Interpretive Article

Suica Technology and Strategy for Future Development

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1 Introduction

In October 2004, sales of Suica achieved 10 million units. A large number of customers are using this product. Today, I would like to introduce technologies used in Suica cards and the deployment strategy, or future direction, of the Suica business.

2 Background of Introduction of Suica

Various types of Suica-related studies were conducted around 1998, before the beginning of the new millennium. One of these studies was about an electromagnetic ticket gate machine which was introduced in 1990 before the Suica generation. It was already known that this ticket gate machine needed to be replaced after 10 years of operation, and it was reaching the point where its maintenance cost started to rapidly increase; therefore, we were conducting studies on the next generation system.

Meanwhile, from the technological point of view, electronics showed rapid development. Since the establishment of the company, we have been studying application of IC card technologies to the railway business. In FY1997, it was finally concluded that the technology level had reached the level of practical application.

At the same time, from the management perspective, the medium-term business plan (New Frontier 21) was being reviewed, with a view toward the 21st century. New Frontier 2008 has now been published, but back then, there was a management plan to promote creation and development of new business through improvement of competitiveness of railroading and also through synergistic effects of life-style service business and railroading.

For these reasons, there were active discussions on whether the aging system should be replaced with an electromagnetic system or IC card system in 2000. As a result of comprehensive studies on cost, service, scalability, safety, and trends of new technologies, it was concluded that a new ticket gate system using IC cards would be introduced. As Mr. Tokiwa mentioned in his keynote speech, I believe this decision is an example of "management of technology."

Approximately 46 billion yen has been spent on this Suica project. Of which, 33 billion was necessary for replacing the aged system regardless of whether or not the IC card system was introduced. Being a member of this project since it started, at the outset I studied

this issue from various perspectives since an additional 13 billion yen would be necessary to make the introduction of the IC card system possible. After this was completed, it was decided to introduce the IC card system, and finally, the service started on November 18, 2001.

3 Current Suica Status

3.1 Suica network and terminal configuration

Figure 1 shows the inside of a Suica IC ticket card. There is a coil-shaped antenna inside the card, and a chip is attached to this antenna. The chip is usually square-shaped, but it appears round because a thin stainless steel plate is put on it. Use of this stainless steel plate started as chip protection after there were a large number of cases where people in Hong Kong put an IC card in a wallet, put the wallet in a back pocket and sat while the wallet was still in the back pocket, thus applying high bending stress to the card resulting in breaking of lines inside the chip.

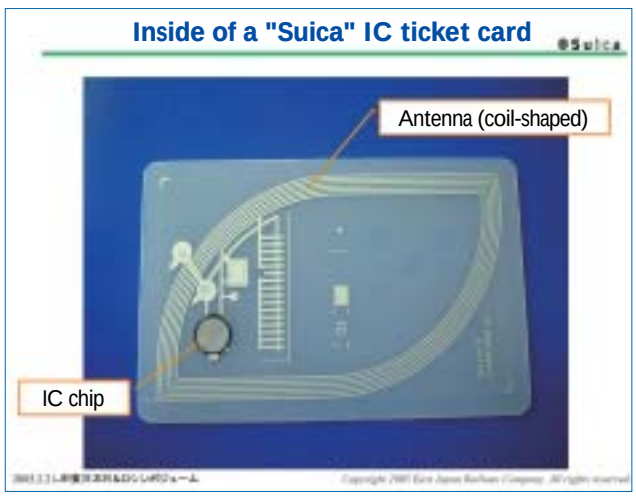

Fig. 1 Inside of a "Suica" IC ticket card

As for Suica network and terminal configurations, terminals such as automatic ticket gates, train pass vending machines that also sell Suica cards, and ticketing systems that take cash are all connected to a station server via the station LAN. This station server, in turn, is connected to a wide area network (ID management network), and finally to the center server. There are almost 10,000 terminals (Figure 2).

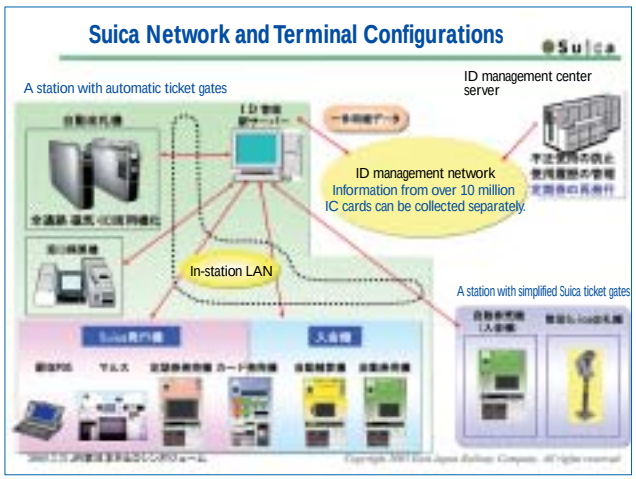

Fig. 2 Suica Network and Terminal Configurations

3.2 Suica card sales

Data as of February 13, 2005, shows that approximately 10.9 million Suica cards had been purchased within a little less than three years since its release in October, 2004.

Breakdown of the data is as follows: 4.64 million Suica passes, 5.84 million Suica IO cards, and 370,000 View Suica cards (Figure 3).

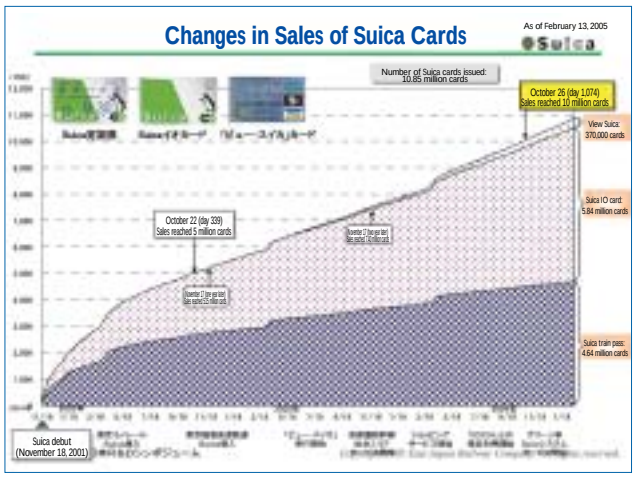

Fig. 3 Changes in Sales of Suica Cards

3.3 Collection of Suica Itemized Event Information

A unique ID number starting with "JE" is given on the backside of each Suica card, and this ID number and card use information recorded by a station service device are called itemized event information. When a card is used with a ticketing system or an automatic ticket gate machine, money-related information for each card use is sent to the center server as card use information. Recently, there have been over 5 million transactions per day (Figure 4).

