

A research report on Data Centre

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Abstract— The aim of this report is to present the benefits and core aspects of a Data Centre architecture using Storage Area Network design approach including background, design, management, fault tolerance, performance, scalability, energy usage and sustainability and security, described into the context of a proposed solution for University of Manchester.

Keywords—Data Centre, topology, Fibre Channel, Storage Area Network, design, scalability, fault tolerance, security, performance, management

I. INTRODUCTION

In 1946, John Mauchly and Presper Eckert designed ENIAC (Electronic Numerical Integrator and Computer) for United States Army to store artillery firing codes. Then years later, John Peake Knight invented TRADIC (TRAnsistorized DIgital Computer), and he was using transistors and diodes and no vacuum tubes. In 1971, Intel invented the 4004 programmable processor, which was used for multiple customizations for electronic devices. In the same period, Xerox Alto was the first machine that supported graphical UI and large internal memory storage and ARCnet built the first LAN (Local Area Network), able to connect up-to 255 devices. The 1980s, was a boom period into the computers industry, being marked by the personal computers (PCs) and of the NFS (Network File System) protocol developed by Sun Microsystems. From that moment the users can access files over the network as they did on a local storage.

At the beginning of 1990s, the concept of a data centre came on the market, as the companies started to group and connect multiple machines into the same room. [1] [2]

As Miniman [3] mentioned, a Data Centre is a physical place that group together multiple connected specialized computers (known as servers) responsible for store and compute data. But, based on the needs that now a data centre meets and the exponential growth of technological changes, it represents more than a “room”. Building a data centre requires a deep analysis of the physical building location, building and floor layout, electrical and mechanical system, security regulations, cost, and scalability. [3]

II. OVERVIEW

Designing a Data Centre would not be efficient without taking in consideration aspects as manageability, availability, performance, scalability, and security. These properties derive the classification of Data Centre networks into multiple categories, based on the functional areas [4]:

- Infrastructure services: Routing, Switching, Server-Farms
- Application services: Load balancing, Secure Socket Layer (SSL) offloading
- Security services: Packet filtering and inspection, Intrusion Detection, Intrusion Prevention
- Storage services: Storage Area Network (SAN), Fibre Channel switching, Backup and archival
- Business continuance: Storage Area Network extension, Site selection

For University of Manchester case study, the proposed solution includes Storage Area Network built on a Fibre Channel (FC) architecture as a suitable Data Centre design approach.

A. Fibre Channel Arcitecture

Fibre Channel is an architecture that provides the ability to interconnect multiple devices (nodes) at a very high-speed level. Fibre Channel architecture contains five layers [5]:

- FC-0(physical layer), which includes cables, drivers, connectors, transmitters, and receivers and defines physical data and transmission rates
- FC-1(transmission layer), which defines the encoding schemes
- FC-2(signaling layer), which defines the flow control and framing protocol
- FC-3(common services layer), which defines the services for nodes
- FC-4(upper layer protocol mapping), which defines the upper layer protocol mapping (protocols: FCP (Fibre Channel Protocol), FICON (Fibre Connection Protocol), and IP (Internet Protocol))

Node interconnection is possible in Fibre Channel architecture by using one of the following topologies:

- Point-to-point

In point-to-point topology, there is a single connection between two nodes and the entire bandwidth is dedicated to them. Based on the used optical cable fibre (orange-colored cables – OM2, aqua-colored cables - OM3 and yellow-

colored cables – single fibre) the most supported distance for direct connection is 10km [1].

- Arbitrated loop

In arbitrated loop topology, the nodes interconnects in a ring manner. All nodes connect in a loop and shar the bandwidth, but only two devices can communicate at a time, which results in a reduced efficiency of the system [1].

- Switched

Switched architecture is one of the most used today. It comes with the benefit of multiple concurrent communication between nodes. Also, the usage of SAN (Storage Area Network) components and routers helps to increase the distance up to thousands of miles [1].

