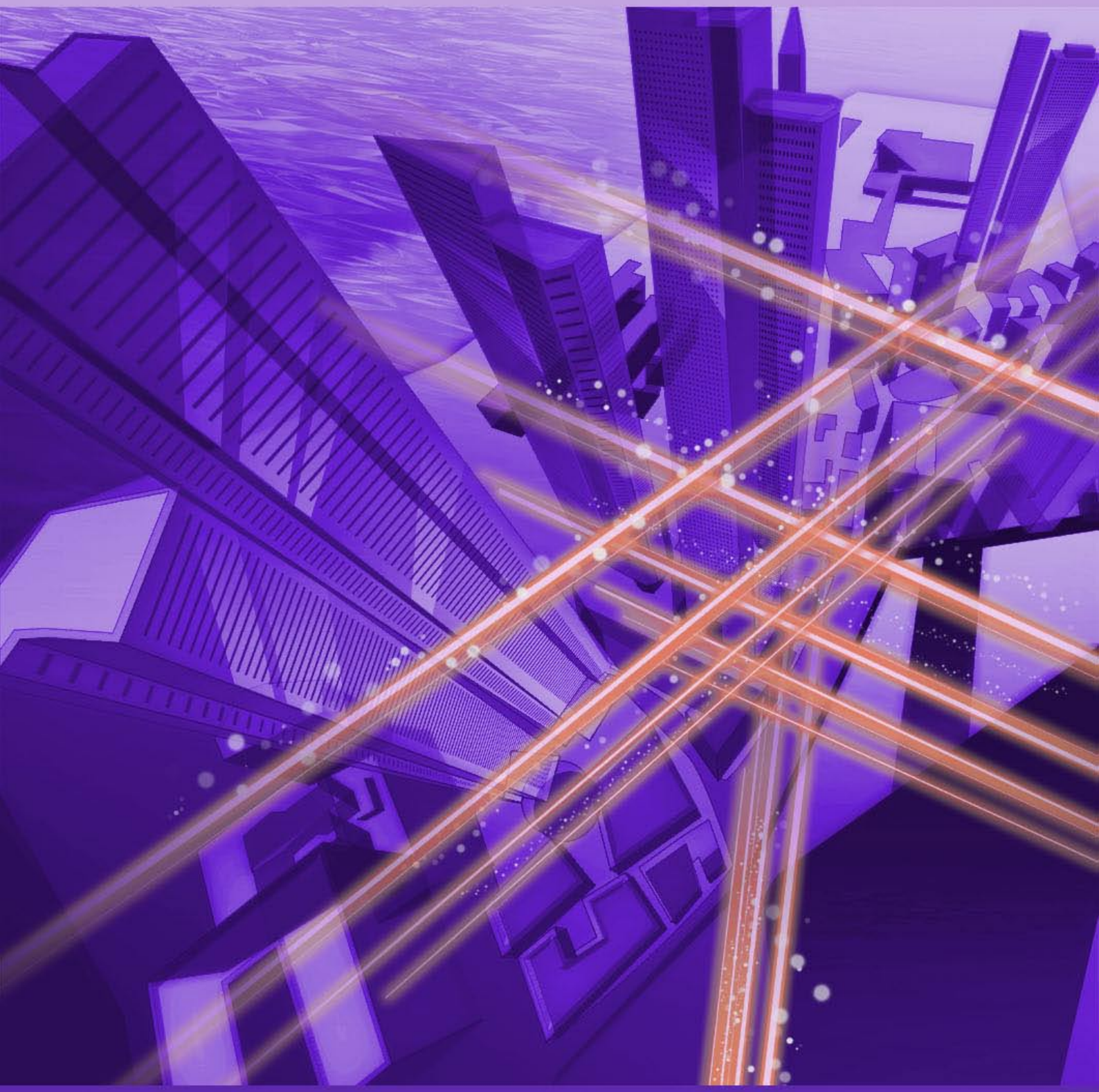
NTT Technical Review

12
2014



December 2014 Vol. 12 No. 12

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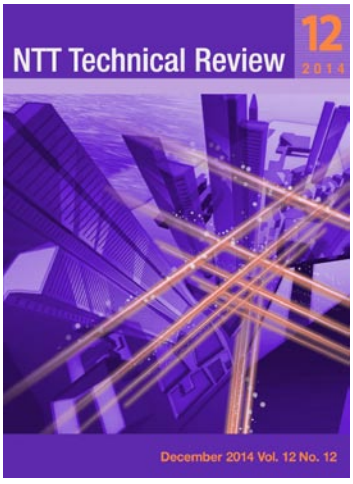

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External Awards/Papers Published in Technical Journals and Conference Proceedings

Taking "Innovation & Japan Quality" Global! —Adopting a Co-creation Mindset to Become a Major Leading Company

Satoshi Kurishima, Senior Executive Vice President, NTT DATA

Overview

Today, as the information and communication technology (ICT) investment in Japan appears to be moving upward but is still sluggish, and as ICT becomes increasingly commoditized, NTT DATA is leveraging the power of its group companies doing business throughout the world to create new value on a global basis. We asked Satoshi Kurishima, Senior Executive Vice President, about the approach that NTT DATA needs to adopt to become a major global leading company.

Keywords: ICT, co-creation, data warehouse

Changing our ideas on ICT investment to reflect the business mindset in each country

—Mr. Kurishima, how do you view the ICT industry today?

Among the four NTT DATA internal companies, I oversee the Solutions & Technologies Company. In my daily work, I keep in close contact with our laboratories to keep up with security-related issues and new technologies such as the cloud that are springing up one after another.

I sense that ICT investment in Japan has not been growing much these last few years. As you know, Japan actually experienced negative growth from the time of the bankruptcy of Lehman Brothers in 2008 to the occurrence of the Great East Japan Earthquake in 2011, but in 2012, the economy finally turned back into positive territory. Since then, however, ICT investment has been growing at a rate of only about 1%, and Gartner and other research or advisory firms forecast that it will remain at that level for the time being.

The United States, in contrast, got back on its feet in the year following the Lehman Brothers bankruptcy, and ICT investment there has been growing at an annual rate of 4–5%. Likewise, ICT investment on a global basis has been growing at 4%, and in China, here in the Asia region, it has been growing at a rate of 7–8%. When we compare these figures with those of Japan, we can see that ICT investment here has been somewhat sluggish.

At NTT DATA, we consider ourselves to be a leading company in the ICT industry. And as an industry leader, I feel strongly that it is our responsibility to provide our customers with truly useful ICT services and products that directly benefit their business.

—How did this gap in ICT investment arise?

The fact is, attitudes toward ICT differ between Japan and other countries. Many companies in Japan regard ICT investment as a means of making "back-office" operations more efficient and complete. As a result, about 70% of all ICT investment in Japan is associated with maintenance and management objectives, and the remaining 30% is allocated to the development of new applications and systems that can contribute to revenues. Under these conditions, it is easy for companies to have the preconception that ICT investment incurs costs and that the first thing to do when the economy turns bad is to cut back on such expenses.

In sharp contrast to this approach, companies in the United States and elsewhere invest aggressively in ICT in such areas as e-commerce with the aim of creating new business opportunities and increasing revenues. In addition, ICT investment tends to grow during economic downturns.

There is also a difference between Japan and the United States as to the distribution of system engineers among vendors and customer companies. In Japan, about 80% of all system engineers work on the vendor side, while in the United States, about two-thirds work on the customer side. This seems to reflect a difference in the way that customers themselves approach ICT. In other words, in Japan, product-oriented proposals from the vendor side tend to be the norm, and many of those products are provided for reducing back-office costs rather than enhancing or expanding the customer's core business.

In the United States, the customer is always thinking about how best to use ICT in business, and it is the customer side that may approach vendors with ideas or suggestions as needed. This way of thinking about developing business is completely opposite that of Japan.

Actually, within NTT DATA itself, a difference can be found in business content between our United States and Japan operations. In Japan, we have a long history of working on social infrastructure systems such as financial and public or government systems, and at present, corporate customers are a surprisingly small market for us. The scale of our business here in Japan also differs from that in the United States, but this difference in approach that we have so far been taking is naturally reflected in business content.

—NTT DATA is doing business in many countries around the world. Is the business strategy that the company adopts in the United States and other countries reflected in its Japan operations? And can the opposite be true?

Yes, certainly. I want to bring together and strengthen the uniqueness and positive features of each company in the NTT DATA Group. For one thing, I believe that we should learn the approach to ICT investment as taken in the United States and elsewhere and make proposals that are directly related to the customer's line of business. As a leading company, we cannot simply offer technology; it is important that we offer our customers ways to create new business by using new technologies such as big data and the cloud.

To give an example, the Data Warehouse & Business Intelligence Laboratory (DWH/BI Lab), which is part of the Big Data Business Promotion Office that we established last year, asks customers to bring their business data so that they and laboratory staff can analyze it together and apply the results obtained to new marketing plans. I feel that by creating an environment in which NTT DATA staff and customers can come up with new things together, we can affect a change in attitude about ICT investment from one that dwells on costs, to one that emphasizes the creation of new business opportunities. As a specific example, an NTT DATA customer in a retail business had been granting points to consumers in its loyalty program, but they are now working on using the program to analyze market trends and consumer preferences. Consequently, in addition to using such analysis results for their own business, they are also investigating the provision of such information to other companies as a new line of business. Such real-world activities underscore the remarkable progress that is being made in the effective application of big

data.

Today, interest is growing in data warehouses and business intelligence, that is, analyzing and processing huge quantities of information accumulated in a company's business system and using the results of that analysis in corporate decision making. I believe that this kind of service can be extremely effective as an initial approach to transforming our customers' business endeavors.

Facing the commoditization of ICT with a revolutionary "co-creation mindset"

—It seems that NTT DATA has not declared cloud services as a main line of business, but what does it mean that cloud technology is part of its management strategy?

To begin with, our primary mission is to optimize our customer's infrastructure, and to this end, we use the cloud. And while it may be thought that the cloud is simply a means of reducing costs, it also makes system construction relatively easy and enables swift scaling up. In particular, the cloud is indispensable in creating new services together with the customer. When organizations set out to use the cloud, they usually focus attention on techniques for transferring the existing system to the cloud, but this way of thinking stays within the boundaries of cutting costs. Our objective is cloud usage that directly relates to services and new business opportunities.

As ICT professionals, we at NTT DATA have approached development projects so that our customers are comfortable leaving everything to us. In other words, we have been responsible for efficiently and accurately providing highly reliable ICT products and services because ICT is an advanced and sophisticated tool that has not been prevalent throughout society until now. Recently, however, as can be seen from the appearance of 3D (three-dimensional) printers, it is becoming easy for just about anyone to use ICT to make things. I believe that ICT is becoming a familiar part of our lives and that even manufacturing is becoming commoditized! In the face of this trend, it can be said that ICT professionals like ourselves are entering a new phase.

As I mentioned earlier, it is important that our group companies that have bases in countries throughout the world provide essential services and seek out new business opportunities based on the distinctive characteristics of their respective regions. At the same time, seamlessly providing individual key technologies such as the cloud on a global scale is a vitally important issue.

—What efforts are you making to provide technologies on a global scale in a seamless manner?

One approach to achieving this is to make ourselves into a "business model," and to this end, we have recently adopted "co-creation" as a keyword. This declares our intention to create business opportunities both within the company and in collaboration with our customers. To promote ourselves as a leading company, it is essential that we demonstrate to our customers that we are truly adept at using ICT. To give an example, we have showcased the activities of our ICT department in charge of the company's back-office operations for our customers to assess.

For our customers, I think that seeing how we ourselves apply ICT in an effective manner can be very persuasive. On the other hand, our own ICT department that we used as a showcase here and which had emphasized only efficiency gains to date, can also develop a good sense of how ICT can be used effectively in a customer's business by accumulating experience in showcasing in-house ICT solutions.

Customers have also come to us with specific inquiries relating, for example, to cost reduction methods, brand integration with overseas branches, as in establishing a common mail domain, and methods for

dealing with globalization. Enabling our customers to visualize our achievements through such a showcase presentation has also helped to motivate NTT DATA employees. It is exactly feedback from our customers that helps us to see what policies and measures we should adopt going forward.

Furthermore, at the Society of Project Management in which I preside as vice-chairman, I give employees of the ICT department opportunities to make presentations, which provides them with stimuli from outside professionals. This can also be quite motivating but in a way that is different from customer evaluations.

Innovation & Japan Quality: Developing the positive aspects!

—It appears that providing a clear picture of NTT DATA achievements can be very effective. What kind of attitude do you think is needed for people in an organization and the organization itself to grow?

I value an attitude that develops the positive aspects of an organization. Of course, it's also necessary to make improvements in areas having negative results, but first, I think it's important to make what is good even better. The foundation of each group company having a presence in countries and regions throughout the world is, in the end, the quality of the technologies and services that we have developed to date. To ensure that this quality becomes rooted in the distinctive business characteristics of each region is an issue to be dealt with. This relates to the idea of making something that is "positive" even better.

Let's take quality assurance as an example. The high quality of our services is one of our strengths. How to maintain and improve this quality is an issue that I consider to be important. As I've mentioned before, the NTT DATA Group covers practically every country in the world. Our overseas sales target is more than 400 billion yen, which accounts for about 30% of total sales.

Going forward, we are entering a stage in which we can think about expanding the entire NTT DATA Group, including its global components. In fact, we are aiming for a domestic-sales-to-overseas-sales ratio of 1-to-1. In addition, we have adopted the slogan "Innovation & Japan Quality" to reflect our objective in becoming a leading company in each region of the world.

I can say with pride that the quality of our services and technologies is high even from a global perspective. Some might say that we are overachieving in the area of quality, but I think that being too good won't do any harm. Establishing a business while determining how to provide high-quality services at a reasonable price in a trial-and-error fashion is something that we have to work hard at both in Japan and overseas.

—Mr. Kurishima, can you say a few words to all of our researchers supporting these technologies?

I believe that determining how to create "cutting-edge technology" and "the world's best technology" is an important pursuit. And I would like to see such technology created in collaboration with our customers. This technology, even if considered to be the best in the world, is meaningless if our customers have no use for it. I would truly like to see our researchers produce products together with our customers within today's market.

—Finally, can you leave us with a message for all NTT DATA employees working around the world?

"Japan Quality" is not something limited to Japan. To enhance Japan Quality even further, the technologies and services that we have come to refine and nurture in the countries where NTT DATA has bases must be brought together. In this sense, I would like to ask all of our employees throughout the world to adopt a "co-creation mindset" within the company.

Interviewee profile

■ Career highlights

Satoshi Kurishima joined Nippon Telegraph and Telephone Public Corporation (now NTT) in 1980. After the establishment of NTT DATA Communications Systems Corporation (now NTT DATA Corporation) as a result of the spin off from NTT in 1988, he served as Senior Vice President, Head of Finance System Sector from 2005, Director and Senior Vice President, Head of Group Strategy Headquarters from 2009, and Director and Executive Vice President, Company President of Solutions & Technologies Company from 2011. He assumed the office of Representative Director and Executive Vice President in 2012 and took up his present position in June 2014.

Software Production Technologies that Support Large-scale System Development

Hiroshi Tomiyasu

Abstract

Information systems that support social and industrial activities cannot be constructed without software on a large scale. Production technologies for developing such software, however, have made little significant progress over the past few decades, and what currently happens is that ever-increasing demands are met using labor-intensive methods. These Feature Articles describe innovative software production technologies that can overcome these issues with software development.

Keywords: software production technologies, software development automation, legacy systems

1. Introduction

In the 21st century, it is fair to say that society is growing in tandem with computer systems (hereinafter referred to as *systems*). All elements of society, including global financial networks, transportation infrastructure, telecommunications infrastructure, and corporate activities, in addition to social areas involving individual consumption activities and friendship-related social activities are supported by systems.

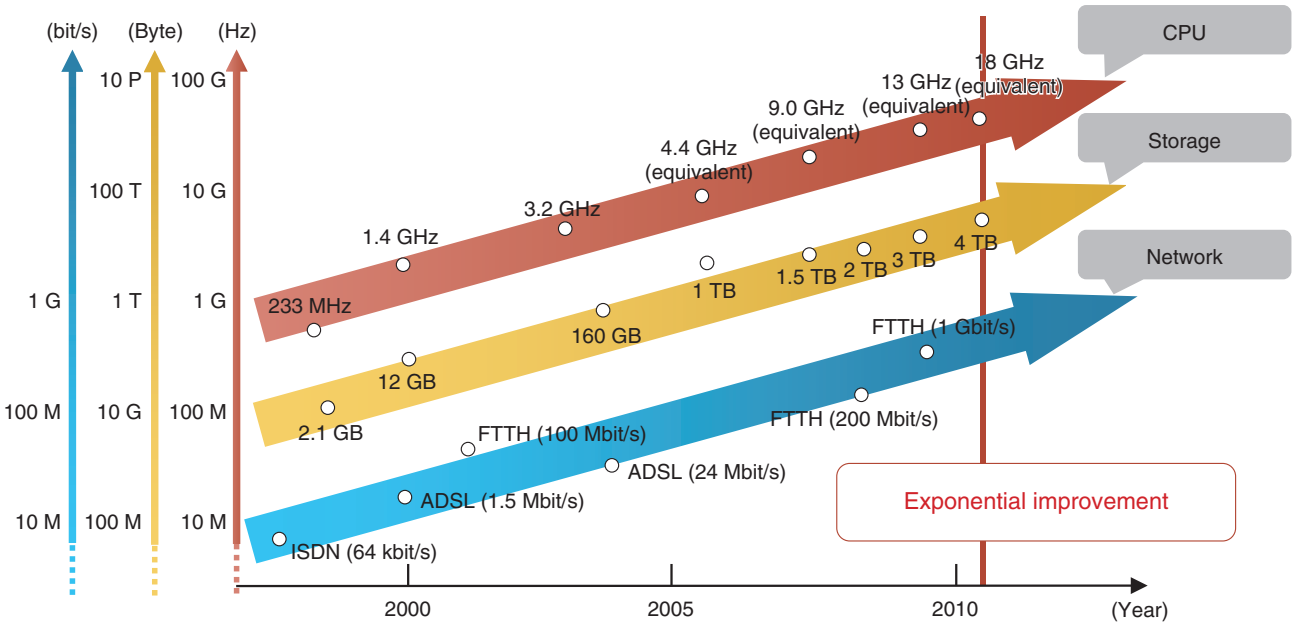
It was not very long ago, however, that the dramatic increase in the demand for systems occurred. The years 1995 and 2000 were respectively known as the *first year of the Internet* and the *year 2000 problem*. Before then, systems were used only in public offices and major companies in the financial, telecommunications, and manufacturing industries, and the presence of systems was not recognized or discussed by the general public. In other words, during the last decade or two, the existence value of systems has risen steeply, and systems have become an essential social infrastructure. This change was brought about namely by the increase in computer power achieved through the progressive technical development of hardware.

The capabilities of the three major element technologies: the CPU (central processor unit), hard disk (for storage), and network, have increased by ten thousand times in the last decade and a hundred thousand times in the last two decades, as shown in **Fig. 1**. In parallel with this, their prices have declined, another major factor that has enabled individuals to easily use computers and systems.

2. Role and progress of software technology

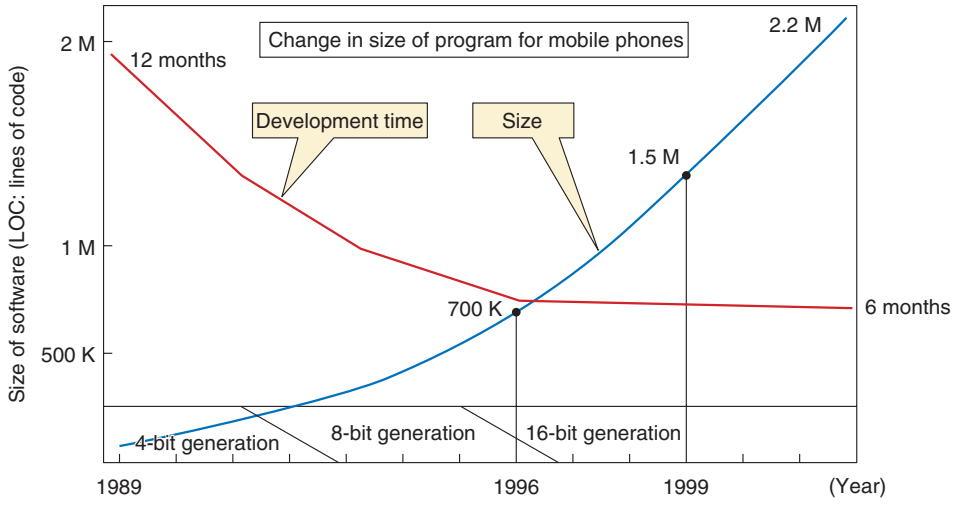
However, software is another element in addition to hardware that makes up systems. The development scale of software has been increasing in the last two decades so that systems can meet the various demands for them in society, while the development time has simultaneously been shortened. The changes in the sizes of software development programs and in the development time for mobile phones are shown in **Fig. 2**. In addition, a wide variety of software has been developed, including software for financial systems run on general-purpose computers, E-commerce software run on widely used operating systems, for example, UNIX and Windows on open servers, and also game software for smartphones. Today, software is an essential component to achieve or support such social activities.

However, the development of software technology



ADSL: asymmetric digital subscriber line
ISDN: integrated services digital network
FTTH: fiber to the home

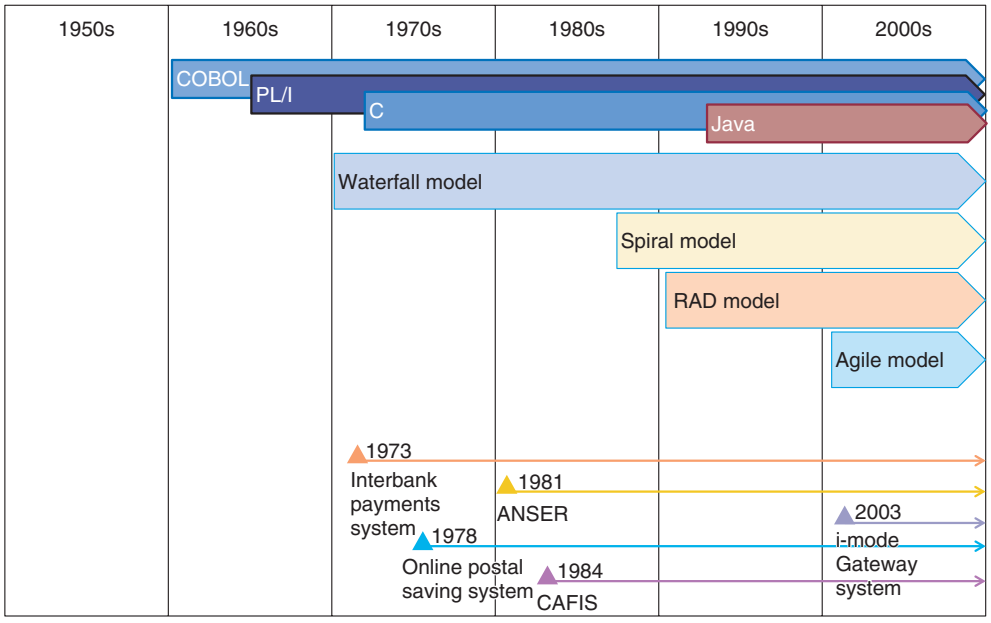
Fig. 1. Progress of three major element technologies.



