A Highly Reliable Storage Systems Based on SSD Array for IoE Environment

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ABSTRACT

Devices in IoE (Internet of Everything) environment generate massive data from various sensors. To store and process the rapidly incoming large-scale data, SSDs are used for improving performance and reliability of storage systems. However, they have typical problem called write amplification which is caused by out-of-place updates characteristics. As the write amplification increases, it degrades I/O performance and shortens SSDs’ lifetime. This paper presents a new approach to reduce write amplification of SSD arrays. To solve the problem, this paper proposes a new parity update scheme, called LPUS. LPUS transforms random parity updates to sequential writes with additional log blocks in SSD arrays by using parity logs and lazy parity updates. The experimental results show that, LPUS reduces write amplification up to 37% and the number of erases up to 50% with the reasonable size of log space.

KEYWORDS

Cloud Environment, Erasure Coding, IoE (Internet of Everything), Log-Structured Approach, Parity, Reliability, Solid State Drives (SSDs), Storage Systems, Write Amplification (WA)

1. INTRODUCTION

With the upcoming IoE revolution, the amount of data transferred over digital universe grows exponentially, which is called data explosion. Gartner predicts 20.8 billion IoT (Internet of Things) devices will be connected by 2020 (Cai et al., 2016), which is five times more than the previous year. The billions of IoT devices communicate with each other while generating massive amount of data that could be used for deriving meaningful information (Liu et al., 2015; Charmonman et al., 2015). Moreover, the tens of billions of devices which are connected by network generate massive data and the data exploration problem is directly related to the storage technologies.

Figure 1 shows the storage system for fast storing and processing of large scale data from various types of devices, such as smart cars, smart homes, smart medical devices, in IoE environment. The storage system is composed of servers which consist of multiple SSDs to improve the latency and throughput. As illustrated in the figure, billions of IoT devices are connected by network and transmit large scale data to the storage systems. Then the aggregated sensor data should be rapidly processed for real-time analysis and various application services. Thus, the improvement of the throughput and latency of the storage systems is the key issue of high performance IoT services.

In these days, SSDs are rapidly adopted since they have a lot of benefits such as fascinating performance, low power consumption, shock resilience and light weight. Nowadays, they have become

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a common storage device by replacing HDDs. Recently, efficient data management on multiple SSDs have started having much attention with the emergence of high performance storage systems including All-Flash-Arrays (AFA) which are composed of several SSDs to meet the performance and capacity requirements (Yi et al., 2015).

However, SSDs bear some obvious drawbacks like poor random write performance, erase-before-write issue, increasing error rate, and wear-out problems. The main reason of these drawbacks is due to the write amplification (WA) problem which degrades I/O performance and shortens the lifetime of SSDs under random write workloads (Sun et al., 2013; Yang and Zhu, 2015). The WA problem is caused by the gap of operation units between the program and erase in NAND flash memories. The erase operation is conducted in a unit of blocks composed of several pages which is a programming unit. This characteristic makes SSDs perform out-of-place update and remove outdated data by triggering garbage collection (GC) periodically. Moreover, the reliability of NAND flash memories rapidly decrease as the SSD gets older because they have a predetermined number of P/E cycles and the aging strongly affects the bit error rate (BER) (Kim et al., 2016; Jiang et al., 2014).

The most important role of storage systems is that the massively injected data should be kept confidentially without failures since they should be consistently used for finding meaningful information. Thus, storage systems for IoE environment should provide fault tolerance to recover data failures. In order to manage storage systems reliably, there are two methods to recover the data failures: (1) using data replication (2) using parities. The data replication approach generates copies of the original data for the reliability and duplicates the data when occurring failures. This approach is simple but clearly wasteful in an aspect of storage efficiency. Therefore, it is difficult to keep copies of data in SSDs since they are still expensive.

On the other hand, the parity approach is more reasonable for the storage systems using SSD arrays in comparison to the data replication approach since it improves the reliability of storages by using parities which are encoded with a set of data. However, when using parities for the failure recovery, the WA problem which is the typical problem of SSDs becomes severe since the amount of random write operations increases for updating the parities.

Figure 1. High performance storage systems based on SSD array for IoE environment
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