CEPRM: A Cloud-assisted Energy-Saving and Performance-Improving Routing Mechanism for MANETs

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***Abstract* —**Cloud-assisted Mobile Ad-hoc Networks (Cloud-assisted MANETs) are expected to be popular on the Internet in the future. The simplicity and effectiveness of MANETs coupled with the powerful technologies of Cloud allow for the provide real services and variable multimedia applications. However, the combination of Cloud networks and MANETs also brings some challenges, especially the energy issue. With the dynamic network structure of MANETs, the disconnection issue between MANETs and Cloud can cause cost boom problems. In this paper, we propose a routing solution to energy-saving and improvements performance for MANETs (called CEPRM) through reducing time searching transactions in Cloud-assisted MANETs. The simulation result showed that our solution can help to reduce more times cost than normal methods.

***Index Terms*—**Cloud, Energy Saving, Routing Mechanism.

I. INTRODUCTION

Mobile devices are becoming increasingly popular, an essential tool in modern social life. The network of mobile devices is becoming increasingly complex and diverse in types and technologies. The next generation of mobile networks (5G) has been successfully deployed in several countries and will be expanded globally in the near future. Due to the increasing demand for data transfer speed and quality of service for mobile networks, technical standards, new technologies and settings are being constantly improved. The next generation mobile network research is taking place in a number of important fields, including improving network performance, energy efficiency, data security, etc. From this point of view, many valuable studies have been launched, contributing to new communication technologies [1]-[3].

Mobile Ad-hoc Networks (MANETs) is a very convenient and efficient in communication. Despite the limitations of resources and computing power, MANETs have proven to be superior in communication such as: flexible infrastructure, mobility, better connectivity, secure transfer between different networks, etc. As a result, they promise significant contributions to the development of the Internet [3]. Recently, cloud computing has been widely known. Advances in cloud computing enable the Cloud to provide infrastructure, computing platforms, and software as services to users from a computer/device with an Internet connection. Combine Cloud and MANETs is an indispensable technology trend, receiving particular attention from service providers and the research community [2], [9], [12].

Obviously, Cloud support brings new capabilities, superiority to MANETs due to longer uptime, computing power, and other utilities. These advantages facilitate the rapid development of multimedia applications and services [5], [11]. However, the reality is: MANETs have no fixed structure, constant configuration changes and frequent disconnections [3], [6], [7]. These are the main challenges for MANETs deployment solutions based on Cloud. In this paper, we look at the MANETs assisted by the Cloud (Fig. 1). There, cloud servers join in MANETs with roles such as to provide data, compute or search for services servers. Over time, the role of cloud servers is increasingly important as they accumulate more data and services needed for MANETs. Due to the frequent disconnection occurring in MANETs, service delivery efficiency from cloud servers will be severely affected if the connectivity lost is directly related to them. Indeed, when a service request is received from the MANETs, the cloud server performs services searching and routing (in its database and/or services discovery on the cloud) and return search results. The cloud server will also update the search results to the database to serve future service requests. If the connection between a MANETs and a cloud server is lost, the data and utilities provided by the server will no longer work. As a result, the cost (time, power consumption, computing resources, etc.) of service requests from the mobile network will increase. In the worst case, it corresponds to the cost of searching for services on all of cloud. At this point, we can partly visualize the cumulative cost of the system over time and the urgency to have a good solution.

We propose an effective collaboration mechanism between cloud servers to solve the above problem, called CEPRM (Cloud-Assisted Energy-Saving and Performance-Improving Routing Mechanism). Our mechanism allows cloud servers to collaborate to share and maintain information about the data and services used by MANETs. With this mechanism, the data and services of a cloud server will still be useful even if it is

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no longer directly connected to MANETs. The simulation result shows that our solution is very efficient, which reduces time, costs and energy by many times compared to that of traditional mechanisms.

This paper is the extended result of our research which was presented at the conference on Fundamental and Applied Information Technology Research (FAIR) [2].

