

Providing Data Grid Capability Using Society Network on Mobile Phones

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Abstract: *Today mobile phones are the most widespread devices in the world. The numbers of mobile phones today are, four times more than the number of PCs. This provides high potentials for providing some capabilities like data grid on mobile phones. Unfortunately, there is no suitable software system to provide this capability on mobile phones; however, we have enough hardware capabilities. All previous proposals called mobile grid only focused on hybrid mechanism, which at most mobile phones could conduct process, but all scheduling activities were still done on server. The hardware enhancement of mobile phones has become steady, and Moor's law is not applied to mobile phones anymore due to the limitation in battery power. In this paper, we focus on data grid capabilities, and try to provide the same functionality for mobile phones. Constraints of mobile phones make them unsuitable to port data grid on them, and we should change many mechanism in order to provide this functionality. We consider the non-functional requirements of mobile phones in our proposed system. We define a new concept society network, which is necessary to overcome other constraints of mobile phones. So far, there were not such a system developed on mobile phone, and our idea is quite new to the field.*

Keywords: *mobile phone, grid computing, society network.*

1. Introduction

Capabilities of mobile phones are the same as personal computers in early 90s. This guides us to the fact that much work could be done to enhance processing over mobile phones. This fact also applies to data delivery. Of course deep research has been conducted on grid computing [1]. No one has yet leveraged that research to enhance mobile phone platforms to provide data and service grid over them. Computational grids represent a new and rapidly evolving research area, which has gained a lot of attention in the past several years. A computational grid can be viewed as a transparent aggregation of many computing devices on a network that enables sharing of distributed resources. Typically, computational grids are considered in the context of sharing processor power of many computers interconnected by a wired network [4]. Mobile equipments are integrated either as mechanisms for interfacing the grid or as active resources for the grid itself. In the case of access mechanisms, every incoming mobile device is integrated in a completely transparent way; that is, the mobile user can access the grid and move within the environment without any manual configuration operation. In particular, the mobile user gets automatic access to services as soon as he enters the environment. In addition, whenever he moves within the environment, his device is automatically located and his context follows him [5]. Although concept of mobile grid has been investigated before [4-12], but this concepts, look at mobile

devices as terminal. In mobile grids, mobile devices computational, and memory power is also used, but still all grid activities were conducted still on servers, which are backbone of the grid. In this paper we are looking at mobile phones, as only infrastructure of grid environment, and redesigned mechanisms according to specific requirement of this new environment.

At the first glance, we may think that it would not be possible to have such a system on mobile phones, while most of grid mechanisms, need a high computational power specially for discovery, publishing [8][9][11]. Even replication mechanism [12] of data grid seems impossible to be ported on mobile phones. These all are rooted in two assumptions that we should change when we look at mobile phones. First, we should look at mobile phones as servers, not as a simple lightweight terminal. Second, we should change the goal of data grid for mobile phones. Data grid is provided for scientific data [4]. But on mobile phones, we should think about other data like tacit knowledge, the experiment that everybody has to help others, for example, knowing the best restaurant in London. These are people's experiences and usually put on forums on the internet but if people don't have time, what should they do? The solution is using their mobile phones, and it is the purpose of our paper, to provide the needed functionality on mobile phones.

There are many similarities between grid and mobile phones, which we could leverage in order to provide required functionality of data grid on mobile phones. First, grid resources are dispersed and we don't know where they are [1]. Thus, we need to have discovery services [11]. In grid, data are geographically distributed, and we have the same thing on mobile phones. We have heterogeneity in grid environments, and we have the same thing in terms of operating system, hardware, of course J2ME, solved this problem somehow. But the challenge that is not present in grid is the network heterogeneity. We have it on mobile phones as well, that means that mobile phones are not always connected to the internet like grids, and we should leverage different network infrastructures, like Bluetooth, WLAN, GPRS, and GPS in order to communicate [7]. This characteristic of mobile phone makes this platform more challenging. Although many works have been conducted on mobile grid, but mobile devices in mobile grid, use seamless network, like GPRS to connect to each other, but focus of this paper is on mobile Ad-hoc network (MANET).

