A Media Storage and Transmission System Using MDRUs

Takayuki Nakachi, Sun Yong Kim, Atsushi Okada, and Tatsuya Fujii

Abstract

Developing information and communication technology (ICT) networks and services that are resilient to disasters is a critical task. NTT Network Innovation Laboratories is promoting innovative research and development on a transportable ICT node called the Movable and Deployable ICT Resource Unit (MDRU), which is designed to promptly recover ICT services after a disaster. In this article, we introduce a media storage and transmission system based on the use of MDRUs. It efficiently provides information such as text and image/video data to people in disaster areas in circumstances when ICT resources are constrained such as when network bandwidth is limited or storage failures occur. We demonstrated its feasibility in a field trial.

Keywords: layered coding, distributed storage, image/video transmission

1. Introduction

The Great East Japan Earthquake of March 11, 2011 damaged or completely destroyed many information and communication technology (ICT) resources, which demonstrated that the development of resilient ICT networks and services is a critical issue demanding urgent attention. Immediately after a disaster, it is important to rapidly share accurate information. In addition to text data, image/video data are important in disaster recovery. Image/video content can instantly provide detailed information to people in disaster-stricken areas. Examples of information that may need to be transmitted or exchanged after a disaster are shown in **Fig. 1**.

A portable media storage and transmission system can provide such information to people working in disaster relief offices and to evacuees at evacuation centers and in their own homes. Our media storage and transmission system is based on the specially designed Movable and Deployable ICT Resource Unit, which we refer to as an MDRU. MDRUs will be transported immediately to a disaster area to provide recovery of ICT services. The media storage and transmission system must transmit information to the greatest extent possible within the capacity restrictions posed by MDRUs. The proposed system is implemented by the following steps.

(1) Transport and activation of stand-alone MDRUs to disaster areas

An MDRU with a cache server is quickly transported to a disaster area. The MDRU holds a cache server that runs software for the media storage and transmission system. Layered storage consisting of random-access memory, solid-state drive (SSD)*1, and hard disk drive (HDD)*2 devices is installed in the cache server. The MDRU forms a wireless access network, with or without wired network connections, to reach user terminals such as laptop personal computers (PCs), smartphones, and tablet devices. People within 500 m or so from the MDRU can view information such as text and image/video data stored in the cache server and/or upload data to the cache server.

*1 SSD: A data storage device that uses integrated circuit assemblies as memory to store data persistently. Compared with electromechanical disks such as HDDs, SSDs are typically more resistant to physical shock and have lower access time and less latency.

*2 HDD: A data storage device that uses rapidly rotating disks coated with magnetic material. HDDs remain the dominant medium due to advantages in price per unit of storage and recording capacity.

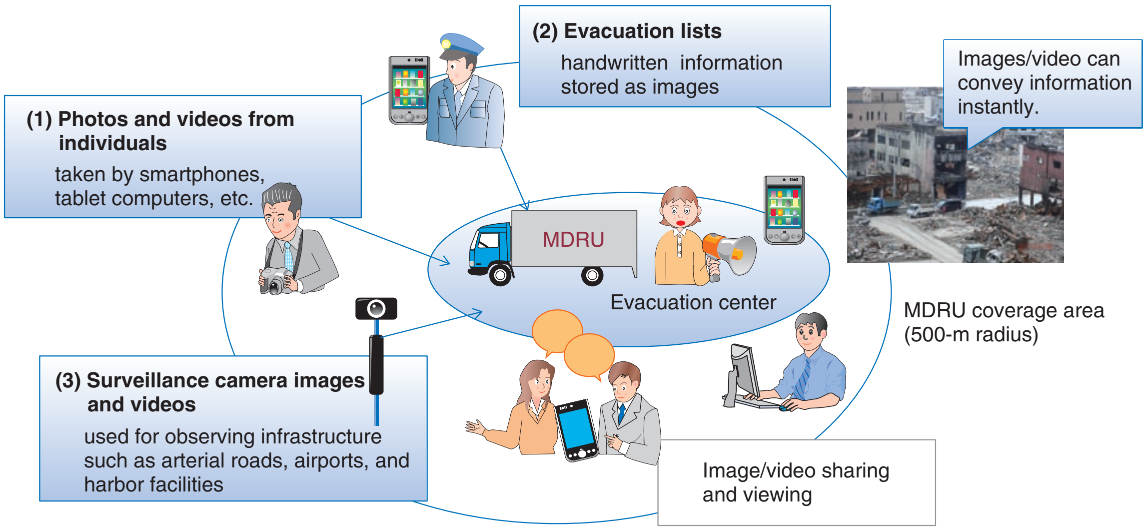

Fig. 1. Information needed in disaster areas.

