Open Issues on the Observance of Cloud Computing Law: A Survey

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Abstract. Cloud Computing is

1 Introduction

The term *cloud computing* became a buzzword around 2006 when Amazon and Google and other companies started using to market their online computational services. Unfortunately, technically, the term is not descriptive or intuitive; thus it is frequently abused and misused. As discussed in [198] cloud computing means different things to different people, all depending on the aspect (for example, ubiquity, transparency, virtualization, business model, etc.) they wish to emphasise. An extensive list of definitions of cloud computing is presented in [99].

In this paper we will define cloud computing as a paradigm that enables cloud subscribers (also called clients, customers and users) network, on–demand and transparent access to a shared pool of computing resources of different levels of abstractions provided by other parties called the cloud providers.

The focus of our interest are public clouds (as opposite to private clouds), that is clouds available to the general public for free or in return of a fee. Thus from here on, we will refer to public cloud providers, simply as cloud providers.

Central to this definition and to the focus of this paper is the concept of *transparency*. At this point we shall only provide and intuitive explanation of this concept and mention that transparency means seamless access to computating resources. Transparency conceal from the client the complexity of the software and harware infrastructure used by the cloud provider to deliver the service. Thus the client gets the illusion of an endless availability of ubiquitous resources whose actual realizations, physical locations and administration are not necessarily under his control or visible to him—all depending on the level of abstraction of the cloud resource used.

Transparency is certainly a useful feature of cloud computing. However its is also a source of several concerns related to data security, privacy and regulatory compliance. For instance, the Cloud Security Guidance published by the UK Government [67] states that *It is important that the locations in which consumer data is stored, processed and managed from* ***are known*** *as organisations will need to understand the legal circumstances in which their data could be accessed without their consent.*

The aim of this paper is to investigate the technical aspect of these issues and present a state of the art discussion of the available mechanisms for specifying and enforcing data security regulations, and for resolving potential conflicts between the parties involved. In other words, we would like to identify what can be solved programmatically (say with current technology) computational means and what needs to be left for human judgement.

Regarding the level of abstraction of the resources is it worth mentioning that the resource made available to consumers range from providing basic computational resources such as network communication, storage and compute power (infrastructure as a service, IaaS) to sophisticate enterprise application services (soft- ware as a service SaaS). Consequently some authors use the term *cloud services* as synonymous to cloud resources. An in–depth discussion of these levels of abstractions can be found in [99, 100].

Regarding accounting of resource consumption, it is worth clarifying that a common business model is to charge consumers on a pay–per–use basis where they periodically pay for the resources they have consumed. This business model is currently in use by Amazon AWS and other leading cloud providers. An alternative and widely used model is the *free of charge* model used my Google gmail, Yahoo email, FaceBook and other companies that provide free of charge services in return for collecting data about customers and displaying advertisements. As discussed in [4], this revenue model is the basis for the "free cloud" services that many users rely on. Another possible alternative that has been suggested by supporters of good causes is free cloud services to citizens, that is, paid from public funds.

2 Law and Cloud Data Protection

In our definition of subscriber cloud data we include both application and administration data. By application data we mean data used or produced (either directly or as by–product) by the applications deployed by the subscribers. In the same order, by administration data we understand data collected by cloud providers about their subscribers for administration and regulatory purposes.

Similarly to data transmitted, stored and processed by conventional computation means, cloud data is subject to legal regulations that depend on several factors such as the nature of the data and its physical location.

A detail description of the different categories of data and the legislations that apply to them fall out of the scope of our work. Our aim is to examine whether it is possible to guarantee the observance of the legislations of interest with current technology.

For example, the Consumer Data Privacy in a Networked World [69] states that *Consumers have the right to reasonable limits on the personal data that companies collect and retain.* The problem with this statement it that it is hard to express it programmatically so that it can be mechanically manipulated. For instance, the meaning of "reasonable" is subject to personal interpretation.

3 Deployment of Cloud Applications

We envisage cloud applications of arbitrary complexity including scientific computations (for example, scientific workflows) that demand large amount of computational resources [160, 159] and collaborative applications that involve several independent parties that share resources (for example, databases) but does not necessarily trust each other. Good examples of collaborative applications that highlight the importance of data legislation are cross–organizational business processes that involve the participation of several business partners such as car–rental [348] and conference management systems like EasyChair [346].

The deployment of complex applications demands the deployment of several cloud components (virtual machines, storage, databases, etc.) that the customer requests from a single of several cloud providers. This idea is illustrated in Fig. **??**.