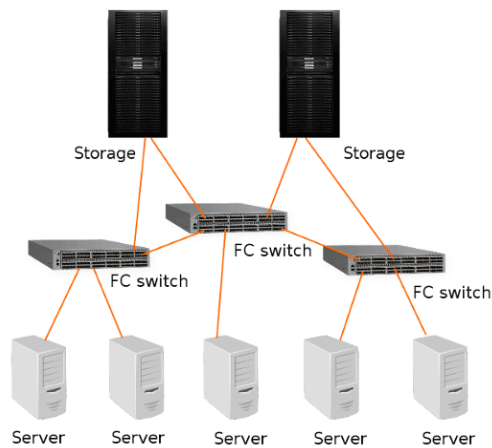


Fig. 1: Switched fabric topology [12]

The switched fabric topology is further classified based on the tiered approach:

- Core-edge

Core-edge topology provides advantages of performance and administration but comes with the limitations of scalability.

- Edge-core-edge

Edge-core-edge topology provides capabilities of long-distance traffic and scalability as the core switch connectivity is used only for connect to edge switches.

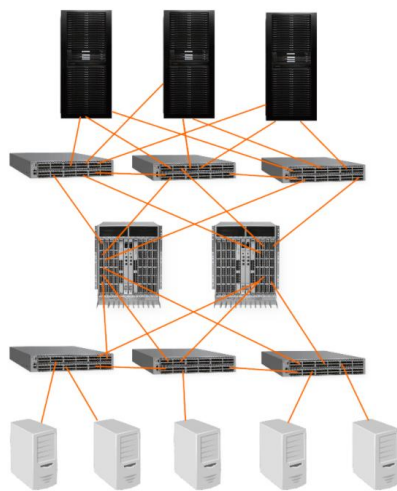


Fig. 2: Edge-core-edge topology [12]

B. Storage Area Network

Any network with high level of performance and the ability to enable communication of storage devices with each other and with computer systems may be consider a storage area network. It is already known that the computer can be already interconnected or connected to storage devices, but SAN comes with the substantial benefit of its property of universal storage connectivity[5]. For example, companies can use multiple techniques for moving data from a computer to another like file transfer or backup and restore, but these are coming with additional cost and effort. Computer B needs to copy data existing on Computer A which includes a cost of duplication and the cost of resources needed for copying and storing it on both sites. On top of that, serious issues may seem when data cannot be copied immediately, and it becomes out of date for Computer B. These issues are simply addressed by using storage area networks. In this scenario Computer B does not need to copy data because it can access all the storage devices used by Computer A.

SAN involves a totally new network attached to the main communication network. As shown in Figure 1, the application servers can access the storage devices through the storage area network layer [5]:

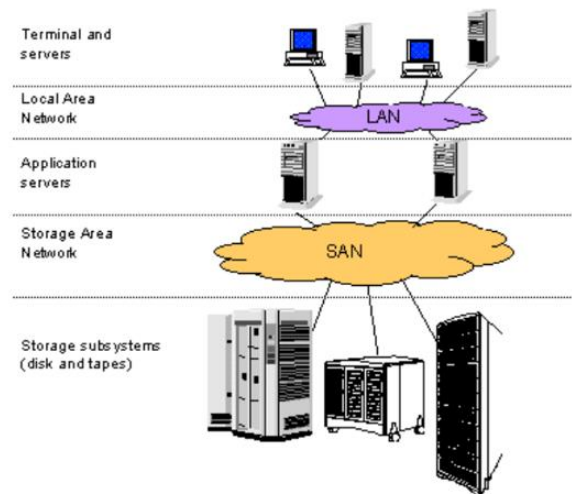


Fig. 3: SAN architecture [14]

As an overview, SAN comes with the following major benefits:

- Reduced cost
- High level of availability and security
- High level of performance
- Easy management

