Check for updates

RESEARCH ARTICLE

API-based evidence acquisition in the cloud - a survey

[version 1; peer review: 1 approved, 1 approved with reservations]

Dr. Dirk Pawlaszczyk[1], Martin Bochmann[1], Philipp Engler[1], Coert Klaver[2], Christian Hummert[3]

[1]Department of Computer Sciences, Hochschule Mittweida - University of Applied Sciences, Mittweida, Saxonia, 09648, Germany
[2]Netherlands Forensic Institute (NFI), The Hague, 2497 GB, The Netherlands
[3]Agentur fuer Innovation in der Cybersicherheit, Halle(Saale), 06110, Germany

v1 **First published:** 31 May 2022, **2**:69
https://doi.org/10.12688/openreseurope.14784.1
Latest published: 31 May 2022, **2**:69
https://doi.org/10.12688/openreseurope.14784.1

Abstract

Cloud services and cloud storage solutions are special challenges in digital forensic investigations. Cloud services allow their users, with relatively little technical knowledge, store, manage and share content with others. At the same time investigators are faced with a wide range of technical, legal and organizational issues. Unfortunately, evidence acquisition for such services still follows the traditional way of collecting artefacts on a client device. In this article, first, an overview of the state of research is given. Next, technical and legal challenges related to the forensically sound acquisition of cloud data are presented. Since accessing these data is highly challenging, basic techniques for acquiring data from the cloud are discussed and compared, using the example of 30 cloud storage services. We introduce the concept of an API-based evidence acquisition for cloud services that utilize the officially supported API of the service. We show how well this approach applies to most current cloud drive services in the survey context. We present the first glance of a proof-of-concept acquisition framework called CLOUDxTRACT, which can acquire evidence from selected cloud service providers.

Keywords

Digitals Forensics, Mobile Phones, Data Acquisition, Cloud, Cloud Security

H2020 This article is included in the Horizon 2020 gateway.

Open Peer Review

Approval Status ? ✓

	1	2
version 1 31 May 2022	? view	✓ view

1. **Andreas Attenberger**, Central Office for Information Technology in the Security Sector (ZITiS), Munich, Germany
2. **Nikhitha Yathiraju**, University of Cumberlands, Kentucky, USA

Any reports and responses or comments on the article can be found at the end of the article.



This article is included in the Data Science gateway.



This article is included in the Cloud-based Technologies collection.

Corresponding author: Dr. Dirk Pawlaszczyk (pawlaszc@hs-mittweida.de)

Author roles: Pawlaszczyk DD: Conceptualization, Formal Analysis, Funding Acquisition, Investigation, Methodology, Project Administration, Resources, Software, Supervision, Validation, Writing – Original Draft Preparation, Writing – Review & Editing; **Bochmann M**: Conceptualization, Methodology, Resources; **Engler P**: Conceptualization, Formal Analysis, Methodology, Software; **Klaver C**: Conceptualization, Formal Analysis, Project Administration, Supervision; **Hummert C**: Conceptualization, Supervision, Writing – Original Draft Preparation, Writing – Review & Editing

Competing interests: No competing interests were disclosed.

Grant information: This research was financially supported by the European Union's Horizon 2020 research and innovation programme under the grant agreement No [832800](From mobile phones to court – A complete FORensic investigation chain targeting MOBILE devices [FORMOBILE]).

Copyright: © 2022 Pawlaszczyk DD *et al*. This is an open access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

How to cite this article: Pawlaszczyk DD, Bochmann M, Engler P *et al.* **API-based evidence acquisition in the cloud - a survey [version 1; peer review: 1 approved, 1 approved with reservations]** Open Research Europe 2022, **2**:69 https://doi.org/10.12688/openreseurope.14784.1

First published: 31 May 2022, **2**:69 https://doi.org/10.12688/openreseurope.14784.1

Introduction

The usage of cloud storage solutions is permanently increasing. Cloud services like Dropbox and Google Drive (Google, RRID: SCR_005886) allow their users, with relatively little technical knowledge, to store, manage and share content with others. Cloud forensics today is an integral part of nearly every criminal investigation. 85% of crime investigations include electronic evidence[1]. An increasing number of this data is managed in the cloud. So, examining cloud storage systems takes on particular importance for law enforcement agencies (LEAs)[2]. Cloud forensics describes cloud services' systematic, scientific, and technical investigation[3,4]. Data acquisition from the cloud is highly challenging since there are so many providers. Many of the technological, organizational, and legal problems related to retrieving this data are still unsolved. Before we describe different acquisition strategies, we must first introduce a definition and terminology for cloud computing. For this purpose, the technical background of the problem will be examined since this is essential for understanding further explanations.

Technical background

Cloud computing is a central concept of this work. From a technical perspective, cloud computing describes the approach of making IT infrastructures available *via* a computer network without having to install them on the local computer[5,6]. It is a model that provides ubiquitous and convenient on demand network access to a shared pool of configurable computing resources (such as networks, servers, storage, applications, and services), which can be deployed and shared quickly with minimal administrative overhead[4,5]. The term resource pooling in the context of cloud computing environments describes a situation where providers serve multiple clients with scalable services and virtualized hardware[5]. This makes it easy to add additional virtual central processing units (CPUs) and memory on the fly. This process is completely transparent for the user.

The idea behind resource pooling is that through modern, scalable systems involved in cloud computing, providers can create a sense of infinite resource pool. More precisely, the cloud provider's customers share the hardware resources provided. From the customer's point of view, the leased system appears to be practically infinitely expandable[5].

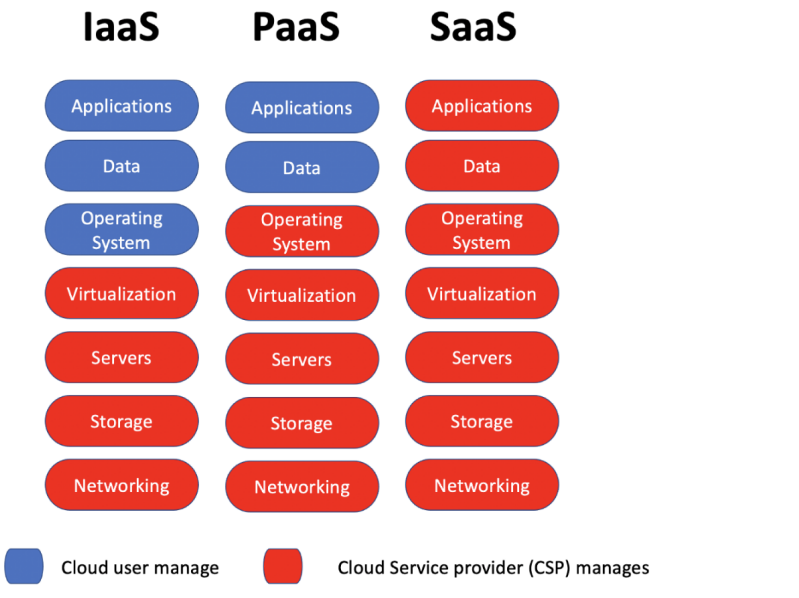
The definition of the National Institute of Standards and Technology (NIST)[5] distinguishes three fundamental service models for cloud computing, namely infrastructure as a service (IaaS), platform as a service (PaaS) and software as a service (SaaS) (see Figure 1). The main difference between the three models is how much influence the cloud user has on the management of the cloud service[5,7]:

Infrastructure as a service - IaaS[4]

The cloud supplies resources. The cloud itself needs resources to exist at all. The term "cloud infrastructure" describes both aspects. On the IaaS model, an infrastructure of "server, storage, network, archiving, backup, and data centre infrastructure as an abstract, virtualized service" is made available to the cloud user[5]. The cloud user has complete freedom of choice of operating system (*e.g.* Linux or Windows Server) and all other applications that are used. The cloud user has no access to the underlying layers of cloud computing. They handle the security of the applications and operating system(s) located on the IaaS.

Platform as a service - PaaS[7]

In the PaaS model, the cloud user gains access to the cloud service provider's (CSP) cloud infrastructure. Furthermore, the



IaaS .. Infrastructure as a Service ✦ **PaaS** .. Platform as a Service ✦ **SaaS** .. Storage as a Service

Figure 1. Basic cloud service models.

CSP must provide the user with access *via* interfaces since the user should act with the cloud. Therefore, operating systems and development environments are provided by the CSP. The user does not have to take care of the maintenance of the virtual machines in this model. A virtual machine provides the same functionality as physical computers. Just like these, virtual machines run applications and an operating system. However, virtual machines are computer files that run on a physical computer. Microsoft, with its Azure platform (Microsoft) (RRID: SCR_011880), provides an excellent example of this cloud model[8].

