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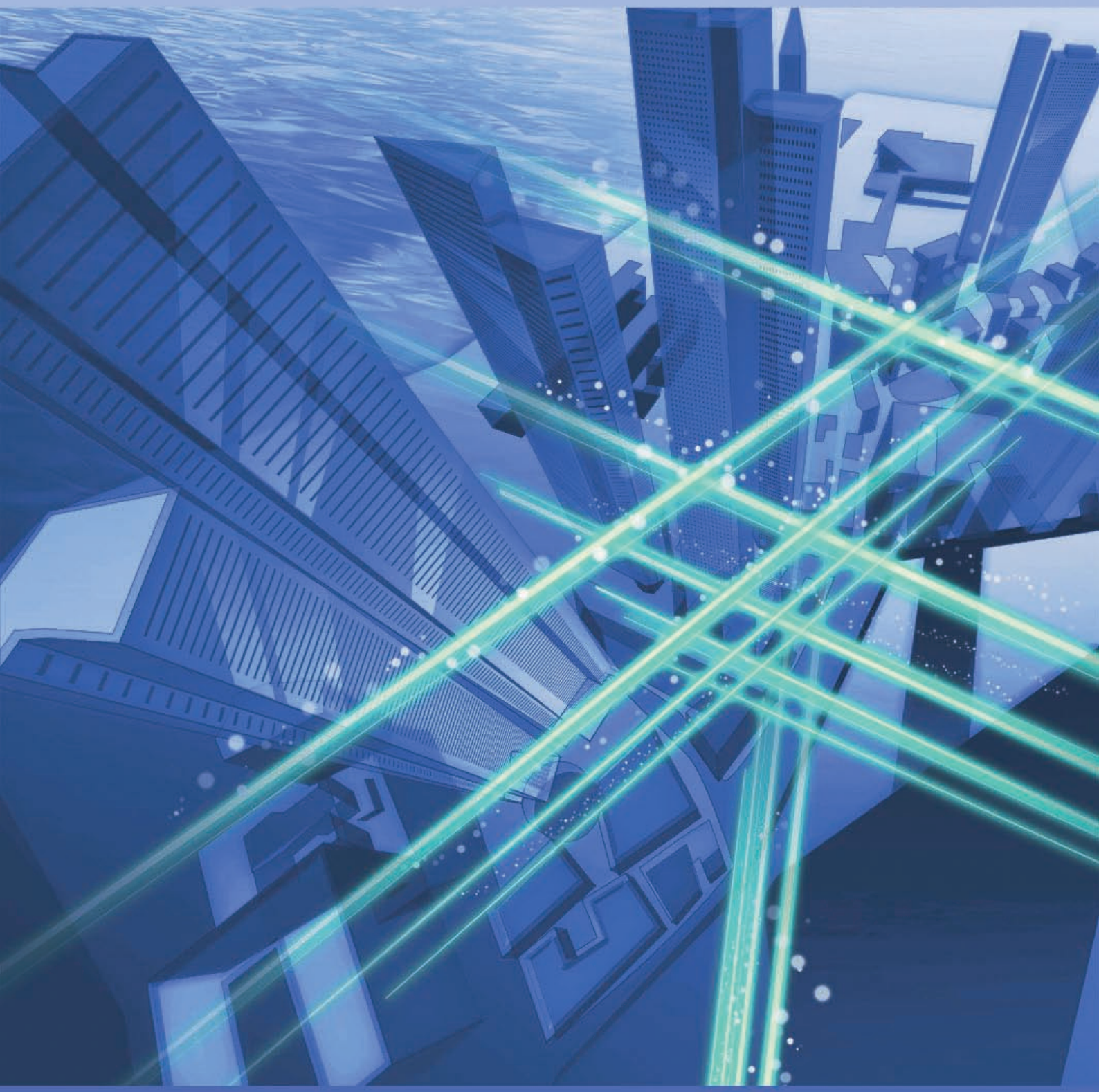

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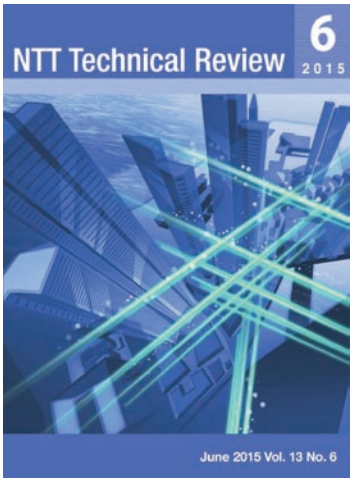
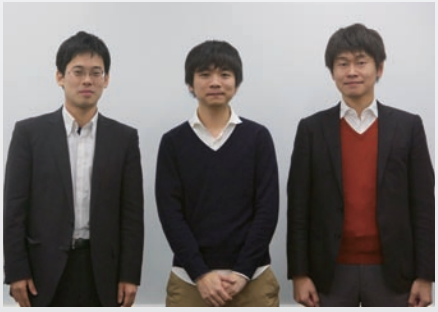


Being Hadoop Committers is an Intermediate Goal—Young Researchers and Developers Looking to Become Future Pioneers

Tsuyoshi Ozawa, NTT Software Innovation Center
Akira Ajisaka, NTT DATA
Masatake Iwasaki, NTT DATA



(From left) Akira Ajisaka, Tsuyoshi Ozawa, and Masatake Iwasaki

In December 2014, three employees from the NTT Software Innovation Center and NTT DATA Corporation were elected as Hadoop committers (chief developers) in recognition of their activities in the Apache Hadoop development community and particularly their work in Apache Hadoop and related projects. The development of Apache Hadoop is progressing through the collaboration of software engineers around the world. About 3000 individuals are contributing to this effort, although there are only about 100 committers, who have the authority to rewrite programs in development and maintenance projects. The election of these three NTT Group employees represents the first committers from Japanese industry. We present here a close-up of these three individuals responsible for this outstanding achievement.

Keywords: Hadoop, committer, open source

Appointment to an important role shared by only about 100 people worldwide

—Congratulations on your election as Hadoop committers! What was your reaction on hearing about this?

Ajisaka: Thank you very much. Although I didn't know much about the election procedure or criteria for selection, one day I suddenly received an email from the Project Management Committee (PMC) informing me that I had been elected as a committer. I had been participating in the development of Apache Hadoop thinking that one day I would like to be appointed as a committer, but on hearing that my dream had actually come true, I was thrilled.

Ozawa: I was sometimes asked by people around me, "Is there a chance that you might be elected?" but I had my doubts, so on actually receiving an email inviting me to become a committer, I was surprised. But at the same time, I took great pride in my election thinking, "At long last, I've been notified!" The group

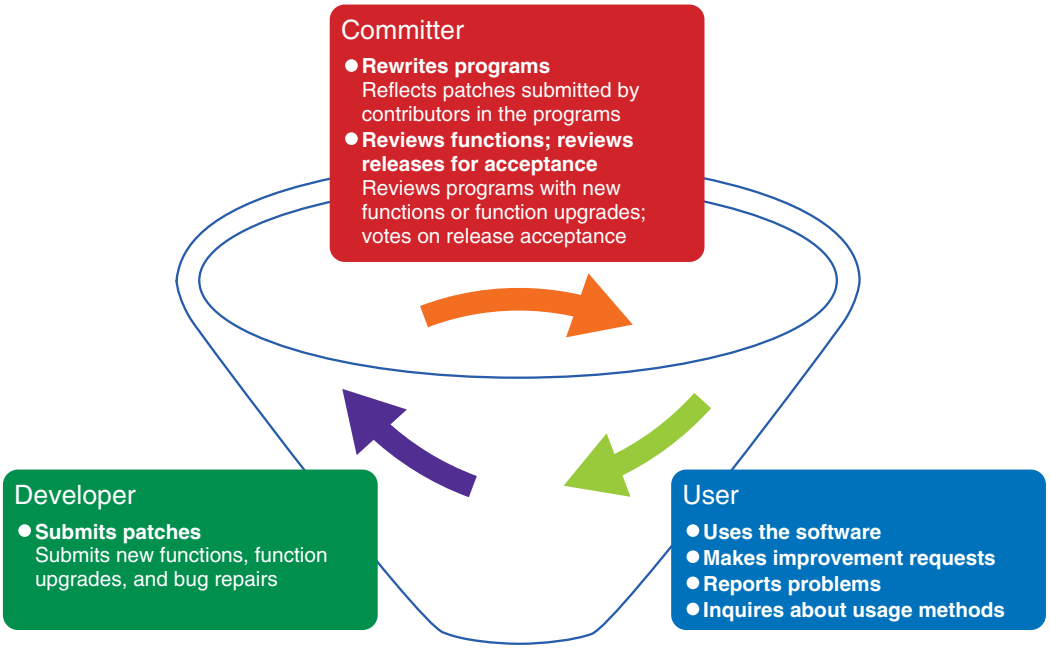


Fig. 1. Committer role.

of Hadoop committers is said to include the board members (chief members), and no doubt, committers are elected based on discussions among them, but I really don't know the details. In the end, I believe that our election as committers is the result of our activities to date in helping to raise the quality of Hadoop through bug fixes and other work.

Iwasaki: I share the same sentiments as my two colleagues. I myself have been chosen to be a committer for the HTrace project of Hadoop. HTrace is a tool for analyzing how software such as Hadoop operates. HTrace was originally developed by a certain company and donated to the Apache Software Foundation, and once it was decided to further develop HTrace as open source software, I came to be chosen as its first committer.

—What exactly is Hadoop?

Ozawa: In short, Hadoop is software for achieving parallel distributed processing of very large data sets. Parallel distributed processing is technology for using a cluster of computers to perform processing that is traditionally difficult to handle on a single computer. Hadoop is one type of software for implementing this technology. Hadoop is based on ideas set forth in papers released by Google Inc. in 2003 and 2004 and is implemented as open source software that continues to expand. As one of many projects of the Apache Software Foundation, Hadoop is being developed through the worldwide collaboration of about 3000 software engineers called contributors. The use of Hadoop was initially centered on web and social-networking firms. However, with the rise of big data applications and the quantum leap in the scale of data processing due to expanding customer bases and services as companies go global, Hadoop is also coming to be used by a wide variety of enterprises and is being developed as open source software through the collaboration of people throughout the world.

—What is your role as committers?

Ajisaka: An open source community consists of three types of individuals (**Fig. 1**): software users, developers who submit new functions or bug repairs, and committers who review those submissions and decide whether to reflect them in the programs themselves. About 3000 software engineers from around the world are participating in the Hadoop project, but there are only about 100 committers. As committers, the three of us take part in Hadoop development and have the authority to make changes to source code.

Although all kinds of requests such as function additions and modifications are proposed by individuals involved in development work, it is the committers who are able to decide whether those changes should be made. We are the first committers to come out of Japanese industry. Basically speaking, there is no set term for a committer; however, if a committer should lose the confidence of the community, his or her voice will no longer be heard. I therefore think that it is necessary to raise one's profile and community confidence by providing and contributing one's skills and knowledge to the community in an ongoing manner and by fulfilling one's responsibilities with vision.

—As NTT Group employees elected as committers, what kind of synergetic effect do you expect to occur between the NTT Group and the Hadoop community?

Ajisaka: The NTT Group operates a number of systems using Hadoop, and NTT DATA provides outside customers with Hadoop-based systems as a business. One of our jobs is to support our customers by solving problems that occur in the actual operation of Hadoop and to clarify any areas of Hadoop that the customer is unsure about. Our most important task in this daily work is to make sure that the Hadoop-based systems that we are providing are functioning smoothly. Thus, an additional effect of being elected a Hadoop committer is that our customers will come to have even more confidence in NTT DATA as a service provider.

Ozawa: It is said that the majority of Hadoop committers come out of vendor enterprises where working on Hadoop is their full-time occupation. In such enterprises, priority is given to attractive functions that customers tend to purchase. However, companies such as NTT DATA that develop systems and provide services using Hadoop are more interested in ensuring stable operation and making improvements, which generally have low priority from a vendor viewpoint. In short, as three committers sharing the viewpoint of people from a company that provides services, we seek to have a collaborative relationship, with one of us reviewing change requests and another incorporating those changes, for example. I think dividing up roles within the NTT Group in this way has major benefits. This involves a lot of responsibility, but we enjoy our work here. Additionally, as the Hadoop community has many expert software engineers, we can rest assured that someone will be willing to lend a hand if some kind of problem arises.

—Does your election as committers help NTT to increase its presence?

Ozawa: I recently gave a lecture at a database-related academic conference, and I had the occasion to talk with many people involved with Hadoop. In the sense of being engaged in the development of software with great name recognition, yes, I feel that our election as committers can help NTT increase its presence in this field.

Iwasaki: "Presence" can refer to a company name that is well known in society, but there is also an aspect of presence among Hadoop users and developers. As we mentioned earlier, NTT DATA provides services that make use of Hadoop, so if some kind of problem occurs, we committers can interact with each other and review the problem within the NTT Group, and if necessary, make software changes promptly. One could say that we can exercise our influence on Hadoop users and developers.

Ajisaka: Incidentally, on measuring our degree of contribution to the Hadoop community in terms of the number of issues solved and lines of code contributed, we ranked 4th place in the world for the first half of 2014.

Learning from each other and joining forces to solve problems

—You are three committers inside the NTT Group. What points do each of you excel in, and what advantages do you three bring together?

Ozawa: Mr. Ajisaka can do a proper review even if I make a major change, which gives me a sense of reassurance. Mr. Iwasaki, meanwhile, can thoroughly persuade those concerned to accept what may appear at first glance to be a difficult change; he's good at long-running battles.

Iwasaki: Mr. Ajisaka may be concerned about his English ability, but he has a quick mind and an optimistic outlook with the ability to get to the heart of a problem quickly. Mr. Ozawa has excellent technical skills as well as people skills; his amiability is a real asset.

Ajisaka: Both Mr. Iwasaki and Mr. Ozawa have a thorough knowledge of programming and technology, and they reply quickly to my questions on points that are unclear to me. I go on business trips with Mr. Iwasaki often, and his thoughtfulness is truly amazing. Even on long business trips, we can concentrate on our work without any problems!

Ozawa: Each of us fulfills our role as a committer from a somewhat different perspective. I myself am a researcher, so I tend to approach development with a somewhat forward-looking frame of mind. I consider ways in which Hadoop may be used and problems that might occur in the next stage. NTT laboratories are involved in big data processing technologies. Today, with Hadoop on its way to becoming a major software solution in database systems, we are thinking about using Hadoop as the basis for creating something new in this field, and I am leading this endeavor by expanding my knowledge of Hadoop and increasing my presence in the Hadoop community.

Ajisaka: NTT DATA solves problems that occur in the process of providing support services. Since I myself am participating in the development of Hadoop, I feel obligated to support services that are being provided for actual commercial use in a prompt and accurate manner.

Iwasaki: I have been engaged in the development of the HTrace tracing framework to simplify the analysis of problems that occur in support services provided to customers. However, carrying out analyses by HTrace means that modifications have to be made to Hadoop itself, so interacting with the Hadoop community is essential. In addition, the presence of three committers involved in business applications and research within the NTT Group means that we work hard and learn from each other while recognizing the different points of view that each other holds.

Ozawa: It is said that the basic software that we call middleware must be able to operate without a hitch. Software that does not run well regardless of how sophisticated the research behind it may be will never be accepted. My two colleagues and I are learning this through our collaboration, and I think that being able to feed back the knowledge and experience that we gain here to the Hadoop community is a great thing.

Aiming to become leaders in the future of Hadoop beyond our generation

—What are your goals going forward as a researcher and as developers?

Ozawa: Colleagues of my generation often tell me that working in an open source community provides the benefits of being able to interact with a variety of people and being able to work on a major development like Hadoop and be inspired by it. As a researcher, having the opportunity to become a committer in a major software development is of course an honor, but I would like to develop my own products too, if at all possible. That will likely take time, but if I can make that a reality, I can become a driving force in this field. My passion is in sharing information with the people around me, whether they are involved in research, open source development, or other areas. Looking forward, I would like to become part of the core PMC of the Hadoop community, which elects committers, decides on release periods, and carries out other important tasks.

Facebook CEO Mark Zuckerberg gave some powerful advice when he said that it's okay to release services early even if they're unfinished. In this way, I am making a daily effort to respond as rapidly as possible to movements in the world around us.

