모바일 디바이스를 위한 iSCSI 기반의 원격 스토리지 서비스에서 중간 서버를 이용한 성능 개선 방안

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요 약

모바일 기기가 널리 보급되면서 모바일 기기를 이용한 다양한 서비스에 대한 요구가 증가되었다. 특히, 멀티미디어, 게임, 데이터베이스[1]와 같은 데이터 용량이 큰 응용 서비스에 대한 요구가 크게 증가하고 있다. 하지만, 모바일 기기는 그 특성상 저장 공간이 충분하지 못하기 때문에 유선 환경에서와 같은 다양한 서비스를 적용하는데 어려움이 있었다. 따라서 모바일 기기의 저장 공간의 한계를 극복하기 위한 노력의 하나로 iSCSI를 이용해 모바일 기기에 원격 스토리지 서비스를 제공하는 연구[5]가 진행되었다. 그러나 모바일 기기에 iSCSI를 적용했을 때, 지연 시간에 민감한 iSCSI의 구조적인 특성 때문에 iSCSI 클라이언트가 서버에서 멀리 떨어진 위치로 이동하게 되면 iSCSI I/O 성능이 급격히 떨어지는 문제가 발생한다. 쓰기 작업의 경우 네트워크 지연이 64ms가 되는 경우 28%의 성능 저하가 발생했다. iSCSI 프로토콜은 동작 방식의 특성상 Initiator와 Target간의 데이터 이동 지연 시간이 커지게 되면 성능이 급격하게 떨어지는 단점을 가지고 있다. 본 논문에서는 모바일 기기가 스토리지 서버로부터 거리가 멀어졌을 때, 전송 지연시간이 증가함에 따라 iSCSI 성능이 급격하게 떨어지는 단점을 개선하기 위해 중간서버(Intermediate Target)를 이용해 iSCSI Target을 지역화하여 성능을 높이는 방안을 제안한다.

An Improved Way of Remote Storage Service based on iSCSI for Mobile Device using Intermediate Server

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ABSTRACT

As mobile devices prevail, requests for various services using mobile devices have increased. Requests for application services that require large data space such as multimedia, game and database [1] specifically have greatly increased. However, mobile appliances have difficulty in applying various services like a wire environment, because the storage capacity of one is not enough. Therefore, research [5] which provides remote storage service for mobile appliances using iSCSI is being conducted to overcome storage space limitations in mobile appliances. But, when iSCSI is applied to mobile appliances, iSCSI I/O performance drops rapidly if a iSCSI client moves from the server to a far away position. In the case of write operation, 28% reduction of I/O performance occurred when the latency of network is 64ms. This is because the iSCSI has a structural quality that is very sensitive to delay time. In this paper, we will introduce an intermediate target server and localize iSCSI target to improve the shortcomings of iSCSI performance dropping sharply as latency increases when mobile appliances recede from a storage server.

키워드 : iSCSI, SCSI, 모바일 디바이스(Mobile Device), 원격 스토리지(Remote Storage), 블록 레벨 I/O(Block Level I/O)

1. Introduction

The explosive growth of the mobile appliance market has made a lot of demands in mobile-related services. Efforts to apply wired network environment services, which need large amount of storage space, such as multimedia and databases, to mobile appliances with a wireless network environment, were performed. However, mobile appliances should be small and light to support mobility, so that they use a small flash memory instead of a hard-disk having large data space. In the case of PDAs, these usually have memory space of 32~64M. Cell-phones or smart phones permit smaller memory space. Therefore, there is difficulty saving multimedia data such as mpg, mp3, etc. and installing large software such as database engines. Limited storage space in mobile appliances has been a barrier for applying various services in a wired environment. As a result,

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the necessity for remote storage services in mobile appliances has overcome limited storage space of mobile devices, and store large amounts of data, or provide various application services [5, 8, 9].

Remote storage services have two classifications. One is file-level I/O and the other is block-level I/O. File-level I/O service is provided by communication between a server and client file systems. In the case of file I/O, because client□s I/O request is passed to a device via the server file system, data share is possible between other clients through a locking mechanism which the server file system offers. However, file system overhead drops I/O performance.

In block-level service, client's I/O request is directly passed to a storage device without a server file system, in the form of a block I/O command. Therefore, it is not able to provide data sharing services by itself, but I/O performance is better than file-based I/O services [9].

