Choreographing Services over Mobile Devices

Tanveer Ahmed and Abhishek Srivastava

Indian Instititue of Technology Indore, India
{phd12120101,asrivastava}@iiti.ac.in

Abstract. Owing to the proliferation of web services, service oriented architecture (SOA) is widely acknowledged as an ideal paradigm for both enterprise applications and compute intensive scientific processes. In todays world, the present scenario of conducting business has found a new inclination towards the Mobile Device. Mobile devices, however, are constrained by battery power, processing capability, availability and network outages. Achieving service composition in such dynamic environment is challenging. In this paper, we propose a technique inspired by Electromagnetism in Physics to enact service choreography over mobile devices. The focus of the work is to minimize the waiting time and to balance load between services of a similar kind, thereby preserving battery power. The technique is validated through a real prototype. We prove the model minimized battery consumption and achieved a reduction in the waiting time.

Keywords: Service Composition, Service Oriented Architecture, Mobile Phones.

1 Introduction

Service oriented architecture owes its popularity to web services and their temporal collaboration, commonly referred to as web service composition. Using web service composition, an organization can achieve a low operation and maintenance cost. As is evident, the Internet today is constantly evolving towards the 'Future Internet' (FI). In the FI, a mobile device is envisioned to become the center of computation in all aspects of daily and professional life, specially for the applications related to *Internet of Everything*[1].

At the moment, service orchestration is a widely accepted standard to accomplish service composition. In the context of the Future Internet, especially the IoS and IoT, service orchestration is expected to run into several hurdles. The biggest problem is: Considering an ultra large scale of the FI, orchestration is not scalable and the coordination between consumers and providers is impossible [4]. In addition, an orchestrator can become a potential communication bottleneck and a single point of failure [3]. In this context, we believe service choreography is *'the'* solution. However, even on a wired network, enacting service choreography successfully for an ultra large scale Future Internet is a challenge. This is further

[1] http://www.cisco.com/web/about/ac79/innov/IoE.html

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exacerbated in a wireless setting, where the network is highly unpredictable, uncertain and error prone. There are several atypical issues, e.g. availability, battery power, application response time and several others that have to be tackled for a mobile device. In addition, composition over Mobile Devices, specially those owned by ordinary people exacerbates the problem even more. In such cases, the Quality of Experience of a person (both the consumer and provider) must never be compromised, since good user experience is a valuable asset in the service industry.

In this paper, we propose a technique customized from physics to enact service choreography over mobile devices, in particular, Cell Phones. We use the fundamental principles of electromagnetism to select a service from a set of similar services. The focus of the technique is to minimize the waiting time a user request experiences and at the same time preserve battery power. The foundation of the work presented here is the proposal of the electric field and the magnetic field. The proposed electric field is a non-user centered parameter capable of bypassing the hotspots to help conserve battery power. Further, in the World of Devices, user centric computation is one of the objectives, therefore magnetic field is designed to incorporate the preferences of a user in service selection. The magnetic field uses the intuition of a human being to select services. Thus, the electric field circumvents congested services and the magnetic field provides a user centric QoS aware composition parameter. We combine the two fields to make the dynamic service selection decision.

2 Proposed Model

In the real world, whenever a charged particle, e.g. an electron, moves in an electromagnetic field, it experiences an electro-magnetic force (EMF). The particle experiences acceleration (purely electric) and a drift in the direction of motion perpendicular to both the electric and the magnetic field. If we assume the two fields to be in the X and Y axes respectively, then the particle will drift in the Z axis. The Electromagnetic force experienced by the particle is known as the Lorentz's force [8].

In this paper, we have taken inspiration from such a phenomenon in the physical world. In our model, the movement of an electron is analogous to the control flow between services. We have assumed that each service hosted on a mobile device offers both electric and magnetic fields, consequently each node offers an electromagnetic force (EMF) to the next incoming service request. The EMF offered by a service is the selection criterion in our model. Next, we present the definitions of Electric and Magnetic Fields, and show how we make the dynamic service selection decision.

2.1 The Electric Field

To formulate the definition of the electric field, we have used the principle of potential gradient. In physics, electric field is defined as the rate of change of potential with respect to displacement [8].

$$E = \frac{dV}{dx} \tag{1}$$

where, dV is the change in Electric Potential and dx represents the change in displacement, E is the electric field. The electric potential is the amount of work done to transfer a unit positive electric charge from one position to another position.