Collaboration services enable users utilizing mobile devices to share information and communicate with each other. Research has been conducted on various models that support collaboration [4][13]. However most of these models are not scalable and depend on specific technologies, most of them were centralized, and have single point of failure, they are based on GPRS, and this imposed high cost on users, which makes these models unusable. Also they are not configured according to unique specifications of mobile phones, which we will discuss. Additionally these models are not extensible, meaning that they only support designated services. The models depend on an existing wireless infrastructure and operating within the range of a wireless access points. Ad-hoc or infrastructure wireless environments, allow users to make use of these services and not rely on a wireless access point. Reference [13] discusses the design and development of an extensible model to support collaboration services between mobile devices in a wireless environment. However their proposal is only focused on providing communication layer. In this paper we go further and defined detail mechanism of data grids for this environment.

We have the concept of autonomy on grids, that each site could have its own policy [1]. This is the same on mobile phones, while they are personalized; people want to have their own policies according to their mobile's capabilities, and their own preferences. It means that the same concept of Virtual Organization should be provided on mobile phones. The next point is resource sharing like grids that we wanted to use perishable computing services [1]. We have the same meaning on mobile phones that mobile phones together could provide a

huge amount of storage for providing data. The main challenge is that mobile phones should have a mechanism to handle distribution, which is much higher than grids. This distribution in grids is on different servers which have enough capacity around the world but we cannot have such thing on mobile phones, and distribution is dominant, than each capacity. The other characteristic of grids is that they are dynamic; nodes could join, or leave anytime [10]. This characteristic is more severe on mobile phones while they use battery power and wireless network, and this makes this platform highly dynamic. Any node could leave for the purpose of failure, or wireless network out of range, or battery drainage.

Apart from the similarities and differences we have previously mentioned between mobile phones and grids, we have more sever challenges in terms of processing power, and memory capacity. This makes this platform more challenging. Like grids [1] we could not have a single organization centralized control on mobile phones, they are not static. We should have the same thing like QoS concern on mobile phones, and we should let different mobile phones set their own policies.

In data grids we have a middleware which supports authentication, and authorization. We could do something much better on mobile phones by using SIM card's security. In grids we could check the status of data. Data management service includes metadata, indexing caching, reliable transfer. For information discovery and monitoring we are aware of available resource lists, we have the ability to put constraints on this directory, for relevancy, and the best suit resource, we have a publish status, and a list of available resources, and we have hierarchical information discovery service. We must provide the same functionality on mobile phones in order to have data grid capabilities on them, and this is our main contribution, that we will describe in next sections.

The system we provide on mobile phones should satisfy some non-functional requirements, which are: scalability, like grids mobile phone for the same characteristics should provide it; adaptability, which means the system should be adaptable for different user preferences, and device capabilities. Thirdly, it should be lightweight that means it should be optimized, while we have constraint in terms of mobile phones' processor and memory capacity.

Remaining part of this paper is organized as follows: Section 2 will discuss related works, on mobile grid. Section 3 discusses scenarios and requirements of data grid capabilities on mobile phones. Section 4 provides a definition of Society network, and explains why it is suitable for mobile platforms. Section 5 discusses our solution for data grid functionality on mobile phones. Moreover, it provides the details how differently the challenges should be overcome. Section 6 discusses the evaluation issue related to our proposed solution, and section 7 concludes the paper with highlighting our contribution.

2. Related work

Mobile grid means that movable wireless devices are integrated into traditional wired grid through wireless channel to share grid resources (CPU power, storage capacity, instrument, devices, data, software, etc), meanwhile, mobile devices can provide service or resource to grid users, such as PDAs, cellular phones, handsets or wearable computers, laptops with GPS service, mobile service, etc [4]. The main drawback of mobile grid is they still use current grid infrastructure of grid, and they should connect to this infrastructure. This means people should pay high cost, due to high cost of internet data exchange on mobile phones. We tried to solve this problem to redefine data grid only on mobile phone, and without basing our infrastructure on current infrastructure, and consequently, having lower cost of communication.

