An Overview of Cloud-Based Secure Services for Enterprise Drug–Drug Interaction Systems

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Abstract:

Cloud computing has brought a new paradigm shift to the technology industry and has become increasingly popular. Cloud communication is an emerging technology that can be combined with traditional healthcare management used to provide better healthcare services. Today, the adoption rate of cloud computing by small and medium enterprises (SMEs) is much higher than that of large companies. This triggered a debate about whether this cloud computing technology will penetrate the entire IT industry. Small and midsize enterprises are using cloud computing to deploy general IT infrastructure and software systems at low-cost, while large enterprises rely on their own infrastructure to ensure data security, privacy, and flexibility. One of the most demanded healthcare services that needs the cloud privileges is Drug-Drug Interaction – DDI. In this article, we have investigated different traditional systems compared to cloud-based systems, and as a privilege of providing system solutions to the public, what features the cloud brings to improve health management software.

Keywords: Cloud computing; Cloud communication; healthcare management systems; Data Integrity; Potential Solutions

1. Introduction

According to data from Food & Drug Administration of US government – FDA [1], a patient may face some serious situations which led to a sensitivity of some drug product's component, and gradients and of course no one needs to reach out that level of high sensitivity issues when comes to the front because of validation failure. The importance of the validation process before taking a drug product costs nothing compared to the treatment, the one needs when a sensitivity issue comes. The same happens about drug products and their interactions on a patient that has already been taking a set of some other drugs' products. A Drug-Drug Interaction – DDI, and Food-Drug Interaction - FDI lead to serious issues the one may avoid because of validation process. According to a 2007 report on medication safety issued by the Institute for Safe Medication Practices, close to 40 percent of the U.S. population receive prescriptions for four or more medications. And the rate of adverse drug reactions increases dramatically after a patient is on four or more medications [2]. While using a real up-to-date data set of drug bank [3] of US, it is important to analyze a real patient profile with reviewing their historical records to validate and solve the mysterious and uncertainty of adding one more drug product to their daily routine.

A health-care service provided for doctors, and patients together to prevent or minimize Medical Errors – MEs that harm patients [4]. Measuring how a drug product affect a patient is a critical process which requires a validation. Not only a general validation but it should focus on every patient's situation. Validation on both sides, drug product

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level and patient level with avoiding any data limitation. Not all drug products the one may take are descripted by a specialist or a doctor, there are many over the counter - OTC drug products which a patient can buy and add it manually to his daily drug products set as a valid medicine [5]. The importance of the validation process must be available to both doctors as specialists, and public.

The importance of applying such methodology not limited to doctors and patients but also includes pharmacists. In US, state pharmacy Drug Product Selection – DPS laws allow pharmacists to switch prescriptions more easily from brand-to-generic drugs [6]. Since the objective of the healthcare improved applications is to make it simpler for patients to remain linked to their providers, and for their providers to transfer responsible, value-founded care to their populations [7]. Validation process is the basic concept to transform the healthcare daily actions from novelty to actuality [8]. Many systems are presented to help in such cases and validate Drug-Drug Interaction such as Lexi-Interact, Micromedex Drug Interaction by IBM, iFacts, Medscape, Epocrates, and Drug Bank.

In recent years, with the popularity and rapid growth of storage and processing technologies and the success of the Internet, computing resources have become cheaper, more powerful, and more ubiquitous than ever [9]. This technological trend is often referred to as cloud computing and has produced an assessment method that can better respond to current and future information and communication technology (ICT) requirements. Cloud computing provides an adaptable online environment that encourages the ability to handle a large amount of work without affecting the execution of the framework. The use of cloud services establishes a developmental relationship between public and private sector entities and the people served by these elements. Cloud computing is very attractive to business owners because it eliminates the need for users to plan setup in advance and allows businesses to start small and increase resources only when demand for the service increases [10].