II. Cloud-Assisted MANETs

A. *Network Architecture*

The network consists of two components: Cloud and MANETs. The Cloud is formed by the data servers connected to one another. MANETs is a set of mobile devices (computers, smartphones, etc.) that are able to communicate with one another through a wireless environment. The combination of traditional MANETs and the Cloud forms the Cloud-assisted MANETs architecture which aim to create new technological capabilities has been presented in the previous sections.

In order to focus on developing the new mechanisms, avoid the complexity and composition of the underlying physical details, we use the concept of overlay network (or overlay) [2], [9], [14]. From now on, we will use the term whenever we refer to the Cloud-assisted MANETs. The overlay is a set of mobile devices called Peers and cloud servers connected to MANETs called Super-peers (SP). Note that a cloud server is only called a SP when it directly connects to MANETs to provide services or forward service requests from Peers to the Cloud. The overlay architecture is illustrated in Fig. 1.

In the overlay, the peers communicate with each other and with the SP through the exchange of messages on MANETs. Between the two nodes (peer / SP) there may be a direct connection or an indirect connection. For example, in Fig. 1, only two peers have direct connections to SP, while the other peers only have indirect connections to two SP. One node sends a service request and receives the result returned from other nodes via the direct or indirect connection. The overlay is self-organizing, allowing nodes to join and leave it at any time.

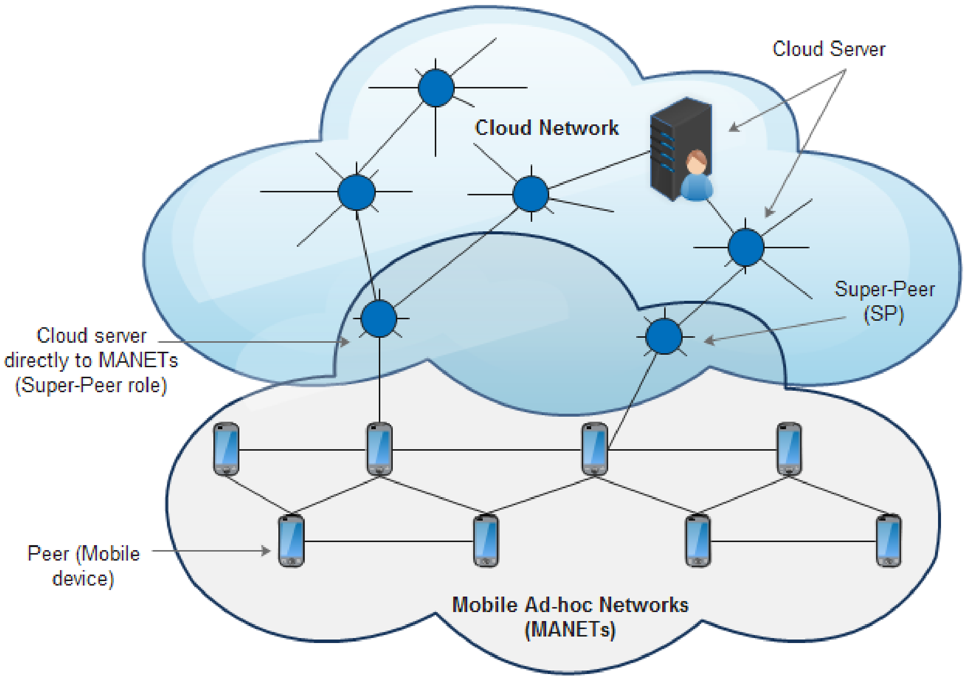


Fig. 1. Cloud-Assisted MANETs architecture model.

B. *The Problem*

Fig. 2, description scenarios of the overlay at different times. Fig. 2(a) is the case where peer A connects and uses the services directly from the super-peer S_j through its direct connection to S_j. Next, A, informs the peers B and C about the service used. Then, C can be connected to S_j by an indirect connection through A as shown in Fig. 2(b). Get requested from C, S_j performs the services required. Typically, S_j will save transactional information to its cache to optimize the cost for next transactions. If the service required by C is currently in the cache of S_j, then S_j can respond to the service immediately for C. In contrast, S_j performs a search in its database and/or initiates service discovery on the Cloud.

