2009 International Symposium on Computing, Communication, and Control (ISCCC 2009)
Proc .of CSIT vol.1 (2011) © (2011) IACSIT Press, Singapore

Applying Computational Economy for Collaborative Processing on Mobile Phones

Meisam Hejazinia and Mohammadreza Razazi +

Amirkabir University of Technology, Dept. of Computer and IT Engineering, Tehran, Iran

Abstract. A mobile phone platform is a huge opportunity for future commercial, informational transactions, and collaborative processing. These activities are often hindered by a lack of incentives to share the computational and informaitonal resources. A promising way to overcome these barriers is the introduction of economically inspired mechanism for the use of resources. The build-up and success of business applications over mobile phones heavily depends on economic incentives for the participants. This guides us to a reward and cost accounting system. Currently, there is no economical system developed for this particular platform. This paper analyzed economic-related issues particularly pricing issues, present in mobile phone platforms for collaborative processing. Based on those challanges the paper proposes a middleware and protocol supporting computational economy for informational and computational elements on mobile phones.

Keywords: Computational Economy, Collaborative Processing, Middleware, Mobile phone.

1. Introduction

In the near future mobile phones would become the key driver of commercial, economical and financial processes. The number of mobile phone devices has already exceeded the number of personal computers. 4.2 billion people worldwide have mobile phones. Mobile phones have the same capability in terms of process power, and memory size as the personal computers of early 90s, yet there are not enough applications developed over this platform [2].

Current applications developed over mobile phones, follow the following architecture: The interactive mode between mobile information device and server adopts the multi-layer architecture. Considering the full sharing of enterprise information and the future extension (based on J2EE), the system adopts J2ME+J2EE architecture. It develops the server program under J2EE platform and the server end uses Servlet, JSP and EJB, etc, and connects JDBC to the backend database. As a client end, the application program on the mobile phone end is composed of various user interfaces. Additionally, some frequently used and simple datasheets with smaller data size are stored in the client database, which are connected with Web server through wireless network [3].

There are driving factors for using mobile phones in commerce: first, there are enormous mobile users around the world, second, most mobile phones at least support SMS and Bluetooth. In addition, there are some opportunities for 3G networks. Mobile phones are the best devices which could be used for personalization purposes.

This platform has some limitations, in terms of power consumption, supporting network, processing power, memory size, and input/output capacity, which should be taken into consideration when designing applications for them.

+ Corresponding author. Tel.: +989376364895

E-mail address: hejazinia@aut.ac.ir

Mobile phones are ubiquitous; they could be used anytime, anywhere, despite laptop and PCs, which need time to be setup, and stable place to be used. This attribute of mobile phones provide us with the opportunity of ubiquitous computing, ubiquitous commerce, and ubiquitous information access. People mostly concern about their mobile phones, for they are private, and it's their own device, and they don't want anyone to control it.

If we look at mobile phones, as a server, for it has enough storage, processing power, and communication capabilities for normal works, we find huge a processing power and storage distributed over the world, with enough capability to communicate. The main problem that mobile phones are not widely used for commerce, information access, and processing applications, in this point of view, is that there is a lack of incentives to share computational resources. Moreover, there is no appropriate middleware to support distributed processing, specially in terms of services (i.e. you can not deploy a service on mobile phones, and you cannot invoke methods remotely). After we gain such capabilities for overcoming incentive challenges, we need to introduce inspired mechanisms for the use of resources.

The solution for these problems we proposed is an architecture style which makes this platform suitable for application development. A mobile platform is a huge opportunity for future commercial transactions. But this platform should be equipped with a proper middleware; consequently, traditional commercial applications could be redefined for this new platform.

This economical system, instead of being static with fixed service allocation, should do dynamic assignments. Dynamic sharing of those resources in a commercial environment in particular requires an appropriate business model. In mobile phones, we have some similar issues like grids; we have mobile phone autonomy, resource detection, security, etc. However, there is a big difference, mobile phones cannot have resource aggregator, like brokers that we have in grid environments. MANET through Bluetooth and WLAN is the main communication facility; as a result of that, we couldn't have resource allocators, like a resource broker. Although there is 3G network that provides internet connection for mobile phones, they are really costly, and this prevents many people to exchange information over them.

