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Dependability in Federated Cloud Environments

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Abstract — Cloud Computing has emerged as a large-scale distributed system model for utility computing, whereby services are supplied on-demand [1][2]. It has been proposed that Clouds are in the process of evolving from single, monolithic Clouds such as EC2 [18] or Microsoft Azure [21] serving many consumers to a federation of autonomous Clouds [3][8]. However, there remain a number of research challenges in building dependable and robust Clouds; a critical research problem that has not yet to be fully understood[5][27]. This paper discusses the issues and challenges surrounding Cloud dependability, and outlines research areas of opportunity for improving the dependability and robustness of federated Clouds.

***Index Terms*— Cloud computing, Cloud federation, dependability, reliability**

I. INTRODUCTION

Cloud computing is a computing paradigm that facilitates large scale, flexible computing infrastructure on demand, allowing the Cloud infrastructure to scale-up and scale-down in accordance to user requirements and to satisfy QoS agreements. It has been proposed that Clouds are in the process of evolving from single, monolithic Clouds to that of a federation of Clouds.[3][8]

The evolution of existing Cloud systems and markets to a federation of interoperable Clouds offers a number of advantages compared to that of single Clouds, including extended scalability, interoperability of Cloud systems, improved QoS, improved economies of scale and removal of Cloud isolation [4][15][16]. The continued increase of enterprises wishing to take advantage of Cloud computing can be seen as a natural progression for the integration of private and public Clouds [13]. It has also been forecasted that as Cloud systems mature, more sophisticated services shall emerge that will require multiple Clouds to function [14].

There are limited papers specifically investigating the dependability, and more specifically the reliability of federated Cloud systems. This paper will investigate and explore current Cloud and federated Cloud reliability issues and future areas of opportunity in the research area which will enable the creation of a suitable system model to improve the reliability of Cloud federation.

II. PROBLEM STATEMENT

The provisioning of reliable Cloud applications and services on a single Cloud remains a critical research problem [5]. Cloud applications are composed of various components, which can be situated in different geographical locations and are typically large scale and complex, requiring improved automation and scalability [1][7][8][15]. Moreover, building reliable and robust Clouds has not yet been clearly understood [5][27].

A *Cloud federation* is defined as two or more independent cloud providers that are able to share resources and are ‘able to scale applications across multiple domains to meet QoS targets of Cloud customers [6] [15]. A *dynamic federation* is when a federation is not static, with *a priori* policy agreements, with entities joining and leaving the federation autonomously[16]. The majority of the problems mentioned above are further amplified with the introduction of a Cloud federation, with each individual Cloud potentially varying in deployment model, administration domain, dependability specification and varying QoS requirements dynamically joining one or more Cloud federations. Despite this, the provisioning of not only complex services, but also reliable services *"across a federated network of possibly disparate data centres is a difficult and unsolved problem"* [6].

III. RELATED WORK

There has been initial work in addressing Cloud federation dependability with the majority of the work focusing on federation models and VM migration. [12] focuses on the interoperability of Clouds. [4] addresses interoperability, resource allocation and identifying the key attributes of the federation as availability and security. [13] focuses mainly on interoperability of hybrid Cloud environments, but does not discuss dynamic federation. [15] focuses on performance evaluation and resource management in federated environments and [16] addresses federated Clouds architecture, including varying Cloud deployment models, but focuses on security and trust mechanisms. Despite this, there are limited papers specifically investigating the reliability of federated Cloud systems.

Research into single Cloud application reliability is equally as limited. There has been some

preliminary work in addressing reliability of Cloud systems; for example, FTCloud [5] is a component ranking framework for selecting the optimal fault tolerance scheme to apply to a Cloud application. Other reliability work includes a fault tolerant matrix multiplication implementation using the Cloud [19] and a high level modelling and analysis of Cloud system reliability [20]. A large majority of the Cloud reliability work to date has been focused solely on the reliability of a single Cloud and does not consider federated Cloud applications. FTCloud, a single Cloud fault tolerant ranking framework, only applies its model to addressing Crash and Value faults, but not Byzantine faults. A recent workshop discussed that the use of Byzantine fault tolerance on a single Cloud to achieve consensus could potentially couple the behaviour of multiple nodes, threatening the dependability of the entire Cloud system as a result of failure propagation, termed 'fear of synchronisation' [9]. There are also emerging position and exploration papers about the applicability of Byzantine fault tolerance in a Cloud federation, arguing that the nature of Cloud federation introduces a unprecedented level of independence at little cost to that of the Cloud consumer[26][27][28]. To mirror the problem with achieving some form of consistency, Clouds are built using a large amount of redundant components [5], meaning that achieving consistency on a large system like a Cloud can be time consuming and resource intensive.

