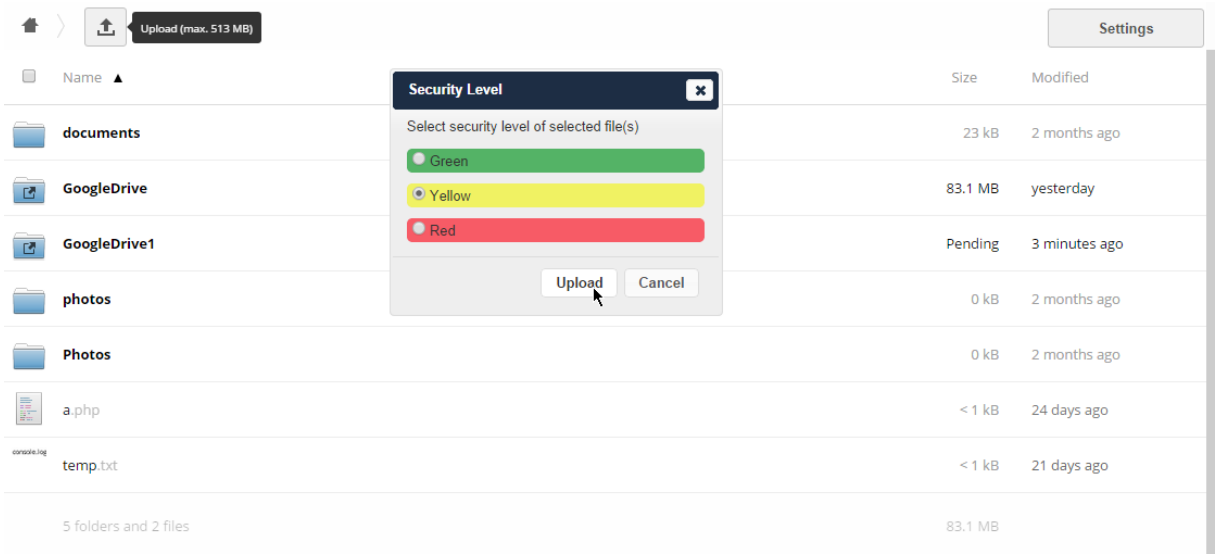

Figure 5.13: Screen shot upload file procedure

5.5.5 Runs on Raspberry Pi

After successfully developing Color Drive, the software artifact also run on Raspberry pi. After installing ownCloud on Raspberry Pi, it works completely on it.

5.6 Chapter Conclusion

In this chapter the specification of the development process of a prototype artifact is presented. The screen shots of the developed artifact presented at the end that are demonstrated a proof to the proposed concept.

6 Evaluation

"What is now proved was once only imagined."

— William Blake

In this chapter the requirements elicited in previous chapter are compared to the result of the implementation part in order to evaluate the developed prototype and demonstrate the soundness of our solution.

6.1 Requirements

In order to do the evaluation based on requirement specification of the prototype, the list of the requirements are recapped in the following:

1. Security and confidentiality:The ability to store, exchange and share data in a secure way
2. Privacy-level awareness technique to data storage
3. Support of multiple users
4. Support of user groups (data sharing)
5. Provide the feature to have multiple level of trust
6. Enable user to set up the trust-level of storage location
7. Easy to use and intuitive user interface
8. Capability to implement in resource constrained devices (e.g. Raspberry Pi)
9. Color Drive needs to supports different levels of trust
10. For these levels besides users' own premises two additional storages have been chosen which are Dropbox and Google Drive.

6.2 Features of ownCloud

To develop a proof of concept to our novel trust level based data storage, we have chosen owncloud, an open source software project. OwnCloud feature lists are gathered in this part, in order to compare our requirements and owncloud features. These features have been gathered from ownCloud documentations [2].

- Access to data: Store files, folders, contacts, photo galleries, calendar, etc on the server of your choice, Later you can access it from mobile, desktop, or web browser.
- Sync data: In the world of gadgets, a normal person has tablet, smart phone, laptop, etc. ownCloud lets you sync all your files, contacts, photo, calendar, etc synced among the devices.
- Share data: In the era of sharing via Facebook, Twitter, Google+, etc, ownCloud lets you share your data with others and share them publicly or privately as per your needs.
- Access external storage: Mount external storage to your ownCloud with Dropbox, SWIFT, FTPs, Google Docs, S3, external WebDAV servers and more.
- Encryption: Enable the encryption app to encrypt data on external storage for improved security and privacy.
- Easy user interface lets you manage, upload, create user, etc in a very easy fashion.
- The search feature in ownCloud is very responsive which is done in background and lets user search by name as well as file type.
- Contacts are organised in categories/groups hence easy to access contacts on the basis of friends, co-worker, family, etc.
- Easy to migrate to/from other ownCloud server.

6.3 Requirements Verification

In the previous section the requirements and ownCloud features were reviewed. This section compares the result of the implementation to the requirements list, it also take into consideration the ownCloud features.

6.3.1 Security and Confidentiality

The security consideration of our prototype is based on ownCloud security feature. ownCloud uses encryption to protect data and provide privacy. ownCloud uses encryption in two major ways: when transferring data to and from the server; and while storing data on an external server [43]. For encrypted data on ownCloud, it is required to enable the ownCloud "Encryption app". One of the main reasons to use the Encryption app is to protect data when they are stored on the mounted external storage. All data sent to external storages can be encrypted by the ownCloud server, and upon retrieval, decrypted before sending them back to users or sharing. The key to decrypt the data stays in the ownCloud server. By this feature of owncloud "Encryption app" it ensures security and privacy of exchanging data when communicating with external services like Dropbox and Google Drive.

It is worth to mention that, according to fundamental principles of information security, it is not feasible to have a system that guarantee security [9] and we are aware of the potential security issues and vulnerabilites of owncloud [38] and [58]. However, the current level of security in ownCloud satisfies what we need for this prototype development.

6.3.2 Privacy-level Awareness Technique to Data Storage

This requirement, to aware users about their privacy is fulfilled when they need to assign colors to each storage. By this technique users first are aware about privacy and security of each storages and then have a right to choose among different levels.

6.3.3 Support of Multiple Users and Sharing

These two requirements also are satisfied with ownCloud feature. ownCloud administrators can manage users and group of users via the web interface with Group Admin feature of ownCloud [44]. File sharing that enables sharing by groups, sharing off/on based on groups are parts of ownCloud. Moreover, admin can force users to set a password or an expiration date when they create shared links.

The developed solution also supports these requirements, it allows to save different levels and corresponding storages in a user level by exploiting user level configuration storing of ownCloud.

6.3.4 Multiple level of Trust and Set up the Trust Level of Storage Location

In the developed artifact, user can have three different storages and assign colors to them. Therefore, our prototype fulfills having multiple level of trust, since users can give different colors to different storage according to their individual preferences and have a trust-level based storage.

6.3.5 Easy to Use and Intuitive User Interface

Choosing only colors and neglecting names, make the interface very user-friendly and intuitive. Users only needs to assign colors to each storage ones and after that the only concern is to remember colors which is straightforward.

6.3.6 Capability to Implement in Resource Constrained Devices

The implementation of provided prototype was tested on Raspberry Pi as a sample of such a device. An instance of ownCloud was installed on Raspberry and all required changes were

applied and configured. The ownCloud instance including developed solution worked successfully as expected on Raspberry Pi. Therefore the artifact can be enabled on resource constrained devices as well.