Over the years, various technologies such as virtualization, grid computing, and service-oriented architecture (SOA) have matured and made significant contributions to making cloud computing feasible [11]. On the other hand, cloud computing is still in its infancy and lacks institutionalization in many respects. Since cloud infrastructure is used globally, security is a major issue. This exchange of frameworks and the way cloud customers need to control the cloud foundation raises huge security concerns. Clouds have different architectures depending on the services they provide. Information is stored in a centralized area called a server pool, which has a large space for information storage and data processing on the server. Therefore, customers must trust cloud resource providers in terms of accessibility and information security. A service level agreement (SLA) is the only legal agreement between a service provider and a customer. The only way a vendor can increase customer trust is through SLAs, so it must be institutionalized. Focusing on current trends in the topic and growing interest, this article explores current models in the field of cloud computing and proposes a research space for future improvements in this technology. The key elements of cloud research opportunities are provided and each element is explained in detail.

The article is planned as follows: Section 2 presents the study of cloud computing architecture. Section 3 presents several security issues in cloud computing. Section 4 presents different DDI enterprises and how cloud improve their features. Section 5 summarizes the aim of the proposed study and the future work.

1. Related Studies

In this section, a review of literature will be displayed about the cloud computing architecture. The term distributed computing appears to start from machine system standard that speak to the web as a cloud. The US National Institute of Standards and Technology (NIST) has created a working definition that blankets the generally concurred parts of cloud computing. The NIST defines cloud computing as, a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction [12]. This NIST definition describes cloud computing as having five essential characteristics, three service models, and four deployment models [10].

The five essential characteristics of cloud computing:

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1. On-demand self-service: Registering could resources be gained and utilized whenever without the requirement for human association with cloud administration suppliers. Computing resources include processing power, storage, virtual machines, etc.
2. Broad network access: The beforehand said resources could be gotten to over a system utilizing heterogeneous gadgets, for example, laptops or mobiles telephones.
3. Resource pooling: Cloud administration suppliers pool their resources that are then imparted by numerous clients. This is alluded to as multi-tenure where, for instance, a physical server may have a few virtual machines having a place with distinctive clients.
4. Rapid elasticity: A client can rapidly gain more resources from cloud by scaling out and can scale back in by discharging those resources once they are no more needed.
5. Measured service: Resources utilization is measured by monitoring storage usage, CPU hours, bandwidth usage, etc. The said metrics are applied to all clouds, but each cloud provides users with services at a different level of abstraction, which is an alternate to an administration.

The three most common service models of cloud computing:

A cloud can collaborate with customer/client in a mixed bag of courses, through capacities called services. Across the web, three major types of models, of services have emerged, Figure. 1 shows the details of cloud computing service model.

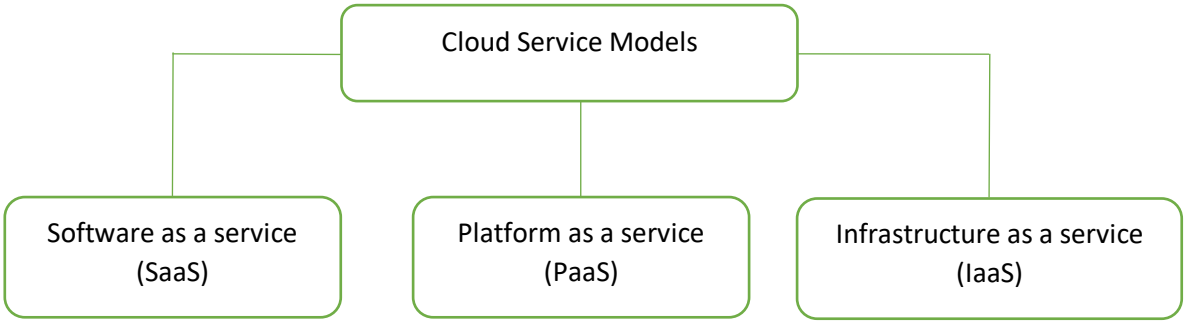

Figure 1. Three service models of cloud computing.

Software as a service (SaaS):

Provides consumer the capability to use applications running on a cloud infrastructure mainly on the web browser to access software that offer as a service over the web. The consumer does not have control or figure out how to the underlying framework including system, servers, network, operating systems, storage, or even individual application capacities, with the conceivable exemption of constrained client particular application setup settings. GoogleDocs1 and Salesforces2 are prominent examples.

