Emerging Issues in Wireless Computational Grids for Mobile Devices

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Keywords: wireless, grid, mobile, resource-sharing, issue, network instability, mobility, quality of service, dependability, handoff.

EXTENDED ABSTRACT

In simulating resource-sharing in order to complete a computationally-expensive task by a grid of wireless mobile devices, we uncovered significant issues hitherto considered trivial. This paper aims to provide a survey of the emerging issues as they pertain to our wireless grid infrastructure [3].

An important factor influencing task execution time is the mobility of the devices. Higher mobility is a critical factor affecting the grid performance. In other words, if the devices in the grid are highly mobile, this adversely impacts the time taken to perform a computationally-intensive task. A related issue is that of subordinates and/or the initiator leaving the cell while partial tasks are still in progress[1]. Currently, if the subordinates involved in working on partial tasks leave the grid, the Brokering service re-allocates the partial tasks to other subordinates in the grid. If this approach is modified to allow the subordinates to carry their partial tasks with them when they leave the grid and migrate to a new service area, then handoff issues become non-trivial. When the initiator of a task moves to a new area, the brokering service in our architecture is currently programmed to abort all partial tasks associated with it [6]. However, if the grid were architected differently to facilitate task completion when the initiator has migrated, handoff issues become a significant management issue.

Soft handoff has to be assured in order to be compatible with today's 3G technologies; soft handoff ensures that the user is unaware of the underlying issues involved with initiator and subordinate migration. The issue of mobility is interconnected to the issue of Quality of Service (QoS) [9]. The long-term goal of the wireless grid is to provide the same QoS to mobile users as experienced by wired users. Soft handoffs aids in improving wireless QoS and should, therefore, be addressed by our wireless grid architecture. The inherent unstable nature of the wireless network causes additional challenges. Due to the inherent characteristics present in wireless networks, frequent disconnection may result in poor QoS. If such abnormal disconnections are anticipated and planned for, mobile devices can expect better QoS than currently in existence. Abnormal disconnections need to be considered in order to address another important issue: network instability.

The nature of the wireless medium and the mobility of the devices cause network instability [8]. Interference can be caused in the wireless channels of communication due to atmospheric disturbances such as electromagnetic storms or environmental factors such as rain. The mobility of the devices involved in the wireless grid can cause network instability because the underlying services, such as the Brokering service and the Keep-Alive server, can be quickly overwhelmed if a large number of devices enter the grid at the same time [1]. By the same token, a large number of subordinates leaving the grid at the same time could also cause the network to become unstable due to the temporary lack of sufficient resources. Techniques to balance network

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[1] In our grid architecture we use the following terminology. The initiator is the device in need to solve a computationally-extensive task. All devices willing to share their computational power are referred to as the Subordinates. Brokering Service is a part of the grid infrastructure responsible for allocating tasks to Subordinates and coordination of the task execution.

loads work toward mitigating temporary imbalances of a bursty nature. Load balancing techniques used in wired networks can also be modified to restore stability in wireless grids.

Users of mobile devices use the buggy and often expensive technology for convenience and flexibility. Since convenience is a predominant factor in the growth of mobile devices, it has driven the characteristics of the devices, such as screen size, overall size, processing power and battery power. Mobile devices are dependent on battery power for their functioning [4]. While mobile users demand longer lasting batteries, they do not desire to carry bulky spare batteries. Since mobile devices consume more power when connected to the network, the grid does not require wasteful high-volume network traffic. The design of the wireless grid architecture assumes that subordinates have sufficient power to accomplish their partial tasks. With advances being made in longevity of batteries, power dependency is not as critical a factor as mobility and QoS issues.

