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Maximum Performance with Minimum Cost in Data Mining Applications through the Novel Online Data Warehouse Architecture by using Storage Area Network with Fibre Channel Fabric

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***Abstract* - The primary issues of data warehouse architecture are higher cost, and poor performance. The reasons for these problems focus the architectural design. The solutions are proposed with the new modified data warehouse design through online data warehouse architecture with the recent technological support from cloud computing - storage area networks through the use of high speed fibre channel based storage devices with fibre channel switches. Finally the benefits and advantages of proposed design were discussed with the costand performance.**

***Keywords* - Data Warehouse Architecture, Cloud Computing, Storage Architecture, Storage Area Network, Network Storage, Fibre Channel Protocol, Fibre Channel Switch/Fabric.**

I. INTRODUCTION

The problems in existing data warehouse architectures were gradually solved stage by stage by the data warehouse designers. Mostly the issues in *business intelligence* (BI) applications running with *data mining* (DM) tools are still completely unsolved. First issue is the cost of the data warehouse system is heavy in the existing models due to the huge amount of storage requirements for data and the memory for data analysis. The second issue is the performance of the BI and DM tools used by the data warehouse system are not satisfactory due to the complex data warehouse architecture design. So, the data warehouse design should be modified as per the technological developments available in the industry and to satisfy the business needs. This research paper proposes a new way of designing the data warehouse architecture using cloud computing technology with the help of fibre channel storage by reducing the overall cost with improvement in the data warehouse performance.

II. REVIEW OF LITERATURE

A. Data Warehousing

1) Components

The major components [1] are operational data store, load manager, warehouse manager, metadata, data mart, and query manager. These can be designed with layered model also [22].

2) Development approaches

Inmon model [2] [13] is based on enterprise data warehouse approach, subject-oriented, integrated, top-down, relational database tools, nonvolatile, and time-variant. *Kimball model* [3] [13] is based on data mart approach, bottom-up, dimensional modeling, plan big, build small. Independent and dependent data mart models were also used in this design.*Real-time (active) data warehousing*and *Virtual data warehousing*[20] also exist. Other architectures may have one, two, and three-level models [17]. Some may use cloud [25].

The four views of a *business analysis framework* [6] are: Top-down view, Data source view, Data warehouse view, and Business query view.

3) Factors determining data warehousing architecture

The major factors determining data warehousing success [5] are: Cross function, campus-wide support, Consistency and integration across subject areas, Security, access control, Support for operational users and Support flexible access for decision-makers. The influencing factors determining data warehouse quality [4][14] are: Completeness, Non-redundancy, Enforcement of (business) rules, Data reusability, Stability and flexibility, Simplicity and elegance, Communication and effectiveness and Performance.

The major problems in data warehouse design [1][14] are: Underestimation of resources for data loading, Hidden problems with source systems, Required data not captured,

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Increased end-user demands, Data homogenization, High demand for resources, Data ownership, High maintenance, Long duration projects and Complexity of integration.

B. Cloud Computing

1) Modern on-demand computing

The on-demand computing [11] model can be used to minimize the investment cost involved in the resources. It is simply pay-by-use type of technology without purchasing any resources within the organization. So, it will completely eliminate the maintenance cost of hardware. The organization would pay only the rental charges for the resources used on monthly or yearly basis. This will drastically reduce the investment and maintenance costs of resources required by the organization.

2) Beyond the desktop

Cloud computing [8, 28] allows us to store and run applications and data over dynamic clouds for universal access. The notion of desktop-centric model used in client/server computing will be replaced by cloud computing with user-centric, task-centric and data-centric model. It is the way of the future. The cloud BI [19] exists also with several cloud challenges [24].

3) Key properties

The key properties [8] of cloud computing are: User-centric, Task-centric, Powerful, Accessible, Intelligent, and Programmable.

4) Benefits

The benefits [9, 15, 21, 23] of cloud computing are: On-demand self-service, Broad network access, Resource pooling, Rapid elasticity, and Measured service

5) Advantages

The advantages [9, 30] of cloud computing are: Lower costs, Ease of utilization, Quality of Service, Reliability, Manageability, Strategic Edge, Outsourced IT management, Simplified maintenance & upgrade, and Low barrier to entry. The new service *Disaster Recovery as a Service-DRaaS* [26] also exists. *High Availability-HA* [27, 29] is a system-level feature (architecture, design, software suite) which ensures system up-time.