Platform as a Service (PaaS):

Provides the capability to deploy onto the cloud infrastructure, consumer created applications, produced using set of programming languages and tools that are supported by the PaaS provider. The consumer does not oversee or control the underlying cloud framework including network, servers, operating systems, or storage, yet has control over the sent applications and conceivably application facilitating environment arrangements. Much the same as the SaaS model, clients do not have control or access to the underlying base being utilized to have their applications at the PaaS level. Examples of PaaS are Google App Engine3 and Microsoft Azure4 are prominent examples that use the PaaS model of cloud computing.

Infrastructure as a service (IaaS):

Provides the consumer with the capability to provision processing, storage, networks, and other fundamental computing resources from an IaaS provider, and allow the consumer to deploy and run any software, which can include operating systems, services and applications. The client has control over operating systems, storage, deployed applications and perhaps constrained control of select systems administration parts. Rather than the PaaS model, the

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IaaS model is a low level of reflection that permits clients to the right of the entrance the underlying foundation through the utilization of virtual machines. IaaS gives clients more adaptability than PaaS as it permits the client to convey any product stack on top of the operating system. Examples of IaaS are Amazon Web Services EC2 and S35 are prominent examples that use the IaaS model of cloud computing.

The four deployment models of cloud computing:

A cloud organization model indicates how resources inside the cloud and shared. Four different cloud deployment models: private cloud, public cloud, community cloud, and hybrid cloud. Each model impacts the comparing scalability, reliability, security, and cost.

Private cloud:

A cloud that is used exclusively by one organization, company, or one of its customers. The cloud may be operated by himself or a third party, private cloud offers increased security at greater cost. The St. Andrews Cloud Computing Co-laboratory6 and Concur Technologies (Lemos, 2009) are illustration associations that have a private cloud. [13]

Public cloud:

A cloud that can be used by general public. Due to its openness the cloud may be less secure. Public cloud is the best option with less expensive. This can be a large organization and offer services. Public clouds require significant investment and are usually owned by large corporations such as Microsoft, Google or Amazon.

Community cloud:

A cloud that is shared by two or more several organizations or company and is usually setup for their specific requirements. This is typically for the shared concern (e.g. such as schools within a university).

Hybrid cloud:

A cloud that setup using a mixture of two or more private, public, or community cloud. In the hybrid cloud could be freely overseen yet applications and information would be permitted to move over the cloud.

With cloud characteristics, services, and deployment models presented, the cloud is now hosting wide range of large scale and small scale applications. Many organizations and companies are now moving key applications from expensive internal data centers to cost effective and resourceful cloud solutions.

Features of Cloud Computing:

Scalability:

When a user lunch website scalability defines a site or application's skill to use traditional solutions on demand. The site may scale up to available additional resources the system is experiencing high user demand and later may scale down recourse when the user demand turns down. Applications that run within the cloud are normally highly scalable. An applicant can manually add or remove resources or application can be configured to scale automatically.

Virtualizations:

Virtualization is to use hardware or software to create the observation of something. Must server have their own CPU that is capable of running specific a specific operating system (OS), such as Windows, Linux, or Mac OS. By using special software, server can be shown as it has multiple CPUs and are running the same or different operating systems and the server CPU switches its processing power frequently among the various operating systems.

In the same way, desktop PCs typically run one operating system. Again, by using special virtualization software, a desktop PC/ laptop can be run simultaneously different operating systems. This provides an excellent platform for

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developer's application testers, and help desk support personal which support multiple operation systems. without having multiple systems on the desk, the user can use multiple operation systems in a single desktop PC.

2. Methodology

We propose a several cloud computing security issues based on different service layer. Figure. 2 shows the overlay architecture of security issues and trust requirement in a top-down service model [14]. Trust basically works in a top-down design, as every layer needs to trust the layer instantly beneath it, and obliges a security ensure at an operational, specialized, procedural and lawful level to empower secure correspondences. But the security is treated as individually in each service layer. Trust could be seen as a sequence from the end client to the application holder, who thusly believes the provider.

