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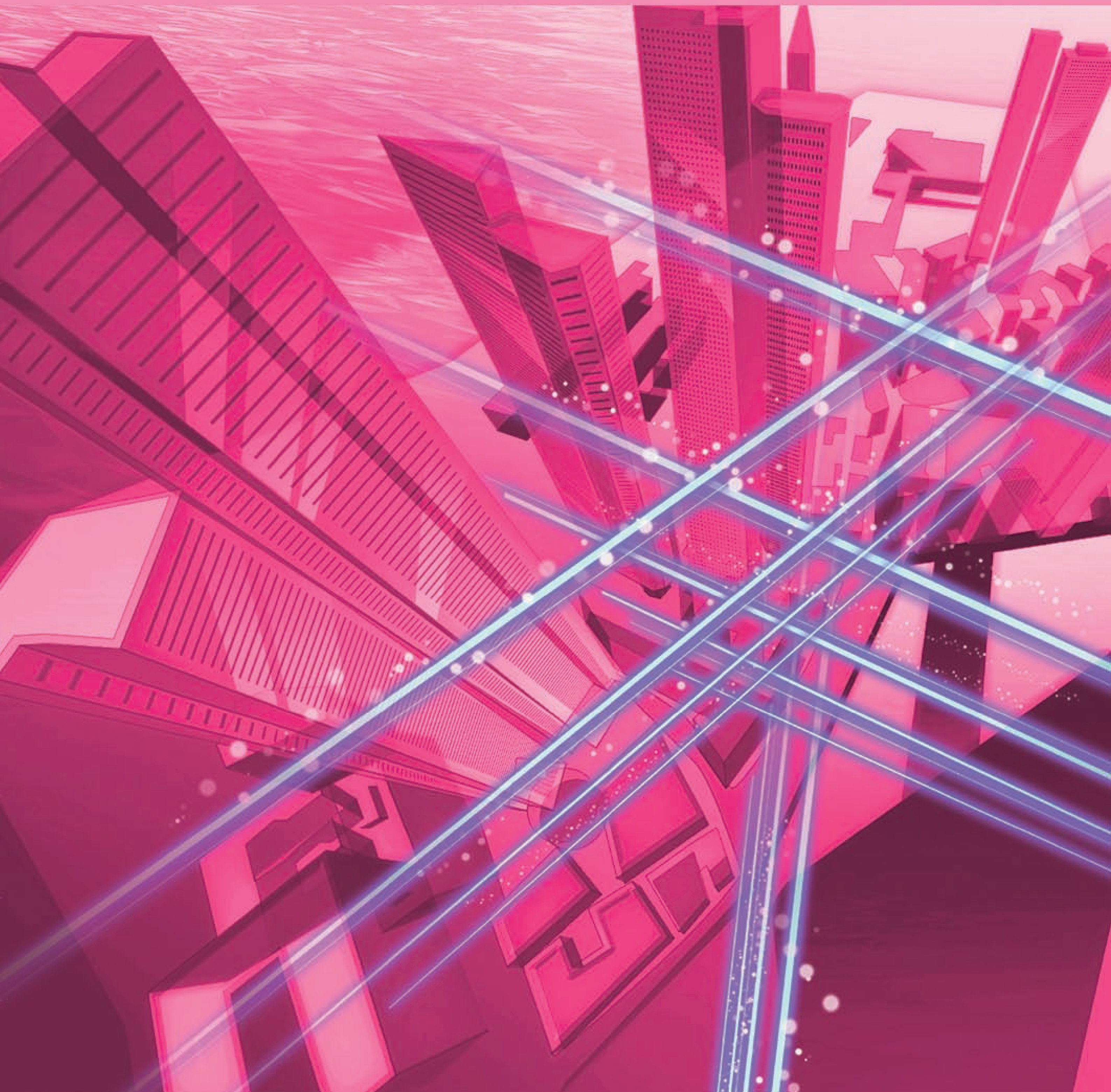

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Thinking and Trying while Running; Heading toward the Inter-service Era as a Value Partner

Mitsuyoshi Kobayashi,
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Overview

Mitsuyoshi Kobayashi, Senior Vice President and Director of the Technology Planning Department of NTT, says that we need to adopt a new corporate mindset that places importance on the new *inter-service* era and the challenges that this market brings. We asked him about NTT's Medium-Term Management Strategy and how he is preparing to work in a telecommunications industry that demands speed and new value creation.

Keywords: telecom, strategy, resilient network

The smartphone and cloud as the lead players of this era—new business opportunities in the market

—Mr. Kobayashi, how would you describe the current conditions in the telecommunications industry?

The speed at which technology is advancing is simply amazing, and foremost among this phenomenon is the rapid expansion of the smartphone market. Far from being a gradual development, the increase in smartphone sales seems to have occurred all at once. The smartphone, so to speak, is a mobile computer. Up to recently, the mobile phone had just been a tool for making calls, but it is now evolving into a solutions terminal that can resolve problems in accordance with customer desires and needs.

Last fiscal year, sales of NTT DOCOMO terminals reached approximately 24 million units, with more than half of that being smartphones. This trend is only getting stronger, and sales are expected to increase by nearly 70% this fiscal year.

The lead player in the telecommunications industry is changing completely from fixed to mobile communications. According to an information-communications white paper published this year, the number of fixed broadband subscribers in Japan, which can be counted among the world's top broadband countries, is somewhat static at approximately 35 million, including optical and other types of broadband services. However, mobile broadband in Japan is increasing at an annual rate of more than 10 million contacts centered around mobile phones.

The number of mobile broadband subscribers at the end of the last fiscal year was around 140 million, which is more than the population of Japan[*1] and thereby greater than the rate of one phone per person. It can therefore be considered that mobile broadband subscribers are entering a saturated state, but new ways of using mobile broadband are nevertheless being thought up. For example, if automobiles are equipped with communication functions, we can envision that the number of mobile broadband subscribers will increase by several tens of millions, and a wide variety of related services will be created. Consequently, we can expect mobile services to expand even further in the years to come.

We must also note the growth of the cloud. It's not simply that corporate customers are coming to use the cloud in increasing numbers, but also that many of the services that you and I use on a daily basis are utilizing the cloud.

Up to now, it appears that carriers like us have mainly been concerned with thinking about and providing services, but over-the-top (OTT) operators have recently entered the market to provide services that combine cloud technology and smartphones. For example, applications that provide free voice calls such as LINE are now appearing, with the result that voice calls are simply becoming an "added bonus." This is a devastating development for telecommunication carriers like NTT, for which revenues from phone services have been a major foundation of their business.

Another development is that traffic is increasing annually owing to the advances made in fixed and mobile broadband services. Traffic from mobile communications in particular is doubling every year. We can attribute this increase in traffic to growth in video-related services. The NTT Group provides video services such as FLET'S TV, Hikari TV, and dVideo, and the total number of subscribers for video services as of the end of July 2013 was approximately 10 million, which is twice that of 2012.

This means that network capacity must expand by that amount, but under the present system of flat-rate subscribers, NTT and other telecommunication carriers cannot expect to increase their earnings in proportion to the amount of communications traffic. In other words, we are faced with a situation in which an increase in traffic is not reflected in revenues.

*1 127.3 million as of October 2013 by Statistics Bureau, Ministry of Internal Affaires and Communications

Medium-Term Management Strategy "Towards the Next Stage"

—It's natural for a business enterprise to think about revenue. How do you plan to deal with this issue?

Our business model and service format must change rapidly to keep up with the times. The NTT Group adopted a new system last fall and formulated a Medium-Term Management Strategy called "Towards the Next Stage."

Although it's still in the planning stage, a key element of this strategy is the concept of "inter-service," which I will believe will become our guidepost going forward. It's been nearly 20 years since the birth of the modern Internet (considered to be 1995) and the first time that the Internet Explorer browser was installed as standard in personal computers (PCs). Since then, the Internet has spread explosively and brought about major changes in our daily lives and corporate business models. When I think about what the Internet could become in the future, I can see that there is still lots of room for improvement.

One area for improvement is ease of use. At present, various types of operating systems (OSs) exist for mobile terminals and PCs, which forces service providers to prepare services that match each OS and device type. To get many customers to use a service, it must be developed and maintained for each OS. In addition, a number of telecommunication carriers exist, and NTT customers, for example, can only use services connected to the NTT network. The types of terminals on which a service can be used are also limited. For customers who would like to enjoy a variety of services, this situation can hardly be called convenient.

In the beginning, the meaning of the Internet was to "connect" or "join together" disparate networks. Now, from the customer's point of view, the prefix "inter" will come to mean more than just the physical connection of networks—it will also mean the open and seamless connection of services on those networks and the OS-free and device-free use of those services. This is the inter-service concept.

However, if the NTT Group were to take up this kind of business, the result would be similar to a Ptolemaic (geocentric) system. Beyond our corporate customers are general customers, and if we were to attempt to provide new services in this field, it would require an around-the-clock effort. Going forward, we should aim to expand in business areas in which we assist our corporate customers as a value partner in creating new services, and at the same time, to search out the best match between different services. It often happens that companies and general customers are ignorant of just what types of services exist, so we can play a role here as an intermediary providing a "connection" function, that is, in finding an optimal service or even multiple services that satisfy a customer's needs and provide greater value all around. This is the type of inter-service world that I would like to create.

Making service-to-service and customer-to-customer connections

In terms of concrete actions, we are beginning by exploring various ideas, for example, "online to offline." In this effort, we aim to provide new added value by linking the network world with the real world.

To take the case of shopping as an example, the conventional way is to go to a retail shop in person and purchase desired products. These shopping actions are usually done independently from those performed when purchasing products on the Internet. However, by combining these two forms of shopping, we can create new added value. Specifically, we can provide the consumer who is searching for products on the Internet with information on where to go to actually see those products in person, and at the same time, we can provide retailers with information on the fact that such customers exist and on what products they find interesting.

One example we are now working on is a link-up between Tokyo Metro and Seven & I Holdings Co. through an information delivery service using a Wi-Fi platform. Here, we install a Wi-Fi antenna in each 7-Eleven convenience store and provide services unique to each store. For example, we can enable musical content of a popular singer to be downloaded only at a specific store, and we can provide information on that service at a nearby train station. This should have the effect of encouraging customers to visit that store, which should, in turn, promote consumer activity, that is, product purchases, while they are downloading content using the Wi-Fi service.

Since Wi-Fi can be used irrespective of the type of terminal or OS, this service can be provided even to customers who receive their telecommunication service through other carriers. Using such an open and direct, carrier-independent means of access can open up lots of business opportunities. In this way, we are exploring ways of making service-to-service and customer-to-customer connections to uncover more inter-service possibilities.

Building a resilient, flexible, and strong network

—How do you feel about the idea that a business strategy should consist not only of entering new fields but also of fortifying existing capabilities?

I would like to think first about a service-driven network. Here, I don't actually mean thinking about services over the network but rather about creating an easy-to-use network that service-providing companies will want to use.

As for fixed communications services, we cannot expect a huge increase in the number of subscribers.

Nevertheless, video services such as those that provide high-quality TV programs must be able to deliver large amounts of information, and developing optimal optical broadband technology for this purpose is still a very active field.

We must also keep in mind that the mobile network employs a fixed optical fiber network running from base stations to the core network. I believe that this optical fiber network will become increasingly important from here on.

Of course, we can hardly think that customers utilize only the fixed network, so we must think about ways of forming tie-ups with the mobile network.

There are regulations covering the provision by NTT of combined fixed and mobile services, so doing so is unfortunately difficult at present. From the customer's point of view, however, I think that a world in which services could be enjoyed over an optimal network regardless of whether they are fixed or mobile would certainly be desirable.

In the wake of the Great East Japan Earthquake, we must think about a stable, safe, and secure network that is robust to disasters and resilient to sudden jumps in traffic as well as an energy-saving network that is less susceptible to nuclear power plant problems and steep rises in fuel costs.

We must also consider the need for a network that can provide low-rate services. An expensive network will not be used, and value comes out of using a network. We need to continue our efforts in making the NTT network all the more competitive.

The NTT business companies are already taking various measures in this regard, but to enhance our ability to provide a highly competitive network, we must look to NTT research and development (R&D). One way of radically lowering costs is to incorporate virtualization and SDN (software-defined networking) technologies, which are now being studied. I think these technologies will be the focus of even more research activity in the future.

Furthermore, considering that fixed, mobile, and domestic/overseas networks have so far been constructed independently by the various NTT business companies, we again look to R&D to drive the construction of an optimal network that applies technologies to be used by the entire group and that minimizes costs. I am confident that all concerned will show a high level of leadership in this regard.

Learning from the words of Hakuin Zenji: Meditation in the midst of activity is a thousand times superior to meditation in stillness.

—What do you think is an essential element of a business strategy in today's world?

In today's rapidly changing world, it goes without saying that responding to the market with a sense of urgency is an absolute necessity. Those who stop and hesitate and fail to think and come up with answers while they are running will be left behind in no time at all in this era.

A dynamic and quick response is certainly the key. In my case, moving suits my temperament more than thinking. In relation to this, the NTT Group once attempted to develop PC equipment at a time when custom-made PCs were appearing. "Custom-made" was an idea that was not born out of conventional NTT thinking.

By grasping the times and making an actual move, we were able to obtain valuable feedback on our customers' way of thinking and advanced business models. Unfortunately, the result was not that great, but the know-how cultivated from this endeavor is still nourishing the NTT Group and myself as well. Try thinking of a moving *shinkansen* train carrying customers in the current era. When viewed from a fixed point, it is very hard to make out who or what is riding on the train. To do so, you have to run parallel to the train at the same speed or even faster.

I once learned from a certain individual the words of *Hakuin Zenji*[*2], a famous Japanese Zen master:

*2 Hakuin Ekaku (1686–1768) was one of the most influential figures in Japanese Zen Buddhism.

"Meditation in the midst of activity is a thousand times superior to meditation in stillness." Certainly, this means that testing out acquired wisdom while moving enables one to acquire new wisdom and make it a part of oneself. These words express the stance that we need to take in this era.

—Mr. Kobayashi, can you leave us with a few words for everyone in the NTT Group?

At the risk of putting on airs, I live by those words—I feel that it is important to think while running. Even if a variety of constraints are said to exist, going ahead and trying something instead of worrying about those constraints and doing nothing will at least enable you to learn something about those restrictions. In fact, you may find out that those constraints were not such a problem after all. Taking up the challenge of achieving what has previously been inconceivable may actually bring change to the world. This doesn't mean we should have a reckless attitude, but it does mean that we should run in a focused manner in a common direction.

Interviewee profile

■ Career highlights

Mitsuyoshi Kobayashi joined Nippon Telegraph and Telephone Public Corporation in April 1982. He served as Senior Manager of the Personnel Department of NTT WEST beginning in 2002, as General Manager of the Okayama Branch of NTT WEST beginning in 2006, and as a Senior Vice President and General Manager of the Service Management Department of NTT WEST beginning in 2008. He took up his present positions in June 2012.

Applying Big Data in Innovative Ways as the Leader of a New Interdisciplinary Research Center

Naonori Ueda
Director of Machine Learning Data Science Center,
Senior Distinguished Scientist,
NTT Communication Science Laboratories

Big data has been attracting a great deal of attention in recent years, but there is still no real sense of the role it can play in society. NTT is now taking a giant step toward the widespread, practical application of big data analysis. Senior Distinguished Scientist Dr. Naonori Ueda is an active pioneer in the research of machine learning. We asked him about his career in research and about the Machine Learning Data Science Center that he directs.

Keywords: big data, machine learning, statistics

From an early interest in statistical learning theory to becoming an expert in machine learning

—Dr. Ueda, please tell us about your research career to date.

After receiving my M.S. degree in communication engineering from Osaka University in 1984, I entered the Electrical Communication Laboratories of Nippon Telegraph and Telephone Public Corporation in Yokosuka, Japan. At that time, I was assigned to a laboratory involved in the research and development (R&D) of image-processing and pattern-recognition technologies, but since the group was right in the middle of using their research results in practical applications, and as I was just a newcomer, I was relegated to doing tasks outside research such as taking the minutes of meetings and carrying magnetic tapes to other research sites. During whatever free time I had, I read books and papers on specialized topics to learn as much as I could, and I found myself yearning to become more involved in pure research.

One year later, Nippon Telegraph and Telephone Public Corporation was taken private to become NTT. I was given the task of covering up labels saying "Nippon Telegraph and Telephone Public Corporation" on a huge number of devices and fixtures with stickers having the name "NTT." I remember with some fondness how I was buried under with this work for days on end and how I even surprised, if not angered, some female employees when I crawled under their desks to affix these stickers. NTT R&D was also targeted for restructuring, and with the establishment of NTT Human Interface Laboratories in 1987, some personnel including myself were transferred there, and I was assigned to do basic research

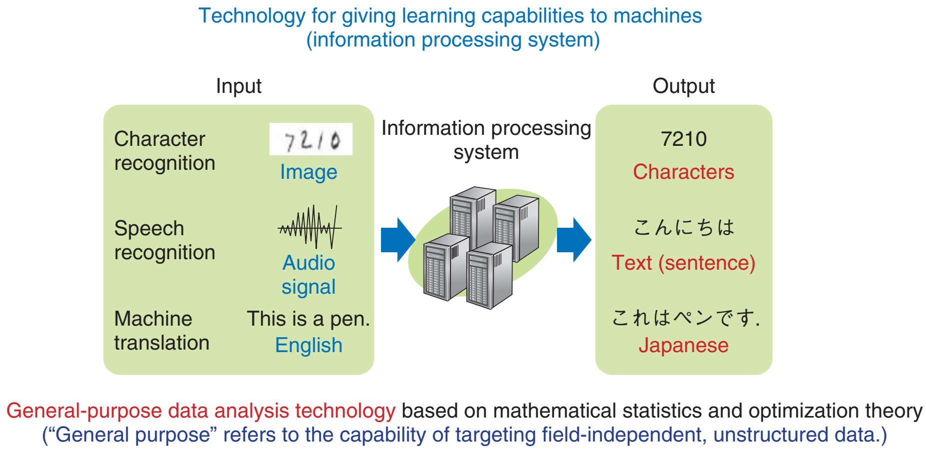


Fig. 1. Outline of machine learning technology.

in the field of computer vision. Specifically, I took up the theme of image understanding from line drawings, and it was at this time that I began to develop an interest in statistical learning theory.

Then, in 1991, I moved over to the newly established NTT Communication Science Laboratories in Keihanna and began doing basic research in the field of statistical machine learning (**Fig. 1**). The next ten years proved to be a very fulfilling time for me as I was able to immerse myself in research with stays at Purdue University in the United States as a visiting scholar, the University College London in the United Kingdom for short-term research, and elsewhere. Then, beginning in 2010, I served for about three years as director of NTT Communication Science Laboratories. Finally, in April 2013, I became a Senior Distinguished Scientist and in July, Director of the newly established Machine Learning Data Science Center (MLC). I should mention here that MLC was initially founded as a virtual organization in April 2013 but was launched as a formal organization in July 2013. My superiors said to me, "There are great expectations that MLC will bring machine learning and big data together and make a huge contribution to the R&D of big data applications at NTT." As director, I take my position very seriously and realize that this is a heavy responsibility.

Machine learning as an optimal tool for creating new value from the analysis of human behavior

—What exactly is machine learning?

Machine learning was developed in around 1970 as a research field within the area of artificial intelligence. Neural networks, by the way, which boomed in the 1980s, are a type of machine-learning technology that has come to be used in a variety of application fields. This boom died down some years later, but machine learning, perhaps as a result of the fact that the boom died down, went on to evolve into a somewhat simple form of mathematics-oriented research called learning theory.

Learning methods can be broadly divided into supervised learning and unsupervised learning. An example of supervised learning would be a mother (as teacher) instructing her child on how to discriminate between a hat and a ball by saying, "this is a hat but that is a ball." This type of learning has come to be used in pattern recognition technology as in the recognition of hand-written characters. An example of unsupervised learning would be a child observing what is common and what is different between a hat and a ball on his or her own. Clustering, or grouping of similar data, which is a basic process in data analysis, can be thought of as unsupervised learning. Various types of cluster analysis have recently come into use for such applications as determining what sorts of communities have formed on a social networking site or what sorts of shoppers are using an e-commerce site.

