Technology Reports

D-SCP Virtualization Reliability

Subscriber Database Virtualization Supporting NTT DOCOMO Services

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NTT DOCOMO supports the provision of diverse types of services in its core network by a service control equipment group. Here, the control of user (subscriber) information that must be carefully managed is handled by equipment called F-SCP (call-control function) and D-SCP (database function). Now, with D-SCP equipment reaching its EoL, we have applied network virtualization that NTT DOCOMO has been energetically promoting in recent years to this service control equipment group and have deployed successor equipment (vDSCP) with improved reliability and economy as benefits of virtualization.

1. Introduction

At NTT DOCOMO, the equipment that provides Home Location Register (HLR)*1 and Home Subscriber Server (HSS)*2 functions for managing user subscriber information and location information and performing location registration and call sending/receiving control in the mobile communications network is called a Service Control Point (SCP) group. Within this group, the call-control section and subscriber database function are achieved by equipment called Front end SCP (F-SCP)*3 and Database SCP (D-SCP)*4, respectively [1] [2].

Now that D-SCP hardware that has been operating commercially is reaching its End of Life (EoL)*5, it has become necessary to develop successor equipment.

With regard to network virtualization [3], NTT DOCOMO

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*1 HLR: A logical node defined by the 3GPP with functions for managing subscriber information and call processing.

*2 HSS: A subscriber information database on a 3GPP mobile network that manages authentication and location information.

*3 F-SCP: A unit of subscriber service control in charge of call control.

deployed virtualized Evolved Packet Core (vEPC)*6 in March 2016 and has since been applying network virtualization to core network*7 equipment. This application of virtualization to core network equipment is about 40% complete as of the end of fiscal year 2019 and continues to this day.

Virtualization provides a number of benefits. In addition to improving the reliability of communication services and the economics of network facilities, virtualization makes it easier to achieve connections during times of congestion and enables early provision of services. (**Figure 1** (1) – (4)). We developed D-SCP successor equipment in line with this policy of applying network virtualization.

This article describes revised equipment configuration and functional allotment in virtualized D-SCP (vDSCP)*8, the successor equipment to D-SCP, the benefits of network virtualization as applied to that equipment, and the mechanisms used for improving reliability and economy.