A. Security issues in SaaS:

In SaaS, the client needs to rely on upon the supplier for fitting efforts to establish safety. The supplier must do the work to keep numerous clients' from seeing one another's information. So it gets to be hard to the client to guarantee that right efforts to establish safety are set up furthermore hard to get confirmation that the application will be accessible when required [15]. Based on SaaS, client can substitute net program or software applications over old one. Hence, the center is not upon portability of uses, yet on safeguarding or upgrading the security usefulness gave by the legacy application and attaining effective information relocation [16]. The SaaS programming seller may have the application on its own private server farm or convey it on a cloud computing framework administration gave by an outsider supplier (e.g. Amazon, Google, etc.). The utilization of cloud computing coupled with the pay-as-you-go (develop) methodology helps the application administration supplier diminish the interest in foundation benefits and empowers it to focus on giving better administrations to clients. Over the past decade, computers have become widespread within enterprises while IT services and computing has become a commodity. Enterprises today view data and business processes (transactions, records, pricing information, etc.) themselves as strategic and guard them with access control and compliance policies. However, in the SaaS model, enterprise data is stored at the SaaS providers' data center, along with the data of other enterprises. Moreover, if the SaaS provider is leveraging a public cloud computing service, the enterprise data might be stored along with the data of other unrelated SaaS applications. The cloud supplier may, also, imitate the information at numerous areas crosswise over nations for the reasons of keeping up high accessibility. Most enterprises are acquainted with the conventional on reason model, where the information keeps on residing inside the endeavor limit, subject to their approaches. Therefore, there is a lot of inconvenience with the absence of control and information of how their information is put away and secured in the SaaS model. There are strong concerns about data breaches, application vulnerabilities and availability that can lead to financial and legal liabilities [17]. There are several highlights security issues in SaaS such as data security, network security, data locality, data integrity, data segregation, data access, authentication and authorization.

B. Security issues in PaaS:

In PaaS, the administration supplier may give some control to the customer to manufacture applications on top of the stage. However, any securities beneath the application level, for example, have and system interruption anticipation will at present be in the extent of the supplier and the supplier brings to the table solid affirmations that the information stays distant between applications. PaaS is proposed to empower designers to assemble their own particular applications on top of the platform. As a result, it tends to be more extensible than SaaS, at the expense of customer-ready features. This exchange off stretches out to security gimmicks and abilities, where the implicit capacities are less finish, however there is more adaptability to layer on extra security [17]. Applications sufficiently perplexing to influence an Enterprise Service Bus(ESB) need to secure the ESB straightforwardly, leveraging a convention, for example, Web Service (WS) Security. The capability to portion ESBs is not accessible in PaaS situations. Measurements ought to be set up to survey the viability of the application security programs. Among the immediate application, security particular measurements accessible are defenselessness scores and patch scope. These measurements can show the quality of application coding. Consideration ought to be paid to how malignant on-screen characters respond to new cloud application architectures that the darkened application parts from their examination. Programmers are liable to the assault noticeable code, including but not constrained to code running in the client

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connection. They are prone to assault vulnerabilities of cloud are connected with the web applications as well as vulnerabilities connected with the machine-to-machine Service- Oriented Architecture (SOA) applications, which are progressively being conveyed in the cloud [17].