In Fig. 2 (c), we assume that C again attempts to connect to S_j to use the transaction, which has been established previously. However, the connection fails because A has left the overlay. Therefore, C must re-establish a new connection to Cloud though S_i by using the routing protocol of the overlay. Once again, the absence of A led to the absence of S_j. As a result, C can't access and use the services of S_j within the overlay. In Fig. 2(d), we assume that C has an indirect connection to another super-peer, named S_i. Then, to perform the request of C, S_i initiates a service discovery process to obtain the result from the Cloud. Assuming that at this time, the service that C requests is available in the cache of S_j. However, since S_i is unknown, it triggers the searching transaction in the Cloud. In this case, clearly, the cost of the transaction (time, energy consumption, computing resources, etc.) is huge.

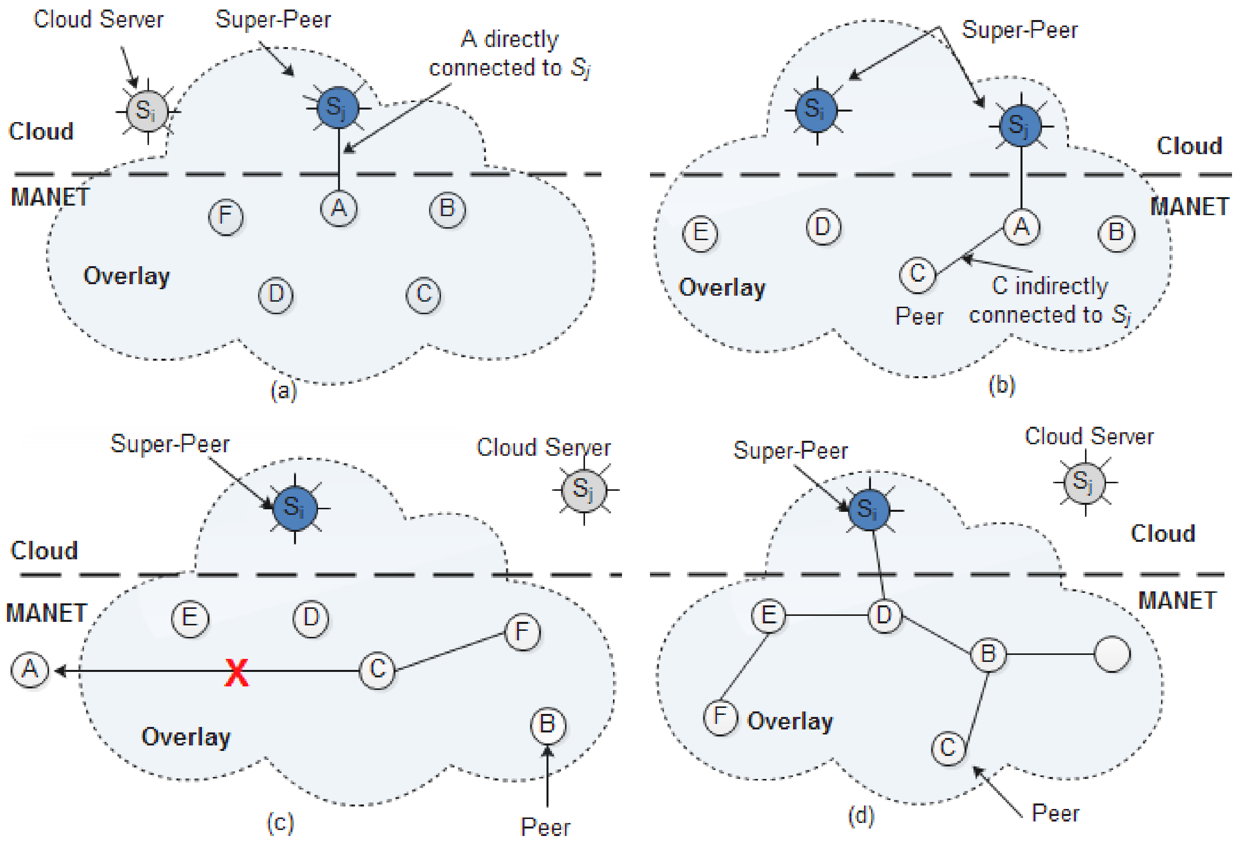


Fig. 2. A case of disconnection in the Cloud-assisted MANETs.