C. Storage Area Network

1) The universal storage connectivity

The cloud computing offers two storage models [7] *Network Attached Storage* (NAS) and *Storage Area Network* (SAN). Among these SAN model has several variants with *Fibre Channel Protocol* (FCP) support which is a high speed storage device with huge data transfer rate. A typical SAN architecture is shown in figure 1.The key feature of SAN is any-to-any connectivity of computers and storage devices. SAN is Universal Storage Connectivity.

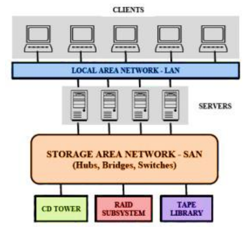

Figure 1: A typical SAN architecture

2) Components

The major components [10] of SAN are: Network part, Hardware part, Software part, and Connectivity part.

D. Fibre Channel

1) High-speed interconnect

Storage networking has been maturing since the introduction of *Fibre Channel* (FC) [7] in the early 1990s. Normally the fibre channel devices are very fast devices working with Gigabit technology. A SAN device is a block-access [18] that connects to its clients using FC and a block data access protocol such as SCSI.

2) Design goals

By chance, the design goals [12] of FC are covered by the requirements of a transmission technology for storage networks such as: Serial transmission for high speed and long distances, Low rate of transmission errors and Low delay (latency) of the transmitted data. Implementation of the Fibre Channel Protocol in hardware on *Host Bus Adaptor* (HBA) cards to free up the server CPUs.

3) Topologies

The topologies [7] of FC are:

Point to point, in which two devices are directly connected to each other by a FC cable as in figure 2(a).

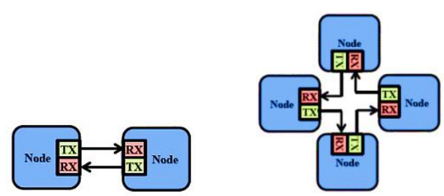

Figure 2: (a) Point to point, (b) Arbitrated loop

Arbitrated loop, in which a number of devices time-share a single transmission path. A FC arbitrated loop can connect up to 126 devices. It is shown in figure 2(b).

Switched or fabric, in which each device is directly connected to a central connecting point called a switch. The switch makes and breaks momentary connections between pairs of devices that need to communicate with each other. Like Ethernet switches, FC switches are high-performance devices that are capable of intermediating several simultaneous communications between pairs of devices. This is shown in figure 2(c).

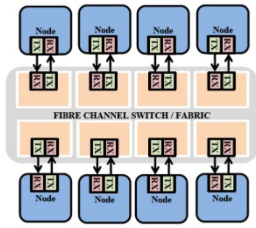

Figure 2(c): Switch or fabric

The features [7] of individual FC topologies are shown in the following table 1.

Table 1: Features of FC topologies

Attribute	*Point-to-Point*	*Arbitrated Loop*	*Switched Fabric*
Max. ports	2	127	~16777216 (2^{24})
Address size	N/A	8-bit ALPA	24-bit port ID
Side effect of port failure	Link fails	Loop fails (until port bypassed)	N/A
Frame delivery	In order	In order	Not guaranteed
Mixing different link rates	No	No	Yes
Access to medium	Dedicated	Arbitrated	Dedicated

E. FC switch/fabric

A FC switch [7] or fabric design [16] appearances similar to a hub. Figure 3 depicts the key characteristics of a FC switch. For simplicity, a four-port switch is depicted. Actual switches contain more ports.

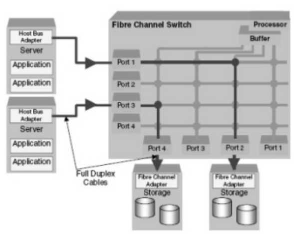

Figure 3: FC switch/fabric

The fabric topology [12] is the most flexible and scalable of the three FC topologies. A fabric consists of one or more FC switches connected together. Servers and storage devices are connected to the fabric by the FC switches. FC switches can exchange data by means of switch-to-switch connections (*Inter Switch Links*-ISL). Several ISLs can be installed between two switches in order to increase the bandwidth.

Figure 4 compares the latency of different FC SAN components. A 10-kilometre long FC cable increases the latency of an end-to-end connection. For hardware components the rule of thumb is that a FC switch can forward a frame in 2–4 microseconds; a FC HBA requires 2–4 milliseconds to process it.

One special feature of the fabric is that several devices can send and receive data simultaneously at the full data rate. All devices thus have the full bandwidth available to them at the same time.