Benefits of economy based-resource management are [8]:

- It offers an efficient mechanism for allocation and management of resources.
- It offers a uniform treatment to all resources. That allows trading of everything including computational power, memory, storage, network bandwidth/latency, and devices or instruments.
- It provides incentives for resource sharing.
- It removes the needs for a central coordinator, especially through negotiation.
- It places the power in the hand of both resource owners and users—they can make their own decisions to maximize the utility and profit.

These attributes are the solution for mobile phone distributed processing requirements.

The paper is organized as follows: Section 2, describes the requirements of economical system needed for distributed processing over mobile phone and motivation for an economy driven resource management system, section 3, describes different network infrastructures, for developing commercial applications on mobile phones; and proposes a solution for heterogeneity. Section 4, proposes middleware architecture and describes modules interaction and protocols, and section 5, concludes the paper.

2. Requirements and motivation of mobile phone computational economy

We predict that the global computation over mobile phones drives the economy of the 21st century. The vision is that Mobile phones would evolve toward world-wide business platforms, which offers services on-demand and creates new market opportunities. We derived the concept of computational economy, from grid computing. Grids have features [8] of flexibility and extendibility, the same as mobile phones. They are domain autonomous; mobile phones should have autonomy for every mobile phone as well. Moreover, grids have scalability, and applications on mobile phones should have the same feature. Grids are easy to use and have a transparent access; mobile phones should have the same feature. Grids should be secure, and interpretable with multiple systems, and should have dynamic adaptability, so should mobile phones. The main difference between grids and mobile phones is that we do not have a global connectivity on mobile phones, and the word, aggregation, could not be used for mobile phones.

Grids are used for research, simulation, and sharing scientific data and processing, while mobile phones are not. Mobile phones are ubiquitous and they could be used for normal life, computations, information sharing and commerce, and do not need such huge computational infrastructure as we have in grids. We should leverage the high quantity of mobile phones, and use distributed processing and sharing over them, mobile phones are the best devices for Computer Supported Collaborative Work (CSCW) and further collaborative distributed processing.

The technology to manage, share, and use computing resources is called middleware. The suitable middleware for mobile phones should offer all necessary functions such as security, data transfer, communication, and scheduling. This middleware provides us with the ability of resource (especially service) sharing. A number of applications need more computing power than can be offered by a single mobile, in order to solve them within a feasible/reasonable time and cost.

As both resource owners and users want to maximize their profit (i.e., the owners wish to earn more money and the users wish to solve their problems within a minimum possible cost), the mobile phone computing environment needs to support this economy of computations. One of the foremost concerns in mobile phone economics is the unit being traded and the respective pricing. Currently, there is no mobile phone middleware providing standard units of trade or pricing scheme and there is a lack of support for managing pricing information.

The build-up and success of mobile phone businesses heavily depends on economic incentives for the participants, in terms of reward and cost accounting system. The services provided need to be measured and prices to enable the business application of mobile phones. The pricing mechanisms must allow both efficient resource allocation and planning reliability, QoS, (in case of computational element sharing), for consumers and providers. From the user's perspective, it is only important that the appropriate computing resource is delivered on-demand.

We could leverage this economical system even in multi-hoping systems, especially for Bluetooth, which multi-hoping should be supported by the software layer. In grid environment, people share their resources voluntarily, but in mobile phones, since there are scarcity of resources, and concept of privacy, and we have no middleware supporting them, we do not have such thing.

The main problem is that, like many other platforms, some users only use other people's resources, however, will not allow other people to share their resources. Secondly, some users may not need high level quality-of-service (QoS), however, they still choose this service, which is wastage of resources.

The appropriate pricing scheme can further help to improve workload balancing by providing self-regulation mechanisms. As in real market economies the prices for idle resources may be lowered to attract "consumers", while those of overloaded resources may be raised in order to reasonably balance average utilization and computational efficiency of mobile phones as a whole. This aspect is most important for the overall throughput of mobile phones [6].

This will allow the users to use multiple services only if their payment is covered. The decentralized service oriented infrastructure allows scalability and adaptability. A reliable implementation of resource allocation mechanisms and policies, based on computational economies, should ensure high throughput, stability, scalability, low computational overhead and compatibility with local policies of different mobile phones.