The bandwidth of wireless networks, which mobile devices use, is usually lower than those of wired networks. If the purpose of the remote storage service is to extend individual storage space for mobile appliances without data sharing, block-level I/O service is more suitable. SCSI is a representative block I/O protocol which is de facto standard. And, iSCSI is a transport layer protocol that delivers SCSI command over TCP/IP network. It solved isolation problem which Fibre Channel has. iSCSI is reliable and its performance in Gigabit LAN was verified through a lot of research papers. However, iSCSI has a problem that I/O performance drops sharply if network latency increases between iSCSI initiator and target in WAN.

In this paper, when iSCSI-based remote storage service is applied to mobile appliances, we improve the problem of iSCSI performance falling rapidly accordingly the mobile client recedes from the storage server and network latency increases. This paper comprises as follows. In chapter 3, we present the SCSI architecture model and iSCSI basic operations to explain the reason why iSCSI performance drops when distance between iSCSI initiator and target is long. In chapter 4, we discuss research related with improving iSCSI performance using a client's local cache. In chapter 5, we propose ways to improve iSCSI performance using an intermediate server, and we talk about system architecture and algorithms in chapter 6. In chapter 7, we analyze the result of simulation with ns2. Finally we shall conclude and describe our future work.

2. Background

In this chapter, we describe the SCSI architecture model-3 and the iSCSI basic operation process, to explain the relationship between iSCSI Initiator-Target's distance and erformance. Then we will analyze iSCSI performance test results using different delay times.

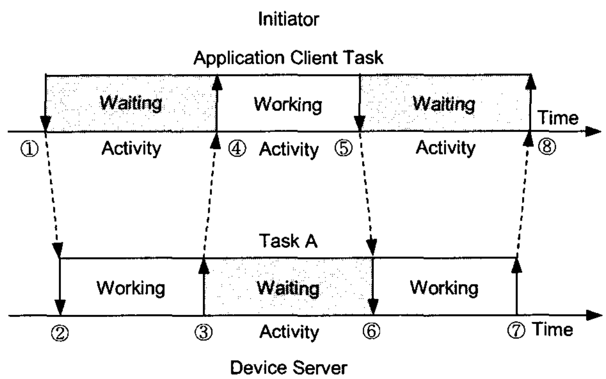
2.1 SAM-3(SCSI Architecture Model - 3)

SAM-3 is a draft for SCSI standard, lead by T10, a Technical Committee of Accredited Standards Committee INCITS(InterNational Committee for Information Technology Standards). SAM-3 specifies the SCSI Architecture Model. The purpose of the architecture is to provide a common basis for the coordination of SCSI standards and to specify those aspects of SCSI I/O system behavior that are independent of a particular technology and common to all implementations [7].

2.1.1 Linked SCSI Command Processing

Serial SCSI Commands are processed sequentially in SAM-3 [7]. Only after previous command processing is completed, can the next command be processed. This sequential processing mechanism causes the SCSI protocol to be sensitive to network latency.

(Figure 1) shows the sequence in which two serial SCSI commands are processed between SCSI initiator and target. SCSI initiator has a waiting time between sending the created command to the target and receiving the result. If the distance of the initiator and target is longer, the initiator's waiting time is larger because an electronic wave delay of the network has grown. Even if the change of response time from one SCSI command is small, all subsequent commands will be delayed by previous response latencies, because SCSI commands is processed sequentially. If there are n serial SCSI commands to be processed, a time lag of n x dt(time lag of response delay per one SCSI command) occurs until the last command is processed.



(Figure 1) Linked SCSI command process

As a result, when the distance between the SCSI initiator and target is long enough, response time of a SCSI command is delayed and a link utilization of SCSI protocol is dropped causing degradation of the I/O performance. Even in the case of iSCSI, which embodies SCSI protocol over TCP/IP networks, a described feature of the SCSI makes iSCSI performance limited by the distance between initiator and target, although iSCSI has an advantage that distance of Initiator and Target can be longer than SCSI cable or fiber channel.

2.2 iSCSI

The iSCSI(Internet Small Computer System Interface) is an emerging standard storage protocol that can transfer a SCSI command over IP network [5]. Since the iSCSI protocol can make clients access the SCSI I/O devices of server host over an IP Network, client can use the storage of another host transparently without the need to pass through a server host's file system [6].