6.3.7 Supports Different Levels of Trust

As mentioned in previous chapters the provided solution enables to add two types of external storages which are Google Drive and DropBox instead of four due to our time limitation. Although it is possible to add more types of external devices, currently this solution only works for these two types. Adding ownCloud itself to this set and considering the fact that each drive will be assigned a different trust level, the artifact fulfills the requirements to having three levels of trust.

7 Conclusion

"Knowing too much of your future is never a good thing."

—Rick Riordan, The Lightning Thief

7.1 Conclusion

The data that is being generated by users is increasing daily and maintaining the personal data storage hardware is costly. Cloud data storage is getting popular for their user friendly and cost effective features. On the other hand, user privacy violation is the main obstacle for massive adoption of cloud storage.

The recent growing interest in both public cloud storage services and private local storages, is extremely in the demand of the solutions that are focusing on privacy awareness of the users. Increasing the security and privacy related problems in cloud storages indicates a demand for an immediate action to improve the security of personal data and to increase privacy awareness.

In this thesis study, a novel trust level based solution for cloud data storage has been introduced. This solution emphasizes in utilizing hybrid cloud technologies. It provides a simple user interface based on colors and it gives the possibility of selecting the storages places very easily and efficiently. Finally, with these aforementioned features of our solution, it has a valuable source of differentiation among other solution.

In addition, to answer the first research question, "What are the current demands of cloud storage users?" and to have a detail requirements of our solution a survey study based on questionnaire had been administered. The questionnaire had been distributed among Internet users and the results consists of 150 responses have been gathered. After a detail review of the results, we realized the interest of users to have up to four levels of trust for our trust level based storage. In addition, we figured out from questionnaire that the top three cloud storages that users prefer to use are Google Drive and Dropbox and iCloud.

Furthermore, to satisfy the second research question "How to design a system to facilitate usage of hybrid cloud storage based on the answer to question one?" and after gathering the requirements, the prototype developed based on ownCloud an open source private cloud storage project. The developed prototype completely fulfilled our requirements.

7.2 Future Work

The most beneficial identified future work, is to expand the introduced prototype further and develop an application programming Interface (API) out of it. A RESTful API, specifies a software component, with a set of functionalities similar to our prototype independent of ownCloud file system which allows developers to use this solution easily. In general, having an API based on this prototype which provide the same functionalists for assigning trust levels for accessing data to application providers could make this solution an ideal services.

Furthermore, for continuing this work the ability to give the permission to external applications, when they request access to data, based on the assigned trust levels is considered as future work of our solution. For example, give permission to Google photo edit [1] to access photos of folder which are categorized in yellow trust level.

From implementation point of view, the development of prototype can be expanded to locate the files to specific target directories of users choice, in the current version the uploaded files only able to locate in root directory of each storage location. Another improvement could be the ability to mount and assign colors to more than three levels to give more freedom to users and the implementation of adding iCloud could be the first next step for implementation improvement.

In survey improvement, adding interviews with market and science experts can be helpful to have more complete overviews of users demands.

[1] https://support.google.com/plus/answer/1053729?hl=en

List of Tables

List of Figures

Bibliography

[1] M.L. Abbott and J. McKinney. *Understanding and Applying Research Design*. Wiley, 2013. ISBN: 9781118605264. URL: http://books.google.se/books?id=ZTOJLml_tZgC.

[2] *Access, Sync and Share your data, under your control*. Accessed: 2014-10-29. URL: http://owncloud.org/features/.

[3] Naser Movahhedinia Ahmad Rashidi. "A Model for User Trust in Cloud Computing". In: *International Journal on Cloud Computing: Services and Architecture(IJCCSA* 2.2 (2012).

[4] Mohammed Alhamad, Tharam Dillon, and Elizabeth Chang. "SLA-Based Trust Model for Cloud Computing". In: *Proceedings of the 2010 13th International Conference on Network-Based Information Systems*. NBIS '10. Washington, DC, USA: IEEE Computer Society, 2010, pp. 321–324. ISBN: 978-0-7695-4167-9. DOI: 10.1109/NBiS.2010.67. URL: http://dx.doi.org/10.1109/NBiS.2010.67.

[5] Cloud security alliance. 2011.

[6] Nils Backhaus. "To trust or not to trust? A survey of models describing trust into cloud services from a UX perspective". In: *Human Factors in Telecommunications Symposium-In ,Proceedings of HFT Symposium* ().

[7] A. Barsoum and A. Hasan. "Enabling Dynamic Data and Indirect Mutual Trust for Cloud Computing Storage Systems". In: *Parallel and Distributed Systems, IEEE Transactions on* 24.12 (2013), pp. 2375–2385. ISSN: 1045-9219. DOI: 10.1109/TPDS.2012.337.

[8] Praveen Shende Bhupesh Kumar Dewangan. "A Model for User Trust in Cloud Computing". In: *International Journal of Science, Engineering and Technology Research (IJSETR)* 1.5 (2012).

[9] Matt Bishop. *Introduction to Computer Security*. Addison-Wesley Professional, 2004. ISBN: 0321247442.

[10] Brad Calder et al. "Windows Azure Storage: A Highly Available Cloud Storage Service with Strong Consistency". In: *Proceedings of the Twenty-Third ACM Symposium on Operating Systems Principles*. SOSP '11. Cascais, Portugal: ACM, 2011, pp. 143–157. ISBN: 978-1-4503-0977-6. DOI: 10.1145/2043556.2043571. URL: http://doi.acm.org/10.1145/2043556.2043571.

[11] E.D. Canedo et al. "File Exchange in a Private Cloud Supported by a Trust Model". In: *Cyber-Enabled Distributed Computing and Knowledge Discovery (CyberC), 2012 International Conference on*. 2012, pp. 89–96. DOI: 10.1109/CyberC.2012.23.

[12] Martyn Casserly. *7 best cloud storage services - 2014's best online storage sites revealed*.

[13] Long Chen and Hongbo Chen. "Ensuring Dynamic Data Integrity with Public Auditability for Cloud Storage". In: *Computer Science Service System (CSSS), 2012 International Conference on*. 2012, pp. 711–714. DOI: 10.1109/CSSS.2012.183.

[14] Cheng-Kang Chu et al. "Security Concerns in Popular Cloud Storage Services". In: *Pervasive Computing, IEEE* 12.4 (2013), pp. 50–57. ISSN: 1536-1268. DOI: 10.1109/MPRV.2013.72.

[15] L.A. Cutillo, R. Molva, and T. Strufe. "Safebook: A privacy-preserving online social network leveraging on real-life trust". In: *Communications Magazine, IEEE* 47.12 (2009), pp. 94–101. ISSN: 0163-6804. DOI: 10.1109/MCOM.2009.5350374.

[16] Anwitaman Datta et al. "Decentralized Online Social Networks". In: *Handbook of Social Network Technologies and Applications*. 2010, pp. 349–378. DOI: 10.1007/978-1-4419-7142-5_17. URL: http://dx.doi.org/10.1007/978-1-4419-7142-5_17.

[17] Idilio Drago et al. "Inside Dropbox: Understanding Personal Cloud Storage Services". In: *Proceedings of the 2012 ACM Conference on Internet Measurement Conference*. IMC '12. Boston, Massachusetts, USA: ACM, 2012, pp. 481–494. ISBN: 978-1-4503-1705-4. DOI: 10.1145/2398776.2398827. URL: http://doi.acm.org/10.1145/2398776.2398827.

[18] Posted by Drew and Arash. *Thanks for helping us grow*. 2014. URL: https://blog.dropbox.com/2014/05/thanks-for-helping-us-grow/.

[19] M.R. Farcasescu. "Trust Model Engines in Cloud Computing". In: *Symbolic and Numeric Algorithms for Scientific Computing (SYNASC), 2012 14th International Symposium on*. 2012, pp. 465–470. DOI: 10.1109/SYNASC.2012.57.

