‘Analysis of the Quality of Service (QoS) and Quality of Experience (QoE) of the Transmission of Ultrasound Videos over 5G Networks.’

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Analysis of the Quality of Service (QoS) and Quality of Experience (QoE) of the Transmission of Ultrasound Videos over 5G Networks.

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the conditions of the award of the degree MSc Cyber Security.

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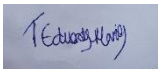
I hereby declare that this dissertation is all my own work, except as indicated in the text:

Signature: 

Date: 12/09/2020

ABSTRACT

It is clear to see that recently 5G technology has gained a lot of popularity in mainstream culture, with the ever-increasing amount of devices connected to the internet, a new framework must be developed to handle this increased strain which is being put on the current cellular network infrastructure. The application of such technologies in healthcare has also become more prevalent and several research papers have been written in this domain. There has been a lot of work done on 4G networks and the (QoS) and (QoE) when transmitting data, however, it is not clear on how 5G networks would respond when transmitting large multimedia video files such as ultrasound videos and x-rays. [1]

Currently, there is a gap in the research area, and a more thorough investigation into the Quality of Service (QoS) and Quality of Experience (QoE) as well as security issues involved with the transmission of these large files over 5G networks is required. Such a dissertation aims to identify key pieces of literature and studies conducted around the topic area, analysis of these findings will then need to be conducted and the results, findings, and the various network simulation tools used need to be evaluated to draw novel conclusions.

The purpose of this research project is to conduct a thorough review of the application area to gather information and study the technologies involved with 5G video transmission, The tools involved with this type of transmission will be identified and tested and an overview of the simulation results for transmitting such files will be studied before considering the possible security risks involved which this type of transmission and possible solutions to these security issues will be presented. A complete view of the research area will be presented, and novel conclusions will be drawn from the research which will hopefully spur further research and development.

Keywords – 5G; 4G; Quality of Service (QoS); Quality of Experience (QoE).

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I would like to thank Dr Ikram Ur Rehman who has been there to support me along the way during the completion of this MSc Dissertation.

I would also like to thank the individuals who are donating their time to investigating such important topics concerning novel technologies within the healthcare industry, without these individuals, the technologies we know today that we take for granted would not be here if it weren't for these great minds.

CONTENTS

CHAPTER 1

[1.1] INTRODUCTION

5G is the fifth generation of cellular technology, it is being developed to increase speed, latency, and improve the flexibility of wireless services [2]. 4G is a collection of fourth-generation cellular technologies. 4G succeeds 3G and is otherwise referred to as 'International Mobile Telecommunications (IMT-Advanced)'. This technology first became available in early 2005 in South Korea and was branded under the name of 'WiMAX' however, the most common widely used technology of 2020 is 4G although 5G services have been made available in some areas. [3].

The acceleration of this 5G technology has uncovered many new concepts and ideas within the field of healthcare and the application of 5G in Healthcare. As technologies progress, the demand for secure, fast and reliable data transfer is needed and this notion has caused a surge in the amount of individuals and organizations who are now developing such technologies which could solve the current issues associated with the 4G cellular architecture [4].

One application which has emerged over recent years is the process of Medical Video Streaming of files such as ultrasound videos [5]. Such technologies have become more widely used and there are many benefits for health professionals. The streaming process allows for medical professionals to be at a different location to that of the patient, this can allow for diagnosis and treatment however, the limitations of the current cellular architecture are threatening the security, QoS and QoE when transmitting medical videos over 4G networks.

A possible solution to the limitations of 4G is 5G which will bring improved security, QoS, QoE, increased amount of base stations and high data transfer speeds when compared to that of 4G [6]. The current 4G infrastructure has reached its theoretical data rate limit of around 1GBps whereas 5G technology has a theoretical peak speed of around 20GBps which is more suitable for the transmission of large files.

[1.2] PROBLEM STATEMENT

The following list details the problems identified when transmitting Ultrasound Videos over 5G Networks.