Software as a service - SaaS[5]

In the third scenario, a complete package is provided to the cloud user at the SaaS model, including applications. The user manages data *via* interfaces with browsers and apps in SaaS. In addition to mail and office programs, other applications such as enterprise resource planning (ERP), enterprise content management (ECM), e-commerce, and more can be offered. In this model, users usually share the infrastructure. The infrastructure is separate, ensuring that only privileged users with rights access to this partition. To avoid vulnerabilities, updates to all the cloud system components are required continuously. This update is the responsibility of the CSP. The third model offers the user the least amount of intervention and design options.

While the IaaS model still offers control over a large part of the infrastructure from the cloud customer's perspective, this control is reduced in the PaaS model and even more so in the SaaS model. At the technical level, there are hardly any interfaces in practice that cloud providers can use to provide access for forensic investigations[4]. In this article we will take a closer look at cloud storage services like Google Drive. Conceptually, these services can be viewed as a sub branch of SaaS paradigm. This means, that we have little influence on the configuration of these services.

Issues and challenges

When considering how to acquire data from a cloud service, we first have to talk about the concept and access strategies for cloud data. Forensics, in general, gives answers to questions about what, where, when and how something has happened. In the digital world, this includes uncovering and interpreting electronic evidence. The goal of digital forensics is to preserve any evidence in its most original form while performing a structured investigation by collecting, identifying and validating the digital information to reconstruct past events[9].

For a very long time, the topic of IT forensics has received little attention in the environment of cloud computing[10,11]. In recent years, several research projects have started on problems in this area. However, IT forensics in cloud environments still has open questions that have only been partially answered from technical, organizational and legal perspective[3,4,12–14]:

- **Legal issues.** From a legal point of view, there are a large number of open questions which can be answered in individual cases and not in general terms[15]. It is evident that in practice, many problems arise because CSPs act globally and offer their services across country borders. Therefore, the storage of data and the different, country-specific legal conditions are subject[9].

- **Organizational issues.** Since access to the spatially separated storage media for an IT forensic analysis is often impossible because the IT systems are now located abroad, investigators often have to request access to data from the operator or are dependent on operators. Even if the servers to be examined are situated in a CSP data centre in the investigator's home country, which is subject to the access of the investigators, access for backup is often ruled out since it would require disproportionate effort and intervention to read the data. If private cloud solutions operated in one's own company are not considered, the first problem is that almost always, that at least two parties are involved, the cloud customer and the cloud operator[16].

- **Technical issues.** At the same time, both providers of cloud services and investigative authorities are confronted with increased technical requirements. Especially in public cloud environments, relevant forensic data is usually mixed with data from uninvolved third parties[10]. The distributed storage of data and the use of distributed storage and computing capacity in cloud computing are other problem areas. Due to the increasingly high availability of broadband Internet, development has begun in which IT resources are no longer stored locally but can be accessed *via* the Internet from large data centres[17]. Today, this includes storage space on the Internet as a matter of course. The trend toward relocating entire IT systems to remote and software-abstract virtual machines seems irreversible[18]. This development means that less and less data is stored locally on the user's premises and physical data carriers contain fewer data relevant to evidence.

- **Forensic issues.** Established forensic investigation procedures are designed to collect relevant information locally and are unsuitable for collecting data from a remote, often globally operating cloud provider[16]. Even if physical access to a cloud provider's infrastructure should be possible, an investigation is hardly possible without the active assistance of the cloud provider[9,19].

In addition to the organizational challenges in individual service and organization models of cloud computing, there are also numerous technical difficulties[20,21]. The technical characteristics of cloud environments present new challenges[22,23]. Cloud infrastructures can consist of tens of thousands of servers[9]. This search and securing of the right physical system is a problem that should not be underestimated. Established forensic investigation procedures are designed to collect information from local devises and are unsuitable for collecting data from remote cloud servers[3,19]. Even if physical access to a cloud provider's is feasible, a full investigation is incredibly difficult without active assistance of the cloud provider. A good overview of these technical challenges can be found in 3, 24, 25 and 11. Well-known data extraction and analysis methods are accompanied by further questions related to the localization of data.

The paradigm shift from classic local IT forensics to the cloud is addressed in the work as mentioned above[15,26]. In particular, the following challenges are mentioned[4,15]:

- Loss of control over the data.
- No access to the physical infrastructure.
- Legal difficulties due to different responsibilities, manpower and multiple use.
- Lack of suitable tools for the analysis of virtual environments..
- No standardized interfaces.

As pointed out, there are some unique problems in IT forensics that only come to light in this area of a cloud environment. From a legal point of view, the issues arise from the cross-border structure that is naturally associated with cloud services. Furthermore, relevant forensic data are often mixed with data from uninvolved third parties, especially in public cloud environments[27]. The organizational challenge lies in having two parties, the cloud operator and the cloud user, involved. The current procedural models in IT forensics are not designed for and consequently are unsuitable for collecting data from a global player[4]. It is practically impossible to examine the data without the help of a cloud provider. Even physical access to the cloud provider's infrastructure is not enough. The main criticism here is the lack of access to individual parts of the system because there are hardly any interfaces at the technical level with which cloud providers can enable access for forensic examinations.

In a cloud scenario, we have four ways to acquire data (Figure 2). Typically, an investigation starts on the client's device. In addition to a copy of the data from the cloud drive, you can often find the access keys or credentials for the cloud account. However, the computer or smartphone analysis does not have to be complete, since this approach is based on the assumption that all files in the cloud are also stored 1:1 on the device and are fully replicated. In practice, the data is rarely 100 per cent synchronous[21]. Many traces can only be found in the cloud and not local. Thus, we can often even restore old file revisions *via* the cloud provider's recovery function[28]. Quite often, these can be retrieved *via* the trash function. A critical forensic question is also to find out which devices files were shared to and from.

We can use the information on the client to show which data was loaded from it into the cloud. Whether others have access to the cloud drive and which devices have retrieved the data remains hidden. A second starting point would be for the cloud service provider to access the cloud data. Unfortunately, this is where the problems already discussed are found. We are dependent on cooperation with the CSP. In addition, we have to expect considerable waiting times in this case, which means that evidence may already be lost[22]. Virtually all cloud providers also allow access to the content stored in the cloud *via* a web interface. In addition to a classic website, we almost always find a programming interface[29]. Thus, we can access the data stored in the cloud without delay when we have the correct user credentials[27]. However, accessing and acquiring data *via* the website can sometimes prove cumbersome. From an investigator's perspective, automatic preservation of evidence is

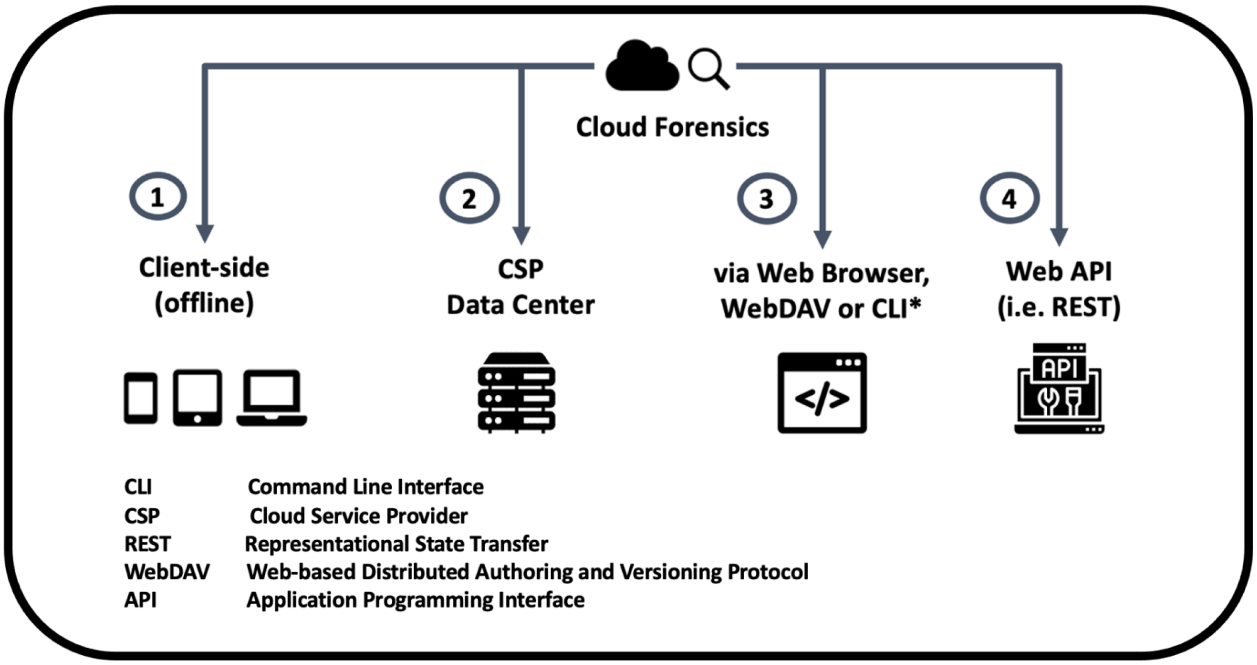


Figure 2. Starting points for a cloud forensic investigation, reproduced with permission from 29.

naturally preferable. Therefore, we will present the idea of an API-based acquisition in more detail in the next section.

