# Data storage architecture for e-government interoperability: Morocco case

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**Article Info**

***Article history:***

Received Jun 25, 2022
Revised Nov 4, 2022
Accepted Nov 8, 2022

***Keywords:***

E-government interoperability
Hyper-converged infrastructure
Morocco
Public data storage
Software defined storage

**ABSTRACT**

Nowadays, the amount of data created by the government and public sector organizations is growing at an exponential rate. Data sharing and the interoperability of e-government systems pose technological challenges. The lack of technical interoperability prevents the successful exchange and sharing of information among public organizations. To meet this challenge, enhancing interconnection and communication between different public infrastructures is an essential condition. To optimize the provisioning of storage resources, software defined storage (SDS) solutions add flexibility and adaptability to the storage process by isolating the hardware from the software. Hyper-converged infrastructure (HCI) is an emerging set of SDS solutions that provide compute, network and storage in a single platform. This paper presents a storage HCI-based architecture to store public data from different public entities, enhance collaboration and improve technical interoperability. The relevance of this approach of e-government interoperability is to allow public organization to store their data in an efficient and flexible manner on one hand, and to participate to Morocco's e-government project on the other hand.



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## 1. INTRODUCTION

Government digital transformation involves exploiting information and communication tools (ICT) as operating systems, storage resources and software to improve organization's performance [1]. In parallel, e-government projects deal to enhance the daily public administration in order to deliver efficient public services. Furthermore, providing efficient public e-services remains delicate due to the repetitive transactions in separated government systems [2]. Indeed, optimizing the process of delivering public services requires a high level of coordination and integration between different e-government systems. To achieve a successful integration, introducing interoperability at all levels between public administrations is a fundamental step [3].

As known, e-government interoperability is the aptitude of national organization to work together and exchange data in an integrated way [4]. This includes many layers that permit to manage and share information between different governmental entities efficiently. Moreover, governments have addressed interoperability in several manners: policies, standards, laws, technical infrastructures [5]. Generally, literature presents two main layers of interoperability, the technical and the non-technical one [6]. The first, is about hardware, software, platforms and infrastructures that enable communication among systems [7]. Technical interoperability deals with the technical points of connecting information systems, it includes many aspects: interconnection services, data integration, data exchange, data storage, middleware, and data warehouse. It is considered as the "starting point" of reaching e-government interoperability [8]. The second is about all other levels: organizational, semantic, and syntactic. To achieve a high level of interoperability, technical requirements should be meted, notably, data presentation, data type and metadata, communication protocol, application, and network infrastructure [2]. Indeed, Data centers as the backbone of IT infrastructure connect data and application under a network of compute and storage resources. In addition, managing resources in a homogenous data centers with an efficient cost is a major challenge of public administrations [9]. Further, software-defined storage (SDS) is a modern generation of storage system that allows economical features for storage unlike the traditional systems [10].

In Morocco, as well as many countries, the government is deploying many efforts to implement digital technologies in the public sector. As Morocco's digital transformation is a key initiative, a strategic digital transformation is emerging progressively. Under the national plan 'Digital Morocco 2020', the government has invested in installing e-government platforms to enhance digital interaction with both citizens and business. In fact, recognizing the benefits of the digital transformation of government services, Moroccan government created the agency of digital development (ADD) in 2017. The main goal of ADD is to reinforce the digital field in the country and supports the growth of digital infrastructure. The agency is responsible for creating digital strategy and implementing general orientations to support the digital development in Morocco by 2025 [11]. At the same time, the COVID-19 crisis had a major impact on the digital transformation of Moroccan public services. It was an occasion for the Moroccan government to invest in digitalization and adopt digital-driven initiatives in the public service delivery [12].

Despite these digital initiatives, the country is facing challenges that compromise progress on e-government domain. According to UN e-government survey 2020, Morocco didn't register a high e-government development index (EGDI) ranking: the 7$^{th}$ in Africa with a middle online service index (OSI) value 0,5235 [5]. More, Morocco doesn't gain the benefits of digital transformation reform efforts successfully and the mission of the agency of digital development (ADD) is limited by the failure of a national digital strategy [13]. As a matter of fact, Morocco is in a low stage of developing data governance compared to other countries in the Gulf Corporation, especially the United Arab Emirates[14].

