CS6006 Distributed, Cloud and IoT Systems

Coursework 1 Report

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# Introduction

A brilliant module to my final year studying BSc Computer Science. I found Virtual Machines (VMs) and Containers very interesting as it provides an efficient way to manage containerized applications. This has deepened my understanding of how cloud platforms like Microsoft Azure help in the professional world by empowering organizations/businesses to better control distributed resources efficiently.

This report evaluates the key topics and delves into what I have learnt so far throughout this semester.

# Overview and Significance

In today’s world, distributed systems, cloud computing, and IoT systems are very important technologies that are working the modern digital environments. These systems allow for scalability and efficiency across various industries which play a vital role for the growing demands for data processing, storage, and connectivity.

Distributed systems consist of multiple independent computers (or nodes) that basically work together to appear as a single unified system. These systems can then distribute computing tasks, resources, and data across different networks to then achieve greater performance, fault-tolerance, and scalability. A good example for this is Google’s distributed architecture, which allows its search engine to handle billions of searches daily. The significance of distributed systems can be shown in the ability to efficiently process large amounts of data, ensuring high availability, and deliver great user experiences by reducing crashes and other failures.

Cloud computing is related to distributed systems as it provides access to computing resources such as storage, servers, and software applications over the internet. This removes the need for organizations/businesses to invest in and maintain a physical infrastructure. Ultimately, this all results in huge savings and increased flexibility. Cloud services are normally divided into three main models which are ‘Infrastructure as a Service’ (known as IaaS), ‘Platform as a Service’ (known as PaaS), and ‘Software as a Service’ (known as SaaS). The platform Microsoft Azure have become vital for businesses, by offering scalable solutions for managing large data sets and deploying virtual machines efficiently. Cloud computing in this modern world has proved consistently that it is important by improving productivity, providing greater accessibility and optimizing cost management. This has all allowed organizations/businesses to adopt the cloud computing model and progress from the old ways of physical infrastructure.

The Internet of Things (IoT) is the invisible connection between the physical and digital worlds. It mainly is used for connecting devices to receive, send, and analyse real-time data. IoT systems generally consist of sensors, gateways, and cloud platforms that allow devices to communicate and function properly. For example, the new trend in connecting home appliances and systems to a smartphone is called ‘smart homes’ and it is very possible to use IoT sensors to monitor and control energy consumption (such as heat and electricity) which can greatly reduce energy bills. The real-time insights are all generated by the IoT systems and this can easily be done for all types of sensors and other components in smart homes. The platform Azure IoT Hub is what’s used to demonstrate the role of cloud services in managing/monitoring IoT devices, ensuring connectivity and data analysis.

In summary, distributed systems, cloud computing, and IoT systems are ever-growing technologies that are shaping the modern computing environments. Integrating this will drive scalability, innovation and efficiency which enables organizations/businesses to perform in today’s digital world while allowing for the new technological changes.

# Cloud Platforms and Azure

Cloud platforms are become increasingly essential in the modern IT field as it allows for access to resources like storage, networking, and computing power over the internet. By using cloud platforms, businesses/organisations can eliminate the need for a costly physical infrastructure, improve scalability, and adapt to technological advances quickly. The main benefits are cost efficiency, accessibility and remote work. Among all the major cloud providers, Microsoft Azure stands out as a popular choice for many businesses/organizations due to its unique features, integrated tools and reduced carbon efficiency (power from their data centres is going to be 100% renewable energy by 2025).

One of the main reasons Azure is so popular is its integration with Microsoft’s existing tools such as Windows Server, Office 365, and the Active Directory, which are already widely used in businesses/organisations. This makes transitioning to the cloud much easier and gets rid of compatibility issues. It can offer hybrid cloud capabilities, enabling organizations/businesses to combine physical infrastructure with the cloud using tools like Azure Arc and Azure Stack. This flexibility is valuable for businesses/organisations to keep their existing equipment but welcome the improvements.