What is the difference between machine learning and conventional data analysis? Predicting the weather, for example, is a *science* that derives answers based on the way in which the atmosphere changes, for example, from the formation of certain types of

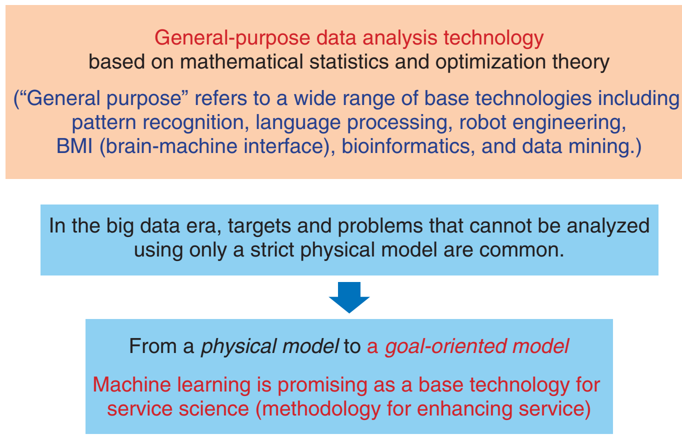
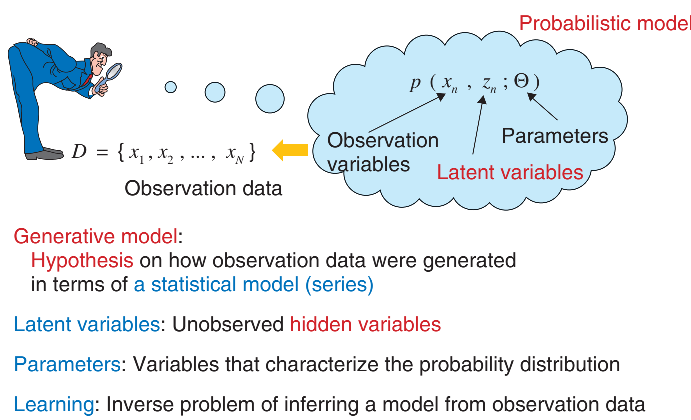


Fig. 2. Usefulness of machine-learning technology in the big data era.



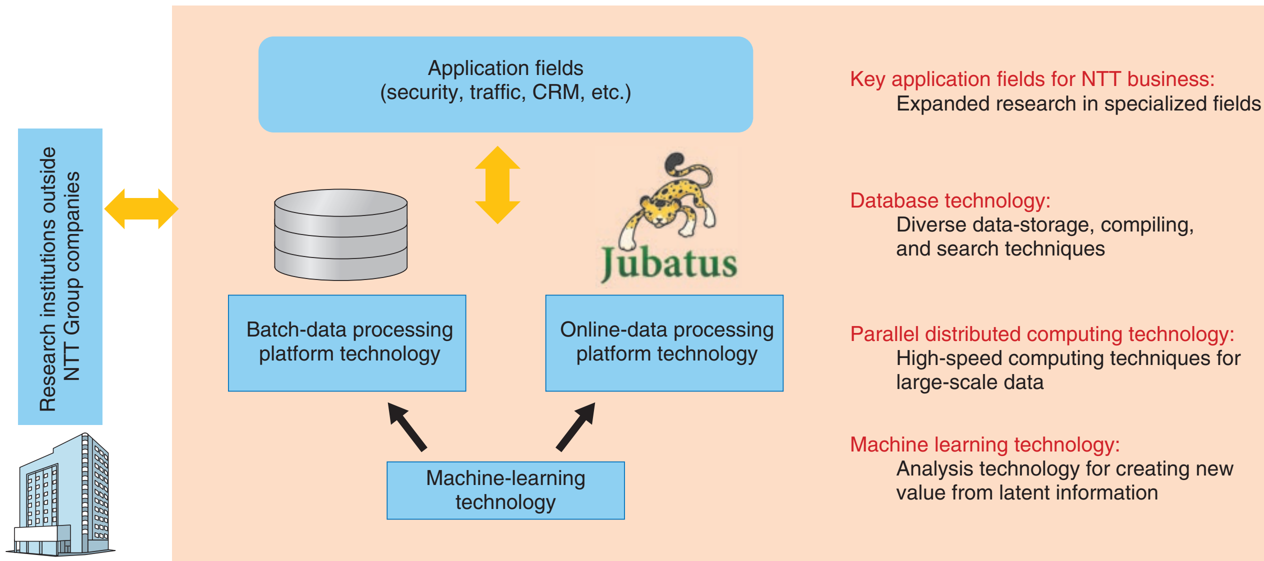
Fig, 3. Statistical machine learning based on a statistical model.

clouds. Machine learning, however, is different in that it obtains knowledge from many observations much like a local fisherman would say, “If these kinds of clouds appear, it will rain tomorrow.”

Although some basic principles may be used, machine learning predicts the future by establishing a model for the mechanism that generates the data behind the observation data. This model is not necessarily true, which lies in contrast with science, in which the theories that it derives must hold true.

For example, if the process of modeling human purchasing behavior came down to the modeling of humans themselves, it could very well take more than 100 years to come up with a good model. A much faster approach would be to use observation data on what kinds of people purchase what types of products under what conditions to realistically determine what actions an individual can be expected to take. This is called a data-driven approach.

Modeling in machine learning can consequently be called a *service science* (science whose purpose is to enhance service), and in this sense, it has come to be applied to big data applications that deal with a huge and diverse amount of real-world data. In short, machine-learning technology has come to be viewed as a useful tool in big data analysis (**Fig. 2**). There are various types of research approaches in machine learning, but I myself am researching a statistical machine-learning approach based on statistical models (**Fig. 3**). With a statistical model, it becomes possible to make use of even vague information and to make predictions in a statistical manner. I believe that



CRM: customer relationship management

Fig. 4. Machine Learning & Data Science Center (MLC).

this is a useful technology for carrying out decision-making using big data.

Research in the field of machine learning predates the big data era, and machine-learning technology has, in fact, come to be used in a variety of fields such as machine translation. Machine-learning technology has also come to be used as an elemental technology in voice-recognition systems such as NTT DOCOMO's Shabette Concier (Talking Concierge) voice agent and in portal-site recommendation systems. It would be no exaggeration to say that machine-learning technology is a general-purpose technology for information processing systems.

Aiming toward a new world merging Jubatus and machine learning as Director of the new Machine Learning Data Science Center launched this spring

—Please tell us about the Machine Learning Data Science Center.

The term "big data" has come to be somewhat of a buzzword today, but MLC was established as an R&D base within the NTT laboratories to create innovative services from big data. It is an interdisciplinary organization bringing together researchers from related fields that have up to now been dispersed across a number of research laboratories. There are various dimensions to big data such as data collection and management and data security, but R&D at MLC focuses on the analysis of big data. It is for this reason that machine learning by itself is insufficient. To process a massive and diverse volume of data in an efficient manner, we are researching and developing, for example, the combination of machine-learning technology with the Jubatus parallel distributed computing environment developed jointly by NTT laboratories and Preferred Infrastructure (PFI), a venture company (**Fig. 4**).

Our mission is twofold. First, we will brainstorm with NTT Group companies as a technology consultant to determine how to analyze big data held inside and outside the NTT Group to create new value, and we will develop new technologies for doing so. Second, we will create innovative general-purpose data-analysis technologies in the context of big data. These two parts of our mission have a mutually dependent relationship. In the second part, the presentation of an academic paper on a new data-analysis technology does not mark the end of our work. The technology is meaningless if it is not applied to a real-world problem and evaluated accordingly. In the big data era, field trials take on even more importance.

We currently have about 20 researchers working at MLC, which is hardly a great number, but I think we will become a substantially larger organization as we broaden our interaction with NTT Group companies going forward.

—The Machine Learning Data Science Center seems to have received much attention at Open House 2013.

Yes, I received questions from reporters on the purpose of launching MLC at the NTT Communication Science Laboratories Open House 2013 held in June. There was also much interest in what types of analysis would be targeted by machine learning. To give a specific example, we are collaborating with the medical-care producer of the NTT Research and Development Planning Department to develop a system for analyzing the health-checkup data of NTT employees. We feel that such analysis will prove useful in health promotion and disease prevention for all NTT employees.

I also received questions from reporters on the key feature of MLC. As I mentioned earlier, the MLC is made up of researchers from diverse technology fields such as machine learning, parallel distributed computing, and database technologies as well as applied technologies like customer relationship management (CRM) and security, all specialties of NTT laboratories. Big data analysis through inter-field collaboration is the strength of MLC.

Creating scenarios with a focus on social problems so that big data does not die out as a temporary boom

—What is the future outlook for big data analysis?

One difficulty in big data analysis is that the outcome of such analysis is unknown. For example, when research is done on a new device, the specifications for that device may be set beforehand as target values, and work to meet those values can then be carried out, but in big data analysis, my colleagues and I must from the start create a basic analysis scenario that describes what it is that we want to do. The big question here is whether such a scenario can help deal with social issues such as disaster prevention. Simply refining an elemental technology will not bring forth a scenario with a sense of innovation. I would like to hold discussions with group companies that have abundant channels to customers and society with the aim of contributing to the solutions of serious problems and creating value through big data analysis.

Up to now, researchers in the field of machine learning have led a somewhat behind-the-scenes existence, and they have had a comparatively high degree of freedom in their work. Now, in the big data era, they suddenly find themselves in the spotlight and thrust onto the front stage. This is essentially a boost for researchers, but it also means that they now have to deal with questions like "What can you do with your research?" and "What have you accomplished?" If researchers produce no truly useful results, big data will come to an end as just a temporary boom. I believe it is necessary for us to use the current flow in big data as a tailwind and work aggressively to refine our technology with the aim of making important social contributions.

Up to now, I myself have been engaged in basic research in the field of machine learning without any specific plans for taking on big data. Perhaps I am therefore an amateur of sorts, but in this era of big data, my aim is to determine how technology can be used to advance society as a major issue in MLC.

Playing golf—a time to forget about research matters and enjoy one's favorite hobby

—Can you tell us how you spend your free time? Do you have any hobbies?

For researchers, the work of research makes it difficult to differentiate clearly between weekdays and holidays and to keep research-related matters out of one's mind. I have said that scenarios are essential to creating new value from big data, but that requires imagination. Since technical books are hardly a source of imagination, I try to read a wide variety of books to expand my interests and broaden my values. I'm not sure whether this can be called a "hobby" as such.

My true hobby is golf. Although I only get out to a golf course about once a month, I also enjoy researching golf theory by reading good books about it and finding information on the Internet. I also played tennis during my student days, but I developed an interest in golf under the influence of my father and older brother. Playing golf was always enjoyable if only for the opportunities it provided for socializing, but about seven or eight years ago, I began in earnest to think about and study how to become a better golfer.

When playing golf, you come to realize that "patience is the key." When starting out, it only took one bad shot for me to feel disappointed in my game, but recently, I have learned that I can recover even if I totally botch one hole. This knowledge is a gift that comes from actually playing the game; there is a limit to what you can learn from golf theory alone. I said earlier that it is difficult for a researcher to keep research-related matters out of his or her mind, but as for me, it's amazing that it's only when I'm playing golf that I am not thinking about research. Golf is a great way to relieve stress!

Don't become a "jack of all trades, master of none" when young! First, sharpen your skills in your own research field.

—Dr. Ueda, can you leave us with some advice for young researchers?

I would be happy to. I have said that imagination is important in creating scenarios in big data analysis and that there is a need to broaden one's outlook and knowledge. However, there is an appropriate time for that depending on one's age, since a young person who tries to do too much at the same time runs the risk of becoming a "jack of all trades, master of none." When you are young, I believe it's important to sharpen your skills in your own research field without worrying too much about results or the usefulness of those results. Today, the research environment is experiencing some difficult conditions, and even universities must compete for funds, which means that even young researchers must be adept at emphasizing the social value of their work. Just the same, research of a superficial nature can hardly lead to success in the end. Since young researchers are blessed with time and physical strength and are at the peak of their mental abilities, doesn't it make sense that they should sharpen their skills in their own research fields while they are still young? The way to succeed is to stay focused and to "seize the bull by the horns" without getting discouraged by criticism such as being told their kind of research is not useful. Of course, there is also a need to maintain a sense of balance in terms of research beneficial to society, but if you are not ready to make an all-out effort to build an appreciable foundation of basic skills in an enthusiastic manner, working only with ideas will soon reach its limit. "Sharpen up your basic skills" is first and foremost a message for young staff involved in basic research, but I believe that skill sharpening could also be a beneficial approach for young staff in other fields too, such as application and development work.

Naonori Ueda

Director of Machine Learning Data Science Center, Senior Distinguished Scientist, NTT Communication Science Laboratories.

He received the B.S., M.S., and Ph.D. degrees in communication engineering from Osaka University in 1982, 1984, and 1992, respectively. He joined the Yokosuka Electrical Communication Laboratories of Nippon Telegraph and Telephone Public Corporation (now NTT) in 1984. In 1994, he moved to NTT CS Labs in Kyoto, where he has been researching statistical machine learning, Bayesian statistics, and their applications to web data mining. From 1993 to 1994, he was a visiting scholar at Purdue University, Indiana, USA. He is a guest professor at the National Institute of Informatics and a visiting professor at Kyoto University. He is a Fellow of the Institute of Electronics, Information and Communication Engineers and a member of the Information Processing Society of Japan and IEEE. He became Senior Distinguished Scientist in April 2013 and was appointed Director of Machine Learning Data Science Center in July the same year, after serving as Director of NTT Communication Science Laboratories for three years.

Applications of Big Data Analytics Technologies for Traffic and Network Management Data—Gaining Useful Insights from Big Data of Traffic and Network Management

Kohei Shiomoto

Abstract

The complexity of telecommunication networks continues to increase. Likewise, the complexity of traffic carried over these networks is also increasing. A data-driven approach is a promising technique for handling those complexities. We have been conducting research and development (R&D) on data analytics for traffic and network management by applying *big data technologies*. This article introduces the R&D activities involving applications of big-data analytics technologies for traffic and network management.

Keywords: big data, traffic, network management

1. Introduction

Big data technology is attracting a great deal of attention, and many research and development (R&D) efforts related to it are under way around the world. These include R&D efforts on data warehouse products and large-scale distributed data processing platforms such as Hadoop, and those on data analytics technologies such as machine learning and data mining. By applying these big data technologies to traffic and network management, we expect to gain useful insights from a huge amount of operational data, which we could not have exploited before without such technologies, to improve traffic and network management processes such as network planning and engineering, and network operation. Telecommunication networks are becoming increasingly complex, and as the Internet becomes ubiquitous in its fundamental role as a social infrastructure, the complexity of traffic carried over the telecommunication networks is also increasing. We expect that a data-driven approach will be effective in handling those complexities. We have been conducting R&D efforts on data analytics for traffic and network management by applying big data technologies. This article introduces the R&D activities centering on applications of big data analytics technologies for traffic and network management.

2. Big data for network management

Various kinds of data such as traffic measurement data, network configuration data, and data from network failure alarms are used in managing networks. By analyzing such data we obtain information that is useful for network planning and engineering, as well as for network operation (**Fig. 1**).

Traffic measurement data include packet count and byte count, which are measured and collected per link and per flow by the router as a management information base (MIB) and as Netflow data. We use more detailed information than MIB and Netflow to

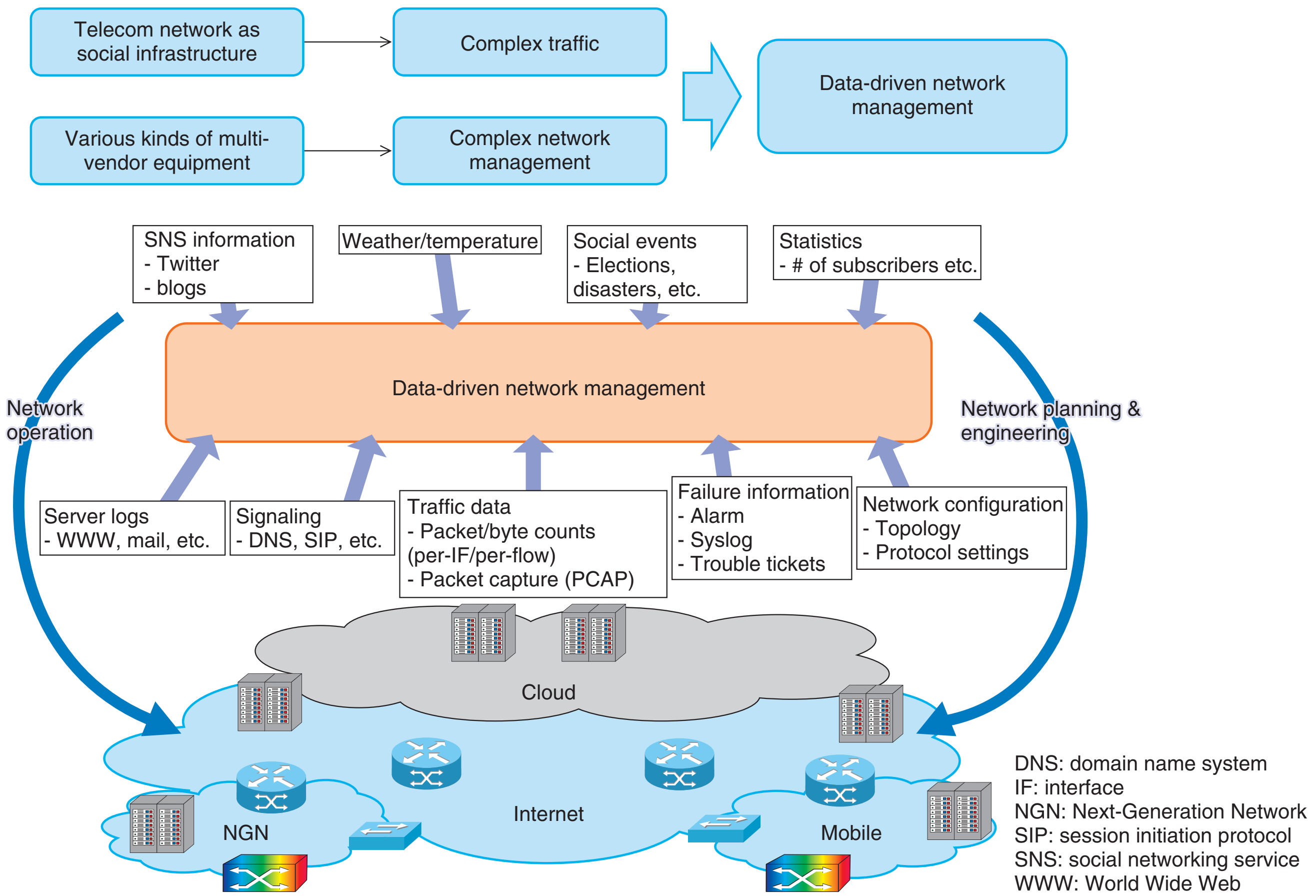


Fig. 1. Data-driven network management.

analyze traffic, which is becoming more and more complex. We capture and analyze all of the network data.

Network configuration data include the connectivity between network elements such as routers, switches, and servers, as well as information on protocol settings. The connectivity between network elements is collected from a database of the network management system or from the configuration files of network elements. Protocol setting information is collected from the configuration files of network elements and captured protocol messages.

Network failure alarms include alarm messages and log files of network elements and trouble tickets. Syslog messages are also exploited. These messages are unstructured and in free-text format, and are specific to each vendor. The original purpose of a syslog message is for debugging. The quantity of syslog messages generated from a network element can amount to thousands of lines per day.