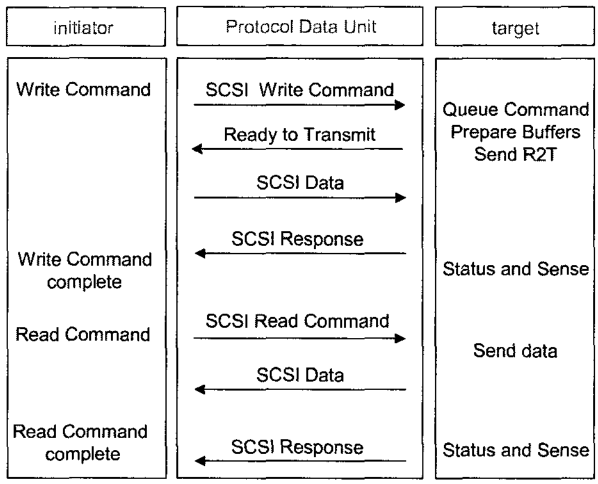
In iSCSI layer, which is on top of TCP layer, common SCSI commands and data are encapsulated in the form of iSCSI PDU(Protocol Data Unit). The iSCSI PDU is sent to the TCP layer for the IP network transport. Through this procedure, a client who wants to use storage of the remote host, can use, because the encapsulation and the decapsulation of SCSI I/O commands over TCP/IP enable the storage user to access a remote storage device of the remote host directly [3].

Likewise, if we build a remote storage system for mobile appliances using the iSCSI protocol, mobile clients can use the storage of a server host directly, like their own local storage. It enables mobile appliances to overcome the limitation of storage capacity, as well as the ability to adapt various application services of wired environment in need of mass scale data. Different from the traditional remote storage system, based on file-level I/O, iSCSI protocol provides block unit I/O. Therefore it can make more efficient transmission throughput than the traditional remote storage systems, like CIFS and NFS.

Another characteristic of the iSCSI protocol is that it operates on a standard and commonly used network component like Ethernet. Since iSCSI protocol can be plugged directly into an Ethernet environment, it is easier to manage than another storage data transmission protocol, such as Fibre Channel. Moreover, iSCSI can reduce the costs to build a storage system due to the use of infra network without additional adjustment. The iSCSI protocol was defined as the standard SCSI transmission protocol recently by IETF and a lot of related research is being conducted with the development of Gigabit Ethernet technology.

2.2.1 iSCSI Basic Operation

(Figure 2) shows the exchanged control and data packets' sequence in the read and write operation of iSCSI protocol [10].

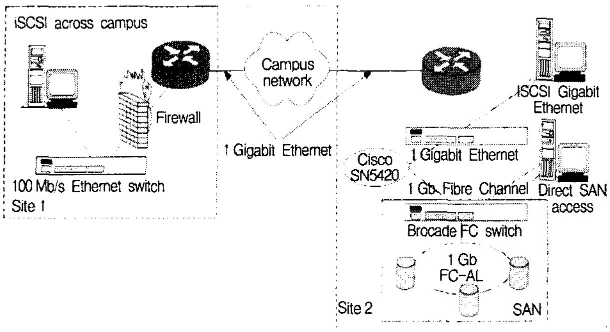


(Figure 2) iSCSI basic operation

Like (Figure 2), iSCSI exchanges the control packets(SCSI Command, Ready to Transmit, SCSI Response) and data packet(SCSI Data) to process one R/W operation. Three control packets and one data packet are used in a write operation and spend 2 × RTT. It takes 2 control packets and 1 × RTT for a read operation. Because the control packet, including header informations, is no more than 48 byte, bandwidth waste becomes serious when the initiator recedes a little from the target. Therefore, the distance between iSCSI initiator and target, and the network latency influence iSCSI I/O performance.

2.2.2 ISCSI performance change by network latency

(Figure 3) shows a storage system constructed at the University of Minnesota, for a performance experiment of the iSCSI based storage service in different network environments [6]. Here, they analyzed the performance change and features of iSCSI when storage is accessed on a Gigbit Ethernet(LAN) and through a campus network(WAN).