Pricing schemes represent the business interface between the provider and the customer. They are used to achieve different objectives such as maximizing profit, maximizing social welfare, or defining certain schemes of fairness. A pricing scheme presents the unit of trade in a specified time period with a certain quality of service for a class of users.

3. Mobile phone network infrastructure

There are four options available for providing a middleware, over mobile phones: Bluetooth, SMS, WLAN, and GPRS. GPRS is based on GSM. In the middle of these two technologies is the improved version of GSM, which cellular operators enhance their systems, to improve to GPRS, and SMS is built over GSM, it is simple, fast highly flexible, scalable, wide spread and user friendly. The specification of each of these infrastructures is shown in figure 1.

	Bluetooth	WLAN	GPRS
Bandwidth	1 Mbps	11Mbps	115-117 kbps
Power	1-10mw	50-70mw	200-800mw
Range	10-100m	100-200m	1KM
Cost	None	Low	High
Frequency	2.4GHz	2.4GHz	900/1800MHz

Fig. 1: Network Medium Comparison

To make decisions over these infrastructures, Bluetooth shows up, for it is free but has some shortcomings upon its limited range. Bluetooth and WLAN support the concepts of same time and same place. At first sight, we may think that this would not be a suitable infrastructure to conduct services. But when we look thoroughly, we find out that there is another thing, which is society network. Society network means people we meet every day, in buses or bank queues, waiting for our flights. We are not staying in a place day and night, and we are moving, and this is a great opportunity for providing exchange with many people. Although we meet and talk with limited people, our device is not limited like us. It could automatically interact with many people we may not see, but they are in our proximity, and it could match profiles, use their processing power, or memory. Our device could even trigger and guide us to the right person. With this mentality, Bluetooth is not limited anymore, while we are not Robinson Crusoe who do not have any people around us in an isolated island, even when we are in an island there are many people around us, and this means a huge opportunity for computing and commerce. The main advantage of Bluetooth is that, we are not controlled by central agents anymore, there is no operator, and we could conduct service without the middleman (operators).

To overcome the shortcomings of each of these options there is a solution, which is a software layer over them for roaming [9] transparently, so that the application over them wouldn't be notified that the underlying layer has changed the network medium. Thus, the first underlying layer searches for the mobile phones in the proximity to check whether they have the special service. If they do not, the software layer under it does the roaming and goes to WLAN or SMS according to the user preference between cost and time. In addition, if it is not found, then automatically it connects via GPRS to another mobile phone, or sends an SMS to a default mobile phone that he knows it contains the required service.

4. Middleware architecture and module interaction and protocols

So far, we have discussed main issues of computational economy for mobile phones. The main challenge today for developing applications over mobile phones is that, there are no middleware supporting incentive for distributed processing and data sharing. Our proposed middleware model could be seen in figure. 2.

We defined eight modules: Client profile module is the abstraction of each real consumer, with a special request profile. Service manager module is responsible for resource selection, initiating service, and returning result to the client module. GPS module is responsible for conducting the general second price auction, which we will describe in the following protocol description. Discovery module is used by the client profile module to find appropriate services; it will return the address of the mobile phone that is the provider of services, to client profile module, in order to connect to the relative service manager module. Broker List module, is the module used in mobile phones that acts as broker, it has the addresses of popular services, which it brokers. History keeper module retains the previous price of services, for the consumer, or the producer of services, to guide the pricing policies. User policy module retains the policy of the users, and is used by the client profile module, to check based on the policies.

We propose the following protocol for service allocation. At first, many requests come and they queue. Each request contains the cost that a consumer wills to pay. Secondly, when the service producer is free, it chooses the first person and the proposed cost from the second one. The first person is served with the cost that the second person proposes. On the third stage, the device provides service. When the middleware delivers the service, it reduces the credit of the consumer, and adds that credit to the producer. The protocol is shown in figure 2.

