Mapping of Sensor Nodes with Servers in a Mobile Health-Cloud Environment

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***Abstract*—Body-sensors such as accelerometers, oximeters and arm cuff based monitoring systems are used to sense patients' health conditions. Any abnormal behavior of patient's data triggers an alert signal to the health-centers to take action. In this paper, we address the problem of mobile patients' health monitoring using Health-Cloud. When a patient changes his/her location from one place to another, the associated default gateway changes. With the change in the gateway connected to the health-cloud, the optimum mapping between the server and the mobile node also changes. We propose an optimal resource allocation framework for health-cloud to monitor patients' health conditions when they change locations. To optimize the resource allocation problem and provide an optimum mapping between the mobile node and the server, we use an auction theory based solution approach. We evaluate the performance of the proposed scheme numerically. The experimental results show that we receive 20%, 58%, and 61% more utility for the three different cases with respect to the default mapping.**

Keywords*—*Mobile Computing, Cloud Computing, Mobile Cloud Computing, Wireless Sensor Network

I. Introduction

Currently, people worldwide have become increasingly health conscious due to the rapid increase of chronic and acute diseases. Patients suffering from chronic diseases such as asthma and diabetes need continuous health monitoring for regular treatment. Due to the high cost and space constraints, it is not always possible for a patient to stay in a hospital at all times. In addition, patients may have to travel for their personal work. To fulfill these demands, the problem of continuous health monitoring in a mobile environment needs to be addressed.

A body sensor network (BSN) consists of various miniaturized body sensors [1], [2] placed on a human body. These body sensors are used to measure the physiological parameters such as blood pressure, electrocardiogram, respiration rate, oxygen saturation, glucose percentage in blood, and electroencephalogram of patients. Due to limited bandwidth, battery capacity, and memory size of sensor nodes, the computational requirements on body sensors are more demanding in a mobile environment than in a static environment.

Health-cloud applications lead to the advantage of solving storage and large-scale computation problem of monitoring health data. Unlike other computing mechanisms, cloud computing is not limited to localized isolated systems. In case of large computing or storage resources, the mobile nodes request services from the cloud servers. A health-cloud [3], [4] may also provide some applicable support services such as checking the abnormal behavior of the patients' data, and sending the patients' abnormal information to the health centers. A mobile health-cloud is an integration of health-cloud into the mobile environment. In a mobile health-cloud environment, the data processing and storage applications are moved from the mobile body-sensor nodes to the servers situated in the health-cloud. The integration of health-cloud into the mobile environment improves data computing and storage facility, which leads to the prolongation of lifetime of batteries in the mobile body-sensor nodes.

To provide round the clock health-care support and get more benefit, the cloud service providers optimize their resources. If the cloud users are mobile in nature, the cloud service providers have to optimize their resources periodically. When a body sensor attached with a patient suddenly switches on/ off, or a patient moves from one location to another, the cloud gateway informs the cloud service provider. In some cases the gateway also changes. If the cloud gateway changes due to the change in location of the body sensor, resource reallocation is required to optimize the cost of the cloud service provider and minimize the time to provide the service to the mobile sensor node. In Fig. 1, a schematic view of mobile body-sensor cloud architecture is shown. In such an architecture, the mobile body-sensor nodes are explored in the mobile network using base stations that are responsible for the connection between the mobile sensor node and the network. While a patient is in contact with a mobile body-sensor node, the mobile network operator authenticates the patients for security purpose. The sensed health data are then sent to the health-cloud gateway through the Internet. In the health-cloud, the gateways send the sensed data to a virtual server within the cloud. The virtual server stores and also processes the monitored health data. Due to the change of the patients' locations, the time required for receiving the monitored data in the virtual server also changes. Additionally, the cost of the server varies with the change of the health-cloud gateway. As an example, in Fig. 1, Patient 1 is already connected to the cloud gateway R_1 at position t_1. The position of the patient shifts to position t_2, but the cloud gateway R_1 remains the same. When Patient 1 moves to position t_3, the default cloud gateway changes to gateway R_{n-1}. So, the new allocation is needed to maintain the optimum resource utilization. Our objective is to optimize the overall cost of the cloud service provider related to the health-cloud services, and also to optimize the time to receive the monitored data due to the change in location of the mobile sensor nodes.