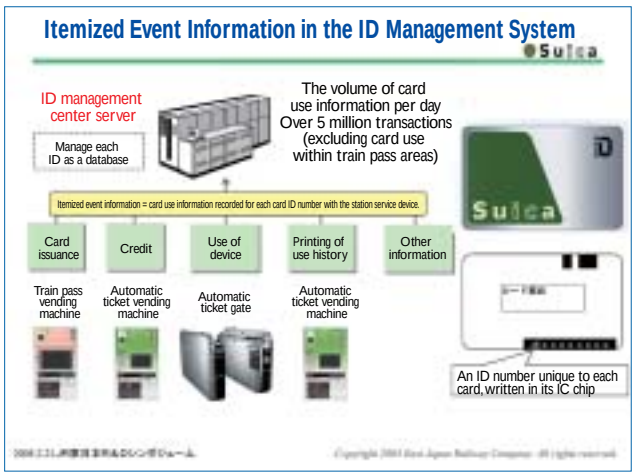

Fig. 4 Itemized Event Information in the ID Management System

Figure 5 shows the number of data transactions recorded since the use of Suica cards started. The number of transactions first went over 5 million per day at the end of 2004 then went down a little, but recently, it is not unusual that the number of transactions is over 5 million per day.

When this data is examined week-to-week, the transaction volume increases from Monday and on, and then drops on Saturday and Sunday. This tendency repeats itself every week. Steep drops in the transaction volume occur during the Obon festival week, year-end holidays, and new-year holidays, and as expected, most activity can be observed on weekdays.

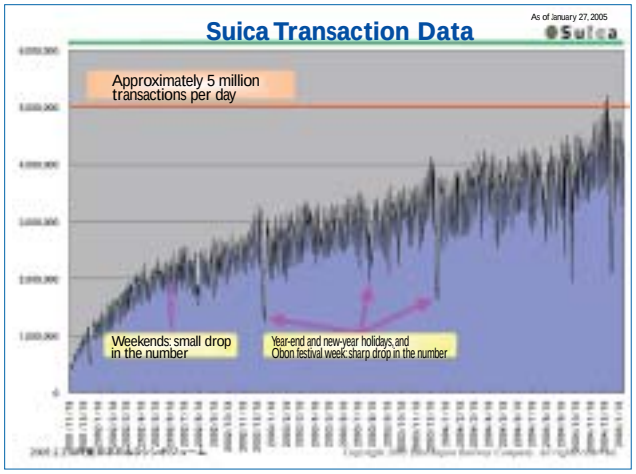

Fig. 5 Suica Transaction Data

3.4 Approach to Suica standardization

Next, I would like to describe the current status of Suica standardization.

When first introduced, Suica was not based on the ISO International Standards. We then worked hard to make it conform to the international standards, and finally gained ISO18092 accreditation for the communication standards in December 2003. These standards are so-called Type C standards. We hope to also receive the ISO1443 accreditation for the IC card standards, and therefore, we will continue to promote our approach to gaining ISO accreditation.

If an IC card conforms to the IC card standards specified by the Consortium of Japan Railway Cybernetics (known as the cybernetic IC card standards), a train ticket can be used with different rail carriers regardless of the location of ticket purchase. These standards were established in March 2001. We are now promoting JIS conformity of Suica based on the above-mentioned cybernetics standards, and Suica is planned to gain JIS accreditation for the high-speed processing IC card standards within this year. We are now considering the possibility of proposing Suica to the ISO after receiving the JIS accreditation.

Suica also has gained ISO15408 accreditation for security evaluation and certification.

As for the current status and future prediction of Suica cards and cards using similar cybernetics standards to that of Suica, according to newspapers and other media, there are in total over 27 million railroad and bus related cards, 11 million of which cards were issued by East Japan Railway Company.

Also, it was recently reported in the news that NTT DoCoMo and Sony will work together to introduce a FeliCa chip to all DoCoMo cell phones. The FeliCa chip is the same chip as the one used in Suica cards. When such introduction is actually made, then more than 70 million IC chips based on the cybernetics standards will be in use domestically as there are approximately 45 million DoCoMo cell phones. Since KDDI and Vodafone have already announced that they would follow the DoCoMo method, the number of these IC chips in use is expected to continue to increase.

Regarding security evaluation and certification, Suica has passed the security evaluation level 4 of EAL4, based on ISO15408. There are 7 levels in total, and level 5 is usually considered as the military level. Therefore, for the purpose of consumer-use, Suica has high security standards. It is usually the case that the manufacturers of cards of this type obtain this certification, however it is extremely rare that a user company obtain such certification (Figure 6). Since there was no domestic organization to accredit level 4 back then, we obtained the certifications in the UK on June 13, 2003. Since there are higher levels such as level 4+, we will continue to make efforts to improve card security.