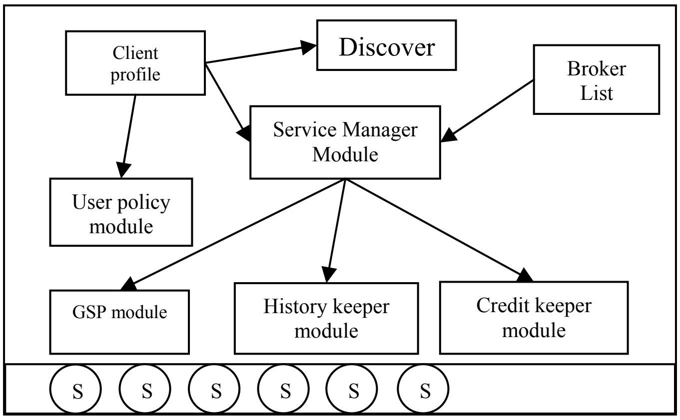

Figure 2: **Proposed architecture for computational economy middleware of mobile phones**

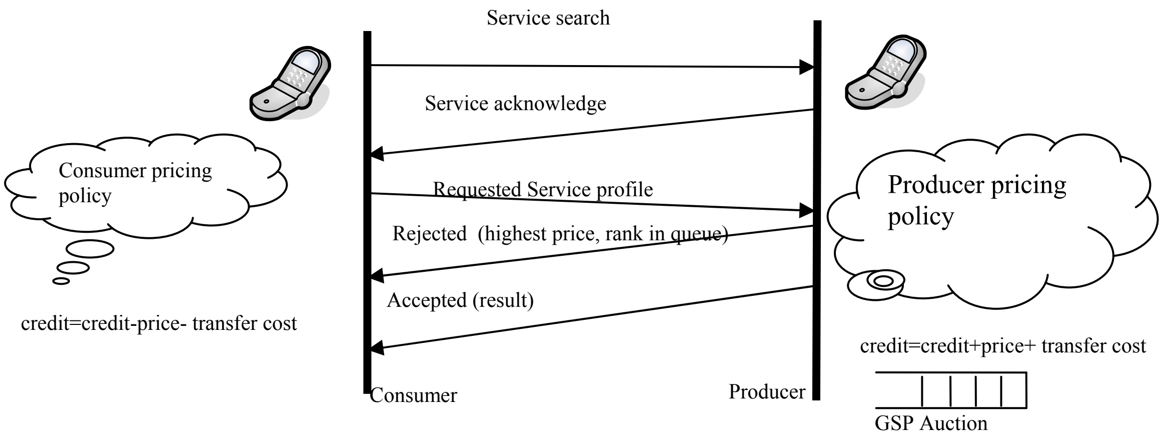

Figure 3: proposed protocol for computational economy on mobile phones

The main point of this protocol is that everything is done within our middleware, and so there will not be any frauds or problems relevant to the credit handling. In our architecture, we have some credit providers who have special phone numbers. At first, by mobile payment, by hidden sms's, or other ways of payment, the mobile phone's credit is charged by the mobile middleware that could be done anytime. There is another way to increase the credit, which is by serving other mobile phones, in this way, the service provider's mobile phone takes the credit of the service consumer's mobile phone.

In our proposed solution for choosing the price of the service, we have conditions of having more than one requests in the queue. If there is only one request in the queue, this request should be payed by its own proposed cost. This is the same as General Second Price Auction(GSP), which is proposed for solving the problem that people are not feeling to pay, more than the previous consumer. While we are doing this tender everytime, this tender process helps us reduce the messages for negotiations.

The negotiation is so costly in terms of the battery power usage in mobile phones. Consequently, we must reduce the number of messages sent during the negotiation. This protocol optimizes the use of battry power mainly in terms of wireless communication. We could have a local pricing policy, in which the service producer could set a lower boundary. In this way, if the derived price from the tender is lower than the lower boundary price of the local pricing policy, the service provider automaticly rejects serving.

In our proposed model, even the transfer has cost. This is because each mobile phone has a limited battery power. When the requester is sending a request for a service to the producer, they are usinge the battery power of the producer's mobile phone (specially in case of bluetooth and WLAN), so they should pay it. Furthermore, this price is so much lower than other services most of the time.

If in the tender someone loses in a stage, this consumer could have two options: first, he could wait some minutes, and if there is no answer, he will count on rejection. The other policy is that, he needs some information about the highest bid, and in this case he is also using the network medium, so he is charged. In our protocol, some information on time limit for returning the result, and a request indicator for answering the estimated time for the result return due to failing the bid, with information about the highest bid could be included.

The consumer's mobile phone, could also poll from the other mobile phones that have the same services. If they find the price of a producer unreasonable, he will not need to reject the service, while he himself proposes the price. After using some services many time, according to the user's preferences, the middleware could save the cost history of proposed services. In this way, middlware could recommend the user, the price, that is suitable for the bid.

