Co-creation with Customers to Accelerate Digital Innovation

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To accelerate digital innovation by customers, Fujitsu has carried out over 1,000 cases of co-creation from 2015 to 2017. Working to realize digital innovation through co-creation with customers, we have found out that issues exist that are particular to digital innovation. To resolve these issues, Fujitsu has started working to deploy standardized business components that implement business know-how acquired through co-creation with customers, and design patterns created by combining such components on a platform built by integrating cutting-edge technologies such as IoT and AI and the latest open-source software (OSS) such as Hyperledger Fabric, an implementation of blockchain, in the form of cloud services. Incorporated into this is the business expertise we have accumulated through co-creation with customers. By using these design patterns, the creation of solutions that accelerate digital innovation by customers can be realized in short periods of time and at low cost. This paper presents examples of our co-creation with customers, including Japan Water Agency and TOMOE Corporation, together with digital technologies offered by Fujitsu and their effects.

1. Introduction

To accelerate digital innovation by customers, Fujitsu has worked on over 1,000 cases of business co-creation from 2015 to 2017. Through co-creation, the following three issues related to the realization of digital innovation have come to light.

1) Customers often do not know which technologies to use to realize ideas for digital innovation. Further, even when they do know which technologies to use, they do not necessarily know how to use them to implement their ideas.
2) Developing just one prototype will not lead to an idea being realized. Unless customers are able to develop multiple prototypes in quick succession, they cannot achieve digital innovation that makes possible things that until now could not be realized.
3) Even when an idea gets realized through rapid development of prototypes in quick succession, because of the impossibility of verifying its business merit in terms of return on investment, the idea does not gain the approval of decision makers and fails to be adopted.

This paper presents examples of our co-creation with customers, including Japan Water Agency (JWA) and TOMOE Corporation, along with Fujitsu's efforts to solve the above issues and their effect.

2. Co-creation with the Japan Water Agency

This section introduces Fujitsu's co-creation activities for disaster preparedness with JWA, which is the agency that implements Japan's policies related to water, a resource that is of particular importance in people's lives and the economy.[1)]

1) Background

JWA maintains the social infrastructure by efficiently solving problems to do with water-related risks that have been emerging and increasing in recent years, including the occurrence of unusual droughts and unusual floods due to climate change, the occurrence of large-scale disasters caused by earthquakes and other natural hazards, and the aging of facilities. The Lake Biwa Development Integrated Operation & Maintenance Office, which is one of the agency's offices, manages a large number of mechanical equipment including pumping equipment and gate facilities at its 14 drainage pumping stations. During sudden rises in water levels caused by torrential rain or typhoons, it is necessary to operate a lot of equipment at the same time in order to reduce the flooding of rivers. However, such emergencies have to be handled by the limited number of personnel available at the time, and demand the participation of all employees on hand, including non-technical staff. Further, frequent personnel reshuffling also means that people with experience handling disasters may not be available.

2) Challenge

The customer wanted to be able to carry out on-site work in a safe, secure, quick, and reliable manner even when those performing the work are not experienced in that type of work. To make this possible, Fujitsu offered a solution that allows remotely located experienced workers and knowledgeable persons to share in real time their skills and know-how with on-site workers through our real-time video and audio sharing technology centered on augmented reality (AR). However, on-site evaluation and verification brought us face to face with the following two technical issues.

The first technical issue was the establishment of technology to realize stable video and audio real-time bidirectional communication even in an unstable network environment. For example, when a worker must deal on the spot with a problem found during a regular inspection, this may require work procedures that are not covered in existing manuals. At such time, even if work instruction information edited beforehand is displayed superimposed on the work site via AR, only unidirectional and static information can be provided. This means that the appropriate work procedures called for by the situation at the work site may not be displayed, which may prevent resolution of the problem and hold back on-site problem-solving performance. To solve this problem, in addition to traditional AR in which pre-edited information is displayed, a technology is needed to enable real-time sharing of video and audio in both directions by on-site workers and remote supporters.

The second technical issue was the establishment of technology to provide stable video and audio even when hardware resource restrictions exist in wearable devices such as head mounted displays (HMDs). As terminals used by on-site workers, HMDs must meet the requirement of hands-free operation that does not hinder on-site work requiring the use of both hands. However, HMDs are restricted in terms of allowable power consumption and availability of CPU and other hardware resources needed to process video and audio in both directions in real time and at high speed. The infeasibility of securing the required resources prevents achievement of the image resolution, frame rate, and audio quality desired for on-site use.