Ajisaka: While colleagues of my generation are somewhat envious of the opportunities that being a committer will provide, I believe that simply being able to work on something that I enjoy is a delight in itself. As a Hadoop committer, I would like to add functions that truly stand out. At present, I have my hands full in just maintaining the status quo, so I talk to lots of people both inside and outside the company to gain support for ways that I would like to improve various products and to develop more relationships with like-minded people. I would also like to be chosen as a member of the Hadoop PMC, but for the time being, I will continue to concentrate my energy on this exciting work of Hadoop development while loving every minute of it. In this way, I would like to be useful to both NTT DATA and our customers who will evaluate my activities in this regard.

Iwasaki: I would hope that the appearance of my name in NTT DATA news releases would inspire people with the same dreams as mine. Actually, only a small group of employees are involved in the development of middleware at NTT DATA, so I think such news releases can have a great advertising effect for careers in middleware development. Although it is difficult to simply keep up with Hadoop development—not to mention being a driving force—I have been holding small study groups for about three or four years with the aim of increasing the number of professional Hadoop developers. My aim is not only to complete products that I am working on but also to expand my influence overseas as a developer.

Interviewees profiles

Tsuyoshi Ozawa

Research Engineer, Distributed Computing Technology Project, NTT Software Innovation Center.

He received the B.E. in information and system engineering from Chuo University, Tokyo, in 2008 and the M.E. in computer science from Tsukuba University, Ibaraki, in 2010. He joined NTT in 2010. He has been working on distributed processing frameworks such as Hadoop at the NTT Software Innovation Center since 2012. His research interests include distributed computing and distributed databases. He received the Computer Science Research Award for Young Scientists by the Information Processing Society of Japan (IPSJ) in 2013 and the 9th Japan OSS Incentive Award by the Japan OSS Promotion Forum in 2014. He has been working as a committer of Apache Hadoop since 2014. He is a member of the Association for Computing Machinery (ACM), IPSJ, and The Database Society of Japan (DBSJ).

Akira Ajisaka

Software Engineer, OSS Professional Services, System Platforms Sector, Solutions & Technologies Company, NTT DATA Corporation.

He received the B.E. in engineering and the M.E. in applied mathematics and physics from Kyoto University in 2009 and 2011, respectively. He joined NTT DATA in 2011 and has since been working on distributed systems using Apache Hadoop.

Masatake Iwasaki

Software Engineer, OSS Professional Services, System Platforms Sector, Solutions & Technologies Company, NTT DATA Corporation.

He received the B.E. and M.E. in aerospace engineering from Tokyo Metropolitan Institute of Technology in 2000 and 2002, respectively. He joined NTT DATA in 2002. He has been working on a database system using PostgreSQL and a distributed system using Hadoop. He co-authored the “Comprehensive Primer for Hadoop, second edition.” He is a member of IPSJ.

Overview of Dwango × NTT R&D Collaboration

Shingo Kinoshita and Ippei Shake, NTT Research and Development Planning Department
Kenichi Miyazaki and Yuji Chino, Dwango Co., Ltd.

Abstract

Nearly two years have passed since Dwango Co., Ltd. and NTT signed a business collaboration agreement to enhance video and social services in July 2013. This collaboration between Japan's largest video streaming service provider and a telecommunication carrier is an endeavor to explore solutions to issues commonly faced by the two companies, such as those related to networking, and it has begun to yield a number of noteworthy results. This article presents the objectives and the scope of this business collaboration and describes some of the results.

Keywords: collaboration, video and social service, network efficiency

1. Introduction

Dwango Co., Ltd. and NTT concluded a business collaboration agreement regarding research and development (R&D) on enhancing video and social services in July 2013 [1, 2].

As a leading and comprehensive R&D organization in the ICT (information and communication technology) field, NTT laboratories undertake a wide range of R&D from innovative communication services to next-generation information network infrastructure technologies and leading-edge basic research on new principles and components. From a different perspective, Dwango, Japan's representative video streaming service provider, provides unparalleled, out-of-the-box services such as *Niconico* (*Niconico* video and *Niconico Live*) and *nicofarre*. It thus handles an extremely large volume of traffic.

The objective of the collaboration is to create a win-win relation between the two companies by bringing together the strengths of each party in collaborative research and experiments. Specifically, Dwango aims to evolve and enhance their services by using NTT's leading-edge technologies, while NTT intends to broaden the scope of the application of its R&D capabilities and enhance its technical expertise by incorporating feedback from the collaborative endeavor. The collaboration is expected to bring about further development of service and networking technologies in the promising field of video and social services.

2. Scope of the business collaboration

This business collaboration involves collaborative research and experiments focusing on three fields: networks, media user interface (UI)/user experience (UX), and big data (**Fig. 1**).

(1) Networks

Since video and social services are expected to expand in the years to come, we are studying efficient ways of using networks while at the same time raising customer satisfaction.

As the first stage, a collaborative experiment is being carried out to study quality of service based on actual user experience and globally optimized control of networks, terminals, and applications. This experiment is backed by NTT laboratories' technologies and know-how in assessing the quality of network/communication services.

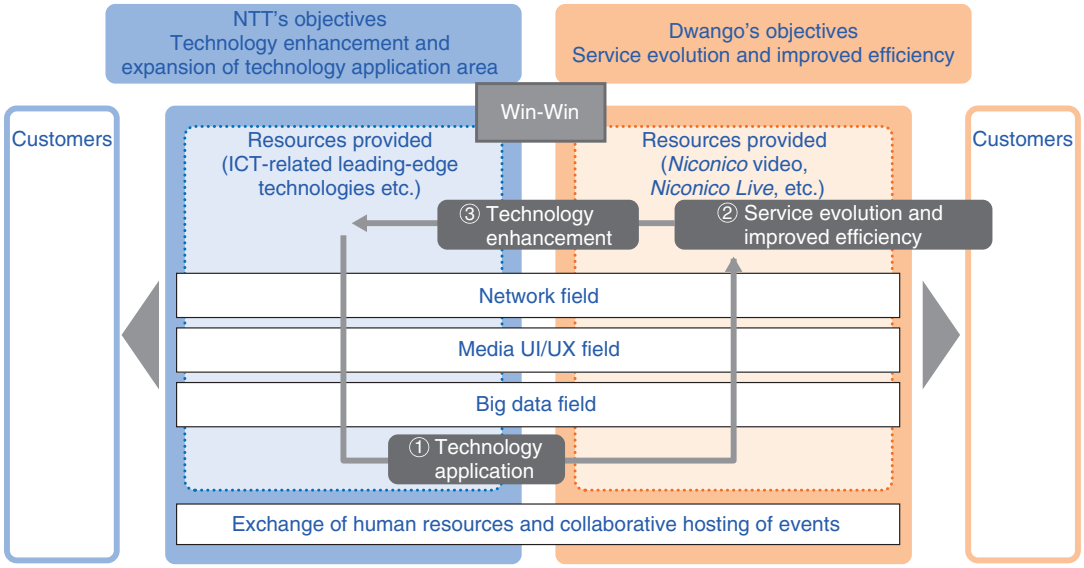


Fig. 1. Objectives of the business collaboration and the roles of each party.

(2) Media UI/UX

We are studying the most appealing and efficient use of a variety of media that arise from Dwango's unique creations such as Niconico and its unique communication culture.

Specifically, we are aiming to achieve efficient delivery of 360-degree video, efficient video coding, innovative video search, and the automatic conversion of audio presentations into text.

(3) Big data

With the explosive increase in the number of items of video content and the number of their users in recent years, it is important to raise customer satisfaction by providing recommendations for video content suitable for individual users. Technologies for collecting and analyzing a large volume of log data will play a major role in creating recommendations.

Currently, we are investigating ways to enhance existing content recommendation technology used in Dwango based on distributed processing technology such as *Jubatus*, which is a framework for large-scale distributed real-time analysis, and machine learning technology developed by NTT laboratories.

Activities in these fields have enabled Dwango engineers, who are characterized by a freewheeling sense of value and judgment, speedy action, and extensive expertise, and NTT researchers, who are exploring leading-edge technologies, to stimulate each other and achieve synergy. The collaboration is being expanded to embrace non-technical areas, for example, exchanges of human resources and hosting of events such as *Niconico Chokaigi*.

3. Results of the business collaboration

The activities undertaken since the implementation of the business collaboration agreement have yielded a variety of results, as summarized below. These results have enabled the two companies to achieve their initial objectives: enabling Dwango to upgrade its services and NTT to enhance its technologies. On top of that, the results will greatly contribute to both companies' meeting the challenges they mutually face. It has been customary to consider the relationship between OTT (Over the Top) companies such as Dwango and telecommunication carriers such as NTT as one characterized by a conflict of interest. However, this collaboration has shed a new light on the relationship. It has fostered an expectation that the two parties can collaborate to achieve their respective objectives, namely, enabling Dwango to raise customer satisfaction by enhancing services, and NTT to improve the efficiency of network utilization (**Fig. 2**).

The featured articles that follow introduce specific results that will strengthen this new collaborative relationship (**Fig. 3**). The first article, "Real-time Omnidirectional Video Streaming System," introduces technology for the interactive delivery of omnidirectional video [3]. This technology enables the

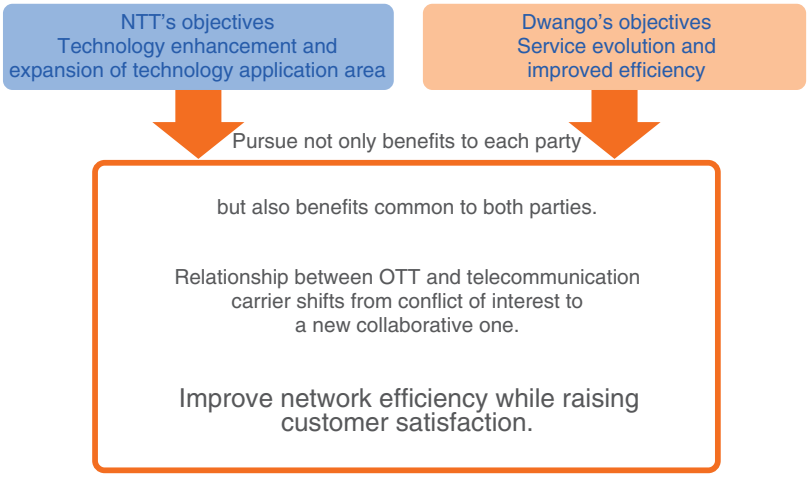


Fig. 2. Development into a new collaborative relationship.

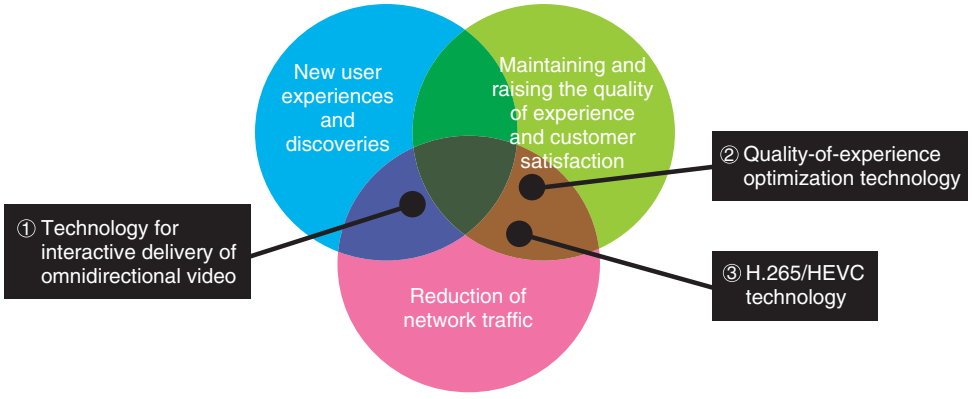


Fig. 3. Major results obtained so far.

user to view a video that is sent from a 360-degree omnidirectional camera installed at a live event site, in any direction he/she wants by using a head-mounted display such as Oculus Rift. This technology provides an innovative user experience while reducing the volume of traffic by selectively delivering at high quality only the video of the direction in which the user is viewing. This technology has been commercially introduced in the virtual reality live delivery service provided by Dwango. On November 17, 2014, a performance by the singer Sachiko Kobayashi at Nippon Budokan was streamed in Niconico Live as part of this service.

Technology that optimizes quality of experience (QoE) is introduced in the second article, "Quality of Experience Optimization Technology (Quality API)." This technology reduces the volume of traffic in the network by controlling the individual user's traffic to suit his/her viewing environment while still maintaining the user's viewing satisfaction [4]. It was confirmed in a small-scale evaluation experiment that the frequency of users selecting "Pause" decreased dramatically, indicating an improvement in QoE. The experiment was expanded in November 2014 to cover all Niconico users.

H.265/MPEG-H, also known as HEVC (High Efficiency Video Coding) technology introduced in the last article, "Collaborative Trial: Application of HEVC Technology to *Niconico Live* [5]," is the next-generation video encoding standard, which boasts a higher compression ratio than the conventional standard, H.264/MPEG-4 (Moving Picture Experts

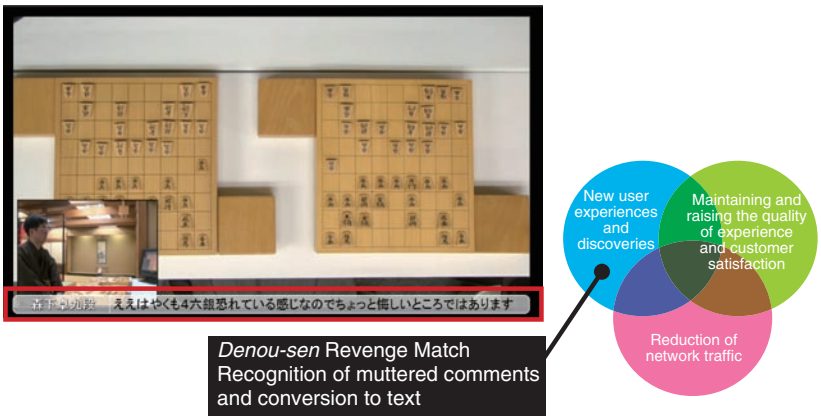


Fig. 4. *Denou-sen* Revenge Match.

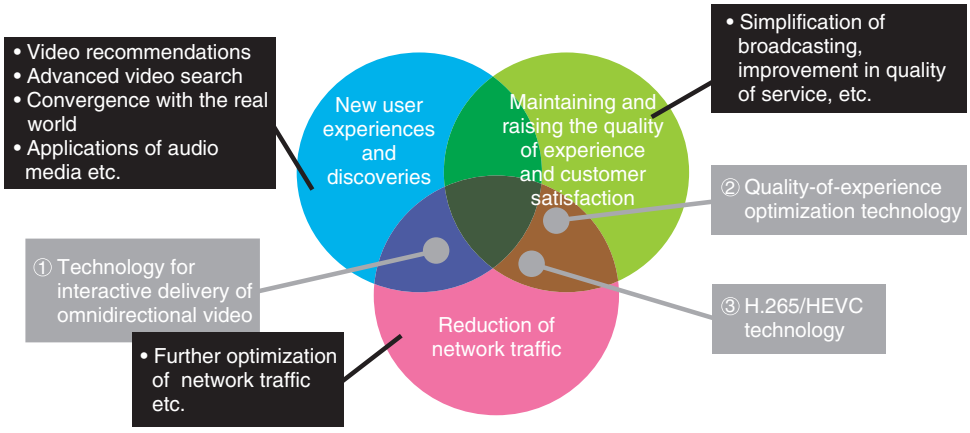


Fig. 5. Future prospects.

Group, version 4) AVC (Advanced Video Coding). Because this compression processing requires an enormous amount of computation, it has been challenging to achieve compression in real time. NTT's technology has made this a reality. Currently, a collaborative experiment is being carried out with a view to applying the technology to Niconico Live. In addition to the technologies introduced above, NTT has provided speech recognition technology that was used in the "*Denou-sen* Revenge Match," a match of the Japanese game of *shogi*. Held on the last day of 2014, this match between the ninth-*dan*-level Taku Morishita and *Tsutsukana*, a shogi software program, attracted widespread attention. *Sotto voce*[*] remarks muttered by Morishita while he was considering the next step were automatically recognized, proofread as necessary, and displayed on the screen as comments. In social networking services, there were favorable comments as to the high accuracy of speech recognition, and the appreciation of this unique service of displaying muttered remarks (**Fig. 4**).