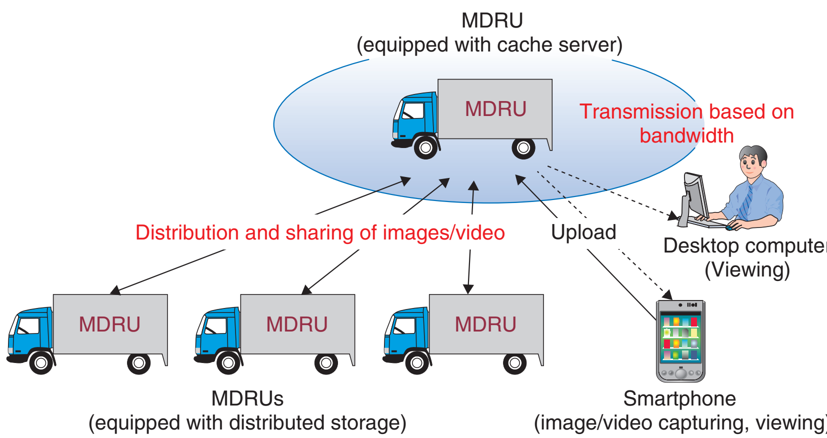

Fig. 2. Operation of multiple MDRUs in local disaster areas.

(2) Operation of multiple MDRUs in local disaster areas

As many MDRUs as needed are deployed to the disaster area. Each MDRU has interworking storage devices that form a distributed storage system along with the cache server. Data uploaded to each MDRU can be backed up to and shared among the multiple MDRUs (**Fig. 2**).

(3) Operation of multiple MDRUs connected to wide area network

MDRUs will be connected to a local datacenter and wide area network. Information data can be widely shared via the local datacenter. People in the disaster area can watch news coverage originating outside the disaster area and share information about other areas.

The media storage and transmission system is based on two technologies. One is disaster resilient layered data transmission [1], and the other is networked distributed storage [2]. The former transfers information efficiently to work within the MDRU's limited network bandwidth and power supply. The latter recovers data lost by 1) network congestion or disconnection or 2) storage failures caused by MDRU accidental power-off or MDRU transport. More details of these technologies are given below.

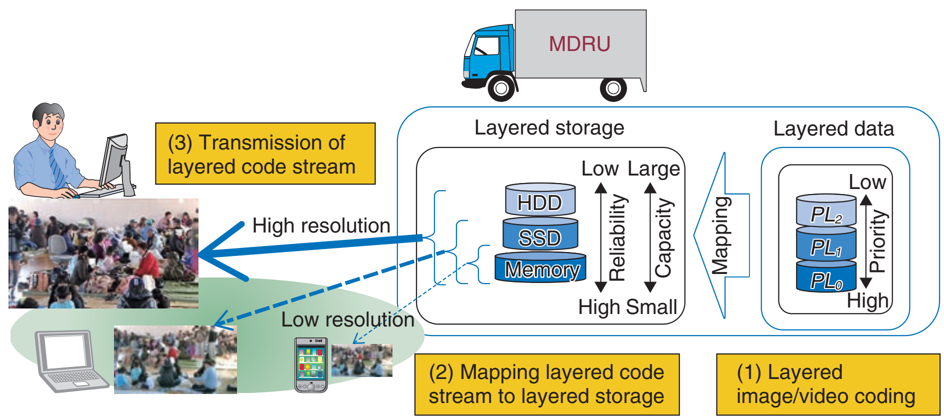

Fig. 3. Layered data transmission.

