QoS-BASED ROUTE SELECTION IN HEALTHCARE CLOUD

A step towards autonomous control for Healthcare as a Service

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Abstract

Today's technology-based health services transforms all Healthcare system substantially - from the provision of services in the hospital to the care of patient in the home. This transformation is a result of rapidly growing health data of patients in all health system. The fast changing face of Healthcare system comes from the integration of cloud computing and the Internet of Services with the requirements for Healthcare. This integration brings the technologically advanced solution – Health Cloud – for the issues of health data processing and managing in health system. However, the requirements for provision and deployment of medical services across a Health Cloud bring new challenges of the selection of suitable cloud service provider during the transmission of medical data over Health Cloud. The reliable, cost effective communication and Quality of Service based routing path between multi-cloud providers is a critical issue for Healthcare entities across over Health Cloud and its deployment models. Due to this, the task of this paper was to investigate the selection of route for health data transmission over Health Cloud according to the requirements of Quality of Service. The authors' proposed analytical model for health data path request and a reply to this request with the results of investigations are presented in this paper. The impact of the proposed Quality of Service based routing path to Health Cloud networking and service's provision effectiveness is presented as well.

1. INTRODUCTION

The evolution of new, technology based, medical services promotes the progress in one of the most important systems of services for humans – Healthcare. The growing number of people increases the need for technology-based health services as a doctor's consultation at a distance or the training and self-management of patient's health at home. The reason behind this is the growing health data of patients in overall Healthcare system. The increasing traffic of a health data raises the many challenges of data processing in all the system. First of all, the health data must be stored and archived for more than several years. The exact time for storing of it depends on the medical regulations of the country. That means the health entities as hospitals or wellness centers must have a strong infrastructure setup, which will be able to manage all the growing health data for many years. And this may affect the rising of investments for health entities or even pricing of health services to patients. Next, the security aspects of health data: the backup of this data have to be made constantly, the specifications for data recovery, rules of access to this data for patients, health entities have to be planned in any case of life event [1]. Very important is the issue of the health data exchange between the Healthcare entities and its accessibility anytime, anywhere with any doctor's or patient's device for communication. Data exchange between the Healthcare entities would help to reduce a duplication of health data, patient's time of waiting for health procedures and strengthen the cooperation between the entities. However, this means a joint database for patient's health, the specific rules for such data exchange, sharing, and access to it. This is very challenging due to lack of fast and secure mechanism of data access, the issues for the interoperability between different infrastructure setup in the health entities. It also includes the sharing of health data across many different devices like smart phones, tablets, personal computers, as this will require very straight process of health data transmission over the all Healthcare system. Due to this, the cloud computing is a good solution for all of these challenges in the Healthcare system. This is an innovative technology, which can help in managing the increasing rate of digital health data. It also can play an important role in the accessibility and availability of Healthcare services in large, scalable on-demand computing infrastructures. The adoption of cloud computing can optimize costs and resources of

Healthcare services as well as achieve high performance and scalability for the Healthcare entities.

Although the cloud computing is a promising technology it brings new challenges raised from the integration of cloud computing and Internet of Services (IoS) [2] with the requirements for today's Healthcare system [3]. One of those challenges is the quality of performance of various Healthcare operations over the cloud based on Service Level Agreement (SLA) and Quality of Service (QoS) requirements. The number of medical services for performance of various Healthcare operations and service oriented architecture compose Health Cloud [4]. Health Cloud should cover the functions of IoS with the requirements for provision and deployment of dynamic medical services in a single cloud infrastructure provider as well as across different cloud infrastructure providers. Due to this, the Quality of service is a critical issue for Healthcare entities across cloud service and deployment models – private, community, hybrid or public clouds [3]. There are limitations to guarantee QoS between deployed cloud infrastructures that are spread across distributed sites or domains. On the other hand, the user requires a QoS assurance, a high reliability and availability for his medical services over Health Cloud. It is very difficult for a single cloud service provider to satisfy this. In addition, if a Health Cloud is distributed over different cloud service providers, it should be designed as inter-cloud system with the ability to displace the medical services from one cloud service provider to another, to find the best ways for location of best resources as computing capacity, storage, connectivity, bandwidth and delay [5]. Furthermore, the networking aspect of cloud computing plays an important role for this as there is many challenges on how to choose suitable cloud service provider during the transmission of medical data over Health Cloud. The establishment of the reliable communication and routing path between multiple clouds over Health Cloud is based on traffic engineering with QoS requirements.