API-based data acquisition

There are a large number of publications that discuss the examination of evidence and metadata stored on a local device[27,28,30]. The concept of API-based acquisition is a relatively new approach. It was first discussed by Roussev *et al.* in 17. We access the data stored in the cloud drive through an API usually provided by the CSP. Sometimes interfaces to special cloud services are also offered by third parties. From a technical perspective, this is almost always a representational state transfer (REST) interface[31]. REST is a paradigm for software architecture of distributed systems, especially for web services[31]. Resources are a core of REST. The resources are uniquely identified by a uniform resource identifier (URI). RESTful APIs provide resources using URIs. A typical URI normally looks like: endpoint-uri/*deviceId/disk/*id. At this point, there are parallels to a classic hierarchically organized file system[17]. In both cases, a path specification is required to gain access to the data. The call is, therefore, very intuitive. A URI contains the location and name of the resource but not the functionality. Thus, this concept is particularly suitable for making files available *via* the Internet. Clients obtain storage device resources and storage services using the URIs accordingly (see Figure 3). Any web provider that only offers entire page content according to the Internet standard HTTP is already REST-compliant. Such pages are requested according to the REST paradigm. REST normally employs the following standard operations to access resources:

- POST: creates resources.
- GET: queries resources.
- PUT: modify resources.
- DELETE: deletes resources.

A RESTful API is defined as an application programming interface (API) that uses HTTP requests to access data *via* GET, PUT, POST, and DELETE. This type of access is often referred to as the CRUD approach. CRUD is an abbreviation for these operations to create, retrieve, update and delete data in a software application or service (Table 1).

To query the data stored with the cloud service provider, we use the official web APIs. In simple terms, a web API describes a data access point that has the following properties:

- Exposed over http(s),
- available over the Internet,
- uses the HTTP response and request schema,
- based on human readable data format.

The respective services essentially differ only in the specification of the endpoint address, which naturally varies from service to service. We can access and store artefacts within the cloud in a controlled manner *via* corresponding client software. Most access to data is given *via* a well-defined interface, which makes it much easier to acquire the data in a forensically sound manner and ensures a high degree of automation.

The following example illustrates how easy it is to call a resource provided *via* REST. The source code shows the login and the query of the directory content for a pCloud account using Python (RRID:SCR_008394)[32]

from pcloud **import** PyCloud

pc = PyCloud (' email@example . com ' , ' SecretPassword ' , endpoint=" eapi ") pc . listfolder (folderid =0)

Data acquisition is straightforward if the investigator has access to the credentials. What's more, the process can be fully

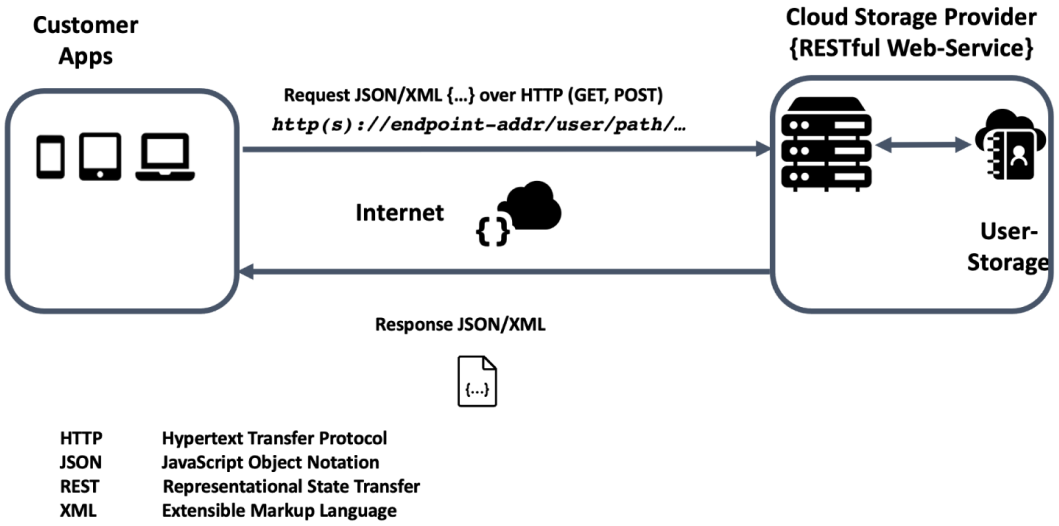


Figure 3. Concept of a representational state transfer (REST) web application programming interface (API).

Table 1. HTTP methods and corresponding basic CRUD (create, read, update and delete) operations.

HTTP-method	CRUD-operation
POST	Create
GET	Read
PUT	Update/replace
PATCH	Update/modify
DELETE	Delete

automated. In addition to being the only means for guaranteeing a forensically-complete copy of the target data, the API approach supports the reproducibility of results, rigorous tool testing (based on well-defined API semantics) and triage of the data (*via* hashes or search APIs). The development effort is significantly lower because client-centric approaches eliminate the entire black box reverse engineering component.

Methodology

In this study we aim to determine whether this approach is practicable based on the preliminary considerations. For this purpose, we examined 30 cloud providers in a case study. The services were selected primarily on the basis of user numbers. Another criterion for selection was forensic relevance. A cloud service like MEGA (MEGA Ltd, New Zealand), for example, is increasingly the subject of police investigations. Of course, the selection is not exhaustive. The focus of the study was primarily on cloud storage providers and file-sharing vendors. An access account was created for each of the cloud services studied.

The aim was to decide whether or not we could manage a forensic sound data acquisition with our API-based approach. It was first necessary to clarify if a corresponding REST interface is available for each cloud service. For this purpose, the interface documentation provided by each cloud provider and source code repositories made available were analyzed. For better traceability, the names of the respective API have been listed again in Table Table 2. With the help of the API name, all information used for the study can be easily found and verified. All of the information listed below is taken from the descriptions found there. In addition, for 8 of the total of 30 services examined, a sample implementation for access was taken.

In the next step, we determined the technical requirements for each CSP. For this purpose, the API descriptions for each cloud service were analyzed. This involves the architectural style and the parameters that had to be transferred. Beyond this, we had to clarify which information could be queried *via* the APIs. Of course, the response format also had to be checked. From an investigator's point of view, it is essential to know whether we can recover deleted data. The interface documentation was reviewed for appropriate access methods to recover deleted data. The user accounts created for testing purposes were also checked for recovery options. Another critical feature of a forensic investigation is retrieving a file's version history. Adding meta-information about a file, such as the creation and modification dates, should be accessible. Another point we have checked was the possibility of retrieving events logs. All of the cloud services examined in the study can be seen in Table 2. The main focus was on storage cloud providers that take a SaaS approach. However, some messaging and chat services such as Steam Gaming Engine (Valve, 2003) or Telegram (Telegram) are also included, not least because they are increasingly the subject of police investigations[33,34]. For the type column, the provider notes the primary purpose of the service. The architectural style is indicated in a separate column.

Results

From Table 2 we can see that there is a corresponding REST interface in place for any cloud service. Beyond this, some vendors offer alternative RPC-based access options or allow retrieval *via* WebDAV (web-based distributed authoring and versioning). However, the last alternative is limited to only a few CSP. API-based access is supported by virtually every vendor in our test, a very encouraging result. If we are looking for an access method that works for nearly all cloud storage solutions, then the API approach *via* REST seems to be a good choice. Except for the ICloud (Apple, 2011) service, all vendors offer official APIs to access the data stored in the cloud *via* REST. For the ICloud, there is again a plethora of third-party providers providing an interface. For our study, we examined the *pyicloud* project closely. As *pyicloud* is an open-source and freely available interface able to provide all necessary functionalities to perform a forensic copy.