In addition to the above-mentioned data, big data generated from outside the network can also be used. Information from social networking services (SNSs) and blogs, and data that can be collected from the web can be used for network management. Additionary, statistics on the number of subscribers, and information on weather, temperature, and social events can be used for this purpose.

3. Value of big data analytics in network management

3.1 Network planning and engineering

Understanding traffic characteristics is crucial for network planning and engineering. Telephone networks have a long history, and methods for managing them have been developed over a long period. As the Internet becomes ubiquitous in its role as a social infrastructure, various Internet applications have emerged, and the complexity of traffic carried over the telecommunication networks continues to increase. In particular, video traffic accounts for a large amount of the total traffic. It is therefore necessary to understand the details of video traffic to implement more effective network planning and engineering. Traffic characteristics will continue to change as new applications are developed and widely deployed. It is therefore crucial to continue measuring and analyzing traffic data. As stated previously, we can also benefit from other data such as statistics on subscriber numbers, weather, and temperature, as well as social event information, which affects the way telecommunications networks are used as a social infrastructure.

3.2 Network operation

As the role of telecommunication networks as a social infrastructure expands, outages of these networks have a huge impact. On the other hand, telecommunication networks are generally based on TCP/IP (transmission control protocol/Internet protocol). Various kinds of network elements such as switches, routers, and servers are deployed in telecommunication networks, and those network elements are manufactured by various manufacturers. Consequently, it is becoming more and more difficult to carry out troubleshooting when network failures and/or service outages occur.

By analyzing big data on alarm information, log information, trouble tickets, and network configurations, we expect to be able to carry out troubleshooting tasks more quickly and easily. Syslog messages are unstructured and in free-text format, and are vendor-dependent. The quantity of syslog messages per day generated from networks could amount to tens of millions of lines in large networks that include tens of thousands of network elements. We expect to be able to extract useful insights from big data of syslog messages. We are also looking at big data from SNSs such as Twitter in order to extract information that will be useful for network troubleshooting. Twitter can be regarded as a medium for disseminating short real-time messages. We expect to be able to rapidly detect network service outages when they occur by analyzing the big data of tweets. The examples of using syslog and Twitter data are discussed in more detail in the next section.

4. Case studies of big data analytics in network management

Here, case studies of the use of big analytics in areas of network management such as network planning and engineering, and network operation are presented.

4.1 Case I: Network operation (failure prediction and detection)

By analyzing a huge amount of unstructured data (syslog messages, SNS messages, etc.), we can develop methods of detecting failures that cannot be detected by existing network failure monitoring systems, as well as methods of analyzing the root causes of such failures. Machine learning is used to extract useful information for network operation (**Fig. 2**).

We are developing methods for analyzing syslog messages generated from network elements to find the root cause of failure and to detect predictive information for failures [1]. A machine learning algorithm automatically detects a set of simultaneously occurring syslog messages to understand the network event behind them. The method is applicable to syslog messages in unstructured and vendor-dependent formats. It helps to reduce the tedious tasks required in trouble-shooting by prioritizing and visualizing network events.

We are also developing methods for analyzing Twitter messages (tweets) [1]. Twitter disseminates short messages in a real-time manner. We expect that we can quickly detect how customers feel about network service conditions by analyzing their tweets. We take an approach for supervised machine learning by collecting tweets that appeared at times when network outages occurred and also at times of normal network operation as training data. We form a classifier based on a support vector machine (SVM) by using training data. We employ the classifier in a real-time manner to detect the tweets associated with network service outages. We quickly detected customer opinions on network service outages by analyzing their tweets as well as by monitoring existing call center operations.

4.2 Case II: Network operation (security)

Security is becoming a major concern in network operation areas. The use of botnets is spreading widely, which is threatening Internet security. Blacklists are used to contain the botnets. To prevent users from inadvertently accessing botnets, we use a blacklist of command and control (C&C) servers of the botnets and block the communication from users to those C&C servers. The botnets are sophisticated enough to expand their coverage by creating and spreading new C&C servers throughout the Internet.

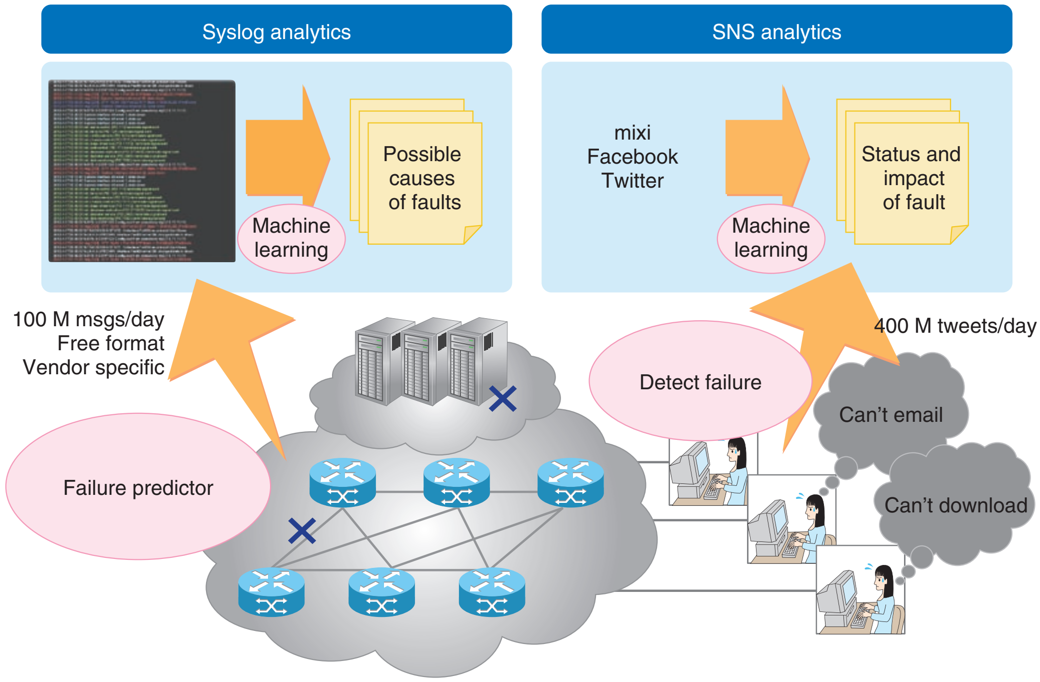


Fig. 2. Network failure detection and root cause analysis for failure prediction.

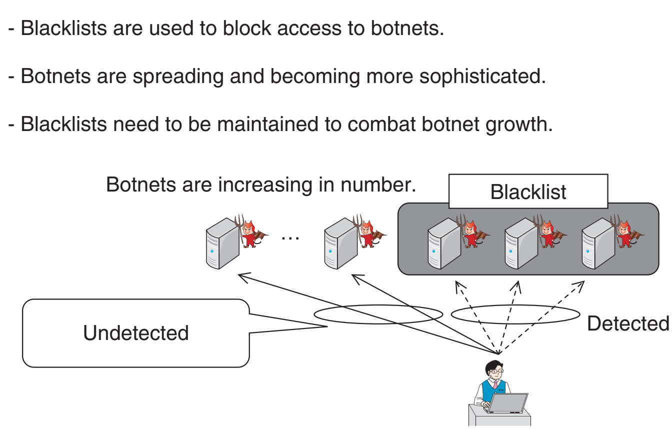


Fig. 3. Communication pattern analytics used against botnets.

To cope with these ever-expanding botnets, we need to maintain and update the blacklists of the C&C servers (**Fig. 3**). We therefore analyze traffic data to improve our coverage of the blacklists.

We have developed a method to find new unknown C&C servers by exploiting the rule of thumb that a user's personal computer (PC) that accesses a C&C server of a botnet and is consequently infected by malware, is likely to access other C&C servers as well [2]. We analyze traffic data and calculate the co-occurrence score between the server communicating with an infected server and the already-known C&C server communicating with the infected server. We assume that a server with a high co-occurrence score is a newly discovered C&C server. We expand the blacklist by registering the newly discovered C&C

servers in the blacklist.

An infected user PC is under the control of the C&C server. It can then be used to carry out security attacks such as DDOS (distributed denial-of-service) attacks, spam mail, and information theft. We analyze the communication patterns to find the ever-increasing C&C servers and block communications to them to contain the spreading botnets.

4.3 Case III: Network planning and engineering

The Internet is becoming ubiquitous and is playing a fundamental role as a social infrastructure. Accordingly, numerous Internet applications have emerged, and the complexity of traffic carried over the telecommunication networks is increasing. In particular, video traffic accounts for a large amount of the total traffic. We therefore need a detailed understanding of video traffic to implement effective network planning and engineering. Video services are categorized as broadcast, VoD (video-on-demand), and OTT (over-the-top). These services have a large amount of content to meet customer needs. Customer behavior is quite different from that of traditional telephone networks. Analyzing customer behavior in their viewing of video services is crucial to understand video traffic. Thus, we take into consideration concurrent weather and temperature data and social event information to better understand video traffic [3].

We anticipate that customer behavior and their purpose in using telecommunication are constantly changing. In addition, when broadband service is provided by both wired and wireless access networks, it is crucial to understand the characteristics of customer demand for effective network planning and engineering. By analyzing the statistics on the number of subscribers of broadband services, we have developed a theory on S-shaped growth that enables more accurate forecasting of future traffic demands [4].

These days, the business structure between telecom network providers and telecom service providers is becoming more complex. Internet service providers (ISPs) and content service providers (CSPs) collaborate in delivering content to customers. The CSP employs a content delivery network (CDN) infrastructure for delivering content to customers using the network infrastructure provided by the ISP. The business objectives of the ISP and CSP are different. The ISP executes its operation including traffic control and network planning and engineering according to its own objectives. The CSP executes its operation including content delivery control and content allocation control according to its own objectives. It is crucial to understand their objectives and how they interact with each other in performing their operations when we execute network planning and engineering operations [5].

5. Platforms for data analytics

5.1 Platform for R&D

We are building a data analytics platform to collect, store, and analyze various kinds of traffic and network management data in order to conduct R&D efforts related to the application of big data analytics technologies for traffic and network management. We are using high-end commodity servers and a software framework for data-intensive distributed applications such as Hadoop to build our data analytics platform.

We are developing algorithms for data analytics using high-end servers and we are making software tools that implement the data analytics algorithms we developed using machine learning, data-mining, and statistical analysis.

The machine learning algorithms we are using to develop the data analytics algorithms include non-negative matrix factorization (NMF) [6], [7] and support vector machine (SVM) [8] to find hidden rules among big data and to make classifiers using training data. We are developing data analytics algorithms for unstructured data such as Twitter data and syslog data using natural language processing techniques including Japanese language morphological analysis and syntactic analysis techniques based on word-classification and clustering methods. We have implemented a real-time Twitter analytic tool using the online machine learning framework Jubatus [9] for pre-processing and an SVM type machine learning algorithm.

Traffic is becoming more and more complex. We need to capture the entire data of packets and analyze them. The amount of data can be quite huge even for a short period. To cope with this, we use a software framework for data-intensive distributed applications such as Hadoop. We are implementing our algorithms using the MapReduce programming model for parallel processing of huge data.

5.2 Platform for data analytics

We are conducting our R&D efforts by applying big-data analytics technologies to traffic and network management data.

Real data is crucial for these R&D efforts. We collaborate with business units including network planning and engineering, and network operations in conducting R&D efforts. Traffic and network management data are measured and collected by the business units. We analyze those data in the R&D labs. We verify the analytic results through discussions with operators and engineers in the business units.

We establish analytics methodologies through the above-mentioned R&D process and transfer them to the business units so that they can apply those methodologies in their operation processes. The R&D outcome, in the form of technical documents, operation manuals, and software tools and engines built into the operation systems, thus contributes to the business process innovations achieved in the business units.

R&D efforts for big data analytics technologies require cross-domain expertise including database technologies such as Hadoop and data warehousing, and analytics technologies such as machine learning, data mining, and statistical analysis. We are collaborating on these technologies with other departments in NTT labs to conduct our R&D efforts.

We expect that our data-driven approach using big data analytics technologies for traffic and network management data will continue to evolve and will contribute to producing a wide range of R&D outcomes. We will continue collaborating with our business units and other R&D departments to conduct our R&D efforts that exploit cutting-edge technologies developed in our R&D labs.

References

[1] T. Kimura, K. Takeshita, T. Toyono, M. Yokota, K. Nishimatsu, and T. Mori, "Network Failure Detection and Diagnosis by Analyzing Syslog and SNS Data: Applying Big Data Analysis to Network Operations," NTT Technical Review, Vol. 11, No. 11, 2013.
https://www.ntt-review.jp/archive/ntttechnical.php?contents=ntr201311fa4.html

[2] K. Sato, K. Ishibashi, T. Toyono, and N. Miyake, "Extending Black Domain Name List by Using Co-occurrence Relation Between DNS Queries," Proc. of the 3rd USENIX Workshop on Large-Scale Exploits and Emergent Threats (LEET '10), San Jose, CA, USA, April 2010.

[3] S. Kouno and H. Hasegawa, "Traffic Management of Video Streaming Services," NTT Technical Review, Vol. 11, No. 11, 2013.
https://www.ntt-review.jp/archive/ntttechnical.php?contents=ntr201311fa3.html

[4] S. Shimogawa, K. Takeshita, and K. Nishimatsu, "Analyzing Macroscopic Demand Structure Based on New Model of S-shaped Growth," NTT Technical Review, Vol. 11, No. 11, 2013.
https://www.ntt-review.jp/archive/ntttechnical.php?contents=ntr201311fa5.html

[5] K. Ishibashi, S. Harada, and S. Kamei, "Analyzing Internet Traffic Structure through Big Data Technology," NTT Technical Review, Vol. 11, No. 11, 2013.
https://www.ntt-review.jp/archive/ntttechnical.php?contents=ntr201311fa2.html

[6] D. D. Lee and H. S. Seung, "Learning the Parts of Objects by Non-Negative Matrix Factorization," Nature, Vol. 401, pp. 788–791, 1999.

[7] K. Ishiguro and K. Takeuchi, "Extracting Essential Structure from Data," NTT Technical Review, Vol. 10, No. 11, 2012.
https://www.ntt-review.jp/archive/ntttechnical.php?contents=ntr201211fa2.html

[8] C. Cortes and V. Vapnik, "Support-Vector Networks," Machine Learning, Vol. 20, No. 3, pp. 273–297, 1995.

[9] K. Horikawa, Y. Kitayama, S. Oda, H. Kumazaki, J. Han, H. Makino, M. Ishii, K. Aoya, M. Luo, and S. Uchikawa, "Jubatus in Action: Report on Realtime Big Data Analysis by Jubatus," NTT Technical Review, Vol. 10, No. 12, 2012.
https://www.ntt-review.jp/archive/ntttechnical.php?contents=ntr201212fa5.html

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Analyzing Internet Traffic Structure through Big Data Technology

Keisuke Ishibashi, Shigeaki Harada, and Satoshi Kamei

Abstract

The volume of Internet traffic consisting of content delivered by large content providers continues to increase. Moreover, the traffic control measures used by those content providers make the dynamics of Internet traffic more complex. In this article, we introduce a method of analyzing the complex dynamics of Internet traffic and present some results obtained after applying the method.

Keywords: Internet, content delivery, traffic

1. Introduction

The volume of Internet traffic has long been increasing exponentially. It was reported recently that not only is the volume increasing, but the composition is also drastically changing. The major portion of traffic is changing from P2P (peer-to-peer) file sharing to video content delivery from large content service providers (CSPs) [1]. This has led to a change in the structure of traffic exchanges among autonomous systems (ASes), specifically, between CSPs and Internet service providers (ISPs) [2]. Those CSPs are deploying their cache servers inside the ISP networks or establishing direct peering to ISPs to reduce the response time for content retrieval as well as the transit cost if they are otherwise required to pay a fee to the transit providers.

In addition to the changing trend in the structure of Internet traffic delivery, these CSPs change the allocations of their content servers for users' content requests. This leads to short-term traffic fluctuations in the ISP networks. These traffic fluctuations and the changing trend in traffic delivery bring new challenges in bandwidth provisioning and traffic management for ISPs. Long-term changes in the content delivery structure lead to changes in peering strategy, and short-term fluctuations make it difficult to predict and manage traffic.

We describe here how to measure and analyze these changes and fluctuations in the Internet traffic delivery structure. Specifically, we decompose traffic delivery into users' traffic demands, CSPs' content supply, and ISPs' content delivery. By decomposing the traffic delivery structure into these three components, we can identify the changes in the structure and the root causes for the changes, making it possible to predict such changes and develop countermeasures.

2. Traffic decomposition and measurement

The decomposition of network traffic into traffic demands of users, content supply by CSPs, and traffic distribution by ISPs is shown in **Fig. 1**. User demands are mapped to network traffic by control techniques applied by both CSPs and ISPs.

2.1 User traffic demands

Content delivery traffic originates with the users' traffic demands. Here, traffic demands indicate users' requests for content, for example, video, to CSPs. Those demands are calculated by monitoring users' access logs that are captured by network monitoring agents [3].

2.2 CSP content supply

CSPs dynamically allocate a content distribution server for each user content request in order to optimize load balancing and the quality of content delivery. Normally, the nearest server to the user is allocated, but in some cases, other servers may be

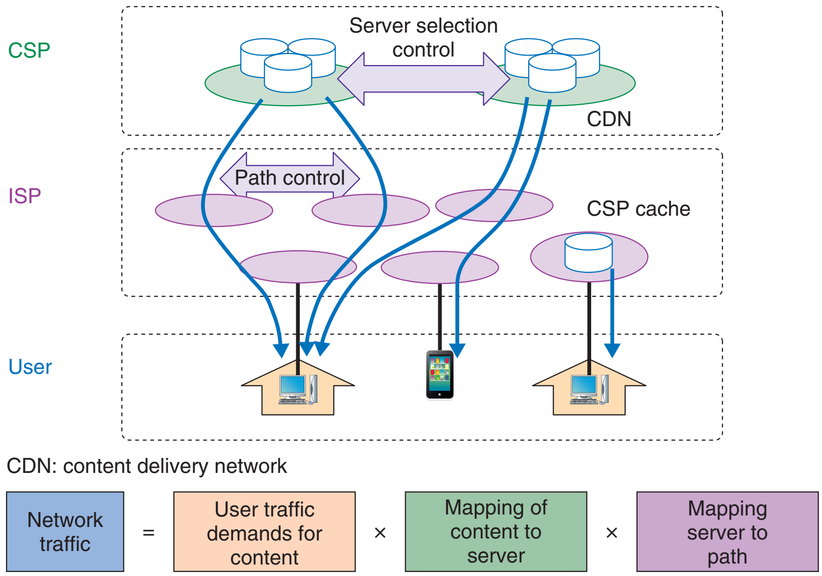
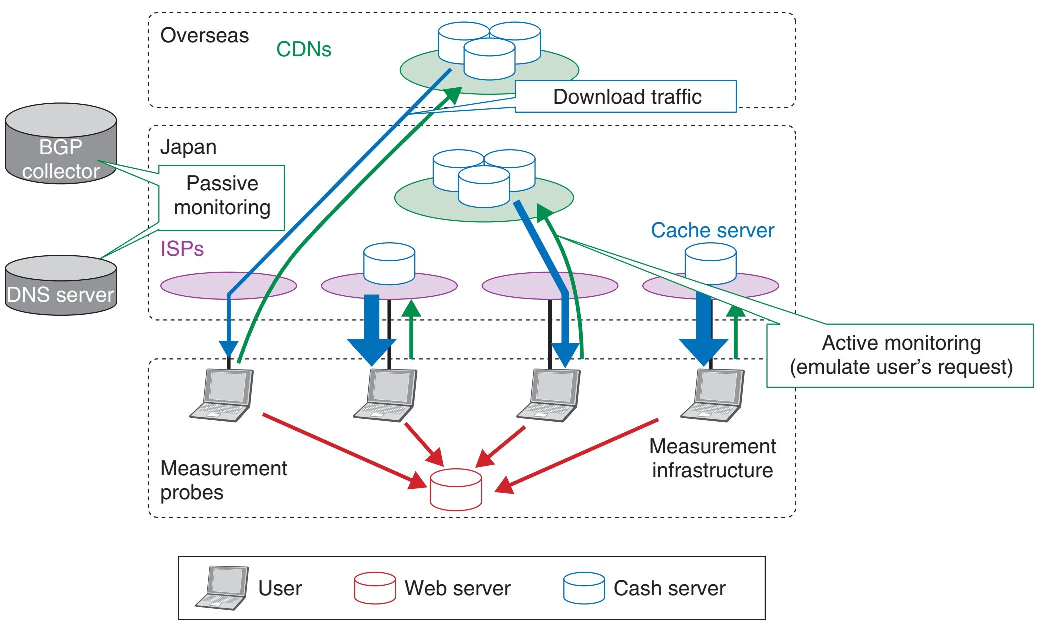


Fig. 1. Decomposition of network traffic into user demand, CSPs' content supply, and ISPs' traffic distribution.