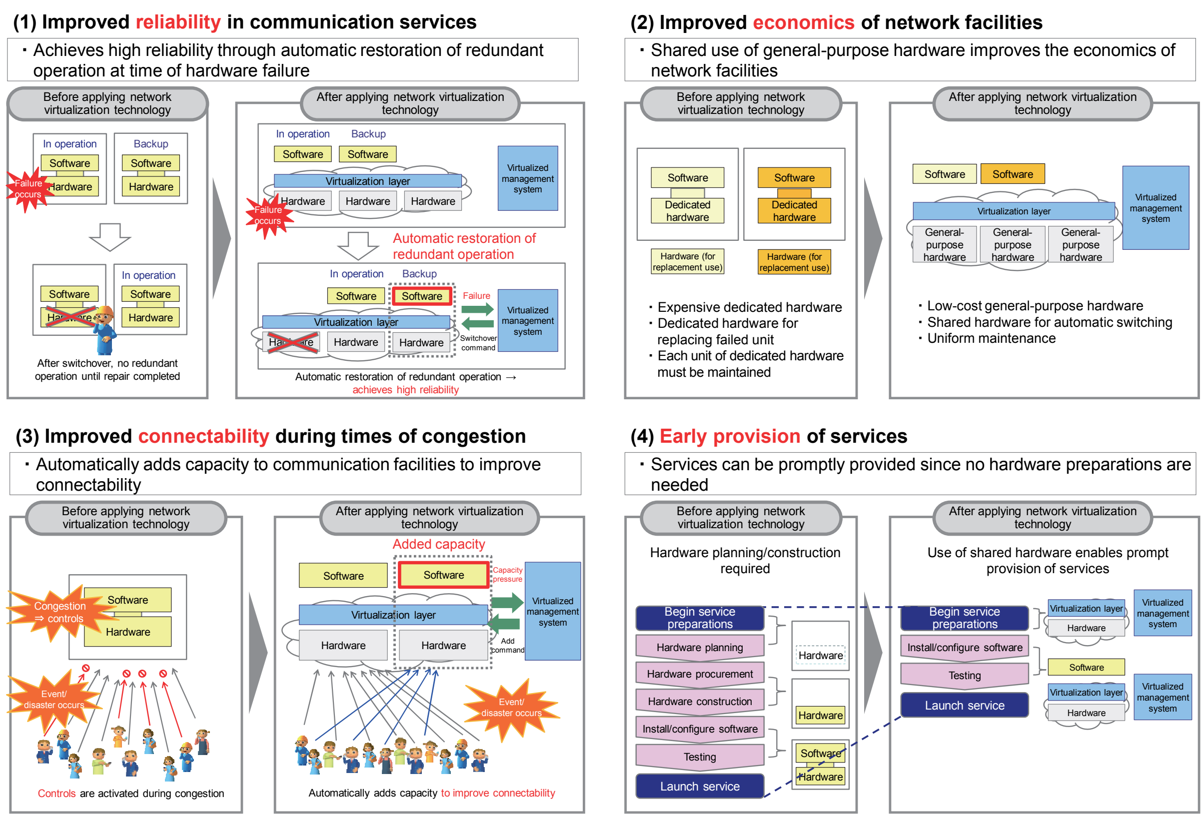


Figure 1　Benefits of network virtualization

*4　D-SCP: A unit of subscriber service control in charge of database functions.

*5　EoL: A term that refers to the end of sales, software support, and updates/revisions for certain products or services.

*6　vEPC: Communications software specified by 3GPP for LTE and other access technologies and provided to enable the EPC IP-based core network to function as a virtual machine (VM).

*7　Core network: A network consisting of switches, subscriber-information management equipment, and other devices. Mobile terminals communicate with the core network via the radio access network.

*8　vDSCP: D-SCP running on a virtualization platform. In this article, this name is also used to refer generically to vSSCP/vDSCP as a VNF.

2. Issues in Applying Virtualization to D-SCP

Given that virtualization is independent of the target hardware, it is relatively easy to support virtualization for stateless functions having no subscriber information on that hardware. At NTT DOCOMO, although control of subscriber information is achieved by F-SCP/D-SCP, F-SCP is a stateless function untied to subscriber information while D-SCP achieves control of subscriber information as a stateful function that holds states on hardware. Consequently, it is not sufficient to simply switch to another D-SCP at the time of a failure—it is also necessary to hand over the subscriber information being held (**Figure 2**).

Subscriber information is extremely important in a mobile communications network, so rapid restoration at the time of a failure is essential. However, in the event of a failure in a D-SCP applying