III. RESEARCH METHODOLOGY

The proposed solution is applicable for the following case study: “As it is known, two UK research-led universities have joined together to become the largest 'super-university'

in the country. The University of Manchester, newly named following a merger between the Victoria University of Manchester and the Manchester Institute of Science and Technology (UMIST), will educate 34,000 students a year and will have more academic subjects and departments than any other UK university. After the merger, the University of Manchester have decided to centralize its IT operations. As a part of this action, they want to build a Data Centre to centralize University of Manchester's IT operation and equipment, and where the university can keep and manage the ICT infrastructure." [4]

In this report, to present the solution, qualitative research method was used, and the following questions were formulated:

- "What are the implications of building an on-premises data centre?"
- "How can the building architecture and mechanical system affect the sustainability, flexibility and scalability of a data centre?"
- "How to implement the security guidelines to meet the real data centre data protection requirements?"

These questions were answered by performing an exploratory research on existing on-premises data centres, architecture and topology design best practices, scalability, performance metrics and security guidelines.

IV. PROPOSED SOLUTION ANALYSIS

In the following sections, a solution for building an on-premises data centre that satisfies the University of Manchester's business requirements will be presented. The solution was decided by performing a detailed research on the existing data centres requirements and limitations and the best practices for assuring data centres important properties as security, sustainability, scalability, performance, and efficiency.

A. Design

For designing the Data Centre architecture for University of Manchester a series of facts and assumptions were considered:

Facts:

- "super-university" (University of Manchester) contains two universities: Victoria University of Manchester and Manchester Institute of Science and Technology
- University of Manchester will educate 34000 students a year

Assumptions:

- Each of the university has several campuses:

- University of Victoria: 3 campuses
- Manchester Institute of Science and Technology: 5 campuses
- Each campus has its own LAN (Local Area Network) infrastructure
- VPN (Virtual Private Network) tunnels assure the campuses interconnection

A modular approach was followed for designing the data centre. Modularity plays an important role in data centres industry and has the advantages of:

- Scalability – each component can be added later based on the requirements which reduce the cost of ownership. The installation time can be reduced by 30%.
- Flexibility – each module can be reconfigured to meet the new requirements
- Sustainability – each module can be changed or repaired without stopping the entire system
- Compatibility – the system can easily mix different servers or uninterruptible power supply devices

The proposed design uses switched fabric topology and in terms of tiered topology, the Edge-Core-Edge topology for implementation. All devices are communicating using switches. The nodes can work at the same time which results in an increase efficiency of the system. In this topology, the servers (initiator) are in edge-tier and the storage (target) are in another edge-tier, so the two are on totally different switches.

B. Site location

The site of the data centre should be in a different building, away from high-risks areas, not in the same building as the universities. An industrial structure type building, where the floor plates are large, and the number of windows is as much as possible reduced, is the ideal solution for the physical architecture of the data centre. The floor should have a rectangular shape with bays of around 40 feet. The floor should have around 13-14 feet high. A total size of 1000 square feet would be enough for the proposed data centre. The roof should have a solid structure without windows.

The greatest distance between Manchester, where all the most users are located, and the building's location is one hour and a half, and all the essential utilities (water, power) must exist. Also, the fire workers and delivery trucks should have an easy access to the building [6].

C. Rack layout

As the data centre design approach is modular and support further extension, 10 racks are considered enough to satisfy for the current requirements and the layout is determined using 7-tile aisle pitch method. An aisle pitch is the distance between a middle of a cold aisle to the middle of a hot aisle.