The above problem occurs due to the loss of link in the overlay. In fact, the mobility characteristics of the devices in MANETs are the main cause of the loss of connectivity. When a node leaves the overlay, all connections based on this node will be lost. In addition, when the mobile nodes turn on power save mode, this also causes the loss of connectivity. Due, the high frequency of disconnection [12], the problem of reducing transactional execution costs needs to be resolved for the Cloud-assisted MANETs.

C. Approach

We propose a mechanism for solving the problem presented in Section 2.2, called CEPRM. The main idea is to set up a mechanism that allows super-peers to always know each other, or more exactly, have information about services of other super-peers when they join the overlay. Afterward, they can collaborate effectively in seeking services even when they are disconnected from the overlay.

Recall that search transactions are the basic function of the overlay. In addition, the routing protocols of the overlay are often designed to make searching the most effective. However, the performance of routing in the overlay is significantly affected by the relationship between the overlay configuration and the underlying physical layers [14]. When adding cloud services to a MANETs, a problem arises, the cloud routing protocols do not support dynamic configuration network types. In addition, due to the limitations on the computing power and the uptime of mobile devices, the routing protocols in MANETs must be very compact. Therefore, designing efficient routing protocols in a Cloud-assisted MANETs is a big challenge.

A feasibility design strategy is to keep the routing protocols in the overlap and add the proposed mechanism to the upper-layer functions. Currently, there are many flexible routing protocols introduced in [4]-[8], [10]-[11] and many efficient search algorithms introduced in [12]-[14]. To take advantage of existing protocols and algorithms, our proposed mechanism must be able to coordinate with them. This approach poses many challenges, but we will offer appropriate solutions, described in the next sections.

III. Proposed Mechanism

A. Description Mechanism

Our proposed mechanism operates at the application layer and consists of the following three procedures:

- *Service Notice (SN)*: The procedure is executed by an SP to inform other SPs in the overlay about the change of its role from a cloud server into an SP.
- *Service Update (SU)*: The procedure is invoked by an SP to update the information map of itself. The information map contains information about the services of other SPs, old SP (now is cloud server) and itself.
- *Service Scheduling (SS)*: The procedure is used by an SP to directly request services from other cloud servers via the Cloud, or to share its database with other SPs.

Suppose each SP maintains an information map, which is a reduced form of the database content of SP in the overlay. Then, any SP in the overlay can request services through its SS procedure to the old super-peers (which was once an SP but currently only acts as a normal cloud server due to being disconnected from MANETs).

When a cloud server first joins the overlay and becomes an SP, the information map contains only its services. Then, this new SP sends a notification by SN procedure into the overlay. If there is an SP with non-empty map information in the overlay, it will use the SS procedure to share the map information with the new SP. The new SP then uses the SU procedure to update its own information map. The schema for these transactions is given in Fig. 3. If the information map of an SP is changed, these changes will be updated to other SPs within the overlay (using the SS and SU procedures) as shown in Fig. 3. In the next section, we will describe the algorithm of the cooperative mechanism.

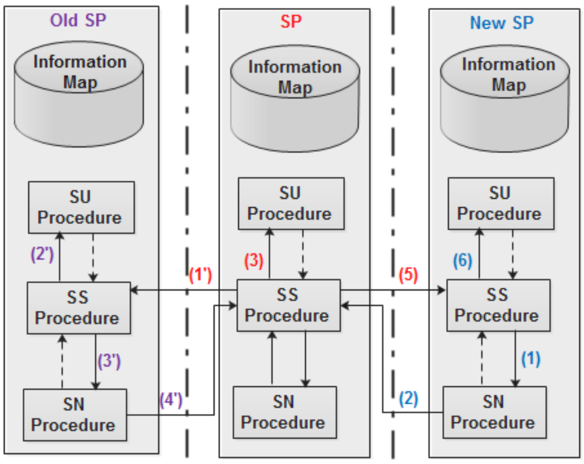


Fig. 3. Describes the proposed mechanism.