In the figure C_A, C_B and C_C represent customers interested in deploying, respectively, their applications A_A, A_B and A_C within cloud providers, CP_A, CP_B and CP_C, respectively. Application In this example, A_A is shown unfolded and consists of five components C_1, C_2, C_3, C_4 and C_5.

The double arrowed lines represent communication channels. They suggest that the three applications interact with each other, presumably to execute a cross–organisational business process. Central to our discussion are the communication lines between the customers and their providers with T&C (Terms and Conditions) lables. We assume that at run time, customers will interact with their cloud providers to deploy, monitor, tune and undeploy his components.

The terms and conditions are legal commitments (contract) agreed and signed between customers and providers. In brief, they stipulate how the cloud service is expected to be delivered by the cloud provider and used by the customer. In other words, they stipulated what actions the parties (customer and cloud provider) has the right, obligation or prohibition to execute during the contractual time in order to observe the expected behaviour of the service. For example, the terms and conditions might dictate that the customer has the right to instantiate up to 64 virtual machines and the obligation to pay the incurred bill by a certain date. In the same order, they might stipulate that the cloud provider is obliged to recover the service within 24 hrs after crashes. Equally important, terms and conditions include clauses related to data security, privacy and regulatory compliance. In practice, they stipulate what national and international regulations they honour. For example, they might referer to national regulations such as Data Protection Act 1998 of the UK [65] or the Consumer Privacy Bill of Right of the US [69] and the EU Data Protection Directive [64].

For example, regarding data location, the terms and conditions expressed by Microsoft in its Azure web page [200] stipulate that *Microsoft may transfer Customer Data within a major geographic region (for example, within the United States or within Europe) for data redundancy or other purposes.* Similarly, the terms and conditions published by Amazon AWS regarding their S3 storage [204] stipulate that *Amazon S3 offers storage in the US Standard, US West (Oregon), US West (Northern California), EU (Ireland), Asia Pacific (Singapore), Asia*

Pacific (Tokyo), Asia Pacific (Sydney), South America (Sao Paulo), and AWS GovCloud (US) regions. You specify a region when you create your Amazon S3 bucket. Within that region, your objects are redundantly stored on multiple devices across multiple facilities. In fact, Amazon AWS offer means for its customers to choose the geographical location of his components at allocation time. Thus a customer is in a position to decide at deployment time, the geographical location (US, Europe, Asia Pacific, etc.) of S3 storage expected to store personal data.

At first glance, from the above disccussion it seems that the cloud computing community has all the elements (legislations and technical means) needed to enforce data protection in the cloud. We believe that this observation holds but only for simple applications, such as those that involve one of two cloud components colocated within a single cloud provider. However, we argue that the problem is of *scalability*. We will explain the challenges we have identified that impact the enforcement of data protection in the cloud. Our view is that the enforcement of regulations of cloud data at large scale can be achieved only with the assistant of programatic means. We consider that manual approaches like Amazon's facilities that allow customers to choose geographycal regions at deployment time, are insatisfactory solution because they no not scale well.

3.1 Legislations

To be effectively used in practice, cloud computing regulations, such as the Data Protection Directive [64], need to be enforced and monitored for detecting potential violations at run time or at off–line log examination. This implies that the textual description of the regulations need to be mapped onto precise notation that is amenable to computer manipulation. The main difficulty that technical people face when presented with this tasks is the gap between the legal and technical domains. Legal documents are written at targeted at humans that are expected to use their judgement to make sense of them. Consequently, they normally contain ambiguities and subjective terminoloy and suffer from omissions and conflicts. As an example, let us take the first princliple of article 25 of the Data Protection Directive which is related to the transfer of personal data to third countries:

1. The Member States shall provide that the transfer to a third country of personal data which are undergoing processing or are intended for processing after transfer may take place only if, without prejudice to compliance with the national provisions adopted pursuant to the other provisions of this Directive, the third country in question ensures an adequate level of protection.

The *adequate* is hard to express in computer notation and can only be interpreted by human judgement. As a second example, let us examine point c) of Article 6 which states that: *Member States shall provide that personal data must be: adequate, relevant and not excessive in relation to the purposes for which they are collected and/or further processed.* Again, the terms *adequate, relevant and not excessive* require human judgement for their interpretation. In summary, the research challenge here is to identify what statements can be capture in computer notation and what needs to be left for humans to interpret.

