TASI
TELECOMMUNICATIONS AND SOCIAL INFORMATICS RESEARCH PROGRAM

Massively Learning Activities

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Table of Contents

1 | Abstract

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2 | Introduction

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2.1 | TASI/PHIDC

ABOUT US

The Telecommunications and Social Informatics Research Program / Pacific Health Informatics and Data Center (TASI/PHIDC), formerly TASI/PEACESAT, is part of the Social Science Research Institute (SSRI) of the College of Social Sciences (CSS) at the University of Hawai'i at Manoa. TASI/PHIDC programs incorporate an interdisciplinary approach to education and research, and work with partners from across the University of Hawai'i system, State of Hawai'i and other government and academic institutions from the Asia and Pacific Islands region. Program and research focus areas include policy, planning, information and communications technologies and systems, health information technology, health informatics in Hawai'i and the Pacific Islands region.

MISSION

The TASI/PHIDC Research Program missions are to: (1) Provide technical assistance in policy, program planning and evaluation; (2) Facilitate public and private sector collaboration to improve community resiliency, sustainability, and health system performance; and (3) Build capacity in information technology, health data management, analytics, and data sciences.

FACULTY RESEARCH

TASI/PHIDC conducts interdisciplinary and applied research and provides policy, program, technical assistance, education, and training in Hawai'i and the Pacific Islands Region related to:

- Accessible and affordable Information and Communication Technology (ICT)
- Health Information Technology (HIT)
- Electronic Health Record (EHR)
- Healthcare and claims data management, analytics, and programs
- Telehealth
- Meteorological and disaster communications

2.2 | Contract Explained (TBD TITLE)

TASI/PHIDC is a Technical Assistance and Research Partner or "TARP" who has an Intergovernmental Cooperative Agreement (ICA) with the Commonwealth of the Northern Mariana Islands (CNMI) State Medicaid Agency (SMA) to design an infrastructure that would allow advanced data analytics and parallel processing of Protected Health Information. After careful consideration, TASI/PHIDC has opted for SAS technologies in a hyper-converged infrastructure.

- Modernize data archive and storage (paper to electronic) of PHI data.
- Want to perform data analytics and machine learning.
- Used RCUH funds to purchase SAS license.
- Therefore, SAS needs to be accessible to multi-tenants and UH themselves.

3 | Hyper-Converged Infrastructure (HCI)

HCI, or Hyper-Converged Infrastructure, is a software-defined, unified system that combines the traditional elements of IT infrastructure (e.g., compute, networking, management, storage) with virtualization, simplifying infrastructure, reducing costs, and increasing scalability and flexibility. In a traditional IT Infrastructure, servers, storage networks, and storage systems are physically separated as stand alone hardware devices (e.g., servers, network switches, disk arrays). Consolidating these components into a single, integrated system simplifies the management, deployment, configuration, and maintenance of your IT Infrastructure.

The benefits of an HCI environment include:

- Scalability: Designed to scale out by adding additional nodes on-demand to your system.
- Efficiency: Improve resource utilization by using or eliminating idle storage capacity.
- Agility: Quickly deploy new applications and workloads without extensive planning across systems.
- Data Protection: Integrated backup and disaster recovery.
- Reduced Hardware Costs: Reduce the amount of hardware required reducing CAPEX[1]/OPEX[2] costs.

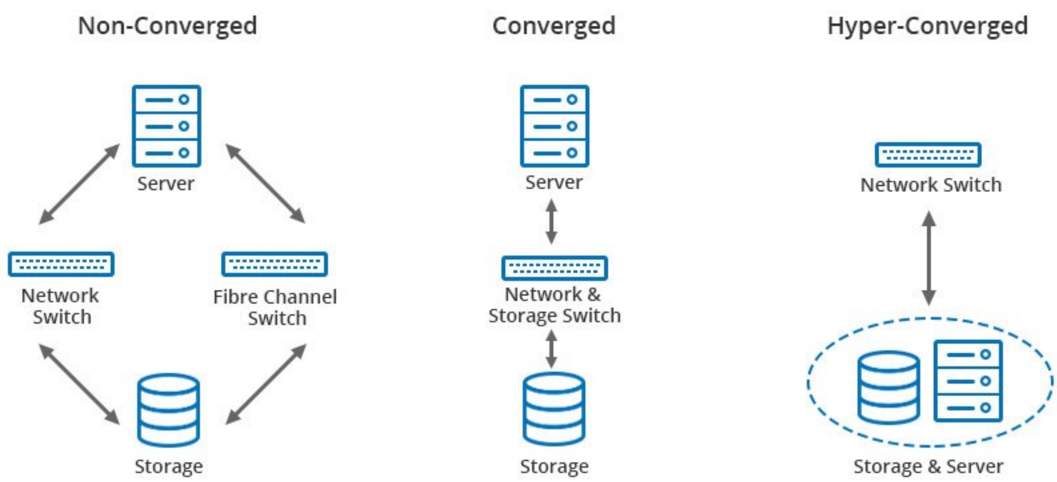

Figure 3.1: Types of IT Infrastructures (STOLEN EXAMPLE)