Meanwhile, the monitoring terminals used by remote supporters are often different in terms of hardware specifications depending on the timing of their introduction. For the above reasons, technology that allows remote supporters to share video and audio in real time in both directions through a browser that does not rely on specific hardware was adopted. However, video and audio decoding by JavaScript on a browser often results in fluctuations in video and audio quality. As this introduces delays and degradation, solving this problem was urgently needed.

3) Solution

For the first technical issue, we applied technology that identifies the parts where changes occur, such as images from the workers' viewpoint, and the parts where no changes occur, such as the UI, and transmits only the data corresponding to the parts that change.[2] As a result, we realized high-speed video data compression processing and improved video data compression rates, realizing the transfer of video and audio of the quality required by remote supporters to accurately grasp the situation at the site. Furthermore, when the network's available bandwidth becomes insufficient, this is automatically detected and the frame rate automatically reduced, minimizing delays and allowing real-time video sharing.

Through the above technology, stable bidirectional and real-time communication was realized even in network environments with narrow and unstable bandwidth. Furthermore, development of a function for transmitting a single video source to multiple support terminals along with a function for mixing the voice sessions received by the server has enabled support by up to six remote supporters simultaneously.

For the second technical issue, we carried out R&D for technology that optimizes the encoding process according to the hardware resources of the device. In

HMDs with poor CPU capability, the problem was solved by switching automatically from video data compression processing using a CPU to video data compression processing by hardware encoder (VP8 codec). As a result, even in the case of HMDs with insufficient CPU resources, highly compressed video transfer with a high frame rate exceeding 20 fps can be realized with effective bandwidth of 1 Mbps or less. Further, we studied technology to automatically switch the codec of the browsers used on the support terminals of remote supporters from the G.711 μ-law codec using JavaScript that is the standard voice codec on the browsers to the latest codec (Opus codec), if that codec is supported. The resulting optimum decode processing according to the situation allows stable audio processing and minimization of audio degradation and delay.

By solving these two technical issues in this way, we achieved a new type of remote work navigation that allows real-time support for on-site operation and maintenance (**Figure 1**).

The camera mounted on the HMD acquires video images corresponding to the workers' viewpoint, allowing recognition of the AR markers affixed to the site equipment, and image-guided navigation of the work to be done with that equipment. At the same time, the images of the workers' viewpoint and work navigation images superimposed by AR are transmitted to the remote supporters via the network. This information allows the remote supporters to grasp the on-site situation and work navigation situation in real time. Furthermore, the remote supporters can draw work instructions (arrows, lines, and so on) on the on-site video in real time while they view it for the site worker to see on his or her HMD (**Figure 2**).

Through this remote work navigation, safe, secure, quick, and reliable equipment operation and maintenance by on-site workers are achieved.

4) Results

The introduction of this remote work navigation system allowed the Lake Biwa Development Integrated Operation & Maintenance Office to reduce the time required to get pumps working by 31%, clearly attesting to the effectiveness of this measure for risk mitigation

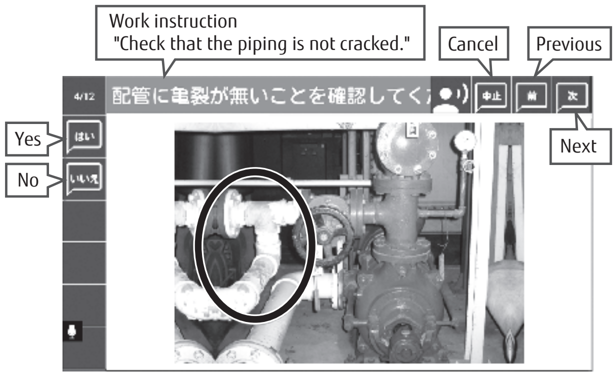

Figure 2
Work instruction information obtained through HMD.