(Figure 3) iSCSI performance experiment environment

Through the experiment results in <Table 1>, we can see that the latency, caused by network distance and bandwidth between iSCSI initiator and target, influences iSCSI performance. iSCSI shows similar performance in the small Gigabit Ethernet environment, such as when a disk is directly accessed through a fiber channel, but shows low performance in a campus LAN(WAN) environment in which network traffic is liable to variation and latency is big. This is why delay time affects iSCSI's I/O performance greatly. Especially, when data size is large, transmission delay, influenced by network bandwidth is much bigger than other latencies. When the data size is small, propagation delay, influenced by the distance of a physical network, is the main part of the iSCSI latency. In the case of mobile appliances, which usually run I/O by small blocks, delay by the distance of the physical network that packet moves is more important factor in degrading iSCSi performance than the delay by bandwidth.

〈Table 1〉 Change of delay by network and data size

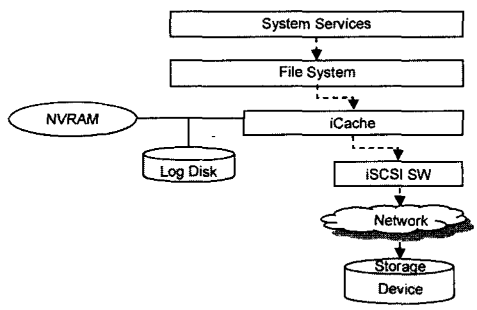
Read(ms)				
Configuration	1KB	4KB	16KB	64KB
GigE LAN iSCSI	9.57	9.7	10.91	15.82
Campus LAN iSCSI	11.37	12.45	14.33	24.2
Write(ms)				
Configuration	1KB	4KB	16KB	64KB
GigE LAN iSCSI	10.08	10.35	11.24	15.0
Campus LAN iSCSI	12.8	12.5	14.62	22.98

3. Related Work

The use of cache to improve disk I/O performance has already been studied for a long time. Usually, research uses part of the memory space as a buffer cache to improve per formance of a local disk. However, research that uses local or network cache to improve iSCSI's performance has been conducted as iSCSI was a standard recently and products supporting iSCSI appeared.

3.1 iCache

iCache is a research to improve iSCSI performance using local cache of a client system. Initiator's systems have specific cache space for iSCSI data, and iSCSI block data is cached to minimize network block I/O. Therefore, iSCSI does not send I/O requests through the network every time the disk I/O happens. Instead it reads cached blocks or send blocks cached in LogDisk at once to the server for improving iSCSI performance. iCache's buffer space consists of two hierarchical caches comprising NVRAM and LogDisk. Data is stored sequentially in NVRAM. When enough data is gathered, iCache process moves data from NVRAM to LogDisk. Blocks which are frequently accessed, are kept in NVRAM where access speed is fast. iCache stores less accessed data in the LogDisk. Furthermore, destage operation is achieved by kernel thread called a LogDestage. In a Destage Operation, NVRAM's data is moved to the LogDisk, or the LogDisk's data is sent to remote storage using iSCSI protocol. Cache techniques used in iCache are based on DCD technology [11] proposed to improve Disk I/O performance.



(Figure 4) iCache architecture

It is difficult to apply iCache to mobile devices which lack memory, because iCache needs additional memory and hard-disk space to embody the local cache, NVRAM and LogDisk. So, we introduce new type of iSCSI cache for mobile appliance, which exists on the network between iSCSI initiator and target instead of inner space of mobile device.

4. Proposed Idea

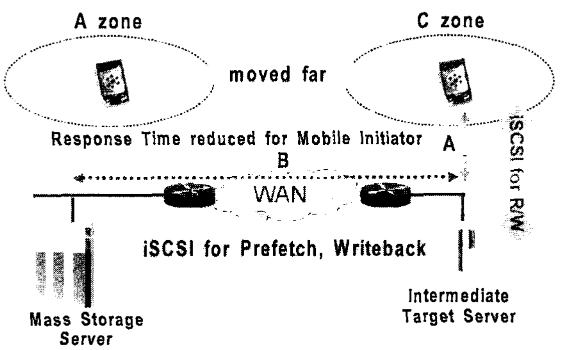
In this chapter, we discuss how localizing the iSCSI target with an intermediate server, called intermediate target, and solve the problem of iSCSI performance dropping when iSCSI mobile clients recede from the storage server. iSCSI response time for I/O operation is minimized with the nearest intermediate target. It is possible due to prefetching read blocks for the client to use, or responsing beforehand packet to iSCSI initiator for the written blocks. That means localization of iSCSI target which brings latency reduction of packet transfer and minimizes protocol overhead to improve iSCSI performance.

