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MOBILE CLOUD COMPUTING AND OTHER MOBILE TECHNOLOGIES: SURVEY

AMAL ABUNASER SAWSAN ALSHATTNAWI
Computer Science Department, Yarmouk University
Irbid, Jordan
sawsan_kh@yu.edu.jo

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Cloud computing is a resulting technology from many fields of computing. The concept core of cloud computing is to get services and processing capacity over the Internet. This technology reduces cost, increase storage, automate systems, and introduce flexibility and mobility of information. Many technologies have been emerged from the cloud computing such as mobile cloud computing. Mobile cloud computing is a combination between mobile computing and cloud computing, aims at providing optimal services for mobile users. Because mobile computing includes using computers during the movement from place to place to provide users with their maximum need, they have the ability to access other computer, other digital and portable devices around them. The emergence of, nearly similar, technology that deal with this issue is called ubiquitous computing. Ubiquitous computing implies making the digital devices available while they are effectively invisible to users. Its aim is to break away from the desktop computing to provide computational services to a user when and where required. These technologies are limited and encountered several challenges. Mobile cloud computing will support these technologies and solve most of these challenges. In this paper, we survey the resulted technology mobile cloud computing, and we explore different technologies that preceded it such as cloud computing, mobile computing and ubiquitous computing.

Keywords:

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1 Introduction

The wireless communication revolution is bringing fundamental changes to telecommunication and computing. Wireless LANs and widespread cellular systems tend to make integrated networks a reality and provide fully distributed and ubiquitous mobile computing and communications [1, 2]. The technology that relies on the convergence of wireless technologies, advanced electronics and the Internet is the ubiquitous computing [3].

Ubiquitous computing is defined as the method of enhancing computer use by making many computers available throughout the physical environment, but making them effectively invisible to the user [4]. Ubiquitous technology is often wireless, mobile, and networked, making its users more connected to the world around them. The goal of working on ubiquitous computing is to create smart products that communicate in an invisible way.

Mobile computing is a new technology that is not differ from ubiquitous computing from the distributed system point of view [5]. It enables users to access a shared infrastructure, independent of their physical location. This provides flexible communication between people and continuous access to networked services. The access is done by web browser or by mobile applications which consist of software that runs on a mobile device and performs certain tasks for the user of the mobile phone.

These two technologies are the reason of appearing nomadic user which means that a user who uses the new mobile technologies be able to move and access data and services from different locations. These technologies present some challenges concerns the mobile devices capacity and the network state. Therefore, the mobile applications are built according to the resource capacity of each mobile device. Currently, mobile applications are tied to a carrier for example, if someone interested in iPhone application, he have to first have a relationship with the mobile operator who carries the iPhone, or if he wants Blackberry application, the same rule applies [6].

This way of designing applications to fit a specific platform is expensive and not practical. Thus, problems concerning the limited resources are adopted to be solved by a new technology, appears in the last decade, which is called cloud Computing [7]. It is a web based processing, in which shared resources, software, and information are provided to the users on demand over the internet. This technology enables on-demand network access to the shared computing resources (such as networks, servers, storage, applications, and services) that can be managed and updated with minimal management effort or service provider interaction.

One of its major advantages is that the users can access all services of cloud-based application from any location, as long as they have an Internet connection and without spending high expense on hardware and software resources. Cloud computing has a great impact in mobile world; it allows mobile telephone holders to use the services of cloud computing without requiring any specific hardware or software. In addition, mobile devices need not a powerful configuration (e.g., CPU speed and memory capacity) since all the data and complicated computing modules can be processed in the clouds [8]. Mobile users are provided with data storage and processing services on a cloud computing platform rather than on the mobile devices themselves.

Mobile cloud computing (MCC) [9] has appeared as a new model and extension of cloud computing to combine the last three technologies as shown in figure 1. This technology extends cloud computing by providing reinforcement service by utilizing information about a users location, context and network intelligence. Leveraging the mobile device storage, sensing and processing resources for optimizing cloud-based application also adds to better user experience [10, 11]. Mobile cloud computing will facilitate applications building because the access is available from any platform when the access to the web is permitted.

