Building Wireless Grids

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INTRODUCTION

The accelerating implementation and remarkable popularity of sophisticated mobile devices, including notebook computers, cellular phones, sensors, cameras, portable GPS (Global Positioning System) receivers, and wireless handhelds such as PDAs (personal digital assistants), contribute to development of wireless grids. **Wireless grids** feature a flexible and adaptable cyberinfrastructure that supports coordinated and economical access to distributed resources and next-generation applications and services.

Generally, **wireless grids** are classified as ad hoc or standalone, and mixed-mode or hybrid. Ad hoc **wireless grids** enable diverse applications via MANETs (mobile ad hoc networks) and consist of mobile devices that operate in infrastructureless environments. Mobile network nodes process tasks and provide best effort delivery service to support wireless grid applications (Lima, Gomes, Ziviani, Endler, Soares, & Schulze, 2005). In the healthcare environment, for example, ad hoc **wireless grids** equipped with sensors monitor the status of critically ill patients and track the location of hospital equipment and supplies. Hybrid or mixed-mode **wireless grids** augment and extend the capabilities of wireline grids to remote locations; facilitate the shared use of resources and processing power; and consist of components ranging from supercomputers to distributed or edge devices such as very small satellite aperture terminals (VSATs) (Harrison & Taylor, 2006).

This chapter features an introduction to factors contributing to the development of present-day **wireless grids**. Wireless grid technical fundamentals, specifications, and operations are examined. Security challenges associated with safeguarding wireless grids are reviewed. Finally, the distinctive characteristics of innovative wireless grid initiatives are explored and research trends in the wireless grid space are described.

BACKGROUND

Established by **virtual organization**s (**VO**s), **wireline grids** facilitate trusted resource exchange in environments that cross multiple administrative domains. **Wireline grids** consist of substantial collections of shared networked components and resources for enabling reliable and dependable multimedia delivery; implementation of sophisticated bandwidth-intensive applications; scientific discovery in fields that include high-energy physics, medicine, astronomy, and bioinformatics; and e-collaborative problem resolution (Littman, 2006).

Wireline grids increasingly employ a high-performance **DWDM (Dense Wavelength Division Multiplexing)** cyberinfrastructure that supports wavelengths of light, or lambdas, on demand to facilitate reliable and dependable access to computational simulations, metadata repositories, large-scale storage systems, and clusters of supercomputers (Littman, 2006). Also called lambda-grids, **DWDM** grids, such as the TeraGrid, enable terabit and petabit transmission rates; teraflops and petaflops of compute power; seamless connectivity to feature-rich resources; and extendible grid and inter-grid services across multi-institutional distributed environments.

The popularity of multifunctional 3G (third generation) wireless technologies and devices and demand for anytime and anywhere access to grid resources are major factors contributing to design and implementation of **wireless grids** by **mobile dynamic virtual organizations (MDVOs**). **MDVOs** are extensions of **VOs** that facilitate wireless grid deployment in infrastructureless and hybrid wireless environments. Wireless grid operations are dependent on network node mobility (Waldburger, Moraiu, Racz, Jahnert, Wesner, & Stiller, 2006). As a consequence, wireless grids are not as reliable as wireline grids in seamlessly and dependably supporting multimedia applications and services.

Wireless grid transmissions are impaired by signal fading, packet delay, and the absence of bandwidth to support applications requiring quality of service (QoS) guarantees. The performance of **wireless grids** is also affected by network node power consumption, the quality of the wireless medium, and the effectiveness of wireless grid security solutions. To counter these limitations, toolkits such **as GT4** (**Globus Toolkit version 4**); security mechanisms providing services such as authentication, authorization, data confidentiality, and data integrity; mobile agent systems; and WSs (Web Services) are utilized in building dependable wireless grid solutions.

CONSTRUCTING WIRELESS GRIDS

With **MDVO** implementation of wireless grids in new geographic environments, the numbers of wireless devices and individuals that are served by wireless grids increase dramatically. A widely used toolkit supporting wireline and wireless grid implementations, **GT4** facilitates resource allocation, detection of connectivity, and location of specific resources in response to user requests (Littman, 2006). **GT4** also enables integration of wireless devices, applications, and services with low bandwidth and variable computational power into hybrid grid configurations. By working in conjunction with middleware architecture such as SIGNAL (Scalable Intergrid Network Adaptation Layers) and **GT4,** mobile devices in hybrid grid environments can support P2P (peer-to-peer) operations that enable each peer or node to function as a client and content provider. P2P implementations in wireless grid environments also aid in resolving problems associated with resource availability and battery power constraints.