In the proposed design, we assume the following three factors to simplify the problem.

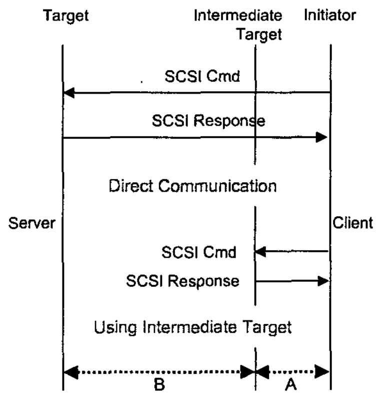
- Supposing a distributed storage server environment, iSCSI intermediate target server spread over wide areas. A mobile client is connected with the nearest iSCSI intermediate target through an iSNS(Internet Storage Name Server) [3].
- As transmission distance increases, propagation delay of physical media, and the sum of the queing delay of intermediate routers increas.
- iSCSI latency includes propagation delay by distance, queuing delay and transmission delay by bandwidth, and ignores processing delay of end nodes including intermediate node.

4.1 iSCSI Intermediate Target

In an iSCSI based remote storage service for mobile nodes, when mobile node serviced in area A moves to area C, the distance between iSCSI initiator and target is prolonged and packet transfer time increases. In chapter 3, we showed that the SCSI command is processed sequentially in SAM-3 [7] and iSCSI basic operations need an exchange of several control packets to process one command. Because small control packets of the iSCSI protocol influence iSCSI response time, if the distance between the server and the client is long, the link utilization drops sharply and iSCSI performance becomes low.



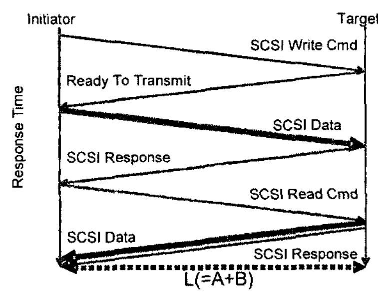
(Figure 5) iSCSI target localization with intermediate server



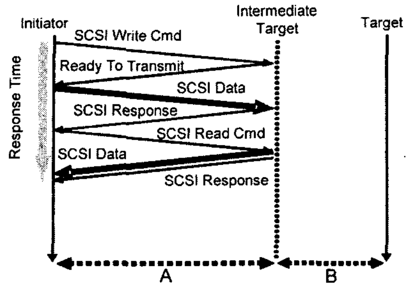
(Figure 6) SCSI response time reduction

We introduced an intermediate server(iSCSI Intermediate Target) to reduce the packet transfer delay time between server and client, and heighten practical utilization of the network bandwidth. Intermediate target prefetches the next block to be used by the client for iSCSI read operations and can give quick responses for iSCSI write operations. The nearest intermediate server from mobile client is selected by iSNS and the client can run iSCSI protocol with the intermediate server, which also has an iSCSI connection with a remote storage server. Therefore, response delay time of an I/O request shortens because the client has an iSCSI connection with a nearby intermediate server, instead of a long-distance storage.

(Figure 7) and (Figure 8) shows that response delay times are different when the iSCSI Initiator and Target communicate directly with each other, and when put with an iSCSI intermediate server. Three control packets should be exchanged to process a write command and two control packets for a read command. If the distance between initiator and target is short, iSCSI I/O response time is reduced because the control packet size is small, but it has same propagation and queuing delay. If the end nodes' processing delay of an iSCSI packet is ignored, response delay time is reduced by A/L ratio when introducing an intermediate server as shown in (Figure 8).