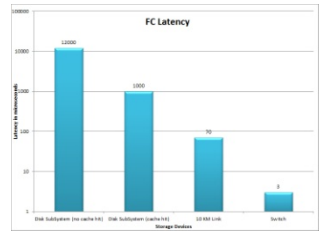

Figure 4: The latency of the FC

1) Advantages

The advantages [7] of FC switch are: Lower Cost, Very High Performance, Long Distance Support, and Less Overhead.

III. THE PROPOSED DESIGN OF DATA WAREHOUSE ARCHITECTURE

This research work proposes a new architecture for online data warehousing by using storage area networks in order to solve the issues namely higher cost, and lower performance faced in the earlier data warehousing designs.

A. The Various Generations of Data Warehouse Architectures

First generation data warehouse architecture: During the invention of personal computers, all software developed was standalone and unsecured. The first generation data warehouse architecture design was also in the same model. Application developers developed software to access the data in the data warehouse directly through the simple versions of data mining tools without any kind of security. These data mining tools extracted knowledge and generated various forms of data using visualization techniques. The first generation data warehouse architecture was based on two tier model as in figure 5(a).

Second generation data warehouse architecture: The rapid development of networking technology, introduced the client/server computing. The second generation data warehouse architecture was based on this model with security over data. It also allows the data access in a geographically distributed locations say servers. The applications developed for this kind of data warehouse systems were run on client systems in a secured manner. The second generation data warehouse architecture was based on three tier model as shown in figure 5(b).

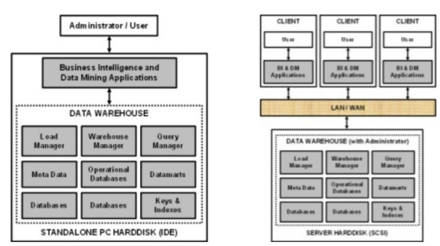

Figure 5 (a): First generation (b): Second generation

Third generation data warehouse architecture: The improvements over client/server computing technology reached the web-based applications using internet technology. The third generation data warehouse architecture is shown in figure 5(c). But, BI and DM applications running on internet were not satisfied with performance due to the protocols used and bandwidth reasons. Because, BI and DM applications require huge amount of RAM space and HardDisk storage space while working with data warehouse databases.

B. The Proposed Data Warehouse Architecture

The need of modified data warehouse design and the features of network storage together form the new online data warehouse architecture. The proposed design is going to use the storage area network model for data warehouse storage. The framework of proposed design is shown in figure 5(d) as next (proposed) generation data warehouse architecture. The fibre channel fabric/switch plays a major role in between servers and storage devices.

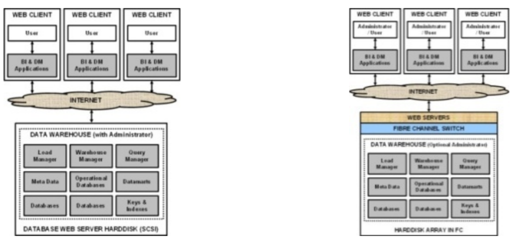

Figure 5 (c): Third generation (d): Proposed design

C. Comparison of First, Second, Third Generation and Proposed Data Warehouse Architectures

The various existing generations of data warehouse architecture designs are compared with the proposed online data warehouse design with several technical features as in table 2.