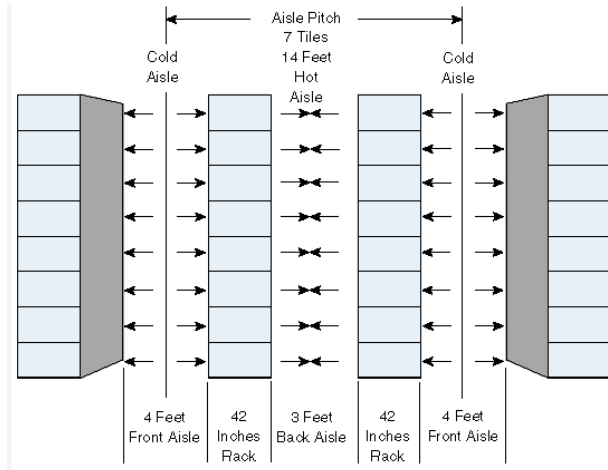


Fig. 4: 7- Tiles Aisle Pitch [13]

D. Fault tolerance, power and cooling

Uptime Institute [6] defines fault tolerance as the capacity of the system to continue to operate in case of failures. It [6] establishes four levels of fault tolerance:

- Tier 1 – up to 28.8 h/year downtime – use of single path for power and cooling and no redundant components
- Tier 2 – up to 22 h/year downtime – use of single path for power and cooling and redundant components
- Tier 3 – up to 1.6 h/year downtime – use of multiple paths for power and cooling and redundant components, but with only one active path at a time
- Tier 4 – up to 0.4 h/year downtime – use of multiple active paths for power and cooling and redundant components

A lower level (Tier 1) of fault tolerance is acceptable for universities.

To achieve Tier 1, the data centre needs one UPS (uninterruptible power supply) device to ensure the power energy for computer equipment, security devices and emergency lighting system for about 15-20 minutes in case of a power interruption. The temperature in the rooms must be maintained between 21-23degrees C and the humidity between 45-50% by installing air conditioning units and HVAC (heating, ventilation and air conditioning) units.

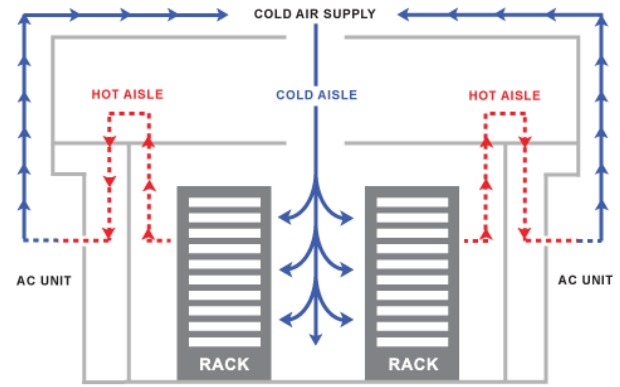


Fig. 5: Cooling system design [13]

The power consumption is evidenced in the following table:

Rack Layout		
Number of racks	10	Racks
Number of servers per rack	15	Servers
Square footage	1000	Square feet
Power supply for servers	240	Watts
Power Draw per server		
kW per server	0.24	kW per server
kW per rack	3.60	kW per rack
Cooling per rack		
BTUs per rack	12283	BTUs
Total Watts per square foot	36.00	Watts per square foot

Table 1: Power usage calculation

E. Fire detection and suppression

Any data centre has an increased risk of fire. To address this issue detection devices are mandatory. A proper system should include heat and smoke detection devices, sprinkler system, portable fire extinguishers and alarms and it is essential for life and property save, but also for a fast recovery operation [6].

F. Management

The data centre management is a critical operation as it provides a top-to-bottom picture of the entire infrastructure. The troubleshooting, maintenance and future design becomes easier operations when the data centre has implemented a strong management system. Automation is one important characteristic of the management system, and it includes scheduling, monitoring, maintenance, application delivery [2][6].

Data centre automation allows the system to execute different actions without the need of human interaction. Using a strong management strategy for a data centre result in the ability of automating every component (networking, compute, storage etc.). Automation brings the

benefits of reducing the human error, increasing the staff efficiency and decreasing the cost in case of downtime.