4. Future prospects

Although Dwango and NTT have completely different corporate cultures, we consider that the combination of Dwango's capabilities to create, develop, provide, and operate something new and enjoyable and NTT's leading-edge R&D capabilities can achieve a wide range of synergy. Looking forward, we will broaden the scope of collaboration, including

* In Italian, *sotto voce* literally means "under voice," and refers to comments made in an intentionally quieter voice.

effective recommendations for video, new search technology and further enhancement of quality of service, in order to develop innovative services and networks (**Fig. 5**).

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Shingo Kinoshita
Senior Manager, R&D Planning Group, NTT Research and Development Planning Department.

He received the B.E. in solid state physics engineering from Osaka University in 1991. Since joining NTT laboratories in 1991, he has been engaged in R&D of distributed computing systems, security, big data computing, and HR of the laboratories. During 2006–2007, he studied the management of technology at University College London and received the M.Sc. with Distinction. His current responsibilities are:
- Planning and managing NTT laboratories
- Supporting Chief Technology Officer of NTT Group
- Establishing and managing NTT global R&D institution in North America, NTT Innovation Institute, Inc.
- Heading the Dwango-NTT capital and R&D alliance
- Heading capital and R&D alliance with ventures

He has published more than 30 journal and international conference papers. He received the 2005 IPSJ R&D Award, 2003 CSS Best Paper Award, and 1998 DiCoMo Best Presentation Award.

Ippei Shake
Senior Manager, R&D Vision Group, NTT Research and Development Planning Department.

He received the B.S. and M.S. in physics from Kyoto University in 1994 and 1996. In 1996, he joined NTT Optical Network Systems Laboratories. Since then, he has been engaged in R&D of high-speed optical signal processing and high-speed optical transmission systems. He has also been engaged in R&D of NGN (Next Generation Networks) and in the area of human resources. He is currently managing a collaborative project between Dwango and NTT. He is a member of IEEE (Institute of Electrical and Electronics Engineers) and IEICE (Institute of Electronics, Information and Communication Engineers).

Kenichi Miyazaki
Platform Division Manager, Dwango, Co., Ltd.

He joined Dwango as a mid-career employee in December 2009. He has developed many Niconico services such as *niconico-jikkyou*[*1] and *niconico-denwa*[*2] as well as Niconico's back-end systems. Since October 2014, he has been in charge of the development of the entire Niconico system.
*1 *niconico-jikkyou* is a communication service enabling viewers to post comments on current broadcast services such as TV programs.
*2 *niconico-denwa* is a communication service enabling live video distributors to talk on the phone with viewers. This service was terminated in Dec. 2014.

Yuji Chino
Deputy General Manager, Corporate Division, Dwango, Co., Ltd.

He joined Dwango in 1998. He became General Manager of the R&D Division in 2006, General Manager of the Niconico Business Division in 2010, and Deputy General Manager of the Corporate Division in 2013.

Real-time Omnidirectional Video Streaming System

Daisuke Ochi, NTT Media Intelligence Laboratories
Shinnosuke Iwaki, Dwango Co., Ltd.

Abstract

NTT Media Intelligence Laboratories and Dwango Co., Ltd. have developed a system that makes it possible to view highly immersive video of live events captured by 360-degree omnidirectional camera using an interactive video distribution technology developed by NTT Media Intelligence Laboratories. Dwango has integrated this system with their *Niconico Live* broadcasting system and is now offering a real-time streaming service. We report the details of this service in this article.

Keywords: omnidirectional video, head-mounted displays, video streaming

1. Introduction

In the field of virtual reality (VR), simulating physical presence and participation at events in remote locations has proved to be a challenging task that VR programmers and engineers have long grappled with. There are many diverse elements necessary for this kind of simulation, including not only the five senses but also ambience and other nonverbal sensations, the perfect reproduction of which is considered to be difficult with current technology.

At NTT Media Intelligence Laboratories, we have decided to focus on issues related to the sense of sight and are tackling the simulation of physical presence through video consumption. Until now, the laboratories' accumulated knowledge and know-how related to interactive video distribution technologies have been directed at distributing video to smartphones and tablets with limited network bandwidth, allowing viewers to immerse themselves in remote events of their choosing [1, 2].

Dwango Co., Ltd., on the other hand, has not only been overlaying comments over videos and in other ways providing brand new viewing experiences with its user-uploaded video sharing service, *Niconico Live*, but it has also made several attempts to share real-world immersion with Internet users through actual events it runs such as *Niconico Chokaigi* as well as event venues that it operates such as *nicofarre* in order to achieve the company's motto of *blurring the borders between the Internet and the real world*.

We have built a real-time omnidirectional video streaming system by using the interactive video streaming technology developed by NTT Media Intelligence Laboratories and taking advantage of the expertise in integrating Internet and real-life experiences cultivated by Dwango. Users of this system can feel as if they were looking at their surroundings while being at the location of a remote event. In this article, we provide an overview of the interactive video streaming technology, describe the techniques employed to build the system, discuss the content design, and introduce topics related to the actual usage.

2. Approach

We make use of two devices in the pursuit of visual immersion: a 360-degree omnidirectional camera that can record video in all directions, and a head-mounted display (HMD) that can track the orientation of the wearer's head. The former is used to record omnidirectional video that captures the sense of being at a (remote) location, and the latter is used to show highly immersive video that responds to the direction in which the viewer is facing [3, 4].

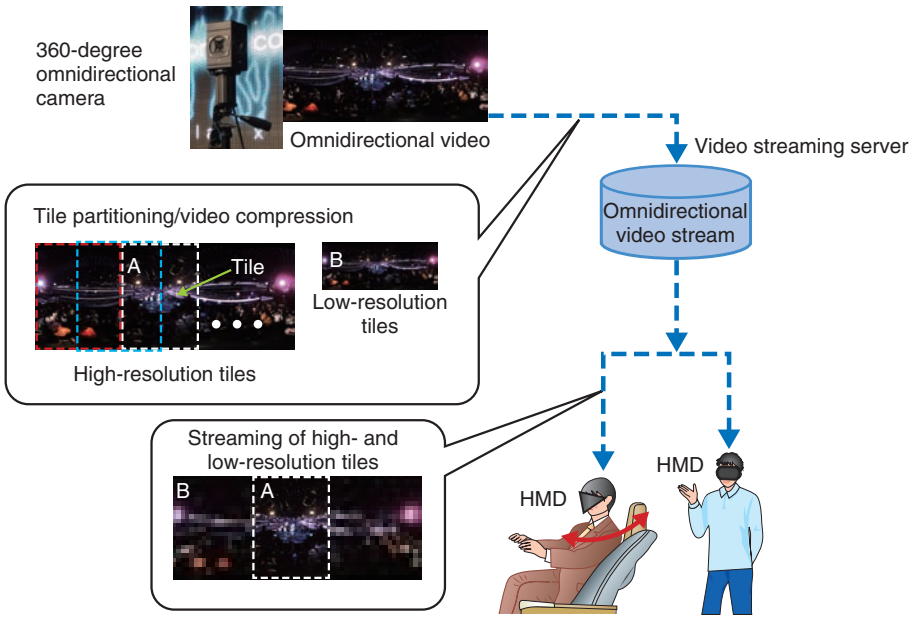


Fig. 1. Overview of interactive video distribution technology.

These sophisticated devices allow viewers to watch highly immersive video, although a broadband network connection must always be available for remote viewers to enjoy clear omnidirectional video that has 4K or higher resolution. However, by applying the interactive video distribution technology [2] developed by NTT Media Intelligence Laboratories and only streaming high-quality images that the viewer is looking at over limited network bandwidth, we have made it possible to create highly immersive experiences even on ordinary networks that are common today, as shown in **Fig. 1**.

3. Interactive video streaming technology

We use interactive video streaming technology that divides pictures captured over a wide viewing angle into several overlapping tile-shaped regions, compresses each of those tiles at high resolution, and then sends only the high-resolution tile that the viewer is looking at. As shown in Fig. 1, this can reduce network bandwidth requirements because viewers no longer need to receive high-resolution tiles for regions they are not looking at. Furthermore, by compressing the entire video into low-resolution tiles that are sent to the viewer along with the high-resolution tile, we can provide it for the viewer while waiting for high-resolution tiles to load when they look at a different area of the video.

This technology allows viewers to watch immersive, wide-angle video while requiring less network bandwidth than an entire video streamed at high resolution.

4. Implementation of a commercial service

We implemented a commercial system by applying the interactive video streaming technology to omnidirectional video, as shown in **Fig. 2**. Our goal was to provide a system with an enjoyable, high-quality viewing experience. To do this, we did not simply implement the aforementioned technology; we also incorporated techniques for preserving the quality of long viewing sessions and techniques for keeping viewers engaged, as well as the culture and expertise that Dwango has accumulated over the years, into both the server and client sides of the system. In the following sections, we describe more detailed specifications related to the system's implementation and the techniques for incorporating them.

4.1 Server side

Omnidirectional video was captured using the Ladybug3 omnidirectional camera (Point Grey Research, Inc., Canada) at a resolution of 1920 × 960-pixels and a frame rate of 29.97 fps. As shown in Fig. 1, the captured video was compressed in real time into seven 480 × 960-pixel high-resolution tiles

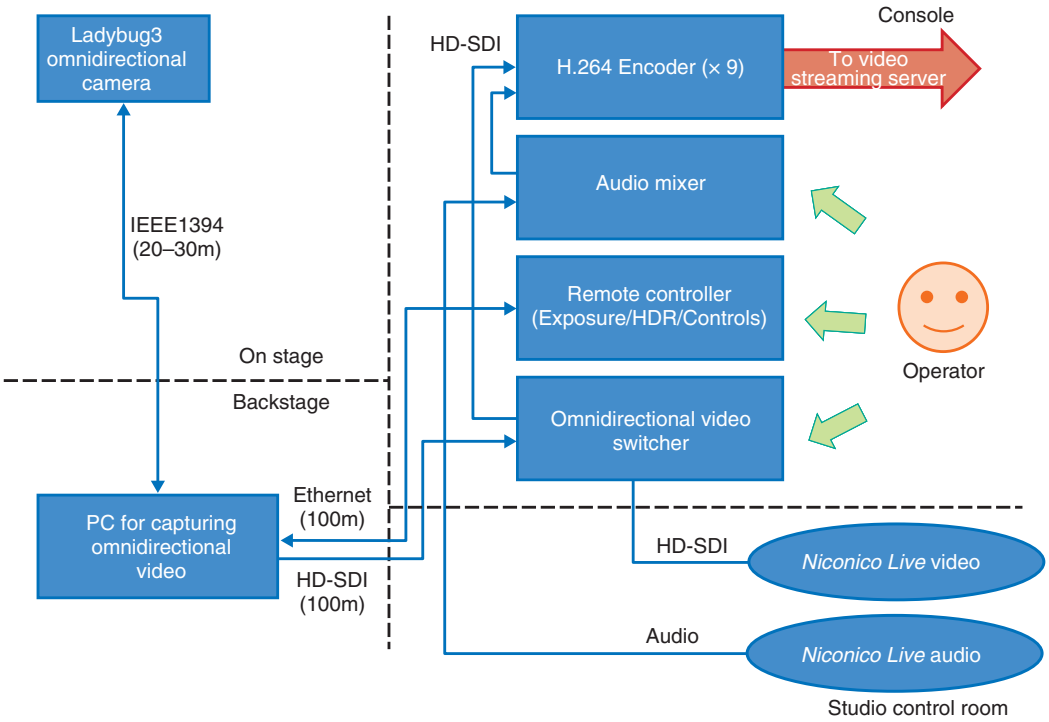


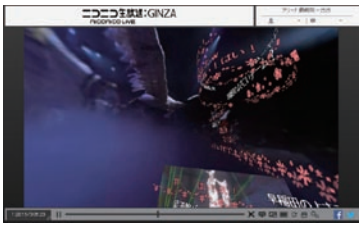
Fig. 2. Overview of commercial system.

(at 1.2 Mbit/s each) and one 512 × 256-pixel low-resolution tile (at 0.5 Mbit/s). The encoded tiles are then sent to the distribution server via the Real Time Messaging Protocol (RTMP) and finally streamed to users over a content delivery network (CDN). Video is ordinarily streamed at a sustained bit rate of 1.7 Mbit/s (for one high- and low-resolution tile), but it can temporarily burst up to 2.9 Mbit/s (for two high-resolution tiles and one low-resolution tile) when the viewer turns to look in another direction because it will be sent along with the formerly viewed high-resolution tile. It currently takes about five seconds for encoding, streaming, and buffering with the viewer's application.

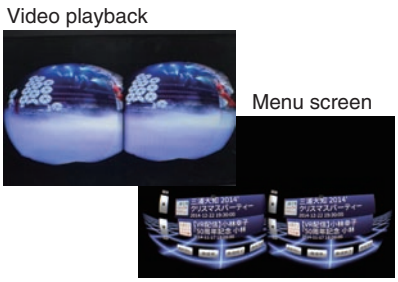
We actually ended up using 3.2 Mbit/s of network bandwidth to stream including a video taken by a professional camera operator (described below) at the same time as the omnidirectional video. This reduced bandwidth by approximately 40% over sending the full omnidirectional video at the same quality as the high-resolution tiles (a total of 5.1 Mbit/s, including 0.3 Mbit/s for conventional video and 4.8 Mbit/s for four high-resolution tiles at 1.2 Mbit/s each). There should be sufficient network bandwidth to handle this in modern homes with fiber-optic connections and on cell phones with LTE (Long Term Evolution) connections. Viewers can also watch highly immersive, time-shifted video on demand because all of the captured omnidirectional video tiles are stored as video files on the video streaming servers.

4.2 Client side

Although there are high hopes for HMDs in the field of virtual reality, they are not yet in widespread use by the general public. Therefore, we developed a client application for web browsers as well as HMDs to allow viewers to enjoy omnidirectional video even without an HMD, as shown in **Fig. 3(a)**. The web-based client allows users to choose a viewpoint by dragging the mouse cursor. As shown in **Fig. 3(b)**, the HMD client allows users to immerse themselves in omnidirectional video once they have plugged their HMD into a personal computer and downloaded the client application. The Oculus Rift (Oculus VR, LLC, USA) is currently the supported HMD; with the gyro sensors installed in the Oculus Rift, the client



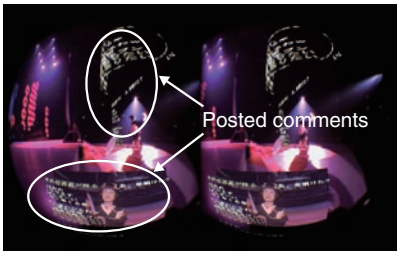
(a) Web browser client



(b) HMD client

Fig. 3. Client applications.

(a) Screen with ordinary Niconico Live



(b) Screen with posted comments

Fig. 4. Monitor placement.

application can detect which direction the user is facing and then request the corresponding high-resolution tile from the streaming server. High-resolution and low-resolution tiles are received by the Adobe Air* runtime system via RTMP and then combined and rendered.

Considering the fact that remote events can continue for long periods of time, we have allowed users who are tired of looking around in the VR environment to watch video (ordinary Niconico Live) that is filmed by camera operators and placed in the omnidirectional video such that it appears to be on a flat monitor, as shown in **Fig. 4(a)**.

Similarly, as shown in **Fig. 4(b)**, we have preserved the fun of using Niconico by floating Niconico's characteristic comments, which allow users to exchange their feelings and impressions with each other, in the same three-dimensional (3D) space as the omnidirectional video. These comments are actually shown with a stereoscopic 3D effect so that they induce the feeling of 3D even though the omnidirectional video was filmed in 2D.

5. Results

This system was used for the first time at the Nippon Budokan on November 17, 2014, during a 50th anniversary event featuring the singer Sachiko Kobayashi (**Fig. 5**). There were no problems during the 185-minute performance. Omnidirectional video of the event was viewed 10,022 times by 4762 separate users via the HMD and browser clients, reaching approximately 10% as many users as those who viewed the ordinary Niconico Live alone. These results allowed us to confirm our expectations with respect to the users who would watch highly immersive (omnidirectional) video. We also learned that it would take longer than the aforementioned five seconds to stream high-resolution tiles for time-shifted video. During long-running performances, the video files accumulated for each tile on the distribution server can grow quite large and thus slow down seeks to arbitrary times in the video stream. We are working on improving the system to solve this problem.