Table 2: Analysis of various generations of data warehouse architectures

Data Warehouse Architecture Feature	First Generation	Second Generation	Third Generation	Next Generation (proposed)
1.Number of tiers	Two tier model	Three tier model	Three tier model	Multi-tier model
2.Number of users	Single user model (or multiple users but, one at a time)	Limited multi-user model	Unlimited multi-user model with network bandwidth limitations	Unlimited multi-user model without any bandwidth limitations
3.Data storage	Local standalone PC hard disk with space limitations	Shared client/server hard disk with space limitations	Shared database web server hard disk with space limitations	Shared array of hard disk (RAID) without any space limitations
4.Storage technology	IDE or Enhanced IDE	Parallel SCSI	Ultra SCSI	FC (or iSCSI)
5.Maximum data transfer rate	IDE - 3.3 to 25 MBps Enhanced IDE 16.7 to 133 MBps	Parallel SCSI 5 to 20 MBps	Ultra SCSI 40 to 640 MBps	1GFC to 40GFC 100 to 4800 MBps per direction
6.Processor load	Heavy due to multi-tasking in PC	Shared heavily but limited users	Shared heavily but limited bandwidth	Shared lightly with FC management (shared by HBA)
7.Network load	Not applicable	Shared with limited users and traffic	Shared with limited bandwidth	Shared without any restrictions
8.Data accessibility	Fast due to local access	Based on network traffic	Based on network and internet bandwidth	Normally fast due to FC
9.Load balancing	Possible with local buffering only	Possible with C/S and network buffering	Possible with C/S, network and internet buffering	Possible with C/S, network, internet, FC and HBA
10.Response time	Fast due to local processor	Medium because shared	Medium because shared	Fast due to FC
11.Application execution	Local	Client	Client or server	Client or server
12.Overall data warehouse performance	Initially good, but poor when data volume increases due to single user model	Initially good, but not satisfactory when data volume increases	Moderate, but not satisfactory when user volume increases	Excellent due to FC
13.Fault tolerance	Not possible	Possible with backup server	Possible with backup web server	Intelligent FC switch, RAID and HBA
14.Recovery time	Usually long time, but based on backup policy	Moderate, but based on backup policy	Moderate, but based on backup policy	Negligible due to FC, RAID and HBA
15.Security	0%	Not 100% due to C/S policies	Not 100% due to C/S, network and internet	100% assured
16.Scalability	Possible only by connecting limited number of hard disks	Possible only by connecting more hard disks in both C/S	Possible only by connecting more hard disks in Web Server	Default and automatic due to RAID and FC fabric
17.Cost	Low	Medium	High	As per usage (daily / monthly / yearly)
18.Services available	Nil (local services only)	C/S services only	Limited web services	Unlimited web services with cloud model

The features include number of tiers, number of users, data storage, storage technology, data transfer rate, processor load, network load, data accessibility, load balance, response time, application execution, warehouse performance, fault tolerance, recovery time, security, scalability, cost and services. From the table, it is clear that the proposed model have more solid reasons than other models.

D. Technology and Business Benefits of SAN

The storage networking is a mechanism for delivering services of benefit to the enterprise [7]. A SAN can

- *Reduce the capital cost of storage*
- *Reduce storage management cost*
- *Reduce I/O bandwidth requirements*
- *Improve the accuracy & timeliness of business data*
- *Extend the useful life of capital equipment*

IV. TESTING

The proposed design of online data warehouse architecture is tested with network storage interconnect. The device used for testing is a network storage array. The device name and model is *Iomega StorCenter px4-300r*. Initially, a data mining application is executed and the network and server data flow is analyzed without the device connection. The result of this is shown in figure 6.

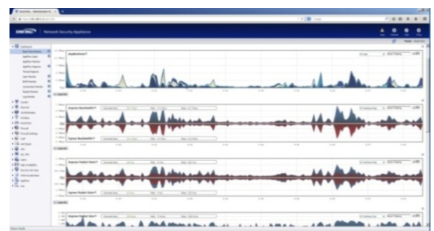

Figure 6: Data flow without network storage

It is observed from the figure 6 that, the data flow is very small in server because of the load is given to the server and network due to its local buffering. The native device speed is not yet reached in this design. So, the storage devices are under-utilized with huge storage capacity and the server & network are heavily loaded which leads to performance degradation. This kind of data flow is not suitable for online data management and applications because it would degrade the performance of the network and server. Further, when the number of user increases, the performance again would go down due to user management along with their data.

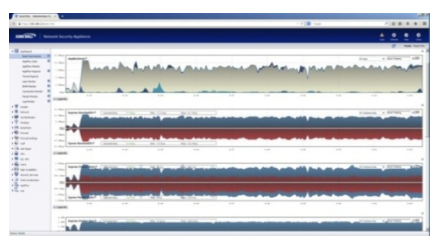

Figure 7: Data flow with network storage

Next, the same data mining application is executed along with network storage connection and analyzed the performance of data flow. The result of the data flow is shown in figure 7.

It is noted from the figure 7that, the data flow is very large in both the network and server because of the load is not given to the server and network due to host bus adaptor. The managed switch is controlling the buffering issues with the data. The fibre channel switch will give us the speed of the native device without any delay in data transfer. The outcome shows that the performance is highly improved in both the network side as well as in server side by reducing the load to them. When the user volume increases the device still behaves in the same way because data is managed by switch and users are managed by server or network. So, the storage devices are utilized at maximum and the server and network are loaded lightly which increases the performance of overall data transfer in both network and server in turn this design improves the overall performance of the data mining application due to the proposed online warehouse architecture design with storage networks with fibre channel fabric model.