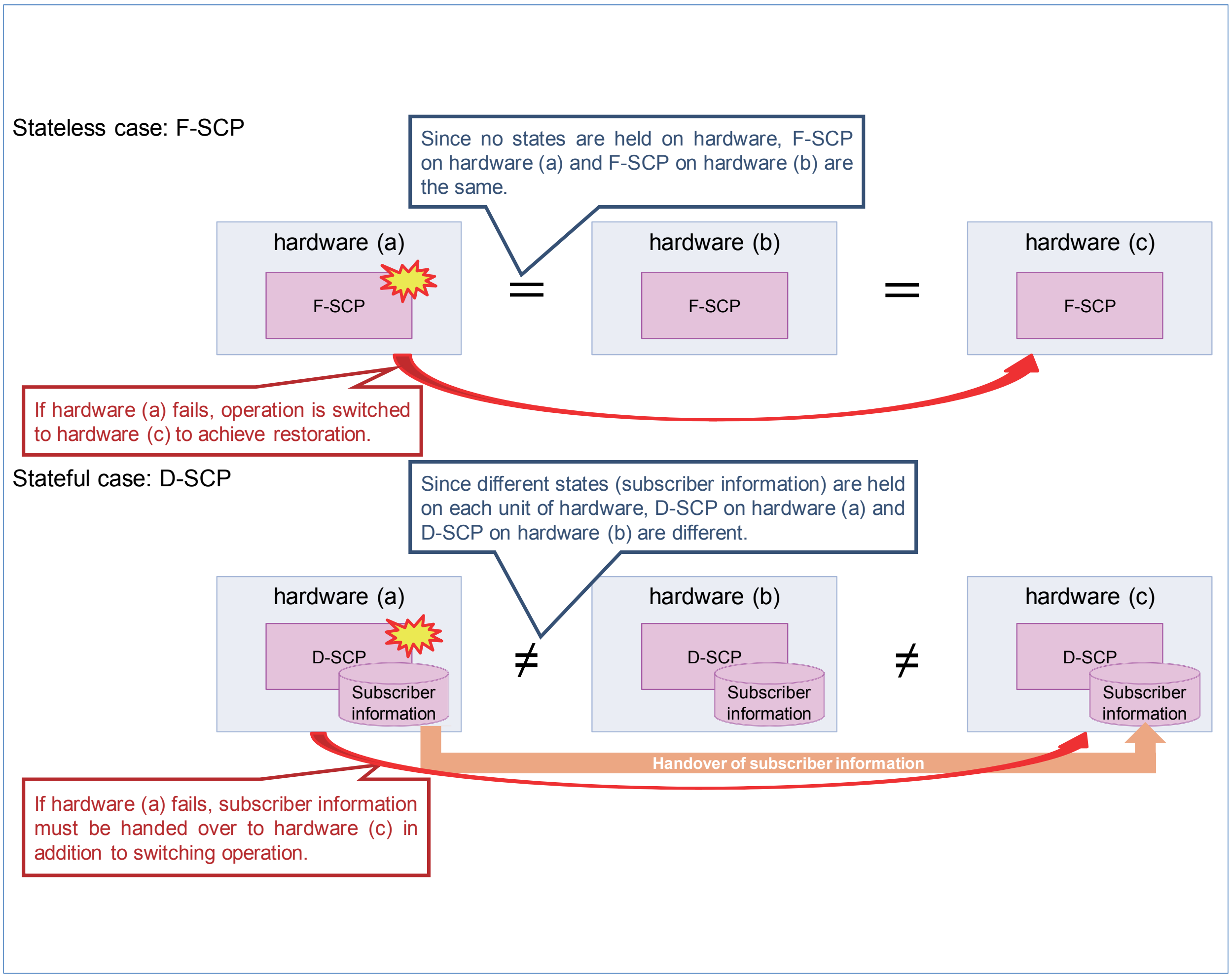


Figure 2　Operation overview at time of a hardware failure

virtualization, processing to synchronize a massive amount of subscriber information is required, but this presents a problem as some time is needed to complete this processing before restoration.

NTT DOCOMO has resolved this issue by implementing some functions on dedicated equipment.

3. Equipment Configuration

The hardware configuration of D-SCP and that of the vDSCP subscriber database after the virtualization upgrade are shown in **Figure 3**. Here, vDSCP is achieved by two Virtual Machines (VMs): Storage/System Manager (SM)*9 and DataBase (DB)*10.

(1) SM-VM in vDSCP corresponds to some of the File Server (FS)*11 functions for holding data related to D-SCP system maintenance operations and equipment control (system maintenance functions, restart control, etc.). The Virtual Network Function (VNF)*12 configured by SM-VM is called virtual SM for SCP (vSSCP)*13 that performs system and storage management.

(2) DB-VM in vDSCP includes the D-SCP Data Base Processor (DBP)*14 function as well as some FS functions (system maintenance functions, Backup Center (BC) switching control). The VNF configured by DB-VM is called narrowly defined vDSCP that performs call control, backup control, BC switching control, etc.