[20] Jon Fingas. *Dropbox bug wipes some users' files from the cloud*. 2014. URL: http://www.engadget.com/2014/10/13/dropbox-selective-sync-bug/.

[21] R. Gellman and P. Dixon. *Online Privacy: A Reference Handbook: A Reference Handbook*. Contemporary World Issues. ABC-CLIO, 2011. ISBN: 9781598846508. URL: http://books.google.se/books?id=KolSg5Cxks8C.

[22] Sonja Grabner-Kräuter and Ewald A. Kaluscha. "Empirical Research in On-line Trust: A Review and Critical Assessment". In: *Int. J. Hum.-Comput. Stud.* 58.6 (June 2003), pp. 783–812. ISSN: 1071-5819. DOI: 10.1016/S1071-5819(03)00043-0. URL: http://dx.doi.org/10.1016/S1071-5819(03)00043-0.

[23] T. Hildmann and O. Kao. "Deploying and Extending On-Premise Cloud Storage Based on ownCloud". In: *Distributed Computing Systems Workshops (ICDCSW), 2014 IEEE 34th International Conference on*. 2014, pp. 76–81. DOI: 10.1109/ICDCSW.2014.18.

[24] Dan Hubbard and Michael Sutton. *Top Threats To Cloud Computing*. Tech. rep.

[25] Frauenhofer Institut. *SIT Technical Reports - On the Security of Cloud Storage Services*. Ed. by Frauenhofer Institut. 2012. URL: https://www.sit.fraunhofer.de/fileadmin/dokumente/studien_und_technical_reports/Cloud-Storage-Security_a4.pdf.

[26] Iulia Ion et al. "Home is Safer Than the Cloud!: Privacy Concerns for Consumer Cloud Storage". In: *Proceedings of the Seventh Symposium on Usable Privacy and Security*. SOUPS '11. Pittsburgh, Pennsylvania: ACM, 2011, 13:1–13:20. ISBN: 978-1-4503-0911-0. DOI: 10.1145/2078827.2078845. URL: http://doi.acm.org/10.1145/2078827.2078845.

[27] Iulia Ion et al. "Home is Safer Than the Cloud!: Privacy Concerns for Consumer Cloud Storage". In: *Proceedings of the Seventh Symposium on Usable Privacy and Security*. SOUPS '11. Pittsburgh, Pennsylvania: ACM, 2011, 13:1–13:20. ISBN: 978-1-4503-0911-0. DOI: 10.1145/2078827.2078845. URL: http://doi.acm.org/10.1145/2078827.2078845.

[28] *ISO/IEC 27001-Information security management*. ISO. 2013.

[29] Ajay Jangra and Renu Bala. "PASA: Privacy-Aware Security Algorithm for Cloud Computing". English. In: *Intelligent Informatics*. Ed. by Ajith Abraham and Sabu M Thampi. Vol. 182. Advances in Intelligent Systems and Computing. Springer Berlin Heidelberg, 2013, pp. 487–497. ISBN: 978-3-642-32062-0. DOI: 10.1007/978-3-642-32063-7_52. URL: http://dx.doi.org/10.1007/978-3-642-32063-7_52.

[30] M. Tim Jones. *Anatomy of a cloud storage infrastructure*. Ed. by IBM Technical Report. 2010. URL: http://www.ibm.com/developerworks/cloud/library/cl-cloudstorage/.

[31] Seny Kamara and Kristin Lauter. "Cryptographic Cloud Storage". In: *Proceedings of the 14th International Conference on Financial Cryptograpy and Data Security*. FC'10. Tenerife, Canary Islands, Spain: Springer-Verlag, 2010, pp. 136–149. ISBN: 3-642-14991-X, 978-3-642-14991-7. URL: http://dl.acm.org/citation.cfm?id=1894863.1894876.

[32] S. Kim and A Yoon. "Do I trust google? An exploration of how people form trust in cloud computing". In: *Proceedings of the American Society for Information Science and Technology* 49.1" year = ().

[33] R.K.L. Ko et al. "TrustCloud: A Framework for Accountability and Trust in Cloud Computing". In: *Services (SERVICES), 2011 IEEE World Congress on*. 2011, pp. 584–588. DOI: 10.1109/SERVICES.2011.91.

[34] Marc Langheinrich. "Privacy by Design - Principles of Privacy-Aware Ubiquitous Systems". In: *Proceedings of the 3rd International Conference on Ubiquitous Computing*. UbiComp '01. Atlanta, Georgia, USA: Springer-Verlag, 2001, pp. 273–291. ISBN: 3-540-42614-0. URL: http://dl.acm.org/citation.cfm?id=647987.741336.

[35] Min Li, Hua Wang, and Ashley Plank. "Privacy-aware Access Control with Generalization Boundaries". In: *Thirty-Second Australasian Computer Science Conference (ACSC 2009)*. Ed. by Bernard Mans. Vol. 91. CRPIT. Wellington, New Zealand: ACS, 2009, pp. 93–100.

[36] Wenjuan Li and Lingdi Ping. "Trust Model to Enhance Security and Interoperability of Cloud Environment". English. In: *Cloud Computing*. Ed. by MartinGilje Jaatun, Gansen Zhao, and Chunming Rong. Vol. 5931. Lecture Notes in Computer Science. Springer Berlin Heidelberg, 2009, pp. 69–79. ISBN: 978-3-642-10664-4. DOI: 10.1007/978-3-642-10665-1_7. URL: http://dx.doi.org/10.1007/978-3-642-10665-1_7.

[37] Jilong Liao, Kefa Lu, and Qing Cao. "Uno: A Privacy-Aware Distributed Storage and Replication Middleware for Heterogeneous Computing Platforms". In: *Mobile Ad-Hoc and Sensor Systems (MASS), 2013 IEEE 10th International Conference on*. 2013, pp. 551–559. DOI: 10.1109/MASS.2013.39.

[38] Ben Martini and Kim-Kwang Raymond Choo. "Cloud storage forensics: ownCloud as a case study." In: *Digital Investigation* 10.4 (2013), pp. 287–299. URL: http://dblp.uni-trier.de/db/journals/di/di10.html#MartiniC13.

[39] Mariella Moon. *Dropbox passwords posted online and millions more might follow*. 2014. URL: http://www.engadget.com/2014/10/14/dropbox-log-in-posted-online/?ncid=rss_truncated.

[40] Talal H. Noor et al. "Trust Management of Services in Cloud Environments: Obstacles and Solutions". In: *ACM Comput. Surv.* 46.1 (July 2013), 12:1–12:30. ISSN: 0360-0300. DOI: 10.1145/2522968.2522980. URL: http://doi.acm.org/10.1145/2522968.2522980.

[41] Daniel Osterwalder. "Trust Through Evaluation and Certification?" In: *Soc. Sci. Comput. Rev.* 19.1 (Mar. 2001), pp. 32–46. ISSN: 0894-4393. DOI: 10.1177/089443930101900104. URL: http://dx.doi.org/10.1177/089443930101900104.

[42] Nouha Oualha, Melek Önen, and Yves Roudier. "A security protocol for self-organizing data storage". In: *IFIP SEC 2008, 23rd International Information Security Conference, September 8-10, 2008, Milano, Italy / Also published in "IFIP International Federation for Information Processing", 2008, Volume 278/2008*. Milano, ITALY, Sept. 2008. DOI: http://dx.doi.org/10.1007/978-0-387-09699-5_44. URL: http://www.eurecom.fr/publication/2567.

