Mobile Service Composition over Oppotunistic Networks: An Energy Consumption Perspective

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Abstract—The abstract goes here.

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1 INTRODUCTION

IN RECENT years, service-oriented computing has become an increasingly important computing paradigm to develop and integrate distributed enterprise information systems [T]. With the rapid developments in mobile devices and wireless technologies, Web services are no longer limited to traditional platforms and they are becoming more flexible and com- plex. The manufacturers of mobile devices have also recently achieved breakthroughs to extend mobile devices capabilities in terms of memory, computational power, storage capacity, and display screens as well as expand their capabilities and functionalities with other integrated devices, such as built-in cameras, infrared ports, and Bluetooth technology [T]. As aresult, theglobal interestof mobileapplications isonthe rise. Both researchers and industrial companies are inspired to pave the road for mobile Web service provisioning [T][2].

Opportunistic computing provides an appealing alternative to the mobile computing cloud by allowing devices to join forces and leverage heterogeneous resources from other devices[1 abstract].

To complement online mobile crowdsourcing services, in this paper we advocate Crowd Foraging,a QoS-oriented selforganized mobile crowdsourcing framework, where a mobile user can self-organize her task crowdsourcing in a proactive manner by leveraging a massive crowd of opportunistically encountered mobile human workers in realtime. Its main rationality is four-fold. First, opportunistic user encounters are prevalent and sufficient in daily life [T], which offers plenty of opportunities to exploit nearby human intelli- gence for task solving [T], [T], [T]. Second, many mobile crowdsourcing tasks require local knowledge and information (e.g., location-based content sensing [T], [T], [T] and content transmission [T][T]), and hence nearby human workers are more adept at executing them than the online workers. Third, D2D communications such as Bluetooth, WiFi-direct and LTE-D2D are promising to replenish traditional cellular communications in terms of user throughput increase, cellular traffic reduction and network

coverage extension [T]. At last, this framework shares the similar spirit with the emerging paradigm cyber foraging over opportunistic networks, such that mobile users opportunistically exploit nearby device resources to facilitate their computational task processing [T][3].

Because the pervasive vision revolves around the human user, it can only be achieved by a flexible networking paradigm that adapts to the user instead of expecting the user to adapt. Human users move around freely and cannot be expected to always be within range of an access point or a mesh router. On the other hand, humans are social by nature, and they can very well be expected to come in contact with each other with a relatively high frequency; it is this very expectation that constitutes the basic tenet of opportunistic networking [1].

1.1 Mobile Web Service

Mobile Web services are deployed on mobile devices and provisioned over wireless networks, and devices may play the roles of consumers, brokers, or providers. Their role as aWeb service requester isfundamental. Shifting such a role from a requester to a provider, however, is feasible only if mobile devices can offer standard Web services with acceptable performance while making negligible impact on their regular usage. The concept of mobile Web services was first introduced as a computing paradigm in the early twenty-first century [T]. It brought many challenges to traditional ser- vice computing techniques mainly due to their technological limitations, summarized as follows.

1) Mobility: Mobile devices frequently change network operators and may handover between different technologies within the same network. Also, because they are expected to experience frequent link failures, services they provide may become temporarily unreachable. This presents major chal- lenges for providing reliable Web services in highly dynamic mobile wireless environments.

2) Limited Resources: Although the capabilities of mobile devices have improved in terms of processing power, memory space, and embedded sensors, they continue to lag behind other forms of computing devices. Mobile devices (smartphones in particular) are still recognized as resource-constrained computing devices [T]. Battery power is the number one limited resource in mobile phones, which remains a major challenge for potential growth of mobile

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computing [T]. Recent developments in mobile computing and growing popularity of mobile applications outpace what current battery technologies can provide.

3) Addressability:

4) Scalability:

Due to the above characteristics, the existing service com- puting protocols and mechanisms can be hardly utilized for mobile Web services. Therefore, it is essential to study new protocols and mechanisms that are more suitable for mobile domains. In this paper, we mainly target at the service selection by considering user mobility [2].