Source: ET2002 TB-6 "Measures for improvement in quality in embedded system development" (Corporate Research & Development Center, Toshiba)

Fig. 2. Changes in size of software program and development time for mobile phones.

over the last two decades has progressed more slowly than that of hardware. The progress achieved in software technology is shown in **Fig. 3**. This progress includes the evolution of programming languages in the beginning of the development period. In the early computer age, software was developed using languages that ran directly on computers such as machine language and assembly language. These languages



ANSER: Automatic answer Network System for Electronic Request
CAFIS: Credit and Finance Information System
COBOL: common business-oriented language
PL/I: Programming Language One
RAD: rapid application development

Fig. 3. Technical progress of software development.

were too complicated for humans to understand, so high-level languages such as COBOL (common business-oriented language), C, and Java were developed later. These languages can be written with a writing system such as English that can be easily understood by humans, and as a result, they became widely used and mainstream programming languages. At the same time, development processes have progressed. Large-scale software development requiring many person-hours must proceed without gaps in awareness occurring between development personnel. This is achieved by defining the procedures and formats of necessary documents for design, programming, and testing. Over the years, a great number of development processes have been accumulated, which are now consolidated into the widely used *waterfall* and *agile* development processes.

As shown in Fig. 3, this progress in technology has enabled large-scale system development since the 1970s. When we look at software development only, however, and if we consider one benchmark for development productivity to be the amount of software that can be developed by one person, we find that these technologies have actually contributed very little to improving productivity in the last 20 years. As mentioned earlier, the hardware capability has been increased a hundred thousand times in the past two decades. Unfortunately, the progress made in software technology has not improved software development productivity.

The reason for this is that these technologies have been developed on the assumption that all of the work related to software development is performed by humans. In other words, we have been developing technologies to create an environment comfortable for humans that is easy to understand or that helps humans understand the flow of a complex development process more easily. However hard one person works, though, there is a limit to the number of documents and the amount of software that can be created or programmed by him/her only.

3. Software development technology to support large-scale software production

The social importance of software is increasing, and as described earlier, the amount of development is also increasing year by year. In addition, in Japan,

large-scale social infrastructure development is planned for the coming years, which will greatly increase the demand for software development. This is referred to as the *year 2015 problem*, because there are concerns that meeting the demand for such large-scale development will be difficult.

One solution to meet the greatly increasing demand is to increase the number of developers. Previously in offshore development, we outsourced development to countries endowed with abundant labor and with lower labor costs such as China and India, and we imported software created in such countries. However, the recent depreciation of the Yen offers little cost advantage in continuing with this approach.

Now, it is necessary to drastically improve the productivity of software development. To do this, we need to use computer power to create a process in which *no human is involved* or *nothing is produced* (explained below). There are differences of opinion as to the feasibility of this, but a look at the automobile industry shows that the same movement occurred in the 1990s and the 2000s, which led to success. Automobile design is now digitized, and the movement and performance of automobiles are evaluated by computer simulation to reduce the number of trial vehicles that are produced, which shortens the period to start a mass production. Needless to say, mass production is automated and performed by robots in the plants. Implementing the same sort of automation process in software development would drastically improve productivity.

NTT DATA is working to substantially improve productivity by carrying out activities to innovate software production technology. These activities target particular areas; these areas are outlined below and described in detail in the other articles in this issue.

(1) Promotion of automated software development [1]
(2) Research and development (R&D) of simulators [2]
(3) R&D for reuse of software [3]
(4) Legacy modernization [4]

With regard to (1), we aim to automate each process in conventional software development by reducing human involvement. Software development broadly consists of three processes: design, production (programming), and testing, and these processes are implemented using automation tools that can minimize the involvement of humans. The key point is that conventionally implemented workloads can be reduced with no involvement of humans, which leads to improved productivity. R&D of these automation tools was done previously, and many similar types of products exist around the world. However, they have not come into wide use. NTT DATA has been promoting this software development style since 2010, and the key point is how we expand the use of our style and make it the de-facto standard.

Regarding item (2), the objective is not to automate the processes that have been previously implemented by humans but to simulate the operation of software using digitized design information to determine whether the operation is normal before initiating production. This activity is modeled after the automobile industry mentioned earlier. This way of carrying out the process differently from that in conventional software development can achieve a significant improvement in productivity.

The approach for item (3) is to *produce nothing*. NTT DATA possesses a great amount of software and related documents including design specifications. We have tried reusing these assets many times and have failed every time. This is not an experience that pertains to NTT DATA alone but a phenomenon present in the software industry in general. Thus, we started R&D not only to clarify what prevents us from reusing them but also to derive conditions for successful reuse. We are also studying not only direct reuse of these software and design specifications but also how to use them indirectly to support other activities using information obtained from them.

Finally, item (4) concerns how we can revitalize the existing systems. Although the purpose is different from those described above, this may be a major issue in Japan in the future. In Japan, as represented by the word *mottainai*, we have a culture of using tools carefully for long periods of time. Systems and software are no exception. Hardware deteriorates with age, while software does not need to be changed unless any major changes are made to operations and services. Therefore, software can be used in society continuously for generations. Every time the configuration of hardware changes significantly, however, the software is affected by such changes.

There is currently a major trend towards migrating systems from hardware known as general-purpose computers or mainframes to open hardware or hardware with UNIX operating systems that include a Linux or Windows operating system. This trend means that we have to not only migrate software but also to make major unnecessary changes and modifications to it. Systems constructed on general-purpose

computers are often called *legacy* systems; therefore, this approach is called *legacy modernization*. Many extremely large-scale systems are nearing the end of their use due to the general aging and deterioration of general-purpose computers. Because many of these systems have been subjected to repeated revisions/changes over several decades, their internal structures are unknown, and there are no skilled programmers able to work with them. An improvement of this situation cannot be achieved with human labor alone; it requires analysis by means of computer power and automation of software development for revitalization, which we are now studying.

4. Conclusion

In the era of mass consumption of software along with the use of larger-scale and more diversified systems, it is clear that we have nearly reached the limit of software development by humans. Software development, however, is associated with risks, and we may face psychological barriers when adopting a new software development method. More time is needed to address this situation. NTT DATA will proceed with plans to challenge the common practices of software development by conducting R&D on tools to achieve a drastic improvement in productivity while steadily emphasizing the need to expand the use of such tools.

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Hiroshi Tomiyasu

Head of Center for Applied Software Engineering, Research and Development Headquarters, NTT DATA Corporation.

He received the B.Eng. in engineering sciences from Tsukuba University, Ibaraki, in 1990. He joined NTT DATA in 1990 and studied image recognition systems from 1990 to 2003. He then moved to the financial system division and developed financial systems for several years. He moved back to the R&D division in 2006, and until recently was leading research on software engineering, particularly techniques and tools for automating the design, implementation, and testing of large software systems. He is currently working on expanding the use of automation tools within the NTT Group. He is a member of the Information Processing Society of Japan.

Automation Technology for Software Development at NTT DATA

Tomoyuki Azuma

Abstract

Automation of software development is aimed at reducing the human workload in each process of software development. NTT DATA has been promoting this concept since 2010. A wide variety of approaches have been taken for automating software development, and as no special technology is required, there is little difference among these approaches. What is important is determining how to expand the use of automation technology and how to make it the de facto standard. This article describes the overview and status of NTT DATA's efforts to expand the use of automation technology.

Keywords: automated development, CASE, TERASOLUNA

1. Introduction

1.1 History of automated software development

The history of software development indicates that two techniques for automation have come into use: assembly and compiler techniques. The assembly technique involves translating the assembly language into machine language, while the compiler technique involves creating an assembly language from higher level languages. Historically, the assembly language emerged first, and then COBOL (common business-oriented language) and C emerged as high-level languages.

The history of automated software development is the history of programming abstraction. Currently, the level of language abstraction is becoming higher with the emergence of Java, an object-oriented language. In addition, new technologies including 4GL (fourth-generation language) have emerged, which are used to automatically create code from special languages at the design level.

1.2. Recent automation technologies for software development

Two well-known approaches for automated software development are CASE (computer aided software engineering tools) and MDA (model driven architecture). Developmental advances were made in both of these technological approaches, but they had little success. They were both affected by two issues:

- Limited versatility (difficulty in expressing operations by using versatile models)
- Limited ability to increase the level of abstraction (difficulty in increasing the level of abstraction while maintaining versatility)

1.3 Automated production and NTT DATA's approaches

As described in section 1.2, versatility is limited in automated software development. The current approaches to automation are divided into two types: (1) those specific to operations in order to increase the ratio of automation; and (2) those designed to increase versatility while maintaining the ratio of automation at a moderate level (**Fig. 1**).

In general recently, we have not been using a single automation technology at NTT DATA. Rather, we have been using a combination of multiple automation tools in these categories, as described in section 2. That is, we are working on developing automation by combining operation-specific automation with versatile automation.

	(1) Automation specific to operational development	(2) Automation to increase versatility
Overview	Achieves a high ratio of automation by limiting the scope of target operations	Based on standard application frameworks, automatically creates templates of configuration files and programs
Productivity (effectiveness through automation)	The use of tools specific to operations and functions for target systems can improve productivity.	Creating only basic templates achieves limited productivity.
Versatility (ease of introduction)	Work including development and customization of dedicated tools, and training including learning of dedicated language is required.	Standard frameworks and languages are used as a base, so barrier to introduction is low.

△: satisfactory
○: good

Fig. 1. Types of automation.

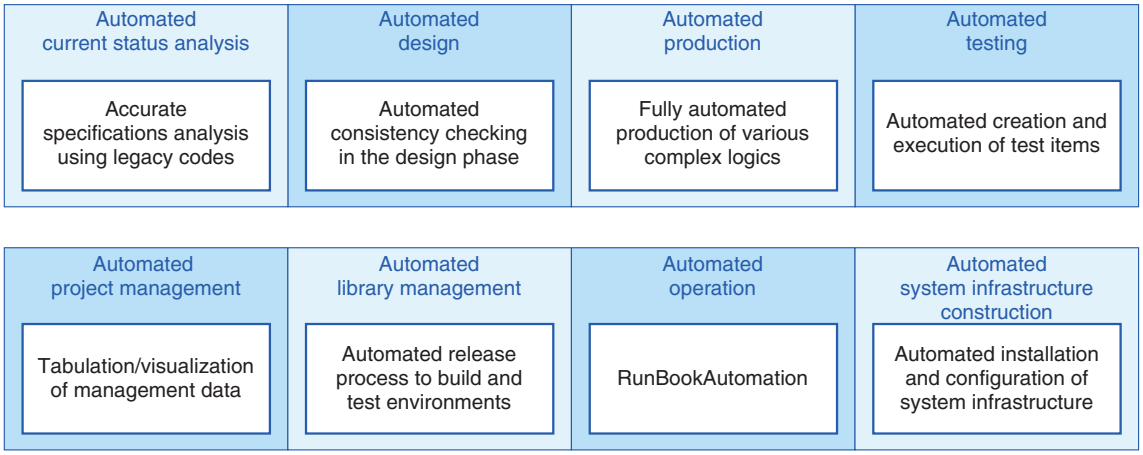


Fig. 2. Eight fields of automated development in NTT DATA's concept.

2. Automation defined by NTT DATA

The previous section mainly explained the history of automated production technology and current trends. NTT DATA uses the word *automation* in a wider sense in accordance with our policy to apply automation technologies to all fields in which we can use computer power.

2.1 NTT DATA's concept of eight automation fields

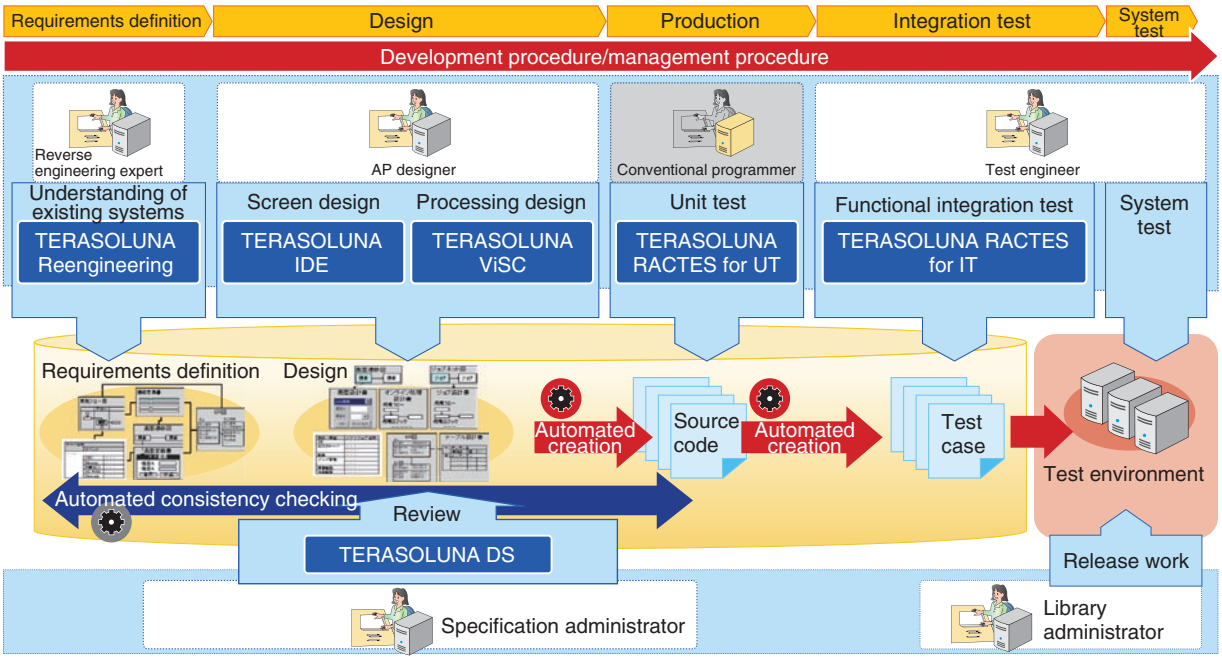
At NTT DATA, there are eight fields of automated software development (**Fig. 2**). The automated production described in the previous chapter is characterized as one of the eight fields. In addition, NTT DATA provides automated analysis of the current status, automated design, and automated testing as a solution called the TERASOLUNA Suite.

2.2 Introduction of TERASOLUNA Suite

TERASOLUNA Suite is an automation solution that can be applied to multiple phases from requirements definition to integration testing. The entire process is illustrated in **Fig. 3**.

In the requirements definition process, an automated current status analysis tool called TERASOLUNA Reengineering is provided.

In the design process, an automated tool for



AP: application

Fig. 3. Illustration of process in TERASOLUNA Suite.

checking the consistency of specifications is provided. This tool is called TERASOLUNA DS (Design Supporter), and it also offers a full-text search function and impact analysis function.

TERASOLUNA IDE (Integrated Development Environment) and TERASOLUNA ViSC (Visual Source Code Creator) are provided in the design process. These are tools to automatically create source code from design specifications.

TERASOLUNA RACTES for UT (Unit Test) in the production process and TERASOLUNA RACTES for IT (Integration Test) in the integration test process are provided to create test code and items automatically.

We can improve productivity in system development at NTT DATA by combining these multiple automation tools.

2.3 Current status of the use of automation at NTT DATA

The automation technology for software development described in the previous section has a long history, and research and development (R&D) of automation technology is also being conducted by other companies. NTT DATA is not alone in such R&D activities.

However, very few of these activities have led to successful results. Automation is effective in improving productivity, but it significantly changes the development standards, which can greatly affect project operations; therefore, many people take a wait-and-see approach before using automation in projects. Project managers have a tendency to avoid any possible risk of failure. It is thus important to accumulate know-how to reduce concern about risk.

3. Key points for successful automation

There is not much point in using automation tools if we cannot achieve satisfactory results. This chapter reviews some key points to improve the productivity of system development by using automation tools.

3.1 Mechanism to improve productivity using automation tools

How does the use of automation tools improve productivity? At NTT DATA, two things are thought to contribute to improved productivity:

- Computers as an alternative to humans can reduce the workload of humans
- Computers as an alternative to humans can prevent errors from occurring, making verification

work unnecessary

3.2 Computers do work traditionally performed by humans

The necessary step to improve productivity is to automate work that has traditionally been performed by humans by using computer power. To do so, it is important to identify what kind of human work is subject to automation. A diagram illustrating two working flows is shown in **Fig. 4**. The flow in Fig. 4(a) shows the work done by humans manually, while the flow in Fig. 4(b) shows the operational fields that can be done using automation tools instead.

Classifying currently performed work and identifying the work that can be automated can reveal work that is unnecessary. Reducing the workload by using automation tools in this way can improve productivity. The work subject to automation can vary depending on the automation tools, so project managers and leaders have to correctly understand what work is unnecessary.

3.3 Elimination of unnecessary verification work

Generally, the process of system development consists of a combination of work done by humans and verification tasks to check their work. This is based on the rule of thumb that whenever a human does something, he/she will make mistakes at a constant rate. To control the quality of work done by humans, a method is used in which the upper and lower limits of an error rate are set as a control index value, and the error rate is later checked to see if it is in the range of the set value. When automation technology is used, work is performed by computers. The results obtained by computer processing basically have no errors. Therefore, the aforementioned verification work that is done based on the assumption that every human makes mistakes is unnecessary. An example of this is shown in **Fig. 5**.

NTT DATA is promoting automation in the production process. In this case, source code is automatically created from the deliverables in the process prior to the production process (detailed design process). Accordingly, source code creation is automated after the deliverables in the detailed design process are confirmed. When the production process is implemented manually, errors in the production process are detected during unit testing. After the production process is automated, this error checking will not be required.

3.4 Verification of processes

NTT DATA has defined internal standards for development processes; these standards are called TERASOLUNA development procedures (**Fig. 6**). Currently, however, as the use of automation tools is not assumed, there is a lot of work remaining that is not required when automation tools are used. As mentioned in the previous section, it is necessary to change the development process standards by reducing the amount of manual work and eliminating unnecessary verification work.

Changing the development process also changes the method of quality management and progress management, which may significantly affect not only the staff in charge of operations but also all those who are involved in the project. Therefore, prior verification is necessary. The details of verification may vary a little depending on the scale of projects and organizations, and in many cases, it is sufficient for a few functions to be developed by a small group in the process.

Through verification of processes, we can understand the effects from the changed development process standards and the increased productivity, which helps us predict the future progress of a project.

3.5 Evaluation of results

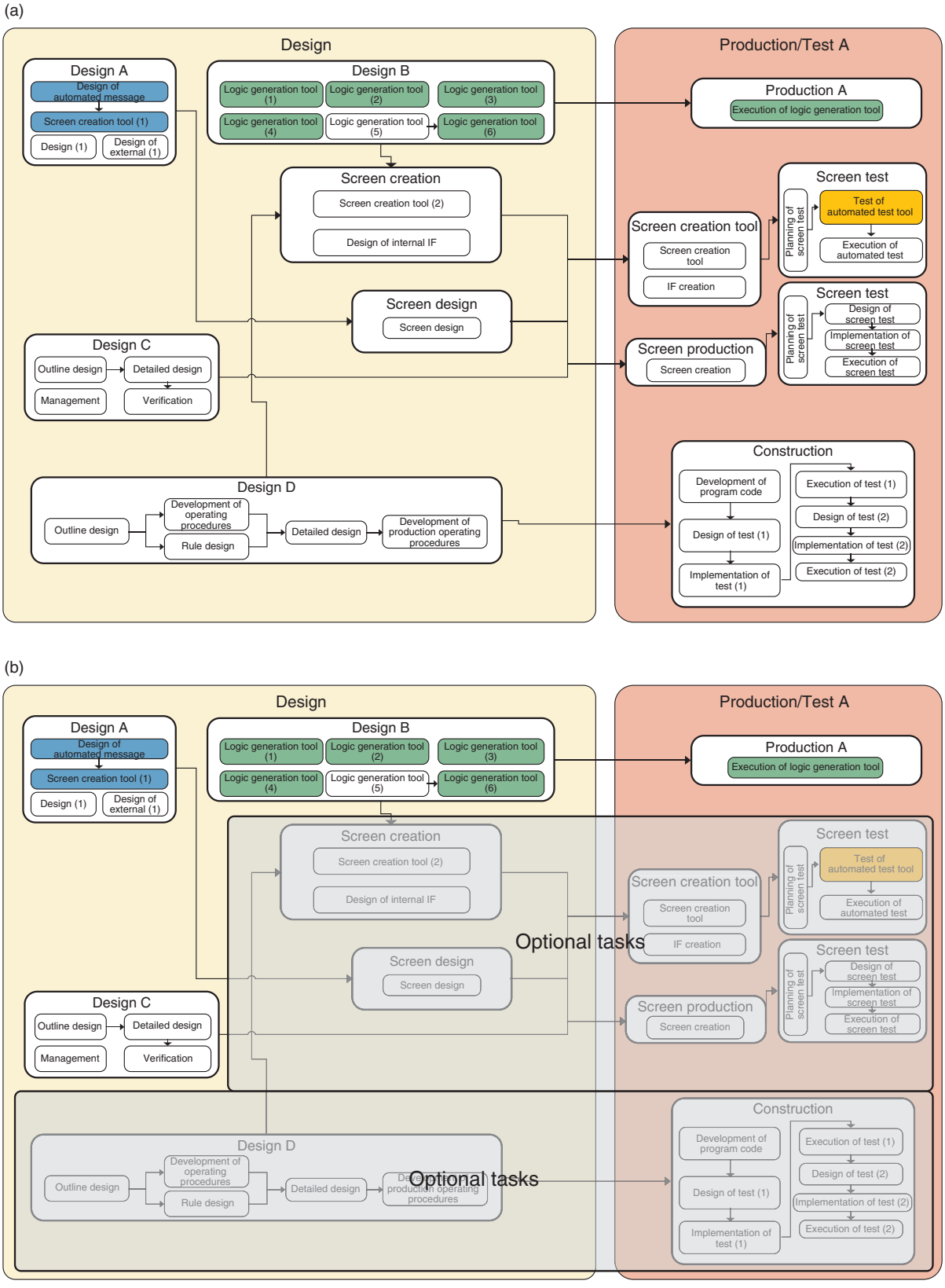
An objective assessment of productivity is important in order to understand the effects of the improved productivity through automation technology and to expand our know-how beyond the organization. To promote automated development systematically, it is important to objectively assess the effects of automation and to clearly determine whether it succeeded or failed. We need, when it succeeds, to expand our know-how beyond the organization, while when it fails, we need to analyze the cause for the failure and find ways to improve. These actions may lead to further increases in productivity through automation.

4. Expanded automation at NTT DATA

Even at NTT DATA, automation was not widespread until a few years ago. Company-wide efforts are ongoing to expand the use of automation technology, and as a result, we will be able to observe the effects in a few years.

4.1 Factors preventing widespread use of automation and NTT's approaches

The following two factors may prevent automation from being widespread:



IF: interface

Fig. 4. Identification of work subject to automation.