[43] *ownCloud Encryption*. Accessed: 2014-10-29. URL: https://owncloud.org/blog/how-owncloud-uses-encryption-to-protect-your-data/.

[44] *OwnCloud features*. Accessed: 2014-10-29. URL: https://owncloud.com/ownclouds-new-group-admin-feature-whats-it-all-about/.

[45] Aditya Patawari. *Getting Started with ownCloud*. Packt Publishing, 2013. ISBN: 9781782168256.

[46] Siani Pearson and Azzedine Benameur. "Privacy, Security and Trust Issues Arising from Cloud Computing". In: *Proceedings of the 2010 IEEE Second International Conference on Cloud Computing Technology and Science*. CLOUDCOM '10. Washington, DC, USA: IEEE Computer Society, 2010, pp. 693–702. ISBN: 978-0-7695-4302-4. DOI: 10.1109/CloudCom.2010.66. URL: http://dx.doi.org/10.1109/CloudCom.2010.66.

[47] Yong PENG et al. "Secure cloud storage based on cryptographic techniques". In: *The Journal of China Universities of Posts and Telecommunications* 19, Supplement 2.0 (2012), pp. 182 –189. ISSN: 1005-8885. DOI: http://dx.doi.org/10.1016/S1005-8885(11)60424-X. URL: http://www.sciencedirect.com/science/article/pii/S100588851160424X.

[48] Peter Mell and Tim Grance. *The NIST Definition of Cloud Computing*. 2009. URL: http://csrc.nist.gov/groups/SNS/cloud-computing/cloud-def-v15.doc.

[49] P. Pradhan et al. "Distributed verification protocols for data storage security in Cloud Computing". In: *Communication, Information Computing Technology (ICCICT), 2012 International Conference on*. 2012, pp. 1–6. DOI: 10.1109/ICCICT.2012.6398205.

[50] B. Priyadharshini and P. Parvathi. "Data integrity in cloud storage". In: *Advances in Engineering, Science and Management (ICAESM), 2012 International Conference on*. 2012, pp. 261–265.

[51] Denise M. Rousseau et al. "Not so Different after all: A Cross-Discipline View of Trust". In: *Academy of Management Review* 23.3 (1998), pp. 393–404.

[52] P. Salant and D.A. Dillman. *How to Conduct Your Own Survey*. Business Reference. Wiley, 1994. ISBN: 9780471012733. URL: http://books.google.se/books?id=jnKFl_F2jgMC.

[53] Sheikh Muhammad Saqib Rashid Muhammad Khattak2 Shakeel Ahmad Bashir Ahmad. "Trust Model: Cloud's Provider and Cloud's User". In: *International Journal of Advanced Science and Technology* 44 ().

[54] Ajit Kumar Shrivastava Shweta Tharwani. "Cloud Computing Trust Models: A Survey". In: *International Conference on Cloud, Big Data and Trust 2013* ().

[55] Josef Spillner, Johannes MüLler, and Alexander Schill. "Creating Optimal Cloud Storage Systems". In: *Future Gener. Comput. Syst.* 29.4 (June 2013), pp. 1062–1072. ISSN: 0167-739X. DOI: 10.1016/j.future.2012.06.004. URL: http://dx.doi.org/10.1016/j.future.2012.06.004.

[56] R. Sravan Kumar and A. Saxena. "Data integrity proofs in cloud storage". In: *Communication Systems and Networks (COMSNETS), 2011 Third International Conference on*. 2011, pp. 1–4. DOI: 10.1109/COMSNETS.2011.5716422.

[57] Luke Stark and Matt Tierney. "Lockbox: Mobility, Privacy and Values in Cloud Storage". In: *Ethics and Inf. Technol.* 16.1 (Mar. 2014), pp. 1–13. ISSN: 1388-1957. DOI: 10.1007/s10676-013-9328-z. URL: http://dx.doi.org/10.1007/s10676-013-9328-z.

[58] *Vulnerability in XSS*. Accessed: 2014-10-29. URL: http://blog.noobroot.com/2014/02/owncloud-600a-when-xss-vulnerability.htm.

[59] Qian Wang et al. "Enabling Public Verifiability and Data Dynamics for Storage Security in Cloud Computing". In: *Proceedings of the 14th European Conference on Research in Computer Security*. ESORICS'09. Saint-Malo, France: Springer-Verlag, 2009, pp. 355–370. ISBN: 3-642-04443-3, 978-3-642-04443-4. URL: http://dl.acm.org/citation.cfm?id=1813084.1813114.

[60] Lifei Wei et al. "Security and Privacy for Storage and Computation in Cloud Computing". In: *Inf. Sci.* 258 (Feb. 2014), pp. 371–386. ISSN: 0020-0255. DOI: 10.1016/j.ins.2013.04.028. URL: http://dx.doi.org/10.1016/j.ins.2013.04.028.

[61] Jiyi Wu et al. "Cloud Storage as the Infrastructure of Cloud Computing". In: *Intelligent Computing and Cognitive Informatics (ICICCI), 2010 International Conference on*. 2010, pp. 380–383. DOI: 10.1109/ICICCI.2010.119.

[62] Wenying Zeng et al. "Research on Cloud Storage Architecture and Key Technologies". In: *Proceedings of the 2Nd International Conference on Interaction Sciences: Information Technology, Culture and Human*. ICIS '09. Seoul, Korea: ACM, 2009, pp. 1044–1048. ISBN: 978-1-60558-710-3. DOI: 10.1145/1655925.1656114. URL: http://doi.acm.org/10.1145/1655925.1656114.

[63] Kehuan Zhang et al. "Sedic: Privacy-aware Data Intensive Computing on Hybrid Clouds". In: *Proceedings of the 18th ACM Conference on Computer and Communications Security*. CCS '11. Chicago, Illinois, USA: ACM, 2011, pp. 515–526. ISBN: 978-1-4503-0948-6. DOI: 10.1145/2046707.2046767. URL: http://doi.acm.org/10.1145/2046707.2046767.

[64] Lan Zhou, V. Varadharajan, and M. Hitchens. "Achieving Secure Role-Based Access Control on Encrypted Data in Cloud Storage". In: *Information Forensics and Security, IEEE Transactions on* 8.12 (2013), pp. 1947–1960. ISSN: 1556-6013. DOI: 10.1109/TIFS.2013.2286456.

Appendices

Appendix 1

1 Visual components for Mounting External Storages

```
<h2><?php p($l->t('Internal Storage')); ?></h2>
<table id="internalStorage" class="grid" data-admin='<?php print_unescaped(
    json_encode($_['isAdminPage'])); ?>'>
  <thead>
    <tr>
      <th></th>
      <th><?php p($l->t('Folder name')); ?></th>
      <th><?php p($l->t('Internal storage')); ?></th>
      <th></th>
      <?php if ($_['isAdminPage']) print_unescaped('<th>'.$l->t('Available for')
          .'</th>'); ?>
      <th> </th>
    </tr>
  </thead>
  <tbody>
    <tr>
      <td class="status">
        <span class="success"></span>
      </td>
      <td class="mountPoint"><input type="text" name="mountPoint" class="disText
          " value="/"/>
      <td class="mountPoint"><input type="text" name="mountPoint" class="disText
          " value="Root Directory"/>
      <td class ="configuration">
        <select id = 'root_color_drp'>
          <option value=""></option>
          <option value="red">Red</option>
          <option value="yellow">Yellow</option>
          <option value="green">Green</option>
        </select>
      </td>
    </tr>
  </tbody>
</table>
<br/>
***************
//Style:
```

```
settings.css
<style>
  #color_drp {
    margin-left: 100px;
    width: 150px;
  }

  #root_color_drp {
    margin-left: 485px;
    width: 150px;
  }

  #internalStorage td.status .success {
    border-radius: 50%;
  }
</style>
```

