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## Software defined cloud: Survey, system and evaluation



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### HIGHLIGHTS

- A comprehensive survey for Software Defined Systems.
- Proposing a novel framework for Software Defined Cloud.
- Integrating different Software Defined Systems components in one platform.
- Validate applicability of the proposed model using simulation.

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### ABSTRACT

Next generation cloud systems will require a paradigm shift in how they are constructed and managed. Conventional control and management platforms are facing considerable challenges regarding flexibility, dependability and security that next generation systems must handle. The cloud computing technology has already contributed in alleviating a number of the problems associated with resource allocation, utilization and management. However, many of the elements of a well-designed cloud environment remain “stiff” and hard to modify and adapt in an integrated fashion. This includes the underlying networking topologies, many aspects of the user control over IaaS, PaaS or SaaS layers, construction of XaaS services, provenance and meta-data collection, to mention but few. In many situations the problem may be due to inadequacy of service abstraction. Software Defined Systems (SDSys) is a concept that help abstract the actual hardware at different layers with software components; one classical example of this abstractions are hypervisors. Such abstraction provides an opportunity for system administrators to construct and manage their systems, more easily, through flexible software layers. SDSys is an umbrella for different software defined subsystems including Software Defined Networking (SDN), Software Defined Storage (SDStorage), Software Defined Servers (Virtualization), Software Defined Data Centers (SDDC), Software Defined Security (SDSec) etc. and ultimately Software Defined Clouds (SDCloud). Individual solutions and seamless integration of these different abstractions remains in many respects a challenge. In this paper, the authors introduce Software Defined Cloud (SDCloud), a novel software defined cloud management framework that integrates different software defined cloud components to handle complexities associated with cloud computing systems. The first part of paper presents, for the first time, an extensive state of the art critical review of different components of software defined systems, constructing the proposed SDCloud. The second part of the paper proposes the novel concept of SDCloud, which is implemented and evaluated for its feasibility, flexibility and potential superiority.

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## 1. Introduction

With the rapid shift to the cloud computing paradigm, one of the most critical issues faced by system administrators is the construction and management of systems in a manner that eliminates or hides their complexity from the end users, and, at the same

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time, maintain their control, flexibility, dependability, and security. To achieve these goals, Software Defined Systems (SDSys) has emerged recently to address these control and management challenges that exist in traditional platforms. The cost of management and administration operations are very high compared to other system operations in today's computing systems [1]. Thus, adopting the SDSys paradigm to cut the management and administration cost has become very appealing.

The cloud computing technology has already contributed in alleviating a number of the problems associated with resource allocation, utilization and management. However, many of the elements of a well-designed cloud environment remain “stiff” and hard to modify and adapt in an integrated fashion. This includes the underlying networking topologies, many aspects of the user control over IaaS, PaaS or SaaS layers, construction of XaaS services, provenance and meta-data collection, to mention but few. SDSys comes to supplement the cloud computing technologies by addressing the way to efficiently relax this stiffness and integrate the elements that are still hard to modify or adapt in cloud computing. SDSys is a concept that help abstract the actual hardware at different layers with software components. Such abstraction provides system administrators with the ability to construct and handle all control and management decisions by a central decision maker, through flexible software layers. For example, one of the most important features of cloud computing is providing “on-demand” services; however, this is challenging to achieve in a decentralized control unit, where every component manages itself and has no information about other components. The request for adding a new decision or make some enhancements on the system requires knowing information about the other components of the system. Such information will have to be collected and analyzed in a single unit. Consequently, there will be some delay in response, which contrasts with the need for timely on-demand response. The problem of combining the achievement of multiple objectives with fast responses required by on-demand services in a single system is what SDSys is set to achieve [2,3].

