The Survey on Efficient Coalition Formation Game in Cloud Federation for Multimedia Applications

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Abstract-This paper studies distributed formation of femto-clouds in a UMTS LTE network. Femtocell access points (FAPs) are equipped with computational resources. They share their resources with neighboring FAPs and form local clouds with the aim to avoid the remote cloud costs while improving the user quality of experience (QoE) in terms of handling latency. In exchange for sharing their excess resources, FAPs receive monetary incentives proportional to their contribution in performing computational tasks in the femto-cloud. The growing demand for various multimedia services and applications has imposed great challenges in terms of real-time processing, storing, analyzing, and sharing of large media data. Federation among media cloud providers can be a promising solution for effectively hosting multimedia applications and provisioning of Quality of Service (QoS)-assured services. In this paper, we address the problem of efficient federation formation mechanism among media cloud providers (CPs) that motivates them to cooperate to fulfill the dynamic resource demands of users for running multimedia workloads. We design a novel media cloud federation formation mechanism based on cooperative game theory. By collaborating to trustworthy providers, our proposed method looks for building federations to minimize the penalties due to possible violation of service quality by untrustworthy providers, and thereby, generate more profit. Simulation results demonstrated that the media cloud federation obtained by the proposed mechanism is stable and provide higher profit for the participating CPs.

I.Introduction

Multimedia is emerging as a popular service that involves in live broadcast, on demand videos, games, video conference and others. Using wireless or wired networks, various users can ubiquitously access and share diverse media services. As the media service demand is increasing day by day, the media traffic volume for all types of services will also increase in near future. This speedy growth of the demand for multimedia services has led to great challenges in terms of large volume of data processing, storing, analyzing, and sharing among millions of users with high interactivity [1]. In order to address the above issues, we propose to utilize the federation paradigm [2][3][4] among various media cloud providers to serve dynamic and fast growing multimedia services. Cloud
federation presents a promising approach for effectively hosting multimedia applications and provision of QoS-assured services. Leveraging infrastructure provisioned by multiple partnership media cloud service providers, we solve problems like dynamic resource allocation and improvement of user experience. The federation creates a pool of virtualized resources which are offered to users as different types of VM instances. The CPs in a federation cooperate in order to provide the resources requested by users with guaranteed QoS. As a result forming cloud federations helps to achieve greater scalability and performance. It may also provide the resources at lower costs[5]. However, one of the major challenging issues in this environment is how to define an effective federation formation mechanism among CPs that motivates them to cooperate to fulfill the resource demands of users [5][6][7] for big data workloads. This issue is very important since it determines how much revenue each CP gets when participating in a federation by proving a certain number of VM resources. In addition, the fairness is also an important issue to be considered which ensures that each CP should gain a revenue based on the amount of VM resources contributed to the federation (Gain-as-you-contribute in short). The stability of a federation is also important and needs to be analyzed for finding whether it is profitable for a CP to work with other CPs in the federation or not. Currently, several strategies [5][6] are present in the literature for forming cloud federations. Among these strategies, game-theory-based federation formation mechanisms are becoming popular[5][6][8]. However, all of these mechanisms mostly focus on forming federation based on the maximum individual profit gained by the CPs in a federation. The profit of any CP varies based on the revenue it can gain by running various types and number of VM resources and the cost of providing those resources. None of these approaches take into account the risk of selecting unreliable collaborating CPs in a federation that may result in additional penalty cost due to SLA violation and finally affect the other CPs reputation. Therefore, we argue that a trust model is also necessary to find the most promising collaborators for forming cloud federation. In this paper, we model the federation formation among CPs as a coalition game, where CPs decide to form a federation to allocate various types of VM instances dynamically, based on users requests with QoS guarantee. The coalition game is modeled as a hedonic game [5][6] whereby each CP can order and compare all the possible coalitions it belongs to based on its preference model satisfying fairness and stability properties. We derive a trust model specifically.
The main idea in this work is to allow FAPs augmented with computational resources to cooperate with each other and form local computational pools, namely, femto-clouds. FAPs share the computational resources exceeding their demands in femto-clouds. Therefore, by maximally exploiting FAPs’ local resources, such femto-clouds reduce latency and, hence, improve end-user QoE. We assume that FAPs are deployed by different residential users. To motivate FAP owners to share their excess resources, it is natural to assume an incentive mechanism. The maximal use of FAP resources then translates into both lower handling latency and higher incentives to FAP owners. The question that this paper focuses on is then: How should FAPs decide on formation of such femto-clouds in a distributed fashion? The data transfer delay and limited computational capacity of FAPs impose stringent constraints that naturally prohibit formation of the grand coalition to which all FAPs join, namely, grand femto-cloud. Since offloading tasks to other FAPs within a femto-cloud incurs delay, it is not beneficial to collaborate with FAPs that are far away. On the other hand, the computation tasks exceeding the computational capacity of the femto-clouds have to be transported to the remote cloud. This incurs both data transfer delay and remote cloud costs. If such a cost exceeds the associated incentives, all FAPs within the femto-cloud will be responsible for the loss. Formation of the grand femto-cloud produces a huge pool of tasks, and increases the probability of such losses.