In this paper we have introduced a summary for mobile cloud computing and its different models. The paper will be organized as follow: a review of cloud computing and its architecture will be explored in section 2, we review mobile computing and ubiquitous computing in section 3. Section 4 will explore the MCC, its architecture and its models. Finally we conclude the paper in section 5.

2 Cloud computing

Cloud computing is Internet based computing where virtual shared servers provide software, infrastructure, platform, devices and other resources and hosting to customers on a pay-as-you use basis [12]. The digitized system submits information as a service in the cloud computing model. The users can access these available services without knowing the physical infrastructure and how resources are managed. So, IT developers and users can concentrate more on their business process rather than spending time and gaining knowledge on resources needed to manage their business pro-

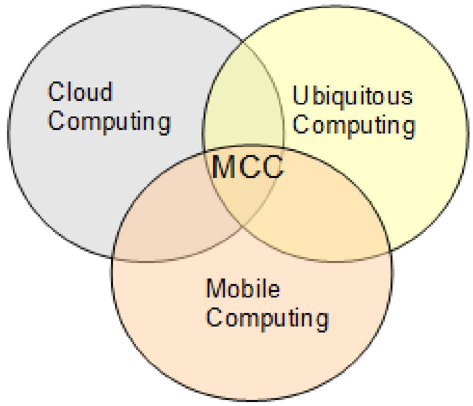

Fig. 1. Mobile Cloud Computing (MCC)

cesses.

This technology has a strong impact on the mobile platform. The cloud computing becoming the dominant way in which mobile applications operate. There is a wide range of people using feature phones in the world and there are web developers capable of building mobile web applications than there are developers for any other type of mobile device [6]. Those factors, combined with the fact that feature phones themselves are becoming more capable with smarter built-in web browsers, will have an impact on mobile cloud computing growth.

New cloud applications will improve features and functionality of mobile phones by allowing mobile users to store and access the large data on the cloud [8]. In addition, sharing resources can reduce costs significantly while increasing the speed of application development [13].

2.1 Cloud Computing Architecture

Cloud computing architecture consists of the following necessary components: a front end clients or cloud clients, this client may be thin or fat, a back end platforms such as servers and storage, and a network such as Internet that can connect the two ends. The client platforms interact with the cloud data storage via an application, a web browser, or through a virtual session [14] to get any type of services provided by the clouds. The three type of services that could be provided are [15]:

1. Infrastructure as a service (IaaS): service providers endure all the cost of servers, networking equipment, storage, and back-ups. The customer needs to pay only for the computing services.

2. Platform as a service (PaaS): service provider only provide platform or a stack of solutions for users. It helps users saving investment on hardware and software.

3. Software as a service (SaaS): service providers will give users the service of using their software.

Mobile cloud is most often viewed as an SaaS cloud, which means that the computation and data handling are performed in the cloud since the mobile devices have limited resources such as less compute power, less memory, and less energy than computers.

3 Mobile Computing and Ubiquitous Computing

Ubiquitous computing environment can be defined as the environment in which all users have access to a variety of digital devices and services, including computers connected to the Internet and mobile computing devices, whenever and wherever they need them. The ubiquitous computing also called pervasive computing [16] which implies also the ability to access information from any location, also, the information could be presented directly to users when the system detect the presence of them each according to his context [17]. The user context consist of some attributes such as physical location, physiological state, emotional state, personal history, daily behavioral patterns, and so on [16].

This technology is changing the daily activities in a variety of ways[11]. The users tend to communicate in different ways, be more active in that they can communicate with any other person and use any service at any time and anywhere, also the users conceive and use geographical and temporal spaces differently, and they have more control in their environment. The ubiquitous computing can be global and local, public and private, social and personal, invisible and visible, and it is an aspect of both knowledge creation and information dissemination [18].

Mobile devices in this environment are small and the other devices may be invisible. For this reason, this technology presents challenges across computer science: battery charge decreases over time, the display space is very limited, the CPU cycle and the memory size are restricted. The traditional ways used in desktop will be inappropriate to be used for this kind of devices. For example, the human-computer interaction models, whether command-line, menu-driven, or GUI-based, are inappropriate and inadequate to the ubiquitous case [19]. Also the range, cost and maintaining the connection is important. With and increased number of nodes, there will be a higher pressure on the network, causing negative effects on its bandwidth.