2 Assigning a color to a drive

```
<script>
  // *** if ownCloud root directory has an assigned color set selected color and
       diasble dropdown
  $.ajax({
    url: colorsConfigUtility.getAjaxUrl('colorsConfig'),
    data: {
      mountPoint : '/'
    }
  }).done(function(response) {
    if (response.data.exist) {
      console.log(response.data.color);
      $('#root_color_drp').val(response.data.color).attr('disabled', 'disabled')
          ;
    } else {
      console.log(response.data.exist);
    }
  });
</script>


<script>
  // *** Add event listener on ownCloud dropdown (#root_color_drp)
  $('#internalStorage').on('change', 'tbody #root_color_drp'
    , function() {

      var mountPoint = "/";
      var selectedColor = $('#root_color_drp option:selected').val();
      console.log(selectedColor);
      console.log(mountPoint);

      if (selectedColor !== "") {
```

```
30          colorsConfigUtility.colorHandler(mountPoint, selectedColor);
31        };
32
33      }
34    );
35  </script>
```

3 colorsConfig.php:

```
1  <?php
2    use \OCP\IConfig;
3
4    OCP\JSON::checkLoggedIn();
5    \OC::$session->close();
6    $l = OC_L10N::get('files');
7
8    $user = OC_User::getUser();
9    $config = \OC::$server->getConfig();
10   $confService = new ConfigService($config, "Files");
11
12   $data = array();
13
14   if (isset($_GET['color'])) {
15       $data['value'] = $confService->getUserValue($user, $_GET['color']);
16       if ($data['value'] == NULL) {
17           $data['exist'] = false;
18
19       } else {
20           $data['exist'] = true;
21       }
22   } else if (isset($_GET['mountPoint']) && isset($_GET['selectedColor']) ) {
23
24       $data['value'] = $confService->getUserValue($user, $_GET['selectedColor'])
             ;
25
26       if ($data['value'] == NULL) {
27           $data['exist'] = false;
28           $confService->setUserValue($user, $_GET['selectedColor'], $_GET['
                mountPoint']);
29       } else {
30           $data['exist'] = true;
31       }
32
33   } else if (isset($_GET['mountPoint'])) {
34
35       $data['exist'] = false;
36       $colors = array("red","yellow","green");
37
38       foreach ($colors as $color) {
39           $mountPoint = $confService->getUserValue($user, $color);
40           if ($mountPoint == $_GET['mountPoint']) {
```

```
                $data['exist'] = true;
                $data['color'] = $color;
                break;
            }
        }
    } else if (isset($_GET['mountPointToRemove'])) {

        $data['exist'] = false;
        $colors = array("red","yellow","green");

        foreach ($colors as $color) {
            $mountPoint = $confService->getUserValue($user, $color);
            if ($mountPoint == $_GET['mountPointToRemove']) {
                $data['exist'] = true;
                $data['color'] = $color;
                $confService->setUserValue($user, $color, NULL);
                break;
            }
        }
    }

    OCP\JSON::success(array('data' => $data));

    class ConfigService {

        private $config;
        private $appName;

        public function __construct(IConfig $config, $appName){
            $this->config = $config;
            $this->appName = $appName;
        }

        public function getUserValue($userId, $key) {
            return $this->config->getUserValue($userId, $this->appName, $key);
        }

        public function setUserValue($userId, $key, $value) {
            $this->config->setUserValue($userId, $this->appName, $key, $value);
        }
    }
?>
```

4 Storage Handlers

```
<script >
  // *** remove selected color for mountPoint if any
  colorsConfigUtility.removeMountPointColor(mountPoint);
</script>


```

```
7  google.js:
8  <script>
9    // *** add dropdown to select a color
10   $(this).find('.configuration').append($('<select><option value=""></option><
         option value="red">Red</option><option value="yellow">Yellow</option><
         option value="green">Green</option></select>').attr('id', 'color_drp'));
11 </script>
12
13 dropbox.js:
14 <script>
15   // *** add dropdown to select a color
16   $(this).find('.configuration').append($('<select><option value=""></option><
         option value="red">Red</option><option value="yellow">Yellow</option><
         option value="green">Green</option></select>').attr('id', 'color_drp'));
17 </script>
18
19
20 google.js:
21 <script>
22   // *** get googleDrive mountPoint
23   var googleDriveMountPoint = $(this).find('.mountPoint input').val();
24   console.log(googleDriveMountPoint);
25
26   // *** get mountPoint's assigned color, if already set then display it on
         dropdown and disable it
27   $.ajax({
28     url: colorsConfigUtility.getAjaxUrl('colorsConfig'),
29     data: {
30       mountPoint : googleDriveMountPoint
31     }
32   }).done(function(response) {
33     if (response.data.exist) {
34       console.log(response.data.color);
35       thisStorage.find('#color_drp').val(response.data.color).attr('disabled', '
             disabled');
36     } else {
37       console.log(response.data.exist);
38     }
39   });
40 </script>
41 <script>
42   // *** Add event listener on #color_drp
43   $('#externalStorage').on('change', 'tbody tr.\\\\OC\\\\Files\\\\Storage\\\\
         Google #color_drp'
44     , function() {
45       console.log("$('#externalStorage').on('change',  #color_drp");
46
47       var mountPoint = $(this).parent().parent().find('.mountPoint input').val()
             ;
48       var selectedColor = $(this).parent().parent().find('#color_drp option:
             selected').val();
49       console.log(selectedColor);
```

```
50        console.log(mountPoint);
51
52        if (selectedColor !== "") {
53          colorsConfigUtility.colorHandler(mountPoint, selectedColor);
54        };
55
56      }
57    );
58  </script>
59
60  dropbox.js:
61  <script>
62    // *** get dropbox mountPoint
63    var dropboxMountPoint = $(this).find('.mountPoint input').val();
64    console.log(dropboxMountPoint);
65
66    // *** get mountPoint's assigned color, if already set then display it on
          dropdown and disable it
67    $.ajax({
68      url: colorsConfigUtility.getAjaxUrl('colorsConfig'),
69      data: {
70        mountPoint : dropboxMountPoint
71      }
72    }).done(function(response) {
73      if (response.data.exist) {
74        console.log(response.data.color);
75        thisStorage.find('#color_drp').val(response.data.color).attr('disabled', '
              disabled');
76      } else {
77        console.log(response.data.exist);
78      }
79    });
80  </script>
81
82  <script>
83    // *** Add event listener on #color_drp
84    $('#externalStorage').on('change', 'tbody tr.\\\\OC\\\\Files\\\\Storage\\\\
          Dropbox #color_drp'
85      , function() {
86        console.log("$('#externalStorage').on('change',  #color_drp");
87
88        var mountPoint = $(this).parent().parent().find('.mountPoint input').val()
              ;
89        var selectedColor = $(this).parent().parent().find('#color_drp option:
              selected').val();
90
91        console.log(selectedColor);
92        console.log(mountPoint);
93
94        if (selectedColor !== "") {
95          colorsConfigUtility.colorHandler(mountPoint, selectedColor);
96        };
```

```
97
98      }
99    );
100 </script
```