2. Disaster resilient layered data transmission

The proposed disaster resilient layered data transmission system offers image/video services to people in disaster-affected areas through MDRUs. The disaster resilient image/video transmission scheme is designed around three technologies: (1) layered image/video coding, (2) mapping of the layered code stream to layered storage systems installed in the MDRUs, and (3) transmission of layered code streams according to network bandwidth (**Fig. 3**).

(1) Layered image/video coding

We utilize the JPEG 2000 standard [3] created by the Joint Photographic Experts Group (JPEG) for layered image/video coding. Input images are decomposed into layered data in a priority manner; that is, JPEG 2000 bit streams are created. JPEG 2000 offers four basic scalability dimensions in each JPEG 2000 bit stream: resolution (R), SNR (signal-to-noise ratio) quality (L), spatial location (P), and component (C). Different scalability levels are achieved by ordering packets within the JPEG 2000 bit stream. We assume that text data consist of handwritten notes on a bulletin board set up in an evacuation center. The handwritten information is captured by smartphones and/or tablet PCs. We use Motion JPEG 2000 (MJ2) for the layered video coding. It specifies the use of the JPEG 2000 format for timed sequences of images (video). Other layered video codecs such as Scalable Video Coding (SVC), which is a scalable extension of H.264/MPEG-4 AVC[*3], or Scalable High Efficiency Video Coding (SHVC), a scalable extension of H.265/HEVC[*4], can also be used. We selected MJ2 because of its transmission robustness and low-complexity compared with SVC and SHVC.

(2) Mapping layered code-stream to layered storage

The layered storage system consists of random-access memory, SSD, and HDD devices. The JPEG 2000 bit streams are mapped to the layered storage as shown in Fig. 3. PL_0, PL_1, and PL_2 are priority-mapping layers and are mapped to random-access memory, SSD, and HDD, respectively. The progression order of the JPEG 2000 bit stream is determined in advance. Different scalability levels are achieved by ordering packets and can be arbitrarily assigned to each form of storage. If MDRU power consumption becomes a problem, we can turn off the HDD devices, and if additional energy saving measures are necessary, the SSD devices can be deactivated.

(3) Transmission of layered code stream

JPEG 2000 is attractive as it can truncate lower priority bit streams from partial ones. This allows for simple responses to changes in network bandwidth and MDRU power consumption. The truncation process consists simply of extracting the required layers from the encoded bit stream; there is no additional

*3 H.264/MPEG-4 AVC (Advanced Video Coding): A video coding standard that was developed by the JVT (Joint Video Team) of the ITU-T (International Telecommunications Union-Telecommunication Standardization Sector) and the ISO/IEC (International Organization for Standardization / International Electrotechnical Commission) in 2003. It covers common video applications ranging from mobile services and video conferencing to IPTV (Internet protocol television), high-definition (HD) TV, and HD video.

*4 H.265/HEVC (High Efficiency Video Coding): The most recent standardized video compression standard developed by the JCT-VC (Joint Collaborative Team on Video Coding) of the ITU-T and the ISO/IEC. It reduces the bit rate by around 50% while maintaining the same subjective video quality relative to its predecessor H.264/ MPEG-4 AVC.

processing of the stream itself. The MDRU forms a wireless access network around itself to reach user-held equipment. The truncation consists of extracting the required layers based on the bandwidth between the MDRU and the user. An example of layered transmission is shown in Fig. 3 when the priority of the resolution is selected. One usage example is that the user can see a specific full-resolution image after overviewing multiple thumbnail-sized images. Sending only the higher resolution components of an image specified by a user results in more efficient use of network bandwidth resources.

3. Networked distributed storage

Here, we assume that the following problems occur after installing MDRUs and launching ICT services: 1) network congestion or disconnection and 2) storage failures caused by MDRU accidental power-off or MDRU transport, which can occur when MDRUs are repositioned in a disaster area. The proposed networked distributed storage system recovers data lost because of the above problems to the greatest extent possible. This scheme is based on three techniques:

(1) Unequal error protection of image/video components

Layered data are protected by unequal forward error correction (FEC) codes. For this, we use previously proposed layered low-density generator matrix (LDGM) codes [4]. The layered LDGM codes provide greater protection for image/video components that have been classified as more significant than other components. Furthermore, it is advantageous in having lower computation complexity and communication cost in recovering lost data than the well-known Reed-Solomon (RS) codes.