BGP: border gateway protocol

Fig. 2. Methods of allocating servers.

allocated based on the status of server load, network congestion, or server failures. These changes in allocation cause short-term fluctuations in network traffic.

Server allocation methods are roughly divided into two categories: DNS (domain name system) based methods and web server based methods (**Fig. 2**). In the former, a content distribution server is assigned to a user request as an Internet protocol (IP) address in a DNS response for the query from the user. In this

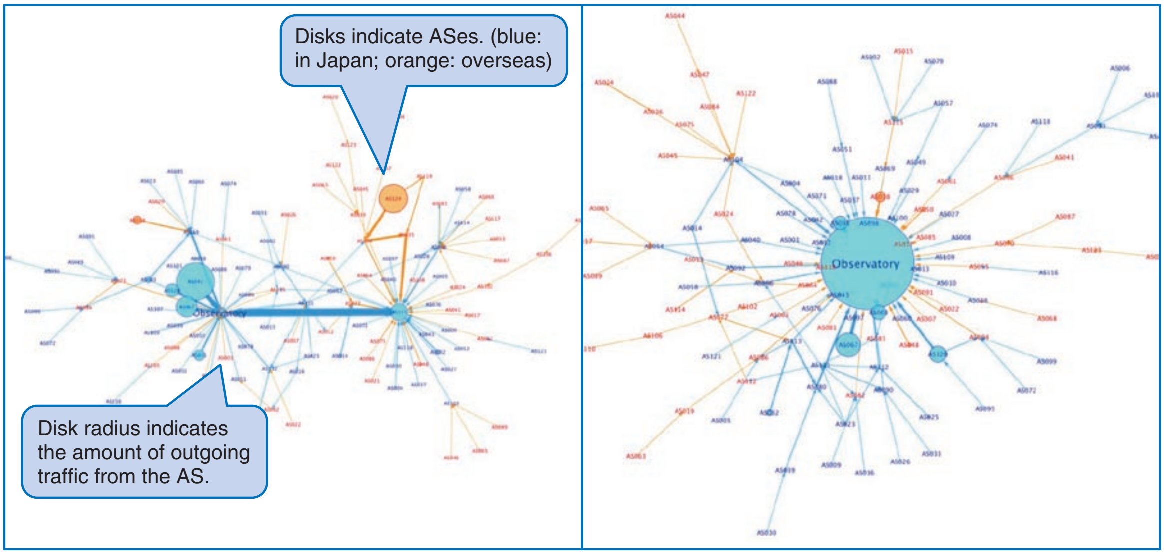


Fig. 3. Visualization of traffic structure.

allocation, the DNS response IP address is determined based on the source IP address of the DNS query, which is normally not the user's IP address but a DNS cache server's IP address. By contrast, in the latter type, when a user accesses a web server to view content, the server dynamically allocates a server for the content request and returns an HTML (hypertext markup language) page with a URI (uniform resource identifier) that includes the server.

These allocations can be measured by using passive or active monitoring techniques, specifically, by passively monitoring the network traffic or by actively accessing the content. By monitoring DNS traffic, we can observe how a user's request for content is mapped to an IP address of the server. This passive monitoring is advantageous in that it allows all user requests to be monitored inside the monitored network. The advantage of the latter monitoring technique is that it can monitor the mapping of multiple networks by sending emulated user requests from outside the network.

2.3 ISP traffic delivery

Once the server for the content request is determined, then the path between the user and the server is determined by ISP routing control. Normally, this control is not limited to a single ISP, but spans multiple ISPs because CSPs, which have content, and ISPs, which have users, are different autonomous systems (ASes). ASes control the routing to optimize the quality of content delivery and also to minimize the transit costs that depend on the relationship between ASes.

Monitoring of the routing controls is also measured by passively monitoring routing control messages such as BGP (Border Gateway Protocol) messages [4], or by actively sending probe packets for routing using a tool such as traceroute. The advantages of both types of monitoring are the same as for the server allocation, in that the former type can monitor all traffic inside the network, whereas the latter can monitor the statuses of multiple networks. Inferring traffic exchanges in a network from outside the network is said to be difficult [5], but by decomposing the user requests, server selection, and routing control, we can infer traffic exchanges from outside the network, as described in the next section. If we can assume that the popularity of the content that users request is roughly the same among the ISPs, then we can infer the network traffic exchanges by monitoring the server selection and routing control from outside the network.

3. Measurement results

We applied the active access measurement method explained in the previous section to analyze traffic. Examples of visualizing HTTP (hypertext transfer protocol) download traffic for two networks using this method are shown in **Fig. 3**. Each node represents

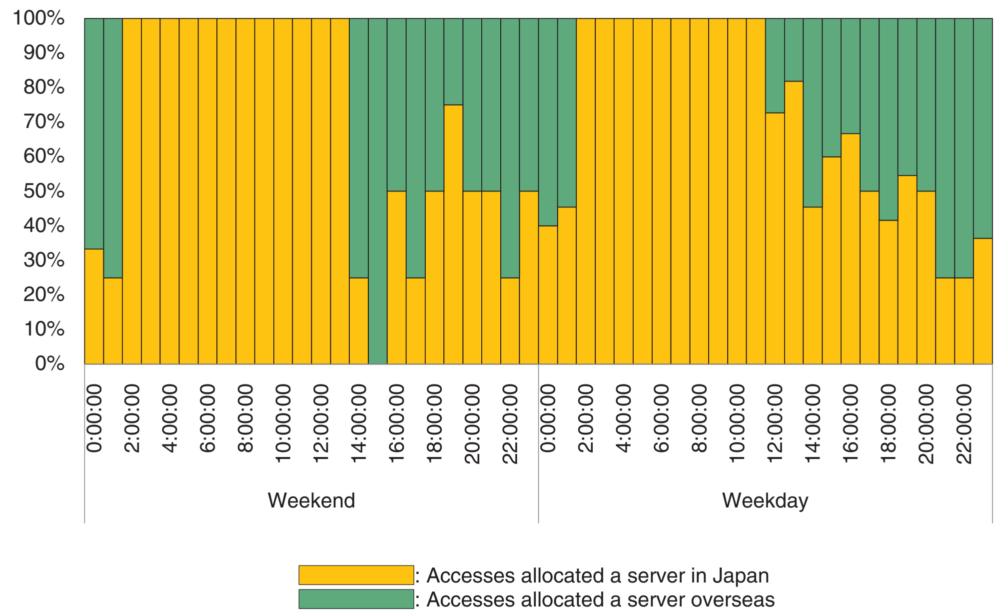


Fig. 4. Results of observing traffic over two-day period from three measurement points in Japan.

an AS, and the edge between two nodes represents the traffic exchange between the ASes. The disks indicate larger nodes; the radius of the disk indicates the volume of traffic from that AS. In these visualizations, users' traffic demands are assumed to be the same for the two networks, but because the server selections and routing controls are different, the resulting traffic structures are significantly different. Specifically, we confirmed that the network on the right has a content cache server of CSPs inside the network and that the server is allocated for almost all user content requests; thus, the traffic for the content requests flows inside the AS. This observation corresponds to a recent report on the trend of Internet traffic structure changes [1].

In addition to the change in the structure of traffic, we also observed short-term fluctuations in CSP server allocation. The results of observing traffic from three measurement points in Japan are shown in **Fig. 4**. The orange bars indicate the ratio of accesses that were allocated a server in Japan, and the green bars indicate the accesses allocated servers from overseas. These changes affect the bandwidth provisioning of links connected to other ASes.

4. Conclusion

We, as an NTT Communications advanced IP architecture center, are now developing an infrastructure for network data measurement, analysis, and visualization that is based on the Internet traffic structure analysis method described in this article. The measurement infrastructure is built on a network that has BGP transit connections with multiple ISPs. We are also developing a visualization tool that shows the inter-AS connection status, as shown in **Fig. 5**.

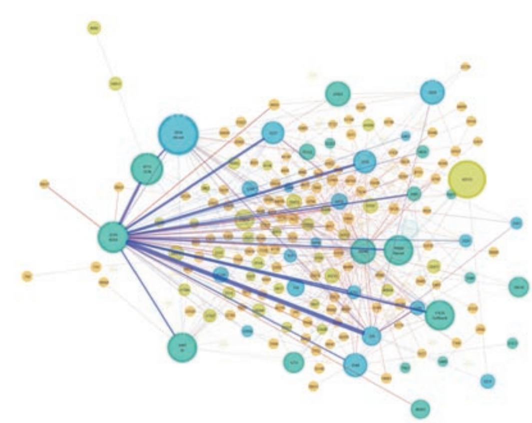


Fig. 5. Visualization of connection status.

References

[1] K. Cho, "Broadband Traffic Report: Traffic Trends over the Past Year," The Internet Infrastructure Review, Vol. 16, pp. 33–37, August 2012.

[2] C. Labovitz, S. I. Johnson, D. McPherson, J. Oberheide, and F. Jahanian, "Internet Inter-Domain Traffic," Proc. of the ACM SIGCOMM'10, pp. 75–86, New Delhi, India, 2010.

[3] Alexa. http://www.alexa.com/

[4] A. Kobayashi, S. Kashima, H. Kurakami, and K. Ishibashi, "Traffic Monitoring System Based on Correlation between BGP Messages and Traffic Data," IEICE Trans. Commun., Vol. E94-B, No. 9, pp. 2532–2542, Sep. 2011.

[5] H. Chang, S. Jamin, Z. M. Mao, and W. Willinger, "An Empirical Approach to Modeling Inter-AS Traffic Matrices," Proc. of the 5th ACM SIGCOMM Conference on Internet Measurement, p. 12, Philadelphia, PA, USA, 2005.

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Traffic Management of Video Streaming Services

Shouji Kouno and Haruhisa Hasegawa

Abstract

The use of video streaming services is becoming more widespread, and as a consequence, the traffic volume of these services is rapidly increasing over the broadband communication network. It sometimes happens as a rare event that many users will start using video streaming services almost simultaneously. This results in an explosive increase in the volume of traffic, which is observed in the network data. Users strongly desire video streaming services that provide clear and high-resolution images for the entire duration of the programs they are viewing. Thus, special attention must be paid to these services in the task of traffic management. In this article, we characterize the variation in the traffic volume of video streaming services based on the viewing activities of users, and we explain what knowledge is necessary to manage the traffic.

Keywords: traffic management, VOD, traffic volume

1. Introduction

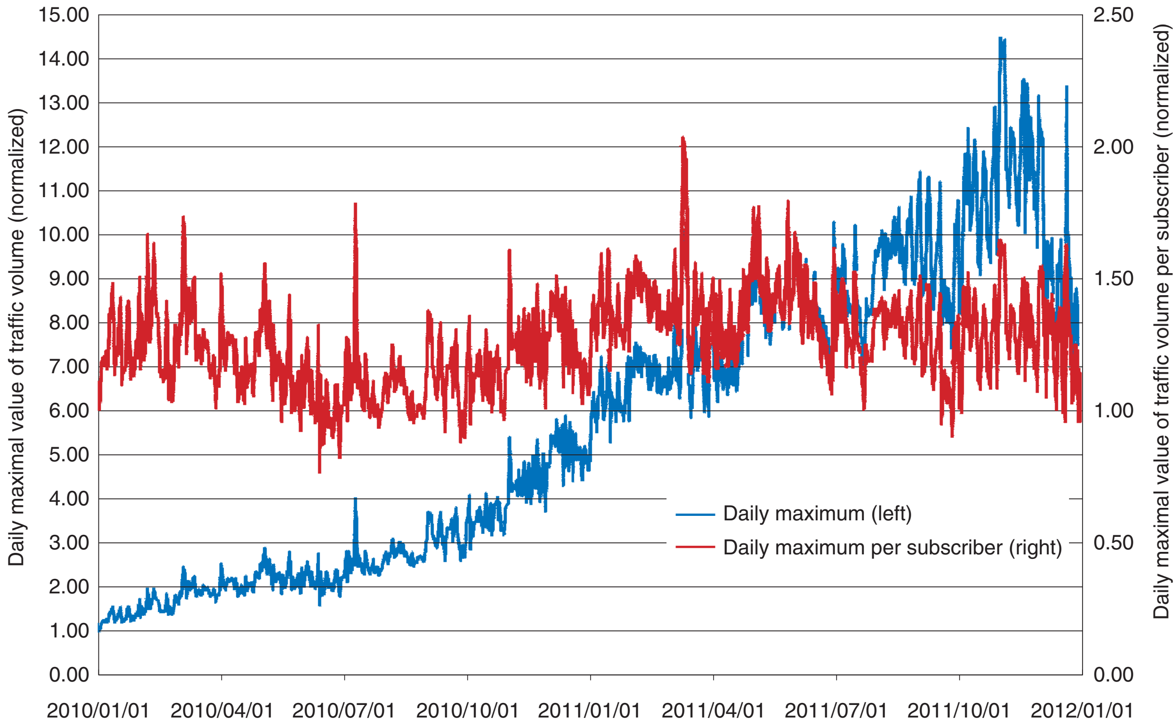
1.1 Traffic characteristics of video streaming services

In July 2011, Japan shifted to a digital terrestrial television (TV) broadcasting system. Around that time, the traffic volume of video streaming services began to increase rapidly over the broadband communication network. Video streaming services can be classified into Internet protocol (IP) multi-channel services and video on demand (VOD) services. With the former, a constant traffic volume can be maintained regardless of the number of users of a service because of the utilization of IP multicast. By contrast, the latter type increases the traffic volume in proportion to the number of users of a service because it delivers video content data according to the requests from users who want to view the video content. Therefore, in managing traffic on a broadband communication network, it is very important to accurately predict the traffic volume of the video streaming service and to dimension the amount of equipment necessary for offering the services. In this article, the term video streaming service indicates a VOD service.

1.2 Spikes

A time series of the traffic volume of video streaming services during 2010–2011 is shown in **Fig. 1**. The Y-axis shows the daily maximam value of the traffic volume of the service. The daily maximam traffic volume per subscriber is shown by the Z-axis. Each axis is normalized by the value on January 1, 2010. The sudden peaks in the traffic can clearly be distinguished. We call these peaks *spikes*. We compared video streaming services with conventional communication services, for example, phone and Internet access services, and found that video streaming services have distinguishable features [1]. That is, their spikes have a special frequency and a relatively longer length. Here, we begin to explain the traffic characteristics and the background mechanism of video streaming services.

The traffic of a video streaming service in July 2010 is plotted in **Fig. 2**. The X-axis indicates a range from 6:00 a.m. to 5:00 a.m. the following day. Before explaining the spiky increases, we first explain the daily characteristics of the traffic volume of the video streaming service. The traffic volume is larger on weekends than it is on weekdays, so it is understood that this service is mainly used by home users rather



* The value of both the Y and Z axes are normalized: The value of January 1, 2010 is 1.00.

Fig. 1. Changes in VOD traffic volume.

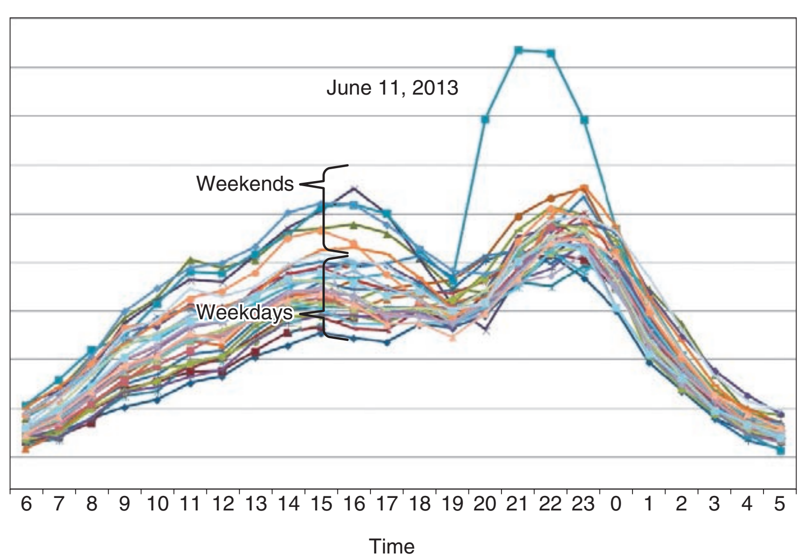


Fig. 2. Impact of news reports on Upper House election on VOD traffic.

than by businesses.

We can see that the busiest hour of the day, which refers to the period with the largest daily traffic volume of the service, is usually from 22:00 to 23:00 regardless of whether it is a weekday or weekend day. An exception is seen at around 16:00 on weekends,

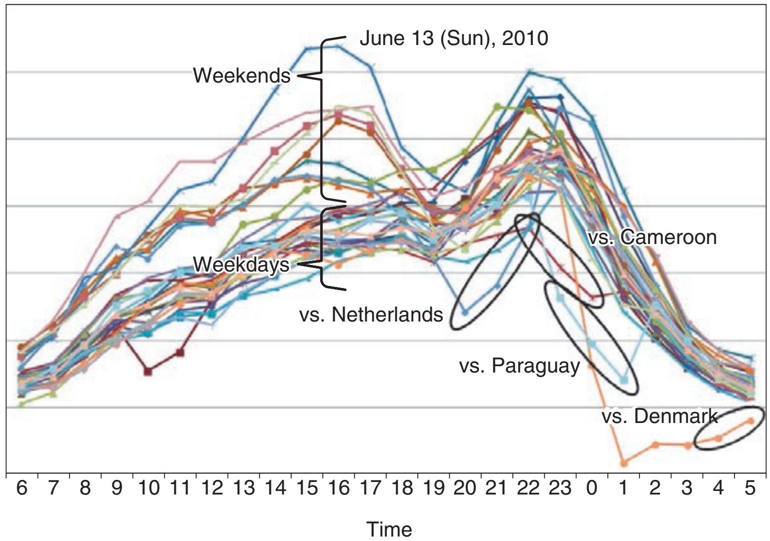


Fig. 3. Impact of FIFA World Cup on VOD traffic.

when the daily traffic volume reaches the highest peak.

Some odd phenomena in the pattern of traffic can be seen. After the peaks in the early evening on weekends, the traffic volume begins to decrease until 19:00 or 20:00, then starts increasing until 23:00. This looks like an unnatural trajectory.

These temporary decreases are special characteristics of the traffic volume of video streaming services.

1.2.1 Illustrative case 1

Let us introduce some illustrative cases of spikes.

At 20:00 on Sunday, July 11, 2010, the traffic volume of video streaming services began to increase suddenly. Note that the traffic volume had shown almost the same volume relative to ordinary weekends until 19:00. In fact, that day was the day of the House of Councillors election in Japan. At exactly 20:00, almost all Japanese TV stations simultaneously started broadcasting a special news report on the election results.

TV stations usually broadcast TV programs in competition with other stations. There are various categories of programs, e.g., dramas, movies, music programs, live sporting events, educational programs, entertainment programs, cartoons, news, and special reports. Therefore, it is possible for people to choose a favorite TV program from the available TV programs whenever they want to watch them.

