Analysis of performance comparison between Software-Based iSCSI SAN and Hardware-Based iSCSI SAN

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Abstract. Nowadays computer data grows rapidly and make a lot of institutions and companies looking for storage solutions that are safe, reliable and trustworthy. One of the solutions is to implement a Storage Area Network (SAN). In this study, the authors chose the iSCSI protocol as an object for analyzing the performance of the SAN server based on software and hardware. The RAID type used are RAID 5 and RAID 10, while the parameters used were Input Output per Second (IOPS), throughput and average latency with workloads 4 KB, 8 KB, and 256 KB. The tests performed on the network running Link Aggregation (LAG) or network without LAG. From the test results, it is seen that a SAN network running LAG have increased throughput by 89.57 MBps. The best IOPS performance was achieved by Software-Based iSCSI SAN with a value of 26729.48 IOPS. The best throughput performance is achieved by Hardware-Based iSCSI SAN with a value of 118.55 MBps. The best latency performance achieved by Software-Based iSCSI SAN with a value of 2.01ms.

1. Introduction

According to the report from International Data Corporation (IDC) study agency, the estimation data growth on enterprise environment from 2010 to 2020 on average grew 42 percent annually and by 2020 an estimated total of data around the world reached 40 Zettabyte [1]. It is means every individual expected to save 5,900 gigabytes of data in year 2020 [1][2]. To save such big data, of course require a method of storing data on computer storage media (storage device) that is safe, reliable and trustworthy to maintain the integrity of the data [3][4].

One of the solution is to implement a Storage Area Network (SAN). Today many large scale companies that have been implementing SAN as a solution to store their data [5]. By considering the benefits of using SAN technology such as availability, reliability, scalability and performance [6][7]. There are several protocols available to implement a SAN such as ATA over Ethernet (AoE), Fibre Channel and Internet Small Computer System Interface (iSCSI) that have advantages and disadvantages of each own. To implement a SAN a user should consider a few things like; (1) the base of SAN either software-based or hardware-based; (2) the protocol of SAN; (3) types of Redundant Array of Inexpensive Disks (RAID); and (4) existing network infrastructure. Besides of several things mentioned above, the most important issue is user should also consider the performance of the selected technology, is it sufficient with the criteria desired by the user or not.
To implement a SAN technology a user should consider few things such as the base of SAN technology whether using software-based or hardware-based SAN, protocol of SAN, level Redundant Array of Inexpensive Disks (RAID) and existing network infrastructure. One type of SAN protocol that can be use for implementation is Internet Small Computer Systems Interface (iSCSI). The iSCSI is a data storage technology that based on Internet Protocol (IP). By working on IP protocol, iSCSI SAN has advantages that may use existing IP-based infrastructure [8].

This research try to implement iSCSI SAN, both software and hardware based, then conducts analysis and evaluates the differences in iSCSI SAN performance based on predetermined criteria. Furthermore, it analyzes the performance of RAID level 5 and 10 on software and hardware based iSCSI SAN and implements LAG on the iSCSI SAN network and then compares the performance obtained to the client when use LAG.

2. Methods
This research method chooses iSCSI as an object to perform SAN server performance analysis. The type of RAID used is RAID 5 and RAID 10, while the parameters used are Input Output per Second (IOPS), throughput and average latency with workloads of 4 KB, 8 KB, and 256 KB. For testing carried out on the Link Aggregation (LAG) network or network without LAG.

RAID is a way of grouping several computer storage media to form a larger storage device called a RAID set [9]. The iSCSI is an Internet Protocol (IP) based storage device technology. The iSCSI protocol has been develop by the IETF (Internet Engineering Task Force). By transmitting SCSI commands on an IP-based network, iSCSI can facilitate block-level storage via intranet and internet [10]. The iSCSI initiator is a computer or client that initiates and communicates with iSCSI targets through a Local Area Connection (LAN) network or internet network provided that it is based on IP technology [11].