5 Visual components for Uploading files

```
1  //Settings button
2  <button class="to-right" id="settings_btn">Settings</button>
3
4
5  //Settings dialog
6  <div id="settings_dlg" title="Settings" style="display:none">
7    <p>Selected target storage for each security level</p>
8    <li id="green">
9      <label>Green Level</label>
10     <div class="to-right"><label id="green_drp" class="mount-point">Not Assigned
           </label></div>
11   </li>
12   <li id="yellow">
13     <label>Yellow Level</label>
14     <div class="to-right"><label id="yellow_drp" class="mount-point">Not
           Assigned</label></div>
15   </li>
16   <li id="red">
17     <label>Red Level</label>
18     <div class="to-right"><label id="red_drp" class="mount-point">Not Assigned</
           label></div>
19   </li>
20 </div>
21
22 //Security Level dialog
23 <div id="dialog" title="Security Level" style="display:none">
24   <p>Select security level of selected file(s)</p>
25   <li id="green"><input type="radio" name="radio-btn" value="green" checked="
       checked">Green</input></li>
26   <li id="yellow"><input type="radio" name="radio-btn" value="yellow">Yellow</
       input></li>
27   <li id="red"><input type="radio" name="radio-btn" value="red">Red</input></li>
28 </div>
29
30 ************************************************************
31 // Add style
32 <style>
33   #dialog{
34     height: 260px;
35     width: 360px;
36   }
37   #dialog li {
38     list-style: none;
39     min-width: 200px;
```

```
40    min-height: 20px;
41    margin-top: 10px;
42      -moz-border-radius: 5px;
43      border-radius: 5px;
44  }
45  #green {
46    background-color: rgba(47, 165, 69, .8);
47  }
48  #yellow {
49    background-color: rgba(242, 244, 65, .8);
50  }
51  #red {
52    background-color: rgba(250, 55, 69, .8);
53  }
54
55  #settings_dlg {
56
57  }
58  #settings_dlg li {
59    list-style: none;
60    min-width: 400px;
61    min-height: 40px;
62    margin-top: 10px;
63      -moz-border-radius: 5px;
64      border-radius: 5px;
65  }
66  #settings_dlg label {
67    font-size: 14px;
68    vertical-align: middle;
69    float: left;
70    padding: 10px 0 0 5px;
71  }
72  #settings_dlg select {
73    float: right;
74  }
75  #settings_btn {
76    min-width: 144px;
77    /*float: right;*/
78    margin: 6px 10px 0 0;
79    z-index: 100;
80  }
81
82  .to-right {
83    float: right;
84  }
85
86  .to-right label {
87    min-width: 120px;
88    min-height: 30px;
89    max-height: 30px;
90    font-weight: bold;
91  }
```

```
92
93    #controls {
94      width: auto;
95    }
96  </style>
```

6 File Handlers

```
1   <script>
2     // *** check if all colors are set,
3     $colors = $.ajax({
4       url: getAjaxUrl('config'),
5       data: {
6       }
7     }).done(function(response) {
8       // *** if success (means all colors are set)
9       if (response.data.success) {
10        // display dialog to select a color for uploaded file
11        $('#dialog').dialog({
12                    autoResize: false,
13                    autoOpen: true,
14                    position: 'center',
15                    draggable: true,
16                    buttons: {
17                      "Upload": function() {
18                        color = $('input[name=radio-btn]:checked').val();
19                        OC.Upload.checkExistingFiles(selection, callbacks);
20                        $(this).dialog("close");
21                      },
22                      "Cancel": function() {
23                        $(this).dialog("close");
24                      }
25                  }
26        });
27      // *** else do not display select color dialog for uploaded file, do normal
            ownCloud upload
28      } else {
29        OC.Upload.checkExistingFiles(selection, callbacks);
30      }
31    });
32  </script>
33
34  <script>
35    data.formData = {
36      requesttoken: oc_requesttoken,
37      dir: data.targetDir || FileList.getCurrentDirectory(),
38      clr: color,
39      file_directory: fileDirectory
40    };
41  </script>
42
```

```
<script>
  // *** get selected color info to display
  $colors = $.ajax({
    url: getAjaxUrl('config'),
    data: {
    }
  }).done(function(response) {
    console.log(response.data);
    if (response.data.green !== "") {
      console.log(response.data.green);
      $('#green_drp').text((response.data.green == "/") ? "ownCloud" : response.
          data.green);
    }
    if (response.data.yellow !== "") {
      $('#yellow_drp').text((response.data.yellow == "/") ? "ownCloud" :
          response.data.yellow);
    }
    if (response.data.red !== "") {
      $('#red_drp').text((response.data.red == "/") ? "ownCloud" : response.data
          .red);
    }

    $('#settings_dlg').dialog({
                autoResize: false,
                autoOpen: false,
                position: 'center',
                draggable: true,
                minWidth: 500,
                buttons: {
                  "Close": function() {
                    $(this).dialog("close");
                  }
              }
     });
  });

  function getAjaxUrl(action, params) {
    return OCA.Files.Files.getAjaxUrl(action, params);
  };

  $('#settings_btn').click(function() {
      $('#settings_dlg').dialog('open');
  });
</script>
```

```
<?php
  // *** get passed color (clr) and retrive its assigned storage
  $clr = $_POST['clr'];
  $user = OC_User::getUser();
  $config = \OC::$server->getConfig();
  $confService = new ConfigService($config, "Files");
  $dir = $confService->getUserValue($user, $clr);
```

```
8
9   // *** if assigned storage is null use normal directory
10  // else add "/" to storage to make correct directory path
11  if ($dir === NULL or $dir == NULL) {
12    $dir = isset($_POST['dir']) ? $_POST['dir'] : "";
13  } else if ($dir !== "/") {
14    $dir = "/" . $dir;
15  }
16 ?>
17
18 <?php
19   class ConfigService {
20
21       private $config;
22       private $appName;
23
24       public function __construct(IConfig $config, $appName){
25           $this->config = $config;
26           $this->appName = $appName;
27       }
28
29       public function getUserValue($userId, $key) {
30           return $this->config->getUserValue($userId, $this->appName, $key);
31       }
32
33       public function setUserValue($userId, $key, $value) {
34           $this->config->setUserValue($userId, $this->appName, $key, $value);
35       }
36   }
37 ?>
38 \\config.php
39 <?php
40   use \OCP\IConfig;
41
42   OCP\JSON::checkLoggedIn();
43   \OC::$session->close();
44   $l = OC_L10N::get('files');
45
46   $user = OC_User::getUser();
47   $config = \OC::$server->getConfig();
48   $confService = new ConfigService($config, "Files");
49
50   $data = array();
51
52
53   $data['red'] = $confService->getUserValue($user, "red");
54   $data['yellow'] = $confService->getUserValue($user, "yellow");
55   $data['green'] = $confService->getUserValue($user, "green");
56
57   if ($data['red'] == NULL or $data['yellow'] == NULL or $data['green'] == NUll)
         {
58     $data['success'] = false;
```

```
59    } else {
60      $data['success'] = true;
61    }
62
63
64    OCP\JSON::success(array('data' => $data));
65
66
67    class ConfigService {
68
69        private $config;
70        private $appName;
71
72        public function __construct(IConfig $config, $appName){
73            $this->config = $config;
74            $this->appName = $appName;
75        }
76
77        public function getUserValue($userId, $key) {
78            return $this->config->getUserValue($userId, $this->appName, $key);
79        }
80
81        public function setUserValue($userId, $key, $value) {
82            $this->config->setUserValue($userId, $this->appName, $key, $value);
83        }
84    }
85 ?>
```

Appendix 2

7 Market Overview

Increasing Growth of structured and unstructured data is one of the key driver for file storing and sharing markets. File storing, sharing and synchronizing is already a growing demand of every users on the Internet. The demand for sharing content and collaborating with others, using multiple devices by single users such as smartphone, tablets, laptops, desktop and smart TV as the same time, reducing office spaces and enabling working from remote location are the main motivations toward using file sharing and synchronization tools.

