

Assignment Task 1

by Rhys Treharne

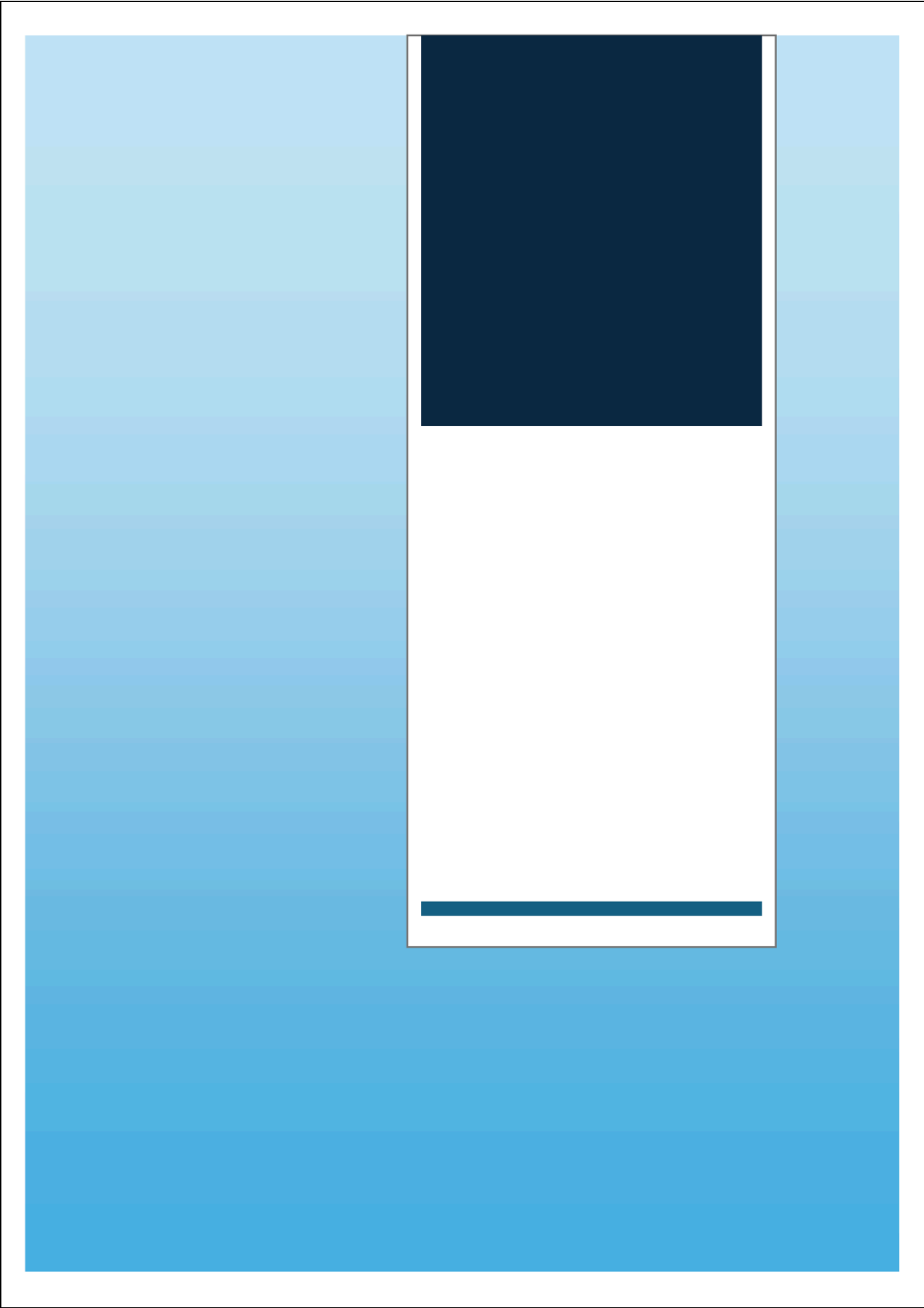
Submission date: 13-May-2025 02:40PM (UTC+0100)

Submission ID: 259079187

File name: 36124_Rhys_Treharne_Assignment_Task_1_664976_859906313.docx (289.46K)

Word count: 3397

Character count: 20462



Abstract

This report examines many key aspects of computer networking such as TCP's guaranteed data delivery methods, impact that MTU size has on data transfers, key differences between synchronous and asynchronous network protocols and the importance of interoperability within different network applications. Understanding these concepts is crucial for effective data transfers and network management.