On this occasion, however, people could not freely select their TV programs because all the TV stations were broadcasting the same content—the election news report.

We can easily imagine that at this time, some people who were unconcerned with the election results, for example, children, could not find a TV program they wanted to watch, so they turned to video streaming services instead.

From this illustrative case, a relationship appears between the traffic volume of video streaming services and TV programs being broadcast at that time.

1.2.2 Illustrative case 2

Now we explain a reverse example to support the relationship of illustrative case 1. A 24-hour graph of the traffic volume of a video streaming service in June 2010 is shown in **Fig. 3**. During that month, the FIFA (Fédération Internationale de Football Association) World Cup games were being held in South Africa.

When the matches of the Japanese national team were broadcast live on TV, the traffic volume of video streaming services was substantially reduced in comparison with the same time on other days that month when the Japanese team was not playing.

The presumption is that even heavy users of video streaming services were refraining from using streaming services at that time so that they could watch the match live on TV and cheer for the Japanese national team.

As expected, we can see that there is a strongly competitive relationship between TV broadcasting

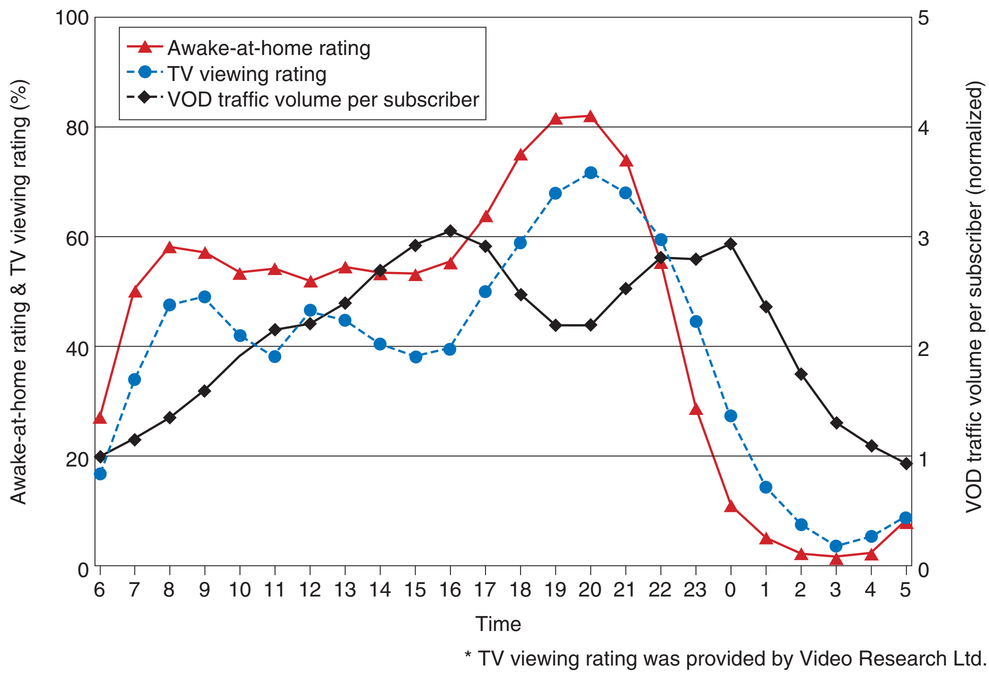


Fig. 4. Fluctuation of awake-at-home rating, TV viewing rating, and VOD traffic volume per subscriber over 24 hours (6 a.m. Sunday through 5 a.m. Monday).

and video streaming services.

2. Human life activities

Here, let us explain the characteristics of the traffic volume of video streaming services in connection with people's activities in their daily lives. Our research is based on the *Survey on Time Use and Leisure Activities* (2006) conducted by the Statistics Bureau, Ministry of Internal Affairs and Communications [2].

This survey aims to obtain comprehensive data on the daily patterns of time allocation and on leisure activities. The survey was first carried out in 1976 and since then has been conducted every five years. In the survey, the enumerators deliver questionnaires to each household to be surveyed, collect the completed questionnaires, and interview the households as necessary. The questionnaires are completed by household members 10 years old and over or by the head of the household. The participants also answer questions from the enumerators. To grasp the distribution of time use during a 24-hour period, each household member is requested to classify his/her own activities into 20 categories (1. Sleep, 2. Personal care, 3. Meals, 4. Commuting to and from school or work, 5. Work, 6. Schoolwork, 7. Housework, 8. Caring or nursing, 9. Child care, 10. Shopping, 11. Moving (excluding commuting), 12. Watching TV, listening to the radio, reading newspapers or magazines, 13. Rest and relaxation, 14. Study and research (excluding schoolwork), 15. Hobbies and amusements, 16. Sports, 17. Volunteer and social activities, 18. Social life, 19. Medical examinations or treatment, 20. Other activities).

For these activities, we define an *awake-at-home rating* as the sum of the ratings of the activities being done at home except for category 1, Sleep.

A 24-hour time series of an awake-at-home rating, TV viewing rating [3], and traffic volume per subscriber of video streaming services of Sundays average from 6 a.m. to 5 a.m. the following day is plotted in **Fig. 4**. We can see that the TV viewing rating has almost the same shape as the awake-at-home rating. In fact, when many people come home, one of the first things they do is turn on the TV. Then they continue watching TV, or just leave the TV on, while they are eating dinner or doing housework. Finally, they turn the TV off just before going to bed. Such a custom is considered to be normal, so this relation between the two ratings is easily understood. In addition to the TV viewing rating, the awake-at-home rating also peaks at around 20:00.

In the field of TV broadcasting, this time occurs during the period called the *prime time* in Japan (19:00–22:00). TV broadcasting companies produce TV programs such as dramas or entertainment programs by assembling casts of popular TV celebrities and actors/actresses in order to achieve a higher TV viewing rating than others. These broadcasting companies are always strongly motivated to broadcast TV programs that are expected to achieve higher TV viewing ratings leading into the prime time because the aim of their business is to obtain higher advertising revenues.

2.1 Relation to TV broadcasting

Here, let us consider the relation between video streaming services and TV broadcasting. The traffic volume of the former has a characteristic in which it temporarily decreases at around 20:00. As mentioned previously, 20:00 is the prime time in the TV broadcasting business when all TV channels are broadcasting programs that are more popular than video streaming services. This is the same as the case of the FIFA World Cup.

In Fig. 4, it is shown that the traffic volume of video streaming services increases on Sunday afternoons. The quality of TV content being broadcast at this time is perceived to be lower than at other periods, so many subscribers feel that video content is more interesting than regular TV programs.

In fact, at this period of time, many TV channels are rebroadcasting previously aired TV programs.

2.2 Relation to awake-at-home rating

Here, we discuss the relation between video streaming services and the awake-at-home rating. The attractiveness of TV programs is often assumed to be at a constant level throughout the day. In this situation, it is considered a natural trend that if the awake-at-home rating increases, then the utilization and traffic volume of video streaming services also increase. What would cause the awake-at-home rating in the daytime to be the highest on weekends, as shown in Fig. 3? It is clear from this figure that the day the traffic volume of the video streaming service was highest was June 13th, which was a Sunday.

An image of a rain cloud at 12:00 on that day is shown in **Fig. 5** [4].

The rain cloud was positioned over the middle of Honshu Island, and it brought rain to the western part of Japan in the morning. Then this cloud brought rain to the eastern part of Japan in the afternoon [5]. We presume this is the reason June 13th had the highest traffic volume among weekdays and weekend days that June.

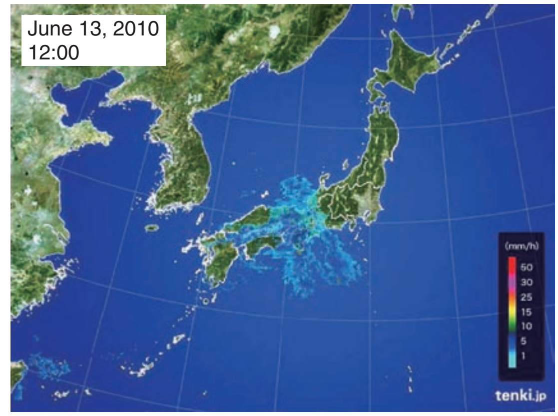


Fig. 5. Satellite image of rain cloud at noon (12:00), June 13, 2010.

Such weather triggers of video streaming services occur not only with rain but also with decreasing temperatures. Both typhoons in summer and cold spells in winter produce this effect.

It is well understood that weather conditions lead subscribers to stay indoors and that an increasing awake-at-home rating generates demand for video streaming services.

3. Future prospects in traffic research

In this article, we introduced the traffic characteristics of video streaming services and explained why the traffic variation has the shape described above. Furthermore, it has been derived theoretically and verified from data that the traffic volume of video streaming services per subscriber obeys a lognormal distribution. The techniques described here are now ready to be investigated as on-site applications of the operating companies of the NTT Group.

It is expected that a great variety of services will be offered over the broadband communication network in future. It is therefore important to analyze and understand the unknown traffic characteristics of such services in order to manage the traffic appropriately.

We are beginning to apply the big data approach in order to acquire more detailed knowledge of traffic. Therefore, we are utilizing not only the traffic data that are measured inside networks but are also acquiring large amounts of information that exist beyond networks such as the weather information mentioned above, TV programs, TV viewing ratings, and awake-at-home ratings.

References

[1] H. Hasegawa, S. Kouno, A. Shiozu, M. Sasaki, and S. Shimogawa, "Predictive Network Traffic Engineering for Streaming Video Service," Proc. of the IFIP/IEEE International Symposium on Integrated Network Management, Ghent, Belgium, 2013.
[2] The Statistics Bureau, Ministry of Internal Affairs and Communications.
http://www.stat.go.jp/english/index.htm
[3] Video Research Ltd. http://www.videor.co.jp/eng/index.html
[4] Weather forecast (in Japanese). http://tenki.jp/past/
[5] Japan Meteorological Agency.
http://www.jma.go.jp/jma/indexe.html

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Network Failure Detection and Diagnosis by Analyzing Syslog and SNS Data: Applying Big Data Analysis to Network Operations

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Abstract

We introduce two big data analysis methods for diagnosing the causes of network failures and for detecting network failures early. Syslogs contain log data generated by the system. We analyzed syslogs and succeeded in detecting the cause of a network failure by automatically learning over 100 million logs without needing any previous knowledge of log data. Analysis of the data of a social networking service (namely, Twitter) enabled us to detect possible network failures by extracting network-failure related tweets, which account for less than 1% of all tweets, in real time and with high accuracy.

Keywords: big data, syslog, network failure detection

1. Introduction

Internet protocol (IP) networks consist of many kinds of equipment from different vendors. These networks are becoming much more complex because of the increasing demand for new and different applications. Additionally, many of these applications are provided by multiple network operators and devices, and this makes it very difficult to diagnose network failures when they occur. Consequently, it is very important to develop methods to efficiently detect network failures and diagnose their causes.

In this article, we introduce two methods for analyzing data from syslogs and from a social networking service (SNS) to achieve early network failure detection and to diagnose the cause of the network failure that current operating methods cannot address.

2. Log data analysis

Network operators monitor various kinds of information such as trap information from network elements, network traffic, CPU (central processing unit)/memory utility data, and syslog data. In particular, the syslog data of network elements such as routers, switches, and RADIUS (Remote Access Dial In User Service) servers include detailed and precise information for troubleshooting and monitoring the health of networks when configurations change. However, analyzing log data has become very difficult for the following reasons:

(i) There are various types of logs, which list messages with low or high severity. In addition, the increase in the number of network elements means there is a massive volume of complex log data, and it is therefore necessary to extract information accurately and efficiently in order to carry out troubleshooting and preventive maintenance.

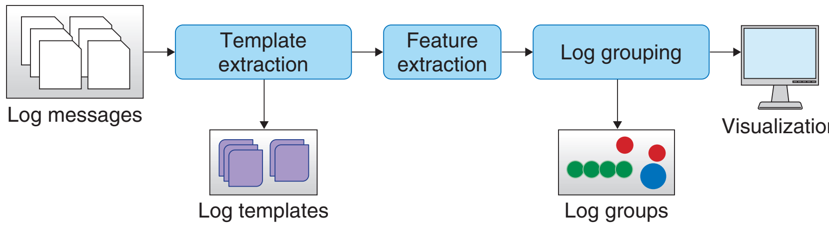

Fig. 1. Flowchart for visualization of logs.

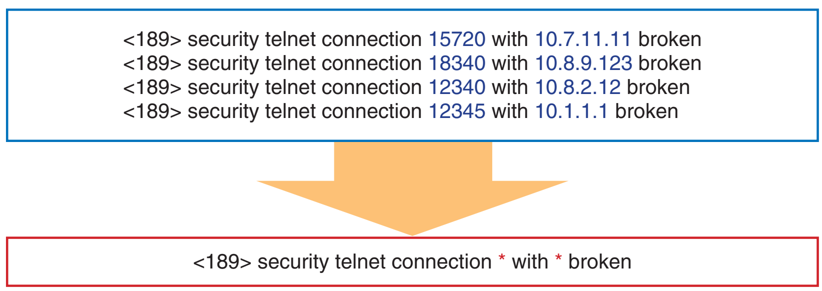

Fig. 2. Conceptual image of log template extraction.

(ii) The log format depends on each vendor or service. Thus, understanding the meaning of each log message requires deep domain knowledge of each format.

To overcome these problems, we have developed a technique to analyze syslogs that involves automatically extracting the relationships or abnormalities from log messages using machine-learning methods without relying on any domain knowledge about the format or the vendor of log data (**Fig. 1**). This analysis technique consists of four steps: log template extraction, log feature extraction, log grouping, and visualization of abnormal events.

2.1 Log template extraction

Log messages contain various parameters such as IP address, host name, and PID (process identification). Because parameter words are very rare, log messages with unique parameters may never appear twice even though the events the messages signify are the same. Therefore, we automatically extract a primary template from all log messages based on the observation that parameter words appear infrequently in comparison with template words in the other positions (**Fig. 2**). The log template enables us to easily correlate log messages.

2.2 Feature extraction

As mentioned before, the vendor's severity of a log message is not necessarily reliable because it is not directly related to the actual network abnormality. Therefore, we need to quantify the abnormality and normality of logs without considering the severity of the message and without requiring any domain knowledge. For example, firewall logs and link down/up logs related to users' connect/disconnect events contain very common messages and can be considered. Also, the logs generated by cron* jobs or in regular monitoring are not as frequent but are generated periodically on a daily basis. Therefore we define the *frequency* and *periodicity* features for log messages.

2.3 Log grouping

Typically, network operators do not use a one-line log message, but rather, a group of logs. For example, a router reboot event induces multiple logs, which indicates that various processes start at the same time. Thus, we need to group them in terms of their co-occurrence. Grouping logs reduces the volume of logs and helps operators make sense of the logs. For

* A time-based job scheduler used in Unix-like computer operating systems

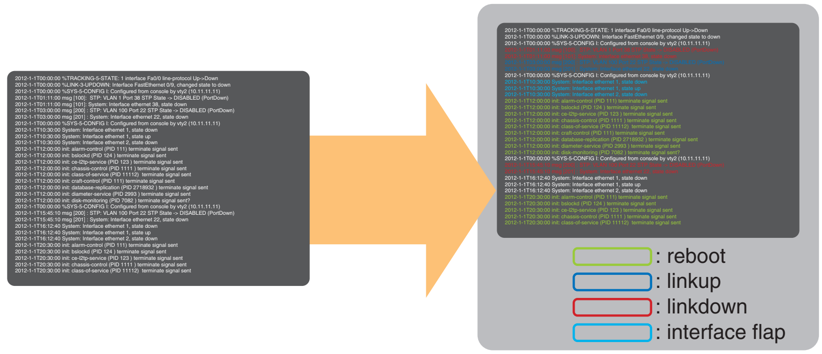

Fig. 3. Image of log grouping.

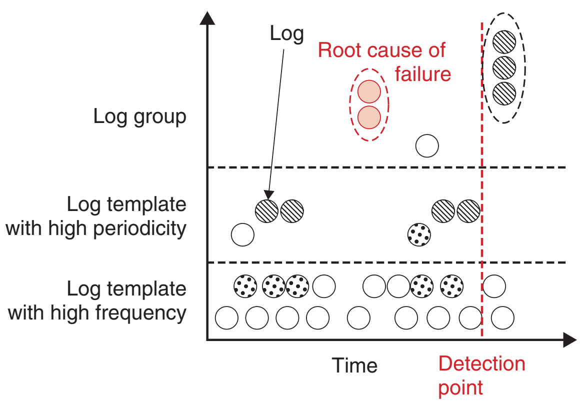

Fig. 4. Conceptual image of log visualization.

log grouping, we use the machine learning technique known as non-negative matrix factorization (NMF) by converting input log data into a matrix (**Fig. 3**).

2.4 Visualization

In this step of the analysis, log data are expressed as a graph. A conceptual image of log visualization is shown in **Fig. 4**, and an example of a log graph is shown in **Fig. 5**. In both figures, the horizontal axis represents time, and the vertical axis represents the template or log groups mentioned earlier. Each point in the graph represents the occurrence of each log template or log group at each time. Hosts are distinguished by their different colors and patterns in this example. The order of log templates or log groups on

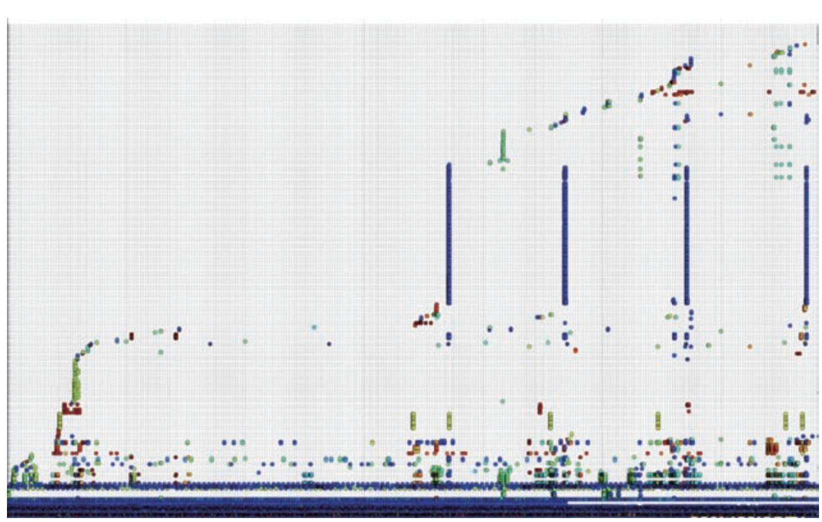

Fig. 5. Example of log graph (one week's syslog data).

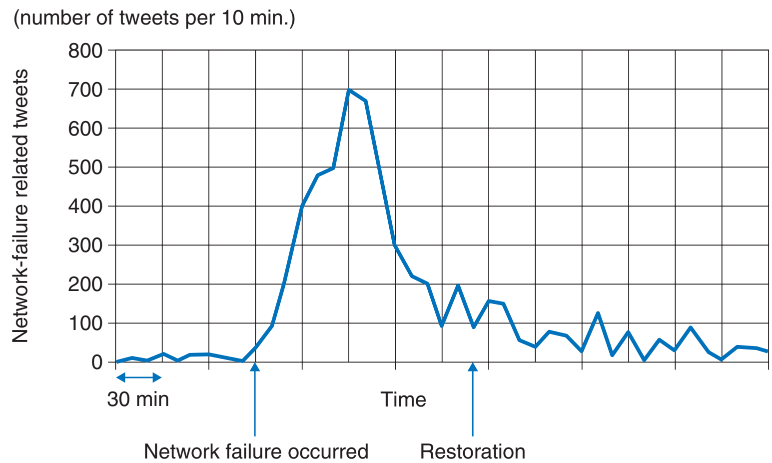

Fig. 6. Time series of tweet counts related to an actual network failure.

the vertical axis is determined according to frequency and periodicity. That is, the log template with high frequency is set at the bottom of the vertical axis; above that is the log template with high periodicity. The template groups are positioned above them. They are sorted by log group frequency and then sorted based on their first appearance. By differentiating log messages with high frequency or periodicity, we can distinguish the log groups that occur independently of time. This makes it possible to visualize millions of log messages in a single screen and to easily understand in a visual way when the log messages occurred and what kinds of log messages appeared. Further, sorting by frequency and periodicity makes it easier to find unusual types of log messages, and grouping log messages helps associate unstructured log messages with real events that occurred in the network.