![Figure 1. Design of iSCSI SAN Network for Software-Based and Hardware-Based](image)

**Table 1. Hardware Requirements**

| No. | Hardware Device | Quantity | Specification | Brand |
|-----|-----------------|----------|---------------|-------|
| 1   | Server SAN (Software) | 1        | CPU Intel Xeon E3-1200v3 3.2Ghz, RAM 4GB DDR3, Ethernet 1 Gbps x 2 Ports | HP ProLiant ML310e Gen8v2 |
| 2   | Server SAN (Hardware) | 1        | CPU Intel Dual-Core 2.13 Ghz, RAM 2 GB DDR3, Ethernet 1 Gbps x 4 Ports | Synology DS1513+ |
| 3   | SAN/Initiator | 22       | CPU Intel Dual-Core 1.33 Ghz, RAM 2 GB DDR2, Hardisk 250 GB | Dell Vostro 230 |
| 4   | Harddisk | 4        | 7200RPM 3.5 Inchi | Hitachi |
| 5   | Managable Switch | 1        | Ethernet 1 Gbps x 24 Ports | Dell PowerConnect 2824 |
Figure 1 illustrates a design of iSCSI SAN network for software-based and hardware-based. The iSCSI target network or SAN server is integrate with the client subnet network. That where the SAN server will switch to managing using two links when LAG is activate.

Implementation of the iSCSI SAN network software-based and hardware-based are doing by configuring the server on the iSCSI SAN side of the software-based target by using a RAID 5 configuration and a set of RAID volumes to be used. Configure Logical Unit Number (LUN) using the available volume. Target configuration along with iSCSI Qualified Name (iQN) uses a LUN or several LUNs that are already available. Then connect the iSCSI initiator to the target iSCSI using iQN. Configure the file system on the iSCSI initiator side. After iSCSI is connected, it conducts testing for iSCSI software-based targets without activating LAG. The LAG configuration is located on the switch. Then do testing for software-based iSCSI targets by activating and deactivating LAG. Server configuration on the iSCSI side of the software-based target using RAID 10 configuration and volume set. Repeat the above steps for the iSCSI SAN target hardware-based implementation scenario.

### Table 2. Software Requirements

| No. | Software         | Descriptions                                               | Version |
|-----|------------------|------------------------------------------------------------|---------|
| 1   | FreeNAS          | Operating system for Server SAN base on Software           | 9.3     |
| 2   | Windows 7 Professional | Operating system for iSCSI initiator                  | SP1     |
| 3   | Iometer          | Used to test throughput, IOPS, latency and processor.     | 1.1.0   |

Figure 2. Implementation of Software-Based iSCSI SAN and Hardware-Based iSCSI SAN
Figure 2 show the implementation of LAG on software-based iSCSI SAN servers using the HP Proliant ML310e Gen8v2 with the FreeNAS 9.3 operating system, there is a problem, namely the default driver of the Broadcom BCM5720 NIC which is only gigabit Ethernet NIC detected by the FreeNAS 9.3 operating system as fast Ethernet NIC running at speed 100 Mbps.

The connection between the software-based iSCSI SAN server uses the FreeNAS 9.3 operating system and the HP Proliant ML310e Gen8v2 hardware using switches Dell PowerConnect 2824, also has problems with only one NIC that can be active at 1 time at 100 Mbps. However, the same problem is “not found” in hardware-based iSCSI SAN servers, so it can be concluded that errors exist on hardware-based SAN servers rather than switches used in implementation and testing. The author also does not find error messages from the system log using the dmesg command for the NIC used which means there is a bug in the Broadcom BCM5720 NIC for the FreeNAS operating system 9.3.

Because the LAG cannot run on a software-based iSCSI SAN server, there is no performance comparison for all parameters on the LAG network. In addition, the software-based iSCSI SAN server is not test using 22 clients, because testing using 22 clients aims to see throughput obtained when the network uses LAG technology.

3. Result

Testing parameter used to analyze the performance of iSCSI SAN are IOPS, throughput and latency [12]. With workloads 4 KB, 8 KB and 256 KB. Details testing parameter and workloads are show in table 3 and table 4.

| Table 3. Testing Parameter |
|-----------------------------|
| Parameter | Description | Unit |
| Throughput | Performance measurement parameter for sequential access operation | MBps |
| IOPS | Performance measurement parameter for random access operation | iops |
| Latency | Performance measurement for average latency | ms |

| Table 4. Workloads |
|------------------|
| Block Size | Description of Operation |
| 4 KB | Random operation with workload 100% read and random operation with workload 100% write |
| 8 KB | Random operation with distribution workload 70% read / 30% write |
| 256 KB | Sequential operation with workload 100% read and sequential operation with workload 100% write |