Although most of the low cost and free cloud-based storages provide robust functionality, as discussed in the background section, serious problems that threaten the public cloud storages markets exist, for example, lack of control over location of data. Therefore, the users demand for high quality and reliable cloud based storage solutions lead them to use private-cloud based solutions. As such system are, Network Attached Storage (NAS) devices which are computer storage devices with network connectivity to provide data sharing for heterogeneous clients. The NAS system users are dramatically increased.

By considering these facts and changes of users demands, our solution, Color Drive, which provide a hybrid solution for managing and control of data between popular public cloud storage and local drivers such as NAS devices will be of particular interest and need of today and future market. Among several local storage systems, for market analysis we focus only in NAS devices because of its rising popularity among the others.

8 Key Market Driver

The significant drivers for the cloud based storage market are the mounting growth in the digitalization life. By using more digital media and producing more data, the fast growing cloud storage technologies like personal storage systems and cloud storage solution are helping to store and share data. The kind of agility, scalability and efficiency and cost affordability of cloud storage make them essentially practical solutions to use in small, medium and large enterprises. In the previous years, enterprise were involved in on-premise data storage for massive data handling and storage and backups but, nowadays the these vendors are moving towards cloud based solution either data protection or achieving in public storage or providing their own private solutions. Additionally, the rising attention for cloud storage data security and privacy issues is the main market drivers towards using

private data cloud solutions.

9 Market Segmentation

For our market segmentation we consider two market domains of our product. The focus of our product is the combinations of two major markets. First it is the cloud storage market and the market of NAS devices.

The cloud-based storage market segmentation is based on type of deployment model, storage products, services, size of organizations, industrial verticals and geography.

based on deployment model, this market divided into four significant segments that are adopted by individuals and organization based on their requirement to storage facility and data security. The four deployment models are:

- Public cloud model
- Private cloud model
- Hybrid cloud model
- Community cloud model

Private cloud storage services are in used in different industry verticals ranging from governments, insurance,life sciences, retail, research to education, telecommunication, media and energy. The private solution is also suitable for large enterprises as well as small business and individual users.

Based on geographical distribution, the cloud computing market broadly is segmented into North America, Asia Pacific, Japan, Middle East, Latin America, Eastern Europe and Western Europe, and Africa. Each of these region have different revenue stream and forecast for the cloud markets. In more specific segmentation, the market can be divided country by country based on based on growth and high technologies usages of the population. [5]

Based on cloud storage products and components the market is divided into three segments [5]:

1. Hardware: Hardware has the different subcategories: infrastructures, servers, storage systems and network equipments
2. Software: software are further divided into data replication software, backup and recovery software, archiving software, security software and storage resource software
3. Services: Services segment includes system and network integration services, deployment of cloud storage infrastructure, analysis and consulting services, education and training service

The market based on NAS devices as part of private- cloud products can be divided according to multiple criteria. Each segment has its own requirements based on performance and feature sets. It is possible to categorize this market in various ways: for example, by application workload type, workload size, or the vertical industry of the NAS end-user. Features and functionality vary among the NAS systems suited for each segment. [6]

The NAS market segmentation based on three major criteria are as follow:

- **Size and Functionality Differentiators Among Segments:** One part of the market is traditional NAS systems that are widely deployed in IT organization. These system are handling storage

of important data and must be quickly accessible. They are among the most expensive categories and usually supported by insurances. The second category is the low-end midrange NAS system which suitable for organization that just need a file server with some level of advanced functionality and reliability. These category targeted at supporting the small offices, remote locations and medium enterprises.

- **Architectural Differentiators Among the Segments:** NAS system can be divided based on two major architectural paradigms, called scale-out NAS and scale-up NAS. Scale-up NAS is designed to be solid system and to scale performance, capacity, or throughput by vertically adding resources where there is a need for increasing performance and scale-out are virtualized system that can scale-out horizontally across nodes and processing powers. Scale-out NAS systems targeted environments that required very high throughput.

10 Market Size and Growth rate

The size of Color Drive market and the its growth rate is affected by three major factors. First of all, the continuous growth rate of data in structure or unstructured way. Second the growing market of the cloud based data storage and finally the rise in NAS devices market.

10.1 Growth in Data

Data and file sharing are growing exponentially [7]. Figure 2 shows the archive file data growth rate in unstructured, database and e-mails data from 2008-2015. Table 1 shows another dimension of data growth according to cisco research for mobile data from 2013- 2018.[7]

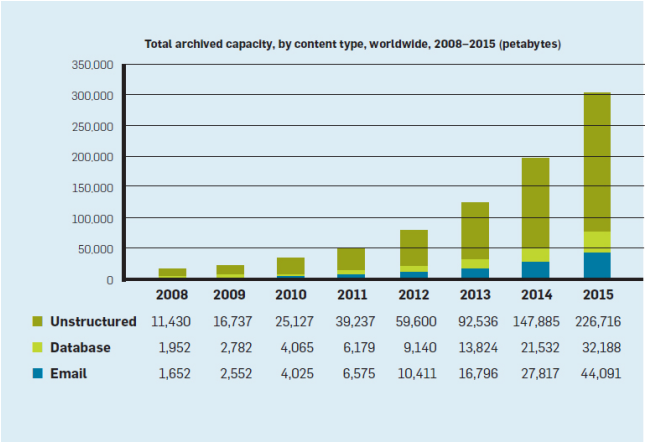

Figure 1: Total Archive Capacity by Content, world wide, 2008-2015 [8]

	2013	2014	2015	2016	2017	2018	CAGR 2013–2018
Data	606,405	957,382	1,437,249	2,073,797	2,832,137	3,531,107	42%
File Sharing	66,671	127,235	221,808	308,643	391,641	466,347	48%

Table 1: Global Mobile Data Traffic, 2013–2018 by Cisco research

10.2 Public Cloud Storage

According to Osterman research estimates that [2] the worldwide total available market for public cloud storage will growth by the rate of 5.7% annually by 2017. The available market seats was was 591.4 million seats in 2012 and will grow to 781.4 million seats by 2017. These result are shown in figure 3. [9]

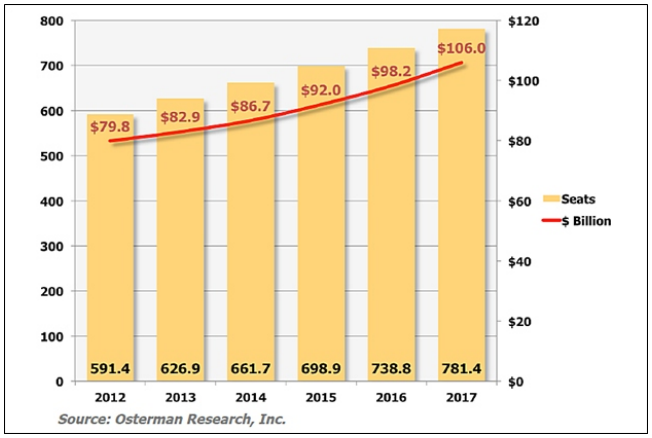

Figure 2: Total Available Market for Cloud storage, 2012-2017

According to marketandmarket market research [3] among the geographically market segmentation the north America have the largest market share and Europe is following to the second position. According to the rising in the demand for cloud storage solutions, the market in developing countries such as Brazil and Russia as well as China and India is also growing. MarketsandMarkets forecasts the global cloud storage market grows from 13.57 billion dollars in 2014 to 56.57 billion dollar in 2019 with an annual growth rate of 33.1% from 2014 to 2019.

