

# Performance and mobility in the mobile cloud

Jakub Krzywda  
Dept. of Computing Science  
Umeå University  
SE-901 87 Umeå, Sweden  
Email: jakub@cs.umu.se

William Tärneberg  
Dept. of Electrical and Information Technology  
Lund University  
Ole Römers väg 3, 223 63 Lund, Sweden  
Email: william.tarneberg@eit.lth.se

**Abstract**—In an mobile cloud topology the cloud resources are geographically dispersed throughout the mobile network. Services are actively located with close proximity to the user equipment. Geographically migrating a service from data centre to data centre with its user equipment imposes a load on the affected data centres. Consequently, user equipment mobility provides a fundamental problem to the mobile cloud paradigm.

This paper determines the fundamental service performance issues in system of mobile users with dispersed data centres, in relation to the placement of the mobile cloud host nodes and explores the user equipment and provider utility of subscribing to an mobile cloud node at a certain network depth.

**Keywords**—Cloud, Mobility, Mobile infrastructure, User experience consistency, Omnipresent Cloud, Infinite cloud, Edge cloud, Latency, Throughput, Virtualization, Geo-distributed resources, VM migration

## I. INTRODUCTION

Mobile services and user equipment functions are at an increasing rate being virtualized and augmented to the cloud. Applications are soon more often than not seamlessly executed, partially or fully in the cloud. Alongside applications, fundamental user equipment resources, such as storage and CPU, are being virtualized to the cloud. In this paradigm, the border between what is being executed locally and remotely is blurred as developers are given more powerful tools to tap into remote ubiquitous generic virtual resources. This resource paradigm, has overwhelmingly augmented the capabilities of mobile applications, simplifying hardware, and enabled collaborative computing. In the years to come, just short of all devices will contribute data to the cloud and/or utilize its resources.

As we begin to rely more on remote resources we also grow more dependant on the communication delay introduced by the intermediate WAN network and by the geographical separation of the user equipment and the data centre. Latency sensitive applications such as process controls, storage, and compute offloading will quickly falter if subject to a significant and varying communication delay.

The virtual resources are accessed through increasingly congested mobile access networks. More devices are crowding the mobile networks and applications generating and receiving more data, this congestion translates into delay. Additionally, the geographic distance to the data centre introduces a propagation delay, bounded by the speed of light.

The mobile cloud paradigm, put forward by [2], [8], attempts to remedy the aforementioned congestion and latency by locat-

ing cloud resources at the edge of and adjacent to the mobile access networks. In the ad-hoc scenario, resources are shared amongst user equipments as each user equipment surrenders its available resources generically to its peers. However, from a network perspective, at one extreme data centre resources can possibly be located in at the edge of the network, adjacent or integrated into an radio base station, catering for the user equipments residing within its cell. Alternatively, or complementarily, data centres can be integrated with resources in the proposed forthcoming virtualized radio access networks. The scale and the degree of dispersion can be optimized for each application, given the applications resource tiers and its users mobility behaviour.

The geographic proximity between the user equipment and the data centre is proportional to application service delay, to that effect, services hosted in the mobile cloud are migrated with the user equipment, through the network, to minimize this incurred latency. In practice, services, or rather the VMs that host the services will be migrated to the node that is available, provides the lowest delay, and incurs least global network congestion. However, by doing so might minimize the experience delay for the user equipment, but will incur a migration overhead in data centre and in the network a VM is migrated. Conceivably, various schemes and cost functions can be deployed to minimize both the delay experienced by the user and the added resource strain to the data centre and the network.

The topology paradigms of tomorrow's all-IP mobile networks (all-IP (Internet Protocol) [7], [10] are yet to be determined, but one can assume that they will be influenced by the notion of virtualized resources [5], [9]. Large portions of radio base stations can possibly be virtualized and centralized to a common local-geographic data centre, shared by several radio base stations, leaving the radio base stations, in principal, with just the radio interface [12]. The expanse of the centralization is geographically bounded by propagation delay and signal attenuation, and is resource hampered by the aggregate traffic that passes through the dedicated data centre. There is extensive research directed at exploring relevant economic and IT models [1], [7], [13].

The concept of geo-distributed cloud resources has been worked on for a few years, but with a clear focus on storage and sharded data. The authors of [4] present a method to geographically migrate shared data resources globally, not only to minimize the distance between the user equipment and the data centre, and thus service latency, but also to globally load-balance the hosting data centres. Their results reveal a

significant reduction in service latency, inter-data centre communication, and contributed WAN congestion. Their proposed control process runs over longer periods of time and operate on a global scale with geographically static users. Although sharing some fundamental dynamics, albeit at different scales, in contrast, in the mobile cloud paradigm, user equipment movement is much more rapid and proportional to the size of a session. Additionally, mobile cloud virtualized resources are assumed to be universal and do not just cover data, and vary in size and capabilities.

The field of mobile cloud bears much in common with geodistributed cloud resources but is dominated by the notions of augmenting user equipment through virtualizing their resources [3] and reducing service response times through geocascaded data caching [2], [15]. As a result, much of the research is concerned with coping with specific dynamics, and do thus not address the generic case of generic locally geo-distributed resources serving a local subscriber populous. There is large amount of work left to explore the fundamental dynamics of the mobile cloud in order to be able to begin to consider specific applications and use-cases.