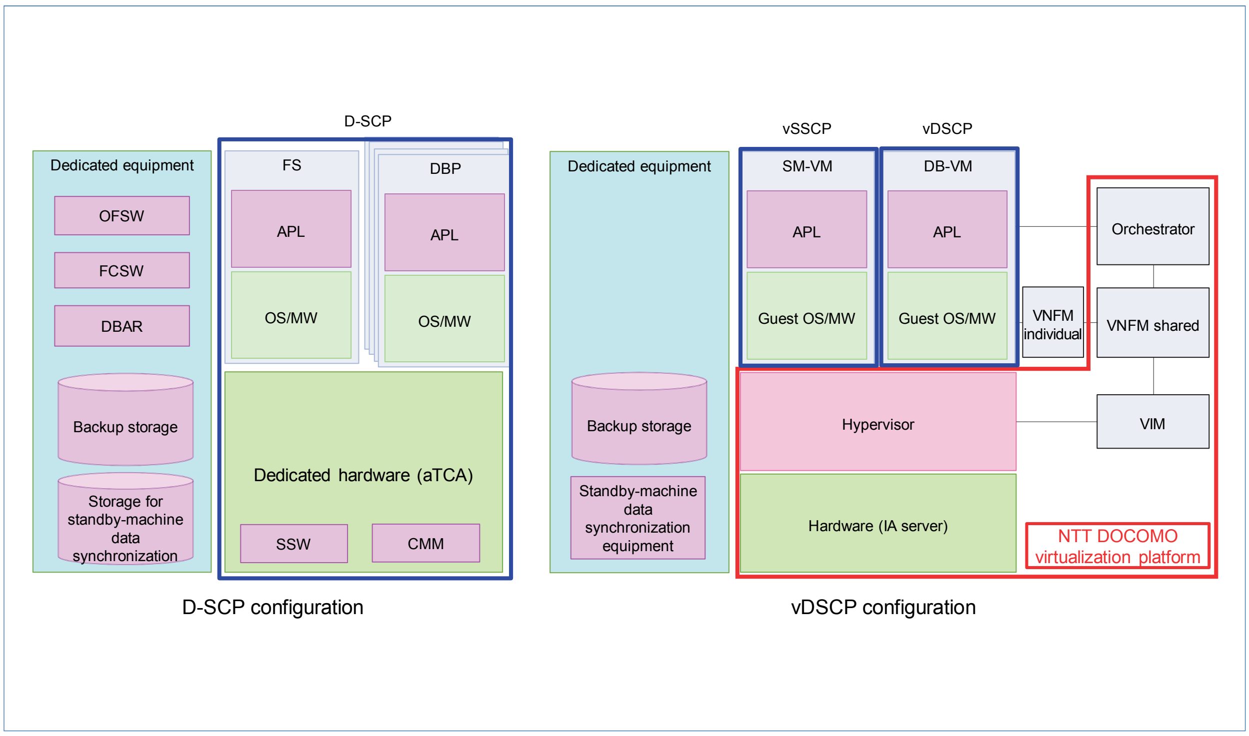


Figure 3 D-SCP and vDSCP hardware configuration

*9 SM: Functions that manage RAID and storage router capacity.
*10 DB: In this article, functions that perform call control, backup control, backup center switching, and relocation control.
*11 FS: Functions that hold data for system maintenance/operation and equipment management and that perform backups to RAID.
*12 VNF: A constituent element of an application running on the virtualization platform.
*13 vSSCP: The equipment that performs vDSCP system management and storage management.
*14 DBP: Database function for subscriber information.

Some of the dedicated hardware and dedicated equipment have been implemented as software-based applications and some have been migrated to the virtualized network side such as the virtual Layer 3 SWitch (vL3SW)*15. In this way, the internal Shelf SWitch (SSW)*16 of dedicated hardware and the Fiber Channel SWitch (FCSW)*17 and Data Base Access Router (DBAR)*18 of dedicated equipment have been virtualized and the Chassis Management Module (CMM)*19 of dedicated hardware and OpenFlow SWitch (OFSW)*20 of dedicated equipment have been discontinued.

As a result, operation of dedicated hardware becomes unnecessary, the shared use of general-purpose products such as IA servers*21 and vL3SW with other virtualized equipment becomes possible as did the lump procurement of such products, and expenditure on facility procurement and maintenance becomes more efficient thereby improving the economics of network facilities.

4. Functional Allotment between vSSCP (SM-VM) and vDSCP (DB-VM)

If the SM-VM supervising section can be made non-subordinate to the DB-VM database section, a configuration in which the number of SM-VMs and DB-VMs can be changed as needed becomes possible thereby inhibiting an SM-VM failure from affecting services. Furthermore, by having SM-VM perform system management without having to be aware of any differences in the DB-VM internal configuration, SM-VM development work in response to the future addition of new types of DB-VM can be minimized. The above configuration is superior in terms of both fault tolerance and extendibility, and for this reason, we adopted a scheme that separates SM-VM and DB-VM as independent vSSCP and vDSCP VNFs (= units) and allocates functions accordingly.

5. Application of Dedicated Equipment

The functions provided by D-SCP dedicated equipment (backup storage, storage for standby-machine data synchronization (HS3*22)) are also installed in vDSCP dedicated equipment (backup storage, standby-machine data synchronization equipment*23) without using functions on the virtualization platform while taking into account the capacity needed for the data being handled and the application using that data.