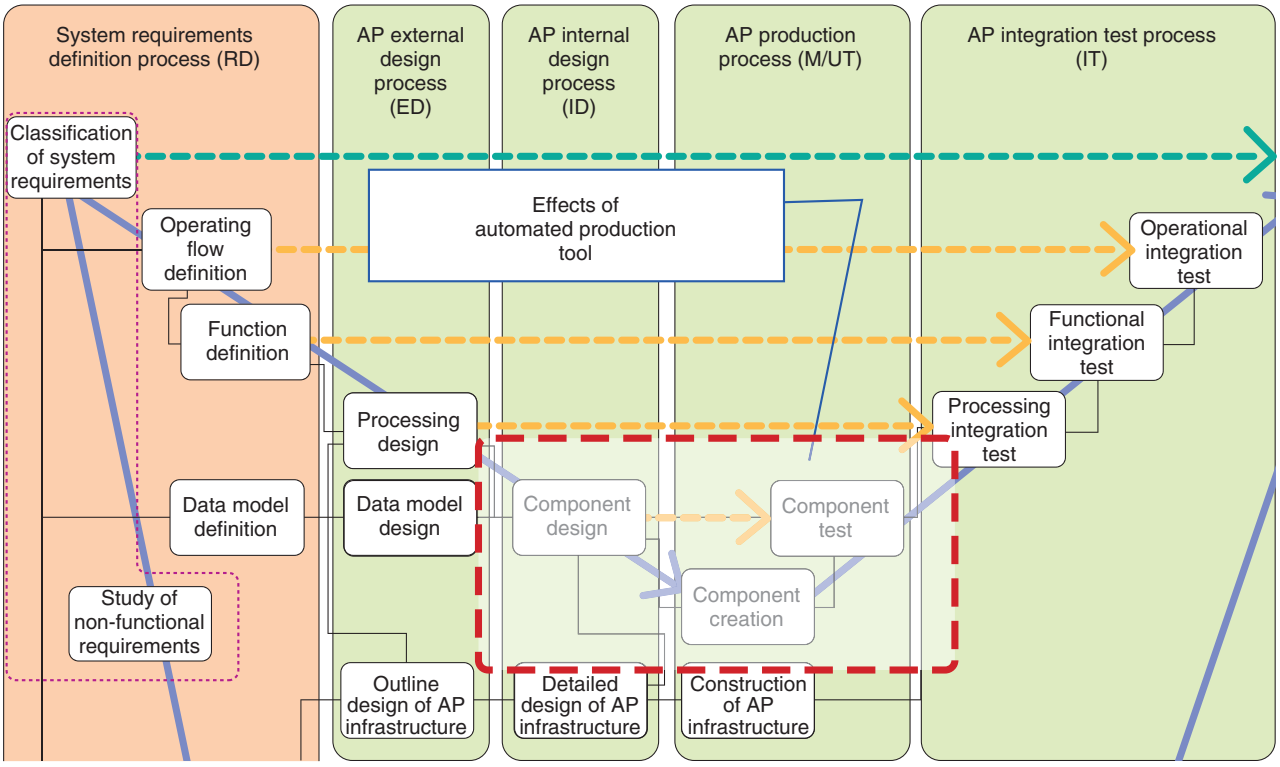


Fig. 5. Example of unnecessary verification work with the use of automation.

- No motivation to use automation due to the difficulty in quantitatively demonstrating its effects
- Difficulty in changing development standards

It is difficult to quantitatively demonstrate the effects not only of automation but also of software development. Because we cannot assess the same project at the same time, it is difficult to determine the difference in productivity achieved when automation technology is used and when it is not used. Without measuring the effects quantitatively, we cannot motivate project managers to introduce automation tools.

NTT DATA has been promoting an approach to demonstrate such effects by systematically measuring the productivity in an automation tool introduction project. In addition, we hold a once-a-year internal seminar to share successful case studies in improved productivity through automation.

As described in the previous chapter, NTT DATA has development standards called TERASOLUNA (See Fig. 6). Development standards define development processes and management procedures as well as other tasks and operating flows in the entire system development process. In system development, development standards are generally defined first. TERASOLUNA development standards are not based on the use of automation tools; therefore, if an automation tool is used, we first have to start changing our standards. However, changing standards is tedious and time-consuming.

NTT DATA can provide development standards for the introduced automation tool. Development standards based on the use of automation tools preliminarily and clearly specify alternative operations and unnecessary verification work. They can also offer operating procedures that define detailed work procedures when automation tools are used, which can reduce the workload in the project.

5. Current status and objectives of the use of automation at NTT DATA

NTT DATA is accelerating the use of automation by setting target values. Efforts to promote the use of automation by setting these target values started in fiscal year 2012. Since these target values of automation were set, the use of automation tools has been expanding. The trend in the expanded use of

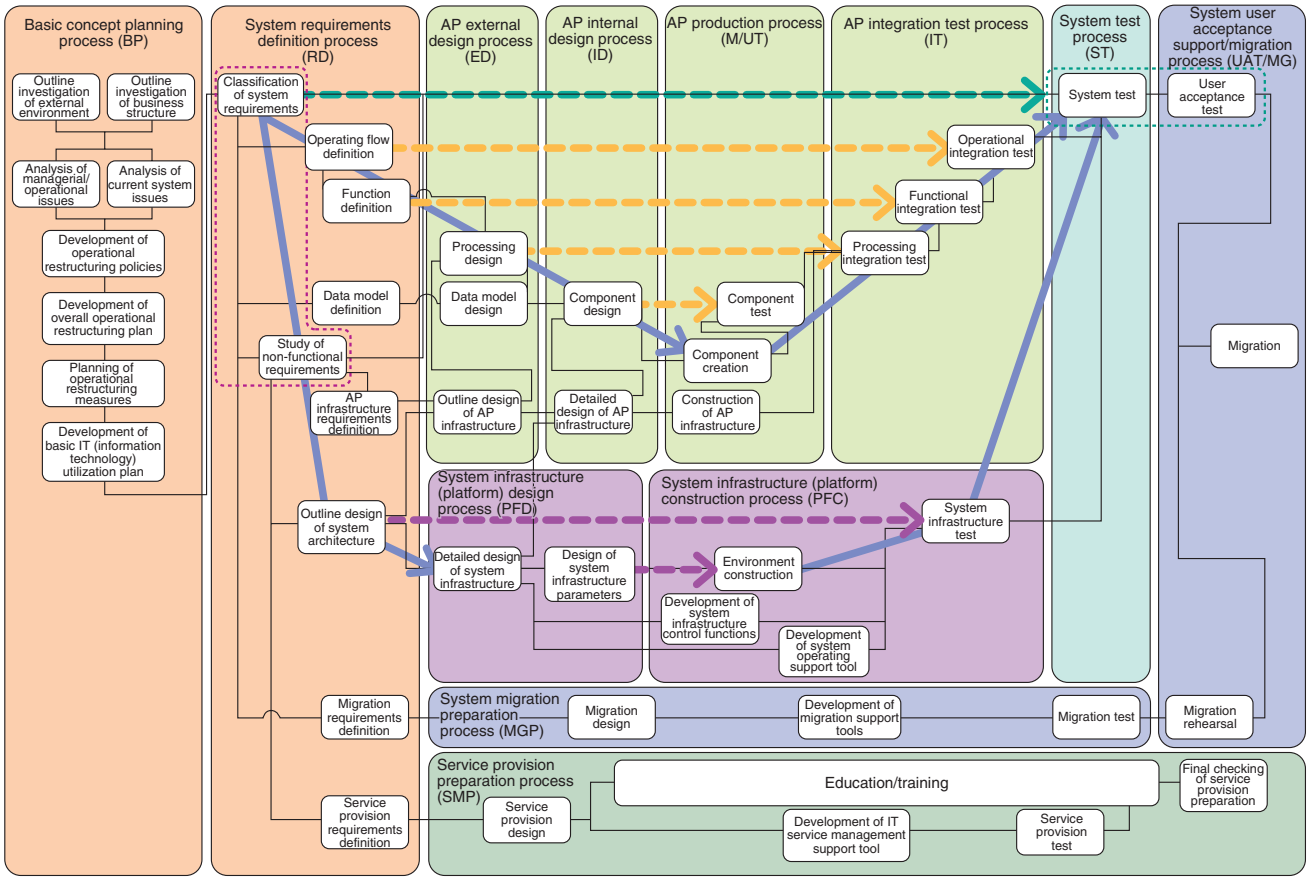


Fig. 6. Entire TERASOLUNA development process.

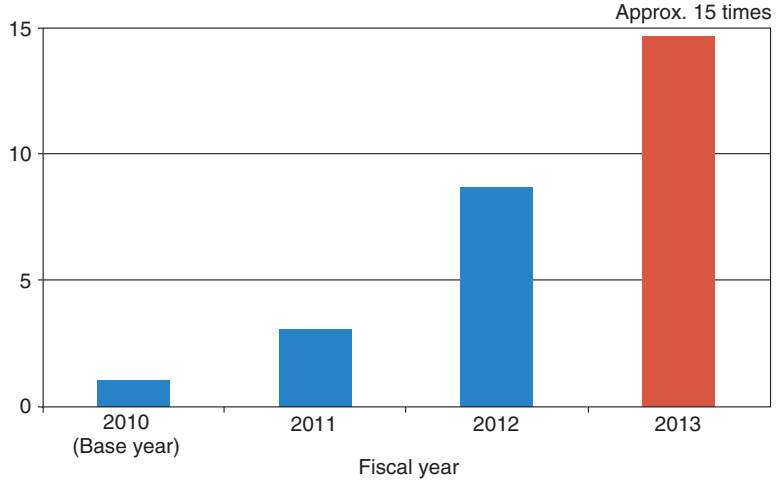


Fig. 7. Current status of use of automation.

automation tools over the last four years is shown in **Fig. 7**. The figure also shows a comparison of the use on a yearly basis, based on 2010 data. We began our automation efforts in 2010, and the use of automation has expanded substantially since 2012 after the target values were set, resulting in 15 times more use in 2013 than in 2010. We can gradually see the effects of the company-wide efforts to expand the use of automation. We will continue working to achieve further expansion of its use.

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From Labor Intensive to Knowledge Intensive—Realizing True Shift to Upper Phases of Development with TERASOLUNA Simulator

Takehiko Kaneko

Abstract

As described in the previous article, NTT DATA is promoting TERASOLUNA Suite as an automation tool product suite for system development and is achieving a significant reduction in workload in in-house projects. However, testing still requires a lot of work and man-hours. Thus, a lot of challenges remain to improve productivity. One solution being developed to meet these challenges is TERASOLUNA Simulator, which can reduce the time needed for the entire integration testing phase.

Keywords: software development automation, review assistance, testing workload reduction

1. Introduction

A software development process that uses a coding automation tool always generates design-based source codes automatically. We do not need to verify whether the generated source codes are actually functioning according to the design because the functioning of the automatically generated source codes is guaranteed by the source code generator. However, there is a possibility that the operator may enter the wrong design information if the design document itself was created based on incorrect business specifications. Thus, verifying the accuracy of the design through actual operation of the program becomes the main objective of integration testing when an automatic source code generation tool is applied. In other words, if the design itself is confirmed to be accurate, the integration testing can be omitted.

2. Difficulty in verifying design accuracy

A reviewer analyzing the design review process carries out the following tasks.

(1) Visualizes the necessary data variations in his/her mind
(2) Simulates how the program would work if the data of (1) were actually entered
(3) Checks whether the simulation result is the same as the one expected

If the complexity of the process is within the reviewer's capability, the reviewer can foresee enough variations in mind and can generally secure the quality of the design information. However, if the process is too complex for the reviewer to handle, the reviewer may not be able to anticipate all of the possible variations (**Fig. 1**). As a result, the reviewer cannot secure sufficient design quality. This often results in design mistakes (slippage) in the design phase. Thus, integration testing is necessary to detect the design mistakes.

3. TERASOLUNA Simulator: Review support tool

If design information is complicated, it is generally difficult to predict sufficient data variations ((1) in the review steps above) and to simulate the application of the predicted data variations the reviewer visualized

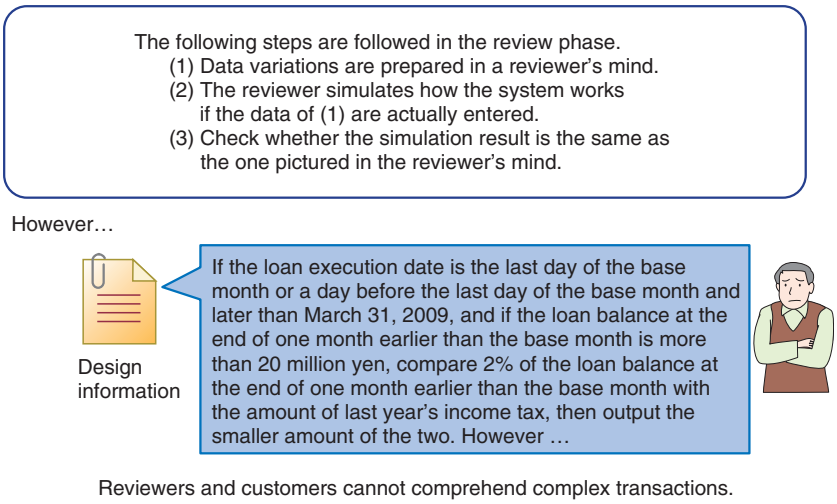

Fig. 1. Why can't errors in design information be fully detected?

((2) in the review steps above). TERASOLUNA Simulator can help to appropriately check the design quality of complex design information in the design phase because it can perform a thorough check by automatically executing processes (1) and (2). More specifically, TERASOLUNA Simulator automatically generates the necessary data variations and simulates the applications of the data variations. The reviewer can check the accuracy of the design by simply verifying the simulation result (the following report) with the expected result ((3) in the review steps above) (See **Fig. 2**). Note that some non-function aspects such as usability and performance cannot be checked.

3.1 Data variations

Data variations generated by TERASOLUNA Simulator are input values for business logic. Data variations need to be information that enables verification of the design of business logic. For example, to verify a data validation check process, we need variations of data that cause errors and that end the process without errors. We also need data variations that can check the thresholds of the design conditions. Data variations are used to verify the validity of the design by checking the process results.

TERASOLUNA Suite can automatically generate data variations from design information by extracting the checking, branching, computing, and editing processes from design information that is provided in logical form. However, there are many challenges in automatic generation of data variations; these are described later.

3.2 Simulation

Simulation is a process that enables us to visualize the expected execution results after feeding the above data variations into business logic. The word *simulate*, which forms part of the tool's name, usually means pseudo execution. However, this tool applies data variations to actual program source codes (business logic) instead of performing pseudo execution. The reason for this is that there is always some doubt that the results of pseudo execution may be different from the execution results with actual program source codes. Note that it is generally difficult to run an actual program because program source codes are not ready in the design phase. However, it is possible to run a process using actual program source codes with TERASOLUNA Suite because TERASOLUNA Suite generates program source codes that can create expected results based on the design. In the future, TERASOLUNA Simulator will be able to simulate screen transitions once the research and development (R&D) is completed, which will require a few more years.

3.3 Reports

A report represents a comprehensible form of information of system input and its corresponding output. It is essential to have a report form that can be easily understood by human operators. This is because the purpose of a design review is to verify the accuracy of the design, and the verification decision depends

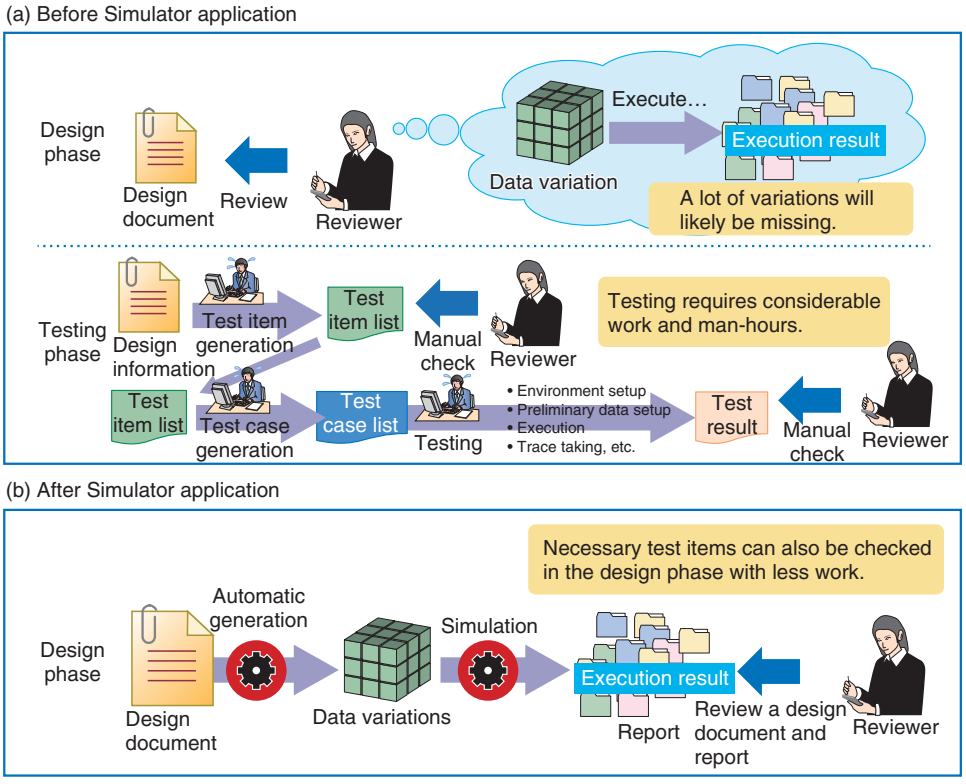

Fig. 2. TERASOLUNA Simulator overview.

solely on the reviewer. Therefore, a report needs to be in a form that is comprehensible to the reviewer, who will make a decision based on the report.

4. Expected effects of TERASOLUNA Simulator

The effects of using TERASOLUNA Simulator in different processes are outlined in this section.

4.1 Effects in design process

- The time to prepare data variations and simulate process executions is reduced.
- The quality of reviews is improved because reviews can be performed by checking execution results.
- Man-hours for rework are reduced because possible errors expected during execution can be identified in the design phase.
- Extra work for reviewing reports is needed.

4.2 Effects in testing process

- Man-hours required in the testing phase are expected to be reduced because data variations are checked on reports and do not need to be rechecked in the testing phase.

4.3 Summary

A summary of the overall effects indicates that although the man-hours needed for reviewing reports in the design phase increase, the time required to prepare data variations and to simulate processes decreases. Thus, the total man-hours will not change. However, the testing work in the testing phase is expected to be drastically reduced, and therefore, the time needed for process integration support and functions integration testing is also expected to be drastically reduced.

5. Challenges

The following challenges remain in the ongoing R&D of TERASOLUNA Simulator.

5.1 Challenge 1: Generation of data variations

Data variations are generated based on design

Table 1. Challenges in generating data variations.

Item attributes	(int/String/double…, null, cast, …)
Data structures	(array, list, structure, …)
Variables	(variable, constant, environment variable, session information, …)
Control structures	(branch, loop, …)
Various processes	(checking, editing, calculation, call, form editing, …)
String operations	(partial reference, concatenation, number of characters, …)
External information	(DB, file, …)
Java dependent	(Exception, annotation, inheritance, class, …)

information; consequently, if the design information is not correctly analyzed, the expected data variations cannot be generated. Typical challenges in this area are listed in **Table 1**. In this case, program components are used for convenience because it is difficult to define necessary patterns if we use design information for a natural language. The underlined components represent difficult components. Loop, DB (database), and, unexpectedly, cast descriptions are difficult. In addition, although it is not included in the table, it is also difficult to output appropriate boundary value data from design information.

One solution is to combine independent methods. Current approaches to dealing with this challenge mostly target program source codes. Therefore, one of the important factors that makes our approach more feasible is that the target areas can be limited because our approach is based on TERASOLUNA Suite.

5.2 Challenge 2: Report forms

Reports need to be in a form that can be easily understood by reviewers and customers. Although the levels of understanding vary from person to person, the general goals are to create reports in which (1) the volume of information is not unnecessarily large and is limited to a size that contains necessary information only, and (2) the relationship between data variations is described in a meaningful context in order for people to identify design errors and shortcomings. Specific examples of (2) include clear descriptions for checking the purpose of each input data variation and correct sorting of a report sequence and categories for checking a report sequence.

In addition, TERASOLUNA Simulator is expected to be used in two scenarios: the reviewers' review process and customers' verification process. Therefore, the actual reports that are required will differ depending on each scenario. Reviewers require a report form that enables them to thoroughly check all data variations. In contrast, customers need an easily comprehensible report form that enables them to quickly review important points.

5.3 Challenge 3: Volume and quality of data variations

Another challenge is that there is no clear definition of data variations required to verify system quality (**Fig. 3**). TERASOLUNA Simulator is a tool for verifying a system concept visualized in a reviewer's or customer's mind with the design prepared for that concept. However, there is no clear answer that explains how many data variations are required for verification. In our case, it is difficult to review many data variations. Thus, balancing volume and quality requirements is a difficult issue.

Moreover, one type of variation that cannot be generated by TERASOLUNA Simulator for quality verification is a variation for a process that is not defined in the design information due to initial design shortcomings. Variations that are not defined in the design information need to be identified during the review process.

5.4 Challenge 4: Very long processing time

Our approach is expected to take a very long time to completely execute all processes. Thus, reducing the processing time is an important issue. There are three possibilities to achieve this: (1) speeding up the process by improving the logic; (2) speeding up the process by using high-performance computing; and (3) making a tool that requires intervention of human knowledge instead of pursuing a fully automated tool. Approach (3) is expected to be the key for solving realistic problems.

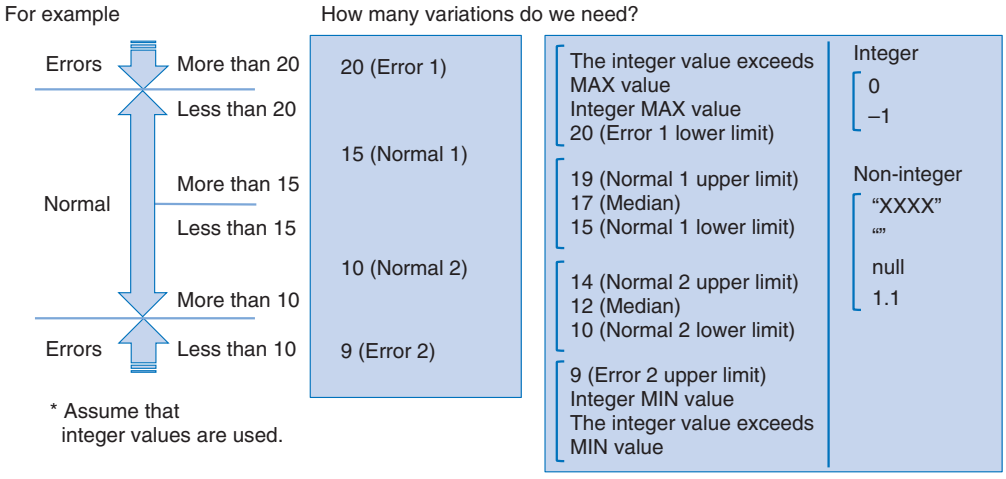

Fig. 3. Data variations required to establish quality.

6. Future outlook

Full-scale development of TERASOLUNA Simulator began in fiscal year 2014. The basic components will be completed by the end of the fiscal year, and the tool will be elevated to a practical level within fiscal year 2015.

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Efforts to Reuse Software Assets

Eiji Yoshida

Abstract

While the technique of software reuse has been successful to some extent, a lot of failures have also been witnessed due to the inherent difficulty of reusing software. However, recent trends in big software data may lead to a solution to this problem. This article describes NTT DATA's latest research and development activities involving software reuse techniques.

Keywords: software engineering innovation, software reuse technique, software repository mining

1. Introduction

Software reuse is an idea that goes back a long way in the software development process. At the first software engineering conference held in Garmish, Germany in 1968, the idea of software *components* was presented. Since then, the development of methods for software reuse has had a great influence on the software development process. Some reuse methods commonly used in the software development process are listed in **Table 1**.