B. CEPRM Algorithm

Nodes in a MANETs can collaborate, exchange information, initiate service requests through direct or indirect connections by popular routing protocols, defined by IETF (Internet Engineering Task Force) like AODV (Ad-hoc On-Demand Distance Vector) [15] or DSR (Dynamic Source Routing) [16]. Each node maintains temporary data that include basic information as identifiers and services such as search or routing. The pseudo-code of the CEPRM is described, as follows:

Algorithm 1: Response Service

Input: A requested service from a mobile device **RS**;
Output: the corresponding service **CS**;
1. Query *RS* on own temporary database;
2. if (*RS* is existing on the peers of the MANETs) then
3. Return *CS*;
4. Else
5. Query *RS* in *Information map* on super-peers
6. if (*RS* exists on this *Information map*) then
7. Return *CS*;
8. Else
9. Query *RS* on the Cloud by Algorithm 2;
10. Return *CS*;
11. endif
12. endif

Algorithm 2: Searching the minimum path (S, D)

1. Input: Cost matrix *A*; Source node: *S*; Destination node: *D*;
2. Output *cost*: Minimum cost; *SP*: The route shortest path from *S* to *D*
3. Apply algorithm shortest path first Dijkstra
4. Return *cost* and *SP*

The summary, in our proposed mechanism, has two issues: (1) a cloud server only becomes a SP when it joins in the overlay, else, it is only a traditional cloud server, and (2) each SP stores an information map and performs three procedures: Service Notice, Service Update, and Service Scheduling to update it information map. In the next section, we will clearly illustrate the effectiveness of the CEPRM mechanism.

C. Analyze the Effects of the CEPRM Mechanism

As presented, the main objective of the proposed mechanism is to reduce costs (time, power consumption, computing resources, etc.), so, the performance of Cloud-assisted MANETs can be improved. In general, performance is determined by the time taken to complete a task. As analyzed, the characteristics of mobile nodes in MANETs are the main cause of the cost explosion problem due to lost connections in the overlay.

So, we created a cost model for service requests from MANETs to the Cloud with two assumptions as follows:

- There are k SP nodes in the proposed model.
- Between the source node and the destination node in the path, there exists n Cloud server S_i ($i = \overline{1,n}$; $k \le n$).

Let t_i be the cost of time to route between two neighboring nodes and t'_i be the cost of time to perform search service on node i.

Let e_r is the cost of energy consumed to perform routing in a unit of time and e_s is the cost of energy consumed to search for services in a unit of time.

So, time and energy consumed by a service request according to the traditional mechanism can be calculated as follows:

$$\begin{cases} T = \sum_{i=1}^{k}(t_i + t'_i) \\ E = e_r \times \sum_{i=1}^{k} t_i + e_s \times \sum_{i=1}^{k} t'_i \end{cases} \quad (1)$$

With CEPRM mechanism, by maintaining an information map on the SP nodes, service requests performed can be routed directly to the destination cloud server. It reduces the cost of searching time, thus, saves the energy consumed by the searching process on cloud servers. The time and energy consumed to implement a service request under the proposed mechanism can be calculated as follows:

$$\begin{cases} T = t'_1 + t'_k + \sum_{i=1}^{k} t_i \\ E = e_r \times \sum_{i=1}^{k} t_i + e_s \times (t'_1 + t'_k) \end{cases} \quad (2)$$

In the next section, by simulating, we will obtain a chart that shows the efficiency of CEPRM mechanism and compare with the traditional mechanism.

IV. Performance Evaluation

In this section, we will create a simulation to test the effectiveness of CEPRM mechanism. We set up a simulation to evaluate the total cost of performing routing and searching for services in Cloud-assisted MANETs. We assume that overlay supports forwarding service queries from MANETs to the Cloud. Then, in the simulations, we only need to calculate the cost of performing routing and searching transactions using the CEPRM mechanism and the traditional mechanism. Equations (1) and (2) show that energy consumption depends on time.