1.2 Motivation Scenario

1.3 Contributions

To address the aforementioned challenges and concerns, we propose a new approach for service selections and compositions in mobile environments. The main contributions are:

1) We propose an architecture for mobile service provision [mobile service sharing community (MSSC)] to address the problem of service selection for mobile service com- position in the mobile community where both service requesters and providers are nonstationary. In such community, mobile users can share mobile services through their mobile devices in specific areas.

2) For MSSC, we propose a mobility model to describe mobile user moving behavior. The model is extended from the random waypoint (RWP) model.

3) Based on MSSC and the proposed mobility model, we transfer the mobility-aware service composition problem to an optimization problem and propose to utilize the Krill-Herd (KH) algorithm to solve it. We conduct a series of evaluations to validate that our algorithm is approximately optimal and performs much better than other standard composition approaches. We compare it with other population-based optimization methods for both optimality and scalability.

The remainder of this paper is organized as follows. Section II reviews the related work. Section III introduces the MSSC architecture. Section IV describes our approach to make service compositions. Section V presents experimental results. Section VI concludes this paper.

2 RELATED WORK AND COMPARISON

Service composition is a significant area of research. As our proposal targets the problem of mobile service composition, we first briefly review the work on how to make such composition in traditional Internet environment, then we review some recent work on it in dynamic/mobile environments.

2.1 Traditional Web Service Composition

2.2 Mobile Web Service Composition

3 MOBILE OPPORTUNISTIC NETWORK

In opportunistic networks [T], node-to-node communication occurs by exploiting any tidbit of connectivity that becomes available. Nodes in an opportunistic network rely on pairwise encounters and a store-and-forward paradigm to send information to each other over multiple hops even in the absence of an end-to-end path. Opportunistic communication is possible as long as there are foris no longer viewed as a disruptive phenomenon that thwarts the laborious routing process, but as a benefit that streamlines communication by offering new data exchange opportunities between nodes. Mobility enables nodes to come in contact with other nodes and makes it more likely for them to encounter useful forwarders that can get their messages closer to its intended destination. Thewarding opportunities. By breaking away from any end-to-end path requirement, opportunistic networks lend themselves to the pervasive vision by making connectivity available anywhere and anytime, though not all the time. Any user can exchange data with any other user from any location at any time, as long as she is not a hermit and is in no hurry. Opportunistic networks allow information to flow to its destination through the combined use of network connectivity and node mobility. Mobility is no longer viewed as a disruptive phenomenon that thwarts the laborious routing process, but as a benefit that streamlines communication by offering new data exchange opportunities between nodes. Mobility enables nodes to come in contact with other nodes and makes it more likely for them to encounter useful forwarders that can get their messages closer to its intended destination [1]. Fig. 1 illustrates the working procedure of the Crowd Foraging framework. In an opportunistic network scenario, a mobile task requester R launches a mobile crowdsourcing task. She moves around in the network and opportunistically encounters a mobile human worker W1. After probing the work ability of the worker W1 via D2D link, if the task requester R decides to recruit the worker in terms of a specific recruitment policy, she will forward the detailed contents of the task (e.g., images, videos and text descriptions) to the recruited worker via D2D link. Once the worker finishes the task, he will send the results to the task requester via either cellular link directly or D2D link when they encounter with each other again before a given deadline. Finally, the task requester receiving the results will grant the task reward to the worker. We should emphasize that, our framework only considers one-hop mechanism for both worker recruitment and result collection, since realistic dataset analyses reveal that users one-hop neighbors are sufficient [7] and can cover most range of the whole network in a reasonable time period [10], and contacting a user would incur long delay if the maximum D2D communication hops are larger than two [15]. Compared with multi-hop mechanisms in existing researches [1], [3], [4], [6], [11], [12], this one-hop feature can lower the network overhead (e.g., no need to transfer a large volume of task contents hop by hop) and ensure framework performance with only local information, which is more practical in real life[3].