On the other hand, deficiency in coordination and interoperability between the public organizations influences the development of Moroccan public e-services. As reported in the national study conducted to assess the E-readiness index of Moroccan public e-services, results show that only 23% of national public e-services are fully digitized (the high level of maturity) and 60% of e-services are still informational (the low level of maturity). Plus, the granular assessment indicates that dependent e-services which data and interactions depend on other administrations (external or internal) have the least rank [15].

Relevant initiatives, frameworks and standards to develop Moroccan e-government interoperability were defined. Moroccan Researches most focused on semantic interoperability [16]–[19]. Another interesting work treats three important aspects for systems-of-systems interoperability which are: barriers, scopes and levels [20]. Other approach that considers the security level of technical interoperability between federated systems using identity management system was presented recently by [21]. Still, small researches address the challenges for storing government data, and getting cost-friendly storage solution. Public data storage management has not attracted much research attention thus far, and no standard architecture is presented for optimizing storage in public organizations.

In this context, we propose an efficient architecture to address the issue of public data storage and introduce a new framework based on hyper-converged (HCI) concept to support technical interoperability. This modern infrastructure aims to manage the storage of data from different ministries and public agencies, achieve better collaboration and improve technical interoperability of information systems in the public sector. The proposed architecture is based on HCI concept to ensure the efficiency and the flexibility of the storage systems. This paper is structured as shown in: Section 2 presents an overview on government interoperability and provides a description of how data centers and IT infrastructures have evolved. In Section 3, the method of dimensioning the storage in the central data center is detailed. Section 4 describes the conceptual architecture of our approach. Finally, Section 5 presents the conclusion and future works.

## 2. BACKGROUND REVIEW AND RELATED WORK

### 2.1. E-government interoperability

Previous studies have presented E-Government interoperability as the ability of government systems to communicate and share integrate information by using common standards [22]. In the first version of the European interoperability framework (EIF), three levels of interoperability were identified, namely: the organizational level that addresses the processes and structures where organizations have to interact. The second, is the technical level that addresses the issues of linking systems and infrastructures to exchange data, and the last one which is the semantic level that addresses the issues of interpreting data by different organizations [23]. In the last version of the EIF published in 2017, a legal layer was added to the existing three levels of interoperability. The commission highlights the need of setting specific information systems and architectures that permit the continuity of public data [24].

The definition of technical interoperability has grown over the years. This category of interoperability does not rely uniquely to infrastructures and communication protocols to connect systems [25], [26], it includes strategies for storing data in a shared central repositories [27]. In fact, to promote and support interoperability in the public administration, serious planning should be implemented to ensure compatibility and storage interoperability of different public institution platforms. In fact, public organizations around the world as the major creators of data, need support in understanding how to harness technologies to overcome the increasing amount of data [28]. In addition, predictions states that the global data sphere–will attend 175 ZB in 2025 [29]. In reality, the exponential growth of public data presents an opportunity for data storing technologies to exploit effectively data storage solutions [30]. Meanwhile, it should be mentioned that budget of public administrations is limited, and it is vital to find solutions to optimize the state budget for ICT costs [31].

### 2.2. Modern data centers: software defined storage concept (SDS)

It is vital for public administrations to have a general approach to its data storage whether installed in cloud or on their own infrastructures. In other hand, as the critical aspect of the data maintained by government administrations, keeping data on its own servers (on promise solutions) are recommended to maintain a level of control that cloud usually cannot allow [32]. The need for flexible and easier manageable storage has contributed to the development of storage models. Software defined storage (SDS) concept changes the data center in practical ways: SDS abstracts the physical storage from the controlling software, unifies different storage solutions and put them in a central virtual store. This approach has attracted both academic and commercial community to overcome the deficiency of traditional storage infrastructures [33]. Unlike the traditional data storage solutions (SAN and Nas), SDS technique does not depend on the capacity of hardware, it is one of the promising approaches in the computer networking field, which enables storage resources to respond to the progressive changes in application requirements. Furthermore, SDS solution is an adequate technique to enhance efficiency, flexibility and effective cost [34]. Therefore, by unifying data and interfaces across different sources and presenting them in a single view, SDS solutions provide new approaches for managing and controlling data storage.