3. Twitter analysis

Network operators can monitor network equipment by using monitoring technology such as SNMP (simple network management protocol). Although they can detect hardware failures, it is difficult for network operators to detect failures caused by software bugs or to detect quality deterioration due to congestion. Consequently, some cases become silent failures, which cannot be detected by network operators.

We have studied a way to monitor a social networking service (SNS), namely, Twitter [2], to discover problems affecting subscribers. For example, we can see a surge in tweets about network failures when a network failure occurs, as shown in **Fig. 6**. We developed a system to monitor Twitter in real-time by checking for surges in these kinds of tweets.

3.1 System requirements

Twitter is a popular platform for discussing countless conversation topics, and the number of tweets now exceeds 400 million per day [3]. Japanese tweets alone account for 80–100 million tweets per day. Since the number of tweets that relate to network problems is very small in the total number of tweets, we need a way to extract only relevant tweets (first requirement). In addition, to detect the area where a network failure occurs, we need a way to determine the location of the tweeters (second requirement).

3.2 Method to extract only network-failure related tweets

We found in our investigation that keyword matching, a traditional way to search tweets, was not sufficient for automated monitoring because it resulted in many false positives. This occurs when the tweets contained the keywords, but the tweets were not related to problems with the network. For example, if we search using the keywords *call* and *drop*, we may get tweets such as: “I dropped my phone in the toilet so I can’t call or text”. Because keywords such as *call* and *drop* are not network-specific words, keyword matching may lead to a lot of false positive tweets that contain the keywords but not the topic of the network problem.

The network failure detection architecture is shown in **Fig. 7**. We use supervised learning, namely, SVM

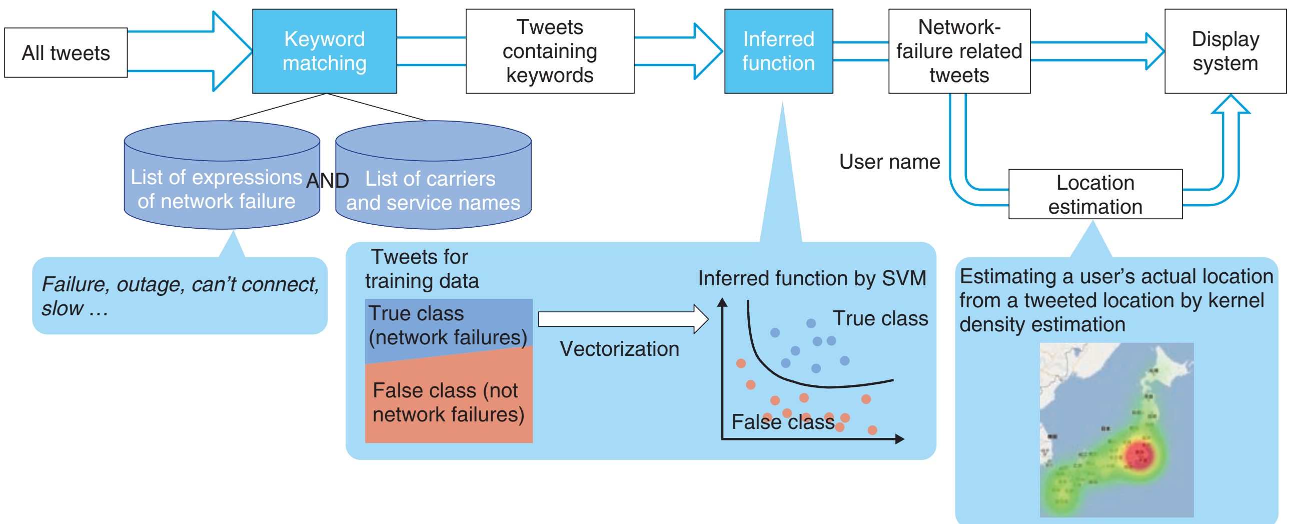

Fig. 7. Framework of network-failure detection system using Twitter.

(support vector machine), to suppress the false positives. Supervised learning uses a data set of training examples. Each training example consists of a pair of the text of a tweet and a label indicating whether the tweet is related to a network failure. A supervised learning algorithm analyzes the training data and produces an inferred function to divide tweets into those that are related to network failures and those that are not. In our approach, each tweet is translated into a vector by using the *bag-of-words* method, which is a traditional method in document classification. This method can be expected to suppress the false positives by statistically considering all words appearing in one tweet.

We evaluated the effectiveness of our method by applying it to an entire year's worth of Twitter data. Six network failures were reported by a network carrier in that period. We evaluated the network failure detection system by counting the number of tweets that were classified by our method. When the count exceeded a certain threshold, we considered it to be an alert of a network failure. We also used the keyword-matching method for comparison. Both methods detected the 6 actual network failures. However, the keyword-only method also falsely detected 94 events, whereas the machine-learning method suppressed almost all of those and had only 6 false detections.

3.3 Method to determine the location of tweeters

Twitter has a function to attach the user's location by GPS (Global Positioning System) data, but most users choose not to opt into this function. Therefore, we need to estimate the location of Twitter users who wrote the network-failure-related tweets. Some studies have used the bias of a distribution of words, which mainly involves dialect characteristics, to estimate a user's location.

However, these studies estimate a rough granularity of areas such as the Kanto region with an error of about 150 km and do not meet our requirement, which is to achieve at least prefecture-level location (an error of less than 50 km).

Therefore, we studied a high-accuracy location estimation method that uses gazetteer information, which includes the pairs of a geographic name and its coordinates. While most tweets do not contain GPS information, many tweets contain a geographic name. Although users may tweet the geographic names of places other than where they are actually located, the overlapped locations of many of their tweets will make it possible to estimate their location because Twitter is a service for users to post what they are doing. We used the kernel density estimation method to overlap the tweets of individual tweeters. We evaluated the estimation error of users whose locations were known and found that the estimation error was less than 50 km for two-thirds of those users. Furthermore, the estimation error was less than 25 km for half of *all* users, which demonstrated that our method was effective.

4. Conclusion

We introduced a big-data approach consisting of syslog and SNS analysis to predict or detect network failures. In cooperation with group companies, we are now evaluating the efficiency of syslog analysis using actual syslog data. We are also preparing a proposal for group companies for the use of SNS analysis as a tool for detecting silent failures.

References

[1] D. D. Lee and H. S. Seung, "Learning the Parts of Objects by Non-Negative Matrix Factorization," Nature, Vol. 401, No. 6755, pp. 788–791, 1999.

[2] Twitter.com.
https://twitter.com/?lang=en

[3] Celebrating #Twitter7.
http://blog.twitter.com/2013/03/celebrating-twitter7.html

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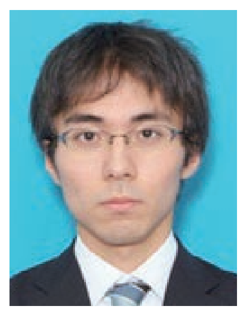

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Analyzing Macroscopic Demand Structure Based on New Model of S-shaped Growth

Shinsuke Shimogawa, Kei Takeshita, and Ken Nishimatsu

Abstract

We tackle the issue of quantitatively evaluating the impact competitors have on a market. In this article, we introduce a method for estimating this impact based on a new theory of S-shaped growth in innovation diffusion.

Keywords: S-shaped growth, structural change, innovation diffusion

1. Introduction

It is important for network planners to forecast the demand for network traffic at high resolution. Whereas short-term forecasting, for example, within a one-year range, may be possible by extrapolating it linearly from past demands, medium- and long-term forecasting is much more difficult.

The growth curves of the number of people using a new service are often S-shaped. That is, growth is small when the service is first introduced; it increases soon after at an accelerated pace, and then slows down in the final stage as the service becomes more widespread. The S-shaped growth curve is often observed with new services, products, methods, or ideas. However, the structure of the S curve has not been revealed despite the large number of studies that have been done on it.

Studies on the diffusion of innovations, a concept that involves how, why, and at what rate new ideas and technology spread through cultures, began in the 19th century. Empirical studies [1] have revealed important facts including that the population ratio of earlier adopters of an innovation is small and that they tend to communicate about the innovation with people beyond their local communities, whereas later adopters tend to communicate about the innovation inside their local communities. However, even the basic question of why growth curves are often S-shaped had not been answered.

Most of the proposed models to explain or capture the S shapes were given by mathematically explicit formulas with few parameters. Many studies examined these models with diffusion data and showed fairly small errors of fitting with the data. However, it has been revealed that these models have rarely succeeded when they are applied to forecasting the growth over a long term. We show how such forecasting fails by extrapolating a traditional model, namely the Bass model [2], in **Fig. 1**. The graph in this figure shows the subscribers of a fixed broadband access service. The blue lines are forecasting results obtained by extrapolation using the Bass model with different times of starting the forecasting. The results vary greatly when the time to start the extrapolation is changed, and all of the results of long-term forecasting eventually fail. In contrast, the results achieved using our method (red line) fit the actual numbers quite well.

NTT Network Technology Laboratories has been investigating this issue, and we recently proposed a new theory [3] that explains the S-shaped growth. Our new theory offers at least two findings regarding forecasting. First, the final adopter population cannot be estimated by extrapolation of growth curves. Second, stable long-term forecasting is possible until the demand for something reaches the final stage. In this article, we give an overview of our new theory and

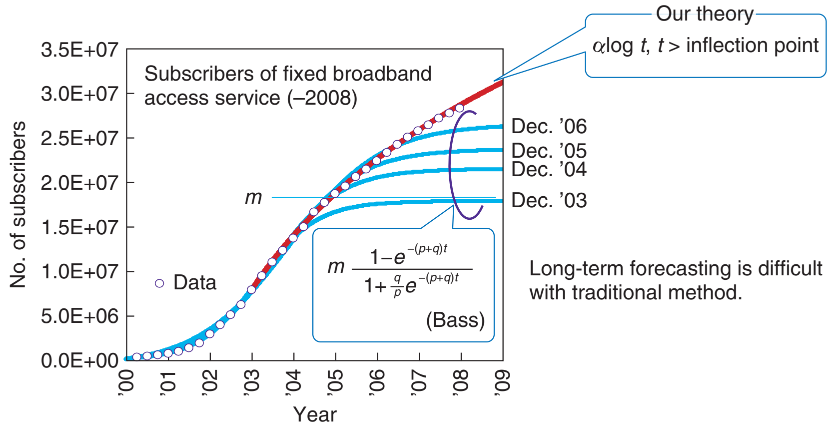


Fig. 1. Failure of forecasting using traditional method.

describe how it can be applied to analyze the demand for broadband service in the Japanese market.

2. New theory of S-shaped growth

The key to our new theory follows the basic hypothesis: *the heterogeneity of adopters follows power laws*. The hypothesis regarding the heterogeneity of adopters has been proposed in previous studies [1]. Although the researchers in those studies assumed mathematically tractable distributions of heterogeneity such as normal distributions, our hypothesis adopts a pair of power distributions. This pair of power distributions has been widely observed; e.g., the distribution of income and that of the frequencies of using content. These distributions have discontinuities that consist of a boundary point between the domains of two power distributions and the upper and lower cut-offs of the distributions. These two power distributions indicate that a society can be seen as consisting of a strong minority and a normal majority when we evaluate individual performance using a certain measure.

We can derive a structure of S growth on three levels: the structure of individual adoptions of an innovation, the social structure of the flows of information about the innovation, and the S shape of a growth curve. The social regularities (power laws) are represented as the characteristics of the flows of innovation information. Our new theory clarifies the macro-micro relationship between the structure of individual adoptions of innovations and the S shape of a growth curve, which will provide a new basis for understanding the diffusion of an innovation.

We can describe the net increase in the demand for a certain service by using two different power-law distributions, which transit at an inflection point on the S growth curve, as shown in **Fig. 2**. An inflection point is a point that represents the maximum value of a net increase.

The forecasting model for the days after the inflection point can be formulated as $y(t) = \alpha\log(t)+y_0$, where t represents the days that have elapsed since the first day of an innovation diffusion, $y(t)$ is the total demand at t, α and y_0 are constants, and the base of the logarithm is natural. This formula stably extrapolates the number of subscribers of broadband and mobile phone services.

3. Analysis of demand for a broadband service

Our new theory enables us to forecast the number of subscribers of a broadband service if the market structure does not change. Conversely, a large error between the forecast and the actual values means that a change in the market structure occurred. The number of subscribers of a fixed broadband service is plotted in **Fig. 3** as a red dotted line. Since the growth curve can be described by $y(t) = \alpha\log(t)+y_0$ after the inflection point, the number of subscribers grows linearly on the logarithmic x-axis. The number of subscribers grew along the line, and then the red line changed its gradient twice, which means market changes occurred. We infer that these changes in the market situation were due to mobile broadband services that started diffusing at those times.

We can quantitatively analyze the change in the market as seen in the graph, which will enable us to

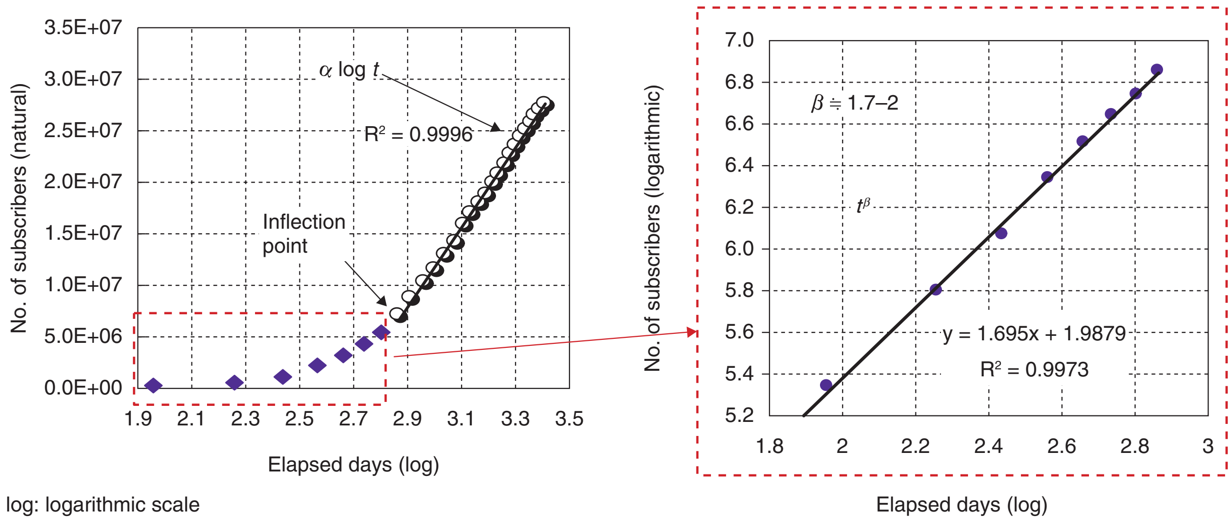
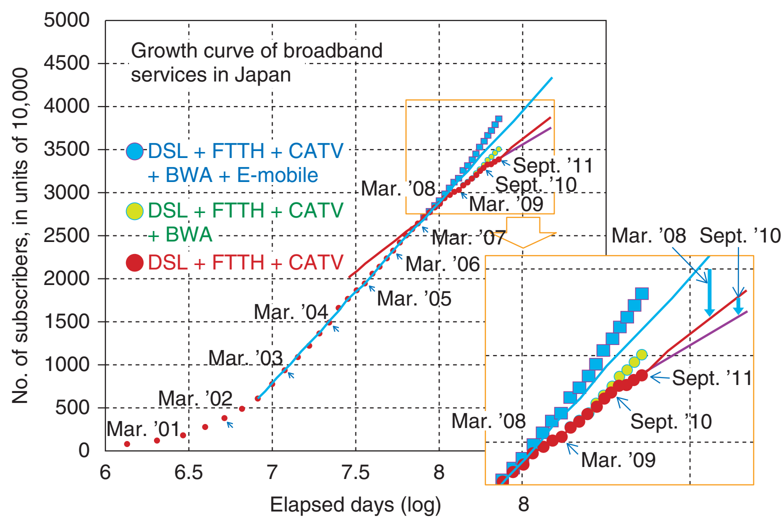


Fig. 2. Forecasting model applied by using discontinuity and two different power laws.



BWA: broadband wireless access
CATV: community access television
DSL: digital subscriber line
FTTH: fiber to the home

Fig. 3. Impact of mobile broadband services to fixed broadband services.

develop an effective strategy and to allocate costs appropriately. We can identify the change by inspecting the red dotted line showing the number of subscribers on a logarithmic axis (**Fig. 4**). We found that while the curve representing a nationwide scale described only high-impact changes, the curve representing the prefecture scale showed differences in the competition circumstances of each prefecture.

4. Conclusion and future work

We expect our method to be utilized for planning network and service strategies effectively and in a timely manner considering that the competition in the Japanese broadband market is intensifying for both fixed and mobile services. Our goal is to model the market behavior in order to predict the efficiency of supply-side actions. As the first step, we are planning

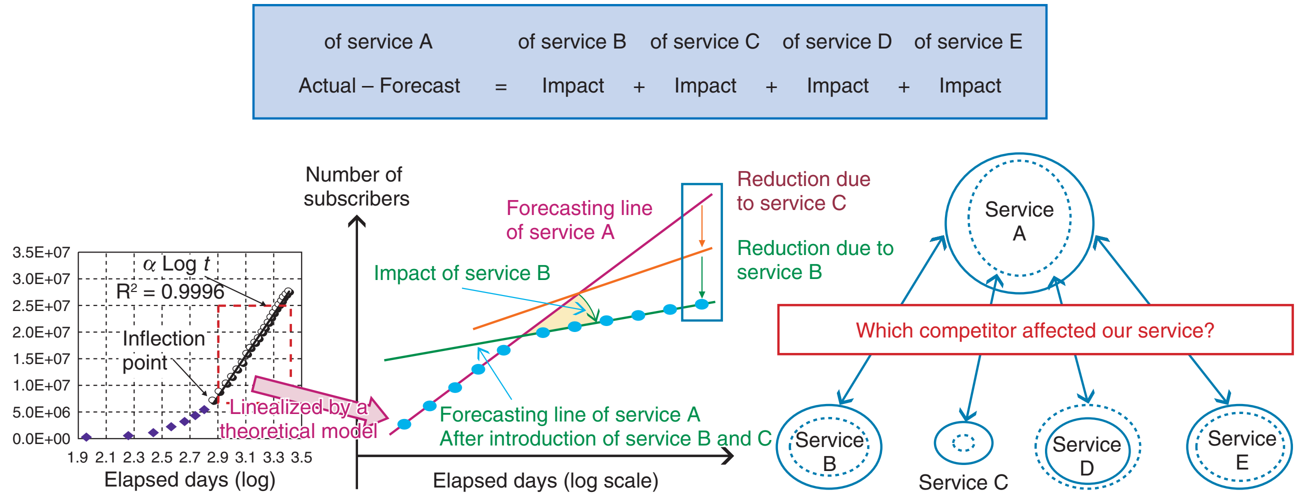


Fig. 4. Analysis of factors affecting broadband service.

to analyze the market on a more granular level to learn more about the behavior of individual consumers.

References

[1] E. M. Rogers, "Diffusion of Innovations," 1st ed. Free Press, New York, 1962.
[2] F. M. Bass, "A New Product Growth Model for Consumer Durables," Manage. Sci., Vol. 15, No. 5, 1969.
[3] S. Shimogawa, M. Shinno, and H. Saito, "Structure of S-shaped growth in innovation diffusion," Phys. Rev. E, Vol. 85, 056121, 2012.