The main contribution of the paper is in optimizing cost-effective resource utilization of the cloud server and mapping of the nodes with the servers in the mobile environment. The rest of the paper is organized as follows: Section II presents the related work in the area. In Section III, the problem formulation is given. Section IV presents the solution approach of the proposed resource allocation problem in the mobile environment. The experimental results are provided in Section V. Finally, Section VI concludes the paper.

II. Related Work

The integration of cloud computing into the mobile environment provides benefits for the mobile users, the network operators and the cloud providers. This integration introduces some typical mobile cloud computing applications such as mobile commerce, mobile learning, mobile health-care, and mobile gaming [5]. In [6], the QoS-constrained resource allocation problem is studied, in which service demanders try to solve the "sophisticated" computing problems by requesting the usage of resources across a cloud-based network. In such a scenario, the cost of each service depends on the amount of computation. The authors present a game-theoretic method to schedule dependent tasks under time and cost constraints. For cloud services, a new resource allocation algorithm is stated in [7]. Both the algorithms are modeled to provide the benefits of the users. Niyato et al. [8] focused on the long term reserved resources along with the short term on-demand accesses. In [9], priority-based resource allocation in cloud is addressed. In addition, much of the existing works for resource allocation focus on only the user benefits. This paper presents a resource allocation scheme in cloud-based mobile environments to offer benefits to the mobile users and also the cloud providers. When a mobile device switches on or off, or it changes its position, the cloud provider is intimated by the cloud gateway. When the connection between the gateway server in the cloud and the mobile node changes due to the change in the position of the mobile node, the cost of the cloud provider also changes. The service is provided on the availability of the resources. A resource allocation algorithm is designed to optimize the cloud providers' cost as well as the mobile users' resource allocation time.

III. Problem Formulation

We consider that there are m number of servers present in the health-cloud and n number of mobile body-sensor nodes. Each server $S_i, i = 1, 2, ..., m$ connects with a maximum of a_i nodes and each mobile body-sensor node N_j connects with a maximum of b_j servers. This work considers that a mobile node has a single server connection (i.e., $b_j = 1$). The sum of the total maximum possible connections of each server S_i is termed as the total availability, T_a, which is denoted by $\sum_{i=1}^{m} a_i$. The sum of the total maximum possible connection of each mobile node N_j is termed as the total demand, T_d, which is denoted by, $\sum_{j=1}^{n} b_j$. Each server has a utility per unit connection for each mobile node, denoted by c_{ij}. If the mobile node changes its location, the gateway connected to the cloud server also changes, and correspondingly, the hop count between the server and the mobile node also changes. The change in hop count h_{ij} leads to the change in utility per unit connection value. If the hop count between the mobile node and the server increases, the utility per unit connection value decreases. Each node has an individual capacity to connect with the server, which depends on the hardware specification of the body-sensor node. If the capacity of the mobile node is quantitatively more, the server has to bear less price to connect. The utility per unit connection is defined as:

$$c_{ij} = \alpha / h_{ij} - p_j \tag{1}$$

where α is proportionate constant.

We attempt to assign the nodes to servers, so that the total utility is maximum at the point of time. The mapping of the mobile body-sensor node N_j with the server S_i is denoted by r_{ij}.

$$Maximize \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} r_{ij} \tag{2}$$

subject to

$$\sum_{j=1}^{n} r_{ij} = a_i, \;\; \forall i = 1, 2, ..., m \tag{3}$$

$$\sum_{i=1}^{m} r_{ij} = b_j, \;\; \forall j = 1, 2, ..., n \tag{4}$$

$$b_j = 1, \;\; \forall j = 1, 2, ..., n \tag{5}$$

and

$$r_{ij} \geq 0, \;\; \forall i = 1, 2, ..., m; \forall j = 1, 2, ..., n \tag{6}$$