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Introduction

In the world of computer networking, understanding concepts of data transmission protocols can have an impact on the transfer of data. When developers create applications, they need to ensure that the data transmission aspects of the application are efficient. This report dives into several important concepts such as TCP (Transmission Control Protocol) and how it guarantees data delivery such as the three-way handshake. It's also key to know what the challenges are that TCP protocol faces such as the Two General's problem. Investigating how the significance of the MTU (Maximum Transmission Unit) size can influence the transfer of data, in consideration of other concepts such as PDU (Protocol Data Units) and IP fragmentation. Understanding the difference between synchronous and asynchronous network protocols and reviewing their applications and I/O dispatch models. Finally, reviewing how interpretability in network applications can seamlessly retrieve data across different systems.

TCP and Reliable Data Delivery

TCP stands for transmission control protocol, its purpose is to ensure that the transformation of data between devices on a network is reliable. TCP is a part of the transfer layer on the OSI (Open Systems Interconnection) model [1]. TCP and IP (Internet Protocol) work together for data packets to be delivered across different devices on the network. Below is a diagram of the OSI model:

The OSI Reference Model

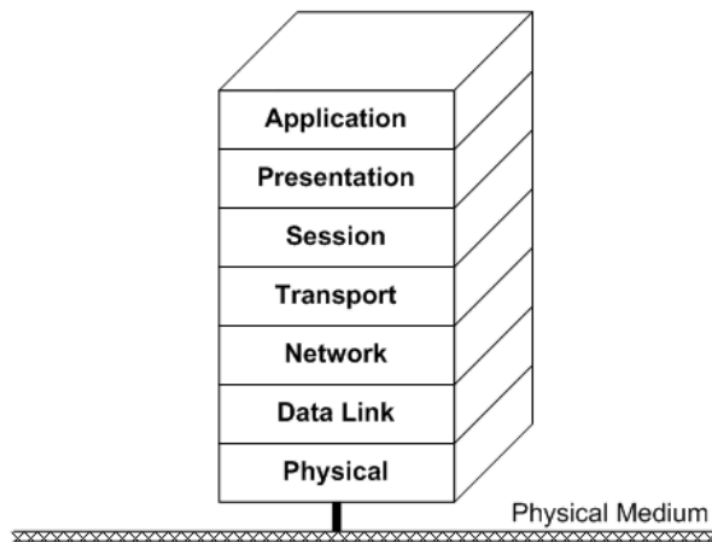


Figure 1: OSI Model [2]

For devices to communicate through a reliable connection they use a principle called "Three Way Handshake" which allows both devices to synchronise and acknowledge each other [3]. The synchronise and acknowledge process is completed in an orderly manner:

1. Synchronise:

At this stage, the client computer (initialising computer) will send a synchronising sequence number packet to the computer that receives the packet (also known as the server). The packets that get sent are set to arbitrary numbers [4]. An arbitrary number is considered as any number without any criteria [5].

2. Synchronise -> Acknowledge

At this point, the receiving computer has open ports which can accept connections coming from the client computer. Once a connection has been accepted, the receiving computer will send a synchronise-Acknowledgment packet back to the client computer. Both packets will include the receiving computer's synchronise number (which is arbitrary) and the Acknowledgement number which is the initialising computers "Plus One" [4].

3. Acknowledge

Finally, the client computer (or known as the initialising computer) will send an acknowledgement sequence number to the receiving port. This is a form of confirmation to let the receiving computer know that the packets sent have been acknowledged. Once these steps have been completed, the data transmission can then begin [4].

Below is a diagram showing how the three-way handshake principle works:

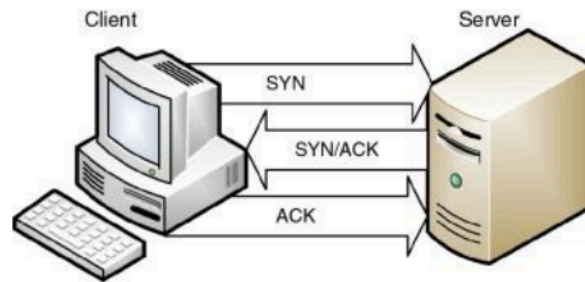


Figure 2: Three Way Handshake Principle [3]

The three-way handshake principle is used in applications/services that we use on a regular basis. Those applications/services are listed below:

Application/Service	Description
Web Browsing	Once a user visits a website, the three-way handshake principle is used to load the web page
File Transfers	Some processes such as FTP (File Transfer Protocol) and SCP (Secure Copy Protocol) use the three-way handshake to establish a secure connection to begin file transfers
Email Exchange	Processes such as SMTP (Simple Mail Transfer Protocol), POP3 (Post Office Protocol 3) and IMAP (Internet Message Access Protocol) use the three-way handshake to create sessions to allow the sending and receiving of emails
VPN Connections	VPN Applications use the three-way handshake to ensure secure tunnels between clients and servers. This ensures the communication is encrypted
Cloud Services	Cloud based applications use the three-way handshake to establish a secure session between users and the cloud servers.