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Fiber-mounted Electro-optic Probe for Microwave Electric-field Measurement in Plasma Environment

Hiroyoshi Togo

Abstract

The demand for greater precision in electric-field measurements is increasing. To meet this demand, NTT Microsystem Integration Laboratories has developed an electro-optic (EO) probe that is mounted on the tip of an optical fiber and has no metal components. This article describes the basic principles and improvements in sensitivity stability and thermal and magnetic resistance of the EO probe. It also presents the results of microwave electric-field measurements conducted in an electron cyclotron resonance ion engine installed on an asteroid explorer under the collaboration of NTT and the Japan Aerospace Exploration Agency.

Keywords: electro-optic (EO) probe, optical fiber, plasma environment

1. Introduction

Electric-field sensors are widely used to measure various kinds of electromagnetic fields such as weak ones existing naturally in the environment and artificial ones generated by high-power microwaves. Measurement of these fields usually disturbs the radiated electromagnetic waves. Conventional electric-field sensors contain metal components that can increase these disturbances, and are approximately as large as a wavelength that can determine a spatial resolution which is an inherent problem when attempting to precisely measure the desired electric field. To overcome this issue, at NTT Microsystem Integration Laboratories, we have developed an electro-optic (EO) probe that employs an optical fiber typically used in optical communications [1], [2]. The EO probe was designed based on the Pockels effect and contains no metal; thus, it can reduce the disturbances in the electromagnetic field that occur during measurement. Moreover, the size of the EO probe is small and can be determined based on the optical beam propagating in an EO crystal.

Moreover, the Japan Aerospace Exploration Agency (JAXA) has been researching and developing an electron cyclotron resonance (ECR) ion engine that can be installed in an asteroid explorer and has also improved its propulsion performance [3], [4]. To improve the performance, JAXA needed to be able to measure the microwave electric-field distribution of the internal plasma in the ion engine during actual operation. However, conventional electric-field sensors cause disturbances such as scattering of the electric field, which makes it necessary to modify the structure of the ion engine in order to insert a probe in it. This makes it difficult to precisely diagnose internal phenomena based on microwave electric-field measurements of the accelerated plasma in the ion engine during operation.

Thus, NTT Microsystem Integration Laboratories and JAXA have been collaborating in the research and development of microwave electric-field measurements in the ion engine with a focus on achieving noninvasiveness and high spatial resolution of the EO probe. The configurations and basic properties of the EO probe are described in section 2, and the improvements made to the probe are explained in section 3. The experimental setup is described in section 4, and in section 5, the results of the microwave electric-field measurements in the ion engine during actual

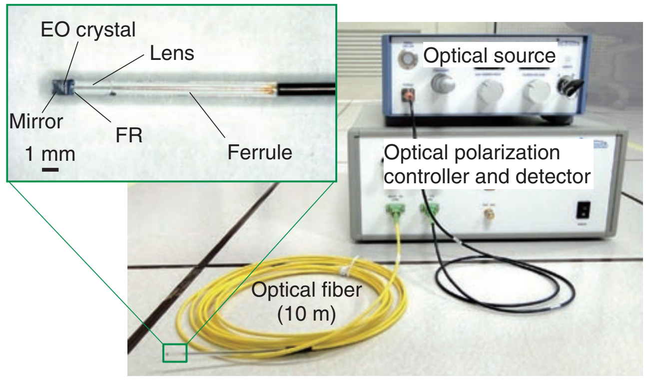

Fig. 1. Fiber-mounted EO probe system.

operation are presented.

2. Fiber-mounted EO probe

A photograph of the EO probe developed by NTT Microsystem Integration Laboratories for the microwave electric-field measurements is shown in **Fig. 1**. The EO probe employs photonic techniques based on the Pockels effect to detect the microwave electric field. It consists of a dielectric reflector, an EO crystal, a Faraday rotator (FR), a collimator lens, a ferrule, and a polarization-maintaining fiber (PMF). The reflector, EO crystal, FR, lens, and ferrule are longitudinally mounted on the tip of the PMF with optical adhesive that has a refractive index as high as that of fused quartz. The diameters of these mounted components are 1 mm, while that of the PMF is 0.256 mm, and the lengths of the EO probe and the PMF are 15 mm and 10 m, respectively. The EO crystal is zinc telluride (ZnTe) with a Pockels coefficient of around 4 pm/V at an optical wavelength of 1550 nm. A lightwave propagates through these components without any distortion at zero electric field. In this probe, the refractive index along the crystallographic axes of the EO crystal changes, and then the phase of the lightwave propagating along each axis in the EO crystal shifts in linear proportion to the intensity of the applied microwave electric field. That is, the refractive index of the EO crystal depends on the optical polarization relative to the crystal axes. ZnTe has a cubic zinc-blende lattice, and the polarization of the lightwave propagating normal to the (110) plane changes as the microwave electric field is applied to the axis normal to the (001) plane. The microwave electric field can be measured by detecting the polarization change of the lightwave propagating round-trip through the crystal in the EO probe. In Fig. 1, the measurement direction of the microwave electric field is transversal to the longitudinal one of the EO probe.

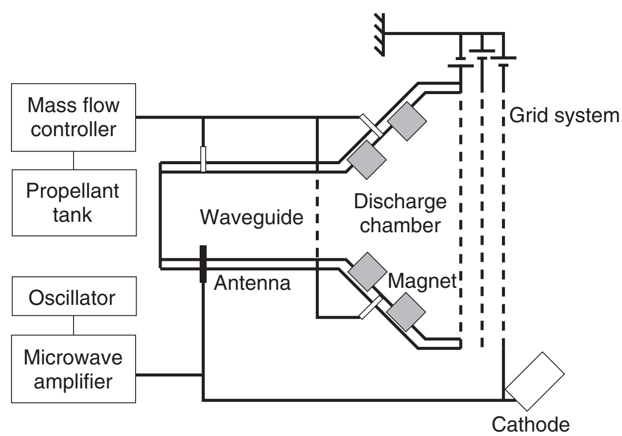

Fig. 2. ECR Ion Engine.

3. ECR ion engine installed in asteroid explorer

A schematic diagram of the ECR ion engine that was installed in the asteroid explorer developed by JAXA is shown in **Fig. 2**. The ECR ion engine basically consists of a waveguide, a discharge chamber, and a three-grid system. Inside the ECR ion engine, there is a dipole antenna and a propellant inlet at one end of the waveguide. The other end of the waveguide is connected to the discharge chamber (right side in Fig. 2). The ECR ion engine uses a microwave with a frequency of 4.25 GHz to produce plasma, which is transmitted through the waveguide to the discharge

Issues in microwave plasma measurement:	Improvements
(1) Improvement of sensitivity stability	16% ⇒ 10%
(2) Improvement of magnetic field resistivity	0.1 T ⇒ 0.8 T
(3) Improvement of thermal resistivity	100°C ⇒ 1200°C

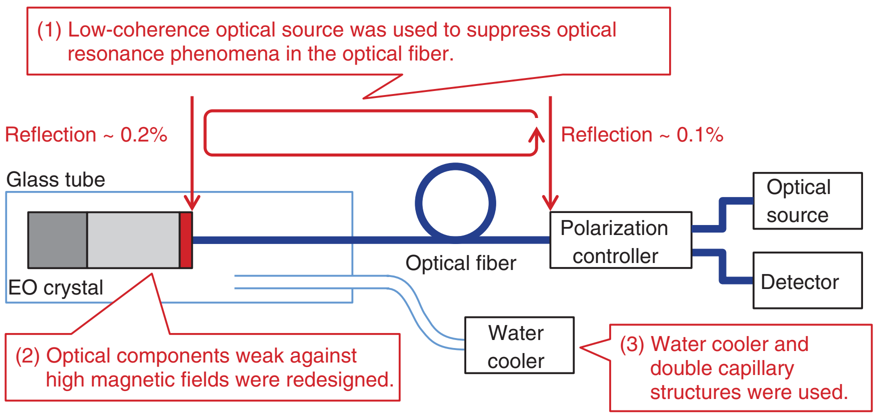

Fig. 3. Improvements of EO probe.

chamber. The 4.25-GHz microwave and a propellant, xenon (Xe), are injected from the waveguide and travel to the discharge chamber. In the discharge chamber, Xe electrons are continuously accelerated by the ECR heating of the microwave and the mirror magnetic field generated by two rings of magnets. ECR plasma is formed through subsequent electron-neutral and electron-ion collisions. JAXA has improved the thrust force of the ECR ion engine by changing the way the propellant is injected [3], [4]. In conventional ECR ion engines, the propellant inlet is located only at the end of the waveguide. In the improved ECR ion engine, propellant inlets are added between the magnet rings in the discharge chamber.

4. Improvements to EO probe for measurements in ECR ion engine

As described in the previous section, the environment inside the ECR ion engine is very severe, and thus, the EO probe needed to be modified to improve its performance in carrying out the specified measurements in the ECR ion engine during actual operation, as shown in **Fig. 3**.

(1) To achieve stable measurement with less fluctuation than that of a microwave oscillator output, a low coherence optical source was used to suppress the optical resonance phenomena in the optical fiber. Accordingly, the sensitivity fluctuations of the fiber-optic EO probe were reduced from 16% to less than 10%.

(2) To enable the EO probe to be applied to high-magnetic-field areas in the ECR ion engine, the optical components that were weak against high magnetic fields were redesigned. This increased the magnetic-field resistance from 0.1 T to over 0.8 T.

(3) To enable application of the EO probe to high temperature areas, a water cooling system with a double capillary structure was introduced [5]. The outer diameter of the capillary structure is 3 mm, which made it possible to insert it into the ECR ion engine through the grids without requiring any additional perforations or modifications.

5. Measurement setup

The experimental setup [6] used to conduct the electric-field measurements inside the ECR ion engine is shown in **Fig. 4**. In the vacuum chamber, the EO probe is placed in a silica glass tube 3 mm in diameter, which is mounted on a linear stage and a rotary stage positioned by stepping motors. The probe is remotely inserted in the discharge chamber through the center aperture of the grids. The measurement interval is 1 cm. The rotational angle is adjusted so that the measurement direction of the EO probe is parallel to the longitudinal direction of the dipole antenna, where the maximum electric field is detected. The input microwave power is 34 W.

A laser diode (LD), polarization controller, photodetector (PD), and spectrum analyzer are set outside the vacuum chamber. The polarization controller comprises a polarizer, a circulator, half and quarter-wave plates, and an analyzer. The lightwave emitted from the LD is polarized linearly by the polarizer and input into the PMF; it reaches the tip of the probe through the circulator. The lightwave makes a round-trip pass through the EO crystal via reflection by the dielectric reflector, and the polarization of the lightwave changes in proportion to the microwave electric field along the measurement direction. The polarization-changed light is returned to the polarization controller and converted to linearly polarized light by the analyzer. That is, the lightwave is intensity-modulated by the microwave electric field. The intensity-modulated light is detected and converted to an electric signal by the PD. The amplitude and phase of the electric signal are proportional to those of the microwave electric field, and the frequency of the electric signal is the same as that of the microwave electric field. As a microwave signal is input into the ion thruster at a frequency of 4.25 GHz, the spectrum analyzer displays the spectrum with the intensity proportional to that of the measured microwave electric field at a frequency of 4.25 GHz.

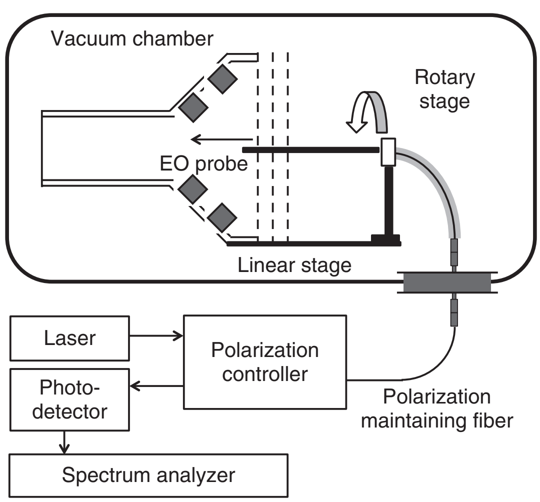

Fig. 4. Measurement setup.

Prior to the measurement, the probe is calibrated using a rectangular waveguide with a cross section of 2.0×4.0 cm^2 in atmospheric pressure. The calibration results agreed well with the theoretical electric-field intensity in the waveguide at a known microwave power.

In the measurement, the EO probe was kept at 25°C by a cooling system under beam acceleration in order to achieve the same accuracy as the calibration. The measurement was conducted at various points inside the thruster, as shown in **Fig. 5**.

6. Electric-field measurement [7]

The intensity distribution of a microwave electric field parallel to the dipole antenna in the ECR ion engine is shown in **Fig. 6**. The measurement was conducted with respect to the propellant inlet positions of the waveguide and the discharge chamber at a flow rate of 2 sccm under beam acceleration. Each graph has a different scale of intensity to express the differences in the intensity of the electric field between the center axis and the ECR region.

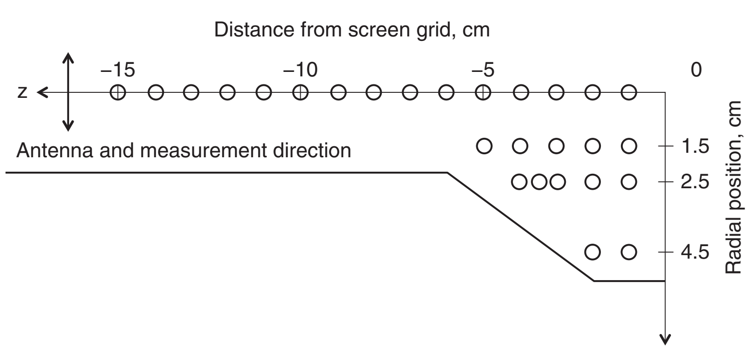

Fig. 5. Measurement points.

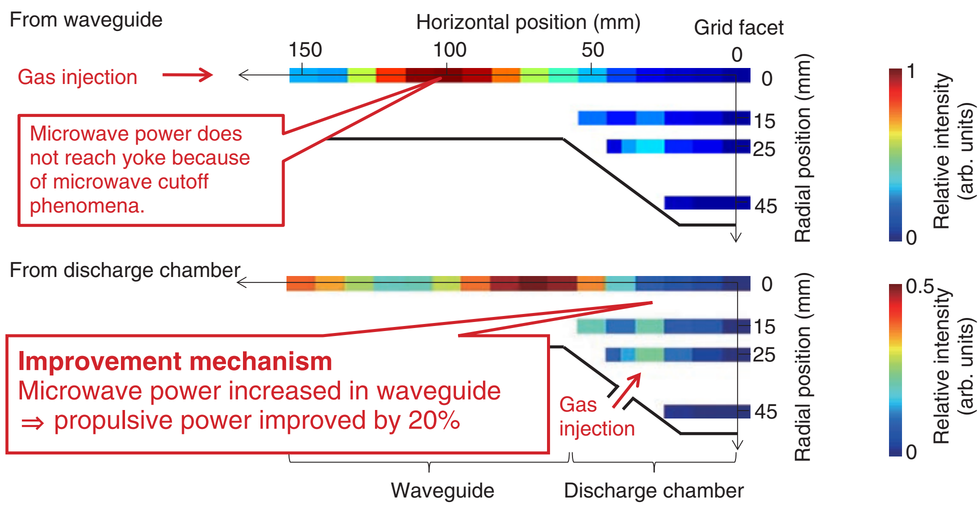

Fig. 6. Electric-field distribution inside ion engine (lower half of engine).

As shown in the figure, the intensity distribution of the electric field with plasma is completely different between the propellant inlet positions. From the waveguide inlet, the highest value was recorded at 100 mm from a grid facet. By contrast, from the discharge chamber inlets, the highest value is located more downstream. Moreover, the absolute value of the propellant injection from the discharge chamber inlets is half of that from the waveguide inlet. This phenomenon resulted in the saturation of beam current at 2 sccm from the waveguide inlet. The highest intensities exist at over 12,000 V/m around 100 mm from the grid facet. At that point, the intensities of the ECR region are quite low. Hence, it is highly possible that insufficient microwave power is supplied to the ECR region, which results in the reduction of the beam current.

This measurement revealed that the difference in the low-beam current mode and the high-beam current mode corresponds to the presence of the peak of the electric-field intensity of the microwave in the waveguide. This peak is possibly suppressed by changing the way the propellant is injected from the waveguide inlet to the discharge chamber inlets. This result indicates that the tendency is the same as that in the laser absorption spectroscopy of Xe I 828.01 nm [4], which can explain the mechanism of improvement of the propellant force in the ECR ion engine.

7. Future tasks

We are now considering the operability of the optical components in the probe because of their complicated design structure and the long-term reliability of the optical adhesive resin used to fix the optical components such as the EO crystal and the optical fiber. NTT Microsystem Integration Laboratories aims to improve the operability by using a novel structure for the fiber-mounted EO probe and to increase the probe's reliability by improving the optical adhesive resin. The last step will be to finalize the design of the fiber-mounted EO probe used for obtaining microwave electric-field measurements within the microwave discharge ion engine.

References

[1] H. Togo, N. Kukutsu, N. Shimizu, and T. Nagatsuma, "Sensitivity-Stabilized Fiber-Mounted Electrooptic Probe for Electric Field Mapping," Journal of Lightwave Technology, Vol. 26, No. 15, pp. 2700–2705, 2008.

[2] H. Togo, S. Mochizuki, and N. Kukutsu, "Optical Fiber Electric Field Sensor for Antenna Measurement," NTT Technical Review, Vol. 7, No. 3, 2009.
https://www.ntt-review.jp/archive/ntttechnical.php?contents=ntr200903sf5.html

[3] K. Nishiyama, T. Nakai, and H. Kuninaka, "Performance Improvement of the Microwave Discharge Ion Thruster u20," Proc. of the 42nd AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit, AIAA 2006-5176, Sacramento, California, USA, 2006.

[4] R. Tsukizaki, H. Koizumi, S. Hosoda, K. Nishiyama, and H. Kuninaka, "Improvement of the Thrust Force of the ECR Ion Thruster μ10," Trans. JSASS Space Tech. Japan, Vol. 8, pp. Pb 67–Pb 72, 2010.

[5] T. Ise, R. Tsukizaki, H. Togo, H. Koizumi, and H. Kuninaka, "Electric field measurement in microwave discharge ion thruster with electro-optic probe," Review of Scientific Instruments, Vol. 83, No. 12, 124702-1-6, 2012.

[6] T. Ise, R. Tsukizaki, H. Togo, H. Koizumi, and H. Kuninaka,

"Elucidation of Internal Phenomena in Microwave Ion Thruster μ10 Utilizing Electro-Optic Fiber Probe," Proc. of Space Transportation Symposium, STEP-2012-040, Kanagawa, January 2013 (in Japanese).

[7] R. Tsukizaki, T. Ise, H. Koizumi, H. Togo, K. Nishiyama, and H. Kuninaka, "Plasma Diagnostics of the μ10 ECR Ion Thruster Using Optical Fiber Probes," Proc. of 33rd International Electric Propulsion Conference (IEPC2013), IEPC-2013-270, Washington D.C., USA.

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International Standardization Trends in China

Daisuke Ikegami

Abstract

In China, independent technological innovations are progressing in accordance with the National Guideline for Medium and Long-term Plan for Science and Technology Development, announced by the State Council of the People's Republic of China in 2006. In the context of such innovation, standardization activities are under way in various industrial fields, with specific goals set for each area of technology. Standardization in the communications industry is being implemented by the China Communication Standards Association (CCSA). This article reviews recent developments in the CCSA's standardization activities and explains the structure of the Chinese standardization system and recent trends in the communications industry.