As part of the survey, we also wanted to find out which authentication options the respective providers support (see Table 3). This information is of particular importance. A large number of the cloud services examined support login with password and user name. Other providers only support open authorization (OAutho) authentication. In this case, access to the cloud data must always be authorized *via* a browser session or an app. For a forensic investigation, we need an unlocked phone before we can access the data *via* the API. After approval *via* OAuth, the app receives an access key. This time-limited token can then be used to access the data. This way, a password never has to be used directly to access the data. Among the cloud services examined, there was only one service - Telegram - that forces a two-factor authentication (2FA). For others, this login method is optional.

Once we have successfully overcome the authorization hurdle, we can begin to acquire data. Table 4 shows further technical details for accessing the respective cloud services. In addition to the respective API endpoint, the supported request protocol and the supported response formats are displayed. Without exception, all providers follow the CRUD paradigm. Standard HTTP methods such as GET, PUT and DELETE are thus used to access the stored resources. When it comes to the supported response

Table 2. Web application programming interfaces (APIs) for popular cloud storage providers (CSP).

CSP	Type	API name	Architectural Style	Official
Accellion	file sharing	Accellion's API Guide	RESTful[1]	Yes
Amazon Cloud Drive	file sharing	RESTful Amazon Drive API	RESTful	Yes
Box	file sharing	Box API	RESTful	Yes
Datto	backup	Datto RMM-API	RESTful	Yes
Degoo	file sharing	Degoo GraphQL API	RESTful	No
DropBox	file sharing	DropBox API V2	RESTful	Yes
Google Drive	file sharing	Drive API/ Drive Activity	RESTful	Yes
HiDrive	file sharing	HiDrive API	RESTful	Yes
HIGHTAIL	file sharing	Hightail (YouSendIt) API V. 1.0	RESTful	Yes
hubicC	file sharing	hubiC API (OpenStack API)	RESTful	Yes
Huddle	file sharing	Hudlle API	RESTful	Yes
ICloud(pyicloud)	storage, sync	pyicloud	RESTful	No
IDrive	backup/file sharing	EVS iDriveSync RESE API	RESTful	Yes
MediaFire	storage, file sharing	mediafire.com/api	RESTful	Yes
MEGA	storage, file sharing	MEGA API	RESTful	Yes
NextCloud	storage, file sharing	NextCloud OCS API	RESTful	Yes
OneDrive	storage, file sharing	Graph API / OneDrive-API	RESTful	Yes
Oodrive	file sharing	REST API @	RESTful	Yes
Orange Cloud	file sharing	api.orange.com	RESTful	Yes
Open Telekom Cloud	IaaS, Virtualization	Telekom Cloud API	RESTful	Yes
ownCloud	fie sharing	OCS Rest API	RESTful	Yes
pCloud	storage, file sharing	pCloud REST API	RESTful	Yes
PowerFolder	storage, file sharing	Power Folder REST API	RESTful	Yes
SendSpace	file	SendSpace API 1.2	RESTful	Yes
ShareFile	file sharing	ShareFile API	RESTful	Yes
SpiderOak	storage, backup	Accounts API 1.0.0	RESTful	Yes
SteamChat	gaming, chat, share content	SteamWorks Web API	RESTful	Yes
SugarSync	storage, backup	SugarSync API	RESTful	Yes
Syncplicity	content collaboration	Syncplicity-Rest-APIs	RESTful	Yes
Telegram	messaging, file sharing	Telegram REST API	RESTful	Yes
TeamDrive	file sharing	TeamDrive Http Api	RESTful	Yes

[1] REST - Representational state transfer

formats, the picture is twofold. In the vast majority of cases, it is a regular JavaScript Object Notation (JSON) string. Some providers rely on XML. Some CSPs additionally support CSV as a return format. However, parsers are usually available for all offered forms. Decoding the message content should therefore not be a significant problem.

All providers tested allowed the download of individual files as well as cloud directories. The resources can usually be accessed directly as a binary stream. In some cases, the binary information is also embedded directly in the JSON messages. In this case, the providers resort to BASE64 encoding. Of course, the resources stored in the cloud are of the highest interest in a

Table 3. Authorization/authentification.

Cloud service provider	Authentication/authorization method
Accellion	OAuth 2.0[1] with access token
Amazon Cloud Drive	Access token, Authorization Code Grant, Login to amazon
Box	Acces token, OAuth 2.0, JSON Web Tokens (JWT), client credentials
Datto	OAuth 2.0, API Key and API Secret Key (for account activation)
Degoo	Credentials + invariant API-key
DropBox	OAuth 2.0 with offline access token
Google Drive	OAuth 2.0 with application access token
HiDrive	OAuth 2.0 with application access token
HIGHTAIL	OpenText Hightail
hubicC	OAuth 2.0 with access token
Huddle	OAuth 2.0 with access token
ICloud	Credentials (username + password), support for 2SA[2]/2FA[3]
IDrive	OAuth or credentials (username + password)
MediaFire	Credentials, OAuth login style
MEGA	Credentials (email, password)
NextCloud	Password based HTTP Basic Auth or valid session cookie
OneDrive	OAuth 2.0 with application access token
Orange Cloud	OAuth 2.0 with access token, Others
Open Telekom Cloud	Credentials (username + password)
ownCloud	Credentials (username + password)
pCloud	OAuth 2.0 with access token, credentials
PowerFolder	Username + password
SendSpace	Username + password
ShareFile	OAuth 2.0 with access token, SAML
SpiderOak	Password based HTTP Basic Auth
SteamChat	Steam Account info + Web-API key, OAuth
SugarSync	Credentials (username + password)
Syncplicity	Credentials (username + password)
Telegram	Credentials + 2FA
TeamDrive	Username + password, HTTP Basic Auth

[1] OAuth - Open authorization protocol [2] 2SA - Two step authentification [3] 2FA - Two factor authentification

forensic investigation. In addition, however, there are other questions to which the investigator may seek answers. So, for the most part, it is just as important to find out when a particular file was uploaded to the cloud. If several versions of the file exist, then it would be desirable to be able to query this information. When and which users have accessed the files is another crucial question in many investigations. Finally, the recovery of previously deleted files from the recycle bin should also be given if possible. In addition, many providers offer the query of user information. In the case of the Box cloud service (Box inc,), for example, this includes the user's name and user ID, their email address, the time the account was created,

Table 4. Application programming interface (API) - Technical details.

CSP	API Endpoint	Request Protocol	Response Format
Accellion	https://<kiteworks_server>/oauth/	URI Query String/ CRUD[1]	JSON[2]
Amazon Cloud Drive	https://drive.amazonaws.com	URI Query String/CRUD	JSON
Box	https://app.box.com/2.0/	URI Query String/CRUD	JSON
Datto	https://pinotage-api.centrastage.net/api/	URI Query String/CRUD	JSON
Degoo	https://rest-api.degoo.com/	URI Query String/CRUD	JSON
DropBox	https//content.dropboxapi.com	URI Query String/CRUD	JSON
Google Drive	https://www.googleapis.com/	URI Query String/CRUD	JSON
HiDrive	https://api.hidrive.strato.com/2.1/	URI Query String/CRUD	JSON
HIGHTAIL	https://api.stage.htspaces.com/devapi/v1	URI Query String/CRUD	JSON
hubicC	https://api.hubic.com/oauth/	URI Query String/CRUD	JSON
Huddle	https://api.huddle.net/entry	URI Query String/CRUD	JSON/XML
ICloud	https:///ws/com.apple.CloudDocs/	URI Query String/CRUD	JSON
IDrive	https://evs.idrivesync.com/evs/	URI Query String/CRUD	XML[3]
MediaFire	https://www.mediafire.com/api/	URI Query String/CRUD	JSON, XML
MEGA	https://g.api.mega.co.nz/	URI Query String/CRUD	JSON
NextCloud	https://cloud.example.com/ocs/	URI Query String/CRUD	XML
OneDrive	https://graph.microsoft.com/v1.0	URI Query String/CRUD	JSON
Orange Cloud	https://api.orange.com/cloud/v1/	URI Query String/CRUD	CSV, JSON, XML
Open Telekom Cloud	https://ecs.eu-de.otc.t-systems.com	URI Query String/CRUD	(Geo)JSON, XML
ownCloud	http://api.owncloud.org/	URI Query String/CRUD	JSON, XML
pCloud	https://www.pcloud.com	URI Query String/CRUD	JSON
PowerFolder	https://access.powerfolder.com/api/	URI Query String/CRUD	(Geo)JSON, XML
SendSpace	http://api.sendspace.com/rest/	URI Query String/CRUD	XML
ShareFile	https://subdomain.sharefile.com/rest	URI Query String/CRUD	JSON(P), Text, XML
SpiderOak	https://alice.diy.spideroak.com/data/	URI Query String/CRUD	CSV, (Geo)JSON, XML
SteamChat	https://api.steampowered.com/v/	URI Query String/CRUD	JSON
SugarSync	https://api.sugarsync.com/	URI Query String/CRUD	XML
Syncplicity	https://api.syncplicity.com	URI Query String/CRUD	JSON
Telegram	https://core.telegram.org/api	URI Query String/CRUD	JSON
TeamDrive	https://<teamdrive-server>/api	URI Query String/CRUD	JSON

[1] CRUD - Create Read Update Delete, [2] JSON - JavaScript Object Notation [3]XML - Extensible Markup Language

the time zone setting, the user's address and the phone number stored. In Table 5 it is shown to what extent these, forensically, interesting questions are supported by the provided interfaces. For categories that are supported by the API we use a ✓symbol. Properties that could not be found in the API, a minus (-) is used. Of course, the observations represent only a snapshot, as the APIs are constantly evolving.

