Performance and mobility in the mobile cloud

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Abstract—In an mobile cloudtopology the cloud resources are geographically dispersed throughout the mobile network. Services are actively located with close proximity to the user equipment. Georgraphically migrating a service from data centreto to data centrewith its user equipmentimposes a load on the affected data centres. Consequently, user equipmentmobility provides a fundamental problem to the mobile cloudparadigm.

This paper determines the fundamental service performance issues in system of mobile users with disperead data centres, in relation to the placement of the mobile cloudhost nodes and explores the user equipmentand provider utility of subscribing to an mobile cloudnode 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 equipmentfunctions are at an increasing rate beeing virtualized and augmented to the cloud. Applications are soon more ofthen than not seamliessly executed, partially or fully in the cloud. Alongside applications, fundemental user equipmentresources, such as storage and CPU, are being virtualized to the cloud. In this paradigm, the border between what is beeing 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 collaborateive computing. In the years to come, just short of all devices will contribute data to the cloud andor utilize its resources.

As we begin to rely more on remote resources we also grow more dependant on the communication delay introduced by the the intermediate WAN network and by the geographical separation of the user equipmentand the data centre. Latency sensitive applications such as process controlls, storage, and compute offloading will quickly faulter 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 cloudparadigm, put forward by [2], [8], attemps to remedy the aformentioned congestion and latency by locating cloud resources at the edged of and adjacent to the mobile access networks. In the ad-hoc scenario, resources are shared amongst user equipmentsas each user equipmentsurrenders its availbale resources generically to its peers. However, from a network perspective, at one extreme data centreresources can propsedly be located in at the edge of the network, adjacent or integrated into an radio base station, catering for the user equipmentsreciding within its cell. Alternatively, or complimenarty, data centrescan 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 geograpghic proximity between the user equipmentand the data centreis proportional to application service delay, to that effect, services hosted in the mobile cloudare 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 incurrs least global network congestion. However, by doing so might minimize the experiance delay for the user equipment, but will incurr a migration overhead in data centreand in the network a VM is migrated. Conceivably, various schemes and cost functions can be deployed to minimize both the delay experianced by the user and the added resource strain to th data centreand the network.

The topology paradigms of tomorrows all-ap 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 stationscan propsedly be virtualized and centrallized 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 attenudation, 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-disributed cloud resources has been worked on for a few years, but with a clear focus on storage and sharded data. The authors of [4] pressent a method to geographically migrate shared data resouces globaly, not only to minimize the distance between the user equipmentand the data centre, and thus service latency, but also to globaly load-balance the hosting data centres. Their results reveal a

significant reduction in service latency, inter-data centrecommunication, and contributed WAN congestion. Their proposed controll process runs over longer periods of time and operate on a global scale with georgraphically static users. Although sharing some fundamental dynamisc, ableit at different scales, in contrast, in the mobile cloudparadigm, user equipmentmovement is much more rapid and proportional to the size of a session. Additinaly, mobile cloudvirtualized resources are assumed to be universal and do not just cover data, and vary in size and capabilities.

The field of mobile cloudbears much in common with geo-disributed cloud resources but is dominated by the notions of augmenting user equipmentsthrough virtualizing their resources [3] and reducing service response times through geo-cascaded 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 resouces serving a local subscriber populous. There is large amount of work left to explore the fundamental dynamics of the mobile cloudin 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 equipmentmobility 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 cloudof mobile user equipments. The models include a generic mobile network inhabited by user equipmentssubscribing to $N_{service}$ services, served by N_{dc} locally geo-distributed data centres.

This paper provides an investigation into the fundamental effects of user user equipmentin the mobile cloudin relation to the number of subscribers, the abstract placement of the servers, and the numer of services. An optimal or reasonable technical bounds for the mobile cloudtopology is not yet to be determined. This paper disregards the deeper techincal and topological constrains of existing mobile systems in order to provide fundamental resulst that can be employed to shape the forthcoming mobile nework generations.

II. DESIRED MODEL

As the topology of any future mobile cloudand forthcoming proposed mobile networks is yet to be determined, in this paper we propose a generic telecom infrastucture model that disregards from specific generational properies such as the physical layer and cell load-balancing. Nevertheless, conceivably and in order to confine the geographic domain of the model it adheres to current LTE cell plannig pracices.

In order to explore the fundamental dynamics of the generic case, as such, the model does not adhere to any soci-demographic patterns or urban topologies. The mobile network base tstaions are therefore uniformly distributed across its 2-dimensional domain.

The concert of the mobility model and the service model in a uniformly distributed mobile network will provide the
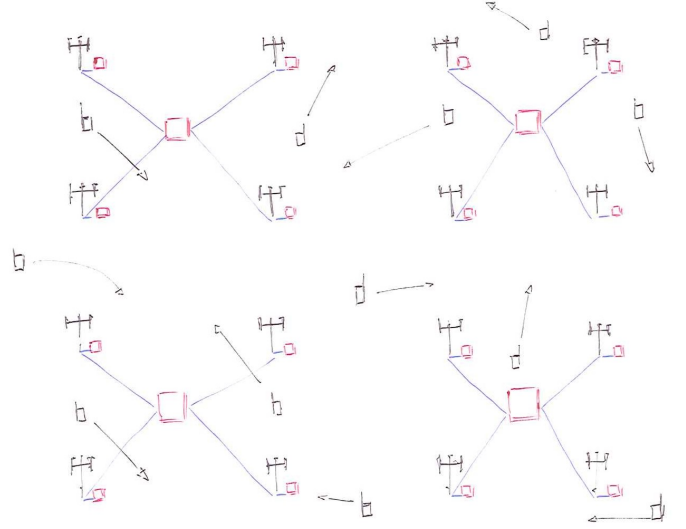

Fig. 1: Performance model

modeled data centreswith relevant request patterns. It is worth reiterating that the traffic load is more relevant to our investigation than specific topological and network properties.

The data centremodel will host multiple VM that will process the arriving requets corresponding to its service commitment. Additionally when a VM is migrated from

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.

B. Mobility

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

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 approch 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 empolyed 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 packetc 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 Provided by Williams SIMJava framework. Handover are instantanious and move

Core network No delay, no routeing

Server The server provides VM and DC models that encompass, inucrred VM migration performance degredation in DC and in VM, resulting in a different service time.
Possible service hosting schemes:
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At all placement modes:

- Measure RTT for all packetc at UE

- Measure DC load

- Measure ratio of requests generated vs. processed in mobile cloudnode

- Identify the incurred VM migration load

V. RESULTS

VI. CONCLUSIONS

VII. FUTURE RESEARCH

- Optimal service/VM migration/placement in relevant topology

- Performance in LTE newtork topology using LTE-SIM [14]

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