### 2.3. Modern infrastructure: hyperconverged infrastructures (HCI)

Hyperconvergence splits into hyper which means hypervisor and convergence. Hyperconverged infrastructure (HCI) is a set of SDS solutions that provide network, compute and storage in a single consolidated unified appliance [35]. It combines compute resources, memory and storage in a single platform. In HCI infrastructure, all components are virtualized which offers a flexible and resilient environment to companies [36], [37]. Instead of the growth adoption of SDS in companies system's storage, academic research's conducted in hyperconverged field is restricted [38]. HCI solutions based on x-86 architecture helps enterprises to reduce expenses with better storage [39].

Data center architectures have moved from traditional infrastructure through converged to now a hyper-converged one:

- The traditional infrastructure (three-tier) model relies on three separate units: Compute, storage, and network components. Each component is configured and managed separately. Moreover, support and warranty are managed individually. This requires different IT staff with expertise in all data center fields,
- The converged infrastructure develops the traditional model by combining compute and storage into a single physical appliance that can be manageable centrally. Even if components are still separate physically, the global management is optimized,
- The Hyper-converged infrastructure is the successor of converged infrastructures; it connects servers, storage, networking and management into a single infrastructure with intelligent software. This, create simple and efficient environment in data centers, optimize overall data center performance and eliminates the need to have different IT administrators. In addition, HCI solutions include software layer that enables to manage, deploy, and easily administer hardware resources from a unique interface.

As shown in Figure 1, converged and hyper-converged infrastructures extended the capability of data centers. Due to the complexity of data storage, HCI architectures are attracting research academics to improve storage efficiency and reach high performance [41]. The major benefit is integrating all functions in software. This new approach simplifies management data, and now it is seen as a future advent of data centers [42], [43]. The architecture we propose essentially completes the work of [44] by ensuring an efficient storage architecture for the central data warehouse presented as a solution for e-government interoperability.

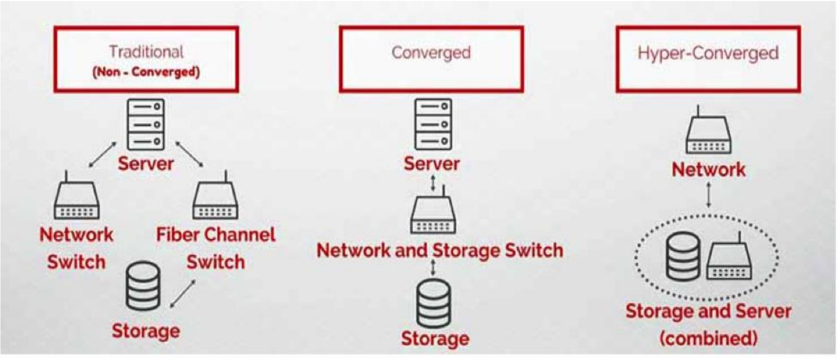


Figure 1. Comparing non converged, converged and hyper-converged infrastructure [40]

## 3. MATERIALS AND METHODS

### 3.1. VMware vSAN HCI solution

There are several solutions for HCI in the IT market. VMware is one of the leaders in the development of HCI solutions. Indeed, according to International Data Corporation (IDC) analysis, VMware vSAN powered HCI is one of the top three companies in the world that lead the HCI market in the third quarter of 2020 [45]. As seen in Table 1, IDC announces that systems running VMware HCI estimated for 40.2% share of the market, and increased at 1.6% over 2019.

Table 1. Top three companies market share source: IDC tracker, december 15, 2020

| Company | 3Q20 Market Share | 3Q19 Market Share |
|---|---|---|
| VMware | 40.2% | 38.6% |
| Nutanix | 25.1% | 27.1% |
| Cisco | 5.9% | 5.4% |
| Rest of Market | 28.7% | 28.9% |
| Total | 100% | 100% |

VMware highlights three reasons to explain this remarkable growth: deployment flexibility, support for cloud-native applications and a path to the hybrid cloud [46]. For this, we propose an architecture based on VMware vSAN systems to store public data. First, we discuss the general requirements and the configurations of VMware vSAN solution, secondly, we present our architecture to store public data and ensure technical interoperability between different public information systems.