First of all, it can be stated that practically all providers offer additional information about their resources. Mostly this is

Table 5. Supported information categories.

Cloud service provider	Trash Recovery	Meta Data	User Activities	Timestamps
Accellion	✓	✓	✓	✓
Amazon Cloud Drive	✓	✓	✓	✓
Box	✓	✓	✓	✓
Datto	-	✓	✓	✓
Degoo	✓	✓	-	✓
DropBox	✓	✓	✓	✓
Google Drive	✓	✓	✓	✓
HiDrive	-	✓	✓	✓
HIGHTAIL	-	✓	-	✓
hubicC	✓	✓	✓	✓
Huddle	-	✓	✓	✓
ICloud	✓	✓	✓	✓
IDrive	✓	✓	✓	✓
MediaFire	✓	✓	✓	✓
MEGA	✓	✓	✓	✓
NextCloud	✓	✓	✓	✓
OneDrive	✓	✓	✓	✓
Orange Cloud	✓	✓	✓	✓
Open Telekom Cloud	✓	✓	✓	✓
ownCloud	✓	✓	✓	✓
pCloud	✓	✓	✓	✓
PowerFolder	✓	✓	✓	✓
SendSpace	-	✓	-	✓
ShareFile	✓	✓	✓	✓
SpiderOak	✓	✓	✓	✓
SugarSync	✓	✓	✓	✓
Syncplicity	✓	✓	✓	✓
Telegram	-	-	-	✓
TeamDrive	✓	✓	✓	✓

information about the account as well as timestamps. Some providers like Google[30] or Microsoft[17] also support the retrieval of user information. For others, the provision of meta-information is limited to resources like files and directories only. There are also significant differences regarding the possibility of accessing deleted data from the recycle bin. Not every CSP provides access here. Services such as SendSpace or Huddle are examples of this. However, some providers do not support a trash function at all - neither *via* the API nor other methods. During our survey, we could identify artefacts of forensic interest, such as information generated during login, uploading, downloading, deletion, and sharing files. Here again, the providers diverge significantly in terms of the information provided.

Differences also occurred in the retrieval of timestamps. In some cases, these are adjusted to the user's time zone. In the case of

the Box cloud service, for example, the timestamps are stored in Request for Comment (RFC) 3339 format and are always given in Coordinated Universal Time (UTC) - 7 zone time, the timestamp of the folder created in the RFC 3339 format was given in the zone time UTC ± 0 and not in the user's time zone. In other cases, the UTC timestamps are not returned as strings but as UNIX timestamps in milliseconds or seconds. For example, you can say that on 2021-12-26 05:32 UTC, 1640496741000 milliseconds (or 1640496741 seconds Epoch timestamp) have passed since 1970-01-0100:00:00 UTC.

However, forensic analyses must always consider that the output time must first be converted to the zone time in which the user carried out the activities to make a correct statement. It is crucial to ensure the integrity and completeness of the data. Therefore, as part of the meta-information, hash values are also offered *via* the interface in many cases. Mostly, these are classic MD5 checksums. In some cases, SHA-1 is supported as a checksum. Here, again, there is no uniform picture. Regarding the completeness of the forensic copy, it can be stated that in our test, a few pieces of information could not be reconstructed. For example, there were sometimes no entries for login activities, changes to settings, or folder accesses in the user events. The cloud service Box is an example of this.

As our study makes clear, virtually all CSPs offer a REST interface. Thus, data access can be easily automated. However, there are some significant differences in terms of the data that can be retrieved and their structure. An additional access layer is needed to ensure easy and sound data acquisition. Access to the data can be significantly simplified with an appropriate framework in place. All steps - even for different vendors - can be unified. Data preparation issues could thus also be quickly resolved. As a proof-of-concept, based on the results of our study, we developed a framework that supports automated acquisition. At the same time, we can use it to demonstrate practical feasibility of the discussed API-based acquisition approach. The framework is briefly introduced in the next section.

Proof of concept - The CLOUDxTRACT framework

Based on the results of our study, we developed an access service that provides prototypical access to numerous cloud services. The novel software solution presented here has the name CLOUDxTRACT. It represents an attempt to provide a simple, automated and forensically sound seizure of cloud resources. Currently, access to eight different storage services is offered: MediaFire, PCloud, Sugarsync, Strato HiDrive, Nextcloud, Skype, Steam Chat and Degoo.

CLOUDxTRACT is designed as a command-line tool without a graphical user interface. This solution offers the highest performance and can be easily integrated in a batch job. In the following, an overview on the principle system design and the interaction of objects is given. Figure 4 illustrates how the CLOUDxTRACT is constructed. The framework consists of multiple classes which are organized into tiers. We start with the Extractor-Class. In the *run()*-method of the Extractor-Class the workflow is started. It implements the main control logic. The *run()*-method again calls the concrete procedures for data acquisition from a specialized adapter class. For each supported cloud service provider, a particular adapter class exists which taps the API from the cloud service provider. Specialized adapter classes like *MediaFireAdapter* use a *xxxClient* classes to handle the communication to the APIs from the CSP. In this way, we obtain a modular framework that can be easily extended with additional cloud services. At the same time, it ensures that all data can be stored in a forensically clean and repeatable manner with timestamps and hash values.

System requirements and installation

The installation process is very simple. For the execution of the scripts a Python runtime environment of version 3 or higher is required (more information here. A special operating system is not required. A minimum of 4 GB RAM is recommended. There are no other special hardware requirements.

The installation consists of 4 steps in total:

1. Download the source code of CLOUDxTRACT from the official project page

   https://github.com/FORMOBILE/CLOUDxTRACT

2. Copy the library files into a folder of your choice.
3. Open a command line terminal and navigate to the folder where the file `setup.py` resides.
4. Use `pip` to register the library in the python environment with the command `pip install -e`.

This completes the installation process. The software can now be used immediately to acquire data from the cloud.

MediaFire use case

Using the tool is very simple. We will show this in the following using the MediaFire cloud service as an example. MediaFire is a file hosting, file synchronization, and cloud storage service based in Shenandoah, Texas, United States. MediaFire has 43 million registered users and attracted 1.3 billion unique visitors to its domains in 2012 (MediaFire about). The input parameter and output are nearly the same for all supported CSPs. For demonstration purposes a test account was filled with simple test files shown in Figure 5. The CLOUDxTRACT can be executed by command line and has a build in help functionality for each service.