Keywords: standardization trend, CCSA, M2M

1. Introduction

Chinese telecommunications technology has made remarkable strides in recent years. Information and communications technology (ICT) is rapidly becoming widespread, with the number of mobile phone subscribers and broadband subscribers respectively reaching about 1.1 billion and 175 million as of the end of 2012. Standards have played an important role in the diffusion of broadband. The national compulsory standard GB[*1] 50846-2012 Design Specification for FTTH (fiber to the home) Facilities in Residential and Construction Areas, enacted this year on April 1, deserves particular attention. The specification makes FTTH wiring compulsory for each household in new multi-unit apartments and residential buildings in cities where FTTH is available. The enforcement of this compulsory standard is expected to make FTTH even more widespread.

In addition to the promotion of broadband, systematic measures are being devised in a variety of fields following the uniquely Chinese model in which political instruction is given by the government on which direction to take. In China, the central government lays out its policies every five years and determines which areas to focus industrial development on. The period from 2011 to 2015 is covered by the 12th Five-Year Guideline, which is focusing on seven industrial fields as key areas: energy conservation/environmental protection, next-generation information technology, biotechnology, the production of cutting-edge equipment, new energies, new materials, and cars employing new energy sources. Macro-development plans to develop the industrial fields established in the Five-Year Guidelines are also subsequently announced with the release of each set of guidelines. In response to these development plans, ministries, agencies, and local governments also set numerous guidelines and plans that include numerical targets and conceptual levels to be achieved by the end of the 12th Five-Year Guideline period (that is, by the end of 2015) [1].

Having joined the WTO (World Trade Organization) in 2001, China is working to ensure transparency in its compulsory standards, optional standards, and conformity evaluation procedures in accordance with the TBT (Technical Barriers to Trade) agreement imposed on member countries. At the same time, it will need to establish domestic regulations by incorporating international standards and guidelines.

*1 GB stands for *Guobiao*, Chinese for *national standard*.

2. National Guideline for Medium and Long-term Plan for Science and Technology Development

In February 2006, China officially announced its National Guideline for Medium and Long-term Plan for Science and Technology Development—a mid- to long-term plan for scientific and technological fields—as a national strategy to cover the period until 2020, and has steadily been implementing it. This plan's four pillars are independent innovation, leaps in key areas, support for development, and drive toward the future. China will promote original innovation (leveraging China's own capacity for innovation), collective innovation (that is, capacity for innovation by leveraging resources it holds intellectual property rights to), and re-innovation (that is, capacity for innovation brought about by the introduction of new technologies) and basic technological research. In doing so, China is aiming to bring about new breakthroughs, support sustainable social development, and aid the diffusion of basic research and cutting-edge technologies.

In this context, specific key areas and high-priority tasks have been established and are steadily being implemented.

3. 12th Five-Year Guideline for Standardization

Since the announcement of the 12th Five-Year Guideline for Standardization (December 2011) in the standardization field, a wide array of standardization activities have been underway in China in line with its long-term targets. Examples of the key areas of standardization in the next-generation information technology industry are listed in **Table 1**.

China is working on international standardization with unprecedented energy, and the number of posts assumed by Chinese industry leaders in organizations such as ISO (International Organization for Standardization), IEC (International Electrotechnical Commission) and ITU (International Telecommunication Union) has been rising year after year.

The number of patent applications has also been rapidly increasing in a variety of fields, with the number of international applications filed in 2012 under the PCT (Patent Cooperation Treaty) reaching 18,627 (up 13.6% over 2011), placing China in fourth position behind the U.S., Japan, and Germany [2]. China has also made its presence felt in the field of technological development. Representative examples of standards recently proposed by China to international standardization institutions include TD-SCDMA (Time Division-Synchronous Code Division Multiple Access), IGRS (Intelligent Grouping and Resource Sharing), WAPI (Wireless-LAN (local area network) Authentication and Privacy Infrastructure) and TD-LTE (Time-Division Long-Term Evolution).

4. Standardization in China

Standardization in China is prescribed by law in the Standardization Law of the People's Republic of China (PRC) (enacted in 1989). All standards currently in effect were established based on this law. These regulations classify Chinese standards into four types: national standards, departmental standards (industry standards), local standards, and corporate standards [1]. Each type of standard is further divided into compulsory standards and optional standards (recommended standards). Standardization documents for compulsory national standards are identified by a code number preceded by GB, whereas those for optional standards are indicated by GB/T. Thus, the status of the standards that are established can be understood by looking at their codes [1].

National standards are established and managed by SAC (Standardization Administration of China), an external bureau of the AQSIQ (General Administration of Quality Supervision, Inspection and Quarantine of PRC), while industry standards are enacted and managed by the central government's relevant departments for each industry. Communications-related standardization is carried out under the lead of MIIT (Ministry of Industry and Information Technology). Regional standards are those established by individual regions (provinces, autonomous regions, and directly controlled municipalities), and are managed by the standards office of each region's Bureau of Quality and Technical Supervision.

The organizations that oversee the various standards are shown in **Fig. 1**. Note that SAC is a member institution of ISO/IEC.

5. China Communications Standards Association (CCSA)

5.1 Overview

CCSA was founded in 2002 as the only standardization institution in charge of standards in the Chinese communications industry [3]. CCSA members come from diverse fields in the communications industry, for example, research institutions, communications carriers, vendors, and universities. The

Table 1. Key points for standardization of next-generation IT industry.

Item	Descriptions
Information network infrastructure and next-generation mobile communication	- Establish standards concerning the optical transmission of high-speed multi-services. - Establish standards for the reinforcement of 2G and 3G mobile communication technology, 4G mobile communication, CDMA communication, digital honeycomb communications, network security, optical fiber, the union of fixed and mobile networks, wireless LAN, wireless broadband access, short-distance communication, etc.
Next-generation Internet core equipment and smart terminals	- Establish standards for improved network equipment efficiency and security, IPv6, domain systems and security, software switch security, Internet data centers, individual information processing equipment, e-books, etc.
Triple play	Establish standards for home networks, audio codecs, video codecs, basic standards and contents security shared by bidirectional digital television platforms and integrated systems, content formats for streaming media, network television, multimedia telephones, standards of interactive services among third screens (television, personal computers and mobile phones), IP phones, smart television connection standards and network transmission security standards for triple play
Integrated circuits and new-type displays	Establish standards for smart card web servers, electronic ID systems operable with smart cards, general IC card and smart card security and system security; electricity semiconductor, MEMS product and process standards; standards for 3D display comfort, compatibility and conversion, and new displays such as digital cinema, hi-vision TV, flat displays and laser displays.
High-end servers	- Establish standards for evaluating the performance of high-performance computers and servers, as well as for energy-saving features and electrical properties. - Push forward with studies on the high-end server standards required for applications such as Internet data centers, domain services and cloud computing.
High-end software and digital virtualization	Establish standards for operating systems, Chinese software formats, document layout, new-type databases, middleware, high-end software such as built-in type software, digital content management and protection, digital storage and interoperability, union of multi-media codecs, computer graphic modeling and simulation, environment data expression, virtual reality/augmented reality/mixed reality and digital content aggregation delivery platforms.
Software service and network added-value services	Establish standards for the plan, design and supervision of information system projects, governance and management of IT outsourcing, IT operation and maintenance, IT services, software services; added-value web service standards for Internet content filtering, interoperability, privacy protection, development and use of information resources, etc.
Wulianwang (a network that links objects):	- Establish and revise standards for the application of wulianwang to fields such as traffic, public safety, agriculture, environmental protection and forestry. - Establish key basic standards for wulianwang, and standards for sensor networks, automatic identification technologies and unified resource identifiers. - Use for RFID army standards.
Cloud computing	Establish standards for cloud computing terminology and reference models, cloud data management and storage, cloud platform interfacing and virtualization, next-generation search engines, next-generation network operating systems, mass storage systems, and intelligent mass data

Source (in simplified Chinese) at http://images.mofcom.gov.cn/lczx/accessory/201201/1325841074090.pdf from p. 14 onwards

IC: integrated circuit
ID: identification
IPv6: Internet Protocol version 6
MEMS: microelectromechanical systems
RFID: radio frequency ID

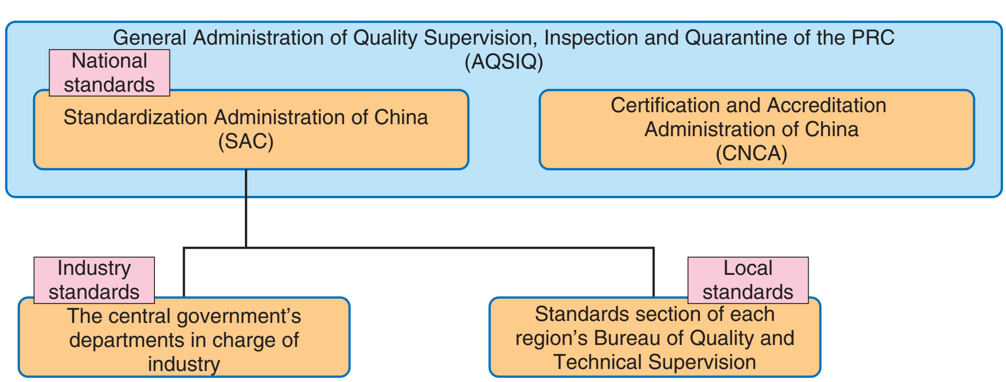

Fig. 1. Government bodies responsible for standards in China.

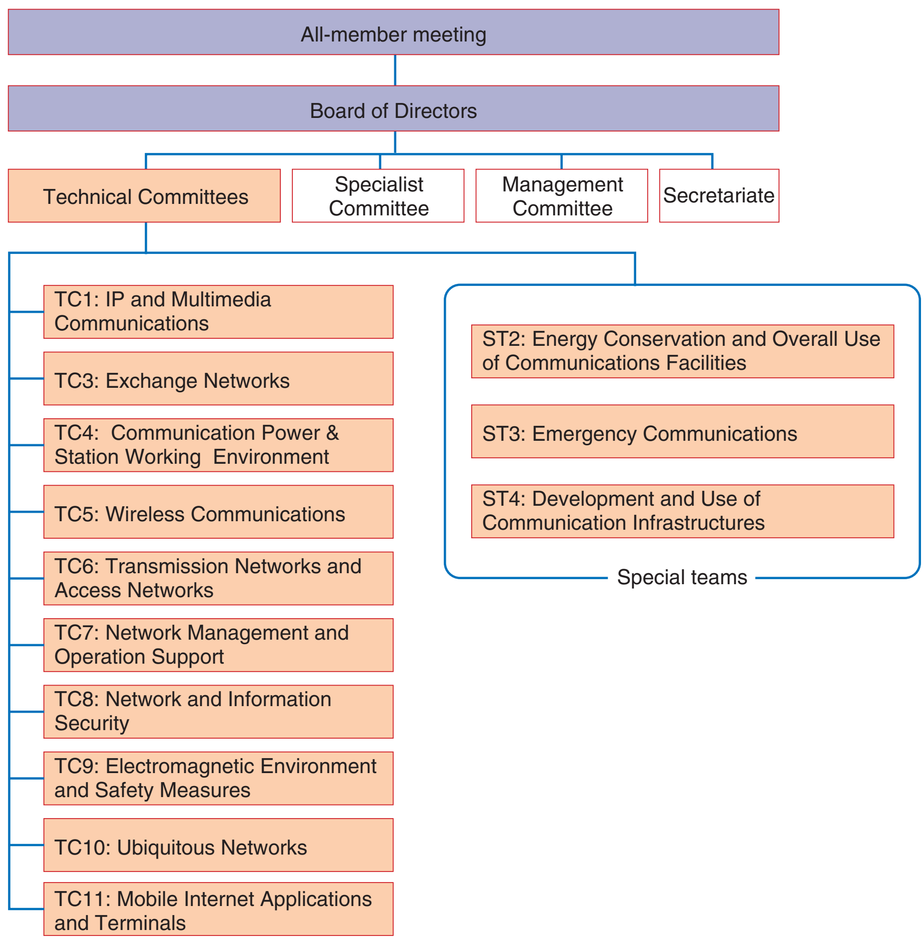

Fig. 2. Organizational structure of CCSA.

membership is divided into full members, affiliate members, and observers. In recent years, the number of members has been on the rise, and in 2012 there were 7 affiliate members, 29 observers, and 1 specialist member in addition to 279 full members.

In addition to carriers and vendors, CCSA's standardization activities revolve around CATR (China Academy of Telecommunication Research of MIIT)—China's only government-funded institution for research on telecommunications. CATR is engaged in providing support for government measures on communications as well as consulting and certification services. At the same time, it is actively involved in CCSA's domestic standardization activities carried out by Technical Committees (TCs) and in international standardization activities carried out by ITU-T.

5.2 Organizational structure and work on domestic standardization

At CCSA, TCs have been established in ten fields. They are working on various standardization efforts ranging from optical access to IPTV (Internet Protocol television), IPv6 (Internet Protocol version 6), and the Internet of Things (IoT). In addition to TCs, Special Teams (STs)—study groups on specific subjects—have also been set up. The CCSA's organizational structure is shown in **Fig. 2**, and the areas that each TC's Working Group (WG) is focusing on are listed in **Table 2**.

In 2013, certain fields were identified as key areas. These were: Broadband China, TD-LTE, cloud computing, IoT, Internet datacenters, SDN (software-defined networking), next-generation satellite communications, information safety, and industry regulations. In terms of numerical targets, 400 projects in total are to be completed, including national standards,

Table 2. Areas of focus for TC WGs.

Study group		Subject studied
TC1	WG1	IP networks and equipment
	WG2	IP services and applications
	WG3	Content protection
	WG4	New technologies and international standardization
	SWG2	IPTV
TC3	WG1	Networks in general
	WG2	Signaling protocols
	WG4	Services and applications
TC4	---	---
TC5	WG3	Wireless LAN and wireless access
	WG4	cdmaOne/CDMA2000
	WG5	3G security and encryption
	WG6	Beyond3G
	WG8	Frequency
	WG9	TD-SCDMA/WCDMA
	WG10	Satellite/microwave communication
TC6	WG1	Transmission networks
	WG2	Access networks
	WG3	Optical fiber/optical cables
	WG4	Optical devices

Study group		Subject studied
TC7	WG1	Wireless communication management
	WG2	Transmission network and access network management
	WG3	General
TC8	WG1	Wired network security
	WG2	Wireless network security
	WG3	Security management
	WG4	Security infrastructure
TC9	WG1	Magnetic coupling of telecommunications facilities
	WG2	Anti-thunderstorm damage measures for telecommunication systems
	WG3	Electromagnetic radiation and safety
TC10	WG1	General
	WG2	Applications
	WG3	Networks
	WG4	Development of technology and standardization
TC11	WG1	General
	WG2	Service platforms and their applications
	WG3	Terminals

TD-SCDMA: time-division synchronous CDMA
WCDMA: wideband CDMA

industry standards, association standards, and research reports.

In recent years, China has pushed forward with technological development concerning its *wulianwang*[*2] and Broadband China, treating this development as a national policy. Technological standards in these fields are also being studied intensively.

Wulianwang is the subject of wide-ranging studies, from the distribution of sensor information to the exchange of information between smart city platforms. The TC10 Technical Committee on ubiquitous networks, established in 2010, has been actively working on the standardization of sensor networks, M2M (machine-to-machine) communications, and smart cities. The *wulianwang* that China aims to create will leverage the necessary applications to enrich people's lives, which places the focus of discussions on the study of applications. Furthermore, Broadband China includes the study of FTTH and IPv6, and CCSA's involvement in IPv6 is especially active, with initiatives such as the management of the world's largest IPv6 network.

In recent years, standardization work has intensified further, with a total of 646 drafts completed in 2012 (national standards, industry standards, technical reports on communication standards, and research reports). Also, documents in the communication technology field drafted over the ten years since the CCSA's establishment include 2,663 industry standards, 506 national standards, 96 technical reference documents, and 115 technical reports.

At the NTT Group, observers from NTT are participating in TC10, and observers from NTT DOCOMO are taking part in TC5, TC10, and TC11, gathering information on the progress of communications standardization in China.

5.3 Cooperation with international standards institutions

CCSA is actively engaged in cooperative initiatives with international standardization institutions and standardization conferences. For example, one can get an idea of the significance of its role from the number of articles contributed to international

*2 *Wulianwang*: a network linking objects. The concept is similar to that of the Internet of Things (IoT); China's *wulianwang*, however, is used as a keyword to indicate a wider scope than IoT.

standardization bodies over the ten years up to 2012, which is in excess of 40,000; reportedly, the acceptance rate for the recommendation is also rising each year. CCSA is also trying to widen the scope of its activities, for instance, by proposing the launch of various new Focus Groups (FGs) in ITU-T. China's role as a global leader in standardization is beginning to become apparent; over 40 key personnel are reported to have been appointed at international standardization organizations, and several hundred Chinese representatives are working as editors of standards. China has made its presence especially felt in the ITU-T's FG-M2M field, where it has proposed the launch of an FG and obtained the chairman's appointment. The FG-M2M field is related to *wulianwang*, which is the focus of much development in China.

In addition, China is actively involved in *oneM2M*, a new M2M standardization body whose establishment was agreed upon by six standardization bodies: ARIB (Association of Radio Industries and Businesses), ATIS (Alliance for Telecommunications Industry Solutions), CCSA, ETSI (European Telecommunications Standards Institute), TIA (Telecommunications Industry Association), and TTA (Telecommunications Technology Association), and in fact hosted a oneM2M conference in Beijing in December 2012 [4].

China has also formulated a large number of proposals in oneM2M; at the 2nd conference held in December 2012, it submitted 12 contributions, including China's standard *Ubiquitous Network Terminology*. This series of initiatives shows China's intention to lead discussions outside of the conventional framework of standardization bodies.

6. Conclusion

Despite the effects of various internal and external issues, China's economy is continuing to grow steadily, and remarkable developments are being achieved in the ICT field. In particular, a variety of systematic initiatives such as the mid- to long-term development plans for 2006–2020 and the 12th Five-Year Guideline are being pushed forward in the fields of science and technology in order to achieve technological innovations originating from China. The same goes for standardization. China is focusing particular efforts on standardization in the communications field and is making vigorous advances: in 2012, 44 out of 211 standards in the 19 industrial fields established by the MIIT were communications-related, accounting for 21% of the total.

At the NTT Beijing Representative Office, we will continue to gather information on standardization trends in the Chinese telecommunications industry on behalf of the NTT Group, and to pursue and promote new cooperative relationships with China.

References

[1] D. Ikegami, "NTT Beijing Representative Office," NTT Technical Review, Vol. 11, No. 7, 2013.
https://www.ntt-review.jp/archive/ntttechnical.php?contents=ntr201307ov1.html

[2] PCT Yearly Review, 2013.
http://www.wipo.int/portal/en/news/2013/article_0021.html

[3] China Communications Standards Association.
http://www.ccsa.org.cn/english/

[4] CCSA, oneM2M Conference (in simplified Chinese).
http://www.ccsa.org.cn/worknews/content.php3?id=2992

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External Awards

IEICE ELEX Best Paper Award in the Year 2012

Winners: Yoshio Takahashi[†1] and Tsutomu Matsumoto[†2]

†1 System Platforms Sector, NTT DATA Corporation

†2 Graduate School of Environment and Information Sciences, Yokohama National University

Date: September 18, 2013

Organization: The Institute of Electronics, Information and Communication Engineers (IEICE)

For “A Proper Security Analysis Method for CMOS Cryptographic Circuits”.

Differential Power Analysis (DPA) aims at revealing secret keys in cryptographic devices by analyzing their power consumption as side-channel information. Although power consumption models based on transition probability were used to evaluate DPA resistance in previous studies, the adequacy of these models has not been adequately confirmed. In this paper, we describe two experiments on obtaining precise information of power consumption, and show that Random Switching Logic, one of the DPA countermeasures, is in reality not secure against DPA.

Published as: Y. Takahashi and T. Matsumoto, “A Proper Security Analysis Method for CMOS Cryptographic Circuits,” IEICE Electronics Express, Vol. 9, No. 6, pp. 458–463, 2012.