Mobile users also drive the tendency toward greater transparency in applications. Transparency in a computer system implies hiding irrelevant details of implementation from the users of the system. Transparent access to grid-based aggregation of computing power grants mobile devices with limited resources the means to obtain results of computationally-intensive tasks by harnessing the collective resources of the grid. Because it shields the user from the system's complexity, the proposed grid-based model provides transparent access to shared resources. With wireless and mobile technologies prevalent in the mainstream, it is imperative to encapsulate the abstract and complex working of the underlying resource-sharing architecture.

If users should not be made aware of the inner workings of the architecture, then the intermittent connectivity suffered by wireless environments needs to be supported as a routine design element. If intermittent connections are not supported, the user becomes aware of the underlying network and connectivity issues [10]. Planning for and recovering from sporadic connectivity provides a seamless and transparent access experience to users. The grid-based problem solving model attempts to encapsulate the complexity of the underlying architecture from clients of the resource-sharing services. The issue of soft handoff explored earlier in this paper is interrelated to the issue of transparent access. Initially cast aside in a simplifying assumption, we were challenged to explore the issue of seamless handoff further after starting the simulator [2]. Handoff mechanisms underlying the protocols used in our grid model ensure a smooth, transparent transition to the next cell if the Subordinates or the Initiator moves out of range of the grid. The user is unaware of the change of control. In a heterogeneous environment of different types of devices running different software, participation in the grid necessitates management of transparent access.

The issue of data loss can be critical when more than one mobile device participates in task-sharing. Since an intensive task is divided into small partial tasks for distribution across the grid, latency in handoffs is a key issue. In a resource-sharing environment such as the wireless grid, loss of data can result in potentially erroneous outcomes. When the Initiator requests that partial tasks be distributed by the Brokering Service, the Subordinates need to obtain correct data in a timely manner to complete the sub-tasks and return partial results to the Initiator so that they are useful and arrive in a well-timed fashion. Otherwise, the usefulness of the grid will be limited as users will be hesitant to share tasks in a latent and error-prone environment.

An emerging issue in networking environments today is that of availability. Grid participants need reliable indicators of dependability of services. According to [5], dependability can be defined as the trustworthiness of a computing system. If a system is dependable, we can rely on its service. Reliability of the system and availability of services are chief attributes of dependable systems. While the wireless grid can be used for computationally-intensive tasks, it must also be dependable if it should become pervasive. Dependability is particularly important for applications such as financial transactions and mobile inventory management. How frequently the components in the grid fail will undermine the availability of services. Since constant uptime is the goal, the grid-based model has to be designed to maximize fault tolerance. The security of mobile transactions across the grid can also be impacted by frequent component failure or high mobility [10]. In our architecture, if the Subordinates involved in working on partial tasks leave the grid, the Brokering service re-allocates these partial tasks to other Subordinates present in the grid. When the Initiator of a task moves to a new area, the Brokering Service is currently aborts all partial tasks associated with it.

Grid dependability is directly correlated with QoS issues. High reliability and fault-tolerant design in the grid-based model facilitate in improving wireless QoS. An efficient method to increase dependability is to have redundant components for critical infrastructure in the grid. If users are switched to a standby component in case of a fault, then dependability levels are increased and availability to grid-based services or network uptime is maintained at pre-fault levels. The two main causes of poor dependability are improper flow control and ineffective congestion control [2]. In our architecture, the flow of data to the Subordinates and the flow of partial results from Subordinates to the Brokering Service are managed efficiently to ensure the security of rid traffic and fault-tolerance of the services. With the assistance of the Keep-Alive Server and synchronous management of the Brokering Service with the mobile devices, the proposed model manages the flow of data in both directions.

In conclusion, simulation of a parallel IDA* search algorithm to prove the feasibility of a wireless grid resulted in elaborating on resolution of several important issues described above. According to the classification of grid applications mentioned in [7], pipelined and synchronized applications are computationally-intensive and are distributed across devices participating in the grid. An example application of this class, the parallel IDA* search algorithm, can be solved in parallel and lends itself to a sub-optimal solution. Results from the simulation are expected.

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