Based on P2P, the P2P Discovery Protocol (P2PDP) coordinates distribution of grid tasks via MoGrid (mobility grid) architecture. MoGrid devices function as task processing nodes and interfaces to wireline grids (Lima et al., 2005). P2PDP separates requests for grid processes, such as file exchange and job execution, into a series of tasks that are processed concurrently, sequentially, or independently.

As a consequence of difficulties in enabling disconnected processes and asynchronous communications in wireless grid environments and the need to minimize the amount of energy consumed by each application, mobile agent technology is emerging as an effective enabler of reliable job execution in wireless grids (Zhang & Lin, 2007). In addition to supporting distributed applications, mobile agent architecture provides a framework for completion of reliable and dependable grid processes.

As an example, the Mobile Agent-based Collaborative Virtual Environment (MACVE) features agile mobile agent architecture for enabling 3-D (three-dimensional) applications in shared large-scale virtual environments. Distinguished by their ability to migrate autonomously among geographically distributed nodes to facilitate resource discovery, resource scheduling, and node monitoring, MACVE mobile agents also optimize grid performance and resource utilization across multiple **MDVO** domains (Zhang & Lin, 2007). Additionally, MACVE mobile agents also support development and management of VRML (Virtual Reality Modeling Language) 3-D applications, and enable load balancing and security services in wireless grid environments (Lin, Neo, Zhang, Huang, & Gay, 2007).

Another option for building wireless grid operations and facilitating dependable access to multimedia resources is utilization of network proxies that support localized storage and computational services. For example, MAPGrid (Mobile Applications on Grids) employs network proxies to ensure resource availability in wireline grid nodes that are situated near mobile devices. Proxies offload tasks and support intermittent proactive data caching to ensure the availability of resources for wireless grid multimedia applications (Huang & Venkatasubramians, 2007).

Wireless Grid Operations

Ad hoc and mixed-mode wireless grid functions are dependent on signal strength, protocols, and middleware for supporting dependable operations and performance (Li, Sun, & Ifeachor, 2005). Ad hoc **wireless grids** supported by a wireless cyberinfrastructure enable data transport between network nodes that are within transmission range of each other. Wireless links are temporary since grid nodes are limited in physical size, storage capabilities, and available bandwidth. As a consequence, algorithms and protocols, such as AODV (Ad Hoc Distance Vector) are used to facilitate dynamic routing between wireless grid nodes and support ad hoc grid functions. In contrast to ad hoc wireless grids, hybrid **wireless grids** are scalable and capable of providing faster transmission rates.

Problems in wireless grid operations typically stem from poor signal strength and cyberinfrastructure instability. Since mobile nodes join and leave wireless grids randomly, intermediate nodes also relay data (Li et al., 2005). Information exchange among mobile devices on **wireless grids** are adversely impacted by latency, inadequate numbers of nodes to support transmissions, multipath signal distortion, battery degradation, and fast handoffs. Inconsistencies in the power of wireless devices and lack of assurance of resource availability also contribute to delays in processing wireless grid applications (2005.) To counter these constraints, mobile agents and P2P (peer-to-peer) paradigms are utilized to foster robust, secure, and extendible wireless grid solutions.

Wireless Grid Specifications

WS (Web service) specifications consist of collections of open standards and protocols that support wireline and wireless grid construction and implementation of wireless grid applications. Developed by the Global Grid Forum (GGF), the **Open Grid Services Architecture** (**OGSA**) is based on a suite of WS standards for optimizing resource integration and resource management in evolving wireless grid environments. **OGSA** also promotes implementation of loosely coupled interactive services to facilitate grid operations, and defines common interfaces to support wide-scale grid initiatives (Harrison & Taylor, 2006).

Core components and design elements initially defined for **OGSA** are now integrated in the **Open Grid Services Infrastructure (OGSI).** The WS Resource Framework (WSRF) builds on OGSI functions originally developed by the GGF. **OGSI** specifies requirements for interface development, resource scheduling, and resource management to optimize wireline grid operations. Based on OGSI and mobile agent technology, Mobile **OGSI**.NET enables

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