### 3.2. Dimensionning vSAN components

To achieve optimal level of performance, planning the capabilities of hosts and the storage configuration is strongly recommended before deploying a vSAN solution in the vSphere environment. The environment must meet all requirements in: hardware, software, clusters and network. Therefore, based on information in the Vmware guide for vSAN planning designing and deployment [47], we design the key elements in a vSAN architecture, namely: the vSAN Cluster, vSAN Storage Components, vSAN Hosts, and vSAN Network. At the same time, the proposed HCI platform must support replication, compression, duplication and ensure high availability.

### 3.3. Sizing virtual SAN cluster

A vSAN cluster must have at least three server nodes; each node includes its internal storage drives (SSD, SAS, or SATA) that are used to create disk groups to make the VSAN Datastore. The vSAN cluster uses Vmware features such as vMotion, to ensure high availability (HA) for the virtual machines and to avoid downtime for maintenance operations. Additionally, to protect site against failures (host failure, disk failure, and rack failure). vSAN features like failure to tolerate (FTT) and fault domains (FD) need to be activated.

The number N of hosts needed for the cluster is calculated as (1).

$$N = 2 * FTT + 1 \quad (1)$$

For example: If FTT=1, N=3, three hosts are required. If FTT=2, N=5, Five hosts are required

### 3.4. Sizing virtual SAN datasore

When sizing the VSAN datastore capacity ($C_{Da}$). We must consider the following major components: Expected virtual machine VMDK capacity ($C_{Vm}$), FTT method and the virtual machine storage policy (VMSP). Expected virtual machine (VM) consumption $\mathbf{C_{Exp}}$ is calculated by multiplying the number of VMs with the storage capacity for each VM.

$$C_{Exp} = N * C_{Vm} \quad (2)$$

Where $C_{Exp}$: expected overall capacity, N: number of VMs in the cluster, $C_{Vm}$: Storage capacity per VM.

### 3.5. Failures to tolerate (FTT)

This parameter defines how a virtual machine can survive host, hard drives or any other device failures. As we discussed earlier, it is related to the number of hosts in the vSAN Cluster. A value of FTT equals to 1, means that the hosted VM inside a vSAN datastore can tolerate one single failure whiteout impacting data integrity and availability.

### 3.6. The virtual machine storage policy (VMSP)

Vmware vSAN allows assigning for each Virtual Machine a storage policy that defines how the virtual machine disk (VMDK) is protected inside the vSAN Cluster. This parameter can be either RAID-1 mirroring or RAID-5/6 (Erasure Coding).

- If the VMSP is set to RAID-1 mirroring, the actual VMDK and its copy are both stored in the vSAN datastore; In this case the real needed capacity is calculated as:

$$C_{Real} = 2\, x\, C_{Exp} \quad (3)$$

where $C_{Real}$ is the actual overall capacity.

- If the VMSP is set to RAID-5/6, about 33% of extra space are added to store the VMDK and its parity. In this case the real needed capacity is calculated as (4).

$$C_{Real} = 1.33x\, C_{Exp} \quad (4)$$

### 3.7. Datastore capacity ($C_{Da}$)

First, we calculate the initial vSAN datastore capacity ($C_{Da0}$) that the vSAN cluster will use to host virtual machine disks (VMDKs) as (5).

$$C_{Da0} = C_{Real} * (FTT + 1) \quad (5)$$

Second, we preserve the vSAN capacity overhead $C_0$ wich represent about 30% of the initial datastore capacity $C_{Da0}$ for vSAN maintenance operations, as recommended by Vmware guide.

$$C_0 = 0.3x\, C_{Da0} \quad (6)$$

The real vSAN datastore capacity $C_{Da}$ is calculated as (7).

$$C_{Da} = C_{Da0} + C_0 \quad (7)$$

Figure 2 shows the flowchart of calculating the vSAN Datastore capacity.

### 3.8. Planning vSAN host

Planning the configuration of the hosts in the vSAN cluster includes sizing memory and CPU in the vSAN cluster. We have to consider carefully the memory per virtual machine, per host and the disk group number per host. Equally, we have to calculate the number of vCPUs based on the expected number of VMs.