The ubiquitous computing and communications require as prerequisite, meaningful connection at any time from virtually anywhere to virtually anywhere, but end-user hardware technology limits the capabilities offered by ubiquitous computing. So the cloud computing and storage offer a way around the limitations faced in any real world hardware that would be used to ubiquitously connect [20, 21]. In addition, the cloud is scale well when the number of users increased.

4 Mobile Cloud Computing

Mobile cloud computing can be defined as a model for increasing the capabilities and benefits of mobile devices through the ubiquitous wireless access to cloud storage and computing resources and the mobile devices is considered as entry point and interface of cloud services.

Mobile cloud computing aims at using cloud computing techniques for storage and processing of data on mobile devices to reduce their limitations [22]. The end mobile user is the benefactor of the mobile cloud computing. He can share information and applications without the need of complex and costly hardware and software [8], [14]. In mobile cloud computing technology, no software is installed on the client machine, and the users often access the cloud through web browsers or thin clients. Therefore, the cloud computing applications can be reached by all mobile users not only smart phone users, as long as the mobile has access to the internet [23].

This access needs a continuous connection to the Inetrnet, but when the connection is intermittent the quality of service becomes unbearable, thus, new technologies and processes are needed to provide acceptable quality of service and user acceptance. HTML5 is the technology that support mobile cloud computing [24], it enable the on-device caching property which means the possibility to store data off-line on the device for further processing, reducing the problem of interruptions in mobile connectivity and discontinuous user experience.

Mobile cloud computing also enhance the reliability; storing data or running applications on clouds is an effective way to improve the reliability since the data and application are stored and backed up on a number of computers. This reduces the chance of data and application lost on the mobile devices [8].

4.1 Mobile Cloud Computing Architecture

The general architecture of MCC can be simply described as, mobile devices are connected to the mobile networks via base stations (like satellite) or wi-fi that establish and control the connections and functional interfaces between the networks and mobile devices [14]. Mobile users requests and information are transmitted to the central processors that are connected to servers providing mobile network services as shown in figure 2. After that, the subscribers requests are delivered to a cloud through the Internet. In the cloud, cloud controllers process the requests to provide mobile users with the corresponding cloud services. These services are developed with the concepts of utility computing, virtualization, and service-oriented architecture (e.g., web, application, and database servers).

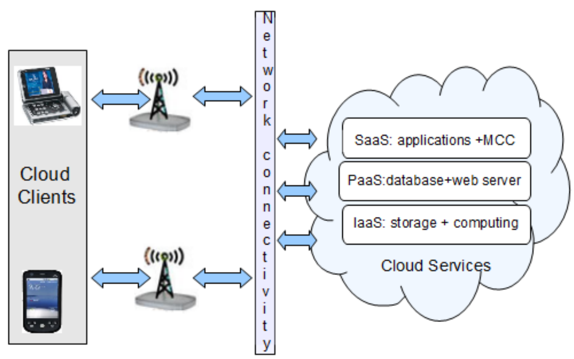

Fig. 2. Mobile Cloud Computing Architecture

4.2 Mobile Cloud Computing Models

Several models have been proposed to use the cloud infrastructure for executing of the mobile applications. The first one has proposed an execution offloading to nearby surrogates (agents), the model is called cyber foraging. The second model, adaptive offloading, propose to partition the application dynamically and offloading part of these partitions with data to a nearby agent. These agents are not trusted, for this reason the third model, VM-based cloudlets, uses trusted cloudlets. Cloudlets are a set resource-rich computer or cluster of computers that is well connected to the Internet and is available for use by nearby mobile devices. Finally, the last flexible model is called elastic model, the application in this model consists of weblets, each of which can be launched on a device or cloud, and can be migrated between them according to dynamic changes of the computing environment or user preferences on the device. The organization of weblets based on their different behaviors such as computation demand, data dependency, and communication need. The weblets location must be transparent to users and the behaviour of weblets should not be affected by the location or environment where it is running. In the following sections, we explore the four models.