Barker [6] explains that business flows can also be fully or partial automated. For example, automation of the “onboard new lecturer” flow includes the following steps: create of an Active Directory user for the Human Resources system information, assign Active Directory permissions/roles/user groups, print physical access badge and update existing applications or services with the information about the created user account.

The data centres use multiple configuration tools to provide the data centre management:

- Ansible – is a software framework, acquired in 2015 by Red Hat, which does not require programming skills and provides functionalities for servers/workstations update or application deployment (e.g., the University of Manchester decides that all the campuses will have the same version of LibreOffice) [8].
- Puppet – is a software framework used to manage and automate the configuration of servers [9].
- Chef – is an open-source and commercial suite of products, written in Ruby and used by large companies like Facebook or Etsy to control and manage their infrastructures [10].

On top of the already mentioned aspects, the data centre management includes the facilities’ management as well: cleaning, building management or shipping services. The University of Manchester should decide who is responsible for performing the management by choosing between three models [11][7]:

- Third-party specialized organization is responsible for data centre management – the benefit of this approach is that the university do not need to hire and train staff and the data centre can meet the standards (security, environment health and safety standards) and policies in a shorter period.
- University of Manchester create an internal IT department – the benefit of this approach is that the university has the maximum control over the entire data centre management. As a drawback, the university need to have specialized staff (hire or train) including electrical and mechanical system engineers.
- The responsibility is split between and internal IT department and a third-party organization – in this matrix approach, the university can decide to hire/train or assign (if existing) a reduced staff which will collaborate with a third-party

organization. This model has higher benefits on a long-term strategy as the training of the specialized staff can be perform on a longer period and the responsibility can be migrated progressive to the internal IT department. Also, the facilities management (cleaning, electrical maintenance etc.) can be provided by the university.

G. Performance and efficiency

Over the last years, associations and scientists invented multiple metrics to determine the performance and efficiency of the data centres. Each metric is analysis different components of the data centre (cooling system, power distribution and supply)[1][7].

The following efficiency metrics can be applied:

- PUE (Power Usage Effectiveness)

The Green Grid created PUE metric, and it is used to determine the energy efficiency of a data centre by dividing the total facility power by the power used to run the infrastructure.

- PAR4

by Power Assure created PAR4 metric, and it is used to analyse the power consumption by monitoring total power usage, idle and peak power, and processed transactions per each watt.

- CCF (Cooling Capacity Factor)

Upsite Technologies created the CCF metric, and it used to determine the cooling infrastructure efficiency.

The usage of PUE and CCF metrics is recommended for the current data centre proposed solution. PUE is one of the most used metrics today, but because an inefficient cooling system could easily drive to a fire disaster, CCF metric would represent an additional measure for prevention, or it can detect an opportunity for energy-saving in case of overcooling of the data centre.

Storage Area Network architecture brings a plus in terms of performance. SAN can maximize the compute capacity. For example, instead of using 10 VMs, each of them with 150GB free, use only one server capable to accommodate one VM with 3TB storage space. SAN resolves the problem of complexity, by consolidating multi-server environment into a single storage. SAN also increase the efficiency and performance by providing features as data deduplication. Data deduplication is used to cut the storage cost by reducing the redundant data. [16]

H. Scalability

Scalability is an important property of a data centre and find its ability to adapt when the IT requirements increased.

Scalability is addressing the network itself, the facilities (power and cooling systems) and the connectivity infrastructure.

Proposed solution for current data centre is using switched fabric topology which brings huge benefits in terms of scalability. Additional switches can be added to the fabric/network without having any downtime.

Possibility to increase the physical space, is already a criterion of the perimeter and site selection. Also, following a modular approach, additional power (UPS systems, generators, power distribution systems) or cooling systems (cooling towers, chillers, pumps, air conditioning units) can be easily integrated to meet the future growing requirements.