3.2 Deployment with the observance of obligations

At run time, the broker will regularly estimate the cost of the service by monitoring the actual resource usage and dynamically perform any changes such as expand (shrink) resource pool, switch between providers and so forth. Furthermore, billing and service usage information is presented by the broker to the customer in a manner that enables the customer to relate this information to their business goals, making the task of revising and re-negotiating service usage policies with the broker straightforward. Such re-negotiation can happen dynamically, as the user needs change.

Cloud applications need configuration in order to be regulation compliance– the designer needs to ensura that execution paths that compromise the regulation are excluded.

service broker implementing the facility of smart metering for the consumer by translating consumers requirements into an adequately provisioned value-added service, that is mapped onto one or more cloud services.

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3.3 Consumer's awareness of data regulations

We expect that a typical cloud customer will dynamically expand and shrink his resource pool and possibly switch between providers, as needed to accomplish his business goals. In response, the provider reacts to his customer requests by executing the low level technical procedures (for example, instantiation of a new virtual machine or allocation of a volume of storage) to realise the requests, under the observance of the terms and conditions agreed with the customer including those related to data regulations. For instance, the provider will not replicate databases outside the EU region if the terms and conditions agreed with the customer estipulate so.

However, the cloud provider can do nothing to prevent the customer from accidentally (or deliberately) violating data regulations. The difficulty is that as explained in [54] regulations apply to specific data. Let us take medical records as an example. In the US the Health Insurance Portability and Accountability (HIPAA) applies to medical records. Thus customers that collect and store medical records about their employees are at risk of inadvertesly uploading those records to the cloud in readble format. The risk of making this kind of mistakes magnifies with cloud applications with scores of components.

It appears cloud data protection is a colaborative commitment between the cloud provider and the customer but demands a customer's clare view of what data he is transfering, processing and storing and what cloud components he is deploying or undeploying. In other to make an informed decision about the deployment (or undeployment) of a given component, the customer needs to have a precise view of the current state of his application.

As argued earlier, cloud applications and regulations might be complex. The fact that cloud providers lease individual components under specific terms and conditions (for example, Amazon S3 buckets come with their own terms and conditions and so do volumes of Elastic Block Store and EC2 instances) add to this complexity.

Thus we argue in favour of formal models that assist cloud customers to deploy their applications. Such models should help customers systematically and mechanically reason (for example at run time or predeployment time) about the behaviour of their application in terms of data protection so that they can assess the risk of data regulation violations. For example, a model can indicate that data D cannot be transfered along path P before it has been proccessed by activity A—a formal expression for requesting that personal data cannot travel outside EU region unless it has been encrypted.

3.4 Formal models for automatic compliance checking

Formal models for automatic checking of regulatory compliance have been suggested in the literature. A good introduction into the topic is [309] where the use of graph–based models is suggested. The deployment of scientific application in the cloud under strict privacy constrainst is dicussed in [427]. The author argues that task allocation becomes a challenging problem when the data that some of the tasks input or output is subject to security requirements such as privacy. In these situations, the workflow designer needs to examine the security guarantees offered by providers to ensure that his security requirements are not violated during task execution, data storage or data transfer between different cloud providers. For instance, the result of the analysis might dictate that some tasks can be executed only within the local cloud. The author suggests a systematic method for workflow partition with the observance of security requirements based on the Bell–LaPadula multi–level access control model.

4

5 Network–centric control

The enforcement of data regulations in cloud computing is a multi–dimentional problem that at technical level involves communication, storage and processing. In this section we focus our attention mainly to communication related issues.

We close the section with the discussion of broader issues and some ideas about storage and processing which are also relevant to the enforcement of regulations of cloud data.

We focus our attention to the following three problems:

Path transparency: how can you tell, a priori, path properties where links and switches are, who runs them, what s/w they run etc? whois, RIPE registery, AS prefix/ownership etc.

Path controls: can you choose provider? yes– e.g. client multihomeing (easier if mobile), YES, often server/data center multihoming, note FIX point below (flatter internet). Yes, if ISP: path choice (by ISP not by client or server). Maybe: loose source routing is an IP (IPv6) possibility but is normally ruled out. Also VPNs and Traffic engineering often allow longer term. Research like the Internet Indirection project might pay off [61].

Path monitoring: can you check that your data flows according to declared path properties? We have some technology like traceroute, geolocation, ping, etc. Also we have regulator SamKnows, etc.