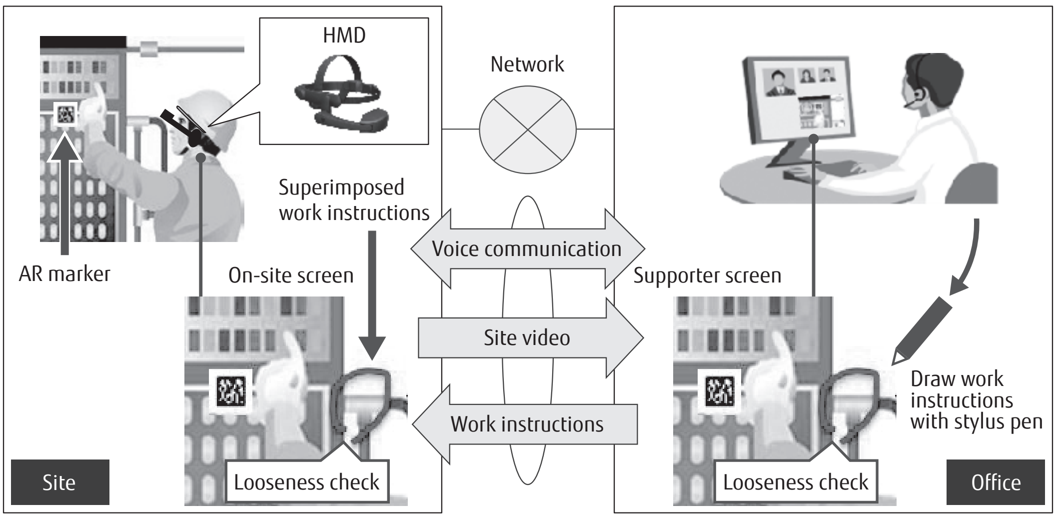

Figure 1
Remote work navigation.

at the time of disasters. Moreover, work reports can be created automatically in real time while the work is being carried out, reducing the time spent on work report creation by 89%.

5) Future technology development by Fujitsu

The growing burden on workers and deterioration in work quality caused by shrinking of the working population, retirement of experienced workers, and growing complexity and aging of facilities, are becoming increasingly common problems at factories and plants. Going forward, we will continue to expand and strengthen remote work navigation to allow safe, secure, quick, and reliable operation and maintenance.

3. Co-creation with TOMOE Corporation

This section introduces our co-creation with TOMOE Corporation, the largest builder of long-span structures in Japan's steel structure construction industry.[3)]

1) Background

TOMOE Corporation manually assembles at its factories and ships steel frame components. These steel frame components have complex and asymmetrical shapes. Moreover, as components are variously shaped, highly difficult mounting and assembly work is required. This is further compounded by the fact that buildings these days use a growing number of different steel frame components, which means that mounting and assembly tasks never encountered before even by experienced workers are becoming increasingly frequent.

2) Challenge

To ensure the quality of its steel frame components, TOMOE Corporation used to carry out visual inspection of assembled steel frame components by comparing them with the design data. However, since component shapes are complex and differ from component to component, visual inspection of one component could take one hour even for an experienced worker. For this reason, it was impossible to perform full inspections and the company was forced to carry out sampling inspections instead.

Presented with these facts, Fujitsu started developing technology to tackle this challenge through the use of AR technology. Specifically, we undertook the development of technology that visualizes and quantifies differences by displaying the blueprints (3D CAD data) superimposed on the image of the steel frame component captured by a camera to allow the detection of defects at a glance and thereby reduce inspection time. However, use of conventional marker image recognition technology for image recognition of special graphics such as barcodes and QR codes necessitates the attachment of AR markers on all the various steel frame components to serve as the reference points for superimposing and displaying 3D CAD data. This in turn necessitates additional work to affix and manage the AR markers. Furthermore, this also necessitates setting in advance the position, rotation angle, and scale for the superimposed display of the blueprints. Therefore TOMOE Corporation needed markerless AR technology that can automatically and quickly superimpose blueprints on assembled steel frame components without AR markers and without the requirement of having to set the position, rotation angle, and scale.

3) Solution

To meet this challenge, we developed optimal image recognition technology specifically designed for the recognition of feature line segments and thus capable of accurate recognition of steel frame components. We developed also optimal feature line segment recognition technology that can accurately recognize 3D CAD data of blueprints. In parallel, we developed algorithms to calculate the position, rotation angle, and scale required for matching the recognized feature line segments. As a result, automatic superimposed display of blueprints on camera-captured images of steel frame components is achieved.

