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A Review on Wireless Grid Computing

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***Abstract*— Grid Computing is a concept, a network, a work in progress, part hype and part reality, and it is increasingly capturing the attention of the computing community. It uses clusters of personal computers, servers or other machines. They link together to tackle complex calculations. In part, grid computing lets companies harness their unused computing power, or processing cycles, to create a type of supercomputer. Wireless grids extend the capability of grid computing to wireless devices. The number of users using laptops, PDAs, cell phones, and other wireless devices is increasing leading to more networked wireless devices, and creating a vast collective potential of unexploited resources. Wireless grid computing with its model of coordinated resource sharing may provide a way to utilize such resources that are normally distributed throughout a grid. We may have Gridnet in the future as we have Internet today. This paper presents a state-of-the-art review of wireless grid computing.**

***Index Terms*— Grid computing, Wireless grid computing, Grid standards.**

I. Introduction

Grid computing [1], [2] is an important and developing computing initiative that involves the aggregation of network connected computers to form a large-scale, distributed system for coordinated problem solving and resource sharing. By spreading computing workload across the distributed system of computers, grid users can take advantage of enormous computational, storage, and bandwidth resources that would otherwise only be available within traditional multiprocessor supercomputers. To give an analogy, grid computing is similar to power grids, where user does not need to know anything about what stays beyond the socket. One can absorb all the power he/she wants according to the agreement with electrical society. Grid computing has attracted worldwide attention in a variety of applications ranging from physics, chemistry, environment, aerospace and healthcare systems [3], [4].

Wireless grid computing is evolving because of the fast developments in wireless technology and grid computing technology. Wireless grids extend the capability of grid computing to wireless devices. Wireless grid computing supports sharing of these resources by mobile, and fixed wireless devices within the virtual organizations. It may include devices like laptops, mobiles, PDAs, sensors, etc., while the resources of these devices can be processor, memory, bandwidth, code repositories, softwares, etc. [5].

Generally wireless devices are characterized by reduced CPU performance, small secondary storage, heightened battery consumption sensitivity, and unreliable low-bandwidth communication. But these devices also may include such additions as cameras, microphones, bar code and RFID readers, GPS receivers and satellite receiver/ transmitters as well as a wide variety of special purpose sensors. Among the many types of sensors currently available are those that measure temperature, air pressure and humidity, those that detect movement, and those that measure radiation and particulate levels.

In general characteristics of wireless grid can be summarized as follows:

- No centralized control.
- Consists of small, low powered devices.
- Includes heterogeneous resources, applications and interfaces.
- New types of resources like cameras, GPS trackers and sensors can be shared among grid devices.
- Dynamic and unstable users / resources.
- Geographically dispersed resources, with different management policies.
- Different security requirement and policies.

The reason for increased scope, popularity, and usage of mobile wireless devices is their small size, low cost, easy handling, and mobility. The device mobility facilitates the user to transparently share the grid resources, execute their tasks, and obtain instantaneous results while they are roaming. Rapid advances in miniaturization, increasing processing power and feature-rich operating systems and applications, along with the proliferation of wireless access points have quickly expanded the usefulness of these devices and made them increasingly capable of taking part in grid networks. The rapid drop in the cost of wireless devices, coupled with the ease of installation for fixed location use, has made them a cost-effective option for small business as well as the general public for mobile use and for home networking [6].

Wireless mobile devices have become an indispensable tool for businesses large and small, especially those where employees must perform their duties away from the office such as field workers or sales representatives [7]. The increasing reliance on these devices has increased the pace at which applications for these devices are developed, as well as expanding the scope and functionality of these applications. As more of these devices are deployed, more potential uses for them are being identified.

While the Grid is the best way to achieve large-scale resource sharing in a heterogeneous environment, the mobile community has to face many challenges to enter this

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application domain. The integration of mobile devices is extremely challenging because of the many deficiencies that wireless communication and mobile devices have. Wireless networks are of low bandwidth and reliability, while mobile devices have much less resources available than desktop computers. Since the purpose of the Grid is to provide a highly available, consistent and ubiquitous environment, integrating mobile devices into the Grid, through wireless links, could degrade all relevant quality of service requirements.

Following an introduction the rest of paper is organized to include wireless grid architectures in section II, challenges in section III, applications in section IV, tools and standards in section V, and finally conclusion in section VI.