5.1 Localization

The topic of localization in cloud computing relevant in the enforcement of data regulations in cloud computing. On can argue that the cloud is not a real physical thing but only a business model for accessing computing resources. Yet as soon as some programme runs and some data is stored, then a there is a mapping of that programme, the data and other resources involved into a physical location. This mapping is not trivial to understand and examine —in particular when the parties involved are mobile— without the appropriate techniques. We believe that the theoretical work on processes with locations conducted by Professor Robin Milner FRS (University of Cambridge) might help as a modelling tool. Professor Milner and others developed *Biograph* around 2006. Biograph is a rigorous generic model that can be used for modelling the concurrent and interactive behaviour of polulations of mobile communicating agents. Through their graphical presentation, Bigraphs can make it easy for non–experts to visualise their system and assemble them geometrically.

5.2 Topology, topography, network administration

We have looked at the notion of topology, topography, and administrative scope in networks (i.e. lower layers) for years. We have a fairly good handle on these notions, and can help from that perspective. We also have practical tools that can help, we discuss some of in this subsection.

1. *geo–loc services:* It is routine nowadays to use geo-loc services to place a client in a (fairly accurate) geographic location for the purposes of filtering what content they get. For example, the BBC do this to stop users outside the UK seeing iPlayer content (actually they also do it to stop users inside the UK

seeing comercial BBC world content). Obviously this technique is used for geo-located targeted advertising, as well. But crucially, it is used by Google and Youtube to control what music and videos they deliver depending on whether they have negotiated rights to do so (e.g. in exchange for advertising revenue or analytics with the rights owner) in a given region. This implies a mapping from geographic location of the browser/computer/client, to a legal region for the purposes of IP ownership/licensing. These ideas migh help so might serve quite well.

2. *XenoSearch:* When we first designed the Xen software [58] we also developed tools for users to launch Virtual Machines (VMs) to specific locations. It was perfectly feasible to start a virtual machine in a specific data center. The same applies to storage. leading cloud providers like Amazon offer location–aware instantiation of EC2 and S3. Our early tools were more aimed at solving constraints (keep latency below some particular bound) but could be more targeted at other purposes. Of course, a cloud provider knows very well where there data centers are located (geographically, administratively and legally for the purposes of tax etc.) so this is trivial compared with fancy geo-loc services for (potentially mobile) browsers.
   Of course, there are more nebulous services (like Gmail and search) which run over a large distributed infrastructures, which may itself run over an even larger lower layer infrastructure. In fact both gmail and Youtube have large distributed storage systems that may not currently map well to a location, but the argument above says that they easily could.
3. *Border gateway Protocol:* In the quite early internet days, around 1992, we devised a system called the Inter–domain routing system, which uses a protocol fittingly called the Border Gateway (BGP) protocol. BGP controls the flow of traffic between regions of the network called Autonomous Systems (ASs). While these regions are topological in nature, rather than topographical, as in point 2, all Border Routers are physically statically located in or near Internet exchange points. Currently many Internet service providers are also operators in the telco sense, within a specific country, and so their infrastructure in terms of AS topography (and, likely, legal boundaries) is well defined. This would be obviously true within the UK, France, SPain, Italy, Germany, etc, where the national largest ISP is also the old PTT/operator/telco (BT, FT, Telefonica, Telecom Italia, DT etc.). In these situations it would be fairly easy to map information flow at the network and constrain it by means of routing policies. For for example, BGP has rules for traffic ingress, egress and transit that can be applied on a per IP–prefix basis. So if neccessary one could constrain traffic from a given cloud provider using today's existing network technology (at some operational cost). BGP is capable of capturing a lot of complex network business relationships and might be a useful source of approaches to constraining where cloud data may and may not go.
4. *Traffic localization:* Some Telco/ISPs/ASs have also integrated the content delivery infrastructures with their backbone networks to control where the traffic goes, to avoid unnecessary transit fee costs from other ISPs. For exam-

ple, Telefonica in Spain works directly with Akamai to optimise traffic flow from TV and Web content servers to stay within their network within Spain specifically (although they obviously have a lot more networks– e.g. most of Latin America. Localization of traffic is seen as a Good Thing for cost (for provider) and latency reasons (for customer). So requiring such controls is not a great burden, but more aligned with the network providers business interests. See ideas like P4P for this approach, even applied to P2P traffic sources like bittorrent.