Reference [4], present a prototype of a grid-based problem-solving environment for wireless mobile devices with limited processing power. Its primary purpose is to allow mobile devices with limited resources to solve problems that they would not be able to solve individually. This goal is achieved by redistributing the computational load among many computing devices. Reference [5], presents a middleware infrastructure able to integrate mobile devices in the grid. As a matter of fact, classic grids do not provide mobile users with support to access resources and services at all (i.e. classic grids consists of wired, pre-configured, powerful stations). Moreover, whenever a user wants to execute her own application, she typically has to: (i) ask the grid for resources; (ii) allocate tasks; (iii) launch and control executions; (iv) get results; and (v) release resources. Reference [6], proposes a MABS platform on the computational Grid for mobile distributed computing. The findings of the experiment show that a Grid based MABS platform can provide a scalable simulation environment for mobile distributed applications. Mobile grid combines mobile computing and grid computing and develops rapidly. Reference [7], provides design of a general architecture of mobile grid, illustration of mobile grid architecture design principle, presentation of a novel architecture, analyzing of the mobile grid constitutes and logical structure. It also discusses mobile grid resource and service management and allocation mechanism from description, discovery, security, QoS and selection and assignment factors, etc.

3. Scenario for data grid on mobile phones

The first question is why we really need data grid on mobile phones. The aim of data grid was providing transparency, and share resources across the world, with the core concept of virtual organization. That platform includes huge data related to genes, huge financial data related to financial markets, or huge astronomical data. Scientists use these dispersed data through grid.

We do not have such a thing on mobile phones, and they are not even suitable for this kind of job. Mobile phones are portable. Thus, they are very useful, when it is difficult for you to use your laptop, or terminal to your server, when you do not want to bother yourself to go and find a PC to handle your job.

Mobile phones are ideal tools for tacit knowledge sharing. Although people usually have knowledge about something, they do not bother themselves to share it and it is difficult for them to open their laptop to write tacit knowledge they have. People have so much free time during the day, for example when they sit in a bus, or when they are at a beach with their family, or on a journey. This free time could be used to insert their tacit knowledge on their mobile phones.

Let us explain ourselves with a scenario: You have a cardiac problem, while your doctor is not aware of that. You know the pain is definitely there. Most of the time, you ask your family members if they know a good doctor. It is the tacit knowledge between people. They have experienced many doctors in their lives but they have never written who they think is better for a specific problem. The idea is that, your mobile phone uses data items related to this area by interacting many other mobile phones automatically while you are doing your ordinary job during the day.

The other scenario could be when you need to use some heuristics to enjoy buying well suit stocks in a stock market. If people have good heuristics on this domain of time, why do not you use them?

The other scenario is when you go to London, in a specific area in the town. You have a meeting and you intend to go to a good restaurant in neighborhood. If other people provide this tacit knowledge, and you consume these data services, the world becomes a heaven. You

may want to go mountain climbing in a specific mountain then you can use the tacit knowledge of the people you have never met. In the middleware we have provided, you will be able use it?

You may have asked these questions previously in forums on the internet. However, people usually do not have enough time to check forums. You may be on a trip, and it is difficult for you to open your laptop, and you may see many people, in your society network, you can just leverage this new channel. Additionally, this new ability will provide usability for publishing tacit knowledge.

4. Society network

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 could be seen 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 data grid 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 don't 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 commerce without the middleman (operators).

After that we have SMS, which is accessible from anywhere, but has a shortcoming in terms of cost and middleman controls and regulations. The third suitable choice is WLAN which is also free and suitable, with the ability to connect to the internet, and the fourth one is GPRS, due to having a high cost of transfer; it makes it difficult for a normal application to communicate.

To overcome the shortcomings of each of these options there is a solution, which is a software layer over them for roaming [6] transparently, so that the application over them would not 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 preferences 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 services.

5. Proposed solution for data grid on mobile phones

The main requirement to provide data grid on mobile phones is publishing service. The main issue is how to publish data on mobile phones, especially on society networks. In Grid we have a distributed system consisting of replica metadata, replica catalog, replica search, replica selection, replica location, replica location index. Grids provide a hierarchical system, and while we have a seamless network, on grid, this is possible, but our proposed society network is not seamless, so such solution does not work. The broader challenge is that we do not even know the topology of the society network.

What we propose is an adaptive request/response method. Each person could request a specific data item. In our proposed system, if it does not receive a response from the approximate mobile phone, the request could become persistent on their mobile phones. If they change their places, and new people locate in their proximity, which means they become members of their society networks. Then, they ask this request, as an agent of the previous mobile phone. Finally, if they get the requested data, they could send that to the person next time he locates in their proximity, or they could save the address of that person and send him, the response through an SMS, or send them the address of that person who owns the requested data.