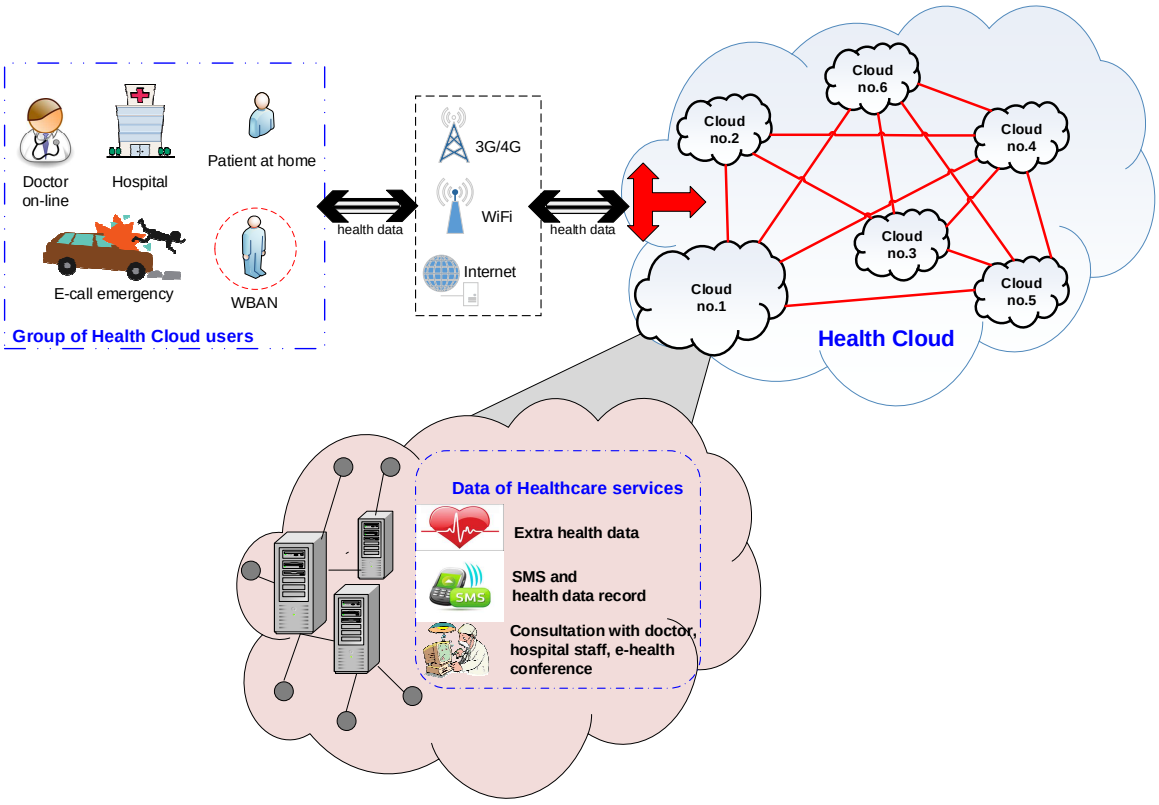


Figure 1. The structure of health data transmission over Health Cloud

One of the critical factors in this is a time interval between path request and a reply to this request. This is the duration for the medical data route selection over Health Cloud. Moreover, it must be as short that cannot cause blockage at the path request and a reply time due to the resource reservation. If this duration will be too long, the resources that were available during the path request may be inaccessible and block the performance of the services. Due to this, the selection of route for data

transmission over Health Cloud based on QoS requirements is very problematic challenge for cloud service providers and it will be analyzed in this paper. The results for QoS-based route selection in Healthcare Cloud can simplify the complexity in cloud networking and increase the efficiency of services' provision. And this is one of the biggest steps towards the autonomous control for Healthcare as a Service (HaaS) [4] over Cloud.

The remainder of this paper is organized as follows: the structure of the health data transmission over Health Cloud and the authors' proposed analytical model for routing path selection are in Section II. Section III describes the results of the investigations from QoS based route selection over Health Cloud as multi-cloud system. Finally, Section IV concludes the paper and gives the new ideas for the future work on autonomous control for HaaS.

2. THE PROPOSED ANALYTICAL MODEL FOR HEALTH DATA ROUTING PATH OVER HEALTH CLOUD

The investigations of health data routing over Health Cloud were carried out for the structure, which is presented in Figure 1. The Health Cloud is designed as inter-cloud system with six different cloud service providers, where the medical services can be displaced from one cloud service provider to another. The users of such Healthcare system can be:

- patients at home;
- users, who are using services over Wireless Body Area Network (WBAN);
- doctors, who are using on-line consultation with their patients;
- staff in hospital, who records any medical documents into databases;
- paramedics, who provide emergency assistance to the patients at home or during any accident (as E-call emergency).

All health data from main Healthcare services are grouped into three groups with different priorities for guaranteed quality of service level:

a) Low priority – on-line doctor's consultation, e-health conference'
b) Best Effort – SMS, health data records
c) High priority – extra health data (from emergency assistance);

All investigations for QoS based route selection over Health Cloud were done by using MATLAB simulation platform. The authors' proposed analytical model for routing path selection is presented in Figure 2.