10.3 NAS devices

Due to the rising the demand for data storage and big data phenomena, the market is expected to keep a high growth in the next few years. NAS devices has taken the largest proportion of over 58.4% among the other primary storage technologies, because it has an affordable price and strong storage capacity [10].

[2] http://www.ostermanresearch.com
[3] http://www.marketsandmarkets.com

TechNavio's [4] analysts forecast the global enterprise NAS market will grow at a CAGR (Compound Annual Growth Rate) of 25.44 percent over the period 2013-2018.

11 Market Leaders

Today, popular and market leaders of public storage cloud and file synchronization are many namely few of them are Dropbox, Google Drive, apple iCloud and Microsoft One Drive. On the other hand there are some private cloud solutions such as ome-Cloud and Seagate Business Storage, these dedicated solutions help to protect critical data and provides a centralized files storage with easy accessibility from anywhere.

Leading vendors in the NAS market are EMC (NYSE: EMC), Hewlett-Packard (NYSE: HPQ), IBM (NYSE: IBM), NetApp and Oracle (Nasdaq: ORCL). Other vendors examined by TechNavio include Buffalo Technology, Hitachi, Iomega, Netgear, QNAP Systems, Synology, Thecus Technology and Western Digital.

12 SWOT Analysis :Strengths, Weaknesses, Opportunities, Threats

The next page shows the results of SWOT analysis for Color Drive.

1. Strength
   - Main Focus of ease of use and user friendly
   - Managing and control over all different storage in creative approach
   - provide transparency for end-user
   - Technical and business expertise
   - Stable management team
   - Economies of scale
   - Financial stability
   - Acquisition capabilities
2. Weakness
   - Multi level one time setup for the product
   - Low of awareness of storage technologies in team
   - Dependency on the third party vendors
   - Marketing Capabilities
3. Opportunity
   - Multi level one time setup for the product

[4] http://www.technavio.com/

- Low of awareness of storage technologies in team
- Dependency on the third party vendors
- Marketing Capabilities

4. Threats
   - Global storage leaders entering developing markets
   - Creative technology disruption by market leaders of other competitors

Appendix 3

Open source and self-hosted services:	Focus	Installation	Encryption		System				Website	Comment	Group Space/User groups	Connect to external storages(e.g)	Mobile Client	Backups/ Duplications	Multiple User	Popularity [1]	Documentation [2]	Limitation
			Client-side	Server-side	Linux	RapsPi	Win	Mac										
owncloud	Self hosted cloud storage	Medium	X	X	x	x	x	x	http://owncloud.org/	Actively Developed / Features to add apps	X	X	**Advanced Android**	X	X	245	XXX	
Seafile	file sharing and collaboration	Easy	X		x	x	x		seafile.com	At early development phase	X		Basic Android		X	36	X	
SparkleShare	Synchronization /concentrates on projects	Medium	X		x		x	x	sparkleshare.org		X					59		Weak encryption/ Not good for Pictures
Syncany					x				www.syncany.org	In development phase								
Pydio	File sharing				x		x	x	http://pyd.io	last update June 2013	X					31		
FTPbox	Synchronize Share Via FTP						x		http://ftpbox.org/							0		
OpenStack swift	Cloud computing/ focuses exclusively on object storage								https://wiki.openstack.org/wiki/Swift	designed to scale/support applications growing unstructured data								
Limbomedia					x		x		limbomedia.net	On early development phase						1		

[1] Popularity based on http://alternativeto.net/
[2] XXX good XX medium X poor

Figure 3: Comparison between available solutions for implementing on-premises cloud storage

Appendix 4

Individuals Data Sensitivity Level UX

SURVEY QUESTIONNAIRE
Greetings!

Please be informed that the researcher is conducting a study on “Privacy level data storage on private cloud”.
public cloud storage services are services including Dropbox, iCloud, GoogleDrive, and etc.
In connection with this the author constructed a questionnaire to gather information for the study. Your participation in the study by way of answering this is very vital. Without it, the study will not be complete as it should be. Kindly fill up the questionnaire with honesty. Thank you very much for your very kind response to my request. The total time for answering is less than 5 minutes.

Very sincerely yours,

1. **1. What is your knowledge level about cloud storage services (like, Dropbox, icloud)**
   Check all that apply.
   - [ ] 1. I have no Idea what it is
   - [ ] 2. I heard about it, but not used it at all (please go to question 2)
   - [ ] 3. I know it and use them, (please continue from question 3)

2. **2. If not, could you specify why?**
   Check all that apply.
   - [ ] I do not need extra storage
   - [ ] They are not trust worthy
   - [ ] Other: .....

3. **3. Which of this public cloud storage you are using?**
   Mark only one oval per row.

	Yes	No
GoogleDrive	◯	◯
Dropbox	◯	◯
iCloud	◯	◯
OneDrive	◯	◯
Box	◯	◯
Others	◯	◯

4. **4. Have you ever paid for additional online storage in any of these?**
   Check all that apply.
   - [ ] Yes
   - [ ] No

5. **5. Do you store the below information in the cloud storage, if not could you specify why not?**
Mark only one oval per row.

	Yes	No
Financial data and banking document		
Governmental (ID numbers, ..)		
Health Documnet		
Personal Images		
Personal Video		
Back up of your hard drive		

6. **6. Why not, please specify your reason for each?**

.....

7. **7. Do you use any private (cloud) storage service?**
Mark only one oval per row.

	Yes	No
Network Attached Storage (NAS)		
Wuala		
ownCloud		
other		

8. **8. If you checked "other option" in previous question, could you specify which service?**

.....

9. **9. What is your general feeling about public cloud storage?**
Check all that apply.

- [ ] I feel completely safe to use public services and send personal data to them
- [ ] I think public services show concerns to my data, but there is a small risk that my data is modified by third parties
- [ ] Public storage does not have good reputation at all

10. **10. How do you prefer to categorize and organize your digital files?**
Check all that apply.

- [ ] Based on content (Holiday, ..)
- [ ] Based on data type, e.g audio, video,..
- [ ] based on date, e.g September 2010
- [ ] Based on relative importance
- [ ] Based on frequency of use
- [ ] Based on average file size (in megabytes or gigabytes)
- [ ] Other: .....

11. **11. Do you store your data in different places based on your categorization?**
for example different drives of hard disk, different hard disks, ...
Mark only one oval.

- ( ) Yes
- ( ) No

12. **12. If you want to classify your personal data, to how many groups you would like to divide it? [according to its sensibility]?**
Personal data e.g. financial data, health, banking, government ID numbers, images, video
Check all that apply.

- [ ] Two groups
- [ ] Three groups
- [ ] Four groups
- [ ] Other: .....

13. **13. Could give a name to each group?**
for example (my two groups are my sensitive and non-sensitive data)

.....

14. **14. According to your defined sensitivity groups, where would you like to store your data?**
Check all that apply.

- [ ] store all groups on my local device
- [ ] a combination of my local hard drive and one public storage (e.g. my hard drive and Dropbox)
- [ ] A combination of my local hard drive and more than one public storage(e.g. my hard drive and Dropbox and GoogleDrive)
- [ ] Store all in public clouds
- [ ] Other: .....

15. **15. What is your opinion about a platform with facility for combining and managing your storage from multiple providers?**
Check all that apply.

- [ ] It won't be useful
- [ ] It could be useful
- [ ] It meets my need exactly

16. **16. Could you specify your reason?**

.....

17. **17. What do you feel about new information technologies in general?**
Check all that apply.

- [ ] Among my peers I am usually the first to try out new information technologies
- [ ] If I heard about a new information technology, I would look for way to experiment it
- [ ] I hesitate to try out new information technologies
- [ ] I strongly avoid to try new information technologies