5.1 Backup Storage

At present, virtual storage provided by the virtualization platform does not support a multi-attach function that mounts a single volume by multiple VMs. For this reason, the system used up to now for data sharing between active/standby VMs in virtualized core network equipment has been to implement on VNF a data synchronization application called Distributed Replicated Block Device (DRBD)*24 and to synchronize data between the volumes in the active and standby systems. However, when using DRBD, there are cases in which total synchronization is necessary between the active and standby volumes such as at the time of a failure. In such a situation, a considerable amount of time is needed to complete this synchronization processing

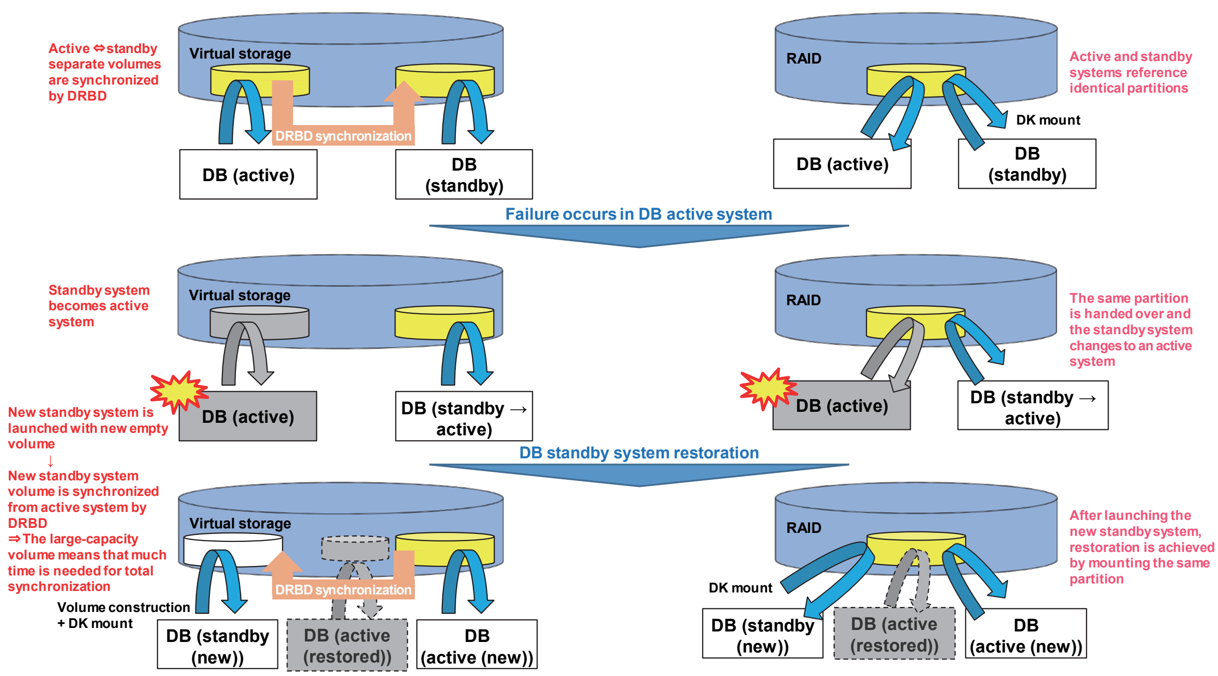
*15 vL3SW: A virtual switch for making L3 connections with service network equipment.
*16 SSW: An internal switch blade between FS and DBP in aTCA, an industry standard for operator-oriented next-generation communication equipment.
*17 FCSW: A switch between backup storage and DBP.
*18 DBAR: A router used for making connections with external associated equipment.
*19 CMM: Performs intra-chassis management in aTCA.
*20 OFSW: A switch having a function for directing an F-SCP seeking data access to the DBP accommodating the target subscriber data.

resulting in a single-system operation state during that period (**Figure 4** (a)). As a consequence, the large amounts and importance of subscriber information handled by vDSCP make using DRBD a risk, so we adopted dedicated storage equipment in vDSCP.

Here, dedicated storage is connected to a network accommodating a virtualization platform and database construction is achieved by mounting identical partitions via this network from both the active and standby DB-VMs, the same as the D-SCP system. Now, if a failure occurs in the active system, the same region is taken over by the standby system. The partition mounted in the current active system can then be mounted in the former active system to restore it thereby eliminating any synchronization time. This enables immediate launching while minimizing the single-system operation period (Fig. 4 (b)).

5.2 Standby-machine Data Synchronization Equipment

Similar to D-SCP, vDSCP installs one master unit that operates during normal times and two BC



(a) DRBD synchronization system

(b) vDSCP adopted system (equivalent to existing D-SCP)

Figure 4 Operation comparison between DRBD synchronization system and vDSCP adopted system

*21 IA server: A server equipped with an Intel microprocessor or an Intel compatible processor. Its internal structure is very similar to that of an ordinary personal computer, and it is less expensive than servers based on other types of microprocessors.