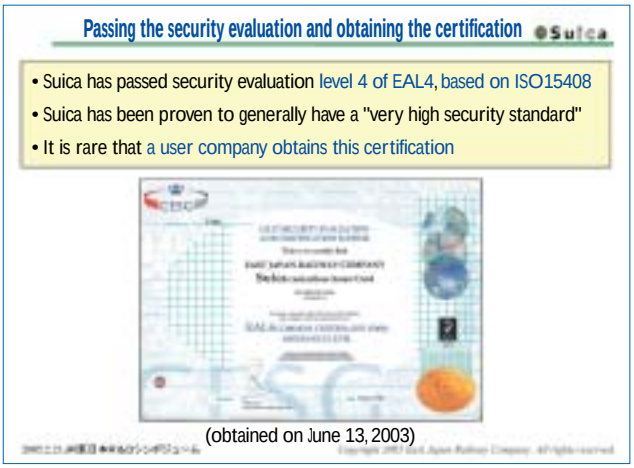

Fig. 6 Passing the Security Evaluation and Obtaining the Certification

4 Technologies Used in Suica Cards

4.1 IC card ticket system requirements

IC ticket system requirements can be roughly divided into terminal-related requirements, network-related requirements, and center server-related requirements. Terminal-related requirements, especially for automatic ticket gates, are for example improvement of the man-machine interface and improvement of data processing speed such that more customers can use the machines. There are also many other kinds of terminals; therefore, coexistence with other terminals as well as system reliability are important issues.

For networks, infrastructures for faster communications and establishment of high reliability network infrastructures are necessary. For the center server, faster data processing and securing of database reliability are necessary. Also, securing of scalability and reliability are important for the whole system.

Improvement of the man-machine interface, improvement of terminal data processing speed, and improvement of reliability of the whole system are generally the most important requirements, and we have been through a lot dealing with these issues.

4.2 Background of railway IC card development by East Japan Railway Company

In this section, I would like to make a comparison of processing

methods between an electromagnetic ticket gate and an IC card ticket gate.

In an electromagnetic ticket gate, once inserted, a card is mechanically and automatically transported and comes out from the machine approximately 1 m away. During this ticket transportation, card data is read and assessed, and necessary data is written on the card and then verified. The whole sequence is carried out in approximately 0.7 seconds.

An IC card ticket gate processes card information in a semi-spherical space having a radius of approximately 10 cm, and a person passes the gate with the card in the hand passing through that semi-sphere. At the same time, the gate confirms the "presence of the card" and that "a card is coming in and it is a JR East card." Then, card data will be processed in the same manner as in the electromagnetic ticket gate system (Figure 7). According to past experiments and experience, it has been understood that data processing time must be 200 ms or shorter. Therefore, we understand that an automatic ticket gate machine of this kind requires the most challenging technologies and thus we are working on technological development mainly for the purpose of overcoming this difficulty.

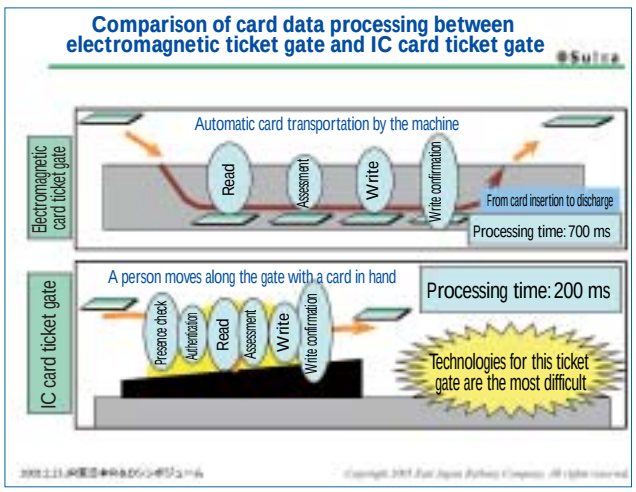

Fig. 7 Comparison of Card Data Processing Between Electromagnetic Ticket Gate and IC Card Ticket Gate

To briefly introduce the history of Suica development, we have been working on it for more than 10 years since the establishment of East Japan Railway Company (1987). First we developed an IC card and card reader/writer, which were the basic Suica technologies.

These development achievements were then evaluated in 1992, and technologies to speed up an important man-machine interface between a card and card reader/writer of a ticket gate and terminal processing were developed. As a result of the third test, the card and the reader/writer became practical. Since these elements alone do not create the Suica system, we started practical development including development of peripheral equipment or improvement of system reliability. We spent approximately 4 years to finally introduce a practical system.

4.3 Improvement of the man-machine interface

At the beginning of the development phase, we were not even sure if the card reader/writer should be arranged vertically or horizontally; therefore, we conducted a survey in the first test. As a result of the survey, we decided to arrange it horizontally. Since it was not very clear where the card must be exposed, we put a picture or a dotted signal as a guide. Finally, we created the current card reader/writer (Figure 8).

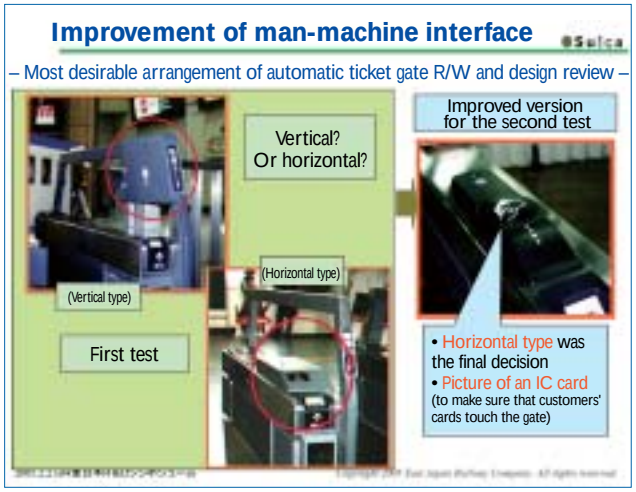

Fig. 8 Designing of the Card Reader/Writer

During the course of various tests, we used a camera to examine how people held the IC card or how long an IC card stayed in the communication area. As a result, a card stayed in the area for 0.52 seconds on average, and the shortest record was 0.2 seconds. Therefore, we have been working on improving terminal processing speed in order to achieve a processing time of 0.2 seconds or less (Figure 9).