Our adaptive request/response method keeps track of data items, which is done by the provider of data. In this case, if the provider of data finds out that this mobile phone asks for specific data more than a specific threshold, the replica could be created on that mobile phone according to local policy of the requester. Thus, after a number of times, the optimal place of the replica could be found, and this could be used by the requester. Our approach consists of two main parts, firstly the queue, which preserves the request until it is responded, or the deadline expires. The second part is the self aware data, which put addresses of the requester in their cache, and if the requester asks for the same data more than a threshold, it will provide the replica on that node.

This queuing also helps us to have routing information on mobile phones; it means that, each intermediate node that keeps the information requested for some time could keep track of who answers this request. Instead of broadcasting the request in next stages, it will send the request to a specific address. This address could be either intermediate or final.

You may think that this approach only solves the problem of not having a seamless network, what about the lightweight requirement of an application. What we propose is using a mechanism like cache; we could implement Least Recently Used mechanism. Each service could only have a limited cache that could be configured according to a specific mobile phone's requirement. We will explain this issue, later in this section.

The solution provided previously, was only a post solution, which means it is adaptive, but what we could do for the first time, when we do not have any routing directives, and no replica is the main challenge. What we propose is to first having a hierarchical structure, which could be adapted then. We could have a domain and some sub domains. At

first, this network is configured with people's expertise. For example, when you are a computer engineer, data requests related to the computer domain, are routed to you. People themselves could configure this routing table according to their knowledge. For example, Jack knows his friend Jenny, who is computer engineer, so it configures his routing table accordingly, and so when a request for computer came to his mobile phone, this request will be routed to Jenny's mobile phone, automatically according to configuration. Consequently, the primary table could be constructed, and then it would be adapted according to our approach. This is the same thing we do in our society. For instance, when our friend has a specific illness, if someone with the same illness wants to know who the best doctor in this field is, we guide them to our friend. Our contribution is that we make this process automatic.

In our adaptive approach, we perform omissions, which mean if more than some time we send someone a request and they do not answer, that next time the probability that we send our request to this person will decrease. Our approach uses probability that is a number between 0 and 1. Moreover, our adaptation is done by simply calculating the number of time we did calculation over the number of time we requested for each mobile phone.

To complete our approach, for lightweight services, which means the content data is only a small number of an SMS volume, the requester, himself, could have a list of popular services. As a result, he could ask for the service through an SMS, which is something like having a phone book for data services.

We have two kinds of identifier in our system. The first one is a UID for each user, and the second one is a DID, which is for data, and both are unique over our platform. They are simply calculated by mapping user/data metadata to one number. We will discuss the shortcoming and solution related to searching data in this section.

The request for specific data roams over a society network. We should have a mechanism to trust the data that we acquire. For this purpose, we propose a rating mechanism that different people rate one person, in a specific domain of knowledge. This could be done first according to the previous knowledge or afterwards when people use data services. This rating mechanism could also have negative effects on the rate of each data provider. As far as according to economical theories, large people could not coalite, this rating could provide a solution for the challenge, since we have a high distribution.

We also define the shortest path optimizer over a society network. Thus, we put the depth of request in each request that is the number of people this request is roamed over, and if it exceeds a certain threshold, then the request will be discarded. We could also put the availability of a specific person, and the time it takes to response the data request, and optimize routing table accordingly.

Additionally, we have a credit mechanism in our system. Each person has a specific level of credit by default. Later on, according to data services this credit system could exchange the credits of people. This system prevents people from free riding, this is somehow an incentive mechanism, and if people want to use tacit knowledge of other people according to this system, they should also provide tacit knowledge to others. The primary credit is provided in order to provide liquidation to the platform, but its price must be investigated.

The search service is not a big deal for grids, but when it comes to mobile phone platforms, it is challenging, because mobile phones do not have enough processing power, and they do not have access to huge metadata related to data items. Even if we want to have a simple search over mobile phones, the input capability is very limited, and makes it difficult to search over them. What is the solution for mobile phones? If we cannot search, then there will not be any data grid over mobile phones.

We think we should use the PC platform to provide search, but on mobile phones, each data has a specific DID as we explained before. We leverage a PC platform just to find DID. Since the data we are searching for could be repeated over time, a simple mapping of

domain, especially ontology to data items, could solve our problem. This mapping is between metadata and DID by using hash functions. But let us review our scenario. If a person does not have time to reach a PC, what should they do? We could have two solutions. At first, a centralized service exists, which you can contribute by SMS. There could be an automatic machine in that center, which according to your history of preferences helps you. Secondly, there could be a person behind SMS system or you can use a call center to find out DID.