* Adobe Air is a registered trademark of Adobe Systems Incorporated.

Fig. 5. Sachiko Kobayashi.

6. Future work

In addition to solving the problems discussed earlier in this article, we also plan to improve the quality of the video that is distributed and further reduce bit rates. Looking ahead to 2020, we plan to expand into sports content and explore the use of sound in pursuit of even more immersive experiences.

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See for yourself

If you have a premium Niconico account, you can watch the omnidirectional video recorded for this article on demand at http://live.nicovideo.jp/gate/1v199935215. Viewers with an HMD can download the HMD client application from https://www.dropbox.com/sh/v3tbi6u4vfze3r2/AACaGb99KeLXvgVsugMXRnaQa?dl=0. Viewers without an HMD can watch the video from their web browser.

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He created *Keitai Douga Henkan-kun* (http://mobilehackerz.jp/) and also developed THETA applications such as "THETA physical remote shutter" and "Oculus THETA," and organized THETA hacking information. When he was broadcasting Niconico Live streaming as a user, he was recruited by Dwango's staff with comments flowing on his Niconico Live screen. As an engineer at Dwango, he is responsible for developing the full range of systems to blur the borders between the Internet and the real world, including the production system of nicofarre, a live house surrounded by 360-degree LED displays.

Quality of Experience Optimization Technology (Quality API)

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Kenichi Miyazaki, Satoshi Sato, Boku Kihara, Kozo Mikami, Kazumasa Yonemura, Shinji Saito, and Kenta Akimoto, Dwango Co., Ltd.

Abstract

A collaboration between NTT and Dwango Co., Ltd., a video distribution company, is expected to improve the quality of experience (QoE) for customers. This article introduces a QoE optimization technology developed by NTT Network Technology Laboratories.

Keywords: QoE, optimization, quality API

1. Introduction

As smartphones, tablets, and other mobile devices have become more popular, the number of people using video distribution services in mobile space has continued to increase. Unlike wired networks such as fiber optic lines, mobile networks cannot always provide sufficient throughput to distribute high-resolution videos. This occasionally causes videos to stop (for rebuffering) in the middle of playback. A graph of the properties of human perception is shown in **Fig. 1**. These properties are known to follow an S curve like the green line shown in the figure. If there is sufficient throughput to handle a video's bit rate, the quality of experience (QoE) follows the line of human perception. If, however, throughput is insufficient, the video will experience rebuffering events, and the QoE will drop precipitously—as illustrated by the red line in Fig. 1 [1].

Therefore, it is impossible to maximize the QoE when a video is distributed at a bit rate that is either too high or too low for a network's throughput. As a result, a video must be distributed at a bit rate that matches network throughput to maximize the QoE; this is what we refer to as QoE optimization.

2. Structure of QoE optimization technology (Quality API)

Dwango and NTT have developed an interface, or quality API (application programming interface), for exchanging quality-related information in order to implement the aforementioned QoE optimization. The quality API provides recommended bit rates to video distribution companies in real time. The sequence diagram in **Fig. 2** shows how videos are played back using the quality API developed by NTT Network Technology Laboratories.

When a user sends a request to a video distribution company to start watching a video, the user's attributes (e.g., location, network usage, and device information) are sent through the user's application (app) or browser along with the request (step 1). The video distribution company then sends network information and encoding conditions (bit rate, resolution, and frame rate) for each of several available video quality

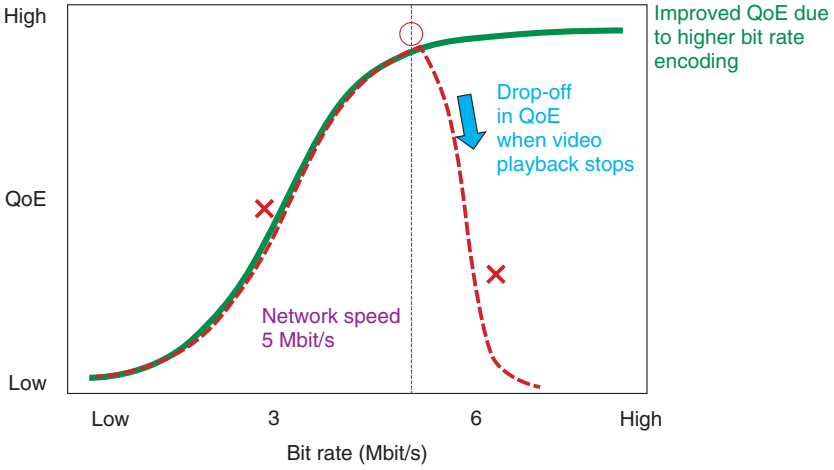

Fig. 1. Perceived quality while watching video.

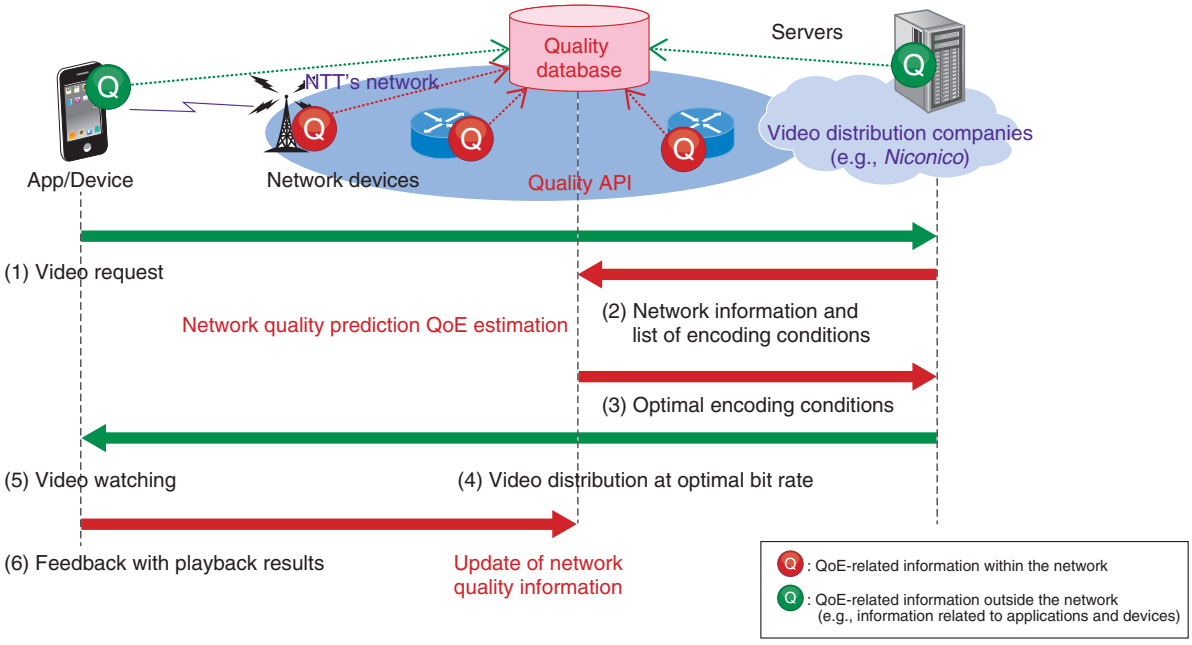

Fig. 2. Video distribution using quality API.

indicators to the quality API to obtain the optimal encoding conditions (step 2). The quality API then calculates the optimal encoding conditions using a combination of three different technologies to be mentioned later. The encoding conditions with the highest QoE are sent back to the video distribution company in response to its request (step 3). The video distribution company then distributes the video to the user under the conditions it received from the quality API (step 4). After the user has finished watching the video (step 5), information on network throughput is sent to the quality API for future reference (step 6). This allows the latest network quality information to be continually updated and high-precision estimates to be made.

The three technologies used by the quality API are indicated in **Fig. 3**. First, the user's network quality (throughput and other statistics) is estimated based on

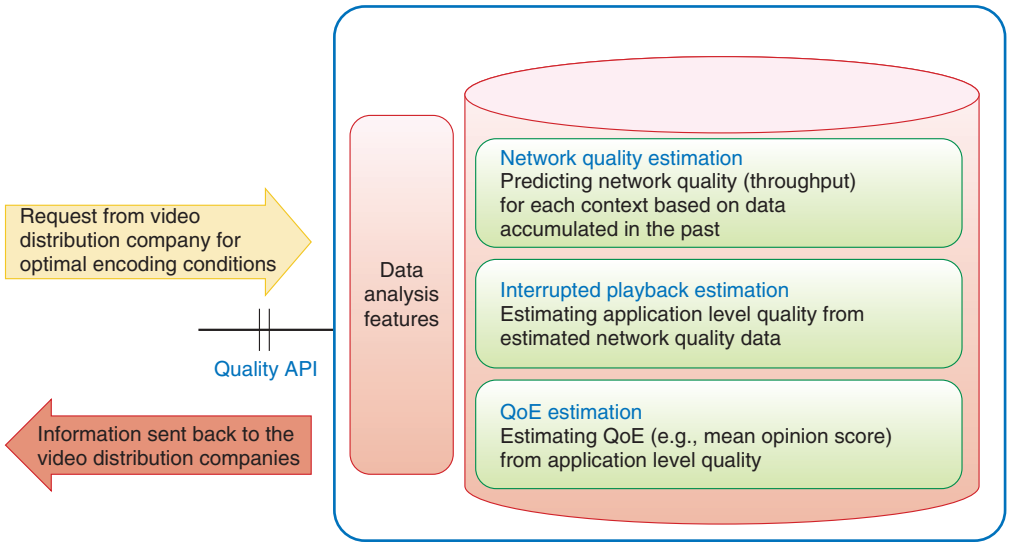

Fig. 3. Technologies used in quality API.

the provided network information (network quality estimation). When the request from the video distribution company for optimal encoding conditions arrives in the quality API, the network quality is estimated from records of throughput for similar network conditions in the past as well as from a quality database that collects information related to the usage of network equipment. Simulations are then run based on this estimated network quality to approximate the number of times video playback would stop for each of the encoding conditions (interrupted playback estimation) [2]. Finally, based on the video quality and the number of times that video playback is estimated to stop, data from past subjective evaluations are used to estimate the QoE (QoE estimation) [3].

To pinpoint even more precisely the optimal conditions for video distribution, it would be preferable to have user information (when and where they use which services, under what kind of network conditions, using which devices in which states, as well as other information on user behavior and user attributes). However, because this information could contain personally identifiable data, it would thus need to be handled carefully to protect user privacy.

3. Experimental results in collaboration with Dwango

Experiments were conducted to determine to what degree bit rates optimized based on recommendations were able to improve the QoE. In the experiments, video playback information was sent to NTT's quality API for users of Android[*1] devices on the NTT DOCOMO LTE (Long-Term Evolution) network on July 3 and 4, 2014. The results indicated that we could expect the quality API to significantly increase the QoE for viewers of *Niconico* videos. Specifically, we found:

(1) Lower incidence of stopped videos

We confirmed that this technology was able to reduce the number of users affected by stopped videos from 33% to just 1–2% during peak hours.

(2) Improved QoE

When we estimated the users' QoE, we saw an improvement of ~35% during peak hours and ~20% for the one-day average, as shown in **Fig. 4**.

(3) Lower overall volume of transmitted data

A secondary effect of optimizing bit rates with this technology was that we saw transmitted data volumes fall by 17%[*2].

4. Future work

A field test of this technology was initiated on November 20, 2014, when we began distributing an official Niconico smartphone app that supports the quality API to some randomly selected users of the Niconico video streaming service. This official app

*1 Android is a registered trademark of Google Inc.

*2 The total increase or decrease in the amount of transmitted data will depend on variations in users' network conditions and bit rates.

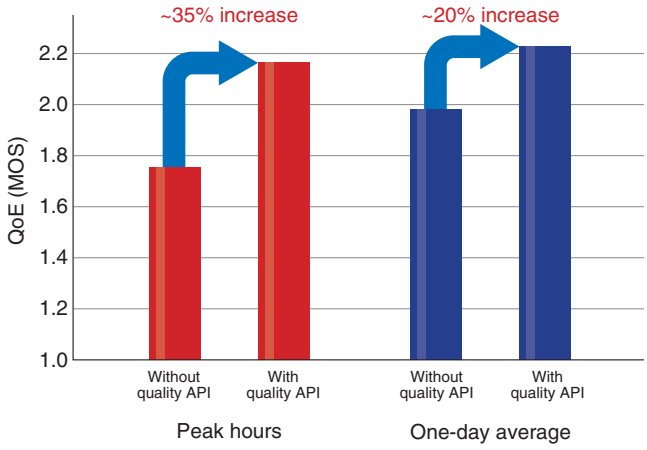

Fig. 4. QoE improvement due to quality API

has since been downloaded by approximately seven million users. With these tests, we plan to evaluate not only QoE changes but also the effect that QoE improvements have on key performance indicators (KPIs) that are important to businesses that run video distribution services. For example, we plan to move ahead with evaluating KPIs such as engagement, which shows how much of a video a user has watched, and site visit duration, which shows how long services have been used in one day. Finally, we plan to complete a distribution control method that benefits both network and video distribution businesses.

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*1 *niconico-jikkyou* is a communication service enabling viewers to post comments on current broadcast services such as TV programs.
*2 *niconico-denwa* is a communication service enabling live video distributors to talk on the phone with viewers. This service was terminated in Dec. 2014.

Collaborative Trial: Application of HEVC Technology to *Niconico Live*

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Abstract

Dwango Co., Ltd. operates *Niconico Live*, the largest live streaming service in Japan based on the legacy video codec H.264/MPEG-4 (Moving Picture Experts Group, version 4) AVC (Advanced Video Coding). Meanwhile, NTT Media Intelligence Laboratories has been working on a high-speed software encoder based on H.265/MPEG-H, also known as HEVC (High Efficiency Video Coding), the updated high-performance successor to H.264. Dwango and NTT have now joined forces in a collaborative trial to test and evaluate the new HEVC video compression standard.

Keywords: live streaming, H.265/HEVC, real-time processing

1. Niconico Live

Niconico Live, run by Dwango Co., Ltd., is one of the largest live streaming services in Japan, averaging about 20 million accesses per day and 4 million visitors per month. The streaming content consists of *Official Program* run by the Dwango group, *Channel Live* run by other corporations or parties, and *User Live* by regular users that has become a popular feature. Another attractive feature of the service is that user comments are overlaid directly onto the video and synced to the playback, which enables viewers and the uploader to react to comments and engage in back-and-forth interaction.

This means that an encoder for the Niconico Live service must not only provide real-time video compression, it must also provide low-delay performance enabling back-and-forth interaction among users and be sufficiently economical that it sees widespread acceptance among ordinary users. The encoder used by the current service is based on the H.264/ MPEG-4 (Moving Picture Experts Group, version 4) AVC (Advanced Video Coding) standard and has been widely distributed to users under the name *Niconico Live Encoder*.

2. Collaborative trials using HEVC

Enhanced video compression efficiency is critically important to improve Niconico Live picture quality and to further expand the user base and scale of the service. Not surprisingly, Dwango took notice when the new international video coding standard H.265/ MPEG-H, also known as HEVC (High Efficiency Video Coding), was approved by the ITU-T (International Telecommunication Union, Telecommunication Standardization Sector) in April 2013. HEVC markedly improves the performance of various encoding tools and effectively doubles the data compression ratio compared to H.264 at the same level of video quality. However, these performance gains sharply increase the compression processing load and thus require dedicated hardware for real-time compression. This hardware would be extremely costly for a live streaming service, especially for a service such as Niconico Live that offers many channels.