In the proposed work, the electric potential experienced at a service is defined in terms of the waiting time experienced at a service node. Mathematically,

$$V_x(i) = tw_x(i) \tag{2}$$

and,

$$V_y(i+1) = tw_y(i+1) \tag{3}$$

where, $tw_x(i)$ is the waiting time at a service x realizing the i^{th} step (the current service/step in the composition), y is the index of the next service to be selected and $tw_y(i+1)$ is the waiting time. Here, service y realizes the $(i+1)^{th}$ step (the next process-step). From equations (1), (2) and (3), the proposed definition of the electric field offered by a mobile node is:

$$E(y) = \frac{tw_x(i) - tw_y(i+1)}{td(x(i), y(i+1))} \tag{4}$$

where, $E(y)$ is the Electric Field offered by the service realizing the next process step, $td(x(i),y(i+1))$ is the data transfer time, defined as "*the amount of time required to pass all the parameters and control from a service at a particular step to a service at the subsequent step*". In mobile devices, the data transfer time also represents latency between two individual devices. It can be seen from the above equation that if a service (realizing the next process step) has less waiting time, then Electric Field value is high. It is understood that the waiting time experienced at a service gives a measure of the congestion experienced at a node. Also, congestion is directly related to battery consumption. Therefore, selecting services offering a high Electric Field value can help preserve battery power. Further, driven by this Field requests will be passed to services that are not overloaded.

2.2 Magnetic Field

From the discussion in the previous sub-section, it is clear that though the Electric Field is runtime dependent, it is not *user-centered*. Today, the consumers are the center of attention in the world of mobile devices. Therefore, '*User-Centricity*' has become one of the most important criteria. In the proposed work, we made an attempt to include this criterion in service composition.

It is a well known fact that human beings have a varied sense of understanding and perception. Human beings exhibit *cognitive bias* preferring certain objects over others. In services computing, if a service is selected via QoS attributes, then human beings will tend to favor certain properties over others. Therefore, selecting a service following such a biased approach should not be the ideal way forward. A feasible strategy would be to select a service based on conscious reasoning as well. In other words, the subjective approach of the human being must be complemented by a reasonable objective approach. The same line of reasoning could be applied to services computing i.e. while selecting a service based on QoS attributes, one must follow a human oriented subjective approach complemented by a reasoning based objective approach. Taking this line of reasoning, we propose Magnetic Field as a preference and QoS based selection function incorporating both the subjective and the objective behavior. An ideal candidate to merge both the two choices is the subjective-objective weighted approach. Therefore, the proposed definition of the Magnetic Field is as follows.

$$M(y) = \beta * wQ + (1 - \beta) * w'Q \tag{5}$$

where, Q is a matrix containing QoS attributes' values. w, w' are the subjective-objective weight matrices respectively. β is bias parameter in the range [0,1]. The QoS attributes chosen for weight calculation and the purpose of experimentation were chosen from attributes commonly found in literature[2]. The method used to calculate weights was taken from [7].

2.3 Coalition of Electric and Magnetic Fields

So far we have presented the definitions of the electric field and the magnetic field. The electric field makes the algorithm congestion aware, thus, aids battery conservation. It is obvious, the combination strategy of the two fields will play an important role in service composition and battery conservation. Basically, the degree of influence each field will have in composition will depend on the method and the parameter of combination. To combine the two fields, there are two broad categories: Linear and Non-Linear. In a mobile environment processing capabilities are limited. Therefore, considering simplicity and computational efficiency, we have chosen a linear combination strategy. It was outlined previously that a node offering electric and magnetic fields offers electromagnetic force (EMF). Therefore, the proposed definition of EMF is:

$$F(y) = \alpha * E(y) + (1 - \alpha) * M(y) \tag{6}$$

where, α is a parameter in the range of [0,1] representing biasness towards either the Electric Field or the Magnetic Field. Using concepts of classical physics, the request (control flow) will move to a service node that has the maximum force value. Therefore, a node is chosen iff it offers the maximum EMF.

$$\forall s \in S_i; s` \in S_i \quad F_{s`} > F_s; s` \neq s \tag{7}$$

where S is a set of all services for a particular process-step, $s`$ is the chosen service, F_s is the EMF offered by a service.

[2] `https://www.ibm.com/developerworks/library/ws-quality/`

Since we are achieving Mobile service composition in a decentralized environment, therefore EMF values must be exchanged between the participants. In the proposed work, the exchange mechanism is based on event based updates. The motivation for event based updates comes from the fact the such an exchange mechanism allows a throttled load on the underlying network. In mobile devices, such a throttled load is beneficial owing to power constraints.

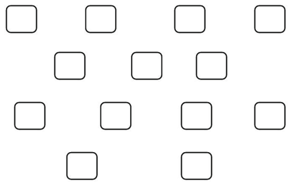

Fig. 1. Experimental Workflow

3 Real World Prototype Implementation

A simple composite application, with a list of redundant services shown in Fig. 1 was chosen for the purpose of experimentation. Though, the Figure represent a simple composition, our motive is to check the feasibility of the model in minimizing the waiting time and balancing load equally. To demonstrate the feasibility of the proposed technique in actual deployment, we have developed a prototype for the mobile device. The procedure for the development and deployment of web services, with a sample service, has been uploaded on github repository[3]. The application container to host the war (Web Archive) files was i-Jetty v3.1. Services were developed using Java and RESTLET[4] framework. Several services were hosted on multiple Android based devices. The battery consumption was monitored via the application GSam Battery (it is freely available at Google play store). The underlying network was the Institute's own WiFi network.