In HCI, multiple servers (nodes) are combined together to create a cluster. Nodes part of the cluster can share their storage and computing resources with other nodes to create a multi-purpose integrated system. The design of your HCI is dependant on (HPC Cluster?)

The software also provides a management layer, which automates tasks like resource provisioning, data migration, and load balancing while abstracting the hardware.

[1]Capital expenditure is the cost a business incurs to acquire assets that will provide benefits beyond the current year.
[2]Operating expenses refer to the money a company spends to run day-to-day operations.

4 | VMware

VMware is a company that specializes in developing technologies for virtualization and cloud computing. Its software products and services enable organizations to efficiently manage their IT infrastructure, improve performance, and reduce costs. VMware offers solutions for network virtualization, cloud management, digital workspace solutions, and security solutions.

4.1 | vSphere 6.5

vSphere is VMware's virtualization software suite that allows you to create and manage virtual machines and computing environments, using a set of software tools and services. With vSphere, you can run multiple virtual machines on the same physical server, each running its own operating system and applications. vSphere includes many features and capabilities that help make virtualized environments more reliable, scalable, and performant, such as:

- **vSphere Web Client**: A web-based management interface.
- **ESXi**: The bare metal hypervisor installed on your machines.
- **vCenter**: A centralized management system for your vSphere environment.
- **vSAN**: A software-defined storage solution to create a distributed storage platform in vSphere.
- **NSX**: A software-defined networking solution for your vSphere environment.

4.1.1 | vSphere Web Client

The vSphere Client is an application that enables administrators to manage and monitor VMware vSphere environments. It comes with a graphical user interface (GUI) and allows users to connect to VMware vCenter Server, which serves as a central management console for multiple VMware vSphere hosts.

Through the vSphere Client, administrators can create and modify virtual machines, manage storage, configure networking, and monitor system performance, among other things. Essentially, it provides a range of tools that enable users to manage virtual infrastructure components effectively.

In addition to the traditional Windows-based vSphere Client, there's also a web-based version called the vSphere Client (HTML5), which is designed to work seamlessly across different operating systems and devices, including desktops, laptops, and mobile devices. This new client offers a simplified interface, improved performance, and support for new features introduced in vSphere 6.5 and later versions.