Conventional feature line segment detection technology processes camera-captured images to extract edges. Depending on the shape of the camera-captured object, edge extraction processing performs poorly, resulting in fractured edges. To solve this problem, we refined the technology so that, when fractured edges can be estimated to originally constitute a straight line, it can recognize this to form a continuous long straight edge. Furthermore, with regard to markerless AR technology, at the same time that feature line segments are recognized from camera-captured images of assembled steel frame components, feature line segments are also recognized from the blueprints (3D CAD data), and differences between the two can be calculated automatically by comparing the respectively recognized feature line segments. To estimate the position and orientation of the camera, the six-dimensional data of the most likely travel-and-rotation matrix is calculated from the space, using four matching pairs of 2D straight lines in the captured image and 3D straight lines in the 3D CAD data as reference. Visualization and quantification of differences is achieved by applying the calculated travel-and-rotation matrix when superimposing the CAD data on the captured images (**Figure 3**).

4) Results

Application of the above-described technologies in the field demonstrated that defects can be detected in just one to two minutes even by people without much inspection experience. This advance allowed the execution of full inspections instead of sampling inspections, resulting in significant yield improvement.

5) Future technology development by Fujitsu

Naturally, 3D products exist not only in the construction industry but also in all manufacturing industries. Aiming for the innovation of manufacturing processes, we will further enhance and strengthen our business expertise gained through co-creation with customers, working toward quality improvement and productivity improvement in manufacturing industries.

4. Co-creation with electric power company

This section introduces co-creation for regional revitalization with an electric power company that has close ties to the community.

1) Background

Virtual currencies such as Bitcoin are beginning to be used as new global payment instruments. Meanwhile, looking at local economic spheres, regional currencies for regional promotion are also increasing through local production and local consumption. For example, the Yano Research Institute announced the prospect of increased issuance of points by electric power and gas retailers due to the liberalization of the low-voltage (less than 50 kW) electric power and city gas markets.[4] This refers to the trend of energy companies to build their own economic territories and introduce and expand the use of point services equivalent to local currencies.

The electric power company that Fujitsu carried out co-creation with prioritizes regional revitalization and always seeks ways for sustainable regional economic development. This customer has built a website that introduces regional shops and information as a way to promote regional revitalization. Through use of this website to offer local store discount coupons, stamp rallies, and points, it seeks to encourage residents to

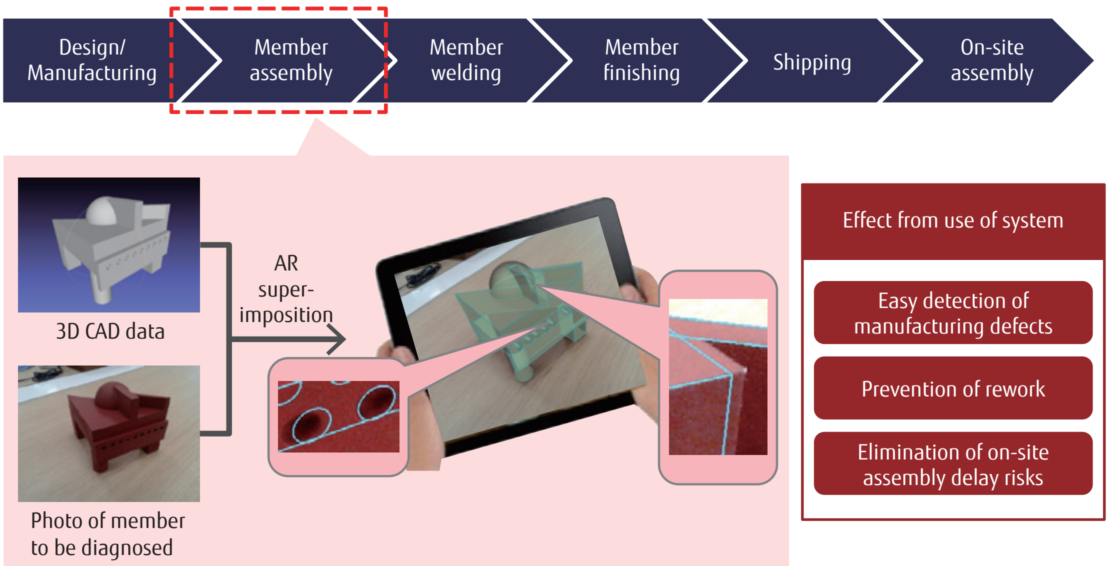

Figure 3
Image of use of manufactured member diagnosis.

make purchases at stores and thereby stimulate the local economy.