IV. Solution Approach

We use an auction theory based solution approach to solve the resource allocation optimization problem in the mobile sensor cloud environment [10]. Each server and each node participate in the auction as a seller and bidder, respectively. The connections of the server-node pair are determined based on the maximum bidding increment. The maximum bidding increment is defined as the difference between the maximum utility and the second maximum utility. Let P be the set of pairs (S_i,N_j), where the server S_i can be mapped with the node N_j. For each server S_i, there exists a set of nodes A(S_i) that can be mapped with the server S_i, and is denoted by

$$A(S_i) = N_j | (S_i, N_j) \in P \tag{7}$$

For each mobile node N_j, there exists a set of servers B(N_j) that can be mapped with the node N_j, and is denoted by

$$B(N_j) = S_i | (S_i, N_j) \in P \tag{8}$$

There also exists a utility c_{ij} per server-node connection. If the resource availability is greater (or less) than the demand, it is required to add a dummy node (or a dummy server) with zero utility per connection for each server (or node). All the pairs of dummy servers (or nodes) are included in the set P.

Let I be a non-empty subset of servers (whose resources are not fully used) and mobile nodes (whose demands are not fully satisfied).

Bidding phase: Each server $S_i \in I$ finds a mobile node N_j

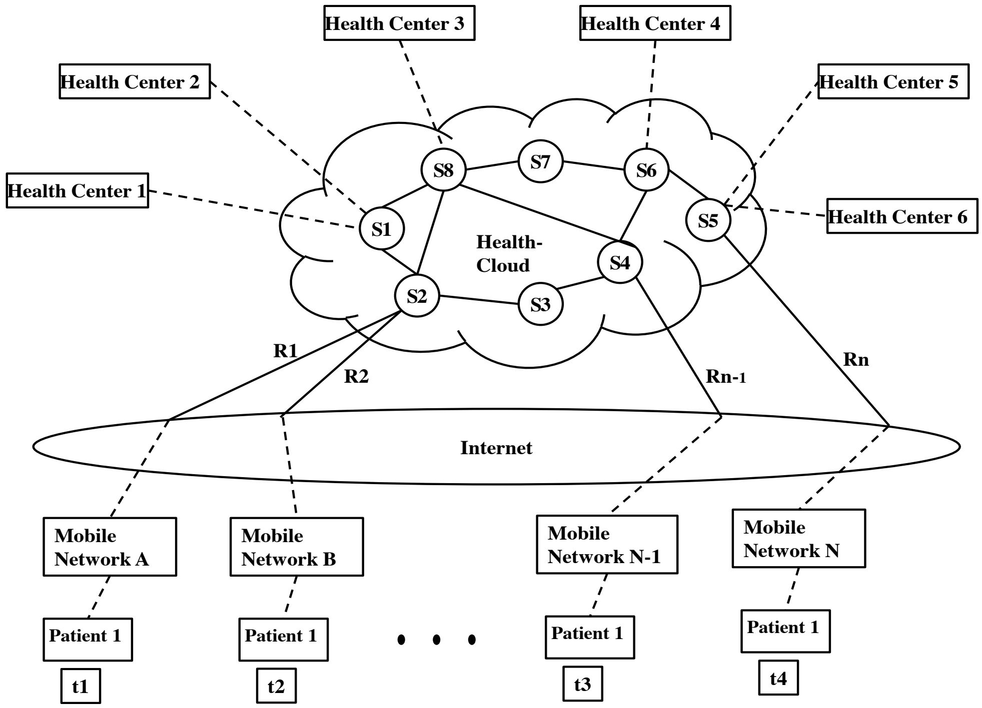

Fig. 1: Mobile Body-Sensor Health-Cloud Architecture

and each mobile node $N_j \in I$ finds a server S_i, which offers the minimum allocation cost, that is,

$$N_{ji} \in max \ \ c_{ij}, \ \ \forall S_i \in I \tag{9}$$

$$S_{ij} \in max \ \ c_{ij}, \forall N_j \in I \tag{10}$$

and computes a bidding increment

$$g_i = v_i - w_i, \ \ \forall S_i \in I \tag{11}$$

$$g_j = v_j - w_j, \ \ \forall N_j \in I \tag{12}$$

where v_i and v_j are the maximum utility values for the server and the node, respectively.