*22 HS3: External storage equipment used to store backup data within a unit and to perform replication with backup centers. Can also be used to store backup data from multiple units through replication with D-SCPs.

*23 Standby-machine data synchronization equipment: Equipment that performs data replication between remotely installed storage equipment.

*24 DRBD: Middleware for mirroring disk partitions among multiple Linux servers. DRBD is a trademark or registered trademark of LINBIT Information Technologies GmbH in Australia, United States, and other countries.

units in separate office buildings and features a function for switching to these BCs in the event of a master-unit fault that could hinder service continuity. To achieve this function, it is necessary to synchronize (replicate) subscriber-information backup data stored in backup storage between different office buildings, but virtual storage on the virtualization platform does not provide a synchronization function between volumes at different office buildings.

For this reason, it was decided to deploy dedicated standby-machine data synchronization equipment in vDSCP the same as that for backup storage. This equipment features a device having a data compression function for use in data transfers, which enables efficient inter-building synchronization without affecting VM call processing performance in comparison with a method that deploys no dedicated equipment and achieves synchronization by a VM application.

The vDSCP master/BC configuration and the backup file flow using the standby-machine data synchronization equipment are shown in **Figure 5**.

6. Benefits of Deployment

6.1 Minimization of Affected Users at Time of Failure

For a vDSCP that manages subscriber information, reducing as much as possible the effect of

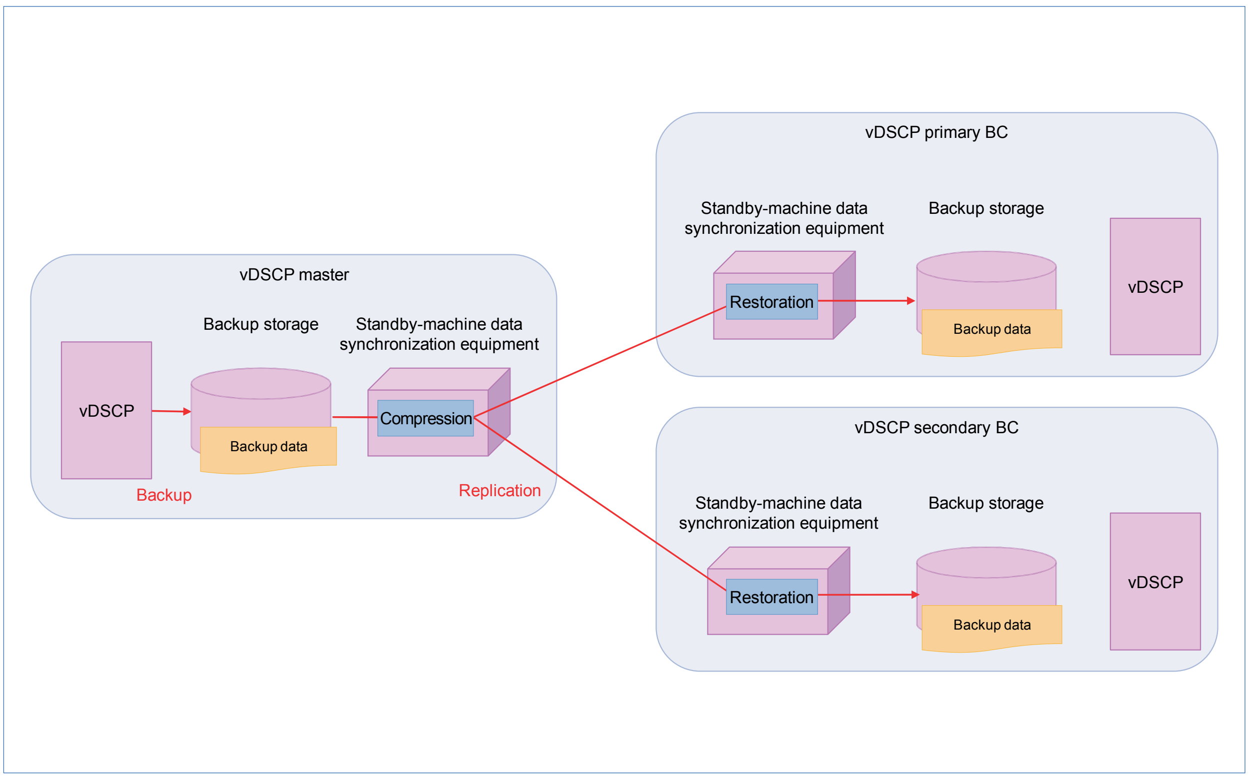


Figure 5　vDSCP master/BC configuration and backup file flow

a failure on users is a high-priority issue. From here on, as the use of IoT devices that demand reliability spreads throughout the social infrastructure and living environments, we can expect vDSCP to become all the more important to society, so we studied schemes for minimizing the effects of failures on users.