In our proposed model, each mobile phone could act as a broker, a consumer, or a producer, which mainly depends on its competency, and the local pereferences of that person. The services proposed are autonomous, and people who provide them on their mobile phones, provide services according to their local policies. For the first time, the producer wants to set a low price for the service provided, they could calculate considering the expected rate of return, the estimated resource usage in terms of memory, disk space, and CPU time.

Each request from the broker has a request cost, and this request should have a higher cost than a simple service request, while we have mediator. Each broker could reject or accept brokering for a person which is mainly related to the proposed cost. After some activities of brokering, the broker will know what is the lowest cost that is benefitical for brokering, it could use the history, and autonomously set the policy for brokering.

Our proposed credit, is the monitory value representative, which is in the hands of a special person, who provides the credit. In this way, if the broker instead of using his Bluetooth which is free, uses sms, could go to the credit provider, and the credit provider pays him the monitory value by reducing his credit, so he could pay his bills. The credit provider could provide the credit by special hash codes through hidden sms's, but they should control the total amount of the credit in mobile phone middleware, for if the credit increases, we may have problems in resource utilization. Of course, this credit provider receives some money for the service they provide.

Each job has its own QoS need. This could be provided by our middleware, and it is included in mobile phone messages. If we have huge hierarchichal processes, which need to be done on several mobile phones concurrently and the final result is aggregated from the results from the involved mobile phones, we could leverage our model, for load balancing.

While there was no such a system previously developed for mobile phones, we can't compare this with similar systems our proposed middleware and protocols provide flexibility and extensibility. It is usable for both developer and end user

5. Conclusion

Presented was an economy based middleware to facilitate distributed collaborative computing on mobile phones; the proposed architecture also improves workload balancing. Supply and demand mechanisms provide the possibility of optimizing the different objectives of market participants, and provide them valuable pricing information. The term "computational economy" is used as a metaphor for the management and regulation of the supply and demand of resources.

This paper analyzed economic-related issues to provide incentives to collaborative distributed computing. We provided a model and protocol for facilitating these activities. The proposed economy service is the first step to enable trading of mobile phone computing services. We expect that economy driven approach to resource management will have impact on the success of mobile phone computing as much as we had on the Internet. There are still open issues related to welfare and allocation efficient sourcing of services and their adequate pricing and billing on mobile phones. While there was no such a system previously developed for mobile phones, we can't compare this with similar systems our proposed middleware and protocols provide flexibility and extensibility. It is usable for both developer and end user.

6. Acknowledgment

This research was created through a financial grant offered by Iran Telecommunication Research Center.

7. References

[1] W. Niu, L. Bai, "Business-based Enterprise M-Commerce Models", IEEE 2008.

[2] D. J. Xu, S.S. Liao, Q. Li, "Combining empirical experimentation and modeling techniques: A design research approach for personalized mobile advertising applications", Decision Support Systems 44.pp. 710–724, 2008.

[3] X.Zhang,"Design of mobile electronic commerce system based on J2ME", proc. International Conference on Electronic Computer Technology, IEEE. 2009.

[4] G.Liu, Y. Xu, "A New Grid Economy Architecture with Resources Pricing Fluctuation Module", Proc. The Sixth International Conference on Grid and Cooperative Computing, 2007.

[5] Ro.M. Piro, A.Guarise A.Werbrouck, "An Economy-based Accounting Infrastructure for the DataGrid", Proc. of the Fourth International Workshop on Grid Computing, 2003.

[6] M. Schwind, Ol.Hinz, R.Beck,"A cost-based Multi-Unit Resource Auction for Service-oriented Grid Computing", Proc. 8th conference of Grid Computing, IEEE, 2007.

[7] A. Caracas, J.Altmann, "A Pricing Information Service for Grid Computing", IEEE, 2007.

[8] Rajkumar Buyya, David Abramson, and Jonathan Giddy, "An Economy Driven Resource Management Architecture for Global Computational Power Grids", 2001.

[9] C.K.Chen, C.W.Chen, C.T. Ko, J.Lee, J.C.Chen, "Mobile Java RMI support over heterogeneous wireless networks: A case study", Journal of Parallel and Distributed Computing, 2008.