A question may be raised, that doesn't our system, contradict its aim? If we could find the index from the computer, why should we use a mobile phone? The point is that, we have tacits on mobile phones and we do not search for tacits on PCs, we just search for DID domains, and we could have many versions, created by many people about this DID. Each mobile phone also has a cache of favorite domains, thus, it should not refer to the search system for DIDs.

We have different data items, in our system, with many replicas, but how could we handle consistency? First, only a person who provides data could change it. Data items have versioning systems, they have a field called validity of data, which we explained before, and searching for a special DID could have the characteristics of validity, which means that if the validity of data is lower than the threshold of the query, it will not be sent.

Each data item has a creation time that will be returned with that data, this could help the requester to decide whether it is valid for his request or not.

Each mobile phone has its own replica policy. According to that, it will let the data producer whether replicate the data over it or not. Replication could also be done by a pull model, which means the person who requests the data after using it, could publish this data as a replica; it will also advertise itself to the approximate node by a push model. The point is that each mobile phone has its own policy to accept the pushed or advertised data.

Since we have no updates, everyone could provide data items through changing previous data items. But the point is that, they would be creators, and should consider rating, which will have effect on their credits. Each mobile phone could have a data invalidator, which means if the validity of a replica becomes lower than a certain threshold it will be omitted.

Each data item could have an expiration time attribute. This is very good for news, and data that need to be overwritten periodically, it is used by data invalidator for replicas; update time attribute could be used also by replicas, to be updated or omitted.

Finally, all data in our system are broken into SMS size data, and the production is done based on it. Large data are broken into multiple SMSs, so apart from DIDs, they have a package number, which is used to find different packages, from multiple sources, and then reassemble them in the last node.

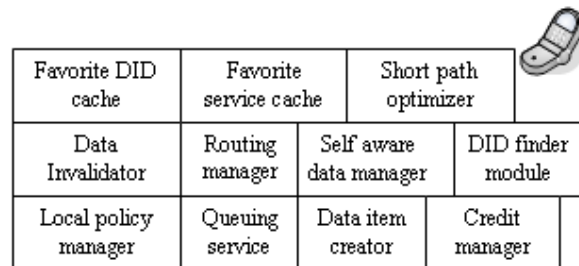


Fig. 2. Proposed System Modules

Figures 2 shows our system modules, detail of their interaction as well as mechanisms described in the text.

6. Evaluation

To evaluate our system, we should first have other systems to compare with. Unfortunately, there is no such a system to compare with, and also previous works on grid were not suitable for this platform due to the unique characteristics of this platform. But we compare the proposed system with non-functional requirement of this specific platform.

Being lightweight is the main non-functional requirement, which is supported by our layered architecture. Modularity of proposed system provides flexibility, and adaptability. This modular system could provide even lightweighness, which means someone who has a mobile phone with a higher memory and processing capacity can install more modules, enjoy the optimized application, and less battery power usage. Our proposed system also provides adaptability, which means the threshold of caches and other parameters could be set according to special devices' requirement.

Our mechanisms are optimized and less computation, and more distribution, makes it more suitable for mobile phones platform. Additionally, our platform is scalable, since our mechanisms are configured for distribution, and do not depend on central components.

7. Conclusion

Today mobile phones, are widespread, however there is no software system to provide data grid capabilities on mobile phones. Most previous works were focused on looking at mobile phone as terminal devices. We changed our view, and look at mobile phones as servers, we defined the concept of society network, which could be leveraged to enhance mobile phone data grid capabilities. Our contribution was redefining mechanisms of data grid modules on mobile phones. Due to unique characteristics of mobile phones, previous solutions are not suitable, and we define the mechanism ourselves. Our publish service was not done globally like grid, but we use locally published self aware data items' concepts. Our approach is adaptable, and makes the performance better overtime. We used caches, to improve performance. Our architecture provides flexibility, adaptability, and performance for mobile phones.

Our work could be enhanced by investigating thresholds for different mobile phones. Moreover, incentive system, like grid economy should be developed in order to launch the system, and prevent free riders.

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