I. Security

The data centre holds sensitive information about staff and students' data, intellectual property or financial data and it must be physically and digitally secured and compliant with data security guidelines and regulations. Physical security measures can be defined in three layers:

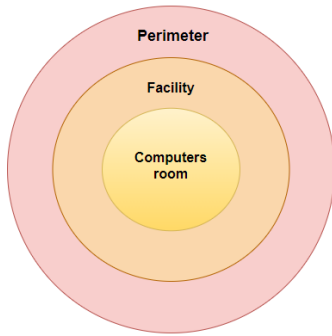


Fig. 6: Physical security layers

“Zero Trust” security model[15] recommends for security strategy, as a first step, the need of creating an access list and conducting a background check on staff members. Fig. 7 illustrates the entire process presented by the “Zero Trust” model:

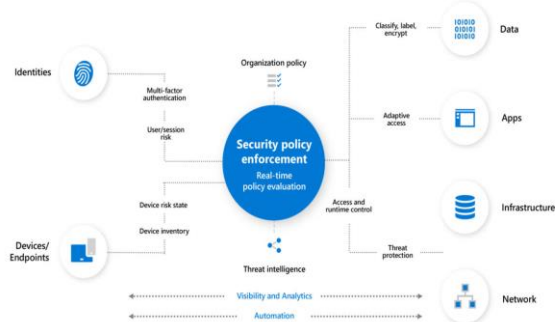


Fig. 7: Zero-Trust model [15]

A third-party organization, based on the matrix model presented in management section, should install video surveillance systems, audio speakers, gates and fences and

security lighting in the data centre to ensure the perimeter security. It should monitor in every moment all building access points and all interior doors by using closed-circuit television cameras (CCTVs) and they should store the camera footage digitally and do regular back-ups outside of the data centre. Alarms are also mandatory. The organization should allocate security staff and that do routine patrols in every zone of the data centre.

Facility security is achieved by using card swipes or biometrics. VCA (Video content analytics) system can be used to perform facial recognition. Multi-factor authentication is required in every access point.

Only authorized staff can access to the computers' rooms. University's internal IT department defines a very specific list of authorized users and collaborates with the security organization to implement smart cards and biometric access entry points.

The IT department should define “exit procedures”. These procedures cover the staff that is leaving the organization (University of Manchester staff or management staff) and includes mechanism of updating the access list, collecting the smart cards or keys or removing the biometric data from the system.

The second aspect of security, despite of physical security, is the virtual access monitoring and protection. IT department installs firewalls to ensure the network security and to monitor the incoming and outgoing traffic and to allow or block the data packages. Also, the traffic within the network is permanently monitored to detect potential threats that bypassed the firewalls. Based on the Zero Trust model, the data should be encrypted and classified, the access to data endpoints should be decided by policies and roles (e.g., an account for a student should not be able to get access to the profile page or marks for another student. The access should be provided only for users with “lecturer” role). By implementing and following strong password policies, encryption mechanism and SSH (Secure Socket Shell) protocol, the IT department increases the network security. The applications should be up to date to eliminate known vulnerabilities.

The University needs to consider a high level of the data centre automation process to realize a continuous monitoring, logging, and reporting of the security events and threats.

V. RECOMMENDATIONS

To accomplish this data centre solution, the following recommendations were offered to the University of Manchester:

- Decide the data centre physical location based on a comprehensive analysis of multiple criteria (high-risk areas, industrial type building, commutation

distance, utilities infrastructure, perimeter security, accessibility, existing space, and possibility of space extension)

- Create an equipment list
- Perform a cost analysis
- Enforce strong security measures (physical and digital security) and conduct regular internal audits
- Evaluate the data centre cost of construction and predict the cost of downtime and scalability
- Perform regular efficiency metrics analysis
- Consider matrix model for data centre management

VI. CONCLUSIONS

In this report, the aspects needed for implementing a data centre that would meet the University of Manchester requirements were addressed and an overview of Fibre Channel and Storage Area Network architectures was presented. The advantages of using switched fabric topology and the requirements and best practices for building the data centre itself, which includes the selection of the data centre physical location, an analysis of the building architecture with focus on racks layout, power, and cooling systems, but also characteristics as management, efficiency, scalability, performance, and security are detailed.