- Both the sending and receiving entities must trust each other and be able to verify this and the whole process which should be safe and secure, and measures put in place to counteract various attacks.
- The privacy of patient data must be considered as this type of application requires personal data to be able to work.
- The quality of the service of the transmission needs to be reliable and accurate.
- Security measures need to be put in place to stop data being intercepted during transmission.
- The quality of the experience of the system must be adequate.

[1.3] PROJECT MOTIVATION

The main motivation behind such a dissertation project is based upon the notion that we all rely strongly on the healthcare system. We often take the complex technologies involved for granted such as Ultrasound scanning machines and X-Ray technology. These technologies are crucial in the treatment and diagnosis of patients with health issues and without such technologies, many patients would lose their lives.

Fifth-generation cellular technology has the potential to improve and develop current methods of transmitting high-quality large medical files.

One believes that there is a gap in the field where more research is needed. This dissertation aims to fill the gaps in the field by providing a full outline of current

and future possibilities and security issues associated with the transmission of large ultrasound files of 5G networks.

[1.4] PROJECT AIMS

The aim of this MSc Dissertation Project is to provide a contribution to the future development and research of 5G technology specifically when streaming large ultrasound video files over 5G networks. Many characteristics such as QoS and QoE as well as potential cybersecurity risks will be thoroughly discussed, and existing models will be extensively reviewed.

[1.5] PROJECT OBJECTIVES

The project can be broken down into three main objectives/research questions:

- Provide an analysis of the Quality of Services (QoS) when transmitting large ultrasound video files over 5G networks.
- Provide an analysis of the Quality of Experience (QoE) when transmitting large ultrasound files over 5G networks.
- Conduct a thorough evaluation of the security risks involved with transmitting such data and discuss possible cyber-attacks and preventative measures to deal with these attacks.
- Overall, explain why adopting such technologies would be beneficial and propose possible future research in the area

[1.6] RELATED WORK

There has been some related work carried out in the topic area however, nothing specifically involving the transmission of ultrasound video files over 5G networks and also, these papers fail to address the many security risks and attacks which could occur when dealing with such data transmission. This research project aims to provide a complete simulation of the network and aims to provide an analysis and reflection of all relevant related work in this area.

A paper written by Dr Ikram Ur Rehman et al, 2014 addresses the *'Performance analysis of medical video streaming over 4G and beyond small cells for indoor and moving vehicle (ambulance) scenarios'* [7] is important to consider as the paper discusses many concepts which are relevant to the transmission of medical video's and also reviews the conditions for transmission in moving scenarios.

A more recent paper by Rehman written in 2018 titled *'Small cell-based ambulance scenario for medical video streaming: a 5G-health use case'* [8]. Which provides a more up-to-date analysis of current technologies and possible 5G use cases is also important to consider when attempting such as research project.

Since 2018, there has been rapid development in 5G and its application in healthcare, one believes that a more recent, thorough analysis of current frameworks and technologies need to be conducted to develop novel ideas and hopefully provide answers to researchers questions and spur future research in the field.

[1.7] PROJECT SCHEDULE

The Dissertation project will begin on 01/06/20 and will continue until the 18/08/20.

A complete project schedule has been implemented below which has been designed to ensure the success of the project in the given time scale.

Tasks which need to be completed have been broken down into different sections from Week 01 to Week 11.

Each week, there are various tasks which need to be completed in a certain time frame and all tasks must be dealt with systematically.