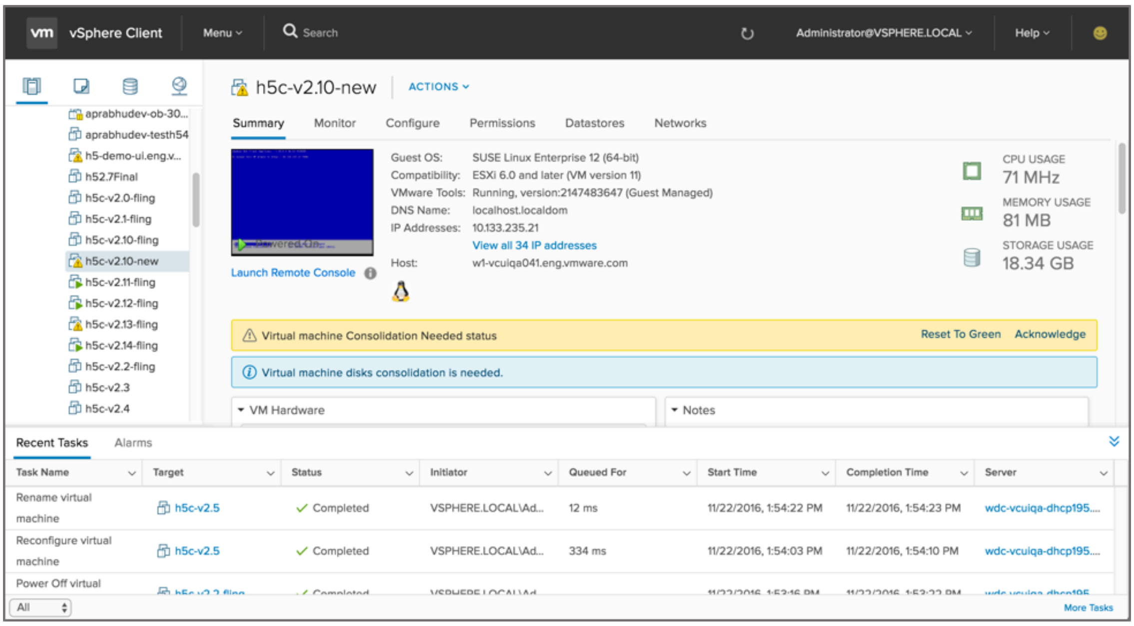

Figure 4.1: vSphere Client (STOLEN EXAMPLE)

4.1.2 | ESXi

VMware ESXi formerly known as ESX is a bare metal hypervisor that is installed directly on the physical server hardware and provides the ability to create, run, and manage virtual machines.

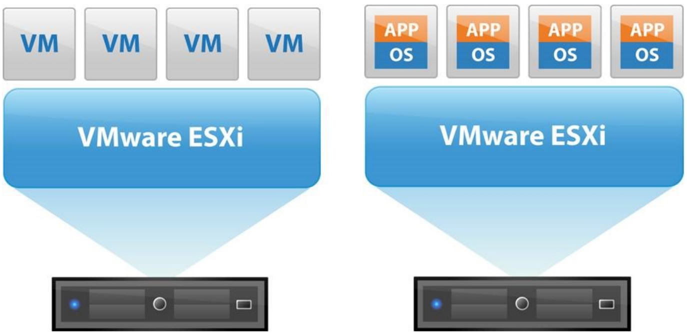

Figure 4.2: ESXi (STOLEN EXAMPLE)

4.1.3 | vCenter

vCenter is a software platform developed by VMware that provides centralized management and control for their suite of virtualization products, including vSphere. Essentially, it allows you to manage multiple virtualized components from a single location, making it easier to manage complex virtualized environments.

With vCenter, you can manage hosts, clusters, virtual machines, networks, and storage resources in your virtualized environment. This includes advanced features like high availability, disaster recovery, and workload balancing, which help improve the reliability, availability, and performance of your virtualized infrastructure.

One of the biggest benefits of vCenter is that it provides advanced capabilities like automation, orchestration, and policy-based management. These features allow you to automate routine tasks, streamline operations, and enforce policies across your virtualized environment. Another key advantage of vCenter is that it enables you to manage large, complex virtualized environments at scale. By providing a single point of control, it simplifies management and reduces complexity, making it easier to manage many virtual machines and components.

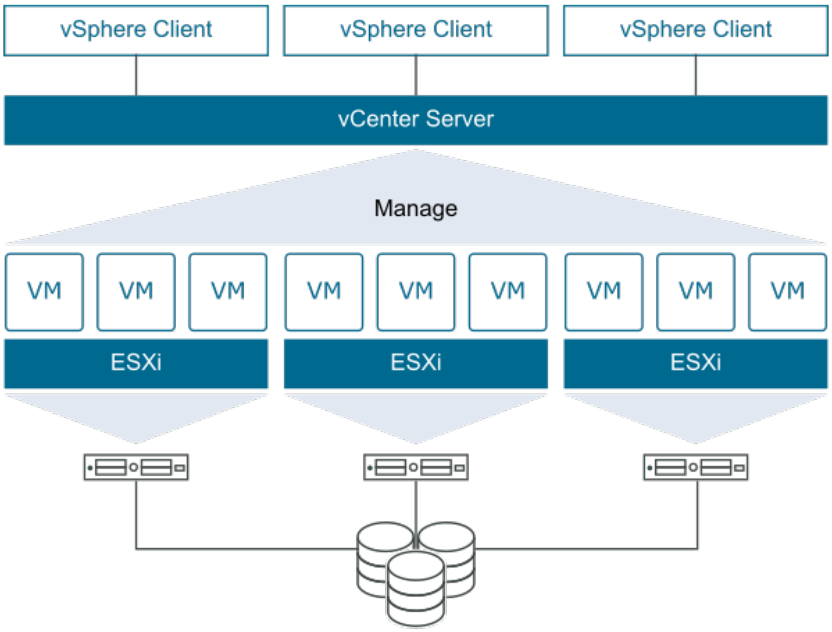

Figure 4.3: vCenter (STOLEN EXAMPLE)

4.1.4 | vSAN

vSAN is a software-defined storage solution developed by VMware, which allows organizations to create a distributed storage platform that is integrated with vSphere. This provides a highly scalable and available storage infrastructure, using standard hardware.