The test is performed on the network that is running LAG as well as on the network running without LAG, also the test is performed both in RAID5 and RAID10. Workload used is 4 KB, 8 KB, 256 KB with 1 client tested on the network without LAG and workload 256 KB which is use 22 Client on network with LAG. Detail of testing are shown in Table 5.

| Table 5. Testing On Hardware-Based and Software-Based of iSCSI SAN Server |
|---------------------------------------------------------------|
| Hardware-Based iSCSI SAN Server | Software-Based iSCSI SAN Server |
| Without LAG | With LAG | Without LAG | With LAG |
| Without LAG | With LAG |
| Without LAG | With LAG |
| 1 Client | 22 Client | 1 Client | 22 Client | 1 Client | 22 Client | 1 Client | 22 Client |
| 4 KB | √ | - | - | - | √ | - | - |
| 8 KB | √ | - | - | - | √ | - | - |
| 256 KB | √ | √ | - | √ | √ | - | - |

The final results of the testing are presented in tabular form to make the reader understand the difference performance between hardware-based iSCSI SAN and software-based iSCSI SAN easily.
Figure 3. Performance of IOPS, throughput, and latency for the 8 KB in RAID5 and RAID10

Figure 3 is the results of testing performance of IOPS, throughput, and latency for the 8 KB workload in RAID 5 show that software-based SAN servers are superior to hardware-based SAN servers. However, on the contrary in RAID 10, it shows that SAN-based hardware servers are superior to software-based SAN servers.

Table 6. Performance Test Comparison 1 Client with Workload 4KB and 256KB

| iSCSI SAN | Workload | Operation | RAID Type | IOPS (iops) | Throughput (MBps) | Latency (ms) |
|-----------|----------|-----------|-----------|-------------|-------------------|--------------|
| Hardware  | 4 KB     | Read      | RAID5     | 914.22      | 3.74              | 69.99        |
|           |          | Write     | RAID10    | 895.55      | 3.67              | 71.45        |
|           |          | Read      | RAID5     | 165.20      | 0.68              | 386.83       |
|           |          | Write     | RAID10    | 161.09      | 0.66              | 397.02       |
|           | 256 KB   | Read      | RAID5     | 443.44      | 116.25            | 144.28       |
|           |          | Write     | RAID10    | 452.21      | 118.55            | 141.48       |
|           |          | Read      | RAID5     | 27.28       | 7.15              | 235.68       |
|           |          | Write     | RAID10    | 27.03       | 7.09              | 235.82       |
| Software  | 4 KB     | Read      | RAID5     | 26729.48    | 109.48            | 2.39         |
|           |          | Write     | RAID10    | 1110.72     | 4.55              | 57.61        |
|           |          | Read      | RAID5     | 188.44      | 0.77              | 339.39       |
|           |          | Write     | RAID10    | 1120.12     | 4.59              | 57.13        |
|           | 256 KB   | Read      | RAID5     | 45.12       | 45.12             | 1416.74      |
|           |          | Write     | RAID10    | 35.74       | 9.37              | 1787.12      |
|           |          | Read      | RAID5     | 44.42       | 44.42             | 1441.09      |
|           |          | Write     | RAID10    | 10.59       | 2.78              | 5958.73      |
From table 6, the best IOPS performance is achieved by software-based iSCSI SAN with workload 4 KB on the read operation with RAID 5 type and value 26729.48 IOPS, while the worst is also achieved by software-based iSCSI SAN with a workload 256 KB on the read operation with RAID 10 and IOPS is 10.59 IOPS. For the best throughput performance is achieved by hardware-based iSCSI SAN with workload 256 KB on the read operation using RAID 10 type with value of 118.55MBps, while the worst was achieved by hardware-based iSCSI SAN with the workload 4 KB on write operations using RAID 10 type with value 0.66MBps. And the last one the best latency performance is achieved by software-based iSCSI SAN with workload 4 KB on the read operation using RAID 5 type and the value is 2.39ms, while for the worst latency performance is achieved by software-based iSCSI SAN with workload of 256 KB on write operations using RAID 10 with value 5958.73ms.