Week	Task Name	Duration	Start	ETA
0	Background Reading on 5G & Data Transmission.	1 day.	01.06.20	01.06.20
1	Research Literature for Literature Review	2 days.	02.06.20	04.06.20
	Read through selected Literature.	2 days.	04.06.20	06.06.20
	Analyse Literature Review Content.	2 days.	06.06.20	08.06.20
	Present findings on this piece of Literature.	1 day	08.06.20	09.06.20
2	Research further Literature for Literature Review	2 days.	09.06.20	11.06.20
	Read through selected Literature.	2 days.	11.06.20	13.06.20
	Analyse Literature Review Content.	2 days	13.06.20	15.06.20
	Present findings on this piece of Literature.	1 day.	15.06.20	16.06.20
3	Research Literature for Literature Review	2 days.	16.06.20	18.06.20
	Read through selected Literature.	2 days.	18.06.20	20.06.20
	Analyse Literature Review Content.	2 days.	20.06.20	22.06.20
	Analyse Literature Review Content.	1 day.	22.06.20	23.06.20
4	Analyse state-of-the-art techniques from Literature.	4 days.	23.06.20	27.06.20
	Present findings in document.	3 days.	27.06.20	30.06.20
5	Identify Simulation Technology and Alternatives.	4 days.	30.06.20	04.07.20
	Provide analysis of technologies	2 days.	04.07.20	06.07.20
	Present findings in document.	1 days.	06.07.20	07.07.20
6	Select simulation technology	4 days.	07.07.20	11.07.20
	Run test simulations with data.	3 days.	11.07.20	14.07.20
7	Run simulation with final data	3 days.	14.07.20	17.07.20
	Analyse findings.	3 days.	17.07.20	20.07.20
	Present findings in document.	1 days.	20.07.20	21.07.20
8	Organize findings & Results	3 days.	21.07.20	24.07.20
	Collate results & findings into single document.	3 days.	24.07.20	27.07.20
	Verify Results.	1 day.	27.07.20	28.07.20
9	Create Report Template	4 days.	28.07.20	01.08.20
	Collate all material.	3 days.	01.08.20	04.08.20
10	Write up first draft	2 days.	04.08.20	06.08.20
	Write up second draft.	2 days.	06.08.20	08.08.20
	Receive feedback from supervisor.	2 days.	08.08.20	10.08.20
11	Update document reflecting the feedback.	1 day.	10.08.20	11.08.20
	Submit Dissertation	1 day.	11.08.20	12.08.20

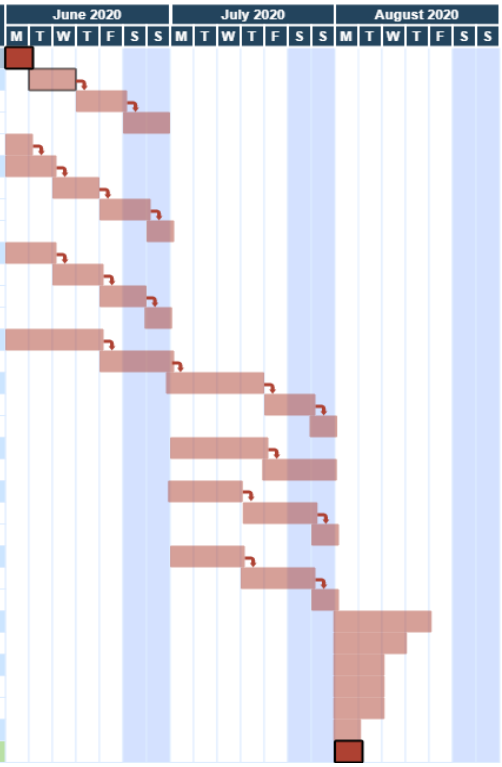

Table 1: *Project Schedule Dual Table.*

The diagram is comprised of two tables combined into one.

Left table: Shows the project timeline which displays the week number, name of the task, duration of the task, date in which the task should be started and finally the estimated time amount given to each task. Different shades of blue are used to highlight when a new week is beginning.

Right table: On the right-hand side of the project timeline, there is a Gant chart which has been created which highlights the estimated duration of the project. The Gant chart lists the months of June, July, and August with the respective days of the week listed and the size of each bar indicates the amount of time each task should take to complete.

The estimated duration of the tasks listed in the table is expected to fluctuate slightly over the duration of the project.

CHAPTER 2

[2.1] LITERATURE REVIEW

[2.1.1] 5G Simulation Environments.