II. Related Work

Here, we provide a brief description of relevant works in the literature.

Collaboration among cloud providers

There is a large body of research devoted to studying cooperation in cloud computing framework; see, e.g., [12], [13], [14]. Cooperation among mobile cloud service providers is studied in [12] for pooling computational resources with the goal to maximize revenue. The authors then use Shapley value to distribute the revenue among the collaborating cloud service providers. In [15], a cooperative outsourcing strategy is proposed which prescribes the providers whether to satisfy users’ requests locally or to outsource to a certain provider. Dynamic cloud federation formation is also studied in [16].

Collaboration among femtocells

Coalition formation in femtocell network has been extensively studied in the literature; see, e.g., [17], [18], [19]. For instance, [20] studies coalition formation among femtocells in order to mitigate interference.
in the network. In [19], an interference management model is developed in a femtocell network wherein the cooperation problem is formulated as a coalition formation game with overlapping conditions. Rami et al. [21] also consider resource and power allocation in cooperative femtocell networks. All these works consider cooperation among femtocells with the aim to improve physical-layer throughput.

**Incentives for cooperation in femtocell network**

Femtocells are typically deployed by mobile network operators in an open/hybrid access mode, in which FAPs are willing to accommodate guest users; see, e.g., [3], [4], [5]. To motivate FAP owners to adopt such an access mode, several incentive schemes have been studied in the literature, e.g., [12]. Incentives can be categorized as reputation or remuneration [28]. Reputation reflects the willingness of wireless nodes’ to cooperate with other nodes. Nodes receive services from other nodes based on their past behavior—misbehaving nodes are deprived from receiving services. In contrast, remuneration-based mechanisms provide monetary incentives for cooperation, e.g., micropayment, virtual currency, E-cash, and credit transfer [4].

**Femto-clouds**

Femto-clouds are relatively recent and only few studies can be found in the literature. For instance, [9] proposes a mechanism for joint optimization of communication and computational resources. In [6], an offloading strategy is proposed for femto-clouds. All these works consider the cloud offloading mechanism while assuming that FAPs are already grouped into coalitions. Femto-clouds differ substantially from cloud radio access networks (CRAN) [5] in that FAPs are endowed with computational resources and the offloaded computations are preferred to be performed locally rather than in a centralized cloud (e.g. remote radio head in CRAN) to reduce handling latency.

**III. Co-operative Cloud Federation Formation Game**

In this section, we introduce our proposed media cloud federation formation game. In this game, a broker announces a price or revenue rate along with the total amount of VM resources required by the media cloud users. Accordingly, a set of available CPs forms a coalition to cooperatively fulfill the requested user demands. However, there are many different coalitions can be formed, each one differing from the other ones in terms of the profit they bring to their members. Therefore, the proposed game model will help to investigate the stability of
different federation structures and find the best federation model that maximizes each CPs profit by considering trustworthy collaborator CPs. We consider a coalition formation cooperative game with transferable utility \([5][6]\). The proposed game also satisfies the two main properties, fairness and stability, which are very important for any CP to decide which coalition to join.

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IV. Distributed Femto-Cloud Formation Algorithm
Define network state pair by \(! = (S; r)\), which contains the femto-clouds structure \(S\) and the incentive vector of FAPs \(r\). The distributed femto-cloud formation procedure relies on the dynamic coalition formation algorithm proposed in [10] and is summarized below in Algorithm 1. The advantage of using the decentralized procedure in Algorithm 1 over centralized solutions is that it retains autonomy of FAP owners as whether to collaborate and better captures the dynamics of the negotiation process among them [10]. In a centralized solution, FAP owners have to be forced to follow the calculated optimal femto-cloud structure. In fact, if an FAP owner decides to not follow the prescription, the implemented femto-cloud structure is no longer the optimal solution. In contrast, the decentralized solution implemented in Algorithm 1 mimics the natural procedure that FAP owners will follow to form collaborative groups—they explore their options and settle in the femto-cloud that provides the highest feasible incentive. The implementation considerations will be addressed in the next subsection. The myopic best-reply strategy implemented of Algorithm 1 defines a finite-state Markov chain, namely, best-reply process [10]. Standard results on finite state Markov chains show that, no matter where the process starts, the probability that the best-reply process reaches a recurrent set of states after \(n\) iterations tends to one as \(n\) tends to infinity. The outcome that which of these ergodic states will eventually be
reached is determined by the initial state. Under the best-reply process, absorbing states do not necessarily guarantee reaching the solution of (10). To address this issue, perturbation has to be introduced. That is, to allow FAPs deviate from optimal strategies and choose sub-optimal strategies with a small probability with the hope of achieving higher incentives. The interested reader is referred to [10] for details and further discussion.