$$v_i = max_{Nj \in A(Si)} \ \ c_{ij} \tag{13}$$

$$v_j = max_{Si \in B(Nj)} \ \ c_{ij} \tag{14}$$

The parameters w_i and w_j are the second maximum utility for the server and the node, respectively.

$$w_i = max_{Nj \in A(Si), Nj \neq Nji} \ \ c_{ij} \tag{15}$$

$$w_j = max_{Si \in B(Nj), Si \neq Sij} \ \ c_{ij} \tag{16}$$

If N_{ji} (or S_{ij}) is the only benefit in A(S_i) (or B(N_j)), we define g_i (or g_j) = v_i (or v_j).

Allocation Phase: Each server S_i (or mobile node N_j), for which the benefit is maximum, is selected by a non-empty subset I with the highest bid.

$$F_{ij} = max_{Si, Nj \in I} \ \ (g_i, g_j) \tag{17}$$

If the available resource a_i (or resource demand b_j) is greater than the resource demand b_j (or available resource a_i), the available resource a_i (or resource demand b_j) is reduced by resource demand b_j (or available resource a_i). We assign a zero value to the least value between the available cost a_i and resource demand b_j, and exclude the least node or server from the subset I.

If the available resource a_i (or resource demand b_j) is equal to the resource demand b_j (or available resource a_i), we assign zero value to both the available cost a_i and the resource demand b_j and then exclude both the node and the server from the subset I. The algorithm for the mapping of body-sensor node with the server situated in health-cloud is presented in Algorithm 1.

TABLE I: Hop-Count matrix

S_i, N_j	N_1	N_2	N_3	N_4	N_5	N_6
S_1	5	6	1	3	2	3
S_2	7	3	3	4	3	9
S_3	9	4	7	5	6	7
S_4	3	10	5	1	5	8

V. Performance Evaluation

We consider five servers S_1, S_2, S_3, S_4 and S_5 with resource availability 2, 1, 2, 3 and 1, respectively, and six body-sensor nodes, N_1, N_2, N_3, N_4, N_5 and N_6, with a single resource demand each. Each mobile node has an individual capacity to connect with the server. In our solution, we randomly select the node price as \$0.05, \$0.05, \$0.1, \$0.15, \$0.15 and \$0.2, respectively. We use the proportionate constant α = \$2 throughout the experiment. We randomly define the hop count for each server-node pair mentioned in Table I.

Algorithm 1 Algorithm for server-node map

Input: Number of server (m), Number of node (n), utility per unit connection (c_{ij}), capacity of each server (a_i)
Output: Optimal combination of server-node maps

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Consider bidder set I, consist of servers and nodes
Calculate T_a and T_d
if T_a is greater than T_d then
    Add a dummy node
else if T_a is less than T_d then
    Add a dummy server
end if
for all Server, (S_i) do
    compute v_i := max_{i∈I} c_ij
    compute w_i := max_{i∈I, i≠v_i} c_ij
    compute g_i := v_i − w_i
end for
for all node, (N_j) do
    compute v_j := max_{j∈I} c_ij
    compute w_j := max_{j∈I, j≠v_j} c_ij
    compute g_j := v_j − w_j
end for
Select the server node pair based on highest bidding increment value of g_i and g_j
if a_i>b_j then
    a_i := a_i - b_j; b_j := 0
    Exclude the selected node from bidder set I.
else if a_i<b_j then
    b_j := b_j - a_i; a_i := 0
    Exclude the selected server from bidder set I.
else
    a_i := 0; b_j := 0
    Exclude the selected node and server from bidder set I.
end if
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Experiment 1: In the 1^{st} experiment, our objective was to find the change in behavior of the utility with the addition or removal of the server or node in the network. We first considered the health-cloud with three servers (i.e., m=3; S_1, S_2, S_3) and calculated the total utility (in \$) of the health-cloud for n = 2, 3, 4, 5, 6. In the presence of new nodes in the network, the mapping of the nodes with the servers was changed. The change in the server-node map leads to the change in total utility of the model. Further, we calculated the total utility of the health-cloud for m = 3, 4, and 5. Fig. 2 shows the total utility change (in \$) when the number of nodes was added serially for m = 3, 4, 5. We observe that the total utility changes in the presence or absence of the mobile nodes as well as the servers.