SDSys is an umbrella for different software defined subsystems including Software Defined Network (SDN), Software Defined Security (SDSec), Software Defined Storage (SDStorage), Software Defined Data Center (SDDC) [4], Software Defined Infrastructure (SDI), Software Defined Management (SDM), Software Defined Compute (SDCompute), Software Defined Server (SDSer), Software Defined Internet of Things (SDIoT) [5], Software Defined Radio (SDR), and Software Defined Enterprise (SDEn). The software layer can control different types of hardware devices in various contexts giving rise to the term Software Defined everything or anything (SDx).<sup>1</sup> Many advantages can be driven from SDSys such as increasing the performance, scalability, and security of the system to facilitate resource management.

SDSys provide the ability to control a wide range of computing resources in a work-flow driven and dynamic fashion by separating the control layer from the data work flow layer, i.e., isolating the control from hardware devices and setting it in a software layer. The main idea behind the SDSys is to build an orchestrated system, controller, to handle the control for all independent devices by using standard and general protocols.<sup>2</sup> This is achieved by means of virtualization. As virtualization is considered to be a key concept of the cloud computing technology, it also plays an essential role in SDSys. Virtualization creates a virtual platform for different devices or system components (like network, OS and storage devices) that emulates the characteristics of the real devices.

The transformation from hardware control to software centric control is, therefore, achieved through virtualization, in which the functionalities of a single or multiple systems can be abstracted allowing the integration of the benefits of these systems into a multiple purpose function. As an illustration, consider the Software Defined Data Center (SDDC) example, which integrates a set of servers, storage devices, and networks into a single comprehensive system or resource pools.<sup>3</sup>

There are many reasons why the world is focusing so much on virtualization. The most important ones are as follows.

1. Resource sharing: If we have idle resources that exceed our need then we can increase the resource utilization by splitting them among several virtual machines. The resources can be anything like storage, disks or even links.
2. User isolation: In certain situations, there is a need to keep a level of confidentiality between the users. Using virtualization, each user may have its own VM, which is separate from other users' VMs.
3. Resources aggregation: If there is a need to perform a task that requires resources beyond what we have, then we can use the virtualization to build suitable and useful virtual resources large enough to complete the task.
4. Dynamic management and control: The users requirements are changing frequently which makes the response for these changes in virtualization easier than when dealing directly with physical resources.
5. Simplify the management: Manage devices through a software layer is easier than manage them in a physical layer.

It is the software defined concept and other related concepts such as “software deployed”. In the former, the APIs and software are used to control and manage resources and devices. On the other hand, the software deployed concept means that the functionality of the service is deployed in a computer hardware object. Using the software to manage and control the resources is not a new concept. The essential difference, which was brought by the software defined concept is the ability of the control layer to control all the underlying resources regardless of their vendor variations by physically isolating them from the hardware resources in the data layer [6]. The concept of abstraction in SDSys is similar to the idea of Object Oriented (OO), where the implementation is separated from the interface representing the data layer and the control layer respectively in SDSys. The reason behind this separation is to simplify the modification process, since any change in the implementation will not affect the interface and vice versa [6].

To recall, implementing SDSys solutions for cloud computing is currently very fragmented and is still a growing research and development project, despite its proven advantages and wider acceptance amongst specialists from academia and industry. The aim to achieve a fully integrated SDSys cloud computing, combining all aspects of software defined systems, is still far from being realized. This ultimate system, is referred to as Software Defined Cloud (SDCloud); a concept which was first introduced in the Harmony system [3]. Harmony proposed to integrate and manage the main components of any computing system such as the computing resources, storage resources and networks into one platform that represents the SDCloud concept. To the best of the authors' knowledge, the main attempt in literature to address a practical implementation of SDCloud is reported in [2] who presented an architecture for Software Defined Clouds for data centers. They consider different cloud applications and services, focusing on mobile cloud applications. However, the

<sup>1</sup> <http://www.memorableurl.com/2013/12/software-defined-anything.html>.

<sup>2</sup> <http://www.meetup.com/MESS-LA/events/14743842/>.

<sup>3</sup> <http://www.tvtechnology.com/from-the-editors/0145/software-defined-systems-virtualization/216662>.

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