Although some reuse methods have become common, there have also been a lot of failures. For example, the San Francisco Project that was initiated in the late 1990s aimed to share and reuse business software components, but the project ended unsuccessfully.

Successful methods of software reuse target components of the software infrastructure such as small common libraries and frameworks for routine processing. Thus, the benefit of reuse to productivity is limited. Although the use of packages is regarded as an effective reuse method, packages tend to be usage- and business-specific. Thus, the usage of packages is also limited. As a result, the progress made in implementing reuse techniques has stagnated.

2. Transforming reuse techniques with big data of software development assets

A notable change has been occurring in systems development that may transform the existing reuse techniques. This change is the digitization of all sorts of development assets. Extremely large volumes of development related assets including not only source codes but also documents, testing materials, and records of development projects are now digitized and distributed. The important point here is that development assets are in digitized form and available for computer processing.

For example, development documents are converted to the XML (Extensible Markup Language) format using Office tools or UML (Unified Modeling Language) editors. Bug information is consolidated in a database using a BTS (bug tracking system) project management tool.

NTT DATA creates and accumulates approximately 50 million steps of source programs annually and more than 1 million files of documents for the programs. In addition, digitized data of development assets have become widely available for different organizations over the web. Currently, roughly more than 100 million webpages of development information are available on the web.

Big data has become a major trend. Techniques and tools supporting this trend, and those used for capturing, storing, and analyzing large volumes of different datasets, are readily available. More specifically, sophisticated data processing techniques including text searching, non-structured data analysis, data mining, pattern matching, natural language processing, large-scale distributed processing, and machine learning can be used. Therefore, it is important to develop new methods for reusing as much as possible large volumes of digitized development assets in the software development process by applying advanced

Table 1. Common reuse methods.

Methods for software reuse	Description
Subroutine	Became widely used as structured programming evolved. Frequently used codes are packed into subroutines as program components. Subroutines are used in relatively limited environments or for specific types of software.
Class library, framework	Became popular as object-oriented language evolved and progressed. Software components are highly scalable and easily reusable. Many components are developed for reuse in multiple projects. Some components are used worldwide as open source software.
Package	A large set of software components for transactions is reused instead of using small program units separately. Packages are commonly used in ERP (enterprise resource planning) by, for example, SAP.
Software patterns	Standard formulas of software development. Typical examples are design patterns containing standard formulas for software design and architecture patterns containing standard formulas for software structure.

data processing techniques.

3. Why is reuse difficult?

The difficulty in reusing software comes down to cost, specifically, the cost related to context mismatching. That is, the cost of reuse increases due to mismatching of contexts (backgrounds and conditions). Each reusable asset has its own suitable context. If an asset is applied to even a slightly different context, the assent cannot be used as is, and it requires customization. As a result, it is often said that if you need to customize 20% (or more) of reusable assets, it is better to spend the money on developing a program from scratch.

If we go deeper into the issue of context mismatching, two difficulties of reuse emerge. One difficulty arises in creating reusable assets and the other in applying reusable assets.

4. Systematic reuse and experience-based reuse

The difficulty of *creating reusable assets* means that it is difficult to systematically create assets with the intention of widely reusing them in different software programs in the future. In other words, it is difficult to develop reusable software components that are not needed for the current software functions but that may be widely used in the future. We often hear that creating a reusable component is three times as difficult as creating a module used in a single program. In fact, if developers know in advance that they will have to develop several similar types of software, a systematic reuse method might be effective. However, functions that are not expected at the beginning of development are often required as the development progresses. Thus, it is extremely difficult to picture a future need and to develop a highly reusable resource in a real development process. In addition, it is likely that functions implemented for expected future use may never be used.

If that is the case, is it possible to modify existing assets that have been developed in order to make reusable assets or to extract reusable assets from the existing assets by analyzing them? Some software development projects have included steps to identify common functions from multiple different development processes and to make reusable components for them. However, most of these activities are not systematically implemented. They are performed without a plan or, in a more favorable sense, are based on experience.

In addition, efforts to create reusable components are not extensively and widely implemented because such efforts depend on the developers' capability and foresight as well as their spare time in projects. Therefore, it is important to support activities carried out to make reusable components based on experience.

More specifically, even if a software program has been developed and reused by a simple copy-and-paste method without any systematic reuse planning, it is possible to extract and generate highly reusable designs and source codes by automatically analyzing source codes and design documents to identify common components and functional differences.

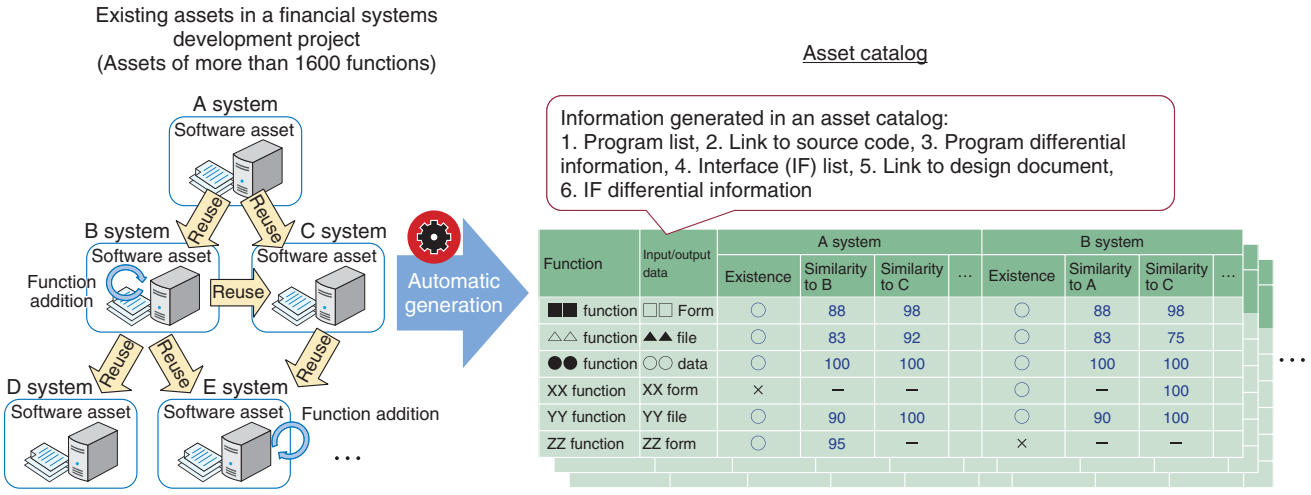

Fig. 1. Example of generation of asset catalog to help developers understand assets.

5. Difficulty of understanding reusable assets

The second difficulty of *applying reusable assets* relates to understanding the reusable assets. When reusing a component, we need to precisely understand what information is required for reuse such as the component's function, application, and customizable parts.

Understanding reusable components is a time-consuming process and is often very difficult. As mentioned earlier, because each reusable asset has a suitable context for application, it is difficult to understand both the asset and its context. As a result, reuse is often avoided. This issue may be solved by manually collecting information required for reuse, although it would incur a large cost. Therefore, we need a method for automatically extracting necessary information from existing assets to help understand reusable assets and expedite the application of reusable assets.

6. Achieving better understanding with asset catalogs

NTT DATA has been implementing a method in a financial systems development project to *automatically* sort existing assets and generate asset catalogs (**Fig. 1**). This helps developers to understand the reusable assets. In the target project, there are more than 1600 function assets in a total of 7 systems. When a new system is developed based on the existing assets, it takes a long time to examine the reusability of the assets and the reuse methods. We have automatically analyzed large volumes of existing source codes and documents to identify information about availability, similarities, and differences of functions and have created asset catalogs that make it easier to understand the reusable assets. We are using the asset catalogs for a new system development and have reduced the man-hours for reuse design by 84% (8% of the total project man-hours).

This achievement is due to the fact that we have targeted multiple functionally similar systems and because design documents are fully standardized for automatic information analysis. NTT DATA is currently studying asset analysis methods that can be applied to wider and more diverse assets.

7. Software repository mining

In terms of utilizing big data generated in development projects, we need to focus on direct use of assets as well as methods that can identify useful knowledge for development from large amounts of data on development assets.

Currently, not only source codes but various data including documents and bug information can be generated and accumulated in systems development projects. Studies on methods of extracting useful knowledge for development from large amounts of development data using data mining techniques are gaining momentum. In the academic field, these studies fall under mining software repositories. Researchers regularly exchange ideas on this topic at an

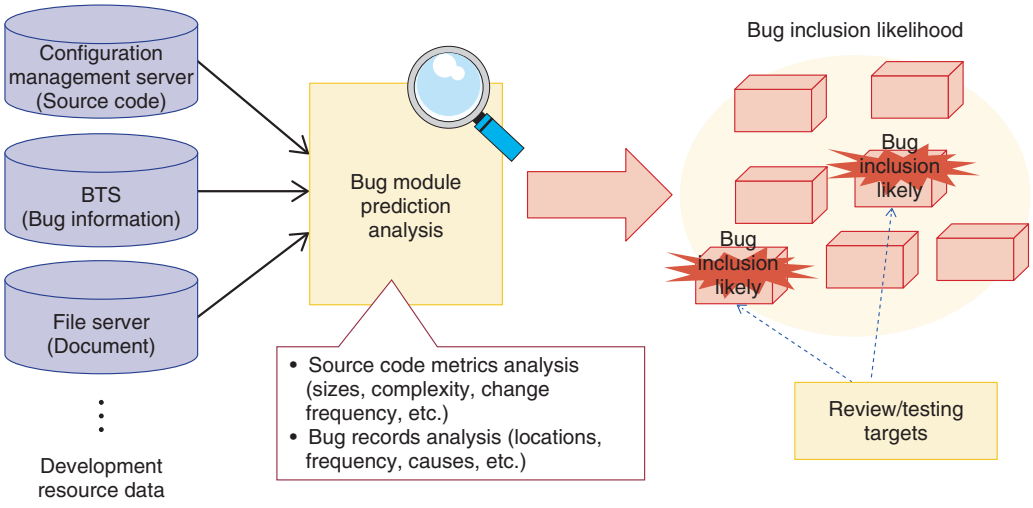

Fig. 2. Example of software repository mining.

annual international conference [1, 2].

Software repository mining does not directly use existing development assets. Rather, it analyzes large volumes of development assets, identifies trends and patterns, and converts the identified trends and patterns into knowledge that is used for development. For example, in bug module prediction, bug records and source code conditions (e.g., size, complexity, degree of coupling, intensity) are analyzed, and modules having a high likelihood of bugs are identified (**Fig. 2**).

NTT DATA is developing methods for applying this bug module prediction technique to quality management in the system development process. If we can quantitatively predict modules having a high likelihood of bugs, we can develop a more effective and efficient testing strategy by focusing on testing of the particular modules and appropriately allocating man-hours for testing. A similar approach involves predicting bug modules according to source code correction logs and using the predictions for review [3].

Possible applications of software mining repositories in addition to bug module prediction include identifying reusable knowledge and communicating the results of analyses within a development team. Recent advances in more mature data analysis techniques such as data mining and machine learning as well as development of high performance computing environments where we can analyze large volumes of development data in a realistic processing time will expedite the evolution of software repository mining.

8. Conclusion

Maximizing the use of development assets that are being accumulated in large volumes is a key to further developing reuse techniques. NTT DATA aims to shift from quantity to quality-based reuse approaches and will continue to develop new reuse methods that will drastically improve software development productivity.

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Legacy Modernization for Continuous Use of Information Systems

Hideaki Tanino

Abstract

Large-scale mainframe systems are becoming more and more complex and their internal structure are becoming unknown, which leads to higher maintenance, development, and system renewal costs. Migration to open systems can reduce these costs, although migration to a completely different platform is not easy. This article explains the difficulties in using open systems for rehosting of large-scale mainframe systems and presents solutions using automated system development techniques to address such difficulties.

Keywords: legacy modernization, rehosting, mainframe

1. Introduction

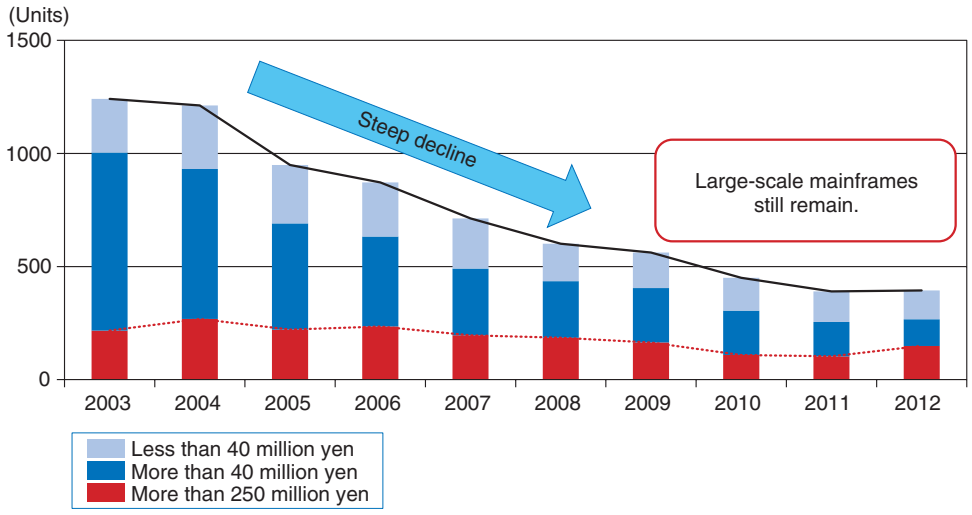
Mainframe computers were at their peak in the 1980s; the volume of domestic shipments was approximately 3500 units, and the value of total shipments amounted to over 1 trillion yen. Since the middle of the 1990s, however, mainframes have been overwhelmed by the wave of open-source computers, which has resulted in production falling to less than one-tenth the number at its peak (**Fig. 1**). The number of small/mid-scale mainframes (less than 250 million yen per unit) has been decreasing especially rapidly. At one point, it seemed that at this rate mainframes would be replaced by open-source computers, but production began picking up in the last one or two years. The number of large-scale mainframes (more than 250 million yen per unit) is now on the increase. This indicates that mainframes will continue to be used for the time being.

2. Issues with legacy systems

NTT DATA uses a large number of the remaining mainframe systems in Japan. Therefore, we are facing a variety of issues with mainframes. The most prominent issue is that system operating costs are high. This is partially due to the expensive hardware that is required and also due to the large and complicated applications, which after repeated modifications over a long period of time, require a lot of investigation and testing even for small changes. In terms of systems running on mainframes in Japan, batch processing (to output many different formats) is particularly complicated and large in scale, and in order to ensure precise operations, detailed applications need to be created. In addition, one effect of the so-called *year 2007 problem*, in which many baby boomers reached the mandatory retirement age of 60, is that many mainframe experts have retired, and systems are becoming *black boxes*, meaning that we have less knowledge of their inner structures, which makes these issues even more serious.

3. Common pitfalls

An open source-based development method called *rehosting* has received attention as a way to reduce operating costs for systems that use mainframes. Rehosting converts applications that have been used on mainframes and also converts job control language (JCL)/job net (which describes the processing sequence) so that they can be operated and reused on



Source: Graph created based on data calculated by JEITA (Japan Electronics and Information Technology Industries Association)

Fig. 1. Changes in production by scale of mainframe computers.

open systems. By directly using currently used assets, rehosting is aimed at achieving rapid migration to open-source systems at low cost and without a change in quality. At first, only systems with a few hundred programs were convertible. Then, as the target systems increased in size, rehosting was successfully applied to enable the use of open-source systems for large-scale systems with more than ten thousand programs.

We have often observed that rehosting requires higher costs and longer periods than initially expected. An investigation shows that the major cause of cost overruns is overconfidence in converting applications. In a conversion project at NTT DATA, a misunderstanding that a new system can be created by merely converting applications meant that we did not pay enough attention to the proper redesign for integration (**Fig. 2**). Particularly in batch processing, system operations and the application infrastructure need to be redesigned. Several tens of thousands of JCLs and job nets are required just for batch processing. To ensure normal operation of the entire system, we need to take into consideration the processing order, boot conditions, processing and backup time, and method to recover from a failure for each JCL and job net. This requires detailed work that is truly like threading a needle. If we try to run these on a new platform with different non-functional requirements, there may be no problem in program unit testing, but a significant number of failures can occur in integration testing. Consequently, we have to continue to play an endless game of whack-a-mole.

Another major cause for the higher costs and longer periods than expected is a less than accurate estimation due to the difficulty in understanding the current status. Systems that have been constructed over a 20–30 year period contain various irregular and temporary modifications. A partial investigation of systems cannot ensure highly accurate estimation because some irregularities and risks may be overlooked. In the worst case, we have to check applications one by one, and the cost and time for doing this outweigh the advantage of rehosting.

4. Automation solution applying N-shaped development

The solution is not to reuse converted applications but to create design specifications using existing assets including reliable source codes and to reuse these design specifications. In the first steps, we obtain correct specifications in order to accurately understand the current specifications of the system. In subsequent steps, we fully automate the development process of new systems to accelerate development and achieve optimum system performance. This process is called the *N-shaped process* because a process for creating design specifications for reuse is added to a preliminary phase prior to the normal V-shaped development process (**Fig. 3**).

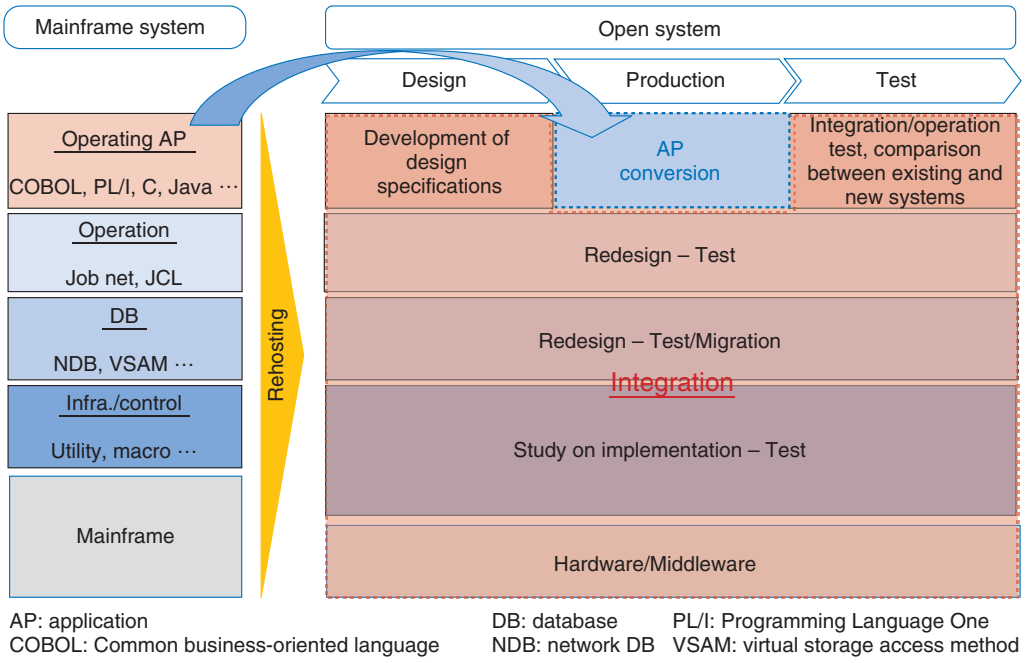


Fig. 2. Integration is easily overlooked during rehosting.

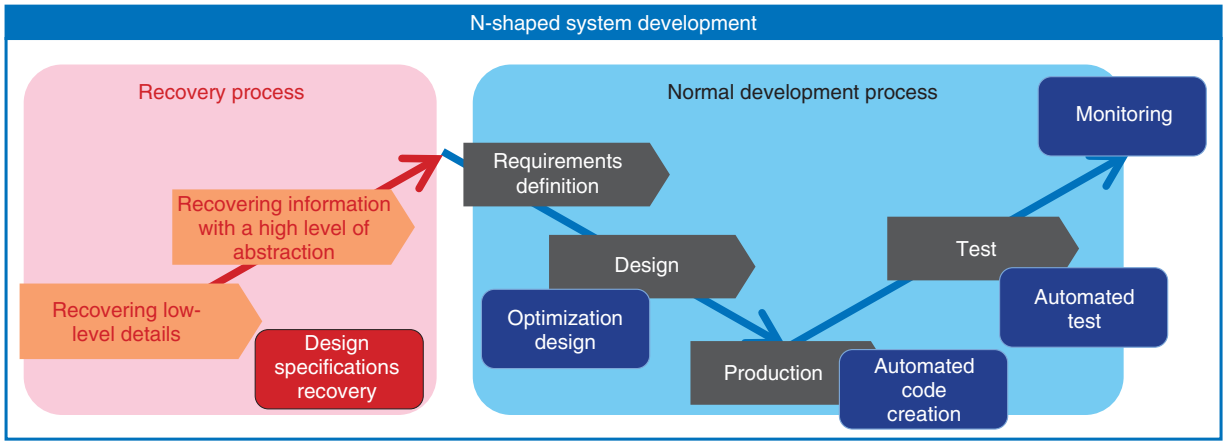


Fig. 3. N-shaped system development for successful rehosting.

The first stroke of the letter N shows the first phase of N-shaped development. This is the recovery process, in which we visualize and understand the system and its current operations. We take full advantage of reverse engineering technology here because visualization of business logic and application structures can be achieved automatically. Next, to enable humans to understand the relation between the operations and the system, we give operational semantics to the visualized structure and data. For example, for online processing, we give consistent traceability and semantics starting from the screens used by system users to applications and databases (DBs) that do the actual processing. For batch processing, semantics is given on a batch basis for easy understanding by humans; furthermore, the semantics for batch processing is arranged in multiple layers, and in the top-level layers, names and descriptions are given using

working language. This process for understanding operations and systems enables us to overview the whole system and understand its details.

Understanding data is as important as understanding the processing. In order to correctly name and define every piece of data used in the system, we have to clarify the derived logic of data after classifying the relation between data and understanding the static structure. Reverse engineering technology can also be used here. Automatically creating a CRUD (create/read/update/delete) matrix* enables us to identify data and derived logic. The final goal of this phase is to reveal operational requirements. Once these requirements are revealed, we can achieve the ideal design in the next system design process, independent of the system's current structure and processing method.

The remaining V portion of the letter N shows the second phase in the N-shaped development: the development process. In this phase, the deliverables obtained in the aforementioned process of visualizing and understanding operations serve as inputs to the upstream design process of the next system. A standardized input format leads to smooth automation of system development. In addition to automated source code generation using TERASOLUNA ViSC and IDE and automated testing using TERASOLUNA RACTES, a variety of tool groups can be used for ensuring high-speed development [1]. For the implementation of new requirements and optimization, TERASOLUNA DS can be used to automatically check the consistency in the design phase. With the use of TERASOLUNA Simulator [2], we can even check the validity of the specifications with a high degree of accuracy in the early phases. Taking full advantage of automation tools by following an N-shaped development process that reuses design specifications is the fastest way to renew systems and secure development.

5. Modernization through optimization

In contrast to rehosting, N-shaped development, in which the system is redesigned, can solve the issues that the current system faces. One of the issues that large-scale mainframe systems face is limited online service time due to a large amount of batch processing, which makes it difficult to understand the operating status in real time. This is because a shortage of computer power at the time of development means that nightly batch processing is implemented as much as possible, as opposed to online processing, which places greater importance on response time. To maximize online and real-time processing operations, the processing needs to be designed after classifying the operational requirements for creating data. An optimization considering the aspect of redesigning the processing in N-shaped development is also required.