IV. AREAS OF OPPORTUNITY

Based upon the existing work and problems outlined in sections II and III, we have identified the following areas that require additional research:

Reliability mechanism applicability - Investigation into whether current reliability tools scale sufficiently to massively scalable federated Clouds, and if current fault tolerant techniques are applicable to the characteristics and technologies of the Cloud.

Grid and Cloud federations - There are similarities to how Grid federations and Cloud federations operate, Clouds heavily rely on the use of virtualisation compared to that of grid. Clouds are also seen as being much massively scalable, configurable and elastic compared to that of Grids [14]. An interesting opportunity area would be to see if these characteristics in Cloud would drastically alter the reliability mechanisms of federated Clouds to that of current reliability practises found in federated Grids.

Reliability architecture retrofitting - It has been argued that current distributed system architectures cannot be retrofitted to achieve sufficient availability and security of Cloud systems [4]. An area of opportunity could be to investigate if this is also true for reliability.

Consensus problem - Problems with large scale consensus in Cloud systems; 'fear of synchronisation' is a phenomenon that is another interesting opportunity area to research into. Potential research could include the exploration of loosely coupled self-diagnosis and self-healing mechanisms such as recovery-oriented computing [10] and consequence-oriented computing [11]. It also invites debate about the merits of consistency vs. decoupling Cloud systems.

Large amount of redundant components - Loosely coupled self synchronising components that attempt to achieve delayed consistency [17] and eventual consistency [25] could be of use and relevance to Cloud systems.

Current federation dependability - Looking into present virtual organisation dependability implementations found in other distributed systems, and how they can apply to Cloud federations.

V. PROPOSED APPROACH

The approach of this research at current time is to define the research problem and scope in more detail, derived from the identified areas of opportunity outlined in section IV. From this, a system model similar to that shown in *figure 1* will extend current federation models, whose present objective is to increase the interoperability between Cloud systems. The system model will assist with the understanding of the proposed system scheme, in relation to the more defined problem area, allowing to abstract the system to a necessary level and define the system in terms of correct behaviour [22][23]. This model, combined with the chosen research scope, will then be extended to research the complex relationship between federated Cloud components to form reliable, and by extension fault tolerant and consistent Cloud applications in a Cloud federation of varying deployment models. From the creation of a system model, a fault model can be made to perform a proper analysis of the identified problem.

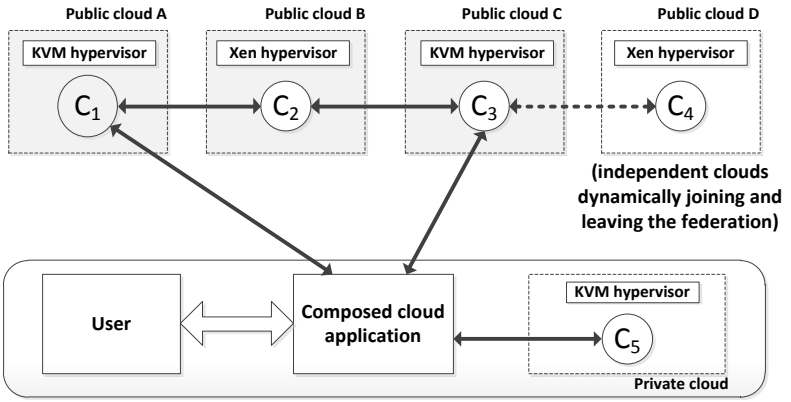

Fig 1: A high level abstract of the proposed Federated Cloud system model

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