ABSTRACT

Efficient information sharing is difficult to achieve in the scenario of emergency and rescue operations because there is no communication infrastructure at the disaster sites. In general, the network condition is relatively reliable in the intra-site environment but relatively unreliable in the inter-site environment. The network partitioning problem may occur between two sites. Although one can exploit the replication technique used in data grid to improve the information availability in emergency and rescue applications, the data consistency problem occurs between replicas. In this paper, the authors propose a middleware called “Seagull” to transparently manage the data availability and consistency issues of emergency and rescue applications. Seagull adopts the optimistic replication scheme to provide the higher data availability in the inter-site environment. It also adopts the pessimistic replication scheme to provide the stronger data consistency guarantee in the intra-site environment. Moreover, it adopts an adaptive consistency granularity strategy that achieves the better performance of the consistency management because this strategy provides the higher parallelism when the false sharing happens. Lastly, Seagull adopts the transparency data consistency management scheme, and thus the users do not need to modify their source codes to run on the Seagull.

Keywords: Adaptive Consistency Granularity, Emergency and Rescue, Hybrid Replication Scheme, Optimistic Replication, Pessimistic Replication

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INTRODUCTION

The data grid (Belalem & Slimani, 2007; Yang, Fu, Huang, & Hsu, 2008; Yang, Tsai, Chen, & Hsu, 2007; Domenici, Donno, Pucciani, Stockinger, & Stockinger, 2004; Chang & Chang, 2006; Guy, Kunszt, Laure, Stockinger, & Stockinger, 2002; Mistarihi, & Yong, 2008) is a wide area computing infrastructure that provides huge storage capacity and great computing power to applications. Various applications (Bernholdt et al., 2005; Astakgov, Gupta, Santini, & Grethe, 2005) collect and analyze a large volume of shared data. These applications can always benefit from data grid of data management and data replication.

In the scenario of emergency and rescue operations (Plagemann, Munthe-Kaas, & Goebel; Plagemann et al., 2007), information (e.g. the list of available human resource and the list of destroyed buildings, etc.) sharing is the key to success or failure of the entire operation. However, efficient information sharing is difficult to achieve in such a scenario because there is no communication infrastructure at the disaster sites.

Usually the rescuers in the same site can use the Wi-Fi technique to set up a temporary wireless local area network (LAN) for the intra-site information sharing. On the other hand, the rescuers in different sites must generally use the GPRS, WCDMA, CDMA2000 techniques or even the satellite to form a wireless wide area network (WAN) for the inter-site information sharing. Although the signal strength could be strong enough in a wireless LAN, it is relatively very low in a wireless WAN. This situation infers that the network condition is relatively reliable in the intra-site environment but relatively unreliable in the inter-site environment. Moreover, the network partitioning problem may occur between two sites in the scenario of the emergency and rescue operation. Therefore, the replication technique (Chang & Chang, 2006; Deris, Abawajy, & Suzuri, 2004; Domenici, Donno, Pucciani, & Stockinger, 2006; Domenici, Donno, Pucciani, Stockinger, & Stockinger, 2004; Guessoum, Briot, Faci, & Marin, 2010; Guy, Kunszt, Laure, Stockinger, & Stockinger, 2002; Hara & Madria, 2009; Mistarihi & Yong, 2008; Saito & Shapiro, 2005; Sun & Xu, 2004; Tikar & Vadhiyar; Yang, Fu, Huang, & Hsu, 2008; Yang, Tsai, Chen, & Hsu, 2007) used in data grid should be adopted in emergency and rescue applications for improving the efficiency of the information sharing.

There are two advantages of using the replication technique. The first is reducing the data transfer time, and the other is providing the higher availability of shared data items. However, the consistency between all replicas of the data items is consequently an important issue in emergency and rescue applications.

The replication techniques (Chang & Chang, 2006; Guy et al., 2002) can be roughly classified into the optimistic and the pessimistic replication schemes. The optimistic replication scheme provides a more relax consistency guarantee, while the pessimistic replication scheme provides a stronger consistency guarantee.

The advantage of using the optimistic replication scheme (Belalem & Slimani, 2007; Saito & Shapiro, 2005) is that the users can access and modify the local replica of the required data item even when the network partitioning problem occurs. However, the optimistic replication scheme needs to handle data conflict errors. The data conflict error may occur because more than one user write data to the same part of a data item concurrently. Obviously, a system that adopts the optimistic scheme should be able to detect and resolve data conflict errors. Vector clock (Charron-Bost, 1991), logical clock (Lamport, 1978) and real-time clock (Mills, 1995) are familiar algorithms for detecting the data conflict error.

On the other hand, the advantage of using the pessimistic replication scheme is that this scheme provides a stronger data consistency guarantee than the optimistic scheme. The pessimistic replication scheme (Belalem & Slimani, 2007) commonly adopts the lock mechanism to maintain the data consistency of replicas. There are two types of lock mechanisms: the advisory lock mechanism (Wang & Yang, 2007) and the mandatory lock mechanism (Hildebrand &