(2) Optimum source*5 and repair*6 packet deployment for distributed storage

Generated source and repair packets are deployed to distributed storage (i.e., a number of storage devices), as shown in **Fig. 4**. To reduce the impact of a storage failure to the maximum extent, source and repair packets are deployed uniformly to each storage device. Furthermore, successive repair packets are deployed to different storage devices; they are not deployed to the same storage device to ensure that they are not lost. This is because if successive repair packets are lost, the error recovery probability decreases because LDGM codes use the staircase matrix.

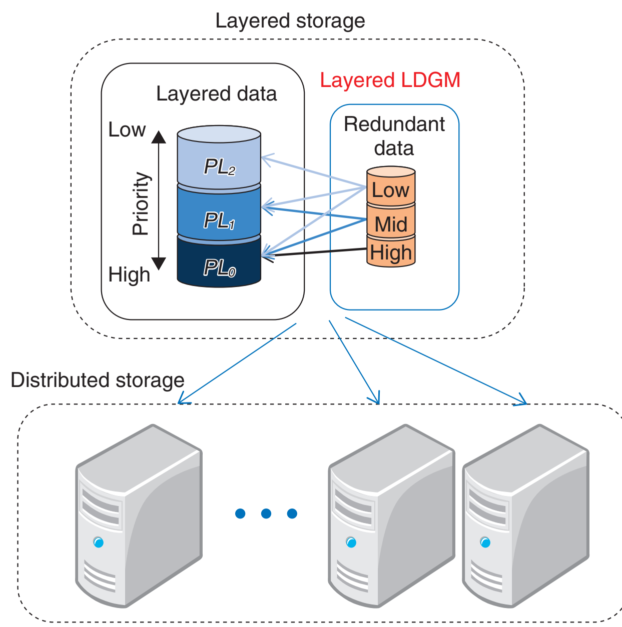

Fig. 4. Source and repair packet deployment for distributed storage.

(3) Implementation compliant with next-generation MMT standard

MPEG Media Transport (MMT) is a new media transport standard being developed as ISO/IEC 23008-1 [5]. MMT specifies technologies for the delivery of coded media data for multimedia services over concatenated heterogeneous packet-based network segments including bidirectional IP (Internet protocol) networks and unidirectional digital broadcasting networks. MMT FEC codes are also specified in ISO/IEC 23008-10 [4]. We developed our networked distributed storage system to be compliant with the MMT standard. Source and repair symbols are packetized to MMT source and repair packets according to the MMT specifications. The packets are delivered by the MMT delivery protocol. This is advantageous in that storage and streaming data can be treated in a unified framework.

4. Field trial

We established an experimental environment in order to evaluate the proposed disaster resilient network and services based on MDRUs. We demonstrated its feasibility in a field trial on February 28,

*5 Source packet: A packet consisting of layered data (JPEG 2000 bit streams).

*6 Repair packet: A packet containing redundancy information for error correction.