To view the help, the optional parameter -h or –help must be provided. To acquire the test account, the following command is used:

```
python -m extractor {service} --logfile file.
log -u "username" -p "password" destination
```

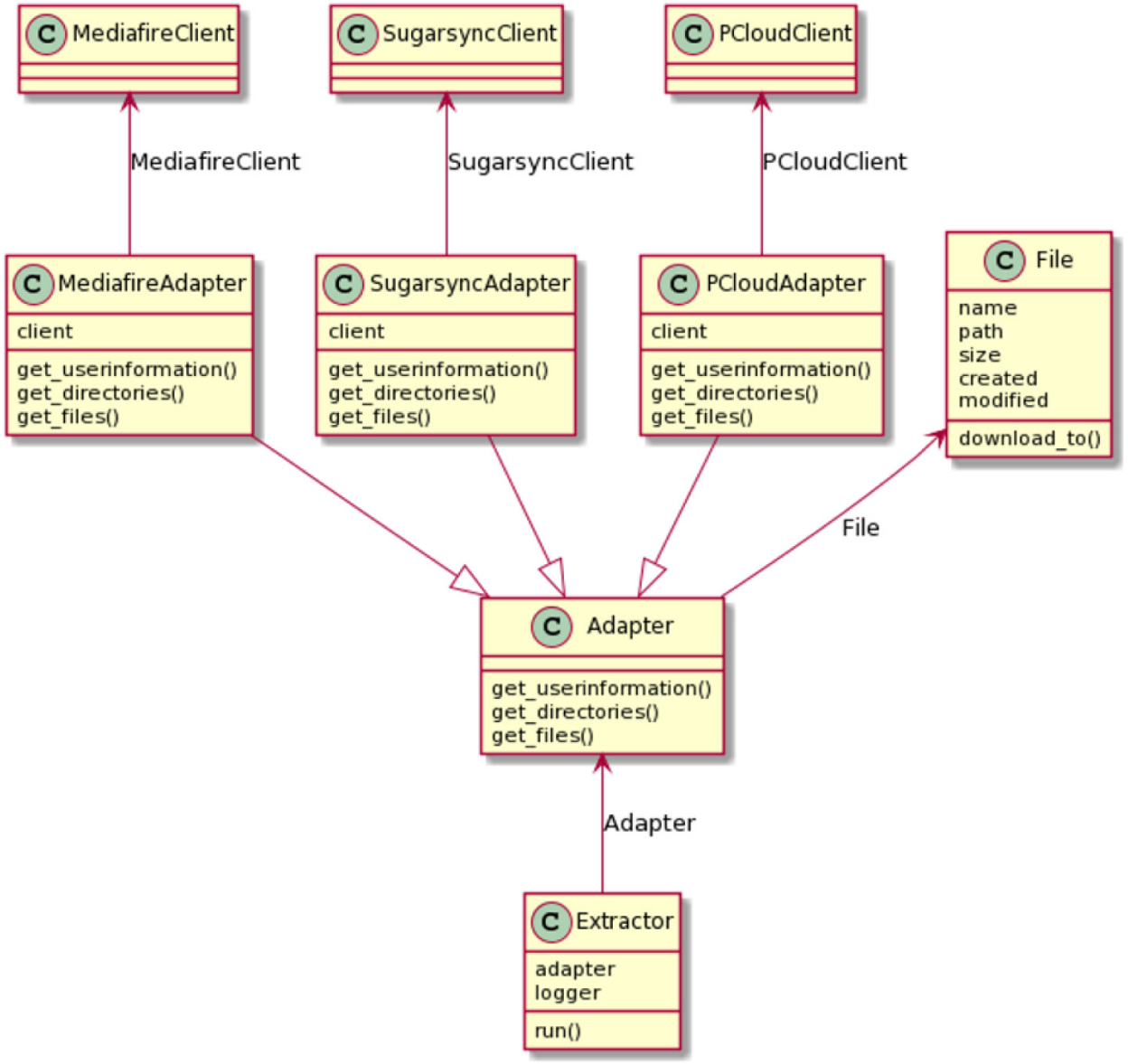


Figure 4. The CLOUDxTRACT framework (class diagram).

This command triggers the extraction process. The name of the respective cloud service must be entered in place of the *service* parameter. In addition to the user name and password, the name of the log file and the destination directory must also be entered.

In Figure 6 the messages of the log file are shown as an example. As you can see in the screenshot, important meta information and timestamps are retrieved in addition to the actual data content. For each file, an additional MD5 hash is automatically calculated during the download. Later modifications to the acquired files can thus be easily detected by comparing the hash values from the download with the most recent once. The source code of this framework is made available as an open-source repository *via* the FORMOBILE Project Github-Account. In this way, practitioners can directly participate from the results of this project.

Conclusions and future work

This paper examined the acquisition of data from cloud drives in more detail. The cloud services of 30 providers analyzed in this context show similarities to a large extent. The

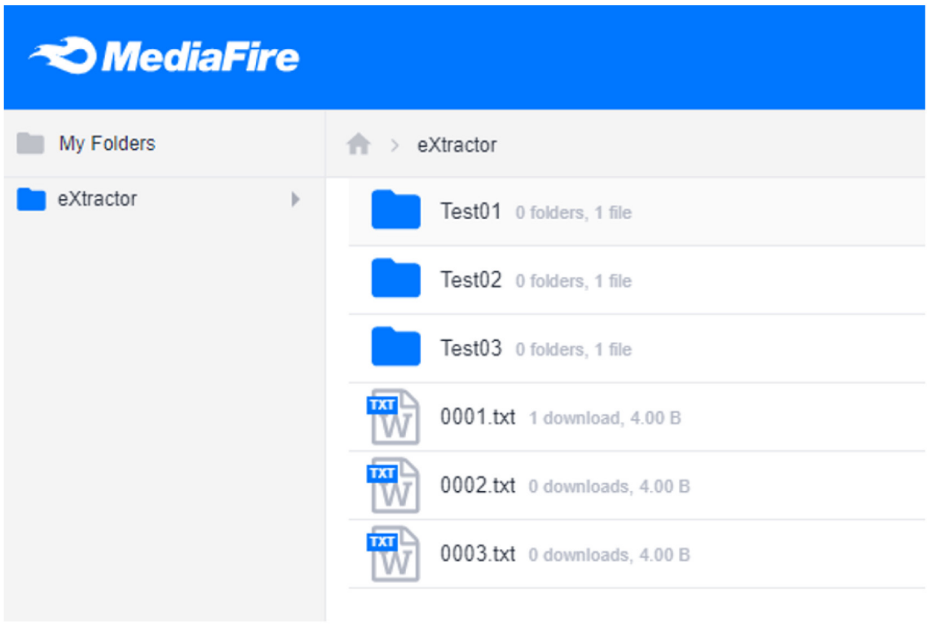


Figure 5. **The MediaFire web front-end populated with test data (screenshot).**

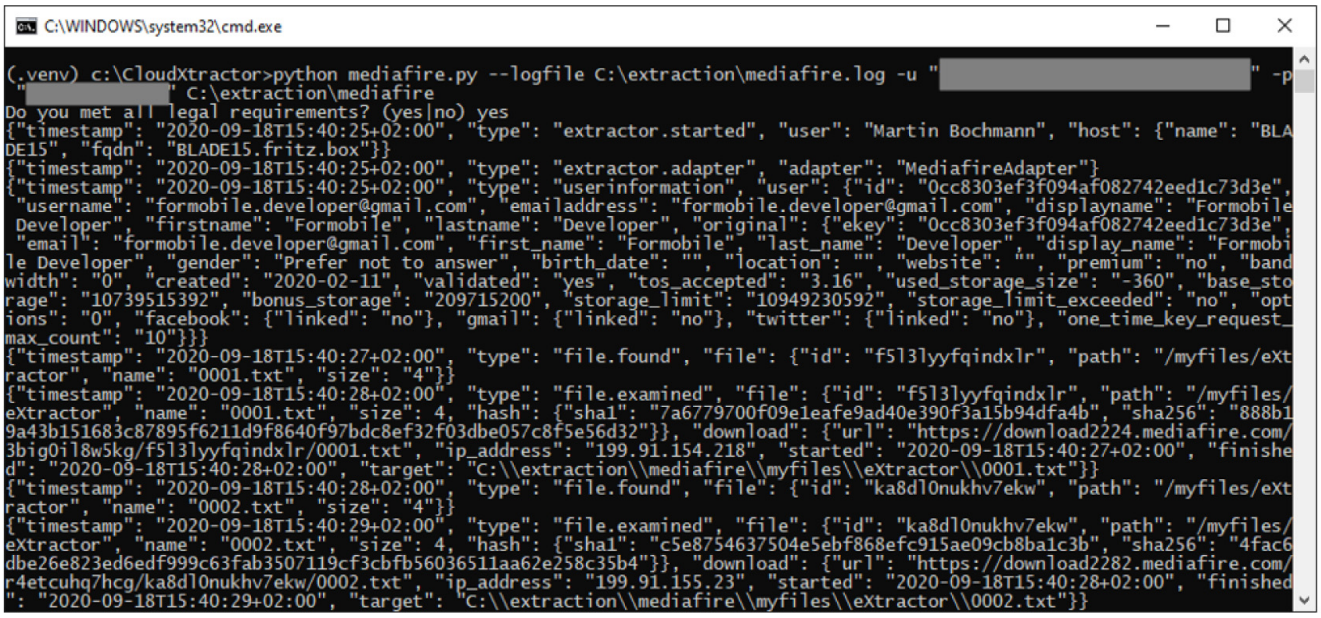


Figure 6. **Extraction Output for a MediaFire cloud account (example).**

heterogeneity of cloud services repeatedly emphasized in the literature appears very uniform on closer inspection. Our findings contribute to an up-to-date understanding of cloud storage forensics. As it turns out, all of the cloud services explored can be queried in the same way. All of the interfaces examined are RESTful services. Significant differences arise, in particular, in the meta-information provided by the respective API and the format and structure of the returned data.