NTT laboratories have been working on the development of a software coding engine for HEVC high-speed compression for some time. This software encoder was specifically designed for 4K and other high-definition video formats for which there has been strong market demand, but repurposing the software for small-screen applications should make it

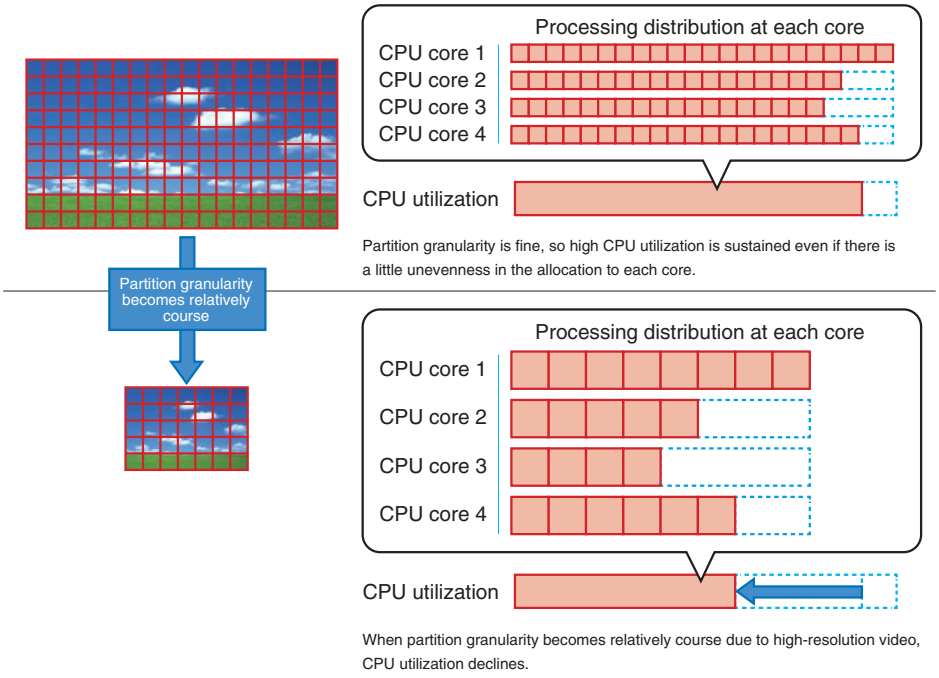

Fig. 1. Reduction of CPU utilization.

possible to run the software in real time on a single personal computer (PC).

It is far more cost effective to build a live streaming system using software than using dedicated hardware. This is basically what motivated this collaborative project to customize NTT's HEVC software encoder for Niconico Live, incorporate the software in Dwango's system, and assess its performance when used to support a streaming service.

3. HEVC software encoder customization

For these trials, we needed to achieve real-time encoding of low-resolution video on a single PC for mobile devices, a starkly different direction from high-definition video encoding. We first customized the HEVC software encoder to enhance picture quality by tuning the bit allocation to place limited bits on critical portions of the image, and to enhance speed by customizing algorithms about parallel processing and mode decision. In particular, customizing the parallel processing algorithm was quite critical.

Just as in earlier encoding schemes, HEVC partitions single-image frames into blocks, then subjects each block to inter-/intra-picture prediction and transform coding. NTT's software encoder features pipelining and therefore handles this processing in parallel with multiple central processing unit (CPU) cores at very high speed. With high-resolution 4K video, there is a very large number of blocks, so tasks allocated to each CPU core can be finely adjusted. This makes it fairly easy to increase CPU utilization. With low-resolution video, however, there are relatively few blocks, which results in processing load variations between the CPU cores. Needless to say, this reduces CPU utilization and can drag down the processing speed (see **Fig. 1**).

Since the current trial involves low-resolution video encoding, the encoder was customized by taking into account the number of blocks shared by each CPU core and the variation in load that might affect the block processing speed (see **Fig. 2**). Adoption of these measures means that the encoder can maintain a high level of CPU utilization even at low resolution, and low-resolution video is compressed by HEVC in real time on the CPU of the node PC.

4. Future developments

The next step is to conduct field trials. During the field trials, we will roll out the HEVC software encoder in the Niconico Live public channel and assess live streaming services delivered to smartphone users who are under especially tight network

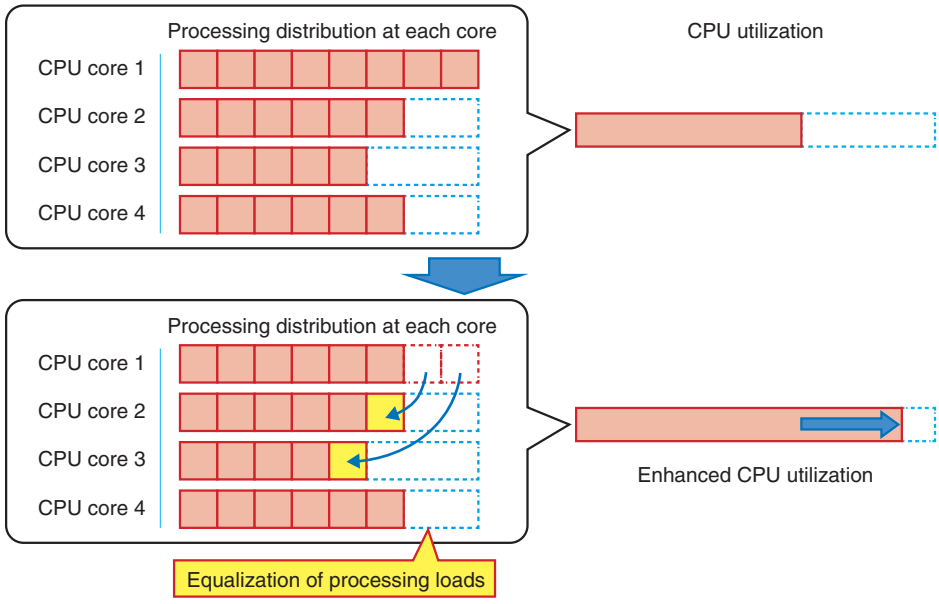

Fig. 2. Equalization of processing loads.

bandwidth constraints. If that goes well, we will extend the encoder deployment to other channels. This project is the largest real-time HEVC streaming trial so far, and it should provide a lot of valuable data on the effects of reduced bandwidth, QoS (quality of service), and a host of other technical matters. Through these trials, Dwango and NTT Media Intelligence Laboratories are demonstrating their ongoing commitment to enhancing the quality and development of new video streaming services.

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Toward the Realization of Disaster-free Networks

Hiroshi Saito

Abstract

This article proposes a network concept called *Disaster-free Network* and the technologies used to implement it: a physical network design that is robust against spatial disaster, and network avoidance control. Two unique contributions are achieved with this research on the Disaster-free Network: a disaster management concept and a new area of research. The objective of a Disaster-free Network is to avoid or minimize encounters with disasters. This is a completely new concept of disaster management, which has previously been based on the provisioning and restoration of networks. The Disaster-free Network concept is implemented by appropriately designing or controlling the spatial and geographical shape of the network or the spatial and geographical locations of network objects. This kind of design and control is based on a method of evaluating the probability defined by geometrical events and opens up a new area of research.

Keywords: disaster management, spatial design and control, network vision

1. Introduction

Every year around the world, people suffer from disasters. Natural disasters are dominant as the direct causes of other disasters, and their number tends to be much larger than that of man-made disasters [1, 2]. In some countries, earthquakes are the largest threat among natural disasters. They are difficult to forecast, and their impact is huge. The earthquake that occurred in March 2011 in Japan triggered a massive tsunami, which served as a reminder of the severity of a huge earthquake [3]. Similar events that cause massive damage occur every few years worldwide [4]. In addition, global warming results in stronger and more devastating natural disasters, and the number of disasters increases exponentially [1]. Therefore, disaster management has become even more crucial for many network operators [5].

Historically, disaster management has been based on protection, which is sometimes called *provisioning and restoration* and sometimes called *recovery* [6]. Protection provides spare resources in advance, and restoration attempts to find resources that will accept traffic using the failed components. In addition, network operators use temporary systems when disasters occur. A transportable terrestrial station of a satellite communication system is such an example [7].

These historical approaches assume that we cannot avoid disasters, and they use the technologies for failure management. The Disaster-free Network concept takes a completely different approach [8] and attempts to avoid disasters as much as possible. The network design approach to implement the Disaster-free Network concept involves designing networks to, for example, minimize the probability of encountering disasters, and is mainly used for unforecastable disasters such as earthquakes. In addition, the disaster avoidance control in a Disaster-free Network reconfigures the mapping between the logical network and the physical network to minimize the probability of disconnection, for example, and is mainly used for forecastable disasters such as hurricanes. These technologies realize the Disaster-free Network concept and open a new avenue of research.

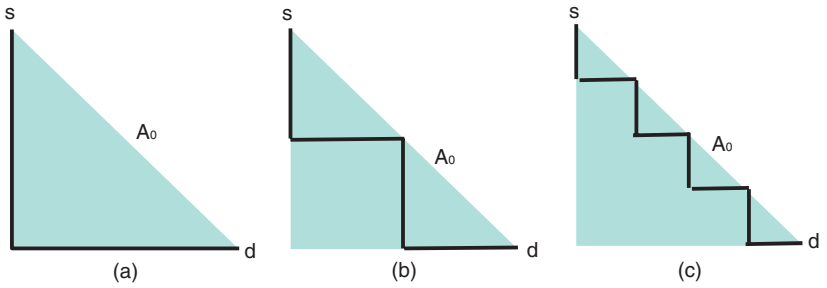

Fig. 1. Three tree networks.

2. Physical network design

Making society, including the communication infrastructure, robust against earthquakes is a serious target in Japan because the possibility of a massive earthquake occurring is increasing. Although we have not had a method to design networks or a method to evaluate the effects of earthquakes, some studies have started investigating geographically correlated failures; several studies of network survivability have been reported that take account of spatial/geographical conditions [9–14]. Some other studies have investigated the location of the worst spatial/geographical disaster for a network [15–20].

Unfortunately, however, these studies do not directly intend to derive a geographical spatial design of a physical network. To respond to this situation, we have conducted a series of studies regarding the geographical spatial design of a physical network [21–23]. These studies assume that a given disaster area occurs with a uniform probability within an area A_0 of interest and can be categorized according to the assumption used for a disaster area—that is, whether a disaster area can be modeled by a half-plane or by a bounded region—and the assumption used for a link (node) failure—that is, whether part of a link (a node) always fails or fails with a certain probability if that part (the node) is in a disaster area. In the following section, the probability P(s,d) of a disconnection between s and d is used as a metric. P(s,d) is equivalent to the probability that none of the routes between s and d are connected. If a link always fails when part of a link is in a disaster area, P(s,d) is equal to the probability Q(s,d) of encountering the disaster. The notation Q(s,d) means that every route between s and d intersects a disaster area.

2.1 Probability Q(s,d) of encountering a disaster when the disaster area can be modeled by a half-plane [22]

The disaster area caused by an earthquake is sometimes huge—much larger than a regional network. In such cases, we can model the disaster area as a half-plane when we design the regional physical network. When the disaster area can be modeled by a half-plane, Q(s,d) can be expressed by explicit formulas for many network topologies and for many connectivity patterns such as the connectivity to either an active server or a standby server. For example, when there is a single physical route between s and d,

$$Q(s,d) = \{L(A_0) + L(CH(r(s,d)))\}/(2\,L(A_0)), \quad (1)$$

where L(x) is the perimeter length of x, CH(x) is the convex hull of x, and r(s,d) is the route between s and d. According to Eq. (1), we can find that Q(s,d) for (a) is the largest, while that for (c) is the smallest in **Fig. 1** because L(CH(r(s,d))) is largest for (a) and smallest for (c).

When s and d are on a convex ring physical network,

$$Q(s,d) = \{L(A_0) + L(line(s,d))\}/(2\,L(A_0)), \quad (2)$$

where line(s,d) is the line segment between s and d. Equation (2) tells us that the geographical shape of the ring network is independent of Q(s,d) if it is convex. In addition, Eqs. (1) and (2) show that the effect of making a ring network is identical to making a straight line route regarding Q(s,d).

In addition to optimizing the geographical network configuration, it is also possible to optimize the standby server location and the number of standby servers using previously derived formulas [22]. For example, when s, d1, and d2 are on a ring network and s needs to be connected to d1 or d2, probability

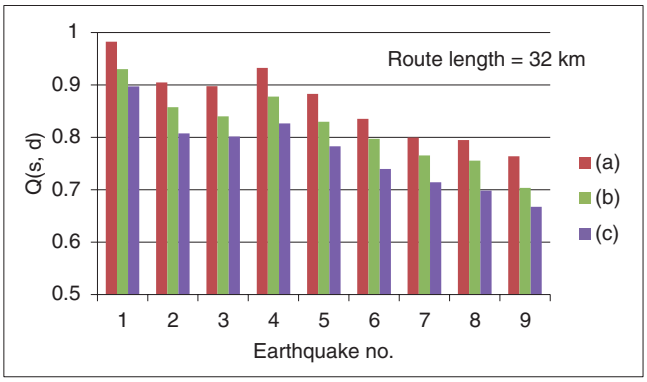

Fig. 2. Simulation result for single route between s and d [23].

Q(s,d1 or d2) that there are no routes out of the disaster areas between s and d1 or between s and d2 is given by the following.

$$Q(s,d1 \text{ or } d2) = \{L(A_0) + L(line(s,d1)) + L(line(s,d1)) - L(CH(s,d1,d2))\}/(2\,L(A_0)), \quad (3)$$

where CH(s,d1,d2) is the convex hull of three points: s, d1, and d2. Because the difference between Eqs. (2) and (3) represents the effect of using the standby server, we can determine whether we should provide the standby server with Eqs. (2) and (3). In addition, Q(s, d1 or d2) is a function of the location of d1 and d2; we can determine their locations by minimizing Q(s, d1, d2).

2.2 Probability P(s,d) of disconnection between s and d, when the disaster area can be modeled by a half-plane, and a node or a link independently fails with a certain probability if a node or part of a link is in the disaster area [21]

Even when the disaster area can be modeled by a half-plane, P(s,d) cannot be expressed by an explicit formula, although an algorithm is given to calculate it for any network topology. When the network is a tree or a ring, the complexity of the algorithm is polynomial in the number of nodes. However, for a generic network topology, it is not polynomial. Although no explicit formulas are obtained, it is shown that reducing the perimeter length of the convex hull of a route reduces P(s,d). Therefore, the straight line route connecting each pair of consecutive nodes minimizes P(s,d) when the location of each node is fixed. In addition, the algorithm enables us to evaluate P(s,d) when the geographical configuration of part of the network changes. This is useful when it is necessary to partially remake the geographical configuration of the existing network.

Furthermore, the results obtained can be used to determine which parts of the network need to be updated with/without changing the geographical configuration. NTT laboratories have obtained statistics on the failure probabilities of old/new network components by investigating damage caused by past earthquakes, and therefore, P(s,d) can be evaluated using the results obtained when a certain part of the network is updated. As a result, we can determine which parts of the network need to be updated.

2.3 P(s,d) and Q(s,d) for bounded disaster area [23]

When the disaster area is not much larger than the network of interest, the shape of the disaster area has an impact on P(s,d) and Q(s,d). For the convex disaster area and a tree or convex ring network (or a combination of convex ring sub-networks), an optimal (or better) geographical configuration of the network regarding Q(s,d) and approximation formulas for P(s,d) are derived.

For a tree network, a short and zigzag route is better regarding Q(s,d). (See [23] for the formal definition of *zigzag*.) Our theoretical result asserts that Q(s,d) for (a) in Fig. 1 is again the largest, and that for (c) is the smallest. This result was confirmed by simulation using empirical data on nine earthquakes under the assumption that a disaster area caused by an earthquake randomly appears with a uniform intensity and intersects A_0. (These data regarding the disaster areas are based on maps released by the Japan Meteorological Agency (JMA) [24] and [25].) The simulation result shown in **Fig. 2** verified the theoretical result, although the actual disaster area may not be convex.

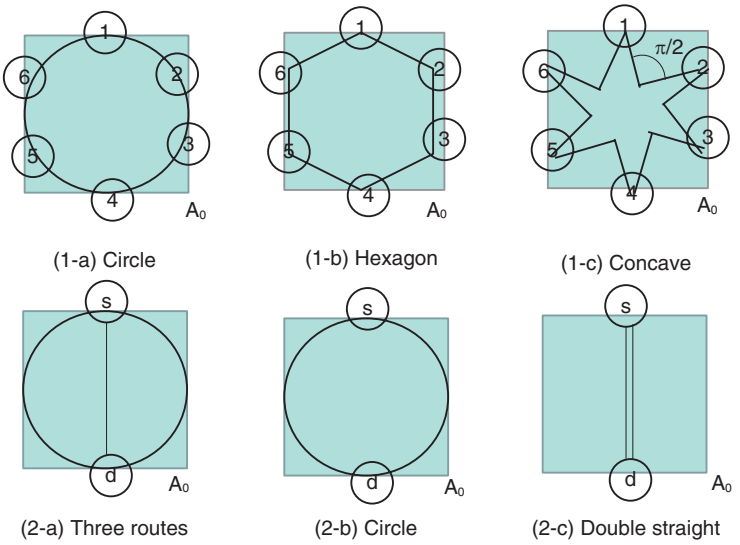

Fig. 3. Two sets of three ring-network models.