By creating a shared data store using the internal disks of ESXi hosts in a vSphere cluster, vSAN allows organizations to pool their storage capacity and performance into a single datastore, scaling it easily by adding more hosts to the cluster. vSAN features data replication, erasure coding, and automatic data rebalancing. Additionally, it offers advanced storage services such as deduplication, compression, and encryption, ensuring optimal storage efficiency and security which streamlines storage management, automates routine tasks, and helps to optimize storage utilization and cost savings.

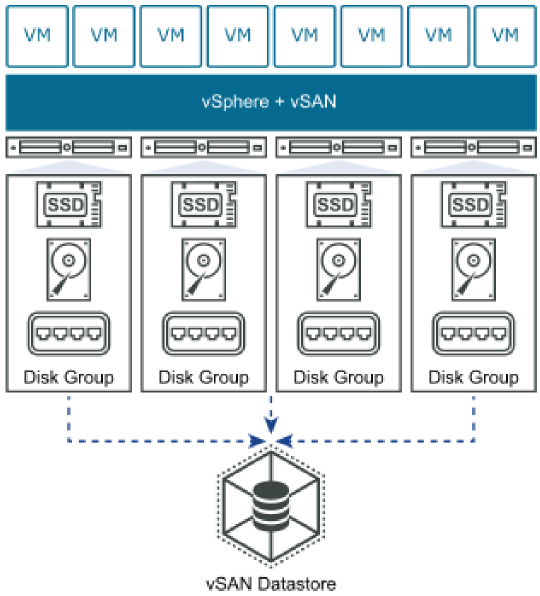

Figure 4.4: Standard vSAN Cluster (STOLEN EXAMPLE)

4.1.5 | NSX

NSX is a network virtualization and security platform created by VMware that provides a software-defined networking (SDN) solution that enables organizations to virtualize their network infrastructure, creating a more flexible, scalable, and manageable network.

NSX allows for all network components in your infrastructure to be virtualized, decoupling your network from existing hardware. This abstraction enables organizations to pool and automate network resources, which can reduce the time and cost of deploying and managing network infrastructure. NSX also offers advanced security features and networking capabilities which allows administrators to apply precise policies to specific workloads or applications. For example, NSX provides: network automation, multi-cloud and on-premises support, network segmentation, minimal cost and resource overhead, switching and routing, and load balancing features.