Table 7. Performance Test Comparison 1 Client with Workload 8 KB

| Thread Queue Depth | Hardware-Based iSCSI SAN | Software-Based iSCSI SAN |
|--------------------|--------------------------|--------------------------|
|                    | IOPS (iops)              | Throughput (MBps)        | Latency (ms) | IOPS (iops) | Throughput (MBps) | Latency (ms) |
| RAID 5             | RAID 10                  | RAID 5                   | RAID 10      | RAID 5      | RAID 10           | RAID 5       |
| 2T2QD              | 305.76                   | 318.57                   | 2.50         | 2.61        | 13.08           | 12.55        |
| 2T4QD              | 387.25                   | 447.20                   | 3.17         | 3.66        | 20.66           | 17.89        |
| 2T8QD              | 442.90                   | 543.14                   | 3.63         | 4.45        | 36.12           | 29.42        |
| 2T16QD             | 300.68                   | 301.05                   | 2.46         | 2.47        | 106.36          | 106.23       |
| 4T2QD              | 388.57                   | 470.54                   | 3.18         | 3.85        | 20.59           | 17.00        |
| 4T4QD              | 442.43                   | 578.66                   | 3.62         | 4.74        | 36.15           | 27.65        |
| 4T8QD              | 413.76                   | 471.71                   | 3.39         | 3.86        | 77.33           | 67.83        |
| 4T16QD             | 408.68                   | 456.97                   | 3.35         | 3.74        | 156.55          | 140.03       |

Table 7 show the performance test comparison of 1 client with workload 8 KB. For the workload testing with 8 KB. The Best IOPS performance achieved is 3198.59 IOPS in software-based iSCSI SAN while running RAID 5, while the worst IOPS performance is 119.58 IOPS in software-based iSCSI SAN running RAID 10. Next for the best throughput performance is 26.20MBps on software-based iSCSI SAN running RAID 5, while the worst throughput performance is 0.96MBps on a software-based iSCSI SAN running RAID 10. The least one for the best latency performance is 2.01ms on the software-based iSCSI SAN running RAID 5, while the worst latency performance is 310.86ms in software-based iSCSI SAN using RAID 10.

Table 8. Performance Test Comparison 22 Client with Workload 256 KB

|                     | Without LAG | With LAG |
|---------------------|-------------|----------|
| RAID 5              | 145.03      | 234.60   |
| RAID 10             | 191.08      | 203.39   |

And lastly, from table 8 for throughput testing with 22 clients using workload 256 KB, the best performance occurs while running LAG in RAID 5 with value 234.60 MBps. While the worst performance occurs in network without LAG running RAID 5 with value 145.03 MBps. Conclusion of test results, the software-based iSCSI SAN has a better performance than hardware-based iSCSI SAN.

4. Conclusion
The best IOPS performance achieved by software-based iSCSI SAN with value 26729.48 IOPS while using workload 4 KB running read operation in RAID 5 and for the worst performance achieved by software-based iSCSI SAN with value 10.59 IOPS while using workload 256 KB running write operation in RAID 10. The best throughput performance achieved by hardware-based iSCSI SAN with value 118.55MBps while using workload 256 KB running read operation in RAID 10 and for the worst throughput performance achieved by hardware-based iSCSI SAN with value 0.66MBps using...
workload 4 KB in RAID 10. The best latency performance achieved by software-based iSCSI SAN with value 2.01ms on workload 8 KB running 2 threads 2 queue depth in RAID 5 and for the worst latency performance achieved by software-based iSCSI SAN with value 5958.73ms using workload 256 KB in RAID 10. Network performance running LAG technology could increase throughput achieved by client computer than network without running LAG technology. With improvement about 89.57MBps more bandwidth throughput while running RAID 5 and about 12.30MBps while running RAID 10. Throughput result from Gigabit Ethernet on full duplex mode in this study is 2Gbps with condition there is gap about 1 minute while testing on every client/initiator. Disk cache on a SAN server could increase throughput around 100 times, this behavior show from throughput comparison on testing between software-based iSCSI SAN and hardware-based iSCSI SAN. Using RAID 5 with workload 4 KB software-based iSCSI SAN achieved a throughput 109.48 MBps while hardware-based iSCSI SAN only gets 3.74MBps on the same testing environment.

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