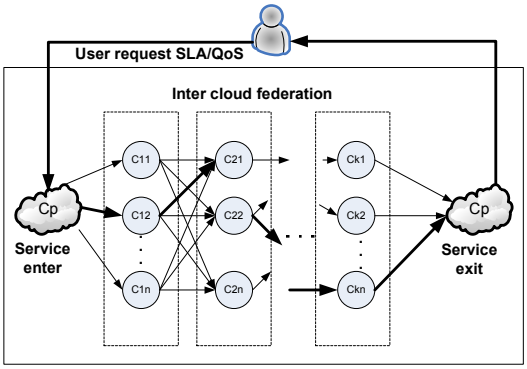


Figure 2. The analytical model for service path request/reply over Healthcare Cloud

General QoS routing problem is to ensure that users transfer data from the source point to the end point, so as to offer end-to-end quality assurance. A typical end-to-end provisioning system for composite network–Cloud services consists of both computing infrastructure that offers Cloud services and network services for Cloud access and inter-Cloud communications. If the end user wants a certain level of performance guarantee from the composite service provisioning, the end user must expect a certain level QoS from each network and Cloud service. The Health Cloud network can be described as an undirected weighted graph. A network is denoted by a graph

$$G(N,L);\ \mathrm{u} \to \upsilon,\ \mathrm{u},\upsilon \in \mathrm{N}, \qquad (1)$$

where *N* is the set of nodes, *L* is the set of links.

Each link can be characterized by a link weight vector $\vec{w}$ consisting of *K* link metrics. In our case QoS metrics can be

- additive: delay, jitter, in which case the path-weight vector consists of summing the link-weight vectors of the links defining the path

$$D(path(i,j)) = \sum_{N \in p(i,j)} d(N) + \sum_{L \in p(i,j)} d(L);$$

- min-max: bandwidth in which case the minimum (or maximum) link weight defines the weight of a path.

$$B(path(i,j)) = \min_{L \in p(i,j)} \{B(L)\}$$

A multicriteria Qos routing approach consists of taking into account all objective metrics of all different services. All metrics have different weight according

with QoS requirements of services and them priorities. For evaluating the route we calculate cost function:

$$Cost \rightarrow f(C1_{QoS}, C2_{QoS}...). \quad (2)$$

Every path cost function are calculate use equation:

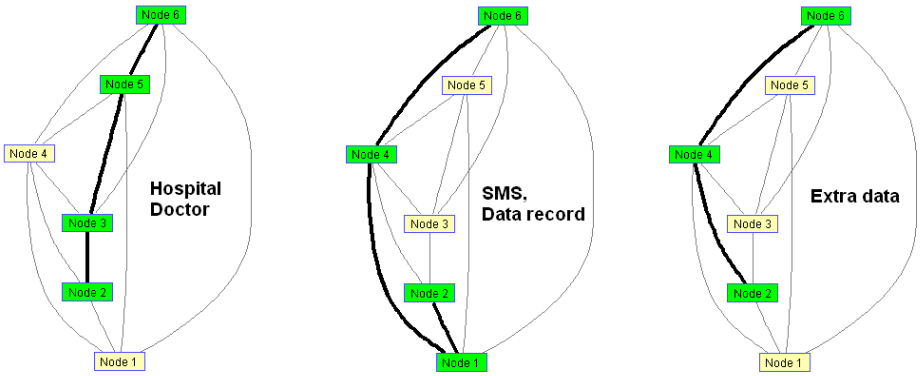
$$Cost = w_i D_i + w_n U_n + ...w_m B_m. \quad (3)$$

The the total QoS routing is

$$QoS_{route} = \min\{Cost_1, Cost_2 ... Cost_n\}. \quad (4)$$

3. RESULTS OF INVESTIGATIONS

The investigations were done in different scenarios: 1) routing path for health data with different priorities; 2) routing path for health data without priorities, but in shortest way; and 3) routing path with minimum QoS cost for service provision (Figures 3–5) The results showed, that the shortest way to provide any Healthcare service is the same for all health services without priorities. However, if the service is with the high priority, such data will be transmitted in shortest way, comparing to other