II. Wireless Grid Architectures

Wireless grid architectures can be broadly classified into the following four categories [7, 8] based on the devices predominant in the grid and the relative mobility of the devices in the grid.

- Fixed Wireless Grids
- Mobile or Dynamic Wireless Grids
- Ad Hoc grids
- Sensor Network Grids

Fixed Wireless grids: The wireless grid extends grid resources to wireless devices of varying sizes and capabilities such as sensors, laptops, special instruments, and edge devices, where these devices are usually static. In wireless grids, wireless devices can act as real grid nodes where part of data processing and storage is taking place. In a special type of wireless grid, all wireless devices are considered pure access devices without processing or storage capabilities [8]; required resources are obtained from a wired, resource-rich backbone grid. Many technical concerns arise when integrating wireless devices into a grid. These include low bandwidth and high security risks, power consumption, and latency. So, several communities, including the Interdisciplinary Wireless Grid Team (www.wireless grids.net) are exploring these new issues to ensure that future grid peers can be wireless devices.

Mobile Or Dynamic Wireless Grids: Mobile grids make grid services accessible through mobile devices such as PDAs and smart phones. As the processing power and other capabilities of these mobile devices increases, researchers and commercial organizations are discovering new ways to use and share their resources. When the large numbers of available wireless devices is considered, the potential of these dynamic ad hoc connections becomes vast [9]. Through wireless grid connections, these devices are able to connect to the Internet, provide peer-to-peer networking, take advantage of the resources of wired grid networks and make their own resources available to the wired grids [7].

In emergency situations, such as during natural disasters and on battle fields, wireless mobile devices might be the only available communication and computation services. The mobile devices integrated into grid systems can actively participate and provide computational or data services [10]. These mobile devices also serve as an interface to a stationary grid for sending requests and receiving results . Sometimes this approach is labeled mobile access to grid infrastructure, or simply mobile access grids. Recently, researchers have made numerous efforts toward establishing mobile grids. Researchers have proposed various techniques for implementing the mobile grid vision, including centralized and P2P structure, intelligent mobile agents, mobile grid middleware, and many more [10]-[13]. Existing mobile grid projects include Akogrimo (www.mobilegrids.org), and MADAM (www.intermedia.uio.no/display/madam/Home).

Ad Hoc grids : Mobile ad hoc network consists of devices with a high degree of heterogeneity. These mobile devices range from relatively powerful computing systems carried by a vehicle, to very tiny, low-power sensors that can be implanted in the human body. Although they may know little about the identities and capabilities of each other, a group of mobile devices are able to organize a highly dynamic and infrastructure-less ad-hoc network, in which nodes can communicate in a hop-by-hop manner. We have to integrate the resource aggregation model of grid with mobile ad hoc networks, so as to build a mobile ad-hoc Grid platform that can be instantly constructed anytime, anywhere [14]. Having been constructed from a group of mobile devices, an ad-hoc grid would allow the networked devices to accomplish a specific mission that maybe beyond an individuals computing or communication capacity. Examples of applications of mobile ad-hoc grids can be disaster management, wildfire fighting, and e-healthcare emergency, etc. The general attributes of mobile ad hoc networks can be extended to ad hoc grids and hence ad hoc grids are attributed by bandwidth and power constraints, multi-hop delivery, network partitioning, and infrastructure unpredictability.

Sensor Network Grids : Sensor networks are composed of tiny devices that are generally dedicated to a single purpose. Though each device in the grid is dedicated to a single purpose, the grid itself may be comprised of a number of different types of devices in order to accomplish the goals of the particular grid. As described in [15], wireless sensor networks integrate detection, processing and communication into the grid. The sensors taking part in a sensor grid may be stationary once they have been deployed [16] or they may be mobile. Sensor networks are currently in use monitoring environmental factors such as temperature or humidity change, motion and light intensity. The developments in sensor networks is leading to advances in agriculture, physical building security, firefighting, warfare and a number of industrial areas. Wireless sensor network that can be deployed in residential and commercial buildings to monitor human presence and turn off the lights when no people are detected [17], is under development by Dust Networks of Berkeley, California. RFID technology to track products from manufacture through distribution and delivery and, potentially, to the consumers shopping cart leaving the store [18], is developed.