Data management is also an important issue. If a network database (NDB) is used in the mainframe system, we need to change to an RDB (relational database) in open systems. At the time of that change, if a table structure is constructed with the NDB structure left mostly as-is, there may be frequent table join operations and data accesses, causing a performance issue due to inefficient DB access. With N-shaped development, optimized table design is ensured in the operational requirements, preventing the data structure from causing problems.

Even in highly advanced systems, if the design specifications are not maintained, and there is any difference between source codes and design specifications, the system can become a legacy system again (**Fig. 4**). Incomplete design specifications may lead to black-box systems and lack of experts, resulting in more complicated systems and higher operating costs. Even a small change would require a large workload and a lot of time. For system renewals, it is important to update the design specifications according to the rules. It is difficult, however, when there is a limited amount of time and limited human resources involved. One solution is to have computers automatically check the consistency between design specifications and check if the changes made are compliant with the rules. If design specifications and programs used for system renewal can be checked and changed anytime, we can detect failures in the upstream process, significantly contributing to improved QCD (quality, cost, delivery). A continued checking process cannot be achieved by humans, whose work may involve oversights and omissions. Automated implementation by computers that is independent from humans is required.

6. Automated development to break a negative spiral

Many of the mainframes are also called legacy systems, and there has been a delay in the transfer of human resources and the introduction of new production technologies. The difficulty of system renewal is

* CRUD matrix

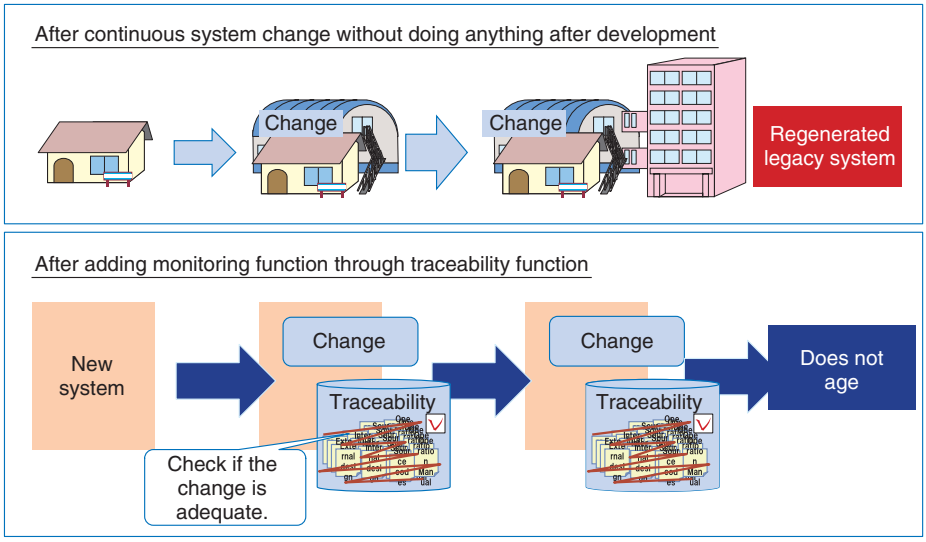


Fig. 4. Preventing rehosted system from becoming legacy system again.

increasing more and more due to its large scale and the increasing complexity, lack of experts, and lack of investment. If any additional issues with scale, complexity, or lack of experts are found, system renewal may be in vain. Case studies have shown that if system maintenance is continued for 10 years, the scale becomes one-and-a-half times larger than the initial scale, and the amount of time required to introduce new products and services can be two to four times larger than the initial amount. In order to break this negative spiral and continuously use information systems, it is becoming more important to switch to automated development and an automated checking process that is independent from human work.

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Auto-calibrating Echo Canceller Software for VoIP Applications on Smartphones

Suehiro Shimauchi, Kazunori Kobayashi, Masahiro Fukui, Sachiko Kurihara, and Hitoshi Ohmuro

Abstract

Automatically calibrating echo canceller software has been developed for voice over Internet protocol (VoIP) applications on smartphones. Because the audio properties of smartphones typically depend on the model, the speech quality of a VoIP application may sometimes degrade, especially during hands-free conversations. We extended the calibration ability of our software in order to handle the variations in smartphone audio properties. As a result, our software exhibited better performance than most conventional software.

Keywords: echo canceller, smartphone, VoIP application

1. Introduction

As smartphones become more widespread, communication is becoming more flexible than that achieved with ordinary fixed or mobile phones or personal computers. When making a voice call using a smartphone, some users may sometimes choose a voice over Internet protocol (VoIP) application instead of the default voice call function embedded in the smartphone. However, to provide good speech quality, the different audio properties of the various types of existing smartphones must be taken into consideration. The audio processing functions for the embedded voice call function can be well tuned to the property of each target smartphone model. In contrast, it is difficult to provide a VoIP application with such well-tuned audio processing functions since the application must be able to run on any model. Therefore, the speech quality of a VoIP application may sometimes degrade, especially during hands-free calls.

We developed auto-calibrating echo canceller software that can be implemented on VoIP applications. The following three functions are included in the software.

(1) Acoustic echo cancellation (AEC)
(2) Noise reduction (NR)
(3) Automatic gain control (AGC)

These three functions have internal parameters that can be automatically calibrated depending on the property of each smartphone model, which means that VoIP applications with our software can support most smartphone models.

2. Problems with audio processing on VoIP applications for smartphones

When we make a voice call by using a VoIP application on a smartphone, some acoustic problems may disturb our communication with the other party. Typical problems are acoustic echo, noise, and unbalanced sound levels (**Fig. 1**).

Acoustic echo is caused by acoustic coupling between the loudspeaker and microphone, both of which are built into smartphones. The sound reproduced from the built-in loudspeaker is conducted to the built-in microphone. Thus, when the far-end talker's voice is reproduced from the loudspeaker, it

Fig. 1. Typical acoustic problems with hands-free voice calls with smartphones.

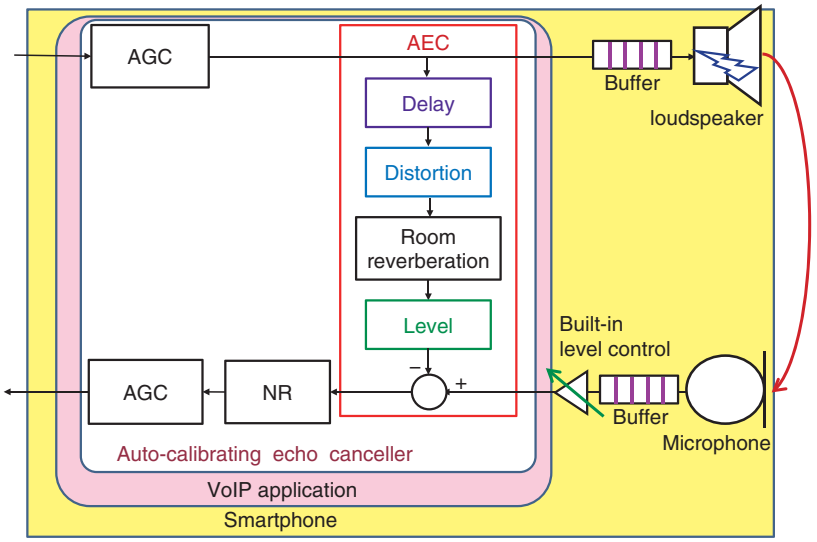

Fig. 2. Functional block diagram of auto-calibrating echo canceller software.

is picked up by the microphone and may be sent back to the talker through the smartphone. This feedback sound is called acoustic echo.

The built-in microphone picks up not only the talker's voice or the above-mentioned acoustic echo, but also background noise. The noise level depends on the environment where the talker is located and the acoustic or electrical properties of the microphone.

Even though a talker may speak into the microphones of various smartphone models at the same volume and from the same distance, the transmitted sound level sometimes differs depending on the model. This is because the microphone sensitivity and amplifier gain of each model are not always designed to be the same. Also, some smartphones have a built-in level-control device such as a compressor or limiter for processing the microphone signal. The loudness of the loudspeaker also depends on the model.

3. Auto-calibrating echo canceller software

To solve the acoustic echo, noise, and unbalanced sound level problems on any smartphone model, we developed automatically calibrating echo canceller software. A functional block diagram of the software is shown in **Fig. 2**. The software has three main functions, as follows.

3.1 Acoustic echo cancellation

The acoustic echo can be cancelled if the acoustic echo signal is properly predicted by the AEC function. The accuracy of the predicted echo signal depends on how the acoustic echo path is modeled and how the model parameters are adaptively estimated. Most conventional AEC functions adaptively estimate only the room reverberation part of the echo path. This is not sufficient, however, for voice calls carried out using a smartphone. Therefore, we extended the parts of the echo path that can be adaptively estimated by taking into account distortion in the small built-in loudspeaker, variation in the sound buffering delay, and abrupt level changes caused by the built-in level-control function [1]. Because the new AEC function can track a wider range of variations in the echo path, it can predict the echo signal more accurately.

3.2 Noise reduction

The NR function is for transmitting a clear voice signal to the far-end listener by suppressing background noise based on the noise's stationarity. The basic algorithm for the NR function is similar to that used for the supporting technologies for Hikari Living, which provides visual communication via a television set [2].

3.3 Automatic gain control

The AGC function adjusts both the transmitted and received sound levels into an adequate range. Controlling both levels makes it possible to automatically amplify or reduce the sound level by up to 12 dB.

4. Performance evaluation

The performance of the developed software was evaluated on five different smartphone models. In a single-talk case, in which no one speaks into the near-end microphone and the far-end talker's voice is reproduced from the near-end loudspeaker, the acoustic echo was reduced by more than 40 dB for all tested models. Even in the case of double-talk, in which both talkers spoke simultaneously, the acoustic echo was reduced by more than 20 dB for all tested models. With the conventional software, the acoustic echo was reduced by only 10 dB in the double-talk case for a certain model.

The speech quality of the near-end talker during double-talk was also evaluated using the perceptual evaluation of speech quality (PESQ), which is described in ITU-T (International Telecommunication Union-Telecommunication Standardization Sector) P.862. The PESQ score for our software was 0.45 better than that for the conventional software on average for five models and at most 1.15 better at maximum for a certain model.

5. Conclusion

We developed auto-calibrating echo canceller software for VoIP applications on smartphones. The new software exhibited better performance than the conventional software did due to its extended calibration capability enabling it to handle variations in smartphone audio properties. Although we focused on implementing the new software on VoIP applications, it can also be implemented on the embedded voice call function and exhibit good performance.

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Development of Optical Access Network Systems in Rural Areas

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Abstract

We have developed a technique and equipment for installing optical cables and closures. The technique is optimized according to the characteristics of the area in order to reduce the construction cost of the facilities architecture and promote fiber-to-the-home services.

Keywords: rural areas, simple installation technique, FTTH

1. Introduction

In Japan, the number of fiber-to-the-home (FTTH) service subscribers now exceeds 23 million. However, there are still some areas where FTTH services are not provided, and therefore, further expansion is expected. The expansion of FTTH services has been focused mainly on urban areas, so the focus is now on rural areas such as small towns. In rural areas, there is less demand for these services than in urban areas of the same geographical size. Therefore, the construction costs for optical access network architecture in rural areas are much higher than in urban areas (**Fig. 1**). In future, to make the deployment of FTTH services economical for rural areas, an optical access network configuration technology is needed that will minimize the construction cost by taking account of regional aspects. In particular, a reduction of the cost of installing optical fiber cables on poles is required because it accounts for half the construction cost of facilities.

2. New development concept

We investigated ways of reducing the construction cost of facilities by focusing on the following two schemes.

(1) Optimization of the distribution area

The size of a distribution area is based on the number of users in that area, and the size affects the construction cost, especially the aerial cable cost. Therefore, we simulated the relationship between the construction cost and the size of the distribution area. When there are more users in a large area, the amount of cable conductor for the segment downstream from the splitter increases with the number of users and the distance to each user.

In contrast, when the area is smaller, the distance to each user is reduced; it is then possible to reduce the amount of cable conductor from the downstream. The amount of cable conductor for the upstream segment from the splitter, and the number of corresponding devices in the central offices are increased if the distribution area has a small configuration. Therefore, we must take the above problem into consideration and configure the optimal distribution area in various locations. If we calculate the optimal relation between the construction cost and the scale of the distribution area in rural areas, then we can optimize the amount of facility construction and reduce the construction cost (**Fig. 2**). For example, if the amount of cable

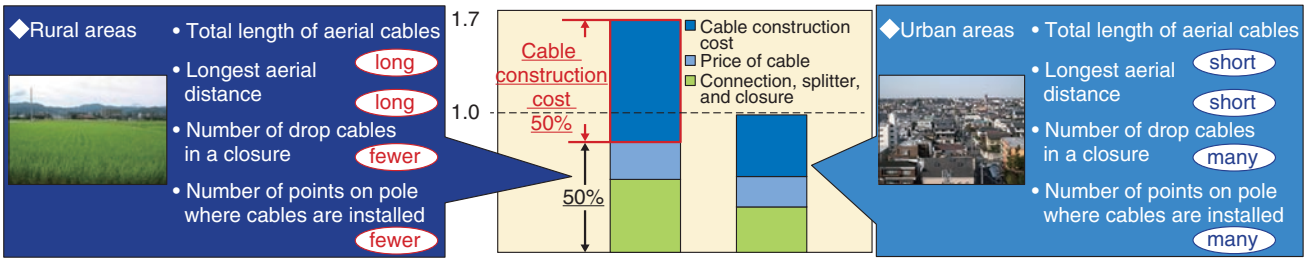
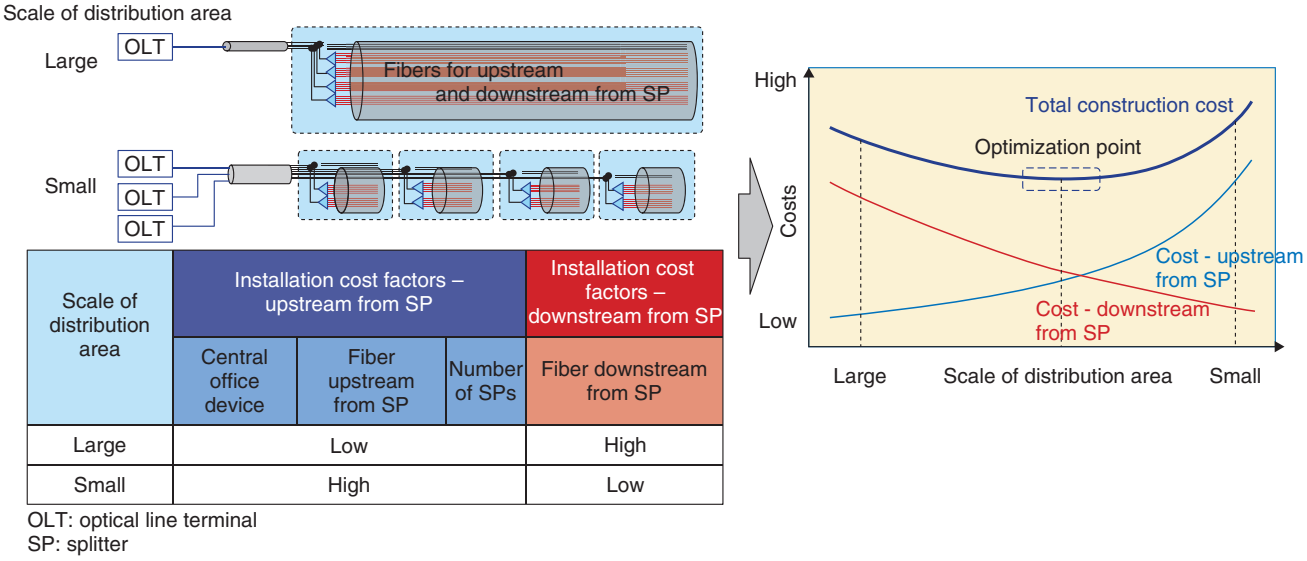


Fig. 1. Differences in characteristics and construction costs between rural and urban areas.



Scale of distribution area	Installation cost factors – upstream from SP			Installation cost factors – downstream from SP
	Central office device	Fiber upstream from SP	Number of SPs	Fiber downstream from SP
Large	Low			High
Small	High			Low

OLT: optical line terminal
SP: splitter

Fig. 2. Scale of distribution area and trends in construction costs.

conductor needed for the downstream segment from the splitter is reduced, we can apply 24-fiber cable in a zone where 40-fiber cable has been installed in the past.

(2) Development of Simple Installation Technique

If the total length of cables installed in rural areas is long, the cost of cable installation will be too expensive because the conventional installation uses a round-trip method. Therefore, we needed a one-way installation technique in order to reduce the cost of cable installation (**Fig. 3(a)**). However, to make one-way cable installation practical, we need a technique for paying out and installing the cable at the same time as well as an effective technique to secure the cable to telephone poles. We came up with a technique that employs lightweight optical cable, which means the cable drum is also lightweight. We have named this technique the Simple Installation Technique. The total weight of all the components is less than 50 kg, so we can install the cable while moving the drum with a cart. When we applied our technique, we were able to install cable using a one-way method by installing cables on telephone poles at each span, in contrast to the previous round-trip method. Thus, we were able to reduce the number of workers usually needed for this task, as well as the working time, and achieve a reduction in the total amount of work (**Fig. 3(b)**).

3. Equipment used in Simple Installation Technique

3.1 New 24-fiber optical cable (Fig. 4(a))

We developed a cable unit (cable and cable drum) that does not exceed 45 kg by reducing the weight of

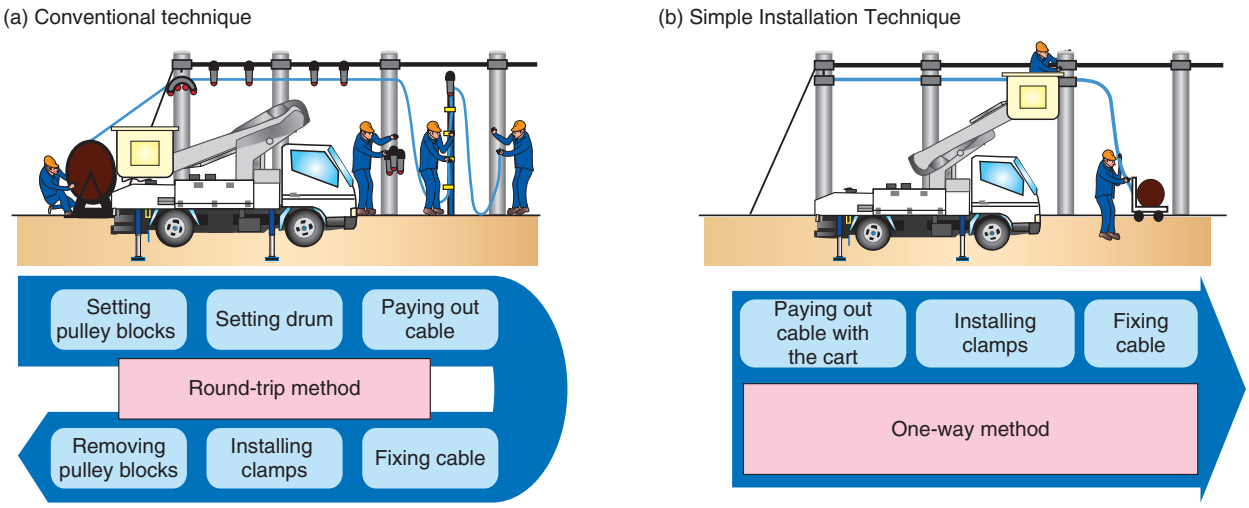


Fig. 3. Conventional technique and Simple Installation Technique.

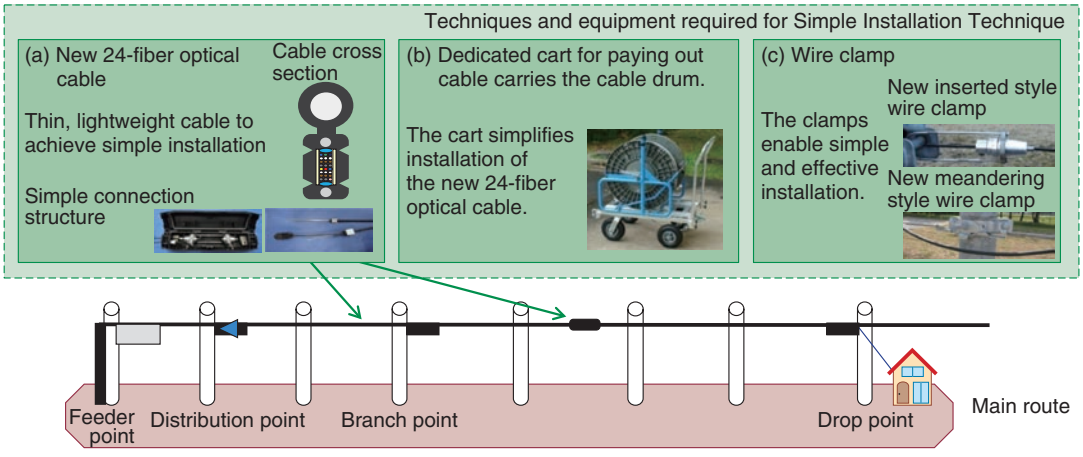


Fig. 4. Model showing the developed equipment (main route).

the conventional 24-fiber optical cable by 60%. The total cable length of the cable drum is 500 m. Therefore, it is possible to install the cable while concurrently moving the drum with a dedicated cart. Also, when we connect segments of the new 24-fiber optical cable together, we do not need to use any tools because there are MPO (multiple-fiber push-on/pull-off) connectors at both ends of the 24-fiber cable. NTT EAST and WEST have been using this cable since 2013 because it costs less than the conventional cable.

3.2 Dedicated cart for paying out cable, and new wire clamps (Figs. 4(b, c))

We developed a dedicated cart that is necessary when the above described cable is installed using the Simple Installation Technique. The cart has a characteristic design consisting of four tires to enable humans to push it on various kinds of roads, a hole to pay out the cable, and a stopper to prevent backlash. We also developed two new types of wire clamps that are needed to clamp the above described cable to a pole when it is installed using the Simple Installation Technique. One clamp is referred to as *inserted style* and is used to fix the installed cable to terminal poles.