In both equations, the execution times of routing transactions ($e_r \times \sum_{i=1}^{k} t_i$) are the same, only the execution times of the searching transaction are different, therefore, the costs of performing a routing transaction in both mechanisms are the same, so we do not consider the costs of the routing transaction and only focus on the costs of the searching transaction.

A. Illustrate the Cost Calculation Method

First of all, we set up a cost model. The model focuses on calculating the cost of performing a search transaction as shown in Fig. 4. We separate three states of the network: *Stable*, *Intermediate* and *Operation*. Stable status means that all network nodes are operating under normal conditions. Thus, routing and searching service transactions can be performed normally. The network switches to an intermediate state when the connection from MANETs to the overlay is lost. From here, it switches into operation state if one peer sends a query to request service from a super peer leaving the coverage. In the operation state, when the disconnection is fixed, the network returns to the stable state.

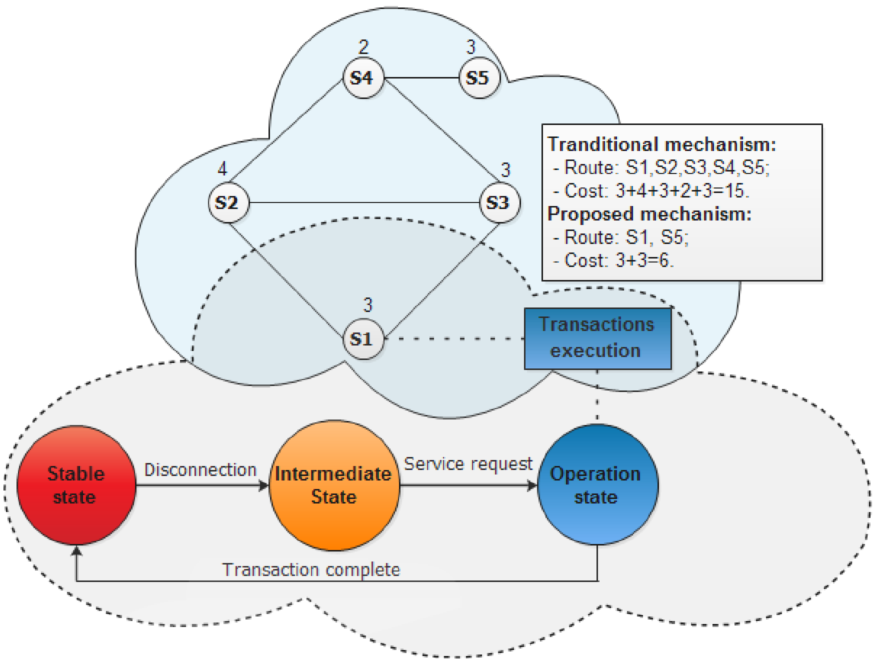


Fig. 4. Cost comparison by the traditional routing method and proposed mechanism.

Now, considering the network in two cases, using and not using the proposed cooperative mechanism, we can observe the differences. We use a network of five cloud servers, respectively named S_1 to S_5 as shown in Fig. 4. Each network node is assigned a random value between 1 and 5 corresponding to the cost of performing a search transaction on that node. We assume S_1 is currently in the overlay (S_1 is a super-peer), S_5 just went out of the overlay and now acts as a cloud server. Then, if the network does not apply the proposed mechanism, the search path is S_1, S_2, S_3, S_4, S_5. The cost to perform a search transaction is 15 (3 + 4 + 3 + 2 + 3). But if we apply CEPRM mechanism, service queries will be sent directly from S_1 to S_5, so the search path is only S_1 and S_5 and the cost is 6 (3 + 3). The cost of the searching transaction is reduced down to 6, is because the system doesn't cost searching in S_2, S_3, and S_4 servers.