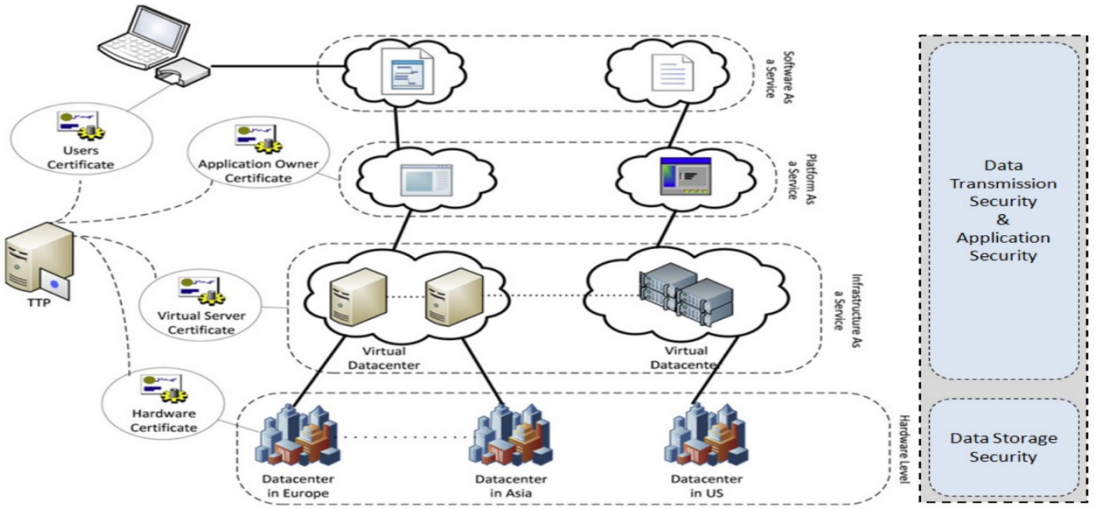
C. **Security issues in IaaS**:

In IaaS, the developer has better control over the security the length of there should not any security gap in the virtualization director. Likewise, however in principle virtual machines may have the capacity to address these issues yet in practice there are a lot of security issues [18]. The other element is the unwavering quality of the information that is put away inside the supplier's equipment. Because of the developing virtualization of "everything" in data society, holding a definitive control over information to the holder of information paying little respect to its physical area will turn into a subject of most extreme investment. To accomplish most extreme trust and security on a cloud asset, a few procedures would need to be connected [19]. The security obligations of both the supplier and the client incredible contrast between cloud administration models. Amazons Elastic Compute Cloud (EC2) (Amazon, 2010) IaaS offering, as a case, incorporates merchant obligation regarding security up to the hypervisor, importance they can just address security controls, for example, physical security, natural security, and virtualization security. The client, thus, is in charge of the security controls that identify with the IT framework including the OS, applications and information [16].

Figure 2. overlay architecture of security issues in a top-down service model.

3. Case Study

In this section, a case of selecting the appropriate drug product against other drugs using multiple exist APIs is presented to approve the importance of using the cloud computing features.



As the number of pills used in parallel grows, so does the probability of dangerous drug interactions. To eliminate the risk of side effects caused by medication combos, hospitals and pharmacies should be equipped with robust drug interaction checkers.

A drug interaction happens when the effect of a certain medication on the body is altered by another substance or factor. Countless cases of such unwanted combinations fall into the following groups:

- drug-drug interactions (DDIs, for short),
- food-drug interactions,
- drug-herb / drug-supplement interactions,

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- drug-disease interactions,
- drug-allergy interactions, and
- drug-gene interactions.

Drug-drug interaction:

Taking together five or more drugs, known as polypharmacy, has become commonplace — not to mention simultaneous administration of fewer medicines.

Drug-food interaction:

Food and beverages can bind to active pharmaceutical ingredients reducing their absorption or catalyzing their elimination. The most common food and drug interactions are

- dairy products decreasing the effect of antibiotics;
- grapefruit juice interfering with some drugs that treat high blood pressure;
- green, leafy vegetables, high in vitamin K, reducing the efficacy of anticoagulants; and
- alcohol causing dangerous reactions when mixed with certain medications.

Drug-supplement and drug-herb interaction:

About a quarter of US adults combine pharmacology therapy with taking herbs and dietary supplements. Active compounds of botanical remedies — for example, (*Hypericum perforatum*) and (*Hydrastis canadensis*) can reduce the effectiveness or concentration of certain medications.

Drug-disease interaction:

Sometimes a drug treating a certain illness aggravates another disorder. For instance, beta blockers used to combat heart disease may worsen asthma.

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Drug-allergy interaction:

Drug-allergy checking involves storing information on patient allergies and their severity in the EHR and warning on possible problems when prescribing drugs.

Drug-gene interaction:

People with certain gene variations may be at risk of unexpected reactions and even toxicity. To alert to this type of interaction, decision support tools must be fed with actual genomic information. Besides that, the effect of drugs can change due to

- age,
- pregnancy and lactation,
- gender,
- weight, and
- lifestyle.