4.2.1 Cyber Foraging

The limited resources problem could be solved by increasing the computing resources dynamically from utilizing the nearby compute and data staging servers [25]. The proposed model could be summarized as follow: when a mobile computer enters a neighborhood, it starts searching for a potential agent in the proximity to looking in their use. In order to detect the presence of agents in the surrounding neighborhood, a versatile surrogate discovery service is used. When a suitable agent is found, the mobile computer passes the computation that has to be performed to the agent, then in order to perform this computation this agent will collect data on its local disk from the internet. Alternatively, according to the expectations for the arrival of users in the neighborhood the agents may have staged data since the beginning. The main goal of data staging process is to decrease the latency in distributed file systems of servicing cache misses. So the agent may behave in two ways: perform computations on behalf of the mobile computer or simply by avoiding Internet delays, service its cache misses with low Latency. Staging servers running on the agent in the proximity can service the cache misses from the mobile client. Finally, when the mobile computer finishes its computation, their agents are broken, and any data staged on its behalf are discarded.

The Challenges in this model that need to solved are:

- urrogates are untrusted and unmanaged, so there is a need to encrypt and decrypt files.
- The data on the staging server is not kept consistent with updates made on the real server.

4.2.2 Adaptive offloading

This model proposes dynamically partitioning the application and offloading part of its execution with data to an agent in the proximity [26]. Also, this model developed an offloading inference engine that is used during the runtime of the offloading process in order to take two important decisions by acquiring execution information from the offloading platforms execution and resource information from the resource monitors. The two important decisions are:

- The suitable time for offloading: so there is a need to specify the modification required to the pervasive computing environment, and settlement of the offloading system.
- Specify the most effective application partitioning that should be selected in an efficient way from the available candidate partitioning plans. This partition that was chosen should be able to simultaneously satisfy multiple user requirements for offloading, such as minimizing average delay, minimizing bandwidth requirement, and minimizing total execution time.

When the application memory requirement approximately reaches the maximum memory capacity of the mobile device, the offloading process is triggered and the new levels of resource utilization are selected, then the effective application partitioning is chosen from many possible partition plans generated by the partition module of the offloading platform. A composite partitioning cost metric has been used in the offloading inference engine in order to choose the best partition plan. The set of candidate partition plans are generated by using a simple heuristic algorithm derived from the MINCUT algorithm as shown in figure 3.

Then the selected application partition plan specify the program objects that should be offloaded to the agent and those that should be withdrew back during the new offloading action to the mobile

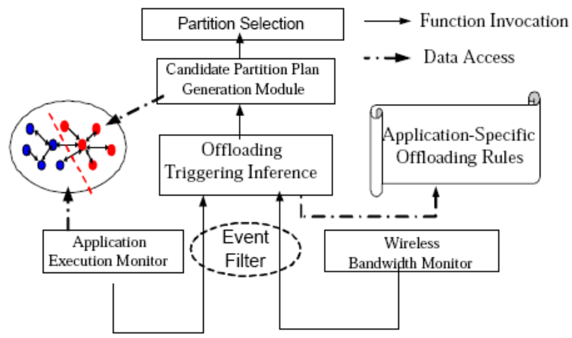

Fig. 3. Adaptive offloading Model [26]

device. The offloading inference engine use, as the basis for the offloading triggering inference module, the Fuzzy Control model. By using application-specific offloading rules this module can be easily configured.

4.2.3 VM-based cloudlets

In the previous model, the processes of partitioning the application dynamically and offloading part of the application execution with data to a nearby surrogates face the problem that the surrogates are untrusted. But in this model, a cloudlet where to offload the execution is a trusted, cloudlets is a resource-rich computer or cluster of computers that is well connected to the Internet and is available for use by nearby mobile devices. So the resource poverty of a mobile device can be addressed by using a nearby resource-rich cloudlet [27]. The cloudlets can solve the resource poverty problem of a mobile device, since the cloudlets is available for use by nearby mobile devices.

The mobile device can execute a resource-intensive application on a far away high performance compute server, and offer to the user interactions with the application via the Internet. But the main problem here is that long WAN latencies. The WAN delays in the path of user interaction have a negative effect on the usability by degrading the crispness of system response.

In this architecture, a mobile user exploits virtual machine (VM) technology to rapidly instantiate customized service software on a nearby cloudlet, in order to use that service over a wireless LAN. Physical proximity of the cloudlet is essential. If no cloudlet is available nearby, the mobile device can gracefully degrade to a fall back mode that involves a distant cloud or, in the worst case, solely its own resources. There are two approaches to delivering VM state to infrastructure.