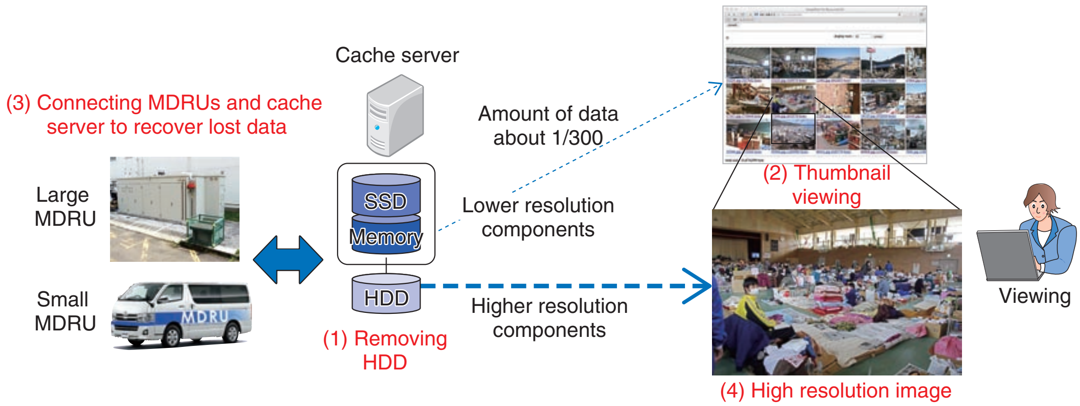

Fig. 5. Overview of hardware trial.

2014 at Tohoku University. A system overview of the field trial is shown in **Fig. 5**. We assumed that multiple MDRUs had been deployed to a disaster area. The cache server was set in the demonstration room. Distributed storage was installed in both a large MDRU and a small MDRU. Input images were decomposed into six resolution levels. For priority mapping, we respectively assigned the three lower and three higher resolution components to internal (SSD) and external (HDD) storage devices. We connected a user terminal laptop PC to the cache server via a wireless local area network. The trial proceeded as follows:

(1) The HDD that replicates disk failure was demounted.
(2) Thumbnails of multiple images were shown using the three lower resolution components stored in the SSD.
(3) The cache server was connected to distributed storage units, and the three higher resolution components were recovered.
(4) The three higher resolution components of the specific image specified by the user were transmitted, and the full resolution version of the image was shown.

This trial verified that thumbnails of multiple images could be shown even with the failure of the HDD device. After the thumbnails were overviewed, the full resolution version of the specific image was shown by transmitting only its additional higher resolution components. We showed that lost data were recovered by using the layered LDGM codes. Details on the complexity and performance of image/video coding and LDGM codes can be found in other reports [1, 2].

This trial also demonstrated the usefulness of the technologies being developed. We plan to continue this research in order to create innovative technologies that will enable rapid access to communication tools under constrained circumstances such as after a disaster.

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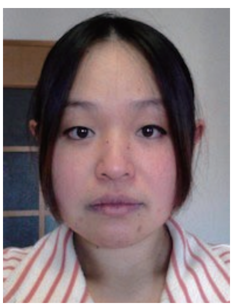
Takayuki Nakachi
Senior Research Engineer, Media Processing Systems Research Group, NTT Network Innovation Laboratories.

He received the Ph.D. in electrical engineering from Keio University, Tokyo, in 1997. Since joining NTT in 1997, he has been engaged in research on super-high-definition image/video coding and communication networks. His current research interests include distributed source coding, super resolution, and secure media processing. From 2006 to 2007, he was a visiting scientist at Stanford University, CA, USA. He is a member of the Institute of Electronics, Information and Communication Engineers (IEICE) and the Institute of Electrical and Electronics Engineers (IEEE).



Sun Yong Kim
Senior Member, Strategic Business Development Division, NTT.

She received her M.S. in computer science from the University of Tokyo in 2004. She joined NTT Network Innovation Laboratories in 2004. Her interests are data mining, machine learning, and statistics.

Atsushi Okada
Research Engineer, NTT Network Innovation Laboratories.

He received the B.S. in systems engineering from the University of Electro-Communications, Tokyo, in 2003, and the M.S. in interdisciplinary information studies from the University of Tokyo in 2005. He joined NTT Network Innovation Laboratories in 2005 and has been researching multi-channel audio transmission systems and reliable content distribution systems.

Tatsuya Fujii
Group Leader, Media Processing Systems Research Group, NTT Network Innovation Laboratories.

He received the B.S., M.S., and Ph.D. in electrical engineering from the University of Tokyo in 1986, 1988, and 1991, respectively. He joined NTT in 1991. He has been researching parallel image processing and super-high-definition image communication networks. In 1996, he was a visiting researcher at Washington University in St. Louis, MO, USA. He was a director of a digital cinema development project. He is currently studying real-time 4K video communication system architecture and reliable content distribution systems. He is a member of IEICE, the Information and Television Engineers (ITE) of Japan, and IEEE.