2) Challenge

The introduction of a system that distributes value in the form of coupons and points requires tackling conflicts between the reduction of infrastructure cost and securing system reliability. Because such a system aims to revitalize an entire region yet has low profitability, system operation costs must be minimized. Yet, aiming for synergies through interregional cooperation, it is necessary to ensure scalability while keeping costs down. Even so, system stability is essential to ensure the orderly exchange of value between residents and shops. Further, a mechanism to prevent double use of value, whether accidental or deliberate, is also required. Double use is an illegal act that consists in illegally dissimulating the fact of a value has already been used, then using the same value again. This has long been considered an issue requiring solution for the realization of a digital currency distribution system. However, raising reliability with conventional technology is not possible without increasing system investment.

3) Solution

Fujitsu has adopted blockchain technology as a way to meet the above conflicting requirements.[5] Fujitsu incorporated its own technology into Hyperledger Fabric, which is one of the Hyperledger[6] projects run by The Linux Foundation and is used as the base for its blockchain implementation.

Blockchain technology itself is suitable for managing the transfer of valuable assets and has been supporting the uninterrupted operation of Bitcoin since 2009. A blockchain, which is a system formed of several servers, can be thought of as a distributed data management technology. However, it differs from conventional distributed technology in that all servers hold the same original data, and each server can operate independently. Moreover, since data is automatically synchronized among servers using peer to peer (P2P) technology, even if some servers temporarily stop, the whole system is still able to provide services as shown in **Figure 4 (a)**. Furthermore, recovery from system downtime and elimination of inconsistencies between operations such as erroneous data ingress are automatically performed as shown in **Figure 4 (b)**.

Fujitsu Laboratories developed a security technology called ConnectionChain that extends block chain technology to allow transactions across multiple blockchains in a highly transparent and tamper-resistant

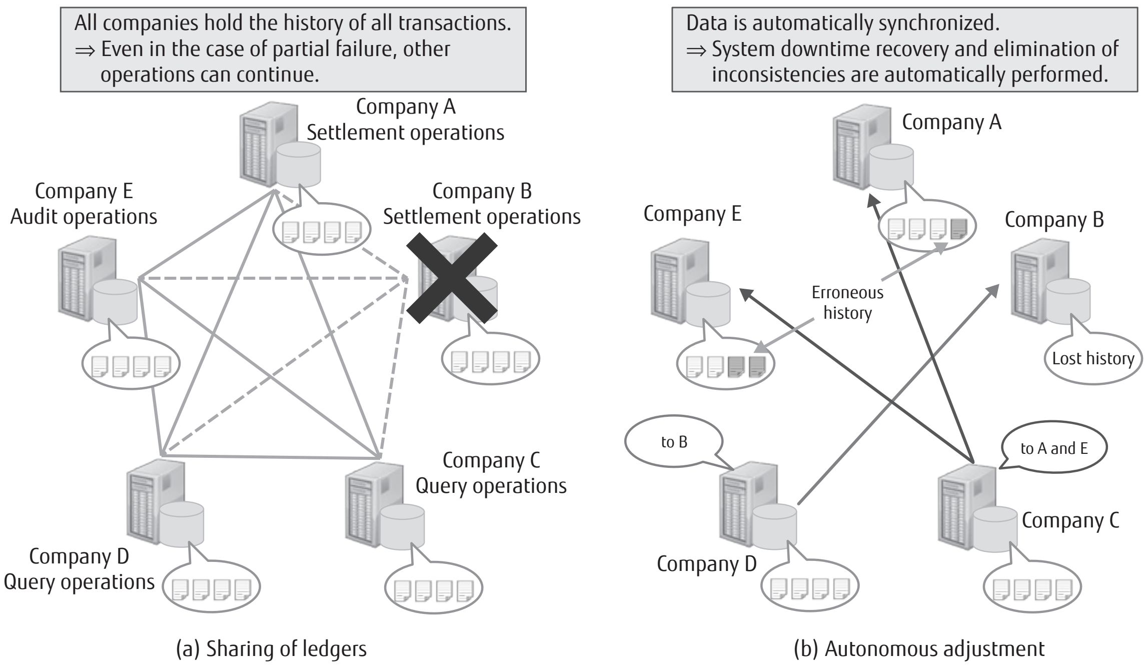

Figure 4
Blockchain technology.

manner.[7] Smart contracts that automate business procedures and contract processing have been enhanced to make them amenable to processing that involves multiple blockchains. In addition to this, we have introduced the concept of asset deposits to realize a holding state for assets, thereby allowing the control of asset transfers according to transactions. As a result, transaction contents across blockchains are recorded in the ConnectionChain, thereby guaranteeing the transparency of transactions. Moreover, we created a waiting state for transactions, which is difficult to achieve with conventional blockchains, so that if the exchange of value fails for some reason, such as lack of resources, processing corresponding to rollback (meaning restoration of the state prior to transaction failure) can be reliably executed.