Figure 3: Three-Way Handshake Examples [6]

However, TCP doesn't always provide a secure method of successfully delivering data across computers. There is a dilemma called "The Two Generals Problem". The two

general's problem is problem that occurs when trying to communicate over an unreliable communication channel. Below is a description of the problem.

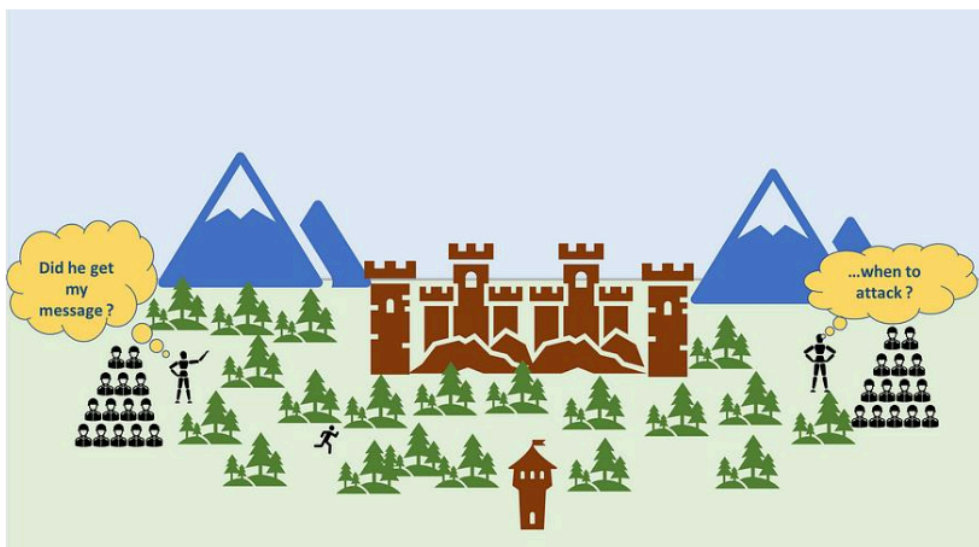


Figure 4: Two General's Problem Image [7]

The image above demonstrates the two generals' problem in a fictional method. There are two generals in the army, both General's plan on raiding the enemy's castle to gain control. Both General's have constructed a strategic plan to split the army in half and position one half on the west side of the enemy castle and the other half east of the castle. Due to the size of the enemy castle, both General's must attack the castle the same time and from each side (west and east). Due to the attack, the only way both General's can communicate is by sending messengers to deliver messages through enemy lines. The issue with this method is that the General's will not be certain the message was delivered successfully. For example, General One wants to send a messenger over to General Two to confirm the attack, however due to the messenger having to travel through enemy territory, General A will not be sure whether the message was delivered successfully. Due to General Two not knowing about the message, General Two may continue with the attack and be defeated. This problem will keep occurring because no matter how many messengers each General sends, the issue will keep reoccurring [8].

The problem can be applied to two computers. For example, computer one and computer two wants to send/receive messages, however there isn't a way to guarantee that the messages have been received and acknowledged. When this happens, data will then get captured (or lost) and won't reach the required destination. Unfortunately, the Two General's Problem doesn't have a solution [8].

Overall, TCP is considered to be a reliable method of transmitting data. Using principles such as the three-way handshake proves that it is reliable. There are other data transmission protocols available such as UDP. Below are brief examples of the differences between TCP and UDP.

TCP	UDP
TCP is a connection-based protocol, which suggests data will not be sent unless there is a reliable connection.	UDP is a connectionless protocol, which suggests that data will be sent without the need of a connection.
TCP is known to be slower when transmitting data, however, is much more reliable.	UDP is known to be much faster at sending data, however, this makes the protocol less reliable.