For a ring network or a combination of convex ring subnetworks, additional routes within each ring network do not improve Q(s,d), and a smaller network than the original ring network increases Q(s,d). In **Fig. 3**, Q(s,d) for (1-a) is the smallest, while that for (1-b) is the second largest and that for (1-c) is the largest, where s,d = 1,…,6. In addition, Q(s,d) for (2-a) and (2-b) is the same, and that for (2-c) is the worst. The simulation result shown in **Fig. 4** verified this theoretical result. (In Fig. 4, (2-a) is slightly better than (2-b) for earthquake 9. This is because the disaster area for this earthquake consists of several separated regions and does not satisfy the convexity assumption at all. For other earthquakes, the disaster area is not convex, but we cannot distinguish the result for (2-a) or for (2-b).)

Approximation formulas for P(s,d) are derived under the assumption that the failure probabilities of nodes and links in a disaster area are very small. Let $P_0(s,d)$ be P(s,d) under this assumption. Because Q(s,d) is P(s,d) when the failure probability is extremely high, $P_0(s,d)$ and Q(s,d) give P(s,d) for the two extreme cases. However, optimality for Q(s,d) may not mean optimality for $P_0(s,d)$. For example, $P_0(s,d)$ for (2-a) may be better than $P_0(s,d)$ for (2-b), although Q(s,d) values for (2-a) and (2-b) are the same. This is because the larger number of routes in a disaster area reduces $P_0(s,d)$.

These results are also useful in determining a geographical configuration of the network that reduces $P_0(s,d)$ or Q(s,d), the spatial/geographical server location that minimizes $P_0(s,d)$, and also which part of the network should be updated. For a generic network, we need to divide the network into subnetworks with tree or ring topologies and apply the results to each subnetwork.

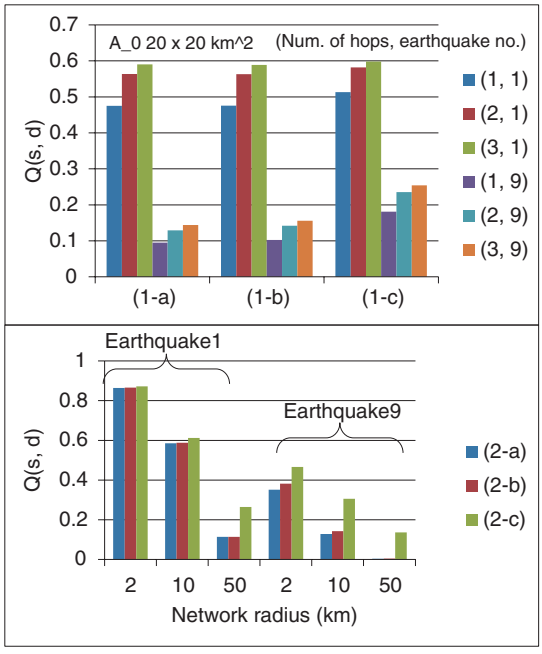

Fig. 4. Simulation results for three ring-network models shown in Fig. 3 [23].

3. Network control

As a result of global warming, natural disasters such as hurricanes and tornados are increasing in intensity and frequency. However, advances in meteorology have enabled us to forecast them with a certain degree of accuracy. In addition, historical disaster data and hazard maps describing high-risk areas for each type of disaster have become public via the web. This means that we have time and data to react to the forecast results.

Disaster avoidance control [26] is a network control mechanism to reconfigure the network in order to prevent damage from a forecasted disaster, specifically, by reacting to the forecast results as they are updated. Of course, it is difficult to move network buildings, poles, and ducts. However, we can relocate software objects and data, and we can reconfigure logical networks or how they are mapped to the physical network. In particular, the progress in software technologies has expanded what we can do in disaster control efforts, and many network functions have become portable and relocatable. Software-defined networking and network functions virtualization are examples of technologies that enable these actions.

The disaster avoidance control algorithm to relocate software objects from a high-risk region to a low-risk region is described as follows as an example. When we receive a warning of a weather disaster for a certain region issued by a meteorological bureau, if this warning specifies a very small region, we identify the network components in the target (warning) region and their failure probabilities under the forecasted disaster and calculate a metric such as a probability of disconnection. However, it is often the case that the warning region is an entire city or prefecture, and the actual disaster area is a certain small area within the warning region. For such cases, we can apply a similar technique to one used in network design. That is, we assume that a given disaster area occurs with a uniform expected occurrence probability within the warning region and calculate a metric.

If the calculated metric exceeds a threshold, the disaster avoidance control will move some objects from the warning region to another region. The region or nodes that accept the objects can be chosen according to a similar or the same metric calculated with the constraint of the resources required by objects that should be relocated. When the new location is determined, we execute the relocation of objects from nodes in the warning region to nodes in the other region to avoid the disaster. Even if the relocation is executed, the services using these objects are not expected to be disrupted.

We developed an experimental system in which voice over Internet protocol (VoIP) call state data of each session can be relocated from one working Session Initiation Protocol (SIP) server in a high-risk region to another SIP server in a low-risk region. In this system, we confirmed that VoIP call state data of a session were effectively relocated without suspending the service.

4. Conclusion

This article proposed the concept and implementation of a Disaster-free Network. This concept attempts to reduce or minimize the possibility of a network encountering disasters. This is a completely different approach from that of conventional disaster management, and it creates a new direction for disaster management research.

The Disaster-free Network concept is based on the analysis of spatial relationships between a disaster area and a network. Therefore, if we apply this same approach to a topic other than disasters and analyze the relevant spatial relationships, we may be able to create other new network concepts.

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Standardization Activities for QoS/QoE-related Technologies in ITU-T

Akira Takahashi

Abstract

In this article, the standardization activities for quality of service (QoS)/quality of experience (QoE)-related technologies in ITU-T (International Telecommunication Union, Telecommunication Standardization Sector), particularly in Study Group 12 (SG12), are introduced. First, the motivation behind efforts to standardize QoS/QoE-related technologies is reviewed, and then some of the key Recommendations are introduced. Finally, the topics attracting the most attention in SG12 are briefly discussed.

Keywords: QoE, QoS, performance

1. Introduction

In the era of conventional telephone services, the International Telecommunication Union, Telecommunication Standardization Sector (ITU-T) investigated and standardized quality assessment methodologies and quality planning rules based on quality of service (QoS). The main purpose of such activities was to guarantee the end-to-end conversational quality of telephone services.

These days, however, it is difficult to achieve the required QoS objectives based only on the predetermined quality planning rules. This is due to the diversity of applications using telecommunication networks, as well as dynamism in the traffic they produce. Therefore, ITU-T has been investigating not only quality of experience (QoE) assessment methodologies for such various applications, but also in-service QoE management technologies, which makes it possible to monitor the QoE of each application and to take necessary actions to solve problems.

The rationale behind the international standardization of QoS/QoE-related technologies is discussed in the following sections, and some important Recommendations and current topics of interest being studied in ITU-T Study Group 12 (SG12) are introduced.

2. Significance of QoS/QoE-related standardization

2.1 Protection of users' convenience

Unlike in conventional telephone networks, it is often extremely difficult to guarantee end-to-end quality in the Internet environment, in which multiple network providers are interconnected in a complex way. However, there is still a need to protect end users' convenience in terms of telecommunication quality from the viewpoint of social fairness.

For instance, the Study Group on the Ideal State of Internet Service Quality Measurements established by the Ministry of Internal Affairs and Communications of Japan has been studying the appropriateness and fairness of various quality indices provided by individual mobile network carriers to end users. This is a good example of the concept of protection of users' convenience that is being considered in the Internet community.

2.2 Uniqueness of quality scales

Before the quality objectives and rules for interconnection can be discussed, it is a prerequisite to agree on common scales of quality. In this sense, it is important to agree on subjective (QoE) quality scales, as well as on objective (QoS) ones. ITU-T plays a

very important role for this purpose as an international organization under the United Nations.

2.3 Achieving better end-to-end quality

Even if the network that one user connects to has very high performance, the end-to-end quality still depends on the performance of the other networks that are accessed towards the destination. Telecommunication is not like home appliances such as refrigerators and microwaves, in the sense that with telecommunication we need to exchange signals with a far-end friend or server. Therefore, we need international rules that define the minimum requirements to achieve reasonable end-to-end quality.

Another example can be found in the situation in which two people are talking over mobile phones. If the nominal sending and receiving levels are not defined at all, users will likely experience speech levels that are too loud or too quiet, which results in very poor QoE.

3. Key Recommendations in ITU-T

3.1 Subjective quality assessment

Subjective quality assessment, in which subjects judge the quality of media such as video, has been studied for many years, and ITU has already standardized various methods of assessing quality for different purposes. Subjective quality assessment, which is a psycho-acoustic/visual experiment, is the most fundamental and reliable way to quantify users' QoE.

The key Recommendation in this category is Recommendation P.800, although there are many other Recommendations that define methodologies for particular evaluation purposes such as speech codec testing. The most typical quality scale defined in Recommendation P.800 is the Mean Opinion Score (MOS), which is the mean evaluation score by many subjects on a 5-point scale (5: Excellent, 4: Good, 3: Fair, 2: Poor, 1: Bad).

3.2 Objective quality assessment

Objective quality assessment is defined as a means for estimating subjective quality solely from objective quality measurements or indices. ITU-T standardized a quality-planning tool for telephony services including voice over Internet protocol (VoIP) and voice over Long-Term Evolution (VoLTE) as Recommendation G.107, which is also called the E-model. The output of the E-model is the transmission rating scale "R." This was also adopted as a standard measure for IP-telephony services in Japan by the Telecommunication Technology Committee (TTC) as TTC Standard JJ-201.01.

In some cases, we need to measure the quality based only on input and output speech signals. For example, in mobile VoIP applications, capturing the IP-packet and measuring the packet-loss rate is often impossible. Therefore, ITU-T standardized Recommendations P. 862 (PESQ: Perceptual Evaluation of Speech Quality) and P.863 (POLQA: Perceptual Objective Listening Quality Assessment). These two Recommendations are essential when estimating the end-to-end conversational quality of VoLTE.

4. Ongoing work

4.1 In-service quality management

As described earlier, in-service quality management is becoming more important than ever because most dominant applications such as web browsing, progressive download video, and VoIP on mobile phones are all provided through best-effort networks. Up to now, ITU-T has standardized QoE monitoring methodologies for speech (Recommendation P.564) and for IPTV (television) (Recommendations P.1201 and P.1202). It has also started working on standardizing the technology for progressive download video such as that seen on YouTube. The code name of this project is P.NATS, and it is expected to be finished in early 2016.

4.2 Terminal characteristics

Many Recommendations have been published for conventional fixed and mobile speech terminals. ITU-T is currently working on the requirements for hands-free terminals for in-vehicle communications, video-telephony, and telepresence, which allow a person to feel as if they were present somewhere else.

4.3 Network performance

Network performance objectives have conventionally been defined as QoS classes in Recommendation Y.1541, for example. However, such an approach apparently has limitations due to the diversity of QoS requirements of various applications.

In addition, network performance indices such as packet-loss rate and delay, which assume a level of performance stability as in fixed networks, cannot fully characterize the spatial and temporal variance of mobile networks. Moreover, the conventional dichotomy of availability and transmission quality does not

hold anymore because of the instability of mobile transmission.

From these viewpoints, we need to introduce new QoS indices that can indicate the characteristics of mobile networks that affect end users' experience.

5. Conclusion

This article summarized the standardization activities of QoS/QoE-related technologies in ITU-T SG12. SG12 has been expanding its coverage from telephone to web browsing, video delivery, network gaming, telepresence, and other applications, in collaboration with various forums and other standardization bodies. One of the most important roles of SG12 is to bridge a gap among these organizations and provide a comprehensive set of technologies for QoS/QoE.

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Method to Identify Conducted Disturbance Source of Malfunction of Telecommunication Services

Abstract

This article introduces equipment used to identify a conducted disturbance source in telecommunication equipment. This is the twenty-ninth of a bimonthly series on the theme of practical field information on telecommunication technologies. This month's contribution is from the EMC Engineering Group, Technical Assistance and Support Center, Maintenance and Service Operations Department, Network Business Headquarters, NTT EAST.

Keywords: conducted disturbance, noise direction detector, malfunction in telecommunication equipment

1. Introduction

Many kinds of devices such as telephones, personal computers (PCs), and televisions incorporate communication functions. These devices are connected to the Internet through a home gateway. In this environment, a conducted disturbance that is generated by a fault in one device can lead to malfunctions in other devices such as audible noise in a telephone or a communication error in a PC.

When a malfunction occurs, the conducted disturbance source (i.e., the device with the fault) needs to be identified and then repaired or removed. However, in a communication environment in which multiple communication devices and home appliances are connected to the same mains and telecommunication network, identifying the conducted disturbance source can be extremely difficult. If the source cannot be identified, it becomes necessary to reduce the conducted disturbance by inserting a noise filter, for instance, a common-mode choke coil, on the telecommunication line (telephone line, Ethernet cable, etc.) and/or the mains line of the malfunctioning telecommunication devices affected by the conducted disturbance.

However, a countermeasure based on the insertion of a noise suppression filter incurs a cost and might have to be applied to another connected device if it is later found to be affected by a conducted disturbance. Accordingly, identifying the conducted disturbance source and repairing or removing the source is a more effective countermeasure than inserting noise filters.

Therefore, the EMC Engineering Group has proposed a simple and efficient method for identifying a conducted disturbance source and has constructed a prototype device for identifying the direction of conducted disturbance propagation. This article describes this simple method for identifying the conducted disturbance source and explains the effectiveness of the prototype device.

2. Background

When responding to a malfunction in telecommunication equipment caused by a conducted disturbance, maintenance personnel use the following procedure to identify the conducted disturbance source in the field.

(1) Measurement of conducted disturbance:
Measure the conducted disturbance voltage and frequency at the telecommunication or mains port of the telecommunication equipment

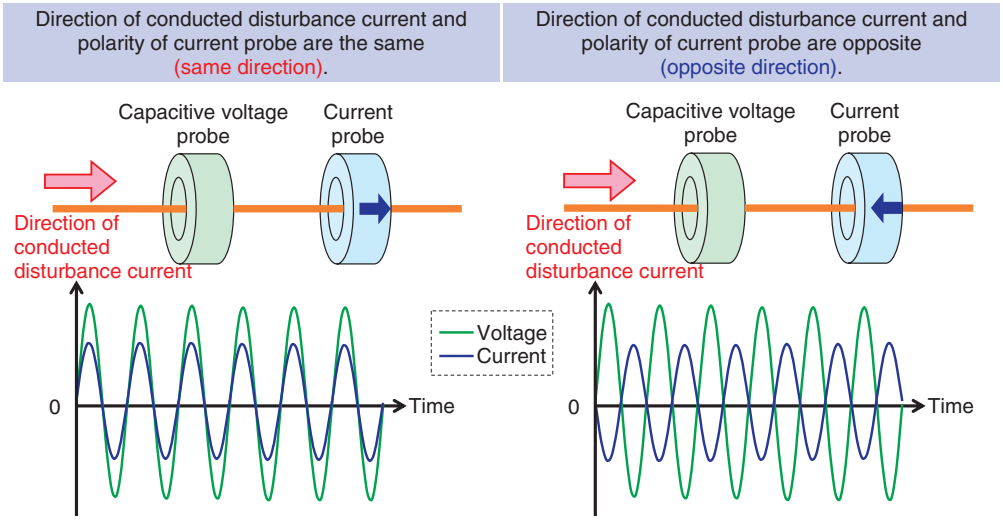

Fig. 1. Basic principle of identifying direction of conducted disturbance propagation.

affected by the conducted disturbance. (A noise search tester can be easily used for measuring the voltage and frequency.)