After gradually getting used to holding the card, some start to hold it only for an extremely short period of time. In 3 field tests with employees, if they were instructed to "hold" the IC card because "it is a non-contact card," some held the card quickly over the processing unit and some held it low, close to the unit. If they held the card in these manners, it was of course impossible to make sure that the card was held for 0.2 seconds for processing; therefore, the card could not

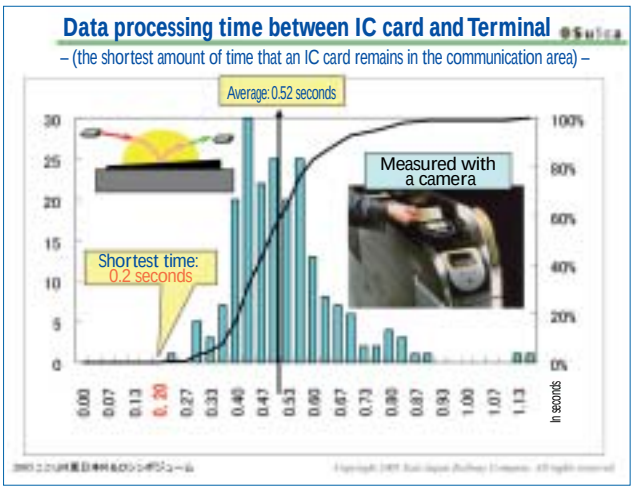

Fig. 9 Data Processing Time between IC Card and Terminal

be processed. In response to this problem, we came up with the touch-and-go method where a card moves in a form of the letter V in order to make sure that the card stays at the processing unit for a certain amount of time for processing. Regardless of the V shape drawn by the card, either steep or gradual, the total amount of time that a card stays in the processing area becomes the same, resulting in stable results (Figure 10).

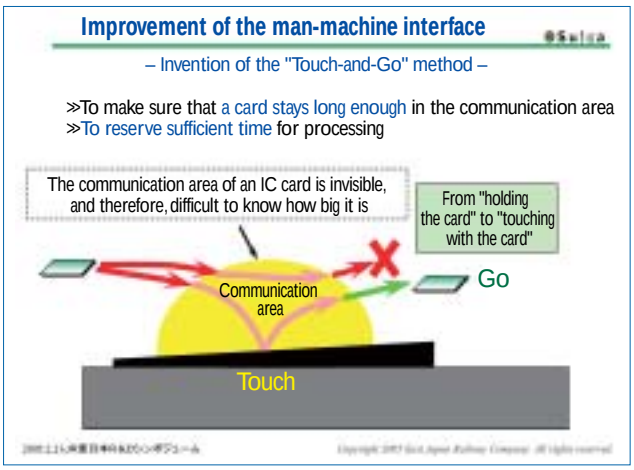

Fig. 10 Touch-and-Go Method

4.4 Improvement of terminal data processing speed

High speed processing is also demanded in fare calculation. Figure 11 shows an example of fare calculation when a person having a Suica train pass valid from stations X to Y rode a train from station A to B, which were outside the pass range. Usually, a cheaper fare would be charged between the route shown in red and the straight route. However, the problem is that the fare between stations A and J is unknown at station B. It is possible to know which station is closer from the base station or which station is used to calculate the fare, but this requires a huge database and complicated calculation which cannot be completed within 0.2 seconds.

As a result of examinations, we developed the temporary fare adjustment station method. In this method, when a person catches a train at station A, a base fare is deducted, meaning that the actual fare between stations A and J is written into the card. So, data will be written even though it is not clear where the person is going to. Station J in this case is called a temporary fare adjustment station, and the fare deducted is called a temporary adjusted fare. When this person gets off the train at station B, since the fare between stations A and J is already known, it becomes possible to calculate the resulting fare extremely fast, under 0.2 seconds.

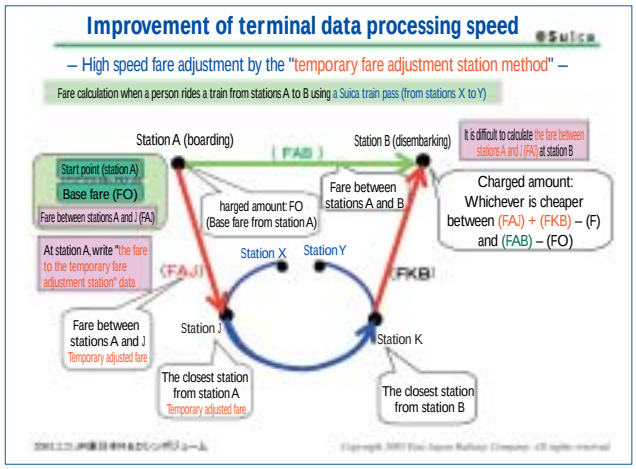

Fig. 11 Fare Calculation by the Temporary Fare Adjustment Station Method

Furthermore, the ticket gate is equipped with the reprocessing function for cases where some people may not be able to go through the gate even if the card is valid. This function allows a customer to turn around and re-apply the card to the processing unit in the middle of the gate because if the first try fails to be processed for some reason and a person stops at the gate, passenger traffic congestion is likely to occur. The slit for inserting the card will be closed when an electromagnetic card is used, but for an IC card, there is no such process because the IC card is free from the gate. Therefore, the function is added to allow a customer to turn around, reprocess the card, and then continue through the gate.

4.5 Improvement of system reliability

Due to the nature of the non-contact card system, data processing for an IC card is finally completed when its card data is updated and there is a confirmation response for it from the card to the gate. If

the card leaves the processing area immediately after the card is updated, the ticket gate data fails to be updated in a certain percentage of cases. This will result in data disagreement and thus inconvenience (Figure 12).