In the end, a list of recommendations was offered to University of Manchester to accomplish the implementation of the data centre proposed solution.

The most evident aspect of this report is that building an on-premises data centre has a high level of complexity and requires a detailed analysis and specialized expertise. It can also be costly and an overwhelming action, comparing with getting the needed services from a cloud provider, but with a detailed analyses and regular audits it becomes feasible, and it comes with the huge benefit of having the complete control over the entire infrastructure.

FIGURES AND TABLES

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- Fig. 2: Edge-core-edge topology
- Fig. 3: SAN architecture
- Fig. 4: 7- Tiles Aisle Pitch
- Fig. 5: Cooling system design
- Fig. 6: Physical security layers
- Fig. 7: Zero-Trust model

Table 1: Power usage calculation 4

LIST OF ABBREVIATIONS

BTU	British Thermal Unit
CCF	Cooling Capacity Factor
CCTV	Closed-circuit television cameras
ENIAC	Electronic Numerical Integrator and Computer

FC	Fibre Channel
FCP	Fibre Channel Protocol
FICON	Fibre Connection Protocol
HVAC	Heating, ventilation and air conditioning
ICT	Information and communication technology
IP	Internet Protocol
IT	Information Technology
LAN	Local Area Network
NFS	Network File System
C	Personal computer
PUE	Power usage effectiveness
SAN	Storage Area Network
SSH	Secure Socket Shell
SSL	Secure Socket Layer
UI	User interface
UPS	Uninterruptible power supply
VCA	Video content analytics
VPN	Virtual Private Network

REFERENCES

- [1] L. Scott, G. James, D. David and H. Kirchner, Building a Modern Data Center, Principles and Strategies of Design, Bluffton: ActualTech Media, 2016.
- [2] IBM Corporation, Introduction to Storage Area Network, SAN, San Jose: IBM Corporation, 1999.
- [3] S. Miniman, "The Data Center: Past, Present and Future," 02 04 2014.
- [4] K. Modak, "ACUA6000 - Data Centre Technologies," [Online]. Available: <https://moodle.uwtsd.ac.uk/>.
- [5] A. Benner, Fibre Channel for SANs, McGraw-Hill Professional, 2001.
- [6] R. Barker and P. Massiglia, Storage Area Network Essentials, New York: Wiley Computer Publishing, 2002.
- [7] M. A. Bell, "Use Best Practices to Design Data Center Facilities," Gartner, Inc., 2005.
- [8] R. H. Ansible. [Online]. Available: <https://www.ansible.com/>.
- [9] Puppet, [Online]. Available: <https://puppet.com/>.
- [10] Progress Software Corporation, [Online]. Available: <https://www.chef.io/>.
- [11] K. Jayaswal, Administering Data Centers: Servers, Storage, and Voice over IP, Indianapolis: Wiley, 2005.
- [12] "Fibre Channel Topologies," 1 07 2021. [Online]. Available: <https://www.storageinfra.com/fibre-channel-topologies/>.
- [13] Sun Microsystems Inc., "Site Planning Guide for Entry-Level Servers Version 1.4," 2004. [Online]. Available: <https://docs.oracle.com/cd/E19095-01/sfv890.srvr/816-1613-14/index.html>.
- [14] SNIA, "Storage Area Network," [Online]. Available: https://www.snia.org/education/storage_networking_primer/san/wha_t_san.
- [15] Microsoft, "Zero Trust," [Online]. Available: <https://www.microsoft.com/en-gb/security/business/zero-trust>.
- [16] Microsoft, "Data Deduplication Overview," 05 09 2017. [Online]. Available: <https://docs.microsoft.com/en-us/windows-server/storage/data-deduplication/overview>.