B. *Simulation Result and Analysis*

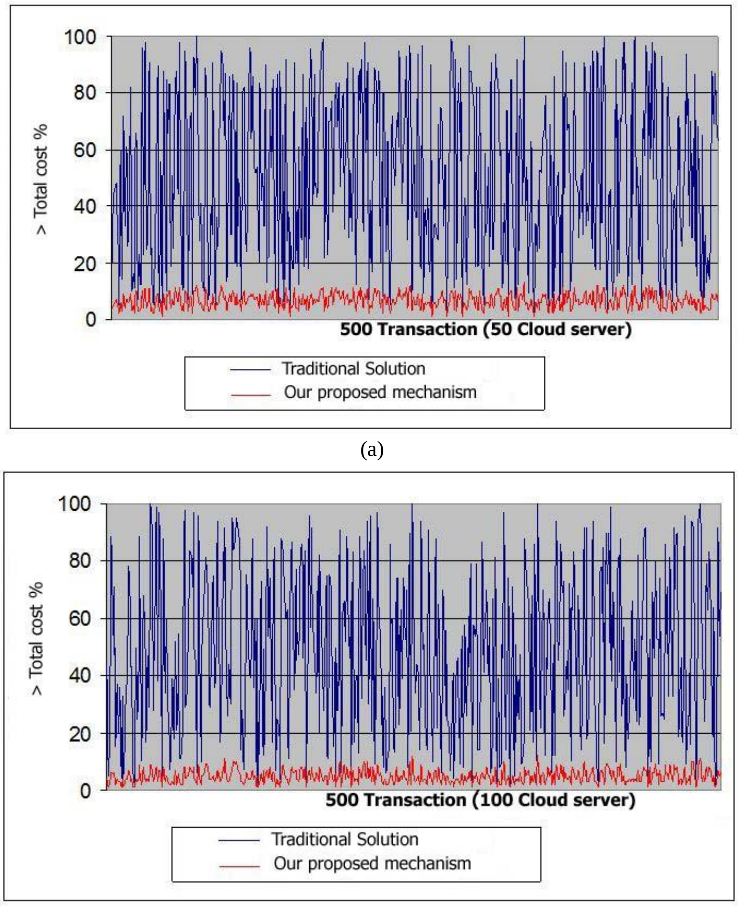
To prove the efficiency of the proposed mechanism, we establish a simple simulation system with the following:

Cloud: Consists of two scenarios: 50 and 100 servers.

MANET: 100 mobile network nodes.

Assume that whenever the network is in the active state, queries sent by a peer can always be connected to an SP ready to serve. In the overlays, disconnections and service queries are generated randomly. We also assume a random integer between 1 and 5 represents the cost of performing the searching transaction at each cloud server. Note that the use of integers instead of a detailed unit of measurement only helps us better illustrate the solution. Then we can calculate the total cost of performing the search transaction to each query.

Fig. 5 compares the costs of performing searching transaction when there are 500 queries in two cases, the network has: 50 and 100 cloud servers. Simulation results show that using our solution, the cost of performing search transaction is two times less than the average compared to that of the traditional solution in both cases, equivalent to 45 % and 50% respectively. Here, the cost of 100% is the worst case, which means that the system must perform search transactions on the overall Cloud.



(b)

Fig. 5. Cost comparison when perform a searching transaction by two mechanisms.

V. THE FUTURE WORK

The simulation results prove the effectiveness of the CEPRM mechanism. However, we still have not tested the performance of the entire network when applying this mechanism. We have not evaluated the costs of setting up and operating the CEPRM mechanism, such as the organization issue and storage of information maps. However, in our opinion, the cost of implementing a collaborative mechanism is negligible compared to the total cost of the Cloud. The issues in this section will be research topics that we are interested in in the future.

VI. Conclusions

With a focus on research, we proposed an Energy-Saving and Performance-Improving Routing Mechanism for Cloud-assisted MANETs, called CEPRM. Our mechanism operates at the application layer, between cloud servers as they join MANETs. This mechanism is highly feasible and very effective in reducing the number of search transactions in cloud servers. The simulation result shows that our solution reduces the cost of performing searching transaction compared to the traditional solution. We are very hopeful that, with simplicity and feasibility, our solution presented in this paper will be applied in practice.

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