III. Challenges In Wireless Grids

Due to mobile nature of wireless devices and limitations of wireless communications a number of unique challenges must be overcome when building a grid application for such devices. Applications must be capable of adjusting to frequent disconnections of specific devices from the grid. Large distributed grid systems pose new challenges in job scheduling due to complex workload characteristics and system characteristics. Due to the numerous parameters that must be considered and the complex interactions that can occur between different resource allocation policies, it encounters lot many challenges. Some of the requirements and challenges of wireless grids are discussed in brief as follows.

- **Resource status monitoring:** Monitoring is the act of collecting information concerning the characteristics and status of resources of interest. Monitoring system must be able to provide information about the current state of various resources such as static, and dynamic resources, and generate alarms whenever certain important events occur. It is responsible for monitoring the overall health of grid. To provide an up-to-date resources status information a device can be monitored either continuously or periodically or when some event occurs. Some works are done to address this issue. Globus toolkit consists of monitoring software called Monitoring and Discovery System (MDS) [19]. The information sources are registered to index servers in MDS [20]. The users can query directory servers to obtain detailed descriptions about resources. Three different methods called as regular, skewed, and interleaved methods are proposed in [21] to monitor resource status of a device in wireless grid.
- **Resource status updation and communication** : In order to keep up-to-date resource's status, a continuous monitoring is needed. The increase in number of status delivery of such monitored observations will consume lot much of bandwidth, making the database size of monitoring server to grow continuously over a period of time. So it is very much essential to keep track of only relevant changes and communicate instantly. In the paper [22], a Grid Resource Information Monitoring (GRIM) prototype is introduced. To support the constantly changing resource states in the GRIM prototype, the push-based data delivery protocol named Grid Resource Information Retrieving is provided. To monitor grid infrastructure and to maintain system-wide invariants and detect abnormal events with minimal communication overhead, paper [23] presents threshold based distributed triggering mechanism. The work given in [24], [25] solved the problem of detecting threshold violations with specified accuracy while minimizing communication overhead, as well as providing the flexibility for users to trade off communication overhead with detection accuracy.
- **Authentication and Authorization of device/user:** Since the system is built upon a wireless and pervasive network, it will be more difficult to perform authentications and to provide general security mechanisms. The authentication of devices and users as they enter the grid presents additional complexities in wireless grids. To access any grid resources or services, each device and user has to be authorized. Though a number of researchers have recognized this difficulty of identity verification in ad hoc wireless grids, few solutions have been forthcoming. The current accepted identity management mechanism relies on the same digital signature certificates in use on the wired Internet. The works given in [9], [26] discuss the need of this issue.
- **Resource description** : It is the formal process to describe the resources to be shared. The heterogeneity of grid devices, operating systems they use, services they provide, data they represent needs a standard to describe the resources so that any wireless grid can utilize the services. Some standards for resource description [27] include XML, RDF, and OWL.
- **Resource discovery**: The concept of resource sharing in grid computing is realized by service discovery mechanisms which transparently and seamlessly locate available resources/services throughout the grid infrastructure upon request. Since user wants the service as faster as possible at reasonable cost, service discovery becomes more important issue in grid computing [27], [28]. Hence proper publishing, indexing, and cataloguing of shared resources become very essential. Standards such as GRDL, WSDL etc. are available for resource discovery.
- **Resource allocation:** Since these wireless devices are more constrained in their processing power, memory, and bandwidth, many users compete for these scarce resources. Some economic market model is preferred to allocate the resources on price basis. Proper job scheduling and/or resource allocation becomes very crucial in order to provide efficient service to grid users. A survey on resource allocation in service oriented grids is presented in [29]. Resource allocation has to be done following the administrative policies, and the conditions under which devices will extend access to other devices.
- **Routing of messages through the grid**: This area is concerned with the reduction of power consumption but through efficiency in the routing of messages. A second concern is the reduction of message latency.
- **Power consumption** : Since mobile devices are resource constrained, identifying techniques to reduce power consumption to extend battery life while retaining acceptable levels of service is an issue. This is particularly important in wireless sensor grids due to the small size of the sensors and the difficulty of replacing those that fail. The work presented in [30] -[32] discusses about reducing the power consumption and routing the information via the paths that reduces power consumption.
- **Mobility**: If the devices in the grid are highly mobile, it will adversely impact on the time taken to perform a computationally-intensive task. The mobility of the devices causes network instability leading to poor QoS. In a resource-sharing environment such as the wireless grid, mobility causes loss of data resulting in potentially erroneous outcomes. The work in [12], [13] described an impact of mobility in wireless grid environment and presented an architecture that tries to minimize the negative effects of mobility.
- **Information Security**: Security of the information processed by the application is another main issue. Due to their wireless nature, devices in the grid communicate and pass information over standard radio frequencies that can be easily tapped. A number of encryption standards such as WEP and WPA have been devised to ensure data security and integrity over these otherwise insecure transmission frequencies.
- **Fault management**: The frequent failures of mobile nodes

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or communication links would always negatively impact the performance of the whole system. The issue of managing the fault that may occur because of device mobility, battery failure, or sudden switch off of a device is of major concern.