Figure 5: TCP vs UDP [9]

The impact of MTU on Data Transfer

MTU stands for 'Maximum Transmission Unit'. MTU is a measurement of bytes within a large data packet that a device can accept through an internet. MTU is a feature that programmers and developers must be familiar with because the smaller the MTU the quicker something can move. The size of the MTU can vary depending on the physical properties of the device. The devices can range from smaller devices to larger devices. For example, a larger device could be a server, and a smaller device could be a switch [10]. Usually in most ethernet networks the standard MTU is 1500 bytes. Once the device's MTU is recognised, the number of bytes that can be delivered will be also recognised suggesting the data can be sent without fragmentation. Fragmentation is applied when large amounts of data is sent across devices. Fragmentation will break the packet down into pieces (fragments), once the packets have arrived at the destination, they will be reassembled [10].

PDU stands for protocol data unit which is a basic unit of exchange between entities that communicate with a specific networking protocol [11]. The PDU plays a role in many different stages of the OSI model and is labelled differently. The table below shows each stage:

PDU Name	OSI Model Layer
Data	Application Layer
Data	Presentation Layer
Data	Session Layer
Segments	Transport Layer
Packets	Network Layer
Frames	Data Link Layer
Bits	Physical Layer

Figure 6: PDU/OSI Layer Table [12]

The PDU holds not only data but also protocol specific control information. Each layer within the OSI model will add or delete protocol information depending on which way the PDU is moving (either up or down through the layers). This is why the PDU name/reference will change depending on which layer the PDU is at [12].

Synchronous vs Asynchronous Communication in Networking

Synchronous communication is a process where multiple parties are continuously listening and responding with each other in real time. An example of synchronous communication would be an online chat system that are used by a retailing customer support service provider. In this case, a member of the support team would be available to help the customer with any queries they may have. For this scenario to

work, the sender and receiver will need to establish a communication session to communicate. Once the communication session has been established, this will allow a two-way conversation to begin. Inside the two-way conversation, one party will send information while the other party will wait to receive the information and respond [13]. The type of applications that would use synchronous are [14]:

- Transfer of large text files
- Chatrooms
- Video Conferencing
- Telephone conversations

Asynchronous communication tends to have a delay when the sender sends a message and when the recipient receives the message. The timing of the delay can vary depending on the communication medium. Asynchronous communication is a process where both parties do not work together in real time [13]. An example of asynchronous communication could be two parties exchanging emails. One party will send an email to the other party, however the recipient does not need to reply instantly. The recipient could reply to the other party in a few days etc. The type of applications that would use asynchronous are [14]:

- Emails
- Forums
- Radios

Below are two tables showing the advantages and disadvantages of synchronous and asynchronous communication:

Advantages	Disadvantages
Large volume of data can be transmitted	The clocks of the sender and receiver must both operate on the same frequency simultaneously
All devices which are connected can communicate in real time	The accuracy will depend on the receiver's capacity to accurately and precisely count the received bits
Data can be sent continuously without any pauses in between bytes	
Errors such as timings are reduced	

Figure 7: Advantages & Disadvantages of Synchronous Communication [14]

Advantages	Disadvantages
No need to synchronise the transmitter and receiver	Synchronicity can be difficult to determine, which can lead to timing errors
Highly flexible method of transmitting data	Overall slower transmission rates
Implementation is simple	Additional data is required in the form of start and stop bits, increasing the overall size of the transmitted data
Signals can be sent from sources with different bit rates	False recognition of bits can occur due to noise on the channel
Data transmission can resume as soon as data byte transmission is available	

Figure 8: Advantages and Disadvantages of Asynchronous Transmission [14]

Synchronous and Asynchronous are very important especially with operating systems. I/O is a process which handles the input and output operating systems. Both synchronous and asynchronous have separate operations when it comes to the IO/Model.

Synchronous operations are performed in a sequential manner which suggests that operations follow a specific order. In this case, if process initiates an I/O operation, the process must wait for an operation to be completed before moving onto the next operation. The I/O process for synchronous is known as 'Blocking I/O' which suggests that CPU will remain idle during the I/O operation. The executing thread is paused until the I/O operation is complete. A common case for blocking would be desktop applications [15]. An example would be if a user was to open Microsoft Word on from the desktop, the user would double click the app icon and wait for the application to open.

Unlike synchronous, asynchronous can initiate more than one operation at once. Asynchronous I/O enables higher CPU utilisation because it can switch to other processes instead of being idle while waiting for other processes to complete. This process is labelled as 'Non-Blocking I/O'. Non-blocking tends to be used in high performing applications such as web servers or real time systems where being responsive is crucial [15].