Conventional D-SCP is database equipment accommodating subscriber information. If we treat DBP with a database function on hardware as a single entity, the number of DBPs in a unit specifies the number of accommodated users per unit. Here, the FS function manages and controls multiple DBPs. The grouping of one FS and multiple DBs constitutes one D-SCP unit.

Now, in vDSCP, we migrated the FS function to DB-VM and adopted a scheme that handles SM-VM and DB-VM as independent VNFs (= units). As a result, user data corresponding to one DBP is handled as a single VNF enabling that VNF to be defined as one unit (**Figure 6**).

In D-SCP, a failure at the unit level given the configuration of a D-SCP unit described above necessitates BC switching on a unit basis.

In vDSCP, on the other hand, distributed deployment of VMs corresponding to DBPs on IA servers means that BC switching can be performed between individual VMs in the event of a failure on a VM unit. This enables the number of affected users at the time of a failure to be minimized (**Figure 7**). Additionally, since database capacity can be increased or decreased in a unit-by-unit manner, facility construction in response to an increase in demand can be handled in a flexible manner thereby reducing expenses.

6.2 Faster Restoration after Failure

1) Operation in D-SCP at Time of Failure

In D-SCP, the occurrence of a double failure in the active system (act) and standby system (sby)

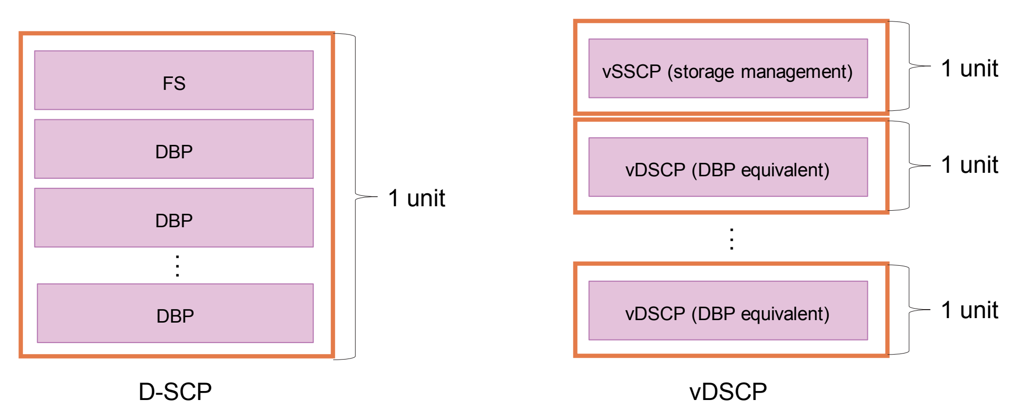


Figure 6　Comparison of unit configurations between D-SCP and vDSCP

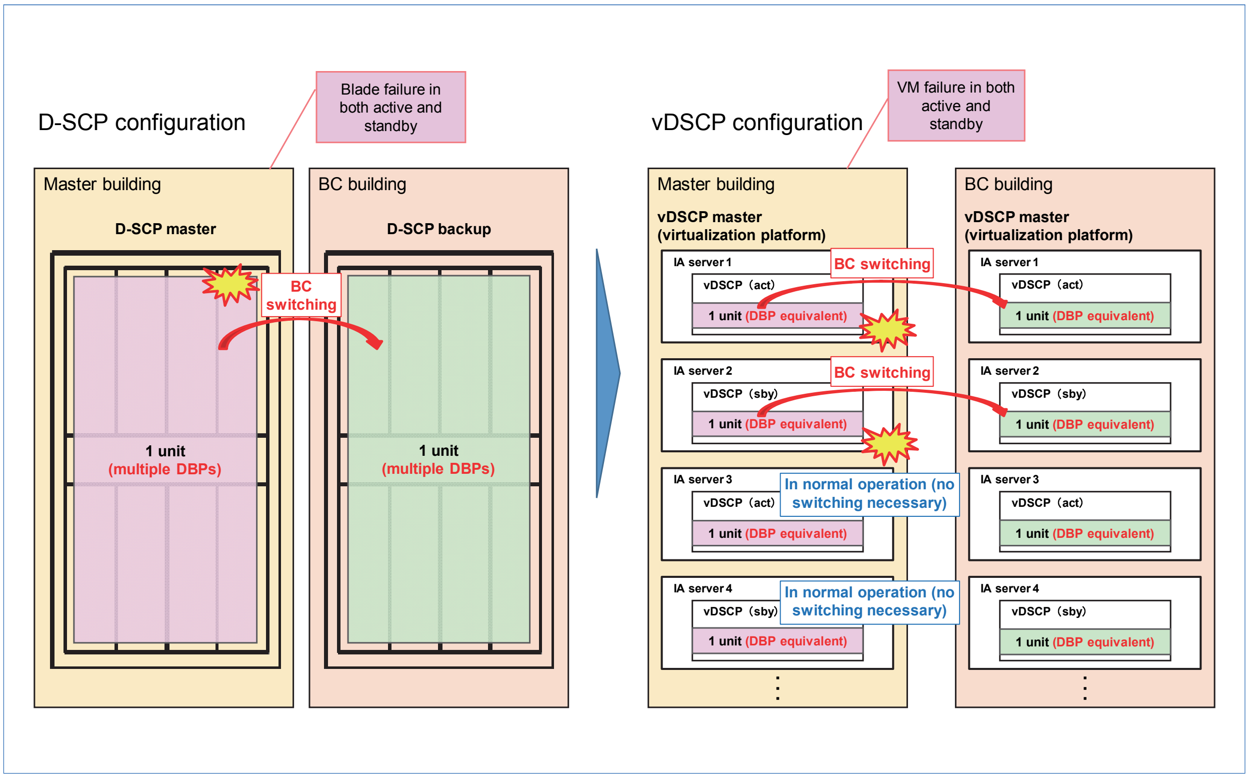


Figure 7 Overview of failure reaction at time of BC switching

of a processor accommodating a database (DBP) would be handled by a function called "relocation" that reallocates users to other DBPs within the same equipment. This function reallocates database information at the time of a failure with the aim of improving equipment reliability. Additionally, if a failure occurs in which service cannot be restored even with relocation, the D-SCP would be switched to a BC as described above and operated as an alternative unit to the equipment in which the failure occurred. This two-stage failure-reaction function in D-SCP minimizes the number of affected users.

During the relocation or BC-switching process, associated call processing that requires database access will be affected, so it is important from the viewpoint of improving reliability that the time required for such operations and the number of affected users be minimized.