Algorithm 1 Distributed Femto-Cloud Formation

**Initialization.** Set $0 < \varepsilon, \rho < 1$, where $\rho$ is the probability of revising strategy and $\varepsilon$ is the experimentation probability. Initialize $\tilde{\omega}^0 = (S^0, r^0)$, where $S^0 = \{1\ldots, K\}$, $r^0 = (r_1, \ldots, r_K)$, and $\tilde{r}_k = U\{1\ldots K\}$.

**Step 1.** Find blocking coalitions by FCM:
Let $A^n = \emptyset$. For all $c \in 2^K - \emptyset$,

if $\sum_{k \in c} r_k^0 < |U(c)|$ then $A^n \leftarrow A^n \cup c$.

**Step 2.** Each FAP $k \in \{1, \ldots, K\}$ independently performs:

**Step 2.1.** With probability $\rho$, continue with Step 2.2.
With the remaining probability $1 - \rho$, stay in the same coalition, set $r_k^{n+1} = r_k^n$, and go to Step 2.5.

**Step 2.2.** Compute

$$C_k^{n+1} = \arg \max_{c \in S^n \cup \{k\}} \left( |U(c \cup \{k\})| - \sum_{l \in c \cup \{k\}} r_l^n \right) \quad (11)$$

$$p_k^{n+1} = |U(C_k^{n+1} \cup \{k\})| - \sum_{l \in C_k^{n+1} \cup \{k\}} r_l^n \quad (12)$$

**Step 2.3.** If $k \in A^n$, with probability $\varepsilon$, go to Step 2.4.
With the remaining probability $1 - \varepsilon$, sample uniformly from the set $S^n \cup \emptyset$, denote it by $C_k^{n+1}$, and set $r_k^{n+1} = \tilde{r}_k^{n+1}$, where $\tilde{r}_k^{n+1}$ is computed according to (12). Go to Step 2.5.

**Step 2.4.** Set $r_k^{n+1} = r_k^n$, and, if non-singleton, randomize among $C_k^{n+1}$ uniformly.

**Step 2.5.** If $k \notin K$, continue with the next FAP.

**Step 3.** Form $\omega^{n+1} = (S^{n+1}, r^{n+1})$.
Set $n \leftarrow n + 1$ and go to Step 1.

V. Evolution

Throughout this section, the NS-3 simulator is used as a realistic simulation of the entire LTE system architecture. We consider a city environment and use the LTE module developed by the LENA project [46], [47] as follows: We use LENA’s RandomRoomPositionAllocator function to randomly locate 15 FAPs inside a 10-story building made of concrete and comprising 20 apartments, as depicted in . There exist 2 FCMs in the building located close to FAP-2 and FAP-15, respectively. The FCMs are connected to the remote cloud via 1Gbps optical fiber link. LENA’s HybridBuildingsPropagationLossModel and 3kmphTraceFadingLossModel functions (i.e., slowly varying Nakagami-m fading model) are used for propagation loss and channel fading between UEs and FAPs, respectively. We further use the Kun2600MhzPropagationLossModel and the Propagation Loss Model functions as the propagation loss model and channel fading for FAP-FAP and FAP-FCM communication. The handover is handled via the LENA’s AddX2Interface function. UEs are further randomly located inside the building and connected to FAP using the AttachToClosestEnb function. At each time slot, sub-channels are allocated to users in each FAP according to the proportional fair (PF) scheduling policy with hybrid automatic
repeat request (HARQ) re-transmission mechanism. Further, the UEs and FAPs are equipped with multiple input multiple output (MIMO) antennas, and support adaptive modulation and coding. UEs transmit UDP packets to the FAP. FAPs also transmit UDP packets for multi-cast communication. The data transfer rates are calculated from the RLCTrace files generated by the NS-3 simulator.

VI. Conclusions
This paper presents a novel cloud federation formation approach that helps media cloud providers to form a federation dynamically to provide various types of VM instances to users’ with QoS guarantee for media data workloads. Based on coalition game theory, the proposed mechanism help CPs to form different federations- each one consisting of a subset of the CPs. Unlike existing works, we consider that the preference of a CP to join/leave any federation will depend on the maximum profit it can gain from that federation with minimum risk of penalty costs by selecting trustworthy collaborators. The proposed model uses the overall trust level of a collaborating CPs. Simulation results demonstrated that the media cloud federation obtained by the proposed mechanism can satisfy the fairness and stability property, while at the same time provides maximum profit to the media CPs as compared to the state-of-the-art approaches.

References