A crucial paper to consider is written by S. Martiradonna et al (2020) and introduces *the '5G-air-simulator: an open-source tool modelling the 5G air interface'*. The simulator is a tool which can be used for modelling various elements of 5G interfaces from a system-level perspective [10]. An overview of the simulation technology is given, and explanation of the many features and functions are provided in the paper. Various important features such as calibrated links to system models for physical and data link layers and enhanced random-access procedures are included which means that the simulator is flexible. The aim of such a tool is to *'design and evaluate the performance of reference 5G-enabled use cases'* [9] hence, such a tool can be used to provide a model to develop 5G systems. Various other simulation tools can be used such as 5G LENA although, this technology requires a licence to be purchased before it can be used and there are various features not included such as frequency division duplexing and spatial user multiplexing whereas the 5G air simulator is free to download from online repositories and allows one to provide a simulation that can deal with very high bandwidth connections which is key in assessing the QoS and QoE of the transmissions of large files of 5G networks.

[2.1.2] Video Streaming over 4G in moving scenarios.

A paper which is relevant to the hypothesis of this research project is titled *'Performance analysis of medical video streaming over 4G and beyond small cells for indoor and moving vehicle (ambulance) scenarios'*. The paper was first published in 2014 by Dr Ikram Ur Rehman et al [7]. The age of the paper can be criticised however, the methodologies and procedures contained in the research paper are important to consider when taking on such a project. The paper explores the QoS and QoE of the medical video streaming process via 4G networks, many techniques which were state-of-the-art at the time are discussed and the strain on the 4G infrastructure is also discussed which leads on to the notion that there is technology beyond 4G, commonly referred to as 5G. The previously mentioned '5G air simulator' is used in this research paper to conduct an analysis of the network and the results are presented in the format of graphs which highlight many different variables such as throughput and packet loss ratio. The conclusion to the paper states that *'there is a significant increase in speed when dealing with 5G and femtocells when compared with standard 4G'*. Such results imply that there is potential in this fifth-generation technology and that 5G can be beneficial when transmitting large ultrasound files.

[2.1.3] Video Streaming over 5G in moving scenarios use case.

The paper titled *'Small cell-based ambulance scenario for medical video streaming: A 5G-Health use case'* is a more recent paper published in 2018 by Dr Ikram Ur Rehman [8]. The paper build upon the ideas which were previously discussed in an earlier paper by Dr Ikram titled *'Performance analysis of medical video streaming over 4G and beyond small cells for indoor and moving vehicle (ambulance) scenarios'* [7] and provides a much more up-to-date analysis of medical video streaming. The paper can be broken down into three main sections. Section one is where an investigation of small cell heterogeneous networks for use in medical steaming as an example of m-health applications in the uplink direction

is carried out. Section two: the proposed use-case and model is presented along with the technical specification. Section three is where the simulation technology is used to analyse the QoS and QoE related to the use case presented and variables which effect the successful transmission of files in different scenarios are explored and discussed in detail which is important to consider when undertaking such a project. Some concepts which relate to this project such as mobile relays, small cell technology and proximity of base stations are explored and examples of successful deployment of these technologies are mentioned. The findings suggest that there is a lack of research conducted relating to the streaming and transmission of two-dimensional and three-dimensional medical images and videos therefore, a gap is prevalent in the research area which will hopefully be filled upon completion of this research project.

[2.1.4] 5G Mobile Systems for Healthcare.

David Soldani et al (2017) published a paper titled *'5G Mobile System for Healthcare'*. [11] which provides a detailed formal analysis of 5G mobile systems and their application within the Healthcare industry. Various complex systems such as the process of 'Wireless telesurgery' and 'Wireless service robots' are discussed and critiqued. The current strain which is being but on the 4G infrastructure is presented and solutions to the problems are given which include the 5G architecture. QoS, security and QoE of 5G mobile system are evaluated and predictions for the financial outcomes for businesses of adopting this 5G technology are given in the form of visualizations.

[2.1.5] M-Health Solutions Using 5G Networks & M2M Communications.

A key paper which provides research linking m-Health, 5G and machine-to-machine (M2M) technologies titled *'Health solutions using 5G networks and M2M communications'* by Willian D. de Mattos; Paulo R.