In this section, we introduce MSSC that is a virtual community formed by multiple mobile users. Within it, users can share services on their own mobile devices through mobile networks. It has three main characteristics as follows.

1) Locality: An MSSC is not established on the Internet. It corresponds to a specific region such as a univer- sity campus, a company building, and a restaurant. Only mobile users who enter the same region can share services with each other.

2) Dynamicity: MSSC participants are not stationary. They can enter or leave the community at any time.

3) Mobility: Services provided by mobile users are not fixed at the same location. Service requesters are also mobile when invoking a mobile service.

In order to provide more details for MSSC, this section gives its basic architecture, operations, and applications.

3.1 Overview

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3.2 Basic Operations

[2]

3.3 Application Scenario

[2]

4 SERVICE COMPOSITION OVER MON APPROACH

4.1 Node Availiable for Opportunistic network

In wireless mobile networks such as ad hoc or mesh networks, the availability of a node to its neighbour nodes is highly related to the nodes mobilityhere it is assumed that battery power is not a concern and as such a node will not out of reach because of battery exhaustion. If node i moves outside the transmission range of its neighbouring node j, then node i is unreachable by node j and as a result the services on node i become unavailable to node j either. Node availability, to some extent, also expresses network availability because if the connection between any two neighbouring nodes in a route from a service provider to a service requester becomes unavailable, then the whole route also becomes unavailable. Here node mobility is utilized to calculate the node availability [4].

Consider, as illustrated in Fig. 2, two mobile hosts MHi and MHj of the same transmission range R. Each node moves randomly and it is assumed that the moving field is a circle with a radius of r. d represents the distance between MHi and MHj. These three parameters are to be used for calculating the node availability. The transmis- sion range of a node R is known (e.g., pre-defined or changing according to certain algorithm). Suppose the location (i.e., coordinates) of each mobile host is known (e.g., via GPSglobal positioning system), then distance d can be calculated using the Euclidean distance formula, i.e.,$\sqrt{(x_i - x_j)^2 + y_i - y_j}^2$ where (x_i, x_j) and (y_i, y_j) are are the coordinates of MHi and MHj respectively. Finally let us discuss how to calculate r.

The moving radius of a mobile host (r) is its speed (s) multiplied by the average service time (t). Here t can be statistically calculated as the average value of last n servings of this component service, namely, $t = \Sigma_{i=1}^{n} t_i/n$. The speed of a mobile host s can be calculated based on its moving distance during a period from t1 to t2 [18], namely: $s = \sqrt{(x_i - x_j)^2 + y_i - y_j}^2/(t_2 - t_1)$. Then $r = s \times t$.

Knowing the values of these three parameters R, r, and d, the probability of MHi staying inside the transmission range of MHj (denoted as P_i^{IN}) can be calculated by

$$P_i^{IN} = \frac{A_i^{IN}}{A_i^T} \tag{1}$$

Namely, P_i^{IN} equals to the area of the MHismoving field inside the transmission range of MHj (denoted as A_i^{IN}) divided by the overall area of the MHis moving field(A_i^T).

As shown in Fig. 2, we have

$$\alpha = arcons(\frac{r^2 + d^2 - R^2}{2r \times d}) \tag{2}$$

$$\beta = arcons(\frac{R^2 + d^2 - r^2}{2r \times d}) \tag{3}$$

Then,

$$A_i^{IN} = [(\frac{2\beta}{2\pi}\pi R^2) - (\frac{Rsin\beta cos\beta}{2}2)] + [(\frac{2\alpha}{2\pi}\pi r^2) - (\frac{rsin\alpha cos\alpha}{2}2)] = \beta R^2 \tag{4}$$

There is also

$$A_i^T = \pi r^2 = \pi \times (s \times t)^2 \tag{5}$$

4.2 Problem Description

4.3 Composition Algorithm

5 SIMULATION AND EVALUATION

5.1 Simulation Setting

5.2 Scalability Evaluation

5.3 Effectiveness Evaluation

6 CONLUSION

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