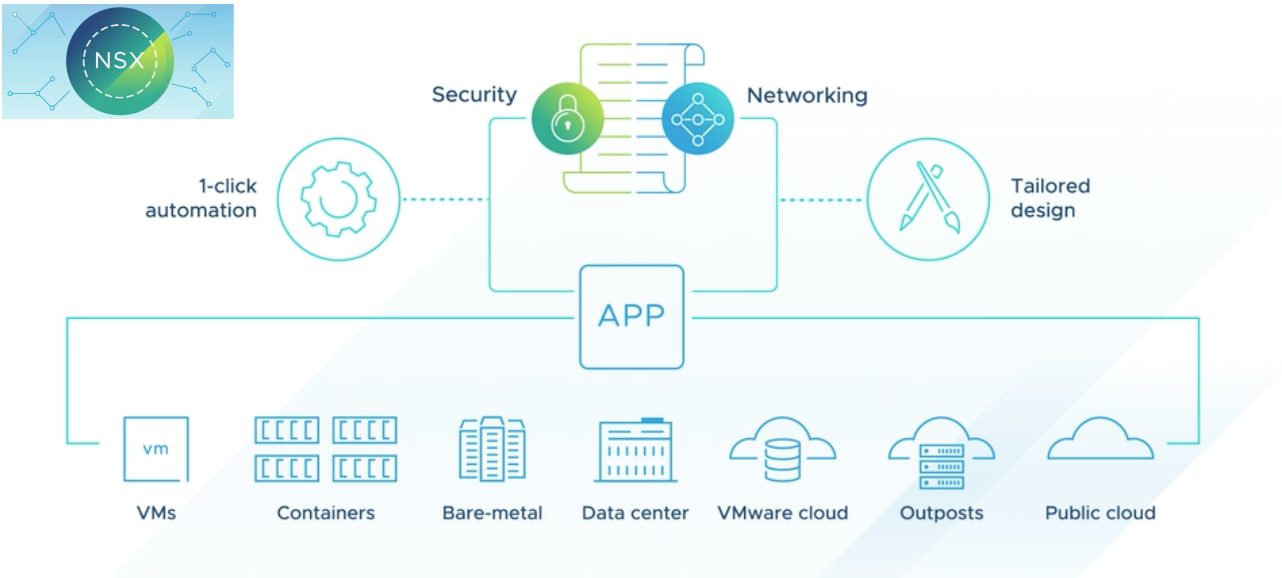

Figure 4.5: NSX Infrastructure (STOLEN EXAMPLE)

5 | Statistical Analysis System (SAS)

SAS, or Statistical Analysis System, is a software suite that has been used for advanced analytics, business intelligence, data management, and predictive analytics since it was first released in 1976. Developed by the SAS Institute, it offers a range of statistical and data analysis tools, which are suitable for many applications including data mining, forecasting, econometrics, quality control, and statistical analysis.

The software provides a user-friendly graphical interface for data analysis and reporting, as well as a powerful programming language that allows users to customize their analysis and automate repetitive tasks. Its ability to handle large and complex datasets and perform advanced statistical analyses make it popular in various industries, including finance, healthcare, government, and academia. SAS is widely used for purposes such as fraud detection, risk management, clinical research, and marketing analysis, and is a popular choice among data scientists and statisticians.

SAS offers multiple product **suites**. The SAS Enterprise Suite is a collection of SAS products designed for enterprise-level data management and analysis, such as SAS 9.4, SAS Visual Analytics, SAS Data Integration Studio, SAS Data Management, etc. The SAS Platform provides two engines for managing foundational capabilities such as distributed processing, security, administration, program development and execution, resource management, user interfaces, cloud integration, operating systems and third-party software. These engines are **SAS 9.4** and **SAS Visual Analytics**. In addition,

5.1 | SAS 9.4

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5.2 | SAS Visual Analytics (SAS Viya)

SAS Viya, or SAS Visual Analytics, is a cloud-enabled, in-memory analytics engine that provides elastic, scalable, and fault-tolerant processing for advanced data analytics, data processing, and machine learning for enterprise environments. SAS Viya includes a variety of tools such as SAS Visual Analytics, SAS Visual Statistics, SAS Data Mining, and SAS Machine Learning. When performing analytics on large datasets, SAS Viya uses a distributed in-memory processing engine called **CAS**.

5.3 | Cloud Analytics Services (CAS)

Cloud Analytics Services (CAS) is the in-memory analytics engine SAS Viya uses for both on-premise as well as cloud-service environments (e.g., AWS, Azure, GCP). CAS uses a combination of hardware and software where data management and analytics take place on either a single-machine or as a distributed server across multiple machines. In either single or distributed deployment, each machine (host, node, etc) will be assigned one of three roles: CAS Controller, CAS Backup Controller, CAS Worker.

Analogy
In a restaurant kitchen, there exists three primary chefs. They are the (1) executive chef, (2) sous chef, and (3) station chef(s). The executive chef's primary role is to manage the kitchen and its staff whilst doing very little cooking. The sous chef's primary role is to be the right-hand to the executive chef, ready to manage the kitchen, share, or take over the responsibility of the executive chef at a moments notice. The station chef(s) merely wait for instructions from the executive chef, then executes the job they are given.

This is the relationship of each CAS node with each other:

- The CAS Controller is the executive chef managing the kitchen and its staff, delegating work.
- The CAS Backup Controller is the sous chef ready to take over the responsibility of the executive chef.
- The CAS Worker(s) are the station chefs cooking what they are assigned to by the executive chef.

5.3.1 | Role 1: CAS Controller

Controller is the first role that can be assigned to a host for SAS Cloud Analytic Services. For both server architectures, single-machine and distributed, one machine must be designated as the Controller. The role of the Controller is to parse out work to each Worker host available. In other words, the Controller manages and controls the overall operation of the CAS environment. As the master node, the Controller is responsible for distributing workload among available CAS Workers, managing user sessions, and providing a secure environment for data retrieval and data storage.

In a single-machine environment, the CAS Controller and CAS Worker roles can be performed by different processes or threads within the same operating system instance. However, we are not limited to this deployment method as it is also possible to have the CAS Controller and CAS Worker(s) virtually separated (on the same hardware) to increase the scalability of the deployment. The configuration of your architecture depends on what you need out of CAS.