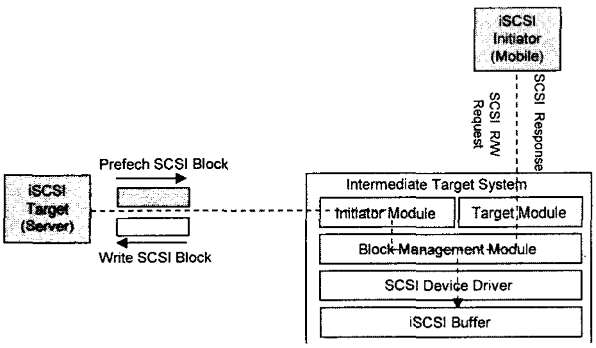
(Figure 7) Direct communication between iSCSI Initiator and Target



(Figure 8) Response by intermediate target

4.2 System architecture

(Figure 9) shows a module diagram of an intermediate target system. An intermediate target system consists of iSCSI initiator, target, and block management module. An iSCSI intermediate server has two iSCSI connections. One is a connection between the intermediate target server and mobile client and the other is a connection with the storage server. The target module has an iSCSI session with a mobile client's iSCSI initiator and the initiator module has one with the iSCSI target module of the storage server. Two modules perform the same role, such as general iSCSI Target/Initiator module. However, the first iSCSI connection between mobile client and intermediate target isused for I/O requests of the client, and the latter is used to prefetch next blocks used by the client from the storage server or to deliver write blocks to a storage server. The target/initiator module of an intermediate server is controlled by a block management module. ISCSI Buffer is managed by FIFO as a way to leave blocks used most recently.



(Figure 9) Intermediate target system

(Figure 10) shows processing algorithm for client I/O requests by block management module of intermediate server. In the case of a read request, a block management module searches requested blocks in the iSCSI buffer to service the requested block with a target module. If the requested block exists in the iSCSI buffer, target module of intermediate target server will reply to the client. But when there is a non requested block in the buffer, the initiator module of the intermediate target server, which has a connection with the storage server, sends the client's request to storage server and receives the block to send to the client. At this time, the block management module sends a read request to the next logical address of the block that the client required. When the intermediate server receives a write I/O request, the intermediate server sends a reply message to the client and sends the write block to the storage server in no time. Therefore, a mobile client's iSCSI initiator has an effect of an iSCSI connection with a nearby storage server.

```
When Intermediate Target Receives I/O Request
i : Requested Block
 {
   if(Read Op)
   {//Client's I/O Request is Read Operation
      if(i exists in iSCSI Buffer)
      {
         Send i and Response to Initiator
      }
      else
      {
          Send Read Request of i to Target
      }
      Send Read Request of i+1 from Target
      and Put at Head of iSCSI Buffer
      //Prefetch next block from Storage Server
   }
   else (Write Op)
   {//Client's I/O Request is Write Operation
    Put i at Head of iSCSI Buffer
    Send Response to Initiator
    Send Write Request of i to Target
   }
 }
```

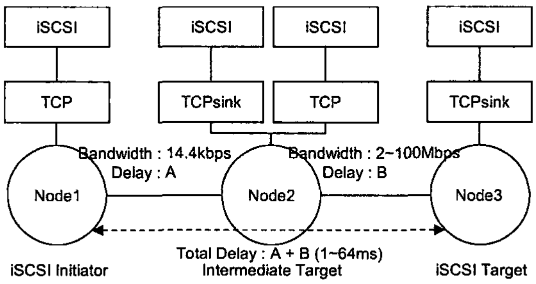
(Figure 10) Block management algorithm

5. Simulation

In this chapter, we measured the change of iSCSI performance by the distance between the iSCSI target and initiator, and the position of the intermediate target. In the case of a read operation, we measured the change of iSCSI performance by the hit ratio of a prefetched block. The results show that iSCSI performance is high when the distance between initiator and target is short, and data is accessed sequentially, such as for multimedia data.

5.1 Simulation environment

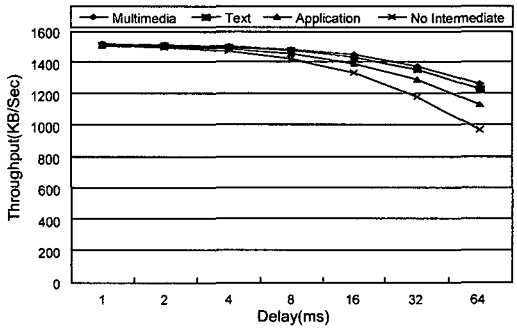
In (Figure 11), the network of an iSCSI initiator, target and intermediate target is simulated using a network simulator 2.27. The bandwidth of the link between node1 and node2 is limited by 14400bps to sumulate wireless network (CDMA 2000 1x). And the link bandwidth between node2 and node3 which is representative of wired network is 2~100 Mbps. Performance is measured by changing the delay time from 1ms to 64ms to analyze the change of iSCSI performance according to the distance between iSCSI initiator and target under the supposition that delay is proportional to distance. We selected 512 byte data size which is SCSI block size used in PDA of Windows CE base, which is one of the representative mobile appliances.