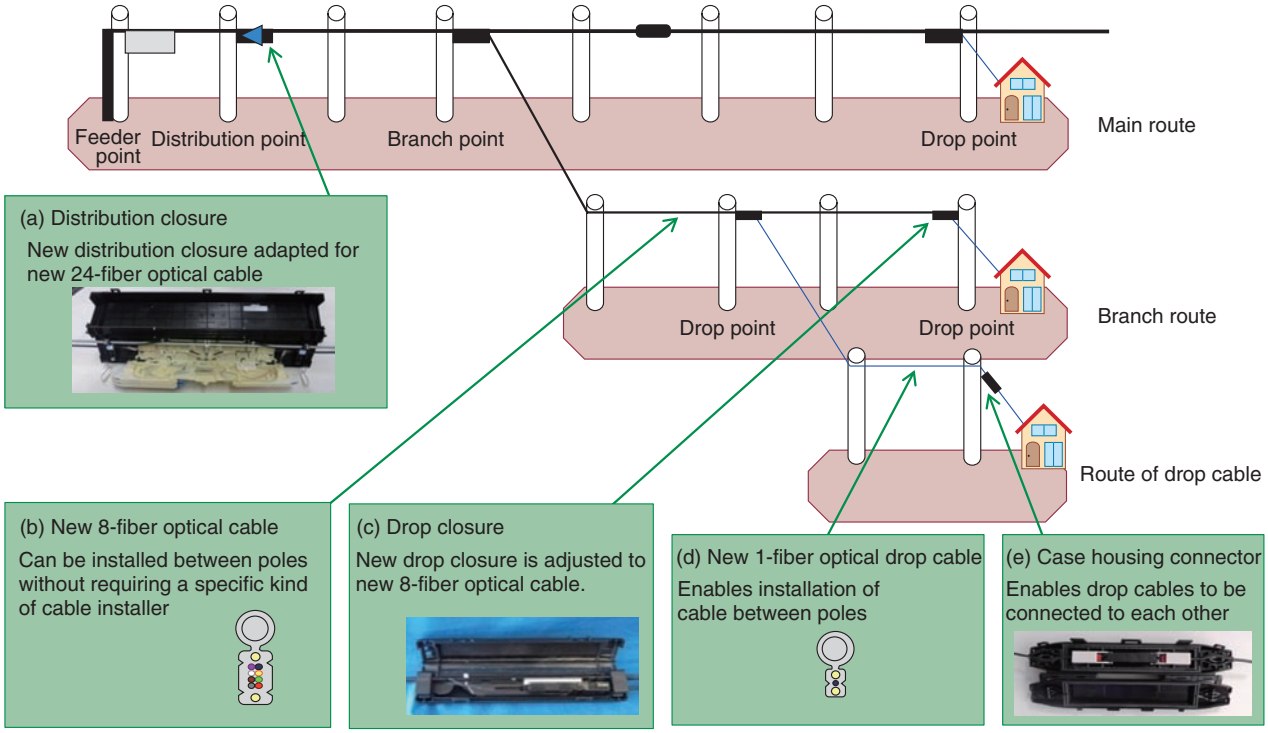


Fig. 5. Model showing the developed equipment (branch route and route of drop cable).

The other clamp is the *meandering style* and is used at intermediate poles. Both clamps are necessary in the Simple Installation Technique because the technique involves a one-way procedure, and we must install the cable on telephone poles at each span.

4. Components developed for Simple Installation Technique

We developed several new components for the Simple Installation Technique. We describe them in this section.

4.1 Distribution closure (Fig. 5(a))

We developed a new distribution closure that is miniaturized compared to conventional closures. This is because it needs to house fewer splitters due to the optimized distribution area. Moreover, this distribution closure can be used with thin and lightweight 24-fiber optical cable. Therefore, the price of this closure is lower than that of conventional closures. Another advantage of this closure is that it enables either a fusion splice, which is economical for optical fiber connections, or a mechanical splice, which makes it possible to supply the optical network service with respect to the demand from each customer when we connect downstream fibers to distribution fibers in the closure.

4.2 New 8-fiber optical cable (Fig. 5(b))

The new 8-fiber optical cable we developed can be installed between poles without a wire grip. This cable is as thin as the conventional 8-fiber drop cable. Therefore, we can reduce the price of the components and the cost of installing this cable compared with the conventional 8-fiber optical cable. We can also use the conventional cable installation tool by adding an attachment to it.

4.3 Drop closure (Fig. 5(c))

We developed a drop closure that is the smallest in Japan and is lighter in weight than all conventional closures. This closure accommodates only two 1-fiber drop cables. Therefore, we were able to reduce its volume by 90% compared with the smallest conventional closure. We also developed the Simple Splice Technique in order to connect a distribution fiber to a fiber in the drop cable even inside this small closure. In addition, we developed a closure for use in

connecting the new 8-fiber optical cable or conventional ribbon drop cable. This closure is used when poles are moved and the cables installed on the poles need to be replaced due to the construction of network facilities, and also when the above cables are severed on account of a traffic accident.

4.4 Thin and SZ twisted optical drop cable (Fig. 5(d))

We developed new 1-fiber optical drop cable with a twisted SZ form that helps to reduce the force of wind pressure. We also strengthened the supporting wire so that we could install a drop cable between poles. These characteristics reduce the cost of facility installation because it is no longer necessary to install closures near customer homes when this drop cable is installed between the conventional closures and customer homes. Furthermore, the development of this drop cable is in line with the policy promoted by NTT EAST and WEST to build facilities that are resistant to natural disasters, and therefore, this drop cable has been installed in some areas by NTT EAST and WEST since 2013.

4.5 Case housing connector (Fig. 5(e))

We developed the case housing connector in order to connect the drop cables together. This case has been used by NTT EAST since 2013 and is contributing to reducing the cost of drop cable replacement.

5. Conclusion

We have developed a cable closure that can be used with lightweight cables, as well as a new Simple Installation Technique. These developments have helped to achieve a facilities architecture that is optimized to the characteristics of specific areas and enables more efficient facility construction. Consequently, we can reduce the construction cost in areas where it was conventionally high and where service provision was difficult. These achievements will allow us to further promote FTTH services.

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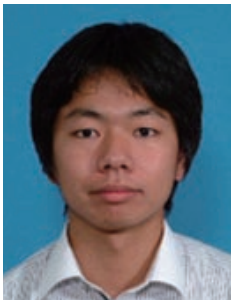

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Dense Space-division-multiplexing Optical Communications Technology for Petabit-per-second Class Transmission

Yutaka Miyamoto and Hirokazu Takenouchi

Abstract

Research and development (R&D) of space division multiplexing (SDM) optical communications technology is well underway at NTT toward achieving high-capacity transmission on the order of one petabit (Pbit) per second or higher, which is equivalent to 100–1000 times the capacity of existing optical fiber. In this article, we describe the current state and future outlook of our R&D efforts in dense SDM. With this technology, we aim to achieve a quantum leap in optical network capacity through the use of multi-core fiber containing multiple optical-signal pathways in a single fiber and a multi-mode fiber capable of mode-division multiplexing.

Keywords: space division multiplexing, large-capacity optical network, multi-core/multi-mode optical fiber

1. Introduction

The history of optical communications technology driving the increasing capacity in optical networks is shown in **Fig. 1**. Up to now, the fundamental transmission medium in the optical network has been single-mode optical fiber designed with only one optical pathway (core) per fiber and one waveguide mode. NTT laboratories have contributed to increasing the capacity by nearly five orders of magnitude over the last 30 years by researching, developing, and commercializing economical cutting-edge optical transmission systems that maximize the broadband characteristics of this single-mode optical fiber. In the 1980s, the capacities of the Gbit/s class were first achieved with electrical multiplexing technology that enabled high-speed modulation of a single wavelength. With this technology, NTT constructed a reliable and economical core network for telephone communications. Then, in the mid-1990s, the need arose for an optical network that could economically transfer the large volumes of data traffic brought on by the spread of the Internet, and the development of optical amplification technology and wavelength multiplexing/demultiplexing technology enabled the deployment of wavelength division multiplexing (WDM) systems for simultaneously transmitting multiple wavelengths. Then, as the performance of WDM filters improved through the use of silica-based planar lightwave circuits, and the number of wavelength-multiplexed channels came to exceed 30, dense wavelength multiplexing systems became a reality.

At present, a dense wavelength-multiplexing, optical-amplification system having a transmission capacity of about 1 Tbit/s (= 1000 Gbit/s) using a single-core fiber is being put to practical use. In addition, recent advances in large-scale, ultra-high-speed CMOS (complementary metal oxide semiconductor) integrated circuits have focused attention on digital coherent technology that can achieve high-sensitivity coherent detection using ultra-high-speed digital

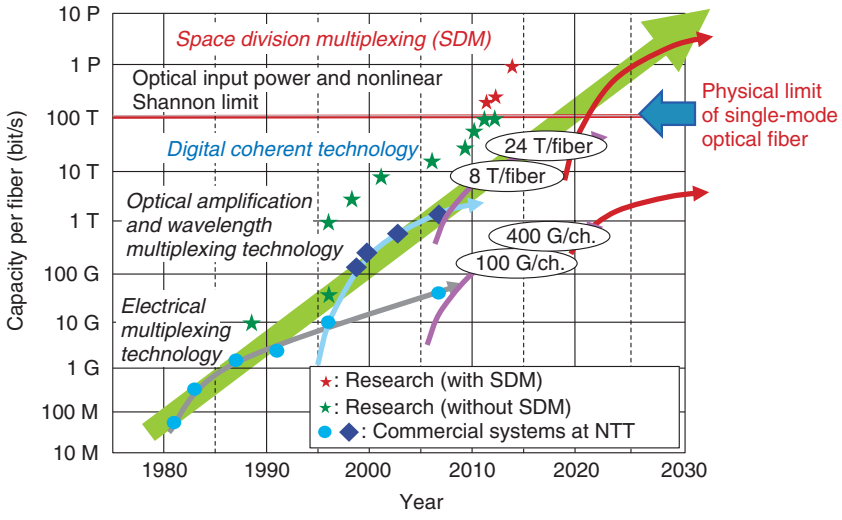

Fig. 1. Evolution of optical communications systems and future developments.

signal processing at speeds above 100 Gbit/s per channel. There is much research and development (R&D) activity at present centered on the deployment of practical communication technologies and the improvement of transmission performance.

Digital coherent technology improves receiver sensitivity and spectral efficiency while also significantly improving dispersion-compensation performance before and after long-distance transmissions. At present, large-capacity transmission of the 100-Gbit/s-per-wavelength class is being achieved through polarization division multiplexing that modulates separate optical signals along different polarization axes in the optical fiber through QPSK (quadrature phase shift keying). With this technology, a high-capacity optical network of the 10 Tbit/s class using existing optical fiber would be practical for a carrier frequency spacing of 50 GHz as used in conventional WDM systems. At the research level, 100 Tbit/s large-capacity transmission has been reported by using higher-order quadrature amplitude modulation (QAM) such as 64QAM and 128QAM.

However, when capacity is increased in excess of 100 Tbit/s, various limitations begin to appear in the optical transmission medium and transmission system. Against this background, space division multiplexing (SDM) has been proposed as a high-capacity optical transmission technology that can overcome the physical limitations of conventional single-mode optical fiber by adding a spatial degree of freedom to the optical-fiber medium and enhancing the level of digital signal processing [1]. The R&D of SDM has been quite active in recent years.

The Innovative Photonic Network Center at NTT Network Innovation Laboratories is engaged in R&D of innovative fundamental technologies for the future that can raise the density of SDM technology and enable the deployment of a long-term, scalable optical network with transmission capacities of the 1 Pbit/s (= 1000 Tbit/s) class, surmounting the 100 Tbit/s level. These technologies will be achieved by bringing together NTT proprietary system technologies, key products, and materials technologies and by establishing extensive collaborative relationships and technology tie-ups both inside and outside NTT laboratories. In this article, we introduce the state of our R&D efforts in dense SDM technology as one of these fundamental technologies for achieving a scalable optical network that can extend transmission capacity in a sustainable manner into the future.

2. Technical issues with optical communications systems using single-mode optical fiber

2.1 Limited spectral efficiency

The first issue in conventional optical transmission technology is a limit to the spectral efficiency due to nonlinear optical effects*1 in the optical fiber. Traditional communication theory states that the upper limit of spectral efficiency (communication capacity

*1 Nonlinear optical effects: The phenomenon by which the phase and frequency of an optical signal are modulated as a function of optical intensity.

per band) with respect to a fixed signal-to-noise ratio (SNR) is given by the theoretical Shannon limit*2. In an optical-fiber communications system, however, increasing the signal power to proportionally increase the communication capacity generates crosstalk (leaking of optical signals) between WDM signals and distorts waveforms because of nonlinear optical effects in the optical fiber, thereby preventing the long-distance transmission of signals. These nonlinear optical effects in such an optical-fiber communications system further limits the spectral efficiency beyond the value given by the Shannon limit.

In recent years, WDM systems have come to apply high-performance error correction techniques that enable the transmission signal power to be designed at a level in which nonlinear effects do not dominate, and high-capacity systems have been achieved in this way. Recent studies have also focused on techniques that use digital signal processing to compensate for the impairment in signals caused by these nonlinear optical effects. Furthermore, in the case of submarine transmission systems, a certain degree of freedom is given in newly designed optical fiber, so optical fiber that reduces nonlinear optical effects by increasing the core diameter have come to be applied. Steady progress can be expected in design technologies for long-distance, large-capacity systems that combine the above elemental technologies to suppress nonlinear optical effects and improve spectral efficiency. Nevertheless, to improve system gain by more than one order of magnitude over the long term, that is, to achieve a dramatic leap in transmission-performance scalability beyond 100 Tbit/s, there is a need for new technology that can surmount the physical limit in spectral efficiency that is characteristic of single-mode optical fiber.

2.2 Limited optical input power

The second issue is optical input power limits due to the damage threshold of optical fiber. In the actual deployment of WDM optical-amplification-repeater systems, high-power input is becoming the norm in optical fibers making up the optical communications system, and at present, the optical signal power is typically on the order of 100 mW (1 mW per wavelength). To raise transmission capacity even further, signal input power in fibers will, in essence, have to be raised, which means that the power output from optical amplifiers will have to be increased above present levels, and the allowable incident power in optical fibers will have to be taken into account. As a physical limit, consideration will have to be given to the fiber-fuse thermal-breakdown phenomenon in optical fibers. This phenomenon can occur while an optical signal is propagating through an optical fiber's core that is approximately 10 μm in diameter. At this time, if local loss and optical absorption should occur at some location in the core for some reason, the temperature of that core section can suddenly rise, causing the core to fuse together and forcing the damaged portion to propagate back toward the optical source. The threshold for stopping fiber-fuse signal propagation in existing optical fiber is being studied in detail, but it is currently known to be in the range of 1.2–1.4 W. To prevent this phenomenon from occurring, operation technologies and safety guidelines that provide for safe handling of high-power signals in the field have been established. As a result of these efforts, safe operations have been achieved in actual commercial systems. Accordingly, with an eye to further increases in capacity, we will need to research and develop optical fiber, optical connector, and optical communication system technologies with high power-resistance qualities and a high level of safety for telecom operators to avoid this fiber-fuse limitation.

3. Overview of SDM optical communications technology

To overcome the two problems described above, we propose an SDM optical communications system as shown in **Fig. 2** that maximizes the use of the optical fiber's spatial degree of freedom and that increases the cross-sectional area of the core to expand transmission capacity without increasing the power density of the optical signal. This system can be divided into two types as described below [2].

3.1 SDM transmission system using multi-core fiber

The advantage of an SDM optical communications system using multi-core fiber (in which a single fiber is configured with multiple cores) is that the total transmission capacity per fiber can be expanded without increasing the power density per core. Here, optical-signal crosstalk between cores is the most important design consideration in a multi-core optical fiber communications system that aims to ensure the independence of each core. With a multi-core optical

*2 Shannon limit: The limit in transmission capacity determined by the SNR of the transmission channel and the frequency bandwidth above which data transmission speed cannot be raised.

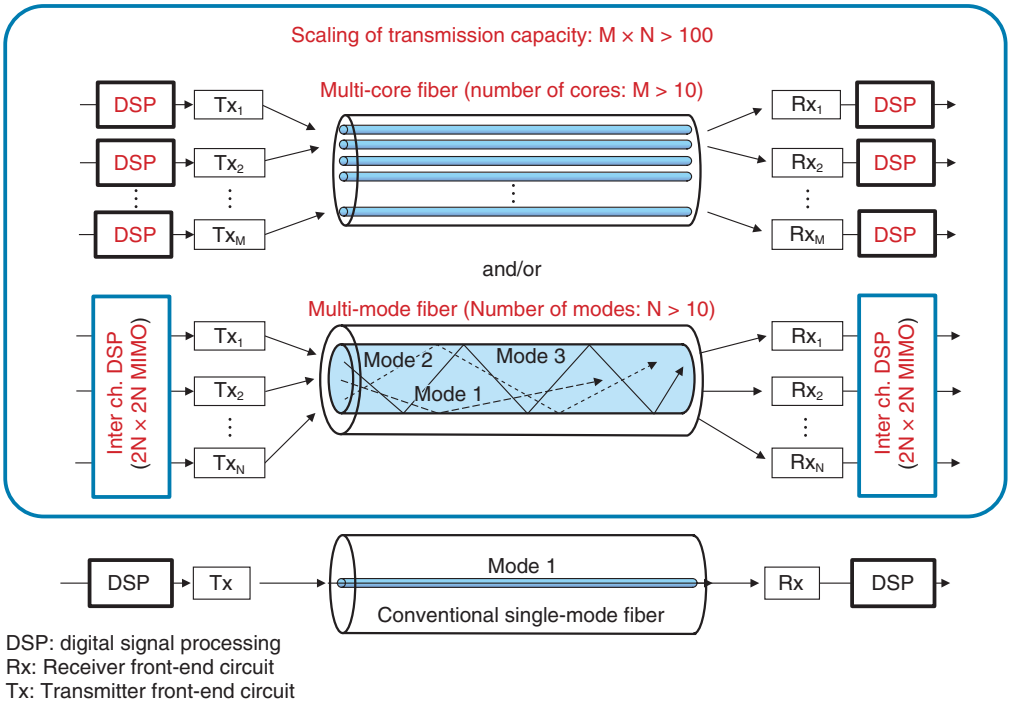

Fig. 2. Overview of SDM optical communications technology.

fiber communications system consisting of single-mode cores as used in conventional optical fiber, appropriately designing the arrangement of cores taking inter-core crosstalk into account makes it possible to increase the system capacity by increasing the number of cores with just one fiber. This type of system can also use the same type of optical transmitters and receivers as that in conventional single-mode optical fiber systems.

3.2 SDM optical communications system using multi-mode fiber

This type of SDM system uses multi-mode fiber that expands the effective area of the core and decreases power density. An inevitable result of expanding the effective area of the core is multi-mode optical fiber having a number of waveguide modes, in each of which a signal can propagate. In past optical communications systems, it was difficult to achieve multiplexed transmission by having the same wavelength (optical carrier frequency) carry individual signals in different modes. This is because it was technically difficult on the receiver side to separate those individual signals transmitted in different modes. However, it has been shown that mode separation on the receiver side can be facilitated by equipping the optical communications system with transmitter/receiver digital signal processing that employs multiple-input multiple-output (MIMO)[*3] signal processing developed recently for mobile phones and wireless LAN (local area network) systems. As a result, mode-division-multiplexing optical communications systems that can increase the spatial multiplexing number by increasing the number of allowed modes are now being intensively studied. The number of modes that can be separated is essentially determined by the amount of delay between modes and the feasibility of digital signal processing. Presently, at the research level, there have been reports of multiplexing/demultiplexing transmission experiments of up to six modes excluding polarization modes performed by experimental (offline) digital signal processing using memory storage and computers.

The above SDM optical communications systems using either multi-core fiber or multi-mode fiber are independent technologies. Combining them in an appropriate manner opens up the possibility of

*3 MIMO: A communications technology that enhances the transmission data rate without increasing the signal bandwidth by combining multiple transmitters and receivers.

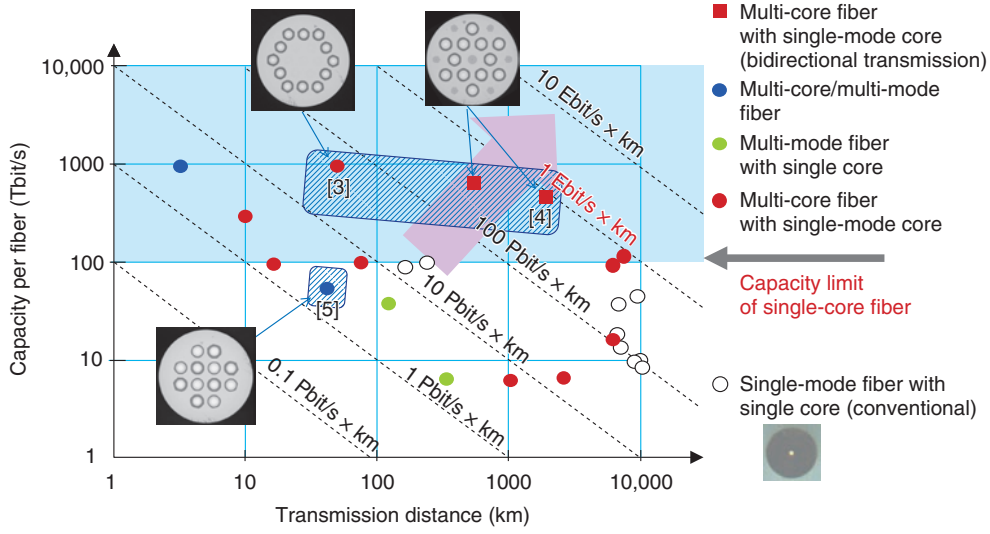

Fig. 3. State of SDM research and development.

achieving a dense SDM optical communications system having a spatial-multiplexing number greater than the 30–100 in WDM systems.

4. SDM optical transmission experiments and future outlook

As mentioned above, the R&D of SDM-based communications has been quite active in recent years, and at the research level, experiments are showing that SDM can achieve values for loss, dispersion, and other properties at nearly the same level as that of conventional single-mode fiber. Device technology is also progressing in relation to using the interface technology (fan-in/fan-out devices, fusion techniques) of conventional single-mode optical fiber with multi-core optical fiber, and a number of high-capacity transmission experiments and long-distance transmission experiments using multi-core fiber have been reported. The current state of R&D efforts in SDM is shown in **Fig. 3**. Recent achievements in top-class transmission capacities correspond to transmission experiments using multi-core fiber. Under partial support provided by the National Institute of Information and Communications Technology (NICT) in the form of commissioned research and through collaboration with other research institutions, NTT laboratories and their research partners have achieved the cutting-edge results shown in the shaded area in Fig. 3 [3–5]. Specifically, we were the first in the world to perform a successful high-capacity transmission experiment above 1 Pbit/s in September 2012 [3] and a successful long-distance transmission experiment of the Pbit/s class in September 2013 [4] by combining single-mode/12-core multi-core fiber with multi-level modulation/demodulation technology such as 16QAM and 32QAM that can enhance the spectral efficiency per core.

To increase the multiplexing number (number of cores) while maintaining signal independence between cores, it is essential that inter-core crosstalk be suppressed to some extent. This requirement calls for core-arrangement design that can increase the number of cores while preserving a core interval greater than a prescribed distance.

At the same time, careful consideration must be given to the upper limit (about 200 μm) of the cladding diameter in a multi-core optical fiber from the viewpoint of ensuring mechanical reliability, so a trade-off exists that prevents the number of cores from being infinitely increased. The relationship between crosstalk over 1000 km and the spatial multiplexing number is shown in **Fig. 4** in relation to large-capacity transmission experiments using multi-core SDM transmission. Multi-core/single-mode fiber transmissions with a core number N of 7–19 have been reported to date, but since crosstalk can increase as the number of cores is increased within the cladding diameter limit, the spatial multiplexing number is limited at 19 under these conditions. In this regard, considering the future progress of higher-order QAM digital coherent transmission technology,

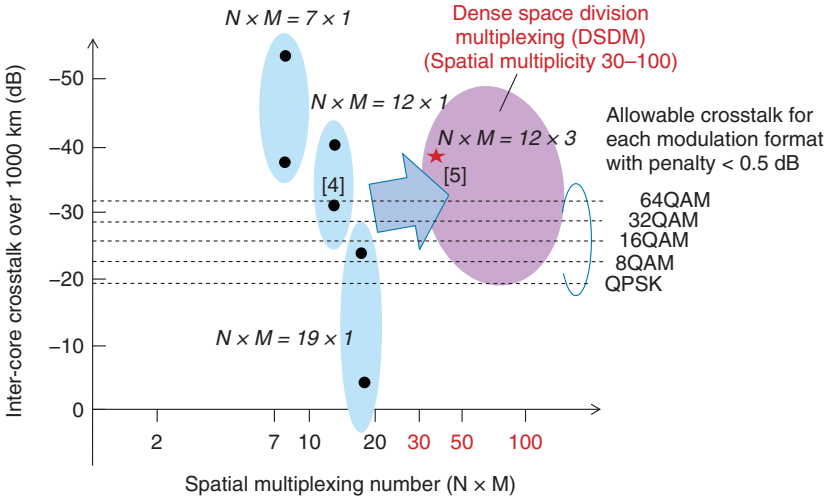

Fig. 4. Study toward dense SDM optical communications.

we can consider the application of multi-level modulation systems above a level of four (8–64QAM). It is therefore thought that allowable crosstalk between cores should be under –30 dB after transmission.