In a distributed environment, the CAS Controller is responsible for managing and controlling the CAS environment whilst the actual data processing and data analytics are performed by the CAS Worker(s).

5.3.2 | Role 2: CAS Backup Controller

Backup Controller is the second role that can be assigned to a host for SAS Cloud Analytic Services. Although optional, the CAS Backup Controller is highly recommended in a distributed server environment. The role of the CAS Backup Controller is to act as a standby or hot-backup for the primary CAS Controller in case of a failure. Its primary purpose is to ensure that the system can continue to function in the event of a failure of the primary controller. The Backup Controller is typically set to passively monitor the primary controller for any signs of failure, such as a loss of connectivity or failure to respond to heartbeat messages. It does not actively participate in task scheduling or job execution while the primary controller is running normally.

If the primary CAS Controller fails, the Backup Controller will take over as the primary controller and assume responsibility for managing the CAS worker nodes and scheduling tasks. In this scenario, the CAS worker nodes will send their status updates and job results to the Backup Controller instead of the failed primary controller.[3]

In some systems, the Backup Controller can also be given jobs to execute as a CAS worker node. This can help to improve the system's overall performance by increasing the number of available processing resources. In this scenario, the Backup Controller can perform both the role of a CAS Controller and a CAS worker node.[4]

[3] If the main CAS Controller fails, how does each CAS Worker respond to the Backup Controller with their completed jobs?
[4] Can the CAS Backup Controller be assigned work as well as passively monitor the main CAS Controller?

5.3.3 | Role 3: CAS Workers

Worker is the third role that can be assigned to a host for SAS Cloud Analytic Services. The CAS Worker is responsible for performing data processes and data analytics sent from the CAS Controller. For example, CAS Workers can perform data manipulations, transformations or computations on large/complex datasets. These computations are but not limited to: statistical analysis, machine learning models, text analysis, time series analysis, optimization, etc. Workers execute these computations using data stored on disk, in-memory, or in a distributed file system.

In a distributed environment, one host will be assigned as your controller and any additional hosts are considered workers (optional CAS Backup Controller). Workers increase the overall computing power of your distributed-server and provides a solution for a scalable (up/down), distributed, and fault-tolerant environment for data storage and data analysis because the worker manages the storage of data/metadata across multiple nodes. The amount of CAS Workers needed to create an optimized distributed environment is highly dependant on data size, computation type, and workload.

Using these three roles, we can create two types of CAS configurations: a single-machine environment using symmetric multiprocessing **(SMP)**, or distributed server environment using massively parallel processing **(MPP)**.

5.3.4 | Symmetric Multiprocessing (SMP)

Symmetric multiprocessing (SMP) is an environment where a CAS server consists of one controller that runs on a single machine. The functionality for a single-machine server is nearly identical to MPP, except that there is no cluster communication. In this architecture, the server acts as a controller. Before a client connects, the server listens on a port for connections. A server running in SMP mode consists of a controller only, and the server starts a session controller process only. It is the session controller process that operates on rows of data.

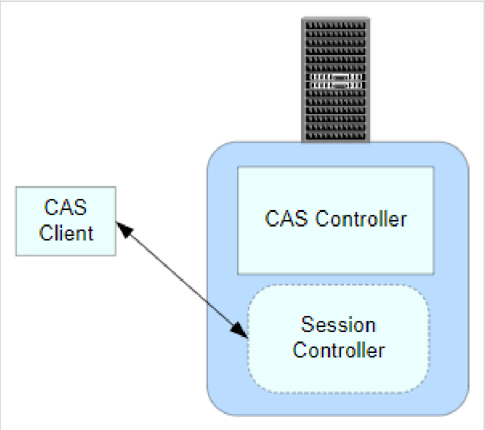

Figure 5.1: Single-machine CAS Server (STOLEN EXAMPLE)

5.3.5 | Massively Parallel Processing (MPP)

Massively Parallel Processing (MPP) is an environment where a distributed CAS server consists of one controller, one or more workers, and one backup controller (optional), each running on a separate machine. In a distributed server (MPP mode), a session process is created on each machine in the cluster. These processes are sometimes referred to as the session controller and session worker processes. Even though the sessions have their own operating system processes, the server processes must continue to run. When the server process terminates, the session processes also terminate.