- **Energy-efficient medium access**: The media access schemes must use low-power communications and must be able to maintain higher throughput and lower delays. An energy efficient MAC protocol for wireless sensor networks is presented in [30]. Energy consumption is crucial for the lifetime of battery-limited mobile devices as well as the whole system. To make Grid functionalities feasible in the network of mobile devices, energy efficiency should be the major concern for their implementation in each node.
- **Communication Paradigms**: The complex environment and the mobility of the devices can lead to frequent disconnections in the wireless grids degrading the performance. Hence a proper communication methodology becomes more essential. The traditional communication approach called *Socket programming* is not suitable for complex environments in which security, heterogeneity issues are to be considered. *Remote Procedure Call (RPC),* is a classical approach for client server communication. While RPC is well suited to the procedural programming paradigm, it is not directly applicable to the object-oriented programming style that has gained much popularity in recent years. So *Remote Method Invocation (RMI)* is evolved that integrates the distributed object model into the Java language in a natural way. In RMI Remote objects can be passed as parameters in remote method calls.

Distributed Component Object Model (DCOM), is an extension to COM for distributed client/server applications [33] and uses a protocol called Object Remote Procedure Call (ORPC) to invoke remote COM components. *Common Object Resource Broker Architecture (CORBA)* is an object-oriented middleware infrastructure for distributed client/server applications. It uses Internet-Inter ORB protocol (IIOP) to invoke remote objects. Now a days other communication paradigm called as *Agent Technology* is of more interest. Software agents are the autonomous programs situated within an environment, which sense the environment and acts upon it to achieve their goals. The paper [34], [35] describes agent's properties, and different agent platforms.

- **Quality of Service (QoS) provision**: The issue of mobility is interconnected to the issue of Quality of Service (QoS). The long-term goal of the wireless grid is to provide the same QoS to mobile users as experienced by wired users. The inherent characteristics present in wireless networks causes frequent disconnection and hence poor QoS. General QoS parameters in realizing mobile wireless grids include Latency, Error Rate, Bandwidth of the data in transmission, Reliable and adaptable communication, Secure authentications and privacy protections. The provision of the QoS requirements for different applications like healthcare emergency, natural disasters, wildfire fighting, etc. is of crucial importance to avoid or overcome the devastation.

IV. Applications of Wireless Grids

The increase in the capability/configuration of wireless devices, reduction in the cost, and the craze of people have made a drastic increase in the number of users making the wireless devices a need of today's life. However, the grids potentiality is not explored yet; but, the aggregated resource pool can offer a tremendous capacity so that any complex application can be made possible to execute. Wireless grids may support many applications in different areas [36], [37] as mentioned below: *Disaster management, mitigation and response* – includes applications like earthquakes, wildfire, floods, tsunamis, etc.; *Critical infrastructure systems* – includes condition monitoring and prediction of future capability; *Energy and environment* – includes safe and efficient power grids; *Health* – reliable and cost effective health care systems with improved outcomes; *Enterprise-wide decision making* - coordination of dynamic distributed decisions for supply chains under uncertainty;

Some of the applications are briefed here:

- **Disaster management:** The natural disasters like earthquake, flooding, volcanoes, Tsunami, wildfire fighting, etc. cause a serious destruction. As a preservation measure one can set up a sensor grid that consists of wireless sensors and wired sensors [36]. The properly installed and maintained sensor grid can provide an advance warning of future disaster. The data-driven forest fire simulation presented in [36], [37] predicts the behavior and spread of wildfires along with detailed information of intensity, propagation speed, and direction. The work considers both dynamic and static environmental conditions.
- **Health care services :** Mobile ad hoc grids can be deployed to provide healthcare services during emergency. If a man is serious because of a road accident, temporary ad hoc grid can be created using sensors (embedded at patient body), mobile/PDA, or mobile devices that collaboratively collect, distribute the data to central health care server where it is processed, and obtain an instantaneous suggestion on first aid or pre hospital treatments [14]. Hence it supports continuous monitoring of a patient. The sensor grids deployed on the battlefield as a means of detecting enemy troop movements by the vibrations as they walk or drive through the unseen grid. Sensor networks are currently in use monitoring environmental factors such as temperature or humidity change, motion and light intensity.
- **Emergency Response System:** Integrated wireless phone based emergency response system is presented in [37]. It helps in detecting abnormal patterns in mobile call activity and its location. It initiates dynamic data driven simulations to predict the evolution of abnormality, and initiates higher resolution data collection in localities of interest.

Another emergency communication scenario could be explained as below: Police can automatically transmit data collected using the mobile devices in their patrol vehicles. Ambulances can automatically send patient data to hospital control centers. In this way, data from mobile devices can be used to provide seamless and automatic transmission of information to the people who need it most.

- **Musical entertainment:** Wireless grid can be used for Musical entertainment. For example, the Wireless Grids research team at Syracuse University is building DARC (Distributed Ad Hoc Resource Coordination) application to demonstrate ad hoc distributed resource sharing [38]. The system lets devices with no prior knowledge of each other collectively record and mix an audio signal such as a concert, speech, lecture, or emergency event. The project demonstrates the potential of wireless grids and distributed ad hoc resource sharing to harness the combined ability of mobile devices in social contexts outside the expected environments for computing.

- **Supply chain management:** supply chain asset monitoring application is proposed in [39]. Using the sensor networks in supply chain management process, it helps in optimizing customer service for customized orders. It keeps track of expensive commodities. As the goods carrier is unloaded, each item can be sensed and easily located within the warehouse.
- **Automobile industry:** Ad hoc wireless grid technology is being applied to automobile industry. These projects share a common goal of developing a mobile wireless network implementation that allows automobiles to form peer-to-peer ad hoc connections in order to pass information on traffic and weather conditions, emergency situations, tracking of vehicles, the occurrence of traffic accidents or the location of nearby points of interest [40]. The embedding of Bluetooth networking capabilities into automobile systems has allowed these systems to link with Bluetooth enabled smart phones to provide hands free telephone capabilities.

V. Tools And Standards

Due to the distributed nature of resources in grids that cover multiple administrative domains, grid resource management cannot be optimally implemented using traditional approaches. In order to investigate new grid resource management systems, researchers utilize simulators which allows them to efficiently evaluate new algorithms on a large scale. Some of the grid related simulators are listed as follows: Bricks [41], SimGrid [42], GridSim [43], GangSim [44], and OptorSim [45]. Similarly, Grid eXplorer [46], and MicroGrid [47] are the emulators.

Since grid computing is a relatively new area, still common standards and specifications are not established. They are in an early definition stage [48] or are just drafts. Some of the existing standards are : Open Grid Services Architecture (OGSA), Open Grid Services Infrastructure (OGSI), Web Services Resource Framework (WSRF), Grid Security Infrastructure (GSI), and Web Services Standards like SOAP, WSDL, and UDDI.

To facilitate transparent access in complex grid environment users or developers should conform to standards established by grid development communities. The work in [49] presents some grid standards establishing bodies : Global Grid Forum (GGF), World Wide Web Consortium (W3C), OASIS, Distributed Management Task Force (DMTF), and Web Services Interoperability Organization (WS-I), etc.

VI. Conclusion

Grid Computing is a concept, a network, a work in progress, part hype and part reality, and it is increasingly capturing the attention of the computing community. The idea of sharing the idle resources through the grid leads to tremendous computing and storage pool, which gives even the resource constrained wireless devices the power of complex task execution. Grid Computing will be the major area of focus in the future days. We may have Gridnet in the future as we have Internet today.

Due to mobile nature of wireless devices and limitations of wireless communications a number of unique challenges must be overcome when building a grid application for wireless devices. Many research works have been done in wireless grid computing to address different issues, but still it has to reach its maturity level by implementing various commercial and industrial applications in different fields. Mostly sensor grids are of more interest in most of applications like patient health monitoring system, wild fire monitoring system, tsunami prediction system, supply chain management system, and others. Future researches may consider enhancement of secured communication and economic models in wireless resource sharing so that accessing is facilitated by usage charges.

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