Furthermore, in terms of optical fiber for infrastructure use, it would be desirable to ensure scalability in the degree of multiplexing over several decades, as in the case of single-core fiber. In March 2014, in collaboration with research institutions both inside and outside NTT, the Innovative Photonic Network Center at NTT Network Innovation Laboratories performed the world's first successful ultra-dense SDM transmission experiment exceeding a spatial multiplexing number of 30 using 12-core multi-core/multi-mode fiber and achieving 3-mode multiplexing/demultiplexing in each core (spatial multiplexing number of 36 = 3 modes × 12 cores) [5, 6]. Looking to the future, we can expect further progress to be made in lengthening the transmission distance of ultra-dense SDM communications using multi-core/multi-mode fiber that can extend the scalability of the multiplexing number beyond 30–100 while suppressing inter-core crosstalk.

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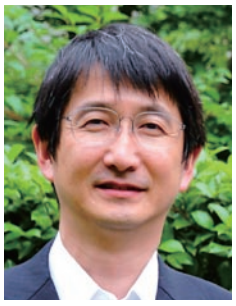

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Results of ITU-T Focus Group on Disaster Relief, Network Resilience and Recovery (FG-DR&NRR)

Noriyuki Araki and Hideo Imanaka

Abstract

The Focus Group on Disaster Relief Systems, Network Resilience and Recovery (FG-DR&NRR) was established within ITU-T (International Telecommunication Union–Telecommunication Standardization Sector) in January 2012, as a Japanese government initiative, to study international standardization related to disaster response by utilizing information and communication technology (ICT). One of the authors (Noriyuki Araki) served as the chairman of this focus group. By May 2014, the FG-DR&NRR had held a total of eleven meetings (including two electronic conferences) and developed eight deliverables.

This article reports the results of the final FG-DR&NRR meeting, provides an outline of the deliverables, and summarizes a plan for future international standardization activities in relation to the use of ICT to cope with disasters.

Keywords: ITU, focus group, disaster relief

1. Outline of FG-DR&NRR

The Focus Group on Disaster Relief Systems, Network Resilience and Recovery (FG-DR&NRR) is a time-limited study committee of the ITU-T (International Telecommunication Union–Telecommunication Standardization Sector), which is undertaking an intensive study of new standards related to disaster relief systems and network resilience and recovery by utilizing information and communication technology (ICT) in the event of a disaster. Its establishment was agreed at a Telecommunication Standardization Advisory Group (TSAG) meeting in January 2012. Noriyuki Araki, a co-author of this article, served as the chairman of this FG because Japan was deeply involved in its establishment at TSAG meetings, and NTT has long had a sense of responsibility that motivates it to contribute to society. The management team and Working Groups (WGs) of the FG-DR&NRR are listed in **Table 1**.

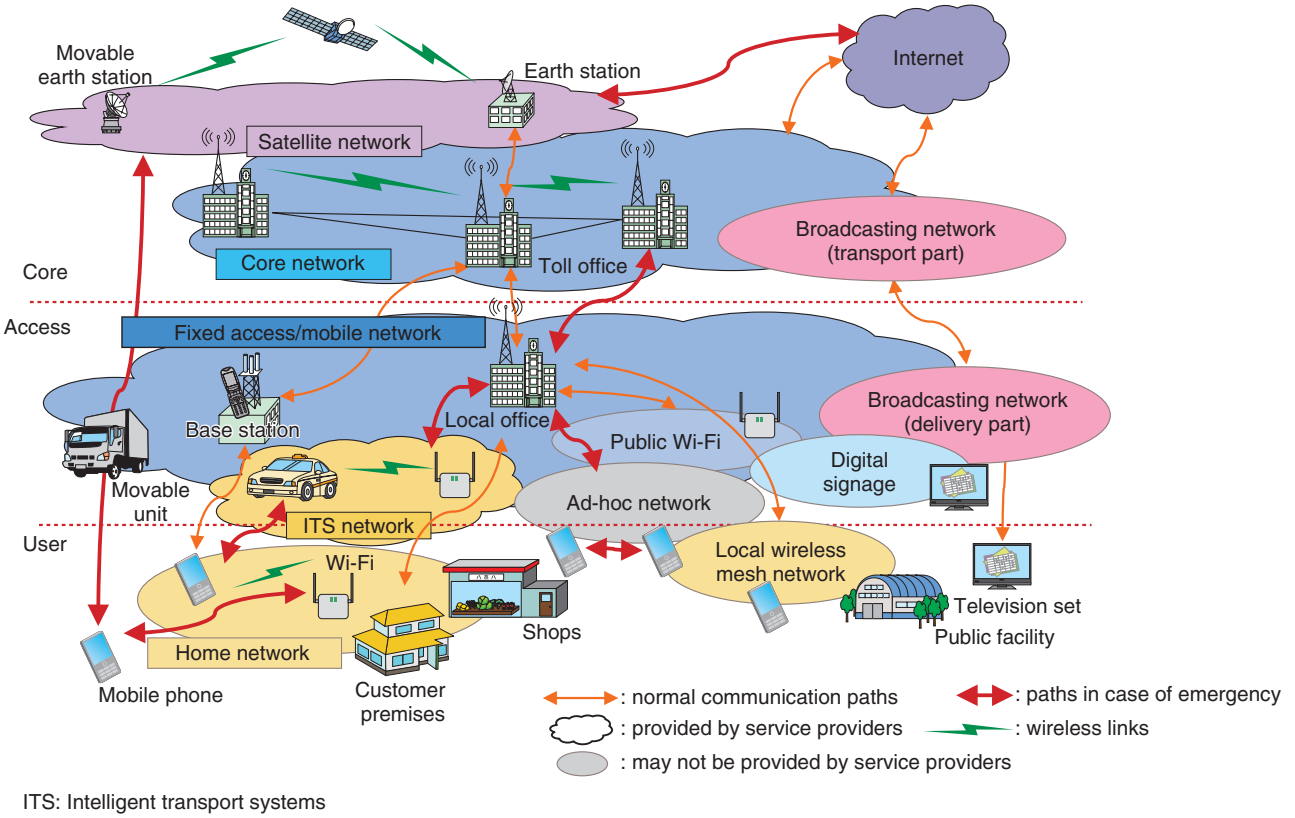
2. Report of 9th FG-DR&NRR meeting

The 9th FG-DR&NRR meeting, the final one, was held at the University of the South Pacific, Suva, Fiji, in May 2014. The organizations from Japan that participated in this meeting were the Ministry of Internal Affairs and Communications (MIC), the National Institute of Information and Communications Technology (NICT), NTT, NEC, and the University of Tokyo. A special session for sharing information about basic policy regarding ICT for disaster response and disaster countermeasures in Fiji and Japan was held at this FG meeting. Information about the disaster response efforts of Telecom Fiji Ltd. (TFL) and the Pacific Island Telecommunication Association (PITA) were incorporated in the use case and requirements deliverables, and disaster countermeasure case studies and the requirements for ICT during disasters in island countries were reflected in the deliverables of the FG-DR&NRR.

Moreover, an integrated view of networks supporting disaster relief services (**Fig. 1**), which includes

Table 1. FG-DR&NRR management team.

Title	Name	Working Group (WG)
Chairman	Mr. Noriyuki Araki (NTT, Japan)	—
Vice-Chairman	Mr. Takashi Egawa (NEC, Japan)	WG 1: Use case and disaster clarification
Vice-Chairman	Mr. Leo Lehmann (Switzerland)	WG 2: Network resilience and recovery
Vice-Chairman	Mr. Ramesh K. Siddhartha (India)	WG 3: Disaster relief systems
Secretariat	Dr. Hiroshi Ota (Telecommunication Standardization Bureau)	—



ITS: Intelligent transport systems

Fig. 1. Integrated view of networks supporting disaster relief services.

research and development (R&D) results related to ICT designed to strengthen disaster resistance in Japan, was updated, and an example of the application of information-centric network technology was added to the framework document. Then, at this meeting, the FG-DR&NRR completed seven deliverables including requirements for disaster relief systems. Some technologies proposed by the NTT Group such as a safety confirmation system and a movable ICT resource unit were included in the deliverables. The deliverables are detailed in section 4.

3. Overview of activity of FG-DR&NRR

The FG visited several countries that had suffered major disasters such as earthquakes, tsunamis, landslides, floods, and tidal waves in order to gather information on disaster experiences from all over the world. The meetings held by the FG-DR&NRR are listed in **Table 2**, which also provides statistical information about the participants, documents, and Liaison Statements. Three ITU workshops on disaster relief systems, network resilience and recovery were also held at the same time as the FG-DR&NRR

Table 2. General information about FG-DR&NRR.

Meeting	Date, venue	Host organization	Partici-pants	Input/Output documents	Liaison Statements In/Out
1st meeting	25–27 June 2012, Geneva, Switzerland	—	32	11/5	2/3
2nd meeting	24–26 September 2012, Geneva, Switzerland	—	26	25/7	4/2
3rd meeting	11–13 December 2012, Istanbul, Turkey	Istanbul Technical University	73	20/10	7/5
4th meeting	5–8 February 2013, Tokyo, Japan	MIC Japan, Bidding Committee *1	83	25/11	7/5
5th meeting	20–24 May 2013, Phuket, Thailand	National Broadcasting and Telecommunications Commission	36	31/15	13/6
6th meeting	21–23 August 2014, Issyk-Kul, Kyrgyz	The Kyrgyz State Technical University	23	20/10	2/2
e-meeting 1	2 October 2014, e-meeting	—	13	0/1	0/0
7th meeting	24–26 October 2014, Santiago, Chile	University of Chile	38	29/7	4/2
8th meeting	3–5 March 2014, Biel, Switzerland	Federal Office of Communications	17	30/10	3/1
e-meeting 2	18 April 2014, e-meeting	—	14	5/0	0/0
9th meeting	12–15 May 2014, Suva, Fiji	The University of the South Pacific	24	12/8	1/1

*1 NICT, NTT, Fujitsu, NEC, the ITU Association of Japan

meetings. Even when no workshops were being conducted, special sessions related to disaster issues were held as part of the FG meeting. At these ITU events, ICT solutions for disaster relief and resilient ICT R&D projects in Japan were introduced, and local experts were invited and information gathered about disaster experiences and requirements for ICT in disaster situations.

4. Summary of deliverables

The FG-DR&NRR has developed eight deliverables as described below. All these deliverables have been published by ITU-T FG-DR&NRR as technical reports and can be found on the ITU-T website [1].

4.1 FG-Overview

This deliverable provides an overview of the activity of FG-DR&NRR, including the objectives and area of study, and an outline of other major deliverables produced by the FG-DR&NRR. It also describes the category classification of ITU-T Recommendations and activities in other organizations outside ITU-T relevant to DR&NRR. This document is useful for understanding the trend in disaster related standardization.

4.2 FG-Frame

This deliverable has five parts. The inputs at FG-DR&NRR meetings are used as the basis of this document, which provides an integrated view of promising technologies for DR&NRR. Parts I to III introduce the specific implementation of disaster relief system tools by public organizations and private citizens during disasters. They also reveal the possibility of maintaining communications through cooperation between fixed, mobile, and satellite communication networks during a disaster, thus ensuring communication capabilities by utilizing public Wi-Fi, home networks, and ad-hoc networks in disaster affected areas, and the transfer of disaster information by employing public broadcasting and digital signage. Information about FG-DR&NRR meeting inputs, which are contained along with brief summaries and references in a common template can be found in Parts IV and V. They are expected to be employed as disaster use cases.

4.3 FG-Gap

This document presents current work on disaster relief systems and network resilience and recovery efforts that have been carried out by different standards development organizations (SDOs) and the disaster communication networks and technologies used by other national and international disaster relief

bodies. This document identifies gaps related to issues that are not currently receiving sufficient attention in ITU standardization work by using these inputs as a basis. The document also describes technologies for standardization that are well developed and being used for disaster relief systems, network resilience and recovery.

4.4 FG-Term

This document contains terms and definitions relevant to providing a common general understanding of the area of disaster relief systems, network resilience and recovery. It is also designed to support the creation of common terms and definitions in this area.

4.5 FG-DR

This deliverable describes requirements for disaster relief systems including early warning systems that are used for actual and potential victims before, during, and after disasters. To facilitate future enhancements, the document consists of a main body as the general part and describes disaster relief services that need further investigation prior to standardization in annexes. Annex 1, "Disaster message board service," and Annex 2, "Disaster voice delivery service," were transferred to ITU-T Study Group (SG) 2 at the TSAG meeting held in June 2013, and work on creating a new ITU-T Recommendation has already begun. It is planned that Annex 3, "Safety confirmation system," will become standardized.

4.6 FG-NRR

This deliverable describes requirements for network resilience and recovery before, during, and after disasters. To facilitate future improvements, the document consists of a main body as the general part and describes disaster relief services that need further investigation prior to standardization in annexes.

4.7 FG-MDRU (Movable and Deployable Resource Unit)

This deliverable introduces an approach designed to improve network resiliency against disasters and to assist network recovery after disasters by packaging movable and instantaneously deployable resources for ICT as one unit. ITU-T SG 15 will begin working on a new ITU-T Recommendation based on this deliverable.

4.8 FG-TR (Technical Report)

This technical report is the first report of the ITU-T FG-DR&NRR. It presents a number of case studies related to the performance of public telecommunications systems in recent disasters along with a review of activities related to the use of telecommunications for disaster mitigation and the standards that have been developed by various organizations.

5. Collaboration with other organizations and SDOs

FG-DR&NRR has initiated relationships with relevant disaster related organizations and SDOs for information exchange and collaboration by sending Liaison Statements and giving presentations about its FG activities, in particular: ASTAP (Asia-Pacific Telecommunity Standardization Program), IARU (International Amateur Radio Union), IEC (International Electrotechnical Commission), IETF (Internet Engineering Task Force), ISO (International Organization for Standardization), ITU-Telecommunication Development Sector (ITU-D), ITU-Radiocommunication Sector (ITU-R), the aforementioned PITA, TARU (Technical Advisory Response Unit), TTC (Telecommunication Technology Committee), UNDP (United Nations Development Programme), and UNISDR (United Nations International Strategy for Disaster Reduction).

It is expected that relationships will be maintained with relevant ITU organizations and related SDOs and other bodies to enable effective standardization work to be undertaken in this area.

6. Future work plan

6.1 Transfers of deliverables to different Study Groups

At a meeting in June 2014 of ITU-T SG 2, the parent Study Group of this FG, it was agreed that the eight FG-DR&NRR deliverables would be taken over by the relevant ITU-T Study Groups as indicated in **Table 3**. Some of these deliverables include promising technologies, so it was therefore decided that ITU-T SG 2 and SG 15 would start making relevant Recommendations as soon as possible. The deliverables also include study items related to network architecture, accessibility, and security issues in disaster situations, so it was agreed that these deliverables would be sent to ITU-T SG 13, SG 16, SG 17, JCA-AHF (Joint Coordination Activity on Accessibility and Human Factors), ITU-D Q5/2 (Question 5/2) and ITU-R SG 5 for information sharing.

Table 3. Deliverables of FG-DR&NRR and ITU-T Study Groups assigned to handle them.

Deliverables	Title	Assigned SGs	Relevant SGs (Information sharing)
FG-Overview	Overview of disaster relief systems, network resilience and recovery	Continued examination by ITU-T SG 2	ITU-T SG 13, SG 16, SG 17, JCA-AHF, ITU-D Q5/2, ITU-R SG5
FG-Frame	Disaster Relief Systems, Network Resilience and Recovery (DR&NRR): Promising technologies and use cases		
FG-Gap	Gap analysis of disaster relief systems, network resilience and recovery		
FG-Term	Terms and definitions for disaster relief systems, network resilience and recovery	Transferred to ITU-T SG 2 with aim of making new Recommendations	
FG-DR	Requirements for disaster relief systems		
FG-NRR	Requirements for network resilience and recovery	Transferred to ITU-T SG 15 with aim of making new Recommendations	
FG-MDRU	Requirements for improvement of network resilience and recovery with movable and deployable ICT resource units		
FG-TR	Technical report on telecommunications and disaster mitigation	Published on the ITU webpage	

JCA-AHF: Joint Coordination Activity on Accessibility and Human Factors

6.2 Future activities

The requirement documents of FG-DR&NRR deliverables—FG-DR, FG-NRR, and FG-MDRU—detail specific characteristics of promising technologies that have already been installed in the field or for which demonstration experiments have been carried out with a view to practical use. The "Disaster message board service" and "Disaster voice delivery service," which were transferred to ITU-T SG 2 at the TSAG meeting in June 2013, are currently being studied in ITU-T SG 2 with the aim of creating a new ITU-T Recommendation. In addition, work will start on Annex 3 of FG-DR concerning a "Safety confirmation system" for business continuity plans and a "Movable ICT resource unit" of FG-MDRU, which is intended to achieve quick recovery of communication services in disaster affected areas, in order to create new ITU-T Recommendations and achieve early standardization in ITU-T SG 2 and SG 15.

7. Conclusion

FG-DR&NRR was terminated in May 2014. At the ITU-T SG 2 meeting held in June 2014, it was agreed that the eight FG-DR&NRR deliverables would be taken over by the relevant ITU-T Study Groups.

It was difficult to cover the entire study area related to this FG within its limited lifetime, because the study area that FG-DR&NRR dealt with is very wide and diverse. Therefore, it is necessary to continue examining this area in the relevant ITU-T Study Groups. However, much information has been collected in countries with disaster experience, including Japan, such as in the large-scale disaster of the Great East Japan Earthquake and tsunami. This information, as well as the extensive Japanese R&D results concerning ICT in the event of disaster, have been reflected in the FG-DR&NRR deliverables in order to cope with disasters throughout the world. The authors consider that the FG activity has helped to specify the study items that should be standardized in the future, and to move certain technologies toward new ITU-T Recommendations.

NTT hopes that worldwide efforts will be made to promote the use of ICT to combat disasters and mitigate the damage that they cause. The authors believe that prompt action regarding the publication of FG deliverables as ITU-T Recommendations will contribute to the promotion of ICT use and prevent some of the damage that could be caused by future disasters.

Reference

[1] Website of FG-DR&NRR, ITU-T, http://www.itu.int/en/ITU-T/focusgroups/drnrr/Pages/default.aspx

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He received the B.E. and M.E. in electrical and electronic engineering from Sophia University, Tokyo, in 1993 and 1995, respectively. He joined NTT Access Network Systems Laboratories in 1995. He then worked on the R&D of operation and maintenance systems for optical fiber cable networks. Since 2006, he has been engaged in work on outside plant standardization in ITU-T SG 6. He was the Rapporteur of Question 6 of ITU-T SG 6 from 2006 to 2008, and the Rapporteur of Question 17 of ITU-T SG 15 from 2008 to 2012. He served as the Chairman of ITU-T FG-DR&NRR. He has been the Vice-Chairman of ITU-T SG 15 since 2013. He has also been contributing to the activities of IEC TC 86 (fibre optic systems) since 2007. He received the ITU-AJ award from the ITU Association of Japan in 2012. He is a member of the Institute of Electronics, Information and Communication Engineers (IEICE).

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He received the B.E., M.E., and Ph.D. in electrical engineering from Mie University in 1985, 1987, and 2001, respectively. After joining NTT Telecommunication Network Laboratories in 1987, he engaged in research on fiber optic access network architecture and network operation process reengineering methods. From 1996 to 2003, he worked on the integration of enterprise resource planning (ERP) systems as a consultant in the Solutions Business Division of NTT Communications. Since 2004, he has been involved in NGN (Next Generation Network) standardization work at ITU-T. He was the Rapporteur of Question 1 of ITU-T SG 13 from 2007 to 2010. He has also played an active role in IPTV (Internet protocol television) standardization work at ITU-T. He is currently in charge of standardization strategies in the NTT Group. In 2014, he also began serving as the Vice-Rapporteur of Question 5 of ITU-D SG 2. He received the ITU-AJ award from the ITU Association of Japan in 2009. He is a member of IEICE and the Society of Instrument and Control Engineers.

Case Studies of Damage Caused by Wildlife in Access Network Facilities and Countermeasures

Abstract

This article introduces case studies of damage in access network facilities caused by wildlife, and also discusses countermeasures. This is the twenty-sixth of a bimonthly series on the theme of practical field information on telecommunication technologies. This month's contribution is from the Access Engineering Group, Technical Assistance and Support Center, Maintenance and Service Operations Department, Network Business Headquarters, NTT EAST.

Keywords: damage caused by wildlife, outdoor access network facilities, countermeasures

1. Introduction

NTT deploys access network facilities that support telecommunication services in every region of Japan. Most of these facilities are situated in outdoor environments, and malfunctions due to climate conditions such as wind, rain, snow, and lightning, and also those caused by animals living in the wild occur annually. Among the inspection requests made to the Technical Assistance and Support Center regarding access network facilities in fiscal years 2010–2012, 19% were related to damage caused by wildlife. This damage can be broken down into that caused by insects (e.g., black cicadas, ants, larvae of swift moths), rodents (e.g., squirrels, flying squirrels, rats, mice), and birds (e.g., crows, woodpeckers), as shown in **Fig. 1** in descending order of prevalence. In short, these animals, which exist throughout Japan, are the cause of many malfunctions.

2. Types of damage and associated countermeasures

Examples of damage caused by birds include pecking of drop cables by crows and pecking of aerial cables by woodpeckers and other birds. Wrapping drop cables with PVC (polyvinyl chloride) cable protective covering is an effective means of preventing damage to cables caused by the pecking of crows, while upgrading aerial cables to high strength sheath (HS) cables that are resistant to damage from birds and other animals is an effective means of preventing the pecking of aerial cables by woodpeckers and other birds (**Fig. 2**). In addition, the latter problem, if restricted to a local area, can also be managed by applying anti-rodent sheets or anti-rodent tape (**Fig. 3**).

Damage caused by rodents includes gnawing of aerial cables and access boxes by squirrels and flying squirrels and gnawing of underground cables in manholes by rats and mice. The aforementioned HS cables and anti-rodent sheets and tape are effective in preventing the former type of damage, while commercially available protective coverings for access boxes are effective in preventing the latter type (**Fig. 4**). In addition, squirrels and flying squirrels climb on to aerial cables from the branches of trees, so cutting down trees in the immediate vicinity of those facilities is also an effective countermeasure. In fact, cutting down nearby trees should be the first idea studied when investigating possible countermeasures to aerial-cable damage. To prevent damage to underground cables, the paths that rats and mice use to penetrate the manhole need to be identified and closed off. It is also effective to close off the cable duct leading into the manhole by using a stopcock or

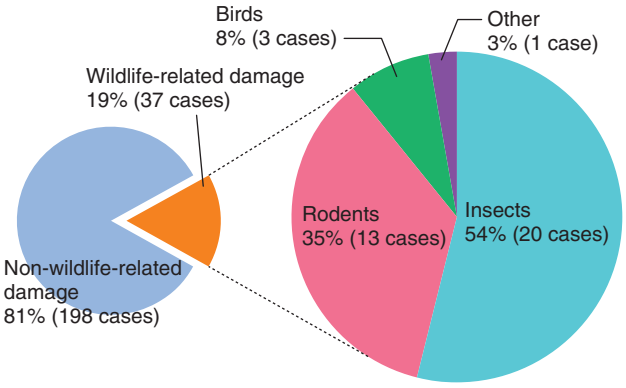

Fig. 1. Breakdown of inspection requests to the Technical Assistance and Support Center in fiscal years 2010–2012.