(2) Relationship between conducted disturbance and malfunction:
Confirm that the malfunction occurs synchronously with the conducted disturbance.

(3) Check the flow of the conducted disturbance current:
Compare the conducted disturbance voltage levels at telecommunication and mains ports. Estimate the conducted disturbance current from the comparison results.

(4) Identify the conducted disturbance source:
Find the conducted disturbance source with the highest voltage level and repair or replace it.

The conducted disturbance source can generally be identified by following the above procedure. However, when a malfunction is caused by a fault in the power supply section of a device, and multiple devices are connected to the same mains line via a multiplug, the same conducted disturbance voltage level would be measured at all of the mains ports of each device. To identify the conducted disturbance source in this case, we need to turn off the power supplies of all connected devices. However, it is not usually possible to turn off the power supplies of all devices.

There is therefore a need for a device that can identify a conducted disturbance source and the direction of its propagation even when conducted disturbance voltage levels are identical.

3. Identifying conducted disturbance source

3.1 Principle

Conducted disturbance voltage measurement can only be applied to check the level of conducted disturbance voltage, which may be ineffective for identifying the conducted disturbance source, as described previously. Therefore, we focus on the direction of conducted disturbance current. However, measuring only the conducted disturbance current does not establish which direction the current is flowing.

To resolve this problem, we have developed a method for identifying the direction of conducted disturbance propagation by simultaneously measuring conducted disturbance voltage and current [1]. A diagram of the proposed method is shown in **Fig. 1**. A capacitive voltage probe and current probe are used to measure the conducted disturbance voltage and current.

As shown in Fig. 1, the current probe has polarity. If this polarity points in the same direction as the flow of conducted disturbance current, the voltage and current will be in phase (the time waveforms of voltage and current are superposed), but if it points in the opposite direction, the voltage and current will be out of phase (the time waveforms of voltage and current are offset). This feature can be used to identify the direction of conducted disturbance propagation.

3.2 Prototype

An external view of the device used to identify the

direction of conducted disturbance propagation that we developed is shown in **Fig. 2**. We call this device a Noise Direction Detector (NDD). The NDD has capacitive voltage and current probes for measuring conducted disturbance voltage and current, a signal processing section that inputs measured conducted disturbance current and voltage, and a display section for presenting the results of calculating the conducted disturbance propagation direction. The display section is a tablet terminal with a touch screen.

The display section is shown in **Fig. 3**. If conducted disturbance current is flowing in the same direction as the orientation of the current probe, the measured values will be displayed in the positive direction on the graph. If current is flowing in the opposite direction, the values will be displayed in the negative direction. The results shown in Fig. 3 are those for a conducted disturbance current flowing in the same direction as the orientation of the current probe.

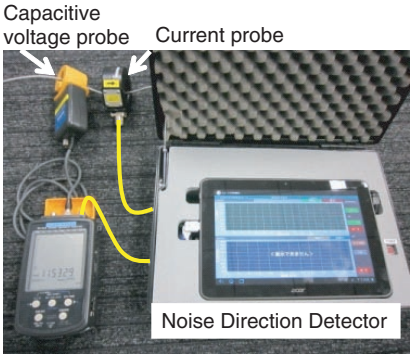

Fig. 2. Photo of NDD.

4. Evaluation of NDD

We present a case study in which the NDD was applied and the conducted disturbance source was identified for a telecommunication malfunction that occurred inside a telecommunication building.

4.1 Malfunction overview and facility layout

A customer claimed to be experiencing telecommunication errors on a digital circuit that made the customer's system unusable. Maintenance personnel checked the telecommunication conditions and confirmed that telecommunication errors were occurring. The customer's facility layout is shown in **Fig. 4**. In this layout, the digital service unit (DSU) has telecommunication and mains ports. The mains port of the DSU is connected to an uninterruptible power supply (UPS) in the power room via a power distribution frame.

4.2 Measurement of conducted disturbance

It was necessary to verify that the communication errors that were occurring were due to conducted disturbance. The conducted disturbance voltage was measured in both the telecommunication and mains ports of the DSU. The measurement results revealed conducted disturbance voltage with a peak at about 200 kHz superposed on the transmission band of the digital circuit. In addition, the conducted disturbance voltage level at the mains port of the DSU was higher

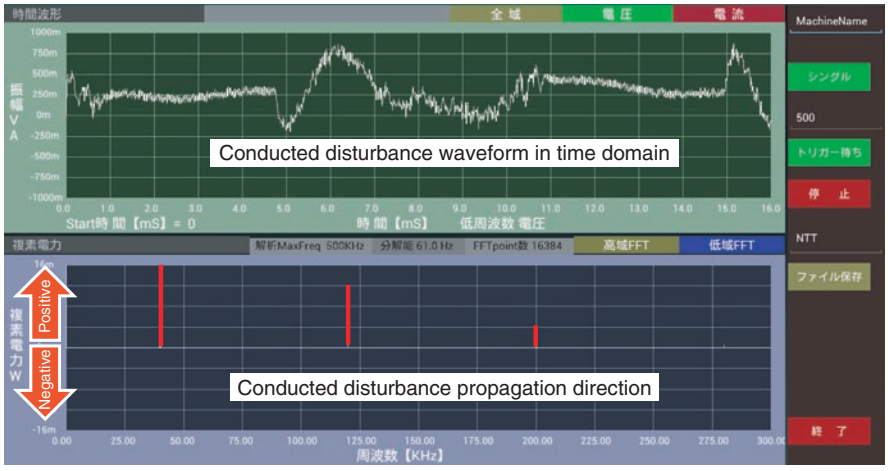

Fig. 3. Display of NDD.

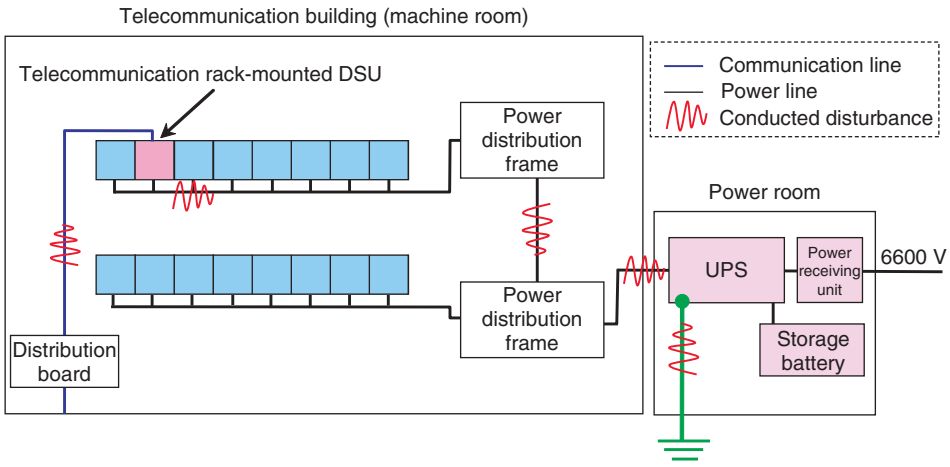

Fig. 4. Facility layout.

than that of the telecommunication port, so it was inferred that the conducted disturbance was propagating via the mains port of the DSU.

4.3 Identification of conducted disturbance source

Conducted disturbance measurements therefore confirmed that the conducted disturbance was propagating from the mains port of the DSU. However, many power supply lines and communication lines are laid under double floors in telecommunications buildings, as shown in **Fig. 5**, and furthermore, many units of communication equipment are connected via a power distribution frame.

Consequently, when the conducted disturbance voltage of power supply lines connected to the power distribution frame was measured, nearly the same level of conducted disturbance voltage was observed on all power supply lines that were measured. The NDD was therefore applied to this power distribution frame to determine the conducted disturbance propagation path.

The orientations of current probes are shown in **Fig. 6**, and the measurement results are shown in **Fig. 7**. These results revealed that the conducted disturbance was propagating from the upper side (power room side) of the power supply line. Then, the same kinds of measurements were repeated, and the source of the conducted disturbance was soon found to be the UPS unit installed in the power room. The UPS manufacturer was consulted, and it was found that a UPS component had failed. The UPS unit was replaced, which eliminated the malfunction in the DSU.

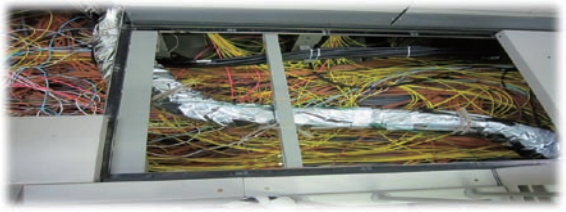

Fig. 5. Wiring conditions under a double floor in telecommunication building.

5. Conclusion

We reported on the development of a device used for identifying the direction of conducted disturbance propagation and confirmed that the device was effective in identifying an actual communication malfunction that occurred inside a telecommunication building. We plan to develop a more compact version of this equipment for use in field operations.

Malfunctions in telecommunication equipment due to conducted disturbance can occur in all types of places including telecommunication buildings, inside homes, and even outdoors. Looking forward, the EMC Engineering Group of the Technical Assistance and Support Center is committed to participating in technology dissemination activities such as technology collaboration, technology development, and technology seminars to contribute to the prompt resolution of malfunctions in telecommunication

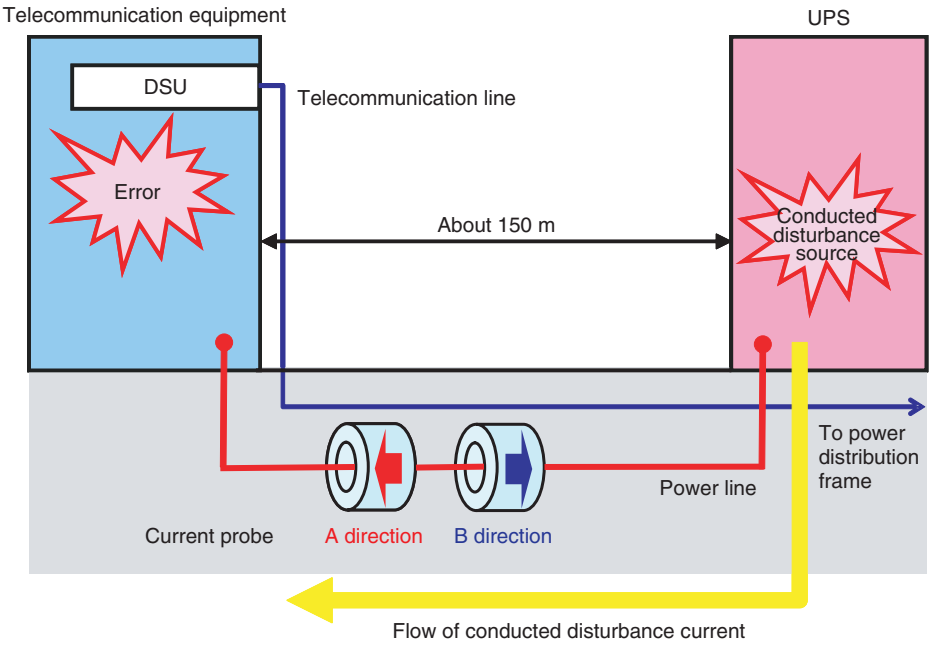

Fig. 6. Measurement system.

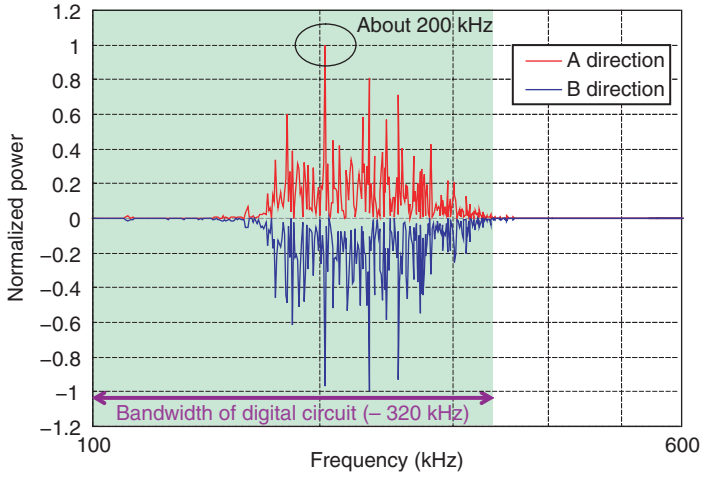

Fig. 7. Measurement results.

equipment and the smooth provision of telecommunication services.

Reference

[1] Y. Okugawa et al., "A Study of Detection Technique of Propagation Direction for Conductive Disturbance Waves," IEICE Technical Report, EMCJ, Vol. 111, No. 420, pp. 31–36, 2012 (in Japanese).

External Awards

2014 IEICE Young Researchers Award

Winner: Shoko Shinohara, NTT Access Network Service Systems Laboratories
Date: March 11, 2015
Organization: Institute of Electronics, Information and Communication Engineers (IEICE), Communications Society

For "Capacity Enhancement with Multi-channel Transmission Technique for High Efficiency WLANs" and "Efficient Transmission of Beacon Frames by Multi-channel Transmission Technique with WLAN-AP Cooperation."
Published as: S. Shinohara, Y. Inoue, B.A. Hirantha Sithira Abeysekera, Y. Asai, and M. Mizoguchi, "Capacity Enhancement with Multi-channel Transmission Technique for High Efficiency WLANs," Proc. of the 2014 IEICE General Conference, B-5-142, Niigata City, Niigata, Japan, Mar. 2014; S. Shinohara, Y. Inoue, K. Akira, M. Iwabuchi, and M. Mizoguchi, "Efficient Transmission of Beacon Frames by Multi-channel Transmission Technique with WLAN-AP Cooperation," Proc. of the 2014 IEICE Society Conference, B-5-105, Tokushima, Japan, Sept. 2014.

2014 IEICE Young Researchers Award

Winner: Masashi Iwabuchi, NTT Access Network Service Systems Laboratories
Date: March 11, 2015
Organization: IEICE, Communications Society

For "A Study on Channel Offset Method for Reduction of Blank Channels Based on Dynamic Channel Selection" and "A Performance Evaluation of Simultaneous Transmission Utilizing Cooperative Back-off Control with Beamforming."
Published as: M. Iwabuchi, A. Kishida, T. Shintaku, T. Onizawa, and T. Sakata, "A Study on Channel Offset Method for Reduction of Blank Channels Based on Dynamic Channel Selection," Proc. of the 2014 IEICE General Conference, B-5-141, Niigata City, Niigata, Japan, Mar. 2014; M. Iwabuchi, A. Kishida, T. Shintaku, T. Onizawa, T. Sakata, "A Performance Evaluation of Simultaneous Transmission Utilizing Cooperative Back-off Control with Beamforming," Proc. of the 2014 IEICE Society Conference, B-5-99, Tokushima, Japan, Sept. 2014.

2014 IEICE Young Researchers Award

Winner: Kei Kitamura, NTT Network Service Systems Laboratories
Date: March 11, 2015
Organization: IEICE, Communications Society

For "Beyond 100G Path Capacity Adjustment Scheme for Elastic Transport Network."
Published as: K. Kitamura, Y. Yamada, M. Teshima, and A. Hirano, "Beyond 100G Path Capacity Adjustment Scheme for Elastic Transport Network," Proc. of the 2014 IEICE General Conference, B-10-31, Niigata City, Niigata, Japan, Mar. 2014.

TAF Telecom System Technology Award

Winner: Yukihiro Bandoh, NTT Advanced Technology Corporation; Seishi Takamura, NTT Media Intelligence Laboratories; Hirohisa Jozawa, NTT Network Service Systems Laboratories, and Yoshiyuki Yashima, Chiba Institute of Technology
Date: March 23, 2015
Organization: The Telecommunications Advancement Foundation (TAF)

For "Generalized Theoretical Modeling of Inter-frame Prediction Error for High Frame-rate Video Signal Considering Integral Phenomenon."
Published as: Y. Bandoh, S. Takamura, H. Jozawa, and Y. Yashima, "Generalized Theoretical Modeling of Inter-frame Prediction Error for High Frame-rate Video Signal Considering Integral Phenomenon," IEICE Transactions on Fundamentals of Electronics, Communications and Computer Sciences, Vol. E93-A, No. 8, pp. 1442–1452, Aug. 2010.