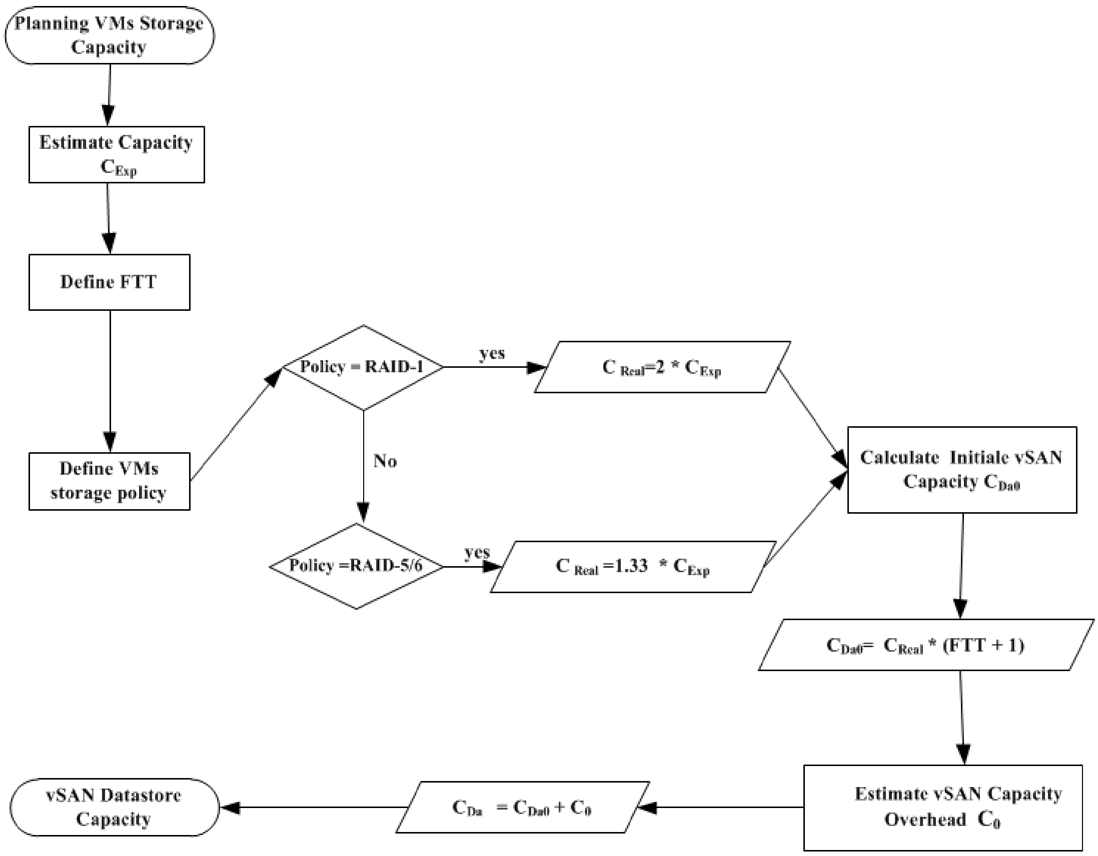


Figure 2. Flow chart of planning vSAN datastore capacity

### 3.9. Planning vSAN network

Planning the networking features offers availability, security, and bandwidth guarantee in a vSAN cluster. For network load balancing, vSAN uses a teaming and failover policy to ensure the network redundancy. It includes teaming algorithm that defines how network traffic is rerouted in case of failure, and failover configuration that selects of the how the switchs distribute the traffic between network adapters in team.

### 4.0. Planning vSAN disk group

Each server of the vSAN cluster must contain at least one disk group that have one device used for cashing and between 1 to 7 other hard drives used for capacity. A disk group is a combined of physical storage capacity on a host and a group of physical devices that furnish the required performance to the vSAN cluster. Each disk group must include one flash cache device and one or multiple capacity devices. Likewise, to achieve a high performance in read and write throughput and low latency, especially when hosting databases, using devices of flash type like SSD or NVME of smaller capacity is recommended.