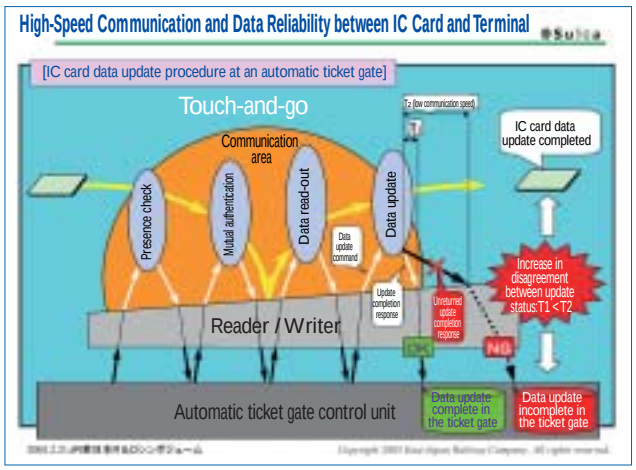

Fig. 12 High-Speed Communication and Data Reliability between IC Card and Terminal

As a measure for this problem, we have been considering implementation of the function for correcting temporary itemized events (Figure 13). When a card leaves A station, if no problem occurs, the data will be identical between the center server and the card. Then, when the card enters B station, if data must be updated, then it will be updated in the card. However, data will not be updated in the center server. Instead, temporary data will be registered. When the card leaves C station afterwards, both the card and the center server will be updated. Itemization data IDs 14 and 16 are checked, and if the temporary itemization data ID 15 is valid, then it is confirmed. We call this technology the autonomous distributed matching technology, and with this technology, we plan to improve

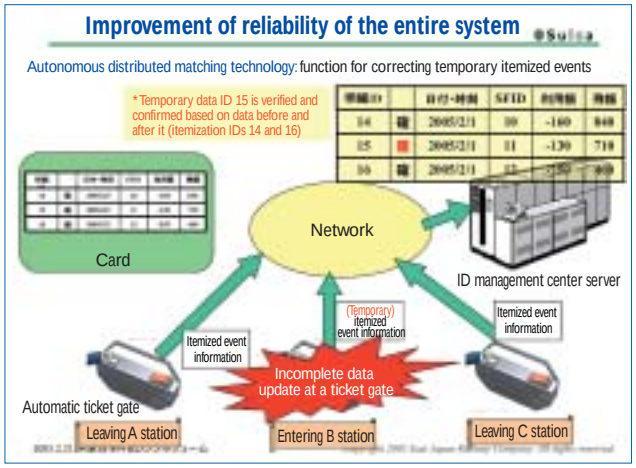

Fig. 13 Function for Correcting Temporary Itemized Events

reliability of the entire system by creating and correcting temporary itemized events. This function is scheduled to be added when a new function called the auto charge function is introduced in FY2005.

At this point I would like to introduce another reliable aspect of the entire system. The ticket gate machines and ticket vending machines are independently operated using the autonomous distributed matching technology. Each card can store 20 data items and each device can store data for 3 days. The center server can hold data for 26 weeks, or half a year. Therefore, even if there was a network problem or if the center server went down, each terminal device can still autonomously function for 3 days. Such configuration is designed without using a duplex system (the center server uses a duplex system) because, if the center server stops, the Suica system in the entire Tokyo metropolitan area can no longer be used, causing great inconvenience (Figure 14).

When the system recovers from failure, data will be read out and processed as if nothing had happed.

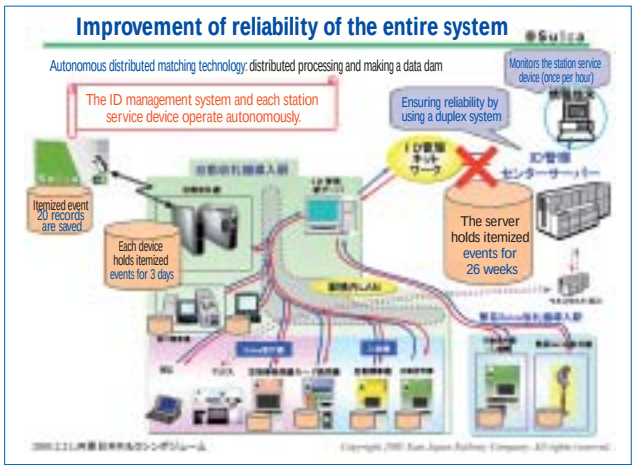

Fig. 14 Distributed Processing and Making a Data Dam

Understanding of the autonomous distributed system, as cited from the lab website of Professor Mori of the Tokyo Institute of Technology, can be "analogous to understanding of animals." Animals always have some parts that are not in use and these parts continue to change due to growth. For the Suica system, too, the idea that it is natural for a system to have parts not currently in use is highly important, and based on this concept, we hope to make the Suica system an even more sophisticated system.

4.6 Suica's useful functions

(1) Suica rewrite function

Some Suica train passes have information printed in blue, and this

printing in blue is put on the cards by the leuco-dye rewrite method. The rewriting material used in this method has an interesting characteristic in which under a certain temperature such as approximately 170 degrees Celsius, the leuco-dye and a developer will be mixed with each other to develop the dye color. The color stays the same if it is rapidly cooled down. If it is slowly cooled down, however, the dye becomes crystallized to create a so-called no-color state. Such technology is used to make a train pass reusable (Figure 15). The material is procured with a quality guarantee for 60 or more times of reprints such that a person can keep renewing a train pass every month for 5 years.

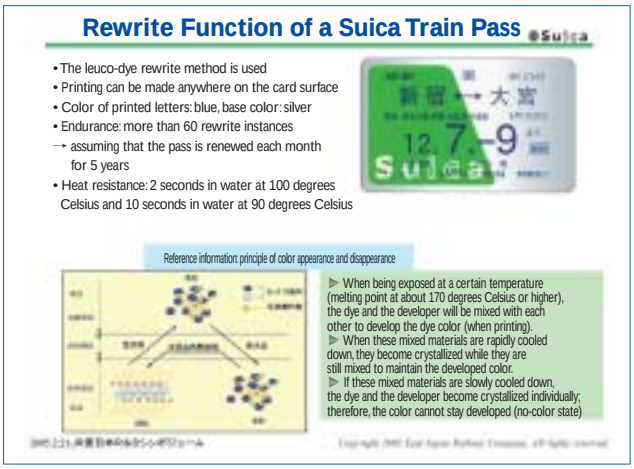

Fig. 15 Rewrite Function of a Suica Train Pass

(2) Suica's barrier-free features

The Suica system is a barrier-free system with a special emphasis on the card itself and audio guidance.