JSAP Poster Award

Winner: Tetsuhiko Teshima, Shingo Tsukada, Nahoko Kasai, Satoshi Sasaki, Aya Tanaka, Hiroshi Nakashima, and Koji Sumitomo, NTT Basic Research Laboratories
Date: April 1, 2015
Organization: The Japan Society of Applied Physics (JSAP)

For "Conductive Silk Films for Manipulation of Adherent Cells."
Published as: T. Teshima, S. Tsukada, N. Kasai, S. Sasaki, A. Tanaka, H. Nakashima, and K. Sumitomo," Proc. of the 62nd JSAP Spring Meeting, 12a-P11-12, Kanagawa, Japan, Mar. 2015.

IACR Fellow

Winner: Tatsuaki Okamoto, NTT Secure Platform Laboratories
Date: April 8, 2015
Organization: International Association for Cryptologic Research (IACR)

For theoretical and practical contributions to areas including encryption, signatures, identification, elliptic-curve cryptosystems, zero knowledge, and electronic cash, and for service to the IACR.

2014 IEEE Signal Processing Society Best Paper Award

Winner: Hiroshi Sawada, Shoko Araki, NTT Communication Science Laboratories; Shoji Makino, Tsukuba University
Date: April 21, 2015
Organization: Institute of Electrical and Electronics Engineers (IEEE), Signal Processing Society

For "Underdetermined Convolutive Blind Source Separation via Frequency Bin-Wise Clustering and Permutation Alignment."

This paper presents a blind source separation method for convolutive mixtures of speech/audio sources. The method can even be applied to an underdetermined case where there are fewer microphones than sources. The separation operation is performed in the frequency domain and consists of two stages. In the first stage, frequency-domain mixture samples are clustered into each source by an expectation-maximization (EM) algorithm. Since the clustering is performed in a frequency bin-wise manner, the permutation ambiguities of the bin-wise clustered samples should be aligned. This is solved in the second stage by using the probability of how likely each sample belongs to the assigned class. This two-stage structure makes it possible to attain a good separation even under reverberant conditions. Experimental results for separating four speech signals with three microphones under reverberant conditions show the superiority of the new method over existing methods. We also report separation results for a benchmark data set and live recordings of speech

mixtures.
Published as: H. Sawada, S. Araki, and S. Makino, "Underdetermined Convolutive Blind Source Separation via Frequency Bin-Wise Clustering and Permutation Alignment," IEEE Transactions on Audio, Speech, and Language Processing, Vol. 19, No. 3, pp. 516–527, Mar. 2011.

ITU-AJ International Activity Encouragement Award
Winner: Kiyoshi Tanaka, NTT Service Evolution Laboratories
Date: May 15, 2015
Organization: The ITU Association of Japan (ITU-AJ)

For his contribution to the international standardization of IPTV (Internet protocol television) and digital signage by leading discussions in the International Telecommunication Union-Telecommunication Standardization Sector Study Group 16 (ITU-T SG16) and ITU-T IPTV Global Standards Initiative. In addition, he was involved in preparing for and carrying out the ITU-T SG16 Sapporo meeting held in 2014, and greatly contributed to the success of the meeting.

ComEX Best Letter Award
Winner: Kazumitsu Sakamoto, Ken Hiraga, Tomohiro Seki, Tadao Nakagawa, and Kazuhiro Uehara, NTT Network Innovation Laboratories
Date: May 15, 2015
Organization: IEICE, Communications Society

For "Performance Evaluation of a Simple Decoding Method for Millimeter-wave Short-range MIMO Transmission through a Wall."

The simple decoding method we have proposed for short-range multiple-input multiple-output (SR-MIMO) transmission is a promising means for reducing power consumption. The method performs MIMO detection with analog devices, thus reducing the number of quantization bits required in the analog-to-digital converter (ADC) of the receiver and the amount of signal processing calculation for MIMO detection. However, when the method is applied to a wall transmissive wireless repeater on a multilayered wall, the transmission performance degrades due to multipaths generated by the multilayered structure. In this letter, we evaluate the method's performance using data for a millimeter wave propagation channel that we measured from wall samples and the measured S-parameters of the method's analog circuit. As a result, we quantify the influence of multipaths generated by a wall's multilayered structure on transmission performance.
Published as: K. Sakamoto, K. Hiraga, T. Seki, T. Nakagawa, and K. Uehara, "Performance Evaluation of a Simple Decoding Method for Millimeter-wave Short-range MIMO Transmission through a Wall," IEICE Communications Express, Vol. 3, No. 4, pp. 131–137, Apr. 2014.

Best Tutorial Paper Award
Winner: Yusuke Asai, Koichi Ishihara, Tomoki Murakami, Riichi Kudo, Yasushi Takatori, and Masato Mizuguchi, NTT Network Innovation Laboratories
Date: May 15, 2015
Organization: IEICE, Communications Society

For overview of very high throughput wireless LAN standard IEEE 802.11ac and experimental evaluation of multiuser-MIMO transmission.
Published as: K. Ishihara, Y. Asai, R. Kudo, T. Ichikawa, Y. Takatori, and M. Mizoguchi, "Development and Experimental Validation of Downlink Multiuser MIMO-OFDM in Gigabit Wireless LAN Systems," EURASIP Journal on Advances in Signal Processing, Vol. 123, pp. 1–10, Jun. 2013.

Best Paper Award
Winner: Ikuma Ando, Gia Khanh Tran, and Kiyomichi Araki, Tokyo Institute of Technology; Takayuki Yamada, Takana Kaho, Yo Yamaguchi, and Kazuhiro Uehara, NTT Network Innovation Laboratories
Date: June 4, 2015
Organization: IEICE

For "Nonlinear Modeling and Analysis on Concurrent Amplification of Dual-band Gaussian Signals."

In the recently developed Flexible Wireless System (FWS), the same platform needs to deal with different wireless systems. This increases nonlinear distortion in its wideband power amplifier (PA) because the PA needs to concurrently amplify multi-band signals. By taking higher harmonics as well as inter- and cross-modulation distortion into consideration, we have developed a method to analytically evaluate the adjacent channel leakage power ratio (ACPR) and error vector magnitude (EVM) on the basis of the PA's nonlinear characteristics. We devise a novel method for modeling the PA amplifying dual-band signals. The method makes it possible to model it merely by performing a one-tone test, making use of the Volterra series expansion and the general Wiener model. We then use the Mehler formula to derive the closed-form expressions of the PA's output power spectral density (PSD), ACPR, and EVM. The derivations are based on the assumption that the transmitted signals are complex Gaussian distributed in orthogonal frequency division multiplexing (OFDM) transmission systems. We validated the method by comparing measurement and simulation results and confirmed that it can appropriately predict the ACPR and EVM performance of the nonlinear PA output with OFDM inputs. In short, the method enables correct modeling of a wideband PA that amplifies dual-band signals merely by conducting a one-tone test.
Published as: I. Ando, G. K. Tran, K. Araki, T. Yamada, T. Kaho, Y. Yamaguchi, and K. Uehara, "Nonlinear Modeling and Analysis on Concurrent Amplification of Dual-band Gaussian Signals," IEICE Transactions on Electronics, Vol. E96-C, No. 10, pp. 1254–1262, Oct. 2013.

Achievement Award
Winner: Kazuhiro Uehara, NTT Network Innovation Laboratories
Date: June 4, 2015
Organization: IEICE

For research and development of software defined radio and cognitive radio technologies.

Papers Published in Technical Journals and Conference Proceedings

Q-value Improvement by Electrical Maximum Ratio Combining in Optical Diversity Transmission through Multi-core Fiber

M. Koga, T. Iida, T. Kobayashi, and H. Takara

Proc. of the 19th OptoElectronics and Communication Conference (OECC 2014), pp. 697–698, Melbourne, Australia, July 2014.

This paper evaluates the Q-factor improvement by maximum ratio combining for optical diversity transmission signals under the condition of the parametric process due to the Kerr effect and group velocity dispersion.

Wavelength-dependent Crosstalk in Trench-assisted Multi-core Fibers

F. Ye, J. Tu, K. Saitoh, H. Takara, and T. Morioka

Proc. of OECC 2014, pp. 308–309, Melbourne, Australia, July 2014.

Analytical expressions for wavelength-dependent crosstalk in homogeneous trench-assisted multi-core fibers are derived. The calculated results from the expressions agree well with the numerical simulation results based on finite element method.

Impact of Adding/Dropping of Nyquist-WDM Superchannels on Transmission Performance in an Elastic Optical Network

M. Jinno, K. Hosokawa, S. Kuwahara, Y. Yamada, and T. Kataoka

Proc. of OECC 2014, pp. 538–540, Melbourne, Australia, July 2014.

The transmission performance of Nyquist-WDM (wavelength-division multiplexing) superchannels with various modulation formats, which are added, passed through, and dropped at various points in a dispersion-uncompensated elastic optical network, is investigated through simulations.

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100 Gbit/s Real-time Digital Coherent Transmission over a 32 km Legacy Multi-mode Graded-index Fiber

T. Hirooka, M. Nakazawa, T. Komukai, and T. Sakano

IEICE Electronics Express, Vol. 11, No. 15, pp. 1–7, August 2014.

We demonstrate 100 Gbit/s real-time digital coherent transmission over a 32-km multi-mode graded-index fiber (GIF) with a 62.5 μm core diameter by compensating for modal dispersion with digital signal processing (DSP). The DSP enables channel estimation and configuration as fast as 20 ms. Furthermore, the optical channel can be switched between GIF and a single-mode fiber within 30 ms.

Fundamental Study on Guided Wave Testing of Cylindrical Bars Embedded in Soil

M. Shoji and Y. Higashi

Proc. of the 2014 IEEE International Ultrasonics Symposium (IUS), pp. 1404–1407, Chicago, USA, September 2014.

Ultrasonic guided wave nondestructive evaluation technologies of long, small-diameter cylindrical steel bars embedded in soil have been experimentally studied using piezoelectric probes attached to the sides of the bars. On the basis of calculated attenuation dispersion curves for cylindrical steel bars surrounded by soil, 60- and 120-kHz longitudinal [L(0,1)] modes were chosen as guided waves for pulse echo measurements of 13-mm-diameter cylindrical steel bars in terms of their low attenuation. Pulse echo measurements were conducted for a 13-mm-diameter cylindrical steel bar embedded vertically to the ground with an underground depth of two meters. The signal-to-noise ratio of the first reflection signal from the bottom end surface of the embedded bar was estimated to be more than 30 dB for both 60- and 120-kHz L(0,1) modes. The evaluated attenuations of the guided waves in the underground part are adequately low for inspecting long bars and consistent with the calculated attenuation dispersion curve.

A Cross-layer Switching of OFDMA and MU-MIMO for Future WLAN Systems

T. Murakami, Y. Takatori, M. Mizoguchi, and F. Maehara

IEICE Communications Express, Vol. 3, No. 9, pp. 263–268, May 2015.

We propose a cross-layer switching method of orthogonal frequency division multiple access (OFDMA) and multiuser multiple input multiple output (MU-MIMO) for future wireless local area network systems. The proposed method, employed on the MAC layer, switches between OFDMA and MU-MIMO as the transmission overhead after processing by using physical layer information such as the overhead of CSI feedback, STA number, and data length in order to improve the transmission efficiency. Simulation results show that the proposed method achieves higher total throughput than conventional OFDMA or MU-MIMO where switching is not performed.

Counting Statistics of Single-electron Thermal Noise

K. Nishiguchi, Y. Ono, and A. Fujiwara

Proc. of the 2014 Workshop on Innovative Nanoscale Devices and Systems (WINDS), Hawaii, USA, November/December 2014.

We introduce a transition between the valid and invalid law of equipartition of energy in thermal noise in a small DRAM (dynamic random access memory). We analyzed Brownian motion, i.e., thermal noise, of single electrons going in and out a small capacitor whose E_c is comparable to k_BT. When $E_c > k_BT$, the electron motion is suppressed due to the violation of the law of equipartition of energy.

Long-reach and High-splitting-ratio 10G-EPON System with Semiconductor Optical Amplifier and N:1 OSU Protection

T. Tsutsumi, T. Sakamoto, Y. Sakai, T. Fujiwara, H. Ou, Y. Kimura, and K. Suzuki

Journal of Lightwave Technology, Vol. 33, No. 8, pp. 1–6, April 2015.

We successfully demonstrate a 41.3-km-reach and 128-split 10G-EPON system with dual-rate semiconductor optical amplifier on a commercial access network infrastructure. It uses N:1 optical subscriber unit (OSU) protection in order to improve system reliability cost-effectively. N:1 OSU protection also can switch from an active system to a redundant system without any frame loss. Moreover, the quality of bidirectional frame transmission is not degraded after switching, even with four-class priority control. Error-free transmission over 130 hours is also confirmed. These results indicate that N:1 OSU protection with automatic level control semiconductor optical amplifiers is a promising approach to practical 10G-EPON systems that are cost-effective and reliable.

All-photonic Quantum Repeaters

K. Azuma, K. Tamaki, and H.-K. Lo

Nature Communications, Vol. 6, No. 6787, pp. 1–7, April 2015.

Quantum communication holds promise for unconditionally secure transmission of secret messages and faithful transfer of unknown quantum states. Photons appear to be the medium of choice for quantum communication. Owing to photon losses, robust quantum communication over long lossy channels requires quantum repeaters. It is widely believed that a necessary and highly demanding requirement for quantum repeaters is the existence of matter quantum memories. Here we show that such a requirement is, in fact, unnecessary by introducing the concept of all-photonic quantum repeaters based on flying qubits. In particular, we present a protocol based on photonic cluster-state machine guns and a loss-tolerant measurement equipped with local high-speed active feedforwards. We show that, with such all-photonic quantum repeaters, the communication efficiency scales polynomially with the channel distance.

Quantum Benchmark via an Uncertainty Product of Canonical Variables

R. Namiki and K. Azuma

Physical Review Letters, Vol. 114, pp. 140503-1–6, April 2015.

We present an uncertainty-relation-type quantum benchmark for continuous-variable (CV) quantum channels that works with an input ensemble of Gaussian-distributed coherent states and homodyne measurements. It determines an optimal trade-off relation between canonical quadrature noises that is unbeatable by entanglement breaking channels and refines the notion of two quantum duties introduced in the original papers of CV quantum teleportation. This benchmark can verify the quantum-domain performance for all one-mode Gaussian channels. We also address the case of stochastic channels and the effect of asymmetric gains.

Deviation from the Law of Energy Equipartition in a Small Dynamic-random-access Memory

P. A. Carles, K. Nishiguchi, and A. Fujiwara

Japanese Journal of Applied Physics, Vol. 54, pp. 06FG03-1–5, April 2015.

A small dynamic-random-access memory (DRAM) coupled with a high charge sensitivity electrometer based on a silicon field-effect transistor is used to study the law of equipartition of energy. By statistically analyzing the movement of single electrons in the DRAM at various temperature and voltage conditions in thermal equilibrium, we are able to observe a behavior that differs from what is predicted by the law of equipartition energy; when the charging energy of the capacitor of the DRAM is comparable to or smaller than the thermal energy $k_BT/2$, random electron motion is ruled perfectly by thermal energy; on the other hand, when the charging energy becomes higher in relation to the thermal energy $k_BT/2$, random electron motion is suppressed, which indicates a deviation from the law of equipartition of energy. Since the law of equipartition is analyzed using the DRAM, one of the most familiar devices, we believe that our results are perfectly universal among all electronic devices.

Real-time Robust Formant Tracking System Using a Phase Equalization-based Autoregressive Exogenous Medel

H. Oohashi, S. Hiroya, and T. Mochida

Proc. of the 40th IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP 2015), Brisbane, Australia, April 2015.

This paper presents a real-time robust formant tracking system for speech signals and electroglottography (EGG) signals using a real-time phase equalization-based autoregressive exogenous model (RT-PEAR). PEAR can estimate formant frequencies robustly even for speech with high fundamental frequencies using phase equalization preprocessing and linear prediction coding (LPC) with an impulse train. To reduce the computational complexity of the original PEAR, a novel formulation of LPC with an impulse train is derived. EGG signals were used for stable detection of pitch marks since PEAR requires them. Formant estimation errors for the proposed method were less than 5% regardless of fundamental frequencies with 12-ms processing delay. This technique will be useful for real-time speech conversion and speech-language therapy.