Experiment 2: In the 2^{nd} experiment, we tested the dependency between the total utility and the hop count. We considered four servers situated in the health-cloud and two mobile nodes present in the network. We moved the mobile node N_j from position t_1 to position t_3 so that the hop count changed, as shown in Fig. 1. We also tested the change in total utility for n = 2, 3, 4, 5, 6. From Fig. 3, we conclude that the total utility changes due to the change in location of the mobile node.

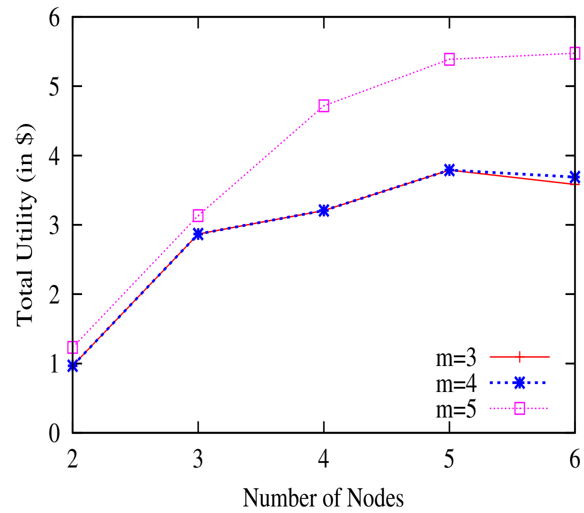

Fig. 2: Change in total utility with number of servers and nodes change

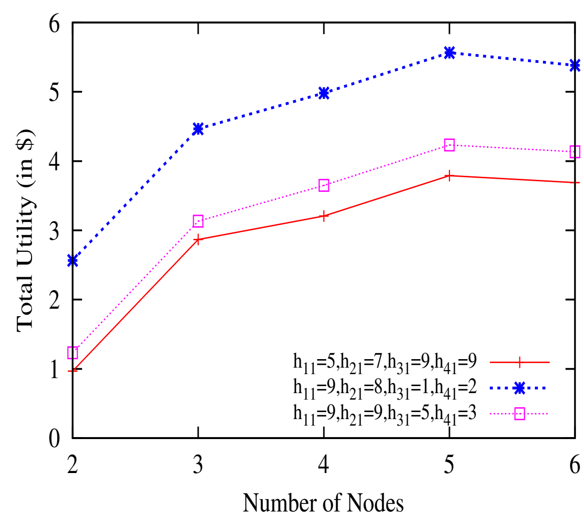

Fig. 3: Change in total utility with hop count change

Experiment 3: The change in server utilization due to mobile node location change was tested in the 3^{rd} experiment. We considered six mobile nodes and five servers in the network. In Fig. 4, the utilization of each server is compared with its availability. Utility 1 represents the server allocation when the mobile node N_1 was at position $t1$ with the set of hop counts $\{h_{11} = 5, h_{21} = 7, h_{31} = 9, h_{41} = 9, h_{51} = 3\}$. Utility 2 represents the server allocation when the mobile node N_1 was at position $t3$ with the set of hop counts $\{h_{11} = 9, h_{21} = 8, h_{31} = 1, h_{41} = 2, h_{51} = 5\}$. When the mobile node N_1 is at position $t1$, the utilization of the server S_3 is 50%, whereas it is 100% at position $t3$. The utilization of the server S_4 varies from 33% to 0% with the change in location of the mobile node N_1.