Azure’s global reach is another advantage which its services are available over 60 regions worldwide. This ensures a very reliable performance for businesses operating internationally. Security is also a major strength of Azure, as it provides advanced security features like Azure Sentinel for threat detection and meets global standards such as the GDPR Laws. This makes it suitable for industries like healthcare and finance where security is necessary. Azure has a wide range of tools and services including AI, machine learning, and IoT tools, highlights its focus on innovation. For example, Azure Kubernetes Service (AKS) simplifies container management, while Azure IoT Hub enables real-time data processing for IoT devices. Also, many businesses and operations are looking for ways to reduce their environmental footprint and Azure can track this using Azure Monitor and Azure Advisor. They have an ongoing approach to reduce all carbon emissions which is set to be completely carbon-neutral by 2025.

The cost management is another factor that makes Azure popular. It has a pay-as-you-go pricing model that can allow businesses only pay for what they use, and tools like Azure Cost Management help organizations monitor and optimize their spending very effectively. This flexibility allows businesses/organisations to track exactly how much they are spending, where the money is going too and if there any ways they can cut back spending if possible.

To summarise, cloud platforms are very important for businesses and organisations to operate more efficiently, to scale quickly, and allow for innovation. Microsoft Azure stands out because of its strong hybrid cloud capabilities, its integration with Microsoft products and the built-in tools/services, global reach, environmental sustainability advanced security, and flexible pricing. All of this is what keeps Azure a strong competitor in the field.

# Distributed Systems Characteristics and Challenges

Distributed systems are independent components (normally found in different physical locations) that work together as a united system to share resources, manage tasks, and improve scalability. These systems are used in modern computing as cloud platforms, web applications, and global communication networks. The main architectures in distributed systems are client-server, peer-to-peer (P2P), multi-tier, and microservices.

The client-server architecture is a centralized model where clients request services and then servers respond to these requests. This is used in web applications, email systems, and database access. The architecture is scalable where you can add more servers to handle larger loads of processes/data. The main advantage is centralized contro**l**, which makes resource management, maintenance, and security easier to handle. For example, all processes such as authentication and data storage, can be entirely controlled at the server level. However, this architecture has disadvantages such as the single point of failure where if the server goes down, the entire system becomes unusable.

The peer-to-peer (P2P) architecture has decentralized control, where each node functions as both a client and a server. This model is very scalable with little faults, as there is no single point of failure. P2P systems are seen in file-sharing networks such as BitTorrent, where files are distributed across nodes which is not dependable on a single device. However, P2P systems can have problems with security and performance as nodes might not always be reliable or consistent with each other. Managing these systems can also be complicated as there is no single management point.

The multi-tier architecture separates the system into layers which includes a presentation layer (the user interface), application layer (the business logic), and data access layer (the database management). This separation allows each layer to be developed, maintained, and scaled independently. Multi-tier systems are normally used in applications and web systems since they can be handled easily. However, it can suffer from performance overhead because of the increased communication between layers. Also, the architecture can be complicated for engineers when troubleshooting problems in the system.

The microservices architecture divides an application into loose independent services that communicate through APIs. Each service is responsible for a specific function such as user authentication or payment processing. In this architecture individual services can be scaled or updated without disrupting the entire system. For example, Netflix uses microservices to handle functions like the recommendation engines, content delivery, and user management. However, microservices struggles with network overhead and data consistency as maintaining synchronization across the services needs advanced coordination.

The distributed system architectures have ways to handle the challenges of scalability, fault tolerance, and resource sharing. While each architecture has its pros and cons, their implementation in real-world systems shows their importance in managing complex, large-scale operations efficiently.

# Cloud Computing Models and Azure Services

Cloud computing is becoming increasingly relevant in modern IT as it offers businesses the ability to access and manage resources over the internet efficiently. It is built on three main service models which are Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). Each model serves different needs and has various levels of control and flexibility.

IaaS provides the basic infrastructure such as virtual machines, storage, and networking, without requiring physical hardware. Businesses use IaaS to manage their own operating systems and applications. Two common examples are Microsoft Azure Virtual Machines and Amazon EC2. IaaS is highly flexible since it allows organizations to customize their environments as they need but it requires technical knowledge to set up and maintain.