(Figure 11) Network Configuration with NS2

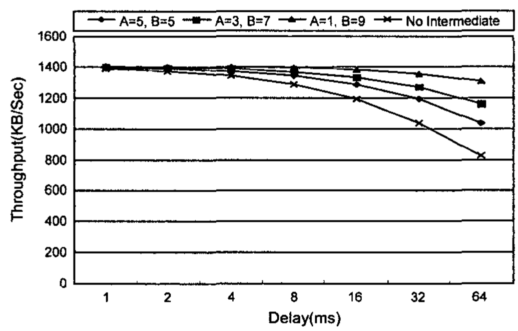
5.2 Experiment results and analysis

(Figure 12) shows the difference in iSCSI performance, by data type, when an intermediate target is used or not. In the case of the ratio of delay time A and B specified by 7 : 3, we can see that the difference in iSCSI performance is very small regardless of data type when total delay is less than 2ms. In a simulation using ns2, iSCSI throughput is influenced by a propagation delay, which depends on physical media, and transmission delay that depends on data size and bandwidth. In cases where iSCSI has a short delay, when the distance of iSCSI initiator from target is short, transmission delay is much bigger than the difference of propagation delay by introducing intermediate target. Therefore it has little influence on iSCSI performance. However, when the iSCSI initiator is distant from the target, the difference of propagation delay time is much longer than transmission delay. And, the intermediate target greatly effects on the iSCSI throughput. According to (Figure 13), we know that iSCSI performance differences appeared greatest when propagation delay of the iSCSI initiator and target was prolonged. In the case of multimedia, text and application data, each has improved throughput by 30%, 27% and 17% when the latency is 64ms. iSCSI service is divided by the type of data which is provided for users. The difference of iSCSI performance according to data type is due to the fact that the iSCSI buffer hit rate for a read block is different. We suppose that the hit ratio of multimedia data, which is accessed sequentially, is 90 percent and hit ratios are 80% and 50% in the case of text and application data.



(Figure 12) Performance result by data type(read operation)

(Figure 13) shows throughput change by distance ratio of an intermediate target for iSCSI write operations. In cases of a write operation, throughput does not change regardless of data type, so we experimented how the performance of iSCSI write operation changes according to the intermediate target□s position. Same as a read operation, iSCSi write operation has a small difference in performance when total distance is short, but the difference is larger if the distance is longer. Furthermore the results show that performance appears high when delay time of the iSCSI initiator and intermediate target is smaller. The difference of iSCSI performance was biggest at the point where total delay time is 64ms, as is the case of read operations. And in the case of the ratios, A : B = 5 : 5, A : B = 3 : 7, A : B = 9 : 1, performance elevation of each 25%, 40%, 59% occured. Therefore, we know that proposed method show high performance when the iSCSI intermediate target is close to the initiator.



(Figure 13) Throughput change by distance ratio of intermediate server(write operation)

6. Conclusion & Future Work

In this paper, we described efficient ways introducing iSCSI intermediate target, to improve the problem of iSCSI performance falling when applying iSCSI-based remote storage services for mobile appliances. In the proposed method, localizing the iSCSI target improved low link utilization and iSCSI performance degradation problems when the initiator receded from the target. Through simulation results we know that iSCSI performance falls rapidly if the distance (latency) of the initiator and target is long, and could see that iSCSI performance is high if the intermediate target is close to the initiator.

In future work, we will apply various prefetch algorithms for data type, or improve present FIFO iSCSI buffer management algorithm to heighten buffer hit rate. To accomplish this future work, we have to research how data type is classified and methods of sending information, and other buffer management algorithms.

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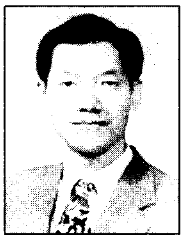

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