One of the important points is the physical proximity of the cloudlet. If there is no cloudlet available nearby, the mobile device can use a distant cloud. In the worst case, the mobile device can use only its own resources.

There are two ways to introduce VM state to infrastructure. One of them is the dynamic VM synthesis, in which a mobile device submits a small VM overlay to cloudlet infrastructure that already owns the base VM from which this overlay was derived. Then, in order to derive the launch VM, the infrastructure applies the overlay to the base. After that the launch VM starts execution in the proper state from which the overlay was derived as shown in the figure 4.

The advantages of this architecture are:

1. Crisp interactive response, which is essential for seamless augmentation of human cognition,

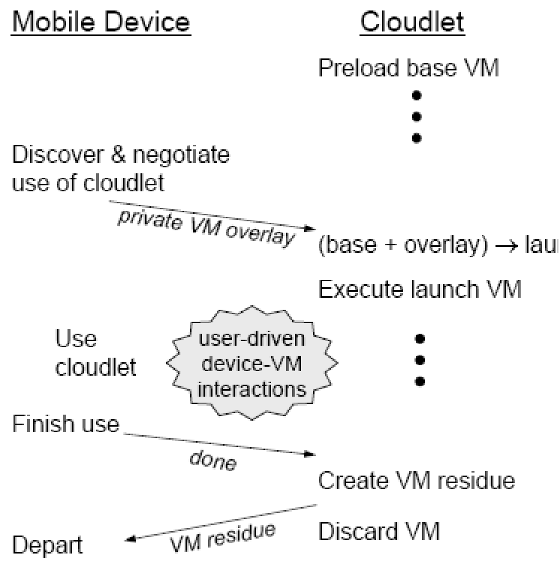

Fig. 4. Dynamic VM synthesis Model [27]

is easily achieved in this architecture because of the physical proximity and one-hop network latency of the cloudlet.

2. Using a cloudlet also simplifies meeting the peak bandwidth demand of multiple users interactively generating and receiving media such as HD video and high-resolution images.

The most important difference between cloudlets and clouds is that a cloudlet only contains soft state such as cache copies of data or code that is available elsewhere. So, loss or destruction of a cloudlet is not catastrophic.

4.2.4 Elastic Application Model

An elastic application consists of one or more weblets [28], each of which can be launched on a device or cloud, and can be migrated between them according to dynamic changes of the computing environment or user preferences. The elasticity manager decide according to the dynamic changes of the computing environment and the user preferences, that certain running weblets should be migrate from the device to the cloud or vice versa.

As first steps, this model proposes a solution for authentication and secure session management between weblets on running device side and those on the cloud, then proposes secure migration and how to authorize cloud weblets to access sensitive user data such via external web services, these ideas not raises in other proposed architectures. If one weblet should be launched on the cloud, the elasticity manager talks to an elasticity service residing on the cloud, which arranges the execution resources of the weblet, e.g., on which cloud node it should be launched, and how much storage should be allocated. The service also returns some information after successfully launching the weblet, such as its endpoint URL.

The Architecture for Elastic Framework typical elastic application includes a user interface UI component and one or more weblets as shown in the figure 5. On the device side, the main component that is responsible for configuring applications at launch time and making configuration changes during run time is called device elasticity manager (DEM). The elasticity manager maintains a cost model which accounts for such factors as power costs and the monetary costs resulting from network and cloud usage. The main function of the router is to pass requests from UI components to weblets.

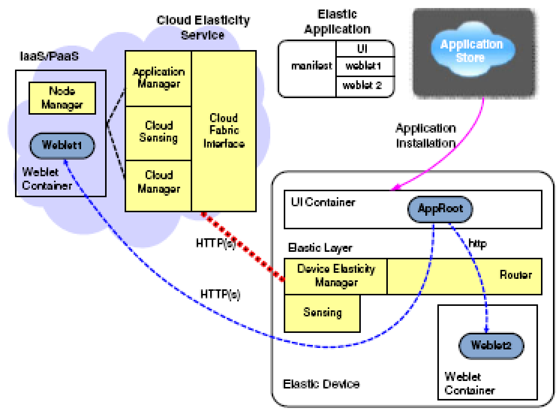

Fig. 5. The Architecture for Elastic Model [28]