a) Low b) BE c) High

Figure 3. Routing path for health data with different priorities

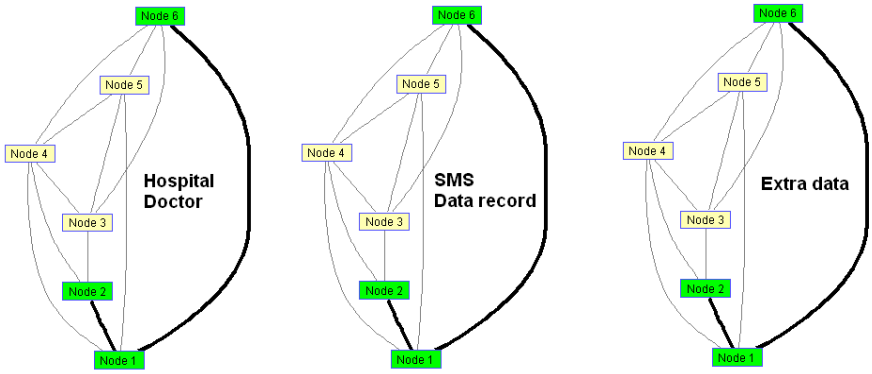


Figure 4. Routing path for health data without priorities, but in shortest way

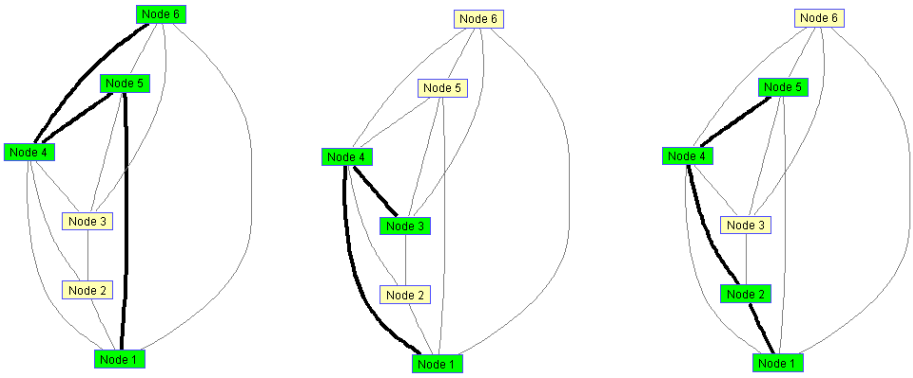


Figure 5. Routing path with min QoS cost to provide service (low priority)

medical services. On the other hand, if the health service is with priorities, the routing path over inter-cloud system will be through clouds, which are not overloaded at that moment and the resource reservation is in minimum cost of quality resources as time for path request/reply, delay, bandwidth, *etc.* (Fig. 5).

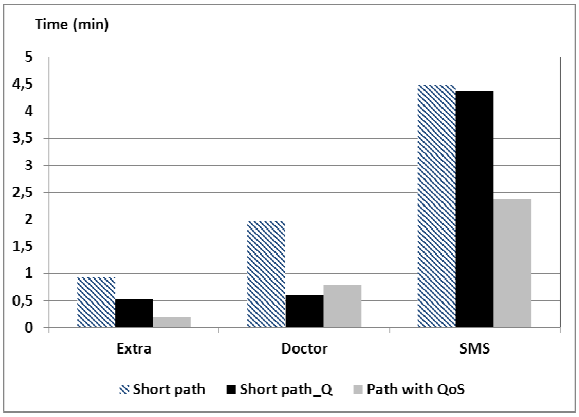


Figure 6. Time of path request and reply

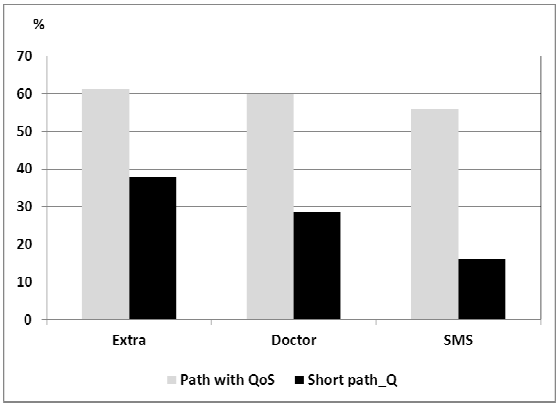


Figure 7. The percentage difference for time of path request and reply

The results for time of path request and reply (Fig. 6) approved that, health data routing with guaranteed QoS level increase the efficiency of medical service provision over Healthcare Cloud in 60% for high and low priority, and in 55% – for BE, in compare with the health data transmission without QoS requirements.

CONCLUSIONS

The investigations for QoS-based route selection over Healthcare Cloud showed, that the health data transmission with guaranteed QoS level can increase the efficiency of medical services' provision in 2 times and simplifies the complexity in multi-cloud infrastructure providers by reserving best resources with min QoS cost for service provision. As Healthcare Cloud should be deployed in reliable communication, the networking aspect of health data (routing model) over inter-cloud system can be used in autonomous control for Healthcare as a Service.

ACKNOWLEDGMENT

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