As for the card, a Suica IO card has two notches and a Suica train pass has one. By creating such notches, it is possible to differentiate the two types of cards from each other, and at the same time, it is possible tell which is the front side of the card. This is necessary since when using a Suica train pass, the printed side must be face-up when being used.

There is also an audio guidance function. Usually, when a Suica train pass goes through the gate, there will be a beep sound, and when a Suica IO card goes through the gate, there will be two quick beeps. It is also possible to ask a crew at the ticket gate to activate the audio guidance function so that when using a Suica train pass, the ticket gate makes two beep sounds when it will expire within 14 days. With these beep sounds, the user can be notified that the train pass needs to be renewed. For Suica IO cards, it makes three quick beep sounds when the remaining credit is 1,000 yen or less to notify the user that the card needs to be charged soon. These functions were originally for visually impaired users, but we believe physically unimpaired users can also benefit from these functions (Figure 16).

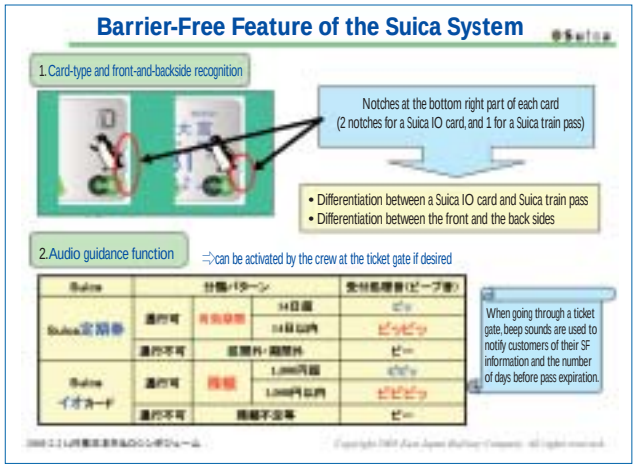

Fig. 16 Barrier-Free Feature of the Suica System

5 Strategy for Future Development of Suica

5.1 Past Suica development

In the development of Suica up to this point we have considered that improvement of the IC card infrastructure was the most important issue and therefore with "infrastructure" as a keyword, we have focused on three fields (Figure 17).

First, in order to improve the infrastructure, we introduced the Suica system to the Shinkansen areas and the Sendai region. It will be introduced to the Niigata area in the fall of 2005. Also, we improved the infrastructure by allowing other company lines to share the Suica use.

Second, in order to effectively use the existing infrastructure, we integrated a credit card "View" and a Suica card, and we also expanded Suica usage from "inside the station" to "into the city" by

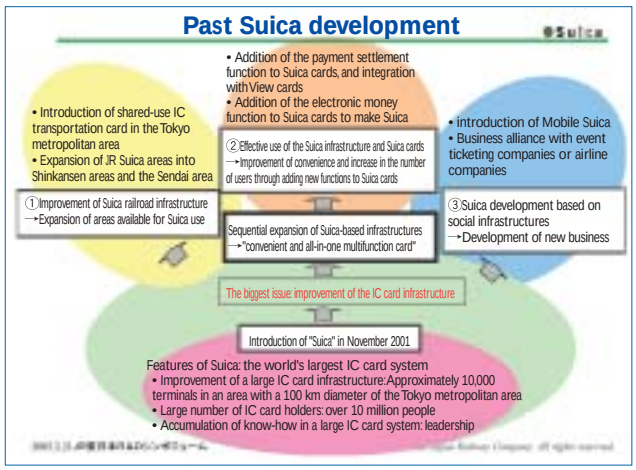

Fig.17 Past Suica development

equipping the Suica IO card with the electronic money function.

Third, as the importance of infrastructure is currently garnering so much attention, we decided to cooperate with companies that provide social infrastructure. As a result, we have worked with social infrastructures such as cell phones and also infrastructures, including members and networks, of airline companies such as JAL.

5.2 Reestablishment of Suica strategies

Recently, we have been reestablishing Suica strategies. The basic strategies are the same as before, but characteristics of an IC card have been reviewed, and now an IC card based on the new strategies is characterized by high capacity, high security, and individual authentication.

Looking back on past strategies, our main focus was to provide services uniformly to the general public, using the high capacity IC card functionality. This strategy has produced a certain level of positive effects in improvement of business efficiency and improvement of railroading competitiveness; therefore, I think this strategy was quite important. However, if we try to bring out more of our business potential, we need to think about a new service called the personal strategy in which high security and individual user authentication are implemented. Through this kind of new service, I think we can increase profit-earning opportunities and better respond to individual customer needs (Figure 18).

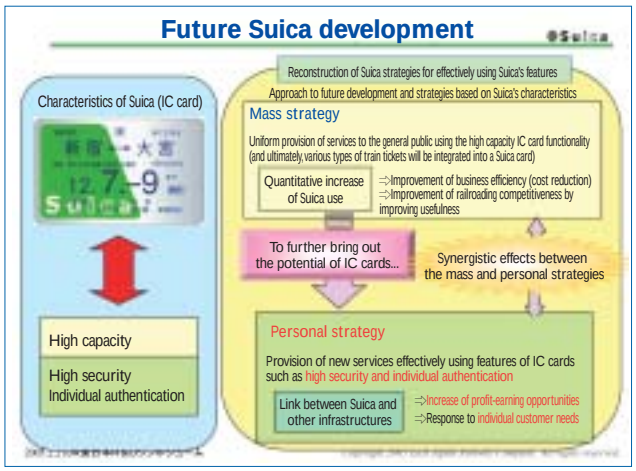

Fig. 18 Mass Strategy and Personal Strategy

Figure 19 shows the Suica future development matrix. The higher on the vertical axis means a more mass-focused strategy, and the lower on the same axis means a more personal-focused strategy. On the horizontal axis, the more to the left means more railroad-focused business, and the more to the right means a more life service-focused business. Based on such a matrix, Suica business now is in the mass and railroad focused strategy and business area. Perhaps the ultimate goal may be making all train tickets IC cards.