A D-SCP adopts a system in which BC is made to stand by in a hot standby state (always running). As a result, the time required for BC switching is much shorter than the switching time incurred by relocation, but since BC switching here would be performed for an entire unit consisting of multiple DBPs, the number of affected users would be larger than that by relocation.

2) vDSCP Effect

In vDSCP, on the other hand, by reconfiguring the user-accommodation unit as described above, BC switching can reduce the number of affected users the same as that at the time of D-SCP relocation in units of DBPs. We therefore evaluated vDSCP from the viewpoints of restoration time and the availability of alternative procedures and adopted a BC switching function that reduces the number of switched users per unit to that of a DB-VM (equivalent to a DBP) while making full use of the D-SCP feature of short BC switching time. In this way, the number of affected users can be greatly reduced compared with that of D-SCP while having a restoration time the same as that of D-SCP.

In addition, there is a function in the virtualization platform system that deals with a failure in a VM or hardware on the virtualization platform by performing VM restoration called "healing" on separate hardware kept in standby. Before virtualization, it was necessary to send maintenance personnel into the field to replace defective hardware, but this virtualized healing function enables restoration to be achieved in a relatively short time. Here, shortening the time from single-system operation to restoration of dual-system operation decreases the probability of a dual-system failure and improves system availability, all of which has the effect of improving reliability.

7. Conclusion

This article described the equipment configuration and functional allotment of vDSCP that applies virtualization to the database function section and the improvements achieved in reliability and economy through virtualization.

NTT DOCOMO is planning to migrate the service control equipment group in a stepwise manner as each type of equipment approaches its EoL period. Since D-SCP equipment that will reach EoL first has the important role of managing user information, we will take all possible measures to prevent a drop in quality by separating the development and introduction of vDSCP virtualized equipment and the development period for the subscriber-data migration function from D-SCP to vDSCP.

Going forward, we plan to study the application of network virtualization to other equipment in addition to the service control equipment group.

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