PaaS offers a development platform where developers can build, test, and deploy applications without managing the underlying infrastructure. Services like Azure App Services provide pre-configured environments and tools that make the development process simple. This allows developers to focus on coding rather than worrying about servers or hardware. However, PaaS offers less control compared to IaaS since the platform itself is managed by the cloud provider.

Lastly, SaaS delivers software applications to end-users that are already ready to use. Applications like Microsoft Office 365 and Google Workspace are popular examples of SaaS solutions. They require no installation or maintenance as everything is managed by the provider. SaaS is ideal for non-technical users but has the least flexibility since users rely on the provider for updates.

Cloud platforms also support three deployment models which are Public, Private, and Hybrid clouds. The public cloud is the most common, where services are shared across multiple organizations and managed by providers like Microsoft Azure. It is cost-effective and scalable which makes it ideal for businesses that need flexibility without the issues of hardware maintenance. A private cloud is dedicated to a single organization, offering greater control and security but usually at a higher cost. The hybrid cloud is a mix of public and private clouds, where organizations/businesses keep sensitive data on private infrastructure while using public resources for less important operations. This provides flexibility and security, making it a popular choice.

Microsoft Azure is a good cloud platform due to its wide range of services, which include being able to compute, storage, and networking. For compute, Azure provides Virtual Machines and Azure Kubernetes Service (AKS) which support scalable and containerized workloads. Azure’s storage options such as Blob Storage and Azure Files ensure secure and reliable data management. In networking, Azure offers Virtual Networks (VNet) for creating private networks and tools like Azure Load Balancer to distribute traffic and maintain performance.

Azure has a pay-as-you-go pricing model that makes it accessible for businesses of all sizes, as users only pay for what they use. The tool Azure Cost Management allows them to monitor and optimize their spending.

# IoT Systems and Azure IoT Hub

The Internet of Things (IoT) refers to a system of connected devices that collect, exchange, and process data using the internet. IoT systems are made up of three main components that are devices, gateways and platforms which all work together to enable communication and data processing.

The first key component is IoT devices are often equipped with sensors to collect and transmit data. These devices can measure things such as temperature, humidity, motion, or pressure. For example, sensors in a smart home monitor energy consumption, while industrial IoT devices track machine temperatures. These devices can be lightweight and operate with limited processing resources making them efficient.

IoT gateways is what’s between devices and cloud platforms. Gateways combine data from multiple IoT devices to be processed and ensure secure communication. They are important for devices with limited network capabilities as gateways can connect devices to the cloud using protocols like MQTT (Message Queuing Telemetry Transport), HTTP, or AMQP (Advanced Message Queuing Protocol).

The third component is the IoT platform which serves as the central hub for managing devices, analysing data, and integrating with cloud services. Platforms provide tools for device monitoring, communication, and data storage. They can also allow users to get metrics.

IoT systems rely on a structured architecture that includes device-to-cloud and cloud-to-device communication. Devices send telemetry data (sensor readings) to the cloud for storage and analysis while cloud platforms can send commands back to devices to adjust their behaviour. For example, a thermostat might send temperature data to the cloud where an automated rule changes the devices settings if needs too.

Azure IoT Hub is a cloud-managed service that plays an important role in managing and monitoring IoT devices. Azure IoT Hub supports secure bi-directional communication between devices and the cloud. It ensures that telemetry data can flow from devices to the cloud while also allowing cloud-to-device commands to be sent securely. One of Azure IoT Hub's main features is per-device authentication which ensures that every device has a unique identity and secure connection. This efficiently minimizes security risks.

The service also supports device twins which are digital representations of physical IoT devices. Device twins store metadata, configuration settings and current state information to allow administrators to monitor device health and manage updates remotely. Additionally, Azure IoT Hub includes built-in device management features, allowing people to provision, monitor, and update devices at scale.

In real-world scenarios, Azure IoT Hub is used for large-scale IoT deployments such as smart cities and industrial automation. For example, a council/borough managing traffic signals can use IoT sensors to collect real-time data which is then processed in the cloud. Azure IoT Hub allows the secure transfer of the telemetry data, monitors the health of devices and scales to support thousands of traffic sensors. This level of reliability is crucial for managing complex IoT solutions effectively.

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