Experiment 4: In Experiment 4, we tested the mapping of the mobile sensor node with the server existing in the health-cloud, when the mobile node changes its location. We first

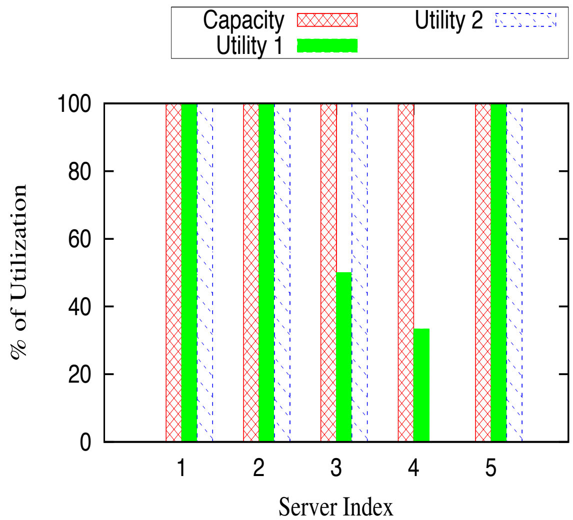

Fig. 4: Server Utilization with changing node location

considered that the mobile node N_1 is initially at position t_1 with the set of hop counts $\{h_{11} = 5, h_{21} = 7, h_{31} = 9, h_{41} = 9\}$, and the mobile node N_2 is initially at position t_2 with the set of hop counts $\{h_{12} = 6, h_{22} = 3, h_{32} = 4, h_{42} = 5\}$. The default mapping of the mobile nodes with the servers, is shown in the 2^{nd} column of Table II. We changed the location of the mobile node N_1 from position $t1$ to position t_3 with the set of hop counts $\{h_{11} = 9, h_{21} = 8, h_{31} = 1, h_{41} = 2\}$. The 3^{rd} column of Table II shows the mapping of the mobile nodes with the servers due to the change in location of node N_1. We did the experiment for another node N_2 which shifted from position t_2 to position t_3. The 4^{th} column of Table II captures the new mapping of server-node pair. The 5^{th} column of Table II describes the server-node mapping when the mobile nodes N_1 and N_2 simultaneously relocate from position t_1 to position t_3 and position t_2 to position t_4 with the set of hop counts $\{h_{12} = 7, h_{22} = 5, h_{32} = 10, h_{42} = 1\}$, respectively. Finally, we conclude that the mapping of the mobile sensor node with the server changes with the change in location of the mobile node due to the benefit of optimization. We receive 20%, 58%, and 61% more utility for the set up of columns 3, 4, and 5 in Table II with respect to the default mapping (column 2 in Table II).

TABLE II: Server-Node Map with change in hop count

Server Name	N_1: $\{h_{11} = 5, h_{21} = 7, h_{31} = 9, h_{41} = 9\}$; N_2: $\{h_{12} = 6, h_{22} = 3, h_{32} = 4, h_{42} = 5\}$	N_1: $\{h_{11} = 9, h_{21} = 8, h_{31} = 1, h_{41} = 2\}$	N_2: $\{h_{12} = 9, h_{22} = 8, h_{32} = 1, h_{42} = 2\}$	N_1: $\{h_{11} = 9, h_{21} = 8, h_{31} = 1, h_{41} = 2\}$; N_2: $\{h_{12} = 7, h_{22} = 5, h_{32} = 10, h_{42} = 1\}$
S_1	N_3, N_6	N_3, N_6	N_3, N_6	N_3, N_6
S_2	N_4	N_5	N_1	N_4
S_3	N_2	N_1, N_2	N_4, N_5	N_1
S_4	N_5, N_1	N_4	N_2	N_2, N_5

VI. Conclusion

This work provides a optimized method of resource allocation for mobile health-cloud. In the proposed scheme, the servers as well as the nodes participate in bidding, and then the resources are allocated based on the maximum bidding increment. Finally, the proposed scheme provides the server-node mapping with maximum benefit utility. Specifically, we receive 20%, 58%, and 61% more utility for the three cases with respect to the default mapping.

In this paper, we assume that all the mobile body-sensor nodes request the same type of services from the health-cloud and all the servers in the health-cloud are capable of providing such services. Considering the above assumption, we evaluated the performance of the proposed scheme. Apart from the mobile health-care applications, the concept of mapping of the mobile nodes with the server cloud is also applicable for mobile gaming, mobile learning, and social networking to provide a cost effective resource allocation. In future, we plan to evaluate the performance of the system in a real-life environment and also compare the applicability of the mapping in other mobile cloud applications.

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