Even when a weblet is migrated, the router will be aware of the new location and will continue passing requests from the UI to the weblet and passing replies back to the UI. Each device also provides sensing data on the device such as processor utilization or battery state. This data is made available to the elasticity manager and is used by the cost model. The cloud elasticity service (CES) consists of cloud manager, application manager, and sensing information collection that refers to the collection of operational data on the cloud platform. The cloud manager oversees resources on the cloud that are used for elastic applications. The application manager provides functions to install and maintain applications on behalf of elastic devices, and helps to launch weblets in different cloud nodes. The resources associated with a particular node (server) within the cloud is administrated by a node manager on each node. It communicates directly with the cloud manager and application manager. Each node runs one or more weblet containers which are the weblet runtime environments hosted on the cloud platform.

Security and privacy are important factors when considering some sensitive weblets and data migrating from device to cloud [29]. For a secure elastic runtime environment the challenges are:

1. Since some weblets are in the cloud and some are on device, authentication between weblets should be provided, this authentication implies a secure communication channel between them.

2. Authorization is needed to give the weblet access privileges to sensitive user data , but only the minimum needed since the weblet may be running on a public and relatively untrusted environment in cloud.

3. How to build and verify a trusted runtime environment of a cloud node used for weblet execution.

4.3 Potential Problems

Although the mobile cloud computing offers cloud solutions to individuals and employees by enabling them to access services from anywhere, there are still several challenges. The shortage of speedy mobile Internet access everywhere is the most memorable problem. For mobile cloud computing to reach its full functionality, the following critical challenges need to be addressed [23]:

1. Resource inadequate: one of the issues of mobile cloud computing is the resource inadequate of mobile devices and this is a major obstacle for many applications. When the mobile devices compared to computers, they have less compute power, less memory, less energy since they are powered by battery, and less screen real estate.

2. Lowering network latency to meet application and code offload interactivity

3. Increasing network bandwidth for faster data transfer between the cloud and devices

4. Providing adaptive monitoring of network conditions to optimize network and device costs against the users perceived performance of cloud applications.

5. Security: the mobile devices will always be less secure, with unstable connectivity. This issue increases with mobile devices, since they are easy to lose. And these mobile devices may contain important data downloaded from the cloud.

There are several steps in order to improve the mobile cloud computing:

1. Reduction of latency limitations: the distance, and the number of network nodes that the data needs to pass increase the latency [30]. So in order to decrease the latency effects moving applications as close as possible to the user [23]. Another way to decrease the latency and to save the bandwidth is to dynamically moving the data towards the mobile user.

2. Increasing bandwidth: limitation of wireless bandwidth capacity and swing in network service delivery is one of the problems in mobile cloud computing. Mobile technology assumes a shared bandwidth capacity [31], so that users within any particular mobile cell share the available bandwidth while accessing the data network, e.g. the Internet. Wireless networks are continuously being upgraded in order to overcome this limitation, and to address the increasing bandwidth demand [32]. usually improve the latency cause a negative affect on the bandwidth especially when many mobile devices are present.

3. Monitor the network dynamically: in mobile cloud, network performance management is important [31]. The good mobile network monitoring systems enable forward traffic dynamically and swapping, between cells depend on traffic load patterns and user location [33]. This help in improving the experience of mobile cloud user and make it more applicable for corporations that are interested in providing mobile access to many of their main applications.

5 Conclusion

In this paper, we have covered several novel technologies that use mobile devices to access different services from any where and any time. The definitions, the advantages and the architecture of each technology is explored. The mobile cloud computing technology was taken, recently, more consideration a caused to its importance.

Because mobile devices in continuous and quick development, they are taken a care from IT developers. Mobile cloud computing will be the dominate technology and the trend now is to develop new applications and to remodify the old applications to be mobile cloudy. We tried to prove that this technology will conquer the challenges and the problems of preceding technologies.

Mobile cloud computing models are presented. These models try to alleviate the problems concerning the limited resources in mobile devices. Despite the enormous development of mobile devices and the support of mobile cloud computing to mobile devices, they still take a lot of attention of researcher because a number of challenges encounter this technology. We are interested to work in this domain and, for future research, we will concentrate on its challenges and explore it deeply.

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