The presented software solution CLOUDxTRACT[35] proves that an automated seizure of data *via* an API-based approach is possible. A total of eight functional interfaces are implemented at the time of publication. Since the source code is published as open source, it can be easily reviewed and proved by other scientists[36].

Hence, many processing steps can be handled by the framework. The straightforward design of the framework enables users to adopt existing and integrate new cloud service providers easily. The number of services provided *via* CLOUDx-TRACT is to be expanded in the future. Concrete plans for further cloud services to be integrated are already in the pipeline.

Data availability

Underlying data

Zenodo: FORMOBILE/CLOUDSURVEY: Survey Datasheet. https://doi.org/10.5281/zenodo.6556669[36]

This project contains the following underlying data:

- Survey_DataSheet.xlsx (Complete datasheet for all 30 cloud services surveyed within this article)

Data are available under the terms of the the Creative Commons Zero "No rights reserved" data waiver (CC0 1.0 Public domain dedication).

Software availability

Source code of CLOUDxTRACT is available here: https://github.com/FORMOBILE/CLOUDxTRACT Archived source code at the time of publication: https://doi.org/10.5281/zenodo.6555508[35]

Licence: GPLv3

Ethics and consent statement

Ethical approval and consent were not required.

References

1. Eurostat Press Office: **Almost 8 out of 10 internet users in the eu surfed via a mobile or smart phone in 2016.** *online newsrelease*, 12 2017. 260/2016.
2. Pawlaszczyk D: **Mobile forensics – the end of a golden age?** *J Forensic Sci & Criminal Inves.* 2022; **15**: 1–4.
Publisher Full Text
3. Alqahtany S, Clarke N, Furnell S, *et al.*: **Cloud forensics: A review of challenges, solutions and open problems.** In *2015 International Conference on Cloud Computing (ICCC).* 2015; 1–9.
Publisher Full Text
4. Herman M, Iorga M, Salim AM, *et al.*: **Nist cloud computing forensic science challenges.** 2020.
Publisher Full Text
5. Mell P, Grance T: **The nist definition of cloud computing.** Technical Report 800-145, National Institute of Standards and Technology (NIST), Gaithersburg, MD, 2011.
Reference Source
6. Velte T, Velte A, Elsenpeter R: **Cloud Computing, A Practical Approach.** McGraw-Hill, Inc., USA, 1 edition. 2009.
Reference Source
7. Kavis M: **Cloud Service Models.** chapter 2, John Wiley and Sons, Ltd, 2014; 13–22.
Publisher Full Text
8. Copeland M, Soh J, Puca A, *et al.*: **Microsoft Azure: Planning, Deploying, and Managing Your Data Center in the Cloud.** Apress, USA, 1st edition. 2015.
Reference Source
9. Pawlaszczyk D: **Digitaler Tatort, Sicherung und Verfolgung digitaler Spuren.** Springer Berlin Heidelberg, Berlin, Heidelberg. 2017; 113–166.
Publisher Full Text
10. Gebhardt T, Reiser HP: **Network forensics for cloud computing.** In Jim Dowling and François Taïani, editors, *Distributed Applications and Interoperable Systems,* Berlin, Heidelberg, Springer Berlin Heidelberg. 2013; 29–42.
Publisher Full Text
11. Pichan A, Lazarescu M, Soh ST: **Cloud forensics: Technical challenges, solutions and comparative analysis.** *Digit Investig.* 2015; **13**: 38–57.
Publisher Full Text
12. Alenezi A, Zulkipli NHN, Atlam HF, *et al.*: **The impact of cloud forensic readiness on security.** In *Proceedings of the 7th International Conference on Cloud Computing and Services Science - CLOSER,*. INSTICC, SciTePress, 2017; 539–545.
Publisher Full Text
13. Ab Rahman NH, Choo KKR: **A survey of information security incident handling in the cloud.** *Comput Secur.* 2015; **49**: 45–69.
Publisher Full Text
14. Zach J, Reiser HP: **Livecloudinspector: Towards integrated iaas forensics in the cloud.** In Alysson Bessani and Sara Bouchenak, editors, *Distributed Applications and Interoperable Systems - 15th IFIP WG 6.1 International Conference, DAIS 2015, Held as Part of the 10th International Federated Conference on Distributed Computing Techniques, DisCoTec 2015, Grenoble, France, June 2-4, 2015, Proceedings*, of Lecture Notes in Computer Science. 2015; **9038**: 207–220.
Publisher Full Text
15. Simou S, Kalloniatis C, Mouratidis H, *et al.*: **Towards the development of a cloud forensics methodology: A conceptual model.** In Anne Persson and Janis Stirna, editors, *Advanced Information Systems Engineering Workshops,* Cham, Springer International Publishing. 2015; 470–481.
Publisher Full Text
16. Bansal P, Patidar M: **Cloud forensics: An overall research perspective.** *International Journal of Scientific Research in Network Security and Communication.* 2018; **6**(2): 5–10.
Reference Source
17. Roussev V, Barreto A, Ahmed I: **Api-based forensic acquisition of cloud drives.** In Gilbert Peterson and Sujeet Shenoi, editors, *Advances in Digital Forensics XII,* Cham, Springer International Publishing. 2016; 213–235.
Publisher Full Text
18. Ruan K, Carthy J, Kechadi MT, *et al.*: **Cloud forensics definitions and critical criteria for cloud forensic capability: An overview of survey results.** *Digit Investig.* 2013; **10**(1): 34–43.
Publisher Full Text
19. Shumba R: **Client forensics: An assessment of existing research and future directions.** *International Journal of Computer Science and Security (IJCSS).* 2018; **12**(3): 45–54.
Reference Source
20. Simou S, Kalloniatis C, Kavakli E, *et al.*: **Cloud forensics: Identifying the major issues and challenges.** In Matthias Jarke, John Mylopoulos, Christoph Quix, Colette Rolland, Yannis Manolopoulos, Haralambos Mouratidis, and Jennifer Horkoff, editors, *Advanced Information Systems Engineering.* Cham, Springer International Publishing, 2014; **8484**: 271–284.
Publisher Full Text
21. Khan S, Gani A, Wahab AWA, *et al.*: **Cloud log forensics: Foundations, state of the art, and future directions.** *ACM Comput Surv.* 2016; **49**(1): 1–42.
Publisher Full Text
22. Almulla S, Iraqi Y, Jones A: **A state-of-the-art review of cloud forensics.** *Journal of Digital Forensics, Security and Law.* 2014; **9**: 7–28.
Publisher Full Text
23. Samy GN, Shanmugam B, Maarop N, *et al.*: **Digital forensic challenges in the cloud computing environment.** In Faisal Saeed, Nadhmi Gazem, Srikanta Patnaik, Ali Saleh Saed Balaid, and Fathey Mohammed, editors, *Recent Trends in Information and Communication Technology.* Cham, Springer International Publishing, 2018; **5**: 669–676.
Publisher Full Text
24. Sree TR, Bhanu SMS: **Data collection techniques for forensic investigation in cloud.** In B Suresh Kumar Shetty and Pavanchand Shetty H, editors, *Digital*

Forensic Science. chapter 6. IntechOpen, Rijeka, 2020.
Publisher Full Text

25. Ali SA, Memon S, Sahito F: **Challenges and solutions in cloud forensics.** In *Proceedings of the 2018 2nd International Conference on Cloud and Big Data Computing.* ICCBDC' 18, New York, NY, USA, Association for Computing Machinery. 2018; 6–10.
Publisher Full Text

26. Grispos G, Storer T, Glisson WB: **Calm before the storm: The challenges of cloud computing in digital forensics.** *CoRR.* abs/1410.2123, 2014.
Reference Source

27. Daryabar F, Dehghantanha A, Eterovic-Soric B, *et al.*: **Forensic investigation of onedrive, box, googledrive and dropbox applications on android and ios devices.** *Aust J Forensic Sci.* 2016; **48**(6): 615–642.
Publisher Full Text

28. Daryabar F, Dehghantanha A, Choo KKR: **Cloud storage forensics: Mega as a case study.** *Aust J Forensic Sci.* 2017; **49**(3): 344–357.
Publisher Full Text

29. Pawlaszczyk D, Friese J, Hummert C: **"alexa, tell me . . . " - a forensic examination of the amazon echo dot 3 rd generation.** *Int J Comput Sci Eng.* 2019; **7**(11): 20–29.
Publisher Full Text

30. Quick D, Choo KKR: **Google drive: Forensic analysis of data remnants.** *J Netw Comput Appl.* 2014; **40**: 179–193.
Publisher Full Text

31. Fielding RT: **REST: Architectural Styles and the Design of Network-based Software Architectures.** Doctoral dissertation, University of California, Irvine, 2000.
Reference Source

32. Ahmad NH, Hamid ASSA, Shahidan NSS, *et al.*: **Cloud forensic analysis on pcloud: From volatile memory perspectives.** In Mahdi H. Miraz, Peter S. Excell, Andrew Ware, Safeeullah Soomro, and Maaruf Ali, editors, *Emerging Technologies in Computing.* Cham, Springer International Publishing, 2020; **332**: 3–15.
Publisher Full Text

33. Tabuyo-Benito R, Bahsi H, Peris-Lopez P: **Forensics Analysis of an On-line Game over Steam Platform.** *10th International EAI Conference, ICDF2C, 2018, New Orleans, LA, USA, September 10-12, 2018, Proceedings*, 2019; **259**: 106–127.
Publisher Full Text

34. Satrya GB, Daely PT, Nugroho MA: **Digital forensic analysis of telegram messenger on android devices.** *2016 International Conference on Information & Communication Technology and Systems (ICTS).* 2016; 1–7.
Publisher Full Text

35. **FORMOBILE/CLOUDxTRACT. Formobile.eu: cloudxtract 0.1.** (published). *zenodo.* [software] 2022; Accessed: 2022-05-18.
http://www.doi.org/10.5281/zenodo.6555508

36. **FORMOBILE/CLOUDSURVEY: Survey datasheet (published).** *zenodo.* [dataset]. 2022; Accessed: 2022-05-18.
http://www.doi.org/10.5281/zenodo.6556669

Open Peer Review

Current Peer Review Status: ? ✓

Version 1

Reviewer Report 18 September 2023

https://doi.org/10.21956/openreseurope.15969.r34589

© **2023 Yathiraju N.** This is an open access peer review report distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. The author(s) is/are employees of the US Government and therefore domestic copyright protection in USA does not apply to this work. The work may be protected under the copyright laws of other jurisdictions when used in those jurisdictions.

✓ **Nikhitha Yathiraju**
University of Cumberlands, Kentucky, USA

Introduction
In an increasingly digital world, it is crucial to collect evidence via cloud storage. In order to assess the current state of API-based cloud-based evidence gathering, the authors of this study recently polled industry professionals. This document presents a synopsis of the survey results and an interpretation of their significance by recognized specialists in the field. In the following paragraphs, there is an examination of the several facets of the survey, such as its background, significance, originality, relevance, methodology, significant findings, and interpretation.

Background & Significance of the Study
There has been a rise in the importance of gathering evidence by use of APIs as more companies move their operations to the cloud. The writers' breakdown of the present-day internet and its most pressing issues is insightful. To learn how effective API-based evidence collecting is and how it affects businesses, it is vital to look into the study's context and significance.

Role of Topic
The subject of how to collect cloud-based evidence via API is crucial for any business to operate in the modern digital market. Application programming interfaces (APIs) are crucial for businesses that want to stay ahead of the curve and ensure the safety and integrity of their data. When gathering data from cloud-based applications, APIs are crucial. Understanding the effects of evidence gathering on businesses requires looking into the difficulties it presents along with any potential upsides. The authors spend some time examining the benefits of APIs for data collecting in the cloud.

Originality & Relevance of the Review
The authors' research into cloud-based API evidence gathering offers a fresh viewpoint on a topic of crucial importance in the modern era of information. In this evaluation, the authors focus on how the survey adds to what has already been learned about the topic and how novel and

important its findings are. Further exploration of the survey's novelty and applicability may shed light on its significance in supporting businesses in overcoming the hurdles and making the most of the opportunities presented by cloud-based evidence collecting. The survey offers suggestions about where to focus future studies.

Analysis of Writing, Organization, Tables, Figures in the Manuscript
The vocabulary, format, and inclusion of tables and data in the survey study demonstrate a high level of understanding and efficiency on the authors' research. An individual will not have any trouble following along or grasping the essential ideas because the material is straightforward and easy to read. The material is well-structured, with each following chapter building upon the foundation laid in the previous ones. By providing visual representations of the data in the form of tables and figures, the results can be better understood as a whole. The survey's findings are presented clearly, and the overall organization of the work is straightforward.

Methodology
The authors took great care to ensure the accuracy and credibility of the survey's findings. Many different types of businesses and occupations contributed members to this survey. The authors developed this extensive poll to gather information regarding gathering evidence using cloud-based APIs. The authors analyzed the data with cutting-edge statistical tools and found some interesting insights as a result. The authors have shown that they are committed to addressing this important question by employing rigorous and credible research methods.

Key Findings & Interpretation
The research article revealed some fascinating information on the challenges and opportunities faced by companies in this industry.

Ethical considerations
When conducting any kind of scientific study, it is imperative that ethical considerations be given due weight. The research on gathering evidence via cloud-based APIs ensured respondent anonymity. All risks were explained to participants before they granted their agreement, and participants' identities were kept confidential. By considering ethical considerations, the survey keeps honesty at its greatest level and protects the rights of respondents.

Conclusion
By analyzing the survey responses, the authors have revealed the challenges and opportunities that exist for organizations in the realm of cloud-based API evidence collection. The survey has a sound methodology, thus the findings may be trusted. Insight into current trends and their implications for businesses can be gained through the study and interpretation of the most important data. The findings of this study offer novel insights that can be used as a guide by companies as they face the difficulties of cloud-based evidence collection.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and does the work have academic merit?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Cybersecurity, Cloud Security technologies, Artificial Intelligence, Data Analytics and IOT Techniques

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 19 July 2022

https://doi.org/10.21956/openreseurope.15969.r29618

© 2022 Attenberger A. This is an open access peer review report distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

?

Andreas Attenberger
Digital Forensics Research Unit, Central Office for Information Technology in the Security Sector (ZITiS), Munich, Germany

The article gives a summary on API-based cloud data acquisition for forensic purposes. A framework as well as test results for an extensive list of cloud service providers is given.

While the presented work gives a solid overview of cloud providers and associated retrieval methods, the article lacks focus and would greatly benefit from a number of specific revisions.

I suggest to shorten the cloud service introduction (Iaas, PaaS, etc.). If figures like Figure 1 are included they should be edited in order to reflect the cloud forensic challenges as associated with the individual service elements.

Some of the issues in cloud forensics should instead be discussed a little more in detail (e.g. the organizational issues on page 4). In technical issues please address some example use cases when the local data is stored at a service provider is an actual challenge (at least technically, as legal issues exist but if those are cleared up, cloud forensics would resolve - in part - to classic data forensics).

Page 5 includes some duplicate information (data from uninvolved third parties, etc).

Clients' devices are mentioned on page 5, if the focus is generally on smartphone / mobile device data being synchronized to cloud services, this should be pointed out in the introduction.

User credentials are also addressed on page 5, the access of whose is of utmost important for successful access. Please be more specific regarding attaining authorization (which is one of main challenges in cloud forensics), especially the concept of authorization tokens that could be spread throughout devices and allow cloud access besides standard user credentials within certain time intervals.

The API-based data acquisition introduction on page 6 as well as HTTP protocol elements can be shortened.

Please be more verbose on the handling of stored as well as deleted files - what is typically offered and what is metadata that is especially useful in a forensic context. Regarding the metadata and hashing, please give a more conceptual overview of what is needed and also how to sync cloud data with the associated mobile device storage, which is one of the most important subsequent processing steps. This could also help towards quantitative evaluation of your approach.

Finally, several companies offer their own cloud forensic services. It would be helpful to analyze these products to identify the gaps and needs and discuss how the presented approach can fill these.

Is the work clearly and accurately presented and does it cite the current literature?
Partly

Is the study design appropriate and does the work have academic merit?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Partly

Are all the source data underlying the results available to ensure full reproducibility?
No source data required

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: Research Unit has also received funding for the same project within the EU Horizon 2020 framework. Christian Hummert and I have previously shared an institutional affiliation.

Reviewer Expertise: Digital Forensics, Web Programming & Scripting Languages

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.