To make it easy to use such blockchain technology, an electronic asset management function that focuses on state transfers of electronic assets such as coupons, stamps, and points was implemented as a REST API (representational state transfer application programming interface) to allow ready use of this function. Combined with the characteristics of blockchains, this guarantees the reliability and expandability of the system (**Figure 5**).

To ensure system robustness, we are working also to enhance the functions of Hyperledger Fabric. For example, one aim is to completely eliminate the possibility of total system failure by eliminating single points of failure in the system, and another one is to enhance security through a data manipulation audit trail.

4) Results

By offering a system that uses blockchain technology, we were able to put into operation a system that provides coupons and stamp rallies for regional revitalization in as little as three months from conceptualization by the customer. The customer is planning new community liaison events and is likely to use this system.

5) Future technology development by Fujitsu

Through the continued co-creation with customers, we will work to expand and strengthen design patterns that support the management and distribution of electronic assets such as coupons, stamps, and points.

5. Conclusion

This paper introduced examples of co-creation with customers to accelerate digital innovation. Customers can evaluate digital innovation with a small start by optimally combining digital technologies of proven effectiveness.

In addition to the practical cases described in this paper, we are working on co-creation with customers in the four digitalization areas of industry/business, society/economy, customer relationships, and organization and working methods. Going forward, we will continue to enhance and strengthen optimal combinations of digital technologies through co-creation with

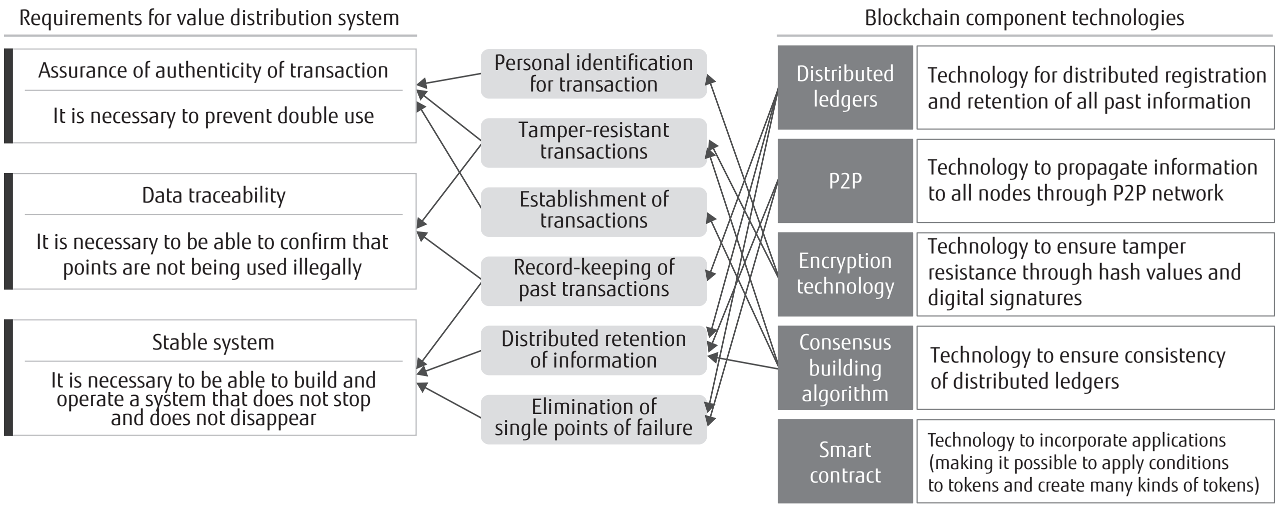

Figure 5
Mapping of requirements for value distribution system and of blockchain component technologies.

customers to accelerate digital innovation.

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