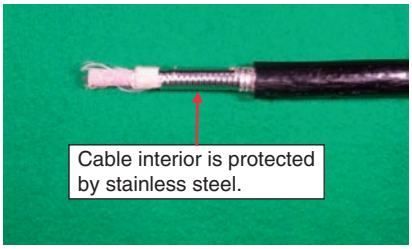

Fig. 2. HS cable.

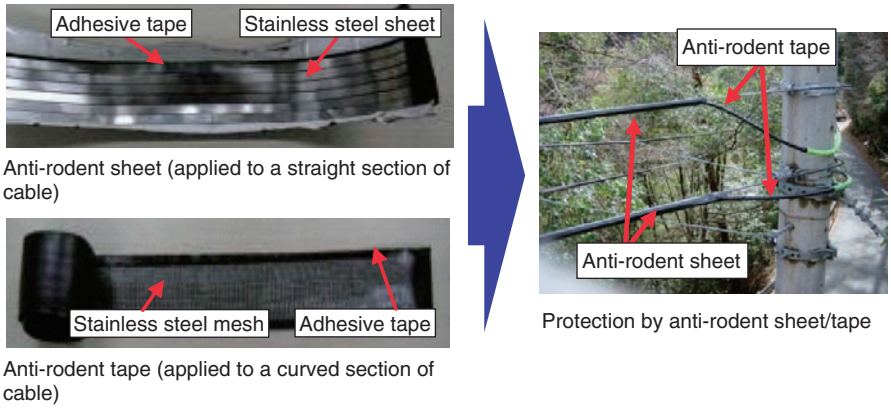

Fig. 3. Anti-rodent sheet/tape.

other mechanism and to apply anti-rodent sheet or tape to exposed cables.

Damage caused by insects includes disconnections in drop cables caused by cicadas, disconnections in core fibers of optical fiber cables within closures caused by ants, and boring into aerial cables by larvae of swift moths. In the past, disconnections in drop cables by cicadas were essentially limited to western Japan, but they have recently begun to appear in eastern Japan as well. Replacing existing cables with cicada-resistant drop cables (V-notch cicada-proof drop cables) is an effective countermeasure. Meanwhile, ants can cause disconnections in the core fibers of optical fiber cables within closures because they can reach the fibers through gaps in the closure (**Fig. 5**). An effective countermeasure here is to eliminate such gaps by coating the interlocking parts of the closure with silicon sealant before closing the lid (**Fig. 6**). Finally, an effective means of dealing with the boring of aerial cables by larvae of swift moths is to upgrade the entire route with HS cables, and if the problem is localized, to apply anti-rodent sheets or tape. In addition, larvae of this type make their way onto aerial cables via trees and ivy, so cutting down and clearing nearby trees and ivy and/or installing ivy guards on stay wires that tend to become entangled in ivy are effective in cutting off the path of penetration.

The above countermeasures to damage caused by wildlife can be broadly divided into two categories: cutting off the penetration path and using protective products, regardless of the type of wildlife.

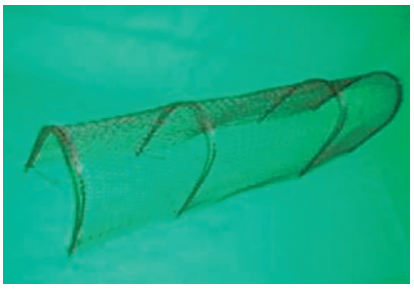

Fig. 4. Protective covering for access box.

Fig. 5. Closure that has been penetrated by ants.

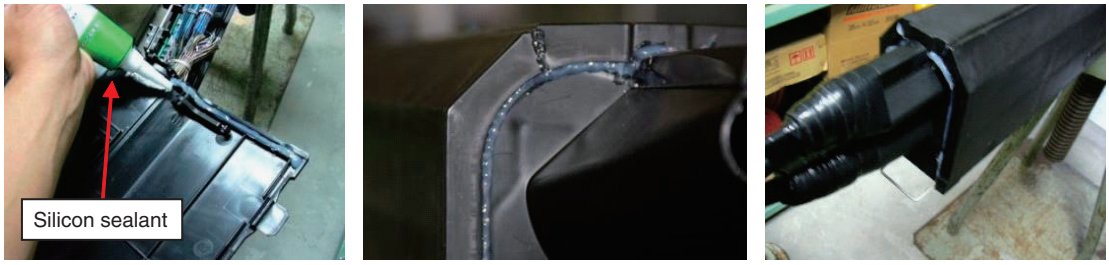

Fig. 6. Example of applying silicon sealant to a closure.

3. Case studies of damage caused by wildlife

The previous section described the types of damage caused by different types of wildlife and the associated countermeasures, but here we introduce two key case studies of recent inspection requests made to the Technical Assistance and Support Center.

3.1 Case study of damage in submarine optical cable due to Formosan subterranean termites

In this incident, a power-supply malfunction occurred in the repeater for a submarine optical cable, and a search for the fault found that there was a drop in insulation resistance in the copper tubing of the power-supply section near a manhole in the landing-station interval. An inspection request was issued to find the cause and determine a countermeasure.

Inside the manhole, a dirt-like substance was found on top of the cable, and the outer sheath of the cable in the range 30–230 mm from the duct inlet was found to have melted (**Fig. 7**). As shown in the figure, the dirt-like substance on top of the cable forms an *ant trail*, which is characteristic of termites, consisting of a mixture of soil and dung. Moreover, a check on the state of the cable's outer sheath revealed a number of marks, and an inspection using a digital microscope found that they had fluffy strings 0.01–0.02 mm in thickness (**Fig. 8**).

In this case study, the presence of an ant trail within the manhole, the similarity to damage in the cable's outer sheath by Formosan subterranean termites confirmed in a past inspection, and the existence of a lumber yard near the manhole led to the conclusion that the damage here was also caused by Formosan subterranean termites. It was also inferred that the melting of the cable's outer sheath occurred because the termite boring reached the copper tubing from the outer sheath and grounded the power-supply current. In Japan, Formosan subterranean termites are distributed along the Pacific coast of the Kanto region and west thereof, and since damage of this type can occur in manholes situated near rivers or coastlines, it is recommended that maintenance work and inspection on manholes in similar environments be accompanied by checks for ant trails, and that specialists be called in to exterminate and control such termites as needed.

Fig. 7. Situation inside manhole.

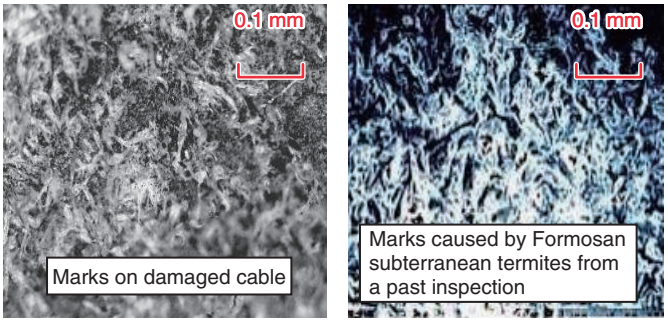

Fig. 8. Appearance of cable damage.

3.2 Case study of damage in outdoor access network equipment due to gecko lizard

In this incident, a continuous ringing malfunction alarm ("RING" alarm) occurred in outdoor access network equipment (remote subscriber module F (RSBM-F)), and an initial inspection revealed a line card with the burnt carcass of a gecko lizard. An inspection request was therefore issued to find the path by which the gecko entered the RSBM equipment and to determine a countermeasure.

The gecko that was stuck on the line card was assumed to be of the Japanese gecko type because of its distinguishing features such as its length and the scales on its footpads (underside of toes) (**Fig. 9**). The RSBM-F equipment that the gecko penetrated was surrounded by a lush growth of trees and plants. A search for the penetration path revealed that minute crevices in the cabinet door, MDF (main distribution frame) door, and cable inlet could not have served as a penetration path for the gecko. However, it is known that geckos prefer to inhabit crevices and other tight spaces, so it was inferred that the gecko must have entered the equipment while the RSBM-F door was being opened or closed. It is therefore recommended that trees and plants in the vicinity of RSBM-F

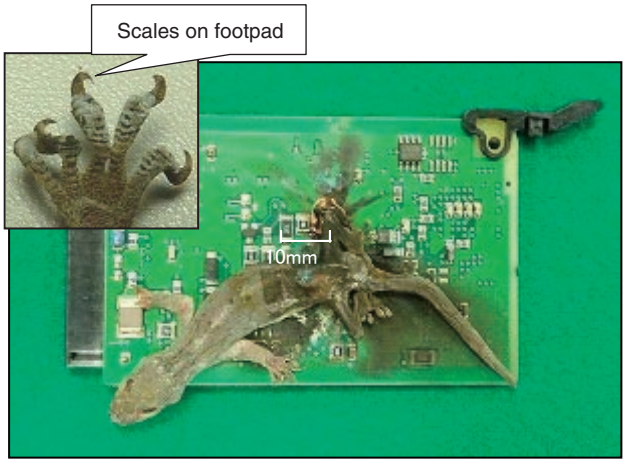

Fig. 9. Shorted line card and remains of gecko lizard.

equipment that can serve as a habitat of geckos and insects be periodically cleared, that a check be made beforehand for the presence of wildlife in door crevices when opening or closing doors, and that any wildlife present be removed.

4. Conclusion

This article explained typical methods for preventing damage caused by wildlife in access network facilities and presented two case studies in which such damage occurred and described how the situations were dealt with. Although it is difficult to completely prevent all facility damage caused by wildlife, it is hoped that the countermeasures and case studies presented here will be useful in at least reducing the scope of this damage. The Technical Assistance and Support Center has been involved for more than 50 years in technical assistance and support activities if we include its predecessor, the Technical Assistance and Support Department. Going forward, we are committed to leveraging the knowledge and experience gained to date to further improve the reliability of telecommunication facilities and reduce the number of problems that occur in the field.

New NTT Colleagues
—We welcome our newcomers to the NTT Group

Here, we welcome newcomers to the NTT Group. This is a corner of the NTT Technical Review where we introduce our new affiliate companies.

Symphony Management Consulting
Established in 2002, headquartered in USA, SAP HCM solutions provider

As a leading provider of human capital management (HCM) solutions, Symphony has the human resource (HR) business knowledge and implementation experience to know that a human resource information system (HRIS) can bring harmony to our customers. With an exclusive focus on HCM, we excel at conducting successful implementations and upgrades, specifically within SAP HCM and SuccessFactors solutions. By aligning IT (information technology) and HR, our customer's HR department becomes a proactive, strategic organizational partner. More than an outsourcing provider, Symphony strives to become a trusted advisor; from the moment you compose a strategic HR roadmap to the last note of your implementation and beyond. Symphony has been an SAP services partner since 2006 and a SuccessFactors services partner since 2012. In October 2014, Symphony was acquired by itelligence AG, a German subsidiary of NTT DATA. For further information, please visit www.symphony-consulting.com

Contacts:
itelligence, Inc.
laure.poquette@itelligencegroup.com

External Awards

Technical Committee Prize Paper Award (Second Prize Paper)

Winner: Munekazu Date, Hideaki Takada, Shiro Ozawa, Akira Kojima, NTT Media Intelligence Laboratories, and Satoshi Mieda, NTT Resonant Inc.
Date: October 6, 2014
Organization: The Industrial Lighting and Display Committee, Institute of Electrical and Electronics Engineers (IEEE) Industry and Applications Society

For "Highly Realistic 3D Display System for Space Composition Telecommunication."

We describe a highly realistic three-dimensional (3D) display system that generates composites of current and remote places for telecommunication purposes. It uses a 3D projector and head tracking to display a person in a remote place as a life-size stereoscopic image against background scenery. Since it generates displayed images that correspond to the observer's viewing position, it well reproduces the fidelity of existence and the feel of materials. We also describe a simple, fast, and high quality background scenery generation method, the development of which was inspired by the visual effects of DFD (depth-fused 3D) displays, and applied it to a single direction conceptual demonstration system. Our system is a promising means of achieving real-time communication between two different places in cases where a sense of reality is required.
Published as: M. Date, H. Takada, S. Ozawa, S. Mieda, and A. Kojima, "Highly Realistic 3D Display System for Space Composition Telecommunication," Proc. of the 2013 IEEE Industry Applications Society Annual Meeting, Orland, FL, USA, October 2013.

Innovative Technologies 2014

Winner: NTT Communication Science Laboratories*
* Researchers involved include Tomohiro Amemiya, Shinya Takamuku, Sho Ito, and Hiroaki Gomi
Date: October 23, 2014
Organization: The Ministry of Economy, Trade and Industry of Japan

For "Buru-Navi3: Creating an Illusory Sensation of Being Pulled."

We have succeeded in developing a small force-display gadget, "Buru-Navi3," for experiencing a kinesthetic illusory sensation of being continuously pushed or pulled. We demonstrated Buru-Navi3 at the Digital Content Expo 2014, Tokyo, Japan, on October 23–26, 2014. At our booth, as a basic demonstration, visitors enjoyed this force illusion by specifying a stimulus direction on a touch screen. We also showcased a virtual fishing game with the downward force sensation of fish tugging on a fishing line and a virtual force interaction via a leash while walking a dog, as applications of our force-display gadgets.

Award for Encouragement of Research in IUMRS-ICA 2014

Winner: Kazuyuki Hirama, NTT Basic Research Laboratories
Date: October 31, 2014
Organization: International Union of Materials Research Societies, International Conference in Asia (IUMRS-ICA)

For "Nitride/Diamond Heterostructure Systems - From Growth to Devices."

I introduced ultraviolet emission from an AlN/diamond LED (light-emitting diode) and excellent thermal properties of an AlGaN/GaN FET (field-effect transistor) on diamond as successful examples of nitride/diamond heterostructure systems. Moreover, I reported the thin film growth of single-crystal c-BN, which has not been successfully applied in nitride semiconductors.
Published as: K. Hirayama, "Nitride/diamond heterostructure systems - from growth to devices," Proc. of the 15th IUMRS-ICA, Fukuoka, Japan, August 2014.

Papers Published in Technical Journals and Conference Proceedings

Efficient Multi-User Transmission Technique with Frequency Division for WLANs

S. Shinohara, B. A. Abeysekera, Y. Inoue, Y. Asai, and M. Mizoguchi

Proc. of the 79th IEEE Vehicular Technology Conference (VTC 2014-Spring), Seoul, Korea, May 2014.

The upcoming wireless LAN standard IEEE 802.11ac extends the channel bandwidth from conventional 20 or 40 MHz to 80 or 160 MHz to increase the data rate. Consequently, there could be stations supporting different channel bandwidths in one area. Stations belonging to the same basic service set (BSS) have to operate on the primary channel, which is a common 20-MHz sub-channel. In such a situation, the secondary channels associated with the primary channel may remain unused and, as a result, the system capacity will be

degraded. To address this problem, we propose a multi-user multi-channel transmission technique to improve the efficiency of downlink transmissions. The computer simulation results confirm the effectiveness of the proposed method.

Reflective Multi-view Screen and Mobile Projectors for Communication Displays

M. Date, T. Kawakami, M. Sasai, S. Ozawa, S. Mieda, H. Takada, Y. Suzuki, and T. Uchida

Proc. of Society for Information Display's (SID) Display Week 2014 International Symposium, Seminar and Exhibition, Vol. 45, No. 1, pp. 892–895, San Diego, CA, USA, June 2014.

A reflective multi-view projection screen for portable video group communication is proposed. Its stack structure of Fresnel lens, mirror, and optical diffuser enables the directivity display that is important for video conferencing, and its high optical efficiency enables the use of mobile projectors.

Large-scale Integration of Wavelength-addressable All-optical Memories in a Photonic Crystal Chip

E. Kuramochi, K. Nozaki, A. Shinya, K. Takeda, T. Sato, S. Matsuo, H. Taniyama, H. Sumikura, and M. Notomi

Nature Photonics, Vol. 8, pp. 474–481, June 2014.

We have demonstrated for the first time that over 100-bit wavelength addressable all-optical memory was monolithically integrated on a silicon photonic crystal chip. We have also demonstrated limitless storage time and random write/readout operation of 28-bit all-optical memory with a total power consumption of less than 150 μW by using a buried-heterostructure InP photonic crystal nanocavity array.

Toward Integrating Overlay and Physical Networks for Robust Parallel Processing Architecture

K. Suto, H. Nishiyama, N. Kato, T. Nakachi, T. Fujii, and A. Takahara

IEEE Network Magazine, Vol. 28, No. 4, pp. 40–45, July 2014.

In this paper, we introduce a design methodology of an overlay-based parallel processing architecture based on integration of overlay and physical networks. Additionally, we introduce basic principles based on the design methodology. Through numerical calculation, we evaluate the effectiveness of an integration approach on the performance of parallel data processing in terms of higher service availability against physical network failures while minimizing traffic load.

Performance Measurement of Broadband Simple Decoding in Short-range MIMO

K. Hiraga, K. Sakamoto, T. Seki, T. Tsubaki, H. Toshinaga, and T. Nakagawa

Proc. of the IEEE 25th International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC 2014), pp. 289–292, Washington DC, USA, September 2014.

This paper presents a demonstration of a simple decoding method for two-branch short-range multiple-input multiple-output (MIMO) transmission in a broadband with eight percent relative bandwidth, which corresponds to two-channel usage in the 60-GHz band. An experimental evaluation of the method was performed after prototyping the array antenna and weight matrix circuit. The evaluation results showed signal separation performance of 15 dB was obtained through the frequency range of 24.0–26.0 GHz. Bit error rate (BER) was simulated using measured transmission characteristics and we determined that 16 QAM signals at this band can be transmitted in the prototype system.

Combining Calibration Schemes on a Real-time Multiuser MIMO-OFDM System with Implicit Feedback

H. Fukuzono, T. Murakami, R. Kudo, S. Shinohara, Y. Takatori, and M. Mizoguchi

Proc. of PIMRC 2014, pp. 87–91, Washington DC, USA, September 2014.

This paper evaluates the performance of a real-time multiuser MIMO system with implicit feedback, we have developed using FPGAs (field-programmable gate arrays), in an indoor environment. It is shown that our proposed calibration scheme, WCC (World Calibration Centre), has superior performance to conventional schemes.

A Basic Study on High Bandwidth Streaming in Realtime over Multipath Using LDPC-IRA Codes and Its Evaluation

M. Kitamura, H. Kimiyama, T. Ogura, and T. Fujii

Proc. of the 7th International Conference on Internet and Distributed Computing Systems (IDCS 2014), pp. 217–226, Calabria, Italy, September 2014.

This paper describes a distributed video streaming system using widely dispersed storage, in which each storage host sends chunked video packets to a single receiver through a multipath network. By adding parity packets by forward error correction (FEC) along with source video data in each storage host, this system enables real-time video streaming even if there is an imbalance between the hosts. In this paper, we introduce a model of this imbalance and its effect on the number of packets that need to be sent, then discuss how to design the redundancy rate in FEC. The results are shown to have a trade-off between the range of balancing and the additional number of sent packets needed for stable video streaming.

Low-loss and Low-power-consumption Wavelength Tunable Filter Enabling Colorless/Directionless/Contentionless Optical Drop in ROADMs

S. Takashina, Y. Mori, H. Hasegawa, K. Sato, and T. Watanabe

Proc. of the 40th European Conference on Optical Communications (ECOC 2014), Cannes, France, September 2014.

We proposed a novel tunable-filter configuration for optical C/D/C (colorless/directionless/contentionless) drop in reconfigurable optical add-drop multiplexers (ROADMs), which achieves low insertion loss and low power consumption. A prototype is monolithically fabricated with PLC (planar lightwave circuit) technologies and its good filtering performance is experimentally confirmed by BER (bit-error-ratio) measurement.

Novel Large-port-count Optical-switch Architecture for Optical Interconnection in Datacenter

K. Ueda, Y. Mori, H. Hasegawa, K. Sato, and T. Watanabe

Proc. of ECOC 2014, Cannes, France, September 2014.

We propose a novel optical-switch configuration for intra-datacenter interconnection that consists of tunable lasers, non-cyclic AWGs (arrayed-waveguide gratings), and combinations of small-size optical switches and couplers. We developed an 800 × 800 switch prototype and verified its good performance and scalability in experiments.

Commuting Quantum Circuits with Few Outputs are Unlikely to be Classically Simulatable

Y. Takahashi, S. Tani, T. Yamazaki, and K. Tanaka

arXiv, 1409.6792v1 [quant-ph], September 2014.

We study the classical simulatability of commuting quantum circuits with n input qubits and $O(\log n)$ output qubits. We show that there exists a commuting quantum circuit that is not classically simulatable (under a plausible assumption). This is the first formal evidence that a commuting quantum circuit is not classically simulatable even when the number of output qubits is exponentially small.

Education × ICT = ?

Y. Kato

Journal of the Japanese Society for Information and Systems in Education (Japanese edition), Vol. 31, No. 4, pp. 249–250, October 2014.

As a preface note of the Journal of the Japanese Society for Information and Systems in Education in October 2014, this paper overviews the history of the field of education × information and communication technology (ICT). It also covers trends such as MOOCs (massive open online courses) and flipped classrooms and reviews future directions.

Influence of InGaN/GaN Multiple Quantum Well Structure on Photovoltaic Characteristics of Solar Cell

N. Watanabe, M. Mitsuhara, H. Yokoyama, J. Liang, and N. Shigekawa

Japanese Journal of Applied Physics, Vol. 53, 112301, October 2014.

We have investigated InGaN/GaN multiple quantum well (MQW) solar cells in terms of the relationship between the short-circuit current and the MQW structure. The dependence of short-circuit current on the MQW structure can be explained by the hypothesis that the transport characteristics of photoinduced carriers are characterized by the specific length within which carriers photoinduced in the InGaN well layer can move before recombination. The carrier collection efficiency is improved by the drift in the barrier layer due to the forward internal electric field and degraded by the carrier accumulation in the well layer caused by the inverse internal electric field and the potential barrier between layers, which well describes the influence of the MQW structure on the specific length. Using this model, we discuss how we can determine the MQW structure that yields higher short-circuit current.

Systematic Hole-shifting of L-type Nanocavity with an Ultrahigh Q Factor

E. Kuramochi, E. Grossman, K. Nozaki, K. Takeda, A. Shinya, H. Taniyama, and M. Notomi

Optics Letters, Vol. 39, No. 19, pp. 5780–5783, October 2014.

We report simple systematic hole-shifting rules applicable to any Lx (x:2; 3; 4; 5;…) nanocavity. The rules specify six sets of holes to be tuned with only two or three shift parameters. While keeping the same cavity wavelength and nearly the same mode volume, the new rule increases the Q factor by nearly one order of magnitude compared with an edge-hole-shifted Lx nanocavity. The Q factor of the high-order mode is also greatly increased. This merit is obvious from the maximum experimental Q factors of over 500,000 at L2 and of over 1,000,000 at L3, L4, and L5 achieved in Si photonic crystals.