## 4. RESULTS OF DIMENSIONING vSAN HCI ARCHITECTURE

In order to build an interoperable solution for data sharing technologies, organizations must store all their data in a central data warehouse. The data warehouse is a system destined to store data from single and multiple sources [48]. For this purpose, we propose to host each public service local data warehouse in dedicated virtual machines (VMs). Each VM is hosted on the vSAN Datasore, and every public administration can transfer a copy of its local data warehouse to its corresponding VM. This allows exchanging data in an interoperable manner without transformations.

To ensure the high availability, we create two sites, the principal site “Production Site” and the secondary one is “Disaster Recovery Site” as depicted in Figure 3. With vCenter HA, we configure the High availability between the two sites. vSphere HA cluster elects automatically a single host as the primary host. The primary host communicates with vCenter Server and checks the state of virtual machines. Interconnection between the two sites is performed by a leased line connection (LL), as a reliable liaison, to ensure continuous data flow. Aditionally, public administrations can use just a broadband connection and initiate a secure protocol for the transfer of data as secure shell file transfer program (SFTP), virtual private networks (VPN), FTP over transport layer security (TLS), FTP over secure shell (SSH).

VMware site recovery manager (SRM) is proposed for disaster recovery management and automation. This extension coordinates VMware vSphere Replication solution to automate the process of recovering. By using the data replicated from the "Production Site", virtual machines assume the safe provision of services. This vMware vSAN architecture takes charge of providing a rapid business continuity solution.

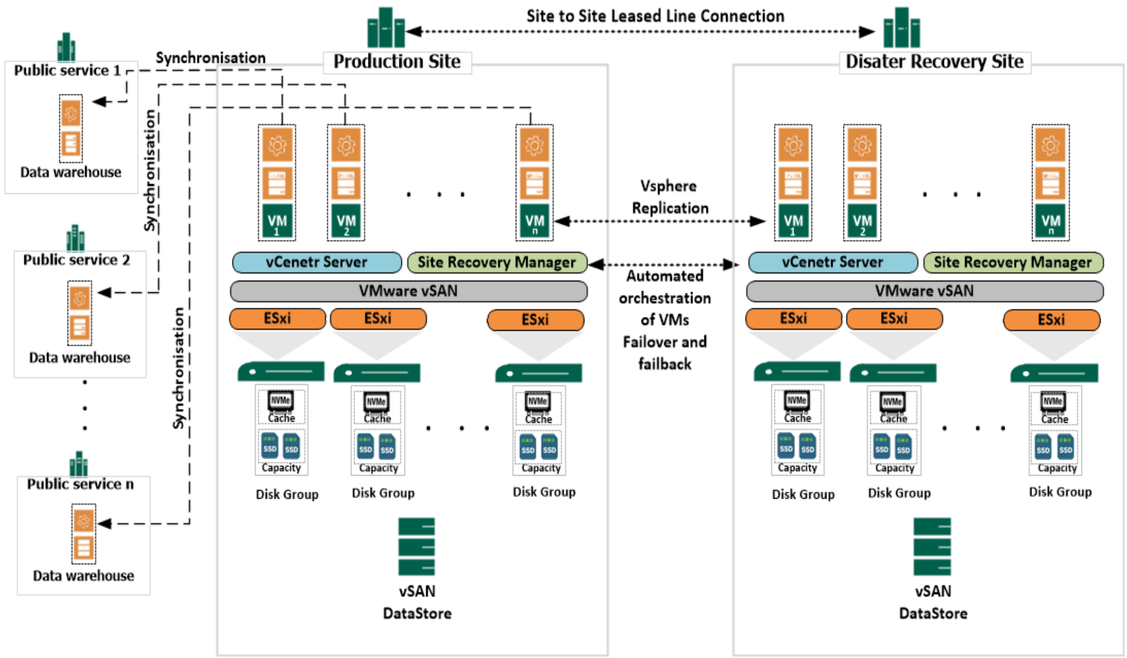


Figure 3. The Proposed vSAN architecture

## 5. CONCLUSION

In this paper, we concentrated on developing an architecture based on hyperconverged infrastructure for e-government interoperability that permits storing public data from different public data warehouses. We presented a global architecture for technical interoperability that ensures high availability, fault tolerance and performance in vSAN environment. In the future, our architecture will present a real case study applied to agency of digital development (ADD) to target practicable features like managing the storage of data from different public agencies and guarantee technical interoperability for public administration data.

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