User mobility is a key differentiator between traditional distant immobile clouds and the mobile cloud, and is a fundamental dynamic property of an mobile cloud. It is therefore essential to understand how user equipment mobility affects the perceived service performance and what load it imposes on the network in the generic case.

This paper contributes with models designed to examine the fundamental and generic resource problems in an mobile cloud of mobile user equipments. The models include a generic mobile network inhabited by user equipment subscribing to  $N_{service}$  services, served by  $N_{dc}$  locally geo-distributed data centres.

This paper provides an investigation into the fundamental effects of user equipment in the mobile cloud in relation to the number of subscribers, the abstract placement of the servers, and the number of services. An optimal or reasonable technical bounds for the mobile cloud topology is not yet to be determined. This paper disregards the deeper technical and topological constraints of existing mobile systems in order to provide fundamental results that can be employed to shape the forthcoming mobile network generations.

## II. DESIRED MODEL

As the topology of the mobile cloud and future mobile networks is yet to be determined, and due to the fact that we want to research the effects of mobility without a socio-economic model, the network

## III. SIMULATION MODEL

Our simulation model is built on a

### A. Service

The traffic generated by and the usage pattern of a simple web application is characteristic of any smaller mobile application. The HTTP traffic model in [11] provides a small scale closed loop traffic model that is representative of light mobile traffic.

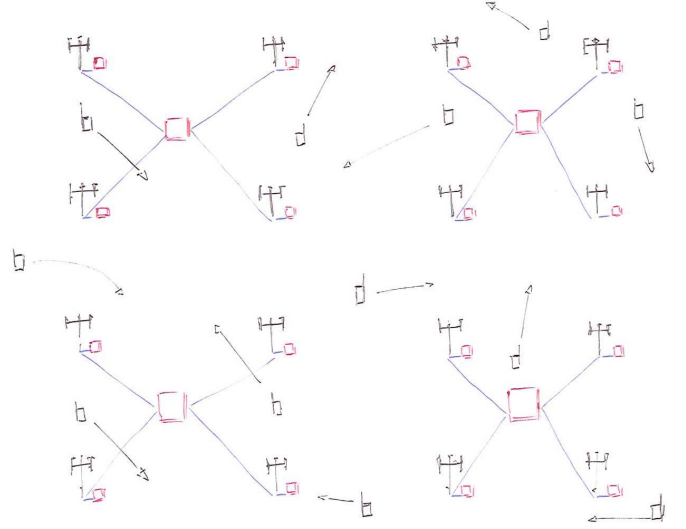


Fig. 1: Performance model

### B. Mobility

The 2 dimensional, multi model, mobility model [6] will provide the uniform mobile network with an relevant distribution of users.

### C. Core network

### D. Data center

To simplify the model of a data center we will not consider CPU, memory, storage and intra data center network separately. Instead, in this paper, we will use an abstraction of one dimensional computational resource.

Hosting VMs in a data center can be modeled in two ways: with or without competition for computational resource.

In the first approach, the resources of a data center are aggregated in one pool that is continuously divisible. The pool of resources is divided evenly among all VMs. Hence, when the number of VMs hosted in the data center increases, the amount of resources available for each VM shrinks. Consequently the service time of processing requests of each VM lengthens.

In the second approach, the resources of a data center are discrete and each computational unit is used exclusively by one VM. Therefore, there is no influence of one VM on another. To incorporate the fact that the amount of resources is finite we put a limit on the maximal number of VMs that can be hosted in one data center.

1) *Overhead of VM Migration:* The overhead of VM migration can be also modeled in different ways depending on the manner how data center resources are represented.

When using the approach where VMs are competing for computational resources, the overhead of VM migration can be modeled by running two instances of VM on both source and destination DC during the time of migration.

## 2) Possible service hosting schemes:

- One service model, one VM is employed to host that service for each user.
- One service model, each VM hosts multiple but each number of users, behaving as multiple services while still being compatible.

At all placement modes:

- Measure RTT for all packets at UE
- Measure DC load
- Measure ratio of requests generated vs. processed in mobile cloudnode
- Identify the incurred VM migration load

## IV. SIMULATION

Multiple runs for each DC/mobile cloudplacement mode.

**Service** The traffic generated by and the usage pattern of a simple web application is characteristic of any smaller mobile application. The HTTP traffic model in [11] provides a small scale closed loop traffic model that is representative of light mobile traffic.

**Mobility** The 2 dimensional, multi model, mobility model [6] will provide the uniform mobile network with an relevant distribution of users.

**Mobile Access Network** Williams SIMJava framework. Handover are instantaneous and move

**Core network** delay, no routing

**Server** The server provides VM and DC models that encompass, incurred VM migration performance degradation in DC and in VM, resulting in a different service time.

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## V. RESULTS

## VI. CONCLUSIONS

## VII. FUTURE RESEARCH

- Optimal service/VM migration/placement in relevant topology
- Performance in LTE network topology using LTE-SIM [14]

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