Cloud Digital Forensic Readiness: An Open Source Approach to Law Enforcement Request Management

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Abstract

Cloud Forensics presents a multi-jurisdictional challenge that may undermines the success of digital forensic investigations (DFIs). The growing volumes of domiciled and foreign law enforcement (LE) requests, the latency and complexity of formal channels for cross-border data access are challenging issues. In this paper, we first discuss major Cloud Service Providers (CSPs) transparency reports and law enforcement guidelines, then propose an abstract architecture for a Cloud Law Enforcement Requests Management System (CLERMS). A proof of concept of the proposed solution is developed, deployed and validated by two realistic scenarios, in addition to an economic estimation of its associated costs. Based on available open source components, our solution is for the benefit of both CSPs and Cloud Service Consumers (CSCs), and aims to enhance the due Cloud Digital Forensic Readiness (CDFR).

Keywords: Cloud Forensics; Multi-jurisdictions; Cloud Digital Forensic Readiness; LE; CLERMS

1. Introduction

Major cloud service providers (CSPs) are legally domiciled in the USA, but do have subsidiaries around the world [41, 30]. CSPs consumers, data, and partners are by de facto scattered around the globe. For example, a Spanish users' data may be stored in a USA datacenter and processed through an Irish facility. Therefore, data localization is a challenging issue especially in case of incidents or cybercrimes.

Moreover, law enforcement (LE) access to digital evidence depends entirely on the CSPs trustworthiness and the complexity of the associated legal procedures [91, 62]. In fact, CSPs' LE guidelines point out the need to foreign LE to address their requests through formal channels such as the Mutual Legal Assistance Treaty (MLAT) [34]. The assertion of a jurisdiction during an investigation —*in some instances*— is problematic. In fact, even if the LE is domiciled in the same jurisdiction as the CSP, the potential digital evidence may be located overseas, and require cross-borders data access mechanisms [89, 38, 67].

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The multi-jurisdictions issue is one of most persistent Cloud Forensic (CF) challenges [83, 87, 62, 48]. Nowadays, CSPs are being tired between domestic and foreign legislations [38]. There is an abundant literature on the multi-jurisdictional issues [97, 59, 90, 18, 3]. However, the existent propositions focus mainly on the legal standpoint, because it is primarily a legal challenge.

Nonetheless, we inhere, aim to propose a technical and organizational solution to simplify the LE request handling process. Our main objectives are: (1) To facilitate the communication between the requester (LE) and the responder, (2) Ensure transparency in handling a LE request, (3) Enhance the due forensic readiness capabilities of the responder.

The main contributions of this paper: (1) Analysis of CSPs transparency reports and law enforcement guidelines, (2) Proposing an abstract architecture for a Cloud Law Enforcement Request Management System, (3) Design, development and deployment of an open source based prototype, (4) Validation of the prototype with two hypothetical scenarios, (5) Economic cost assessment of a real world deployment.

The rest of this paper is structured as follows: In Section 2 we present some background on Cloud Forensics, Cloud Digital Forensic Readiness, Multi-jurisdictions, formal channels for cross-borders digital evidence access, and LE requests management systems; In Section 3, we state the main problem addressed in this paper; In Section 4, we clarify the motives and scope of this study. Section 5 presents a detailed description of the Cloud Law Enforcement Requests Management System. Section 6 provides a discussion on the opportunities that may arise from the proposed solution and its limits. Finally, we conclude this study with some perspectives and future work in Section 7.

2. Background

This section gives an overview of the following concepts: Cloud Forensics (CF), Cloud Digital Forensic Readiness (CDFR), multi-jurisdictions, a description of formal channels for cross-borders digital evidence access, CSPs transparency reports and LE guidelines, and some existent law enforcement request management systems.

2.1. Cloud Forensics

Cloud Forensics (CF) is the application of digital forensics science to Cloud computing [83, 82]. Several works have been done in this field. Researchers' propositions fall in two categories: (a) CF challenges and solutions classification, (b) contributions that focus on a single challenge or a category of challenges.

There are numerous CF challenges classifications; [83] proposed a CF classification based on three dimensions: Technical, Organizational and Legal; [76] made a survey on the technical CF challenges; [87] suggested a new classification based on the DFI process stages; [48] proposed the most enumerative classification (65 challenges and 9 primary categories). And more recently, [62] presented a systematic survey on CF challenges, proposed solutions, artifacts identification, forensic tools, and research gaps.

In regards to the second category, some research works focused on challenges, such as logging, live forensics, and timeline reconstruction. For example, [104] presented a forensic enabled architecture built on the top of the openstack platform [72]; [7] worked on reliable timeline reconstruction; [51] presented a framework for Cloud digital evidence collection and analysis using a Security Information and Event Management (SEIM) tool; And finally, [103] proposed a Secure-Logging-as-a-Service (SecLaaS) solution.

2.2. Cloud Digital Forensic Readiness

Digital forensic readiness (DFR) is the ability to maximize an environment's potential to use digital evidence, whilst minimizing the costs of an investigation. Introduced by [93], it was then clearly stated as a ten step process by [81]. Seminal works in this topic have been done by [27, 94, 45, 20]. Cloud Digital Forensic Readiness (CDFR) in counterpart is the application of DFR in Cloud computing environments. A detailed and concise definition was provided by [19]. Enhancing the CDFR was the subject of many propositions; [95] exposed a proof of concept tool for a centralized Cloud logs; [55] added event reconstruction to a CDFR model; [54] proposed a Cloud Forensic Readiness as a Service (CFRaaS) model. Finally, one of the most significant advancements in DFR and CDFR was the introduction of the *"Forensic-by-design"* paradigm by [79, 78].