3.1 Behavior of Completion Time

To test the behavior of completion time, Volunteers, hosting services on their devices were asked to stay go around their normal business while service composition was in progress. We tracked the application completion in such a situation. The corresponding result concerning the application completion time is shown in Fig. 2.

It is visible from the Figure that the completion times is less, infact it is almost similar. Therefore, the *Instant-Availability* constraint is not violated. Moreover, we can say with concrete proof that the technique didn't make compromises in the real world.

[3] `https://github.com/mb-14/RestDroid`
[4] `http://restlet.org/`

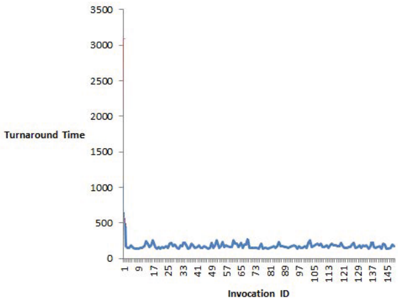

Fig. 2. Completion Time (seconds)

During experimentation we observed that the latency factor kept varying all the time. This observation was due to the fact that mobility played a major role here. Because of the nature of the devices, ignoring such factors during composition is not the best of ways. In the proposed model, we have considered this factor. Therefore, the application completion time is less.

3.2 Behavior of Battery Consumption

In this paper, our motive is to respect 1) *Battery Constraint* 2) *Instant Availability Constraint*. We demonstrated the latter was satisfied by having fast application completion time. For the former constraint, one of the ways is to have a low queue size at a service. A low queue is achievable via load balancing. In this regard, to demonstrate the effect the proposed technique on the battery of a mobile device, we have experimented in two different ways: 1) Service Composition without the electric field i.e no load balancing 2) Service composition with Electric Field. The results concerning the extent of battery consumption for the former case is shown in Fig. 3 (i-jetty Server), and the results concerning the observation for the latter scenario is shown in Fig. 4. Owing to space constraints,

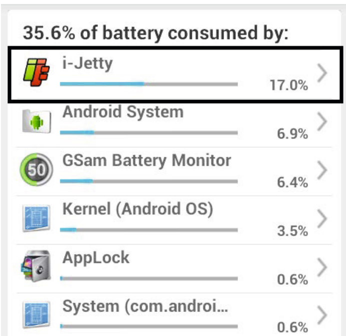

Fig. 3. Power Consumption Without Load Balancing

Fig. 4 shows a snapshot of a few devices only. It can be observed from the two Figures that when there is no load balancing the battery consumption of the device is high, 17%. This is theoretically expected, since all the service requests kept arriving at this service node. A lot of work in literature suffer from this drawback, i.e. repeated selection of a service. Therefore, they violate the battery power constraint, hence degrade the QoE of a user. Looking at the result in Fig. 4, one can clearly see that the battery consumption saw a significant drop. The battery consumption in this case varied from 5.7%-10.7%. This reduction is due to the fact that requests were distributed across devices. Previously we outlined the effect of congestion on battery consumption. Therefore, efficient distribution of requests imply a low queue size, consequently a reduced CPU access, and hence a reduction in power usage. Therefore, in addition to providing a human oriented QoS aware composition parameter, Magnetic Field, the technique performed well in preserving the battery life of person's mobile device.

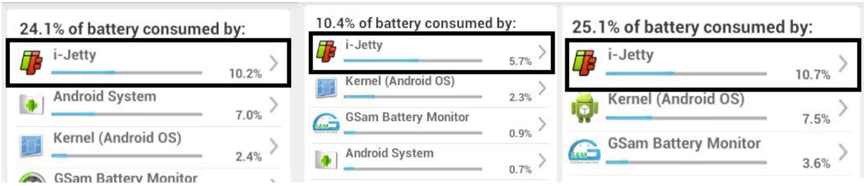

Fig. 4. Power Consumption With Load Balancing

4 Related Work

Service choreography has become one of most important topics of research in the service computing field. However, there only a few techniques purely developed and deployed on real mobile devices. A Technique to enact a service choreography using the chemical paradigm is proposed in [2], [3]. Fernandez et al [3] propose executing a workflow using the chemical paradigm. However, the focus of the proposed middleware is to execute a workflow in wired networks. We have proposed a physics based approach for the mobile platform. Further, the authors in [3] do not focus load balancing, dynamic adaptations. A technique to achieve choreography in peer-peer network is proposed in [2]. The work presented in [5] studies the effect of QoS metrics in message integrity and accuracy of choreographies. A self-* framework for configuring and adapting services at runtime was proposed in [1]. The framework, PAWS, delivered self-optimization and ensured guaranteed service provisioning even in failures. A comprehensive review of service choreographies is available in [6]. However, we did not found any technique with a special focus towards the IoS, let alone a Mobile Device.

5 Conclusion

In this paper, we proposed a technique customized from the behavior of a charged particle in physics to achieve service choreography over mobile devices.

We developed a prototype and conducted experiments with real mobile devices. We showed how the developed prototype achieved a low battery consumption. We achieved a low battery consumption by balancing load between services of a similar kind. Further, we also showed the model produced a reduction in the application turnaround time.

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