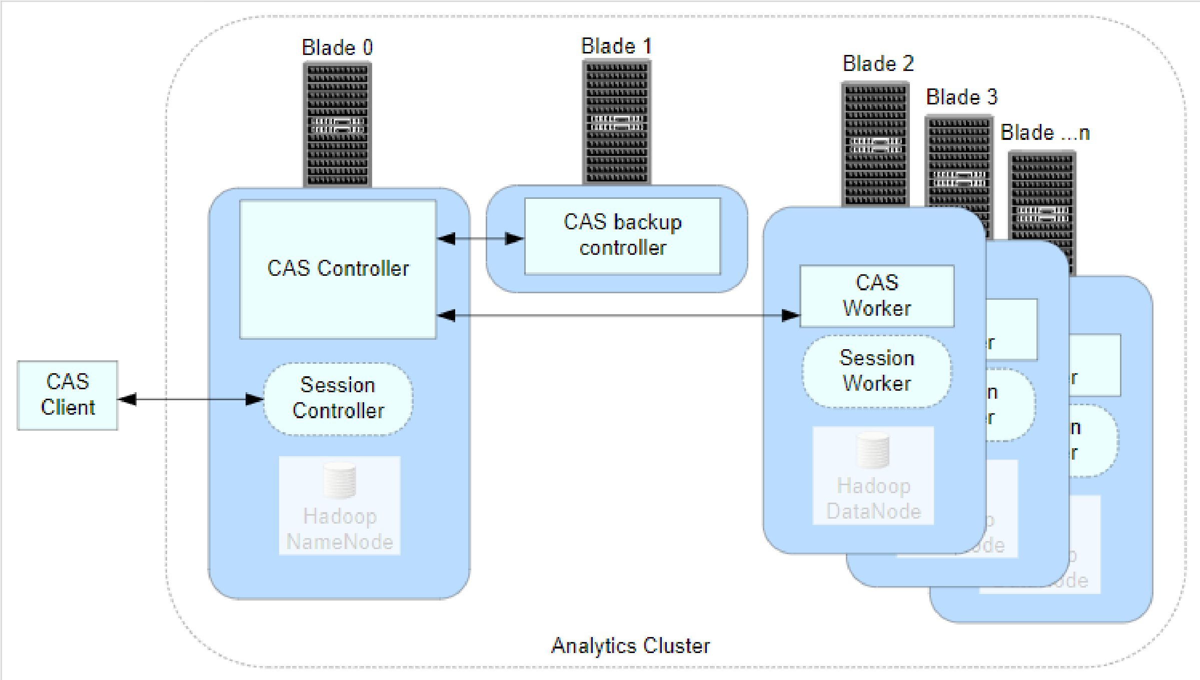

Figure 5.2: Distributed CAS Server (STOLEN EXAMPLE)

6 | Massively Learning Activities

- We are contracted by CNMI to create an infrastructure where we can perform data analytics on PHI. This infrastructure is hosted on-prem first, hybrid later.
- Tenants (e.g. APCD, CMNI, CMA, Criminal Justice) has the data ready.
- Data is submitted from tenants to ETL (data-pipeline) to be processed then sent to SAS (on-prem servers).
- Data analytics is performed on the data using advanced algorithms in SAS programming language.
- Project is time sensitive, deadline is requiring TASI to move onto the development stage with existing on-prem hardware as proof-of-concept ASAP.
- Initially architect the infrastructure using existing on-prem hardware to speed up deployment
- Once deployed, stable, and proof-of-concept ready, move onto the production stage by acquiring new hardware and migrating the previous (virtualized) SAS deployment to the new hardware using vMotion..
- Configure the security relationship between the software, hardware, and tenants (Active Directory, LDAP, Security Groups, etc.

The System Development Lifecycle (SDLC) is a project management model that defines different stages that are necessary to bring a project from conception to deployment and later maintenance. Massively Learning Activities will follow a similar variation to the SDLC project management model where each SDLC stage corresponds to a subsection in this chapter.

6.1 | Planning Stage

Massively Learning Activities (MLA) is divided into two phases, (1) the initial deployment of SAS on existing infrastructure and later (2) the migration of SAS onto scaled infrastructure.

In either deployment stage, SAS Viya will be deployed in a multi-tenant environment. A multi-tenant deployment of SAS Viya allows for a single deployment to serve multiple customers[5]. These customers can share some physical resources while remaining logically separated. A multi-tenant deployment allows for these distinct groups to share IT resources in a secure and cost-effect manner. Multi-tenancy deploys into a Kubernetes namespace. The deployment includes a provider tenant, shared mid-tier services, application-specific database schemas, shared applications, and a designated SAS administrator for the provider tenant. Administrators with elevated Kubernetes privileges onboard one or more tenants. After tenant on-boarding, Kubernetes administrators onboard one or more Cloud Analytic Services into each new tenant, then each CAS server is uniquely configured during the on-boarding process to meet the specific tenant requirements.