Clinicians must keep track of all these factors when prescribing a drug, its dosage, treatment frequency, and duration. Fortunately, automated drug interaction checks make their job much easier. Adverse Drug Reaction, also known as ADR, is a serious problem that should be avoid when using drugs. ADR might worsen the patient condition or to the extent where patients need to be hospitalized. This results in increasing medical expenses. One of the major reasons causing ADR is drug interaction. Patients with multiple chronic diseases under multiple treatments are the potential group of people at risk to develop drug-drug interactions. In addition, it is extremely difficult for doctors to prescribe medications when they cannot get access to the information of all the drugs and possible drug interactions when patients are under cross-disciplinary or even cross-hospital treatments. Hence, how to decrease the incidence rate of ADR is an important issue. Figure 3 shows the possible effect of Drug-Drug Interaction. The DDI may decrease or increase the action of drugs, even cause the adverse effect. These can influence the treatment plan, brig the unexpected result [20]. In [21], the medical cost increased by DDI was analyzed in USA. It is an important issue to provide a rapid and correct DDI query service for reducing the risk of using multiple drugs.

In figure. 3 the 3 scenarios of adding one more drug to others, possible effects are increasing action of drugs, decreasing action of drugs, and/or cause adverse effect.

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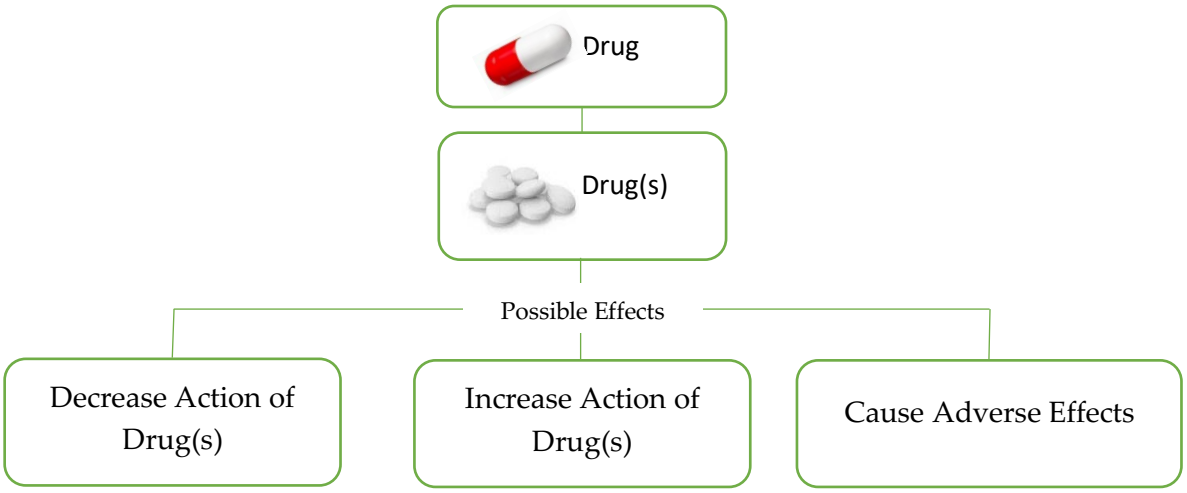

Figure 3. Drug-Drug Interaction Possible Effects.

4. Conclusion

The study presents the cloud computing architecture and its security on different levels and the drug-drug interaction as a domain which needs the benefits the cloud computing. The real up-to-date data of drugs products are gathered and updated daily which needs unlimited storage. Based on the cloud privileges presented in the study such as: Public auditing, [22] data availability, [14] easy workflow scheduling, [23,24] efficient of VMs consolidation for managing heterogeneous workloads, optimization of virtual network topologies, handling dynamic variation in workload, and handling uncertainties. [25,26] using many methods [27: 30] it is important to develop an enterprise system to manage the validation process of adding a new drug to the current drug table using cloud computing for the public.

The future work includes reviewing algorithms that exclude and alert the drug products against sensitivity and handles multiple drugs of patient's current drugs list – CDL that presents DDI to the newly added drug product.

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