5. *Internet is getting "flatter":* Internet is getting "flatter" when seen from a large cloud service provider perspective. Many cloud services connect their regional data centers to all providers in an area, so that the onus for information flow control in the network later is much more likely to involve google or amazon or yahoo (or facebook) doing a lot more work. That may go counter to their business interests to some extent. The model of how the Internet fits together in terms of cloud services, Internet Exchange Points is always changing. See for example this report [62] (from 5 years ago now) and this one [59] from last year. Facebook is certainly the most difficult case in terms of trying to understand how these layers would fit together, but from the point of view of business, the least relevant.

5.3 Broader discussion

For europe, the continental ISPs want to worry if they route there data through the UK, because of the GCHQ intercept and 5–eyes sharing arrangement with the US, effectively rendering data that traverses any UK link being seen in the US too. The same is not true, as far as I know, if you routed data between (say) France and Italy via Switzerland or between Norway and Denmark via Sweden.

The implication is that if you are just routing end–to–end encrypted data, then the risks are small. So recent (post Snowden) practice of routing data between data centers in encrypted form fixes that risk; but if you application layer routes (i.e. go via cloud servers and caches) then data may be stored in places at risk, since keys might be local to storage server or storage may be unencrypted. This issue needs to be regarded as a sort of hierarchy of risks.

Other questions that one can ask is whether your data touch switches or routers in other countries. If so, is it encryped with keys stored and signed/ca in end points located not in those other countries? Does your data get stored on servers in other countries? if so, is the data stored encrypted, with keys kept elsewhere for decrption only elsewhere (at original ends)? The question here is about where the data is encrypted and descrypted as it is transferred over different geographical (for example, countries) and administration domains (for example cloud providers, ISPs). One can ask, where are the encryption and decryption keys located and who manages (create, certify, distribute, revoke, backup, escrow, etc.) them.

BGP allows control of traffic flow, although the direction of control is a bit weird, but you can configure so you do not ingress/egress or transit a given AS, so if we know an AS has any footprint in a given intercept jurisdiction, (or just somewhere we do not trust in general) then one should configure to avoid it– one problem is that it is "all or nothing" configuration. Yet at higher levels (storage, caching, location of keys, certificate authorities etc) we have to do same due diligence.

A question that arises here is what we want this model of network for? I believe that for both:

– for a compliant cloud service to be able to advertise that it does not let info flow beyond borders (transparently) and,
– to be able to measure that a miscreant cloud provider has allowed data or computation to flow (or be stored) where it should not (and produce evidence that will stand up in court)

Another querry is that there is an assumption here that EU member states all trust each other. What is the longer term story within the EU cloud for dealing with members joining or leaving? Should newcomers be able to snoop on the historical cloud data they were not provileged to before? When states leave, how do we partition this EU cloud?

This line of thought does lead to a rather unusable cloud where no components ever trust any other component —that is clearly not a viable way to benefit from scale, but we do need to consider how to make the placement of trust more flexible to survive the inevitable long term geopolitical changes. If crypto is built in to the cloud platform, this is once again largely a (difficult) secure key management problem.

5.4 Data storage

The issue here is to provide the owner (individuals or institutions) of the data with assurance (and ideally means for verification) that his data is stored where he expects it to be (for example, not outside the EU region) so that his data complies with regulations. Also the ownwer needs assurance that the data is retained and available (in readable format) to the entitled parties for as long as he expects to in accordance with his personal expectations and national and international regulations. Equally important, the owner of the data needs to be assured that his data is deleted when the retention period expires. For example, EPSRC Policy Framework on Research Data dictates that "Research organisations will ensure that EPSRC–funded research data is securely preserved for a minimum of 10-years from the date that any researcher privileged access period expires or, if others have accessed the data, from last date on which access to the data was requested by a third party [245]." Regulations of medical records are more difficult to satisfy since they include strict policies about retention and deletion—a hard problem.

It is worth mentioning that some cloud providers offer their customers technical means of selecting the physical location (for example, US, Europe, Asia Pacific, etc.) of their resources. With Amazon for example, a customer is able to dictate that his S3 storage is located in the US, Europe, Asia Pacigic, etc. We believe that this is not enoug, the challenge that cloud computing presents is that due to transparency, the customer is not necessarily aware of the existence and location of cached and backup copies of his data.

5.5 Data processing

The challenge here is about providing customers with assurance that the software that access his data is doing only what it is supposed to do instead of accidentally or deliverately leaking sensitive information. This is still an open research problem. With current practice users have to blindly trust the providers of the software. Ideally, users (or attestation services) should be able to examine the provenance of the software and verify records about its origin, maintenance, testing, etc.

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