The final and completed deployment of SAS Viya will expect a total of 8 tenants:

- **Tenant 1**: Commonwealth of the Northern Mariana Islands (CNMI)
- **Tenant 2**: All-Payer Claims Database (APCD)
- **Tenant 3**: Centers for Medicare & Medicaid Services (CMA)
- **Tenant 4**: Med-Quest
- **Tenant 5**: UH Education 1
- **Tenant 6**: UH Education 2
- **Tenant 7**: UH Education 3
- **Tenant 8**: UH Education 4

MLA is a time sensitive project that requires deployment of SAS Viya in a multi-tenant environment as soon as possible. Therefore, an initial deployment of SAS Viya and SAS DMA will be conducted on existing on-premise infrastructure with only half the amount of tenants by Q4 2023.

[5] Customers are tenants (etc: CNMI, APCD, CMA, Med-Quest, UH Education) but each tenant has its own set of users and groups.

6.1.1 | Initial Deployment

The initial deployment of MLA will involve installing SAS on existing infrastructure[6]. The existing infrastructure is an available Dell PowerEdge FX2 Enclosure located in TASI's NOC. The PowerEdge FX2 Enclosure is a 2U hybrid rack-based computing platform that combines multiple blades[7] into a single enclosure to increase the efficiency of, and reduce the cost of, rack-based systems. This multi-blade enclosure has a fill me GB connection to a storage pool (describe me).

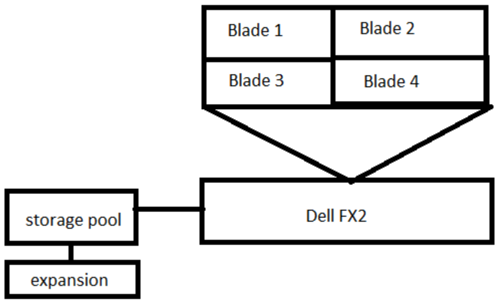

Figure 6.1: TASI On-Premise Environment (needs VISIO)

It is important to note that each blade in the FX2 chassis is already in use by other TASI projects. Therefore, the multi-tenant SAS architecture will be logically separated based on the available resources within each blade. Each blade is equipped with [core count] CPU, [memory count] RAM, and [size] storage.

This deployment will have CNMI, APCD, CMA, and Med-Quest as the initial four tenants and each tenant will have a different deployment configuration based on their requirements. As of March 3, 2023, CNMI and APDC will be configured in a 5-server environment [8] and every other tenant will be configured in a 3-server environment[9]. The other tenants that are yet to be added will be considered during the migration stage of MLA.

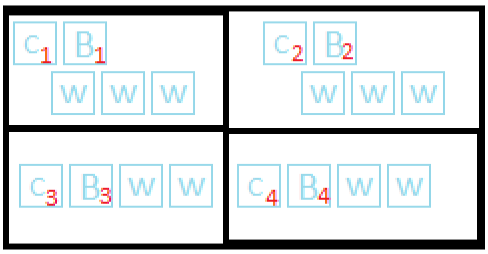

Figure 6.2: SAS Initial Deployment (needs VISIO)

6.1.2 | Migration Deployment

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[6] Infrastructure is used to describe existing hardware available to use on-premises at TASI/PHIDC.
[7] Blades are complete servers in a smaller form factor that have their own CPU(s), memory, storage, and networking components.
[8] 5 Server: (1) Primary CAS Controller, (2) Backup CAS Controller, (3) CAS Worker 1, (4) CAS Worker 2, (5) CAS Worker 3
[9] 3 Server: (1) Primary CAS Controller, (2) Backup CAS Controller, (3) CAS Worker 1

6.2 | Requirements of Analysis Stage (Sizing)

Refer to the sizing documents (2) and the current resources document comparison to see what we are missing.

6.3 | Design and Prototyping Stage

6.4 | Initial Development Stage

6.5 | Testing Stage

6.6 | Implementation and Integration Stage

6.7 | Migration Stage (SDLC II)

6.8 | Operations and Maintenance Stage

6.9 | End-Game Implementation

environmental scan for the future environment

A | Appendix A title

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