Mass-focused and life service-focused strategy and service I think will lead to the introduction of electronic money. Since development of electronic money is essentially for a mass strategy, it is necessary to improve its value of use, meaning expansion of the area of its use. This, however, will entail high expenses; therefore, I think that cooperation with other businesses will be highly important.

A personal strategy is a difficult strategy, and I still cannot provide any complete answers. There is however a personal card called View, so we have been planning alliances between View Suica, which is a combination of View and Suica, and other infrastructures.

As for railroading, we may be able to create various sales strategies by releasing customer segment specific cards such as "Otona no Kyujitsu (Holidays for Seniors)" or "Nombiri Komachi (Relaxation Time for Ladies)" for elderly customers or female customers, and we hope to make detailed proposals in the near future.

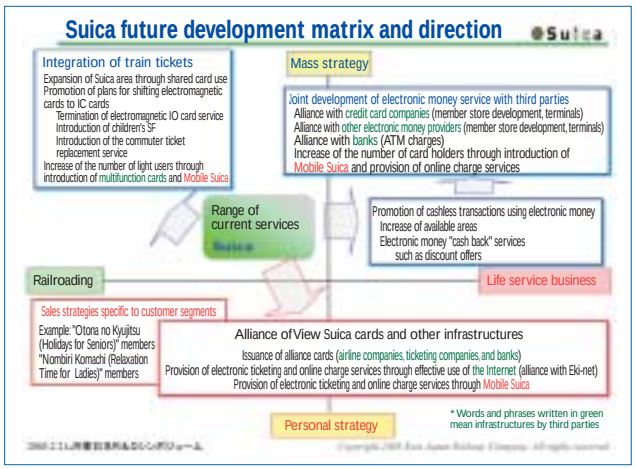

Fig. 19 Suica Future Development Matrix

5.3 Specific strategies

The specific strategies we have been working on are introduced below.

(1) Shared IC card use in the Kanto area

Shared IC card use in the Kanto area will be the most important strategy from now on. For implementation of such card use planned within FY2006, more than 50 companies are willing to participate in shared card use. Companies that manufacture Passnet and Shared Bus Cards have established a new company called the Passnet-Bus IC

Card Corporation.

Also, this new company and our company have capitalized on a new company called the IC Card Shared Use Center, which will be in charge of data exchanges in the center server of the inter-company fare adjustment system. When new IC card train ticket systems are implemented in various areas such as Hokkaido, Kyushu, or Osaka, this newly established company will serve as a hub, and ultimately, we hope that customers will be able to use the same IC card anywhere in Japan in the future (Figure 20).

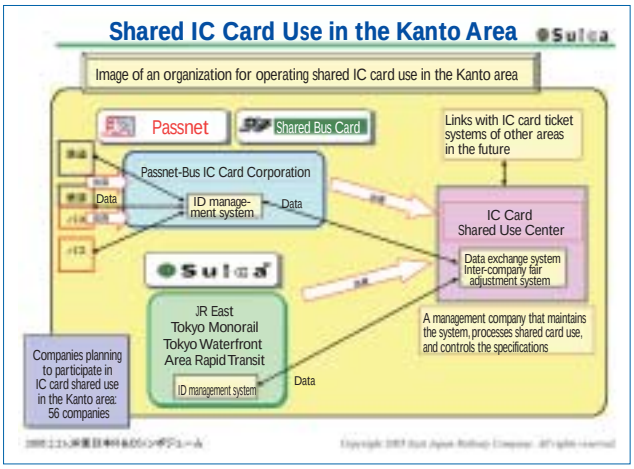

Fig. 20 Shared IC Card Use in the Kanto Area

(2) Suica electronic money

The Suica electronic money service started on March 22, 2004. Since then, Suica service developed from use inside stations to inside cities. Currently, Suica electronic money is used approximately 80,000 times per day, showing extremely dramatic development. By the end of FY2005, we plan to have approximately 1,000 shops where Suica electronic money can be used.

Tomorrow, on February 22, 2005, "Suica Station, Ueno" starts its operation. Here, aside from shops, customers can use Suica at drink vending machines or coin lockers (Figure 21).

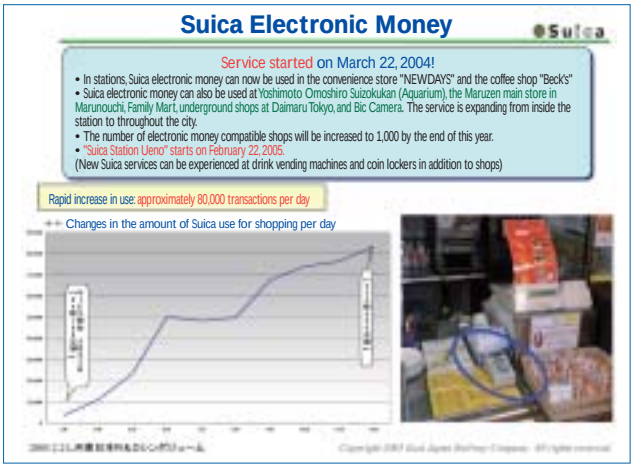

Fig. 21 Suica Electronic Money

(3) Mobile Suica

About Mobile Suica which is a cell phone combined with the Suica function, the most appealing feature is that a cell phone has communication capability and also is equipped with a screen to display information. Although it is not a card, we call it Mobile Suica. In short, it is something like a FeliCa chip with Suica data. Of course it has the IO card and train pass function. It also has the display function; therefore, it goes well with the digital ticket function which will allow customers to use Mobile Suica to reserve a Shinkansen seat and go through the ticket gate to catch that Shinkansen. We will first add the IO card, train pass, regular green ticket reservation, and electronic money functions in order to start the service in the second half of FY2005 (Figure 22).