V. RESULTS AND DISCUSSION

Figure 8 compares the CPU load of TCP/IP and FC data traffic [12]. The reason for the low CPU load of FC is that a large part of the FC Protocol stack is realized on the FC HBA. By contrast, in current network cards a large part of the TCP/IP protocol stack is processed on the server CPU. The communication between the Ethernet network card and the CPU takes place via interrupts. This costs additional computing power, because every interrupt triggers an expensive process change in the operating system. The CPU load of FC is low because its protocol is mainly processed on the HBA.

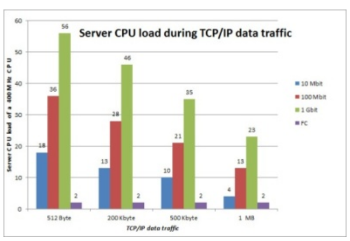

Figure 8: TCP/IP data traffic places a load on the server CPU.

Table 4 lists the cost of inability to process information for various periods for two businesses for which online data processing essentially is the business [7]. A typical home shopping operation processes large numbers of relatively low-value transactions. With a stock brokerage, on the other hand, individual transaction values can be much greater, so the cost per minute of downtime is correspondingly higher. The rows of table are extrapolated from the top row by multiplication. In reality, other factors, such as inability to meet financial obligations, would cause even larger consequences than the financial cost suggested by the table 3.

Table 3: Cost of downtime – Some examples

Percentage of Uptime	Annual Downtime	Annual Cost (Home Retail)	Annual Cost (Brokerage)
99.9999%	30 seconds	$950	$53,750
99.999%	5 minutes	$9,417	$537,500
99.99%	52 minutes	$98,000	$5,590,000
99.9%	8.75 hours	$988,750	$56,000,000
99.5%	43.7 hours	$5,000,000	$280,000,000
99%	87.6 hours	$10,000,000	$560,000,000
98%	180+ hours	$20,000,000+	$1,000,000,000+
95%	450+ hours	$50,000,000+	$3,000,000,000+

The value of uptime may differ for different enterprises, but the overall message of Table 3 that downtime is cripplingly expensive – is a universal one. SAN technology enables new information processing techniques that can sharply reduce downtime, which, as can be seen from Table, can mean very significant cost savings or even survival for an enterprise. Figure 9 illustrates several data and application availability techniques that increase accessibility at increasing cost[7]. The availability baseline illustrated in figure is an adequately managed but otherwise unremarkable computer system that is backed up on a reasonably frequent and regular basis.

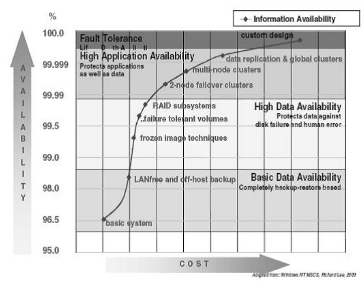

Figure 9: Degrees of system availability.

Figure suggests that LAN-free and off-host backup, both of which are enabled by SANs, increase uptime. Both of these techniques reduce backup impact on applications, which in turn enables more frequent backups. More frequent backup's means shorter restore times and less journal playback or other forms of data reconstruction, which in turn means less time until applications are back in operation after a failure.As figure also suggests, this improvement comes at a cost.

VI. CONCLUSION

The proposed online data warehouse architecture design with storage area network model through fibre channel fabric shows that the improved performance in data mining applications and the cost of infrastructure for storage and computing devices are being drastically reduced by replacing them on rental basis instead of buying, which is the core of cloud computing service called Storage as a Service (SaaS). If we prefer to for buy option then the initial investment cost would be high and the maintenance cost would be less and we should update regularly both the software and hardware as per change in the industry which has several headaches as maintenance. Next, the overall performance of the proposed data warehouse architecture design is more satisfactory than the previous designs because the new design uses high speed storage devices (RAID) with very high data transfer rate (fibre channel fabric) along with scalability as discussed earlier. Finally the data access into the data warehouse is clearly examined that the cloud computing and storage area networks provides any to any connectivity as default. Thus, the solutions suggested in this research work could definitely satisfy the business needs in terms of business intelligence and data mining tools which are being used for data analysis in data warehouse. This work may be extended to mobile computing and pure cloud computing models.

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