Interoperability in Networked Applications

Interoperability is a process which defines how well systems, devices or applications work together. Examples of interoperability would be connecting to data bases, data transmission and cross organisational collaboration. The goal of interoperability is to help organisations achieve higher efficiency of information [16]. There are three types of interoperability:

- Syntactic: Syntactic interoperability are systems that can communicate successfully through compatible formats and protocols. Formatting standards such as XML and SQL are used when communicating data [16]. The purpose of syntactic interoperability is to ensure that any data that is exchanged between systems is formatted in a way that both systems can understand. If

both systems are communicating using the same format this can reduce the chances of misinterpretation and ensuring that data is exchanged smoothly.

- **Semantic:** Semantic interoperability is an ability for systems to exchange and interpret information automatically. For semantic interoperability to be achieved, the structuring and coding data need to be the same standards across all systems [16]. Semantic interoperability ensures that any data shared between different systems is readable and to provide usable data.
- **Cross-domain or cross-organisation:** Cross-domain and cross-organisation is to ensure that different systems can still exchange data despite their differences. Instead of looking at the technical side of the systems for example the code etc, cross domain/cross organisation will look at the systems being standardised through policies or procedures [16].

Below is a table which shows how interoperability is used in different industries:

Industry	Explanation
Healthcare	Due to healthcare industries relying on multiple sources of information they must implement interoperable systems to exchange the data across all these systems. Healthcare industries can range from laboratories, clinics, pharmacies, hospitals etc. Each industry may use different systems hence why interoperability is necessary to ensure the exchange of data between these industries is viable [16].
Telecommunications	For telecommunication industries to be operational the signal availability needs to be consistent for the likes of mobile phones etc to work. However, for telecommunications to work across different manufacturers or models, interoperability needs to be implemented in two-way radios. The ITU-T Standards (The International Telecommunication Union-Telecommunication Standardisation

	Sector) will set international standards to achieve interoperability. This is to ensure that all telecommunication systems can seamlessly work together effectively [16].
Software Development	Interoperability in software development ensures that different programs can exchange data, share files and use the same protocols. A language that is recognised as a highly interoperability is Java due it being able to run and execute on any program with a Java Virtual Machine [16].
Data Management	By having systems with interoperability, this allows organisations to accurately collect information from many sources by only using one query. This makes gathering information more effective by collecting large amounts of data quicker [16]. Interoperability increases organisations speed and productivity by only using one query instead of multiple queries.
Government	Exchanging information from different governments worldwide can be difficult due to language barriers. However, by having interoperable systems, this can make exchanging information easier for governments worldwide. Interoperable systems closes the language barrier gap [16].

Figure 9: Different industries that utilise interoperable systems

Interpretability does have its advantages and disadvantages. A blog was written by the KMS Staff regarding the benefits and challenges of EHR (Electronic Health Records) interoperability in healthcare:

Benefits:

- **Higher Efficiency:** KMS Staff stated that interpretability allowed clinics to access real-time patient data efficiently. This saved clinics a significant amount of time when trying to access patient records, this increased productivity within clinics worldwide which leads in helping to reduce medical errors [17].

- Improved Patient Care and Experience: Overall, patient care and experience has been improved due to the reduced medical errors. This suggests that patients have been seen and treated quicker due to accessing patient records quicker [17].
- Higher Revenue: Through employing efficient population health management services, this allows hospitals to be better equipped. This can reduce hospital readmissions, improve patient management and lower costs [17].

Challenges:

- Patient Data Security: Holding patient data secure can be challenging in EHR Systems. Data providers must comply with standards such as HIPAA Security and other standards. When sharing the data, encryption and decryption methods are required to ensure there's no unauthorised access to the data during the transmission of data [17].
- Costs: For healthcare industries to implement interpretability systems whether that's web-based or server-based the upfront costs and yearly costs can range from \$15,000 to \$70,000 per provider. These costs create a digital divide between large hospital systems who may not be struggling financially etc, and small hospitals that are struggling financially [17].

Conclusion

In conclusion, the TCP (Transmission Control Protocol) clearly plays an important role in reliable data transmission, despite challenges such as the Two Generals Problem. The report defines that the MTU (Maximum Transmission Unit) size does have a significant impact on the efficiency of transferring data. This is in consideration of the PDU (Protocol Data Units) and IP Fragmentation being essential when optimising network performances. Understanding the differences between synchronous and asynchronous network protocol is key when choosing suitable applications, also with I/O dispatch models. Lastly, understanding how interpretability in different systems can help gain quick and reliable data from multiple systems. Each concept covered in this report demonstrates the importance of effective network management. By understanding these concepts, it can make developers think more effectively when developing applications.

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Assignment Task 1

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

66/100

A fairly good report though use of sources needs a little work. You have used a very good number of sources, though a lot of these are non-authoritative web resources.

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