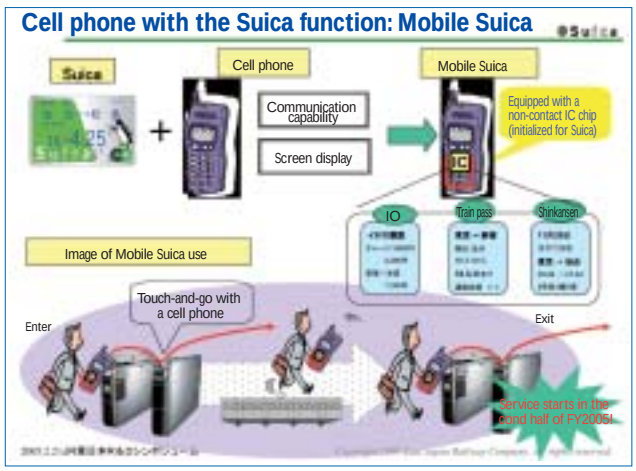

Fig. 22 Mobile Suica

Figure 23 shows four images of potential future Suica services. They are all under discussion currently, but for example, there is a service in which various types of information is provided by putting Suica banner advertisements or icons in the portal site which is displayed before the Suica menu screen. There are already some related companies who wish to sponsor such banners or icons. Therefore, we are thinking about operating such a portal site business.

The second image is a service in which when a Mobile Suica touches a poster, information related to that poster will be sent to the cell phone, and this service will be administered on a trial basis in Ueno. So, for example, when Mobile Suica touches a picture of an onsen or Japanese hot spring, details of that onsen will be sent to the cell phone, and then using that cell phone, accommodations and

transportation means can also be reserved. In general, it is a common understanding that such a service can bring high profit from charging high advertising fees.

The third image shows a point conversion service. This is a system that converts various existing points into SF of a Suica or IO card, and customers are charged a small fee when converting the points.

The fourth one is payment settlement agency business by using SF. This business can only be carried out by a company that issues values, but if a payment is settled on a network, then both credit charges and phone charges are deducted through the network. However, the business we suggest is that these charges will be deducted from the values stored in a cell phone, meaning that charges will be deducted from the money that has already been withdrawn, and therefore the settlement company will never fail to collect charges and therefore can always successfully settle payments. This may be a highly useful method for small-amount payment settlement and we have been reviewing the possibility of operating such a business.

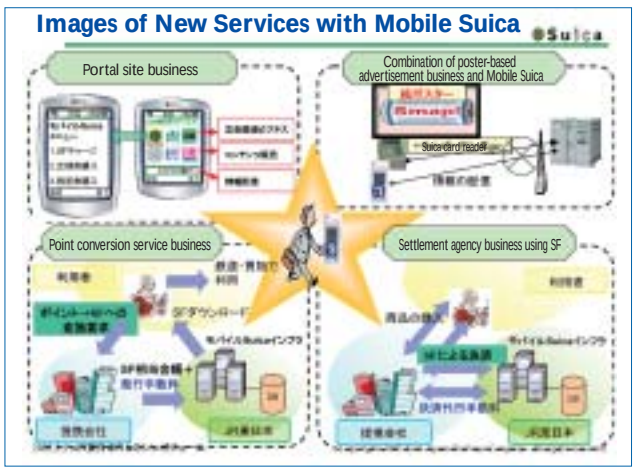

Fig. 23 Images of New Services with Mobile Suica

5.4 Suica as our third core business

As mentioned in the recently published New Frontier 2008, Suica is our third pillar, or third core business. Figure 24 is its conceptual diagram. I would like to introduce the concept of this third core, which comes after railroading and life service businesses.

We hope that Suica will become a tool to revitalize the two major businesses which are railroading and life service businesses, and also, we hope that Suica will contribute to generating synergistic effects between these businesses.

The third core business that we envision is a business based on the Suica infrastructure in which Suica directly interacts with its customers or business partners who are invited to start a new business. We are now in the process of study and research in this aspect.

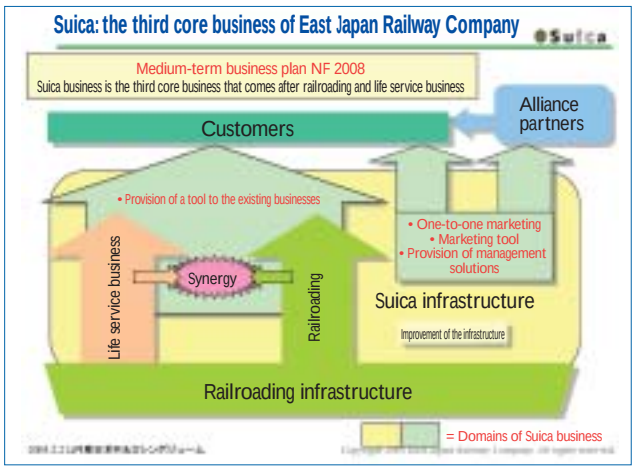

Fig. 24 Conceptual Diagram of Suica as the Third Core Business

6 Conclusion

The introduction of Suica has resulted in cost reduction and profit increases in railroading, and also in improvement of competitiveness. Because over 10 million Suica cards have been issued, this sales record has become our asset and improved the image of our company, and we also believe Suica has became synonymous with IC cards.

From now on, we hope to develop the Suica business into our third core business using both mass and personal business strategies.

The Suica system is an internally developed infrastructure at a sophisticated technological level, and it has realized high speed processing and high reliability of the system. In the future, the Suica infrastructure will rapidly expand beyond its original area. As it becomes a more open and larger infrastructure, ensuring its reliability will become even more important. When that happens, maintenance and improvement of quality, and taking the initiative in IC card standardization will also be very important tasks.

Currently, we have the Suica System Department and also the IT Business Department. We, the Suica System Department, are managing the railroad functions and the infrastructure in an integrated fashion, and the IT Business Department is creating the overall business strategies as well as future business strategies of Suica. I hope that these two departments will work together for future development of the Suica business.

In closing, I would like to express my appreciation to those who helped us with the introduction and operation of Suica , and also, I would like to ask you all for your continued cooperation.