2.3. Multi-jurisdictions

Cloud computing elasticity induces data localization challenges. In fact, data may be stored, processed, and mirrored across multiple jurisdictions. As for data, Cloud services are also consumed by users across the globe. Multi-jurisdictions in its simplistic form may be sketched as follow: *How may a Spanish LE agent investigate a cybercrime against Spanish victims committed by a USA cybercriminal resident in the UK, where the potential evidence is stored in Ireland, and processed in Asia region data centers that belong to a USA domiciled CSP?*

Furthermore, the multi-jurisdictions challenge goes beyond the territoriality, or nationality of customers and providers. In fact, from a legal perspective, a *"Jurisdiction"* may take at least three forms as stated by **(author?)** 89, pg.3.

In the case of cross-borders investigations, international law experts specify two forms of cooperation — *"formal channels"* and *"informal channels"* — between a foreign LE and a CSP [97, 59]. Additionally, [97] formulated four possible courses of action for foreign LE [97, pg.55]. Even so, major CSPs are still restricting foreign LE requests to the formal channel through Mutual Legal Assistance Treaty (MLAT) or Rogatory letter.

2.4. Formal channels for cross-borders data access

There are three formal channels for cross-borders data access: (1) Mutual Legal Assistance Treaties (MLATs) [34], (2) Rogatory letters, and (3) the Clarifying Lawful Overseas Use of Data (CLOUD) act [22, 23]. While the two first mechanisms have been there for decades, the last act was enacted in March 2018.

The MLAT channel is primarily used by LE, and the Rogatory letters are often used by non-government litigants [see 34, pg.5, pg.17]. Even if, the MLAT process is theoretically simple [see 60, pg.2], in practice it faces challenges ,such as procedure complexity, processing latency, guideline issues, and requests processing capacity [21, 92, 53, 99].

As described in [60] (as shown in Figure. 1) , when a country A law enforcement needs access to cross-borders data, the request is sent to its associated central processing agency in step 1. Afterwards, the central processing agency sends the request to the Office of International Affairs (OIA) at the US department of justice (2). The OIA reviews the foreign request in phase 3 and works with the U.S district Attorney's office (4). The request is then sent to a local magistrate judge for review (5). If the judge deems the request receivable, a warrant is served to the company which holds the request data (6). Complying to the warrant, the company provides the requested data to the OIA (7) for post processing overview (8). Finally, the requested data is sent to the country's A central processing agency which forwards it to the law enforcement in the last step (10). The whole process takes from six weeks to ten months.

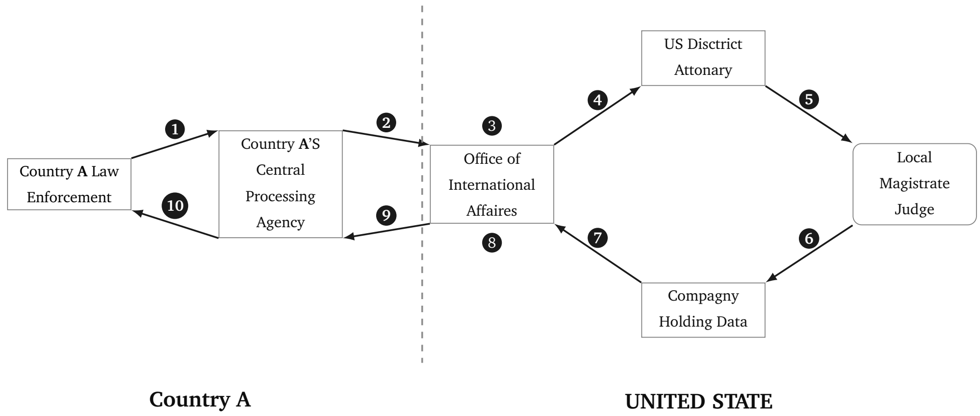

Figure 1: Example of a US MLAT process for Electronic Evidence. (adapted from [60]

Finally, the CLOUD act aims to address some of the MLATs inefficiencies to speed up the access to digital evidence [see 8, page 333]. It authorises bilateral agreement between the US and a *trusted* foreign partner to obtain direct access to digital evidence, wherever they are located. However, eligible foreign countries must meet some requirements such as the protection of privacy and civil liberties during the data-collection activities. In fact, the *"trusted foreign partner"* condition has some political ramifications. As for now, only some countries such as the U.K have gained benefit from this mechanism. Moreover, there are several research works discussing the impact of this new legislation on the existent formal channels, privacy, and international laws [67, 18, 3].

2.5. Transparency reports and LE guidelines

A law enforcement request may vary from disclosure, preservation, removal, and testimony. On counterpart, CSPs may approve, reject or even challenge a request [89, 33]. CSP's response to received LE requests is mainly based on: (a) domestic jurisdiction laws, (b) regulations, (c) internal policies [42, 1], (d) associated legal procedure, e.g., *Subpoenas, Court orders, Search warrants, etc.* [101], and (f) the request status (emergency or not). In fact, emergency requests are handled promptly, and processed with the due priority [6, 1].

Approved LE disclosure requests may lead to the communication of either *"Non Content Data"* or *"Content Data"*, if available data is found for the request stated period [42, 1, 6]. Statistics on disclosed users' information are published in CSPs transparency reports, which are often heterogeneous. In fact, only Microsoft [65] and Yahoo [101] seem to use a similar format. Additionally, CSPs also publish guidelines for LE [101, 64, 42, 1, 6]. Table. 1 provides a summary of transparency and law enforcement guidelines attributes.

Transparency reports	
Attribute	**Description**
Volume	Number (percentage) of received requests, Users' impacted accounts, and delivered responses (accepted, rejected). In case of accepted requests statistics on *"content data"* vs *"no content data"* responses are also provided.
Requester	Type of requester authority: Law Enforcement Agency (LEA), FISA
Legal procedure	LE requests associated documents (subpoena, court order, search warrant, etc.).
Localization	Requester geographical origins, either by country or a comparison between domestic country vs. Foreign.
Status	Specification on requests regime (emergency or not).
Objective	Requested actions on target's data (disclosure, removal, preservation and testimony).
Historic	Indications on past transparency reports.
Law Enforcement Guidelines	
Legal requirements	Request legal ground of acceptance.
Emergency exception	Exceptions to the legal requirements for emergency requests.
Suited actions	Type of receivable requests, and suited actions on data. In the case of a preservation request, the associated preservation delay.
Target	Targeted user required identity (Id, Account, Email, etc.).
Target notification	Target notification policy, when and how a CSP may (or not) notify a user about an issued government request on its data.
Requester identity	Information required from a requester to show authenticity and authentication.
Submission means	Permissible means for request submission (email, mail, fax or online).
Costs reimbursement	Regime, and exception on cost reimbursement to due business disturbances and request compliance induced fees.

Table 1: CSP's Transparency reports and law enforcement guidelines attributes

2.6. LE requests management system

To the best of our knowledge, there is no previous work on law enforcement requests management systems. Certainly, major CSPs do have their own solutions to manage and process LE requests. However, LE pre-submission request is only permitted via Fax or Email. As far as we know, only Facebook and Google [31, 43] propose an online requests pre-submission portal for the exclusive usage of LE agents.

In the following section, we provide details on some of the law enforcement request handling challenges.

2.7. Legal request processing Issues

As stated in Subsection. 2.3 multi-jurisdiction is a persistent challenge in Cloud Forensics and more specially in cross-border data access. However, legal request processing faces also other challenges that are amplified by legal consideration, such as the following:

1. **Volumes**: There is for sure a significant growth in LE requests. For example, the number of legal requests for users' information disclosure submitted to Google grew from $165,894$ in 2019 to $217,424$ in 2020. If this is the current state for

CSPs, the situation may be worse considering the central entity—Office of International Affairs– that evaluates foreign LE requests through —via Formal channel (MLAT)—. Indeed, in the United State, the OIA state that:

> Over the past decade the number of requests for assistance from foreign authorities handled by the Criminal Division's Office of International Affairs (OIA) has increased nearly 60 percent, and the number of requests for computer records has increased ten-fold. [21, see page 1].

The growing number of LE requests implies a need for automation for both the responder and the central entity that evaluate the foreign request.

2. **Delays**: Latency in processing LE requests is observed in two cases: (1) At the CSPs level, in fact a request is not processed until the reception of the associated legal documents via mail, (2) in case of foreign request via formal channel where a nine step process is enacted and which involve many instance other then the CSP (see Subsection. 2.4). The MLAT process takes from six weeks to ten months on average [60, see page 3].

3. **Transparency**: The lack of transparency is observed at least in two cases: (1) Generally, CSPs do not provide any technical capabilities for LE to monitor the process flow of their submitted requests —with the exception of those that propose an online portal—, additionally, CSPs do not provide response to testimony requests, (2) Considering foreign request, formal channel procedure are so complex and involve several parties that it is difficult to monitor the handling of the submit request. Furthermore, in case of requests leading to the collection of digital evidence, the admissibility of those collected evidence stands only on the trustworthiness of the CSPs, and may be challenged in a foreign court of law. Indeed, some researcher have already pointed out this possibility:

   > It is important to recognize that data obtained from a cloud-based service may be excluded from use in court proceedings on a number of grounds [see 97, pg. 64].

4. **Procedures**: Law enforcement guidelines are mainly in English or translated into a few languages. Assisting LE in the submission process is crucial. However, CSPs do not provide detailed procedure for request submission, nor do they provide standard forms. Assuming that LE agents are fully trained or do have the necessary training to make such a request may lead to submission being rejected due to error or misinformation. As for the foreign requests, procedures are more complex. Foreign LE training on how to formulate request through formal channel is required as stated by [24]:

   > Coordinate with OIA to develop a plan to improve its training and outreach efforts including considering the creation of an external site of resources for foreign authorities.[24, see page 29]

A stated above, there is certainly a dependency between the legal and technical aspects of LE requests processing. The complexity of legal procedures for cross-border data access induce some technical challenges, such as latency, volume and transparency.

On the other hand the lack of automation in both responder and central entity (OIA) request processing induce an increase of the cases backlog and therefore latency in legal reviews of the formulated request both domestic and foreign.

The need for a scalable technical solution for LE requests processing for both responder and central entity —in case of a foreign request– is persistent. Indeed, even the OIA have expressed the need for a reform in MLAT processing and the adoption of scalable case management system (CMS) as expressed below in [24]:

> Coordinate with CRM ITM to ensure OIA has access to CRM's Oracle Apex platform and support the automation of OIA's team trackers and leadership dashboards. [24, see page 29].

In the following section, we describe clearly the main problem that we aim to resolve in this study.

3. Problem statement

Certainly digital evidence access in Cloud computing environments is very challenging (see Subsections. 2.3 and 2.4). Technical issues are amplified by legal aspects. If the handling of domestic LE requests seems straightforward, foreign requests in counterpart are subject to more complex procedures. Among the aforementioned challenges, trust and transparency seem to be the most difficult to resolve. Moreover, these two aspects (transparency and trust) are also required to ensure the soundness of the conducted DFI processes and the admissibility of the collected digital evidence.

After the analysis of transparency reports and LE guidelines (see Subsection. 2.5), it appears that there is a need to either maintain the current state of LE request handling —processes and associated technical capabilities— waiting for advancement in legal frameworks establishment especially in case of foreign LE requests, or anticipate the venue of these *"legal frameworks"* by designing and developing new technical capabilities that may resolve some challenges and attenuate the complexity of other ones. In fact, some major CSPs are already providing an online portal for LE request pre-submission (see Subsection. 2.6).

If CSPs possess the resources needed to the design and the development of associated LE requests processing technical capabilities, other organisations (eg., Small and Medium Sized Enterprise) that are outsourcing part of their information system to a CSP may not. And, in some circumstances those organisations may be asked to respond to legal requests.

So, in abstraction of the nature of the responder (CSP or not), in the rest of this paper we aim to answer the following question:

What are the required technical capabilities that a responder should possess in order to handle transparently legal requests in accordance with specified guidelines, laws, and regulations ?

4. Motives and Scope

To the best of our knowledge, there is no prior work addressing specifically cloud legal request management system. Moreover, the only existing systems are proprietary (CSP in-house made), which are exclusively used by the law enforcement agencies without any public or published documentation.

Therefore, our main motivation in this research is to establish an affordable, scalable, and open source based technical solution that may ease some of the LE request handling challenges. More precisely, we are aiming towards the design and the development of solutions that fit any organisation ranging from public CSPs to the smallest enterprise which outsources its Information System (IS) from a CSP. The main objectives to achieve are:

1. Facilitate the communication between the requester and the responder and a ensure a transparent request handling,

2. Provide the responder with a minimal DFR baseline to guarantee a sound DFI process and the admissibility of the collected digital evidence.

5. The Proposed solution

Upon statement of the main problem (see Section. 3), in this section, we propose a technical solution for some of the LE requests handling challenges. Therefore, we will address the following points:

1. Analysis of LE request handling workflow.

2. Proposition of abstract architecture.

3. Analysis of the system requirement.

4. Design, development and deployment of a prototype.

5. Validation of the proposed system with two hypothetical scenarios.

6. Economic assessment of the associated deployment costs.

5.1. LE request processing flow

CSPs governance is based on: (1) business term of services, (2) applicable domestic jurisdiction laws, and (3) compliance to regulations and standards.

That said, governance is also asserted through organizational policies and technical capabilities. Therefore, the specification of the internal workflow, data flow, and external partners' communication channels are vital. In this context, existent incidents response and digital forensic investigation policies may be enhanced with a new law enforcement policy that specifies the communication with LEs. Furthermore, on the technical side, the implementation of a law enforcement request management system will ease the CSP-LE communication and ensure a transparent requests processing.

Based on available CSP LE guidelines [42, 1], a typical LE request processing workflow (Figure. 2) comprises 3 major steps: submission, evaluation and response.

Even if there are some considerations in the processing of some LE requests (see. Subsection. 2.5) (e.g., an emergency request is considered as an exception to the LE guideline and handled promptly), the above cited stages are still present and the handling particularities appear in some procedures and tasks.

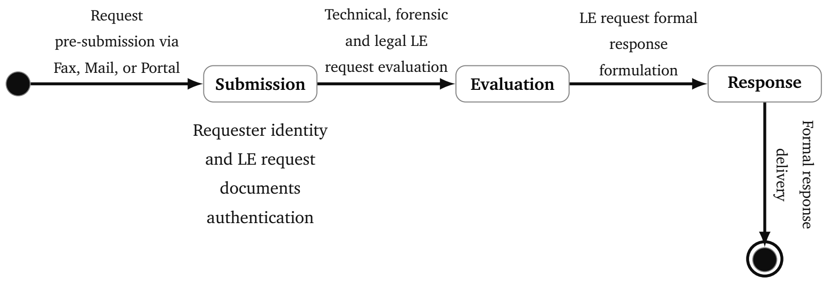

Figure 2: LE request processing workflow

In the following details on the LE request handling stages:

1. **Submission**: we observe that major CSPs accept only requests submitted via Fax or Email. Even if there are some CSPs that offer an online portal for request pre-submission, the effective request evaluation is only initiated at the reception of the legal documents via the mail. However, in case of emergency or preservation requests, some actions may be initiated (anticipated) in due respect to the adopted law enforcement policy.

2. **Evaluation**: upon effective reception of the request's legal documents, a team composed of law assistance, IT manager, incident response members, and forensic experts may gather to evaluate a possible response based on pre-established internal law enforcement policy. In case of approved disclosure (or preservation) requests an escalation to a full DFI is required. In such a case, collected digital evidence, chain of custody documents and other DFI reports may be included within the formal response to the requester.

3. **Response**: a formal answer is transmitted to the requester (via email or mail). Approved requests may lead to: (1) the application of the requested actions (preservation, disclosure, deletion) on the target's data, (2) notification the target (in some cases), establishment of an invoice for the costs reimbursement. Moreover, a responder may also reject a request or even challenge it (see Subsection. 2.5). Finally, we observe that major CSPs do not respond to testimony requests and offer only a certificate in exchange of expert testimony.

5.2. Architecture definition

With the established LE request processing workflow (Figure. 2), the information gathered from CSPs transparency reports, LE guidelines analysis (Section. 2.5), and the composition of the evaluation team, we may sketch an abstract architecture for a law enforcement requests management system (see Figure. 3).

After the submission phase, if an escalation to a full DFI is required, the Digital Forensic Investigation Capabilities (DFIC) are activated through the connection (A), and a new case is opened in the Case Management Capability (CMC). Legal expertise may also be solicited through the connection (B). Once the DFIC is activated, a sound DFI process is engaged. First, the collection of potential digital evidence is made across

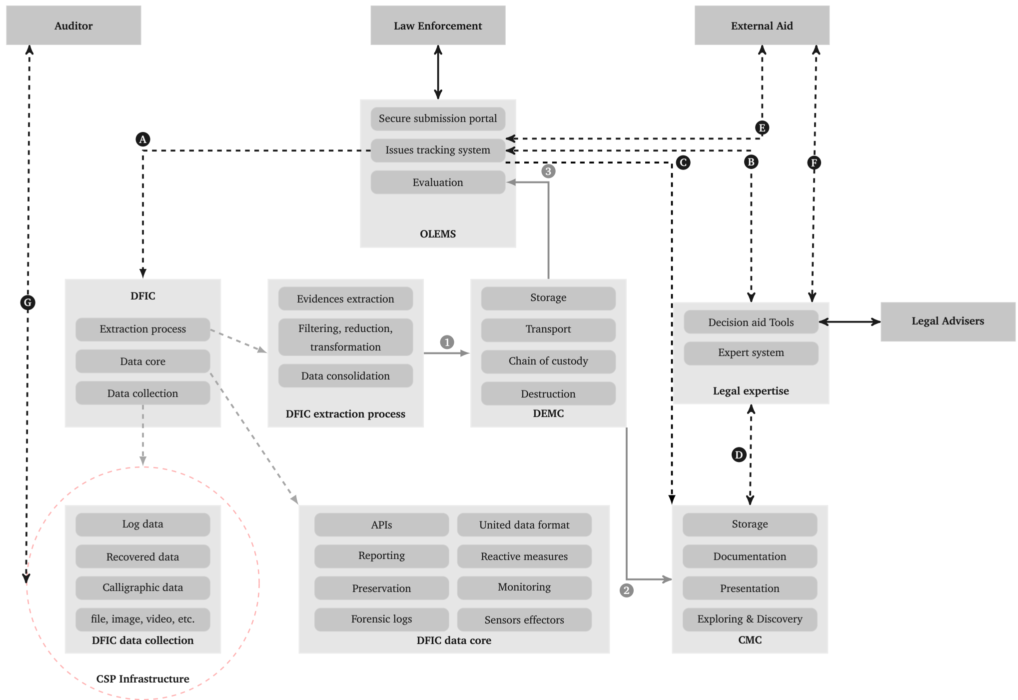

Figure 3: An abstract architecture for a law enforcement requests management system. OLEMS: Online Law Enforcement Management System. DFIC: Digital Forensic Investigation Capabilities. DEMC: Digital Evidence Management Capabilities. CMC: Cases Management Capabilities.

the CSP's infrastructure using the DFIC *data core* sub-capabilities, then evidence are extracted with the DFIC *extraction process*, and securely managed by the Digital Evidence Management Capabilities (DEMC).

When the required digital evidence are available, they are included in the associated case via the connection (2), and the findings transmitted to the OLEMS for reporting via the connection (3). Legal advisor's having a secure access to the CMC via the connection (D) may establish their reports based on elements of the current case, and the knowledge that they may have discovered from similar past cases. Once the technical, forensic, and legal reports are available, the CSP formulates a response to the LE, either via the OLEMS or any available legal means.

The following sections provide details on the different modules of the proposed architecture.

5.2.1. Online law enforcement management system (OLEMS)

This group of capabilities aims to improve the interactions between: (1) CSP and LEs, (2) involved teams in a request processing, and it contains the following:

1. A secure pre-submission portal to accelerate in some instances the evaluation and response delays. In fact, even if the authenticated documents are required, the

emergency and preservation requests may benefit from proactive measures dictated by the evaluation team;

2. An issue tracking system for the internal staff and the LE to monitor the request processing workflow;

3. Productivity tools (information exchange, virtual meeting, redactions tools, etc.) to enhance the collaboration of the involved teams (internal/external).

5.2.2. Digital forensic investigation capabilities (DFIC)

This group contains the required capabilities that ensure a proper and sound DFI. Inspired from [19] abstract reference architect, it includes the following:

1. Data collection: represents the inventory of the *potential* digital evidence sources and the suited collection tools. Therefore, log data, available and recovered artifacts are gathered among the several layers (physical and virtual) of a CSP' infrastructure from the hardware to the application levels.

2. Data core: regroups the locally and remotely accessible core primitives that are required for evidence collection and analysis, monitoring, data format unification, log preservation, etc.

3. Extraction process: contains the suited tools for data consolidation, filtering, reduction and transformation.

5.2.3. Digital evidences management capabilities (DEMC)

This group of capabilities aims to ensure evidence safeguard and admissibility, and the maintenance of the chain of custody. As shown in Figure. 3, this group contains four capabilities: storage, transport, chain of custody and destruction. As for the storage, several formats of digital evidence exist. These include Raw, DEB and AFF4 [14, 77]. In addition, there are also some other attributes related to a storage capability, such as storage area, infrastructure security, and scalability [16]. Concerning the transport, in case of a cooperation among several forensic experts, a secure transport capability that ensures the security of digital evidence and the maintenance of the chain of custody is required. Indeed, the maintenance of the chain of custody is vital for the admissibility of the collected evidence. In this scope contribution such as the one provided by [12] may be considered. Finally, depending on the associated jurisdiction, the destruction of the collected evidence may be considered.

5.2.4. Cases management capabilities (CMC)

Usually, when a request is processed, it generates a case that contains elements, such as a digitized version of the request papers, evaluation reports, briefings notes, artifacts, evidence, and evidence custody documents, etc. CMC capabilities aim to ensure the storage and the preservation of the aforementioned elements. In the following section, we provide details on the proposed system requirements.

5.3. System requirements

This section aims to implement a Proof of Concept (PoC) of the proposed architecture (Section. 5.2). Our methodology is project driven. However, to optimize the costs of the implementation, we adopted the following guidelines: (1) candidate solutions must be open source, or responder's in-house made, (2) scalability, (3) portability and interoperability. On the other hand, note that there some other non-functional system requirements, such as (4) Cloud Digital Forensic Readiness (DFR) (*i.e., ability to collect admissible digital evidence while optimising the costs of an investigation*), (5) ensure a transparent LE request handling, and (6) Trust.

Even if the chosen modules are open source, there are still costs related to the Cloud deployment. Nonetheless, in the following sections, we first assess the requirements for each sub-module (Figure. 3) in Subsection. 5.4 and provide an economic assessment of the proposed solutions costs in case of a real world enterprise deployment in Subsection. 5.7.

5.4. Prototype design & development

Starting from the OLEMS, a secure LE requests pre-submission portal is required. The request processing may be tracked through a tickets system or any help desk solution. Therefore, there is a need for Email and SMS notifications; Tickets assignment and management; Dashboards and reporting features. There are many open source solutions that fulfil the cited requirements, such as [73] and [102]. In this study, we opted for the osTicket solution as sketched in Figure. 4.

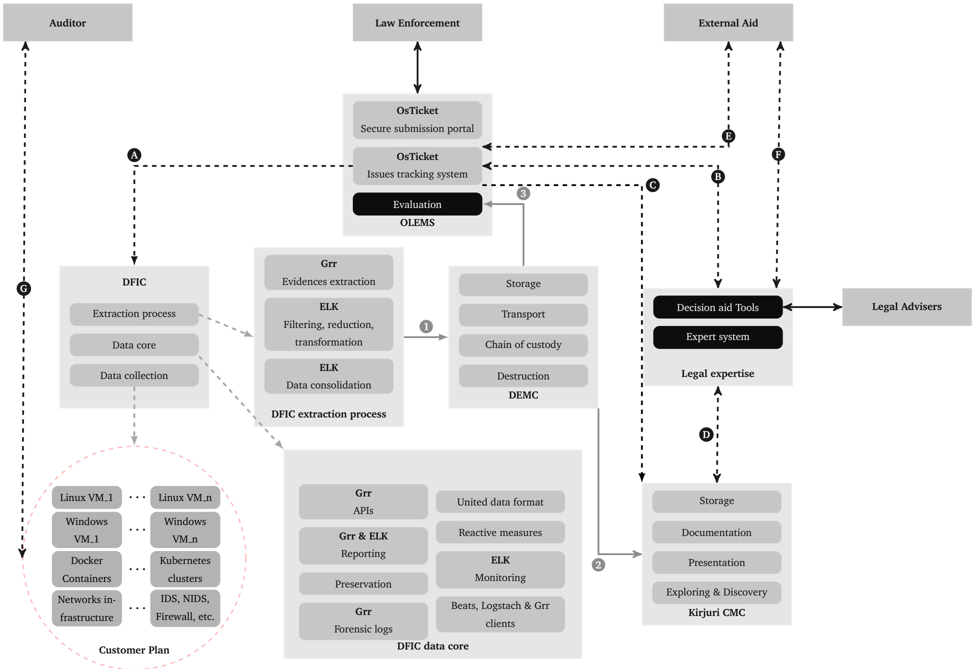

Figure 4: A Cloud Law Enforcement Request Management System (CLERMS) implementation using open source components. The connection A, B, C, 1,2 and 3 represent the interactions between sub-modules as specified in in the abstract architecture (Section. 5.2). Black colored box are capabilities that are not implemented in the prototype.

At the reception of the request papers, they are scanned and stored for legal and technical evaluation. So, there is a need for electronic documents management and knowledge discovery solutions.

If a request is approved, an escalation to a full DFI is initiated. Therefore, the usage of dedicated tools for live forensic, evidence and log data collection (acquisition), analysis and examination are vital. These tools must support multiple types of artefacts, and ensure secure evidence storage.

For the monitoring and log analysis, we opted for the Elasticsearch Logstash Kibana stack [26]. Events, network packets and logs are collected via agents (Beats) deployed on the customers plan and forwarded to the Elasticsearch cluster in real-time. The Kibana dashboards help in monitoring, gaining insight, and hunting threats. For the incident response and live forensic, we opted for the Google Rapid Response (Grr) solution [13, 66, 17].

Finally, for case management, we opted for the open source solution [58] that provides support for (1) investigators and evidence management, (2) investigation and chain of custody documents (request documents, evaluation reports, evidence analysis reports, etc.) management, digital evidence storage. However, digital evidence storage and management may be feasible through a separated data store, such a MangoDB cluster as suggested in [17].

As for the *evaluation* module and the legal capabilities they are not considered in the developed prototype as they may be ensured by offline (in-house made or open source) solutions. Mainly consisting of an assistance and aid tool for reports editing (in case of the evaluation module), and a knowledge database and electronic document discovery for the legal capabilities, these elements may be separated from the connected system.

The following section provides details on the deployment of a proof of concept prototype of the proposed solution on an IaaS infrastructure.

5.5. Cloud deployment

For the deployment of our prototype, we opted for a Cloud (IaaS) platform [40] as shown in Figure. 4. The allocated resources for some modules, such as the Grr-server, Elasticsearch, and Osticket, depend on the costumer plan (i.e, number of targeted nodes). In fact, depending on the demand —growth or decrease in the number of client nodes— the deployment of these modules may be scaled up or down.

Name ^	Zone	Recommendation	Internal IP	External IP	Connect
grr-server	europe-west1-b		10.132.0.2 (nic0)		SSH
kirjurivm	europe-north1-a		10.166.0.3 (nic0)		SSH
linux-client-0	europe-west1-b		10.132.0.5 (nic0)		SSH
linux-client-1	europe-west1-b		10.132.0.4 (nic0)		SSH
linux-client-2	europe-west1-b		10.132.0.3 (nic0)		SSH
log-monitor-vm	europe-west2-c		10.154.0.2 (nic0)		SSH
osticketvm	europe-west4-a		10.164.0.2 (nic0)		SSH
windows-client-0	europe-west1-b		10.132.0.6 (nic0)		RDP
windows-client-1	europe-west1-b		10.132.0.7 (nic0)		RDP

Figure 5: CLERMS deployment on an IaaS infrastructure.

In our case, the customer plan comprises 5 Virtual Machines (VMs) (3 were Linux based, and two Microsoft Server 2010 instances). For larger deployment, the Grr documents [47] specify the type and requirements for the Grr-server deployment. So, in our case a single VM instance was sufficient (see Figure. 5); The Grr-server administration interface is shown in Figure. 6.

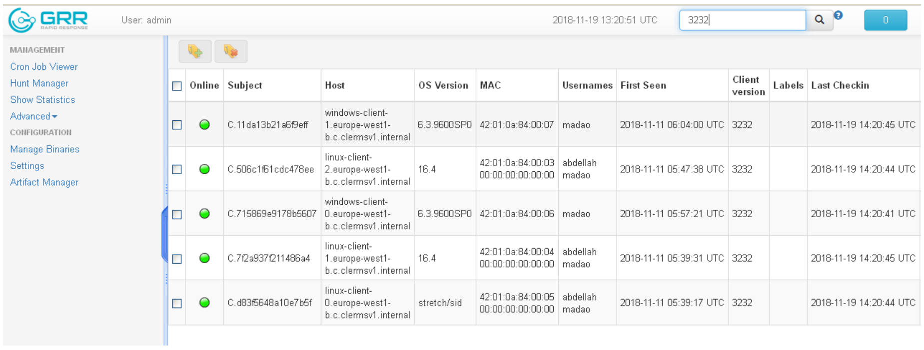

Figure 6: Grr-server administration user interface.

Logging and monitoring are done via agents (LogStach agents, Beats) on the customer's VMs plan. The collected information is forwarded to the ELK cluster. In the production mode —real world case usage— the ELK cluster deployment requires at least three nodes. However, in our case a single node was sufficient. The Figure. 7 shows log visualization through Kibana dashboards.

Figure 7: Monitoring, logs ingestion, and threat hunting via Kibana dashboards.

The online request pre-submission is feasible through an osTicket instance (Fig 8), which was deployed in a single VM instance. In the case of traffic increase, the scaling up may be achieved through redundancy and load balancing.

The required information for request pre-submission based on LE guidelines (see Section. 2.5) are: (a) agent contact information, (b) agent superior contact information, (c) agency contact information, (d) scan of legal documents that support the request, and (e) target information.

When a request is correctly submitted (see Figure. 8), a notification is sent to the crisis manager. Consultation is then made with the legal assistance, and in some cases an investigation is initiated. In case of escalation, tickets and tasks are forwarded to those concerned by the investigation. At the conclusion of the investigation, elements related to the case are forwarded to the case management solution.

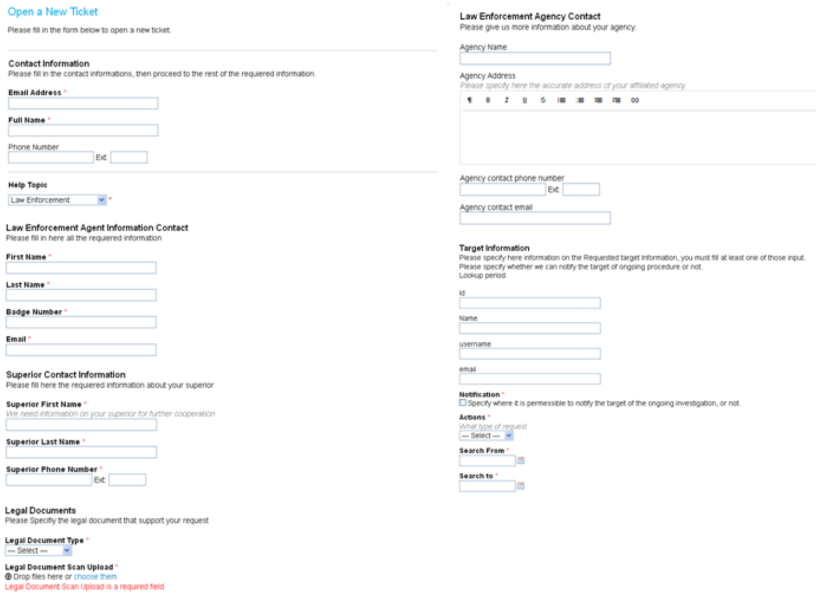

Figure 8: Online LE request pre-submission portal

At the reception of the request documents, a new case is opened in the Kirjuri solution (see Figure. 9). The requester and target information, digital evidence, log, briefing, forensic analysis and examination reports are securely stored.

Figure 9: Kirjuri open source case management User Interface.

The following section provides two hypothetical cases to validate our proposition.

5.6. Prototype Validation

This section provides two hypothetical usage scenarios for the CLERMS:(1) user information disclosure request, (2) content removal request.

5.6.1. User information disclosure request

A LE agent *"Mike Davies"* is filling a user content information disclosure request for the target surname *"John smith"*. The target is suspected of posting illicit content on a discussion forum hosted at *http://wwww.mydomain.com/fluxbb*. At the request approval, the crisis manager decide to escalate the event to a full DFI. Based on the target associated IP, the investigation team interrogate the customer plan (via the Grr-servers) for more indications. Afterwards, the forensic expert may opt for:

1. Remote raw disk image acquisition, for further examining and analysis, or
2. Database files acquisition via the *filefinder* flow (see Grr-server administration panel) on the path *"/var/lib/mysql/fluxbb"*.

Moreover, when the forensic expert gains the target *"Jhon smith"* associated registration IP; A comparison with the provided logs from the ELK stack may confirm whether the illicit content was posted from the target IP address or not. Progressively the associated request case will then comprise elements, such as the digital forensic evidence, logs analysis reports, briefing memos, tasks assignment, a clear investigation workflow and a proper chain of custody documentation. Finally, a response to the request may be provided via the ticket system or by any official means.

5.6.2. User content removal request

The same LE agent is now suspecting that one of the machines in the customer plan is hosting a Command and Control program that is in contact with disseminated malware agents. A removal request with a target machine IP address is then formulated. Upon reception of the request, the crisis manager's main objective is the disinfection of the potential infected machines. A detailed process for such action may be found in [13]. However, the forensic expert may also envision the following: (1) analysis of the processes list flow search (see Figure. 6) for a potential Command and Control process, (2) proceed to a forensic memory analysis of the suspected machines, and (3) analyze the logs, SSH transactions, and bash command history, etc. The aforementioned actions may then help to find the identity of the culprit.

The following section provides an economic assessment of the CLERMS deployment costs.

5.7. Economic assessment

The economic optimality of our solution stands on two facts: (1) open source components, therefore there are no related license fees, (2) Cloud based deployment for a pay per usage model and scalability (up or down) on demand. Thus, the CLERMS solution could fit any enterprise or CSPs. Moreover, in the case of compliance to a LE request, the CSP (requested company) may formulate a concise, detailed and transparent costs reimbursement invoice based on the deployment costs (hourly/minutes), man power charges, consulting and support fees, etc.

Concerning the deployment related charges, Table. 2 provides an assessment of the CLERMS monthly costs for a customer plan that consists of 7000 (7K) nodes which is about the size of the infrastructure of a large enterprise. The costs listed in Table. 2 are related to the functioning of the incident response and forensic plan (see Figure. 4), to be accurate. Considered as the baseline configuration for both the Grrr and ELK deployment in such a case (a customer plan with 7000 nodes), it may be scaled up and down depending on the usage. Moreover, the responder may opt for additional digital evidence storage capacity, such as a Mongodb cluster (more than three nodes with additional storage disks) as specified in [16].

Table 2: *Economic assessment of CLERMS deployment solution for a customer plane of 7000 nodes.*

Module	**Deployment** requirements	**Monthly** costs ($)
Osticket	1 VM (n1-standard-1)	24,27
	(1 vCPU, 3,75 GB Memory)	
Kirjuri	1 VM (n1-standard-1)	24,27
	(1 vCPU, 3,75 GB Memory)	
ELK	3 VMs (n1-standard-2)	
	(2 vCPU, 7.5 GB Memory),	165,63
	500 GB Boot disk,	
	3 persistent disks of 500 GB each [2]	
Grr-servers	Recommended [47] 5 AWS c5a.xlarge ($0.077 per hour)	1,940.4
	, and one r3.4xlarge [5] ($1.328 per Hour)	6,693.12
	Total	8.847,69

6. Opportunities & limits

The proposed solution aims to: (1) ensure a transparent LE request handling, and (2) enable a responder with a due digital forensic readiness capability in order to guarantee the soundness of conducted digital forensic investigation and the admissibility of the collected evidence. Based on open source components it permits : (a) a reduction of inherent in-house or solution acquisition fees, and (b) an effortless integration process. Designed to fit any sized responder (i.e., going for a public CSP to the smallest enterprise that is outsourcing parts of its own IS to a CSP) the proposed solution will aid a responder to formulate a concise and precise estimation of LE request processing costs reimbursement fees.

By ensuring the due digital forensic readiness the proposed solution empower a responder to conduct sound investigation both in case of a response to a legal request, and an internal investigation in case of a security incident.

In regards to legal request processing, the proposed solution induces automation — and scalability– that for sure will reduce: (1) the request's volume and lower its growth rate, (2) latency and expected response delays.

Distributed and scalable technical solutions are not only envisioned for a responder. Indeed, it is also recommended for the central entity (OIA) that handles incoming foreign requests via formal channels such as MLAT. Such technical improvement will for sure reduce the case backlog and processing delays and therefore accelerate the handling of foreign legal requests. In fact, in an effort to reform the MLAT processing the US Department of Justices has already expressed the following recommendation:

> Coordinate with CRM ITM to ensure OIA has access to CRM's Oracle Apex platform and support the automation of OIA's team trackers and leadership dashboards. [24, page 29].

Even if there are promising opportunities that may emerge from the adoption of the proposed solution there are still some remaining challenges, such as multi-tenancy and digital evidence collection in PaaS or SaaS service models.

7. Conclusion and future works

In this paper, we proposed a Cloud Law Enforcement Requests Management System. Interests in this proposition come from the growth of law enforcement request volume, the latency, and the complexity of requests processing.

Our primary goal was to provide CSPs and organizations with an affordable solution to comply with the received requests. Therefore, we first analysed CSP's transparency reports and law enforcement guidelines. Second, we sketched a request processing work flow, enumerated the involved teams, and provided an abstract architecture. Afterwards, we enumerated the system's requirements, provided a proof of concept prototype based on available open source components, and advanced to the deployment phase.

The optimality and validity of our proposition was shown through the response to two hypothetical scenarios and an economic assessment of its related costs. As a future work, we would like to investigate how to integrate automatic (or semi-automatic) request evaluation via decision aid tools and legal expert systems.

Finally, we were concerned by the technical aspects of the proposition, it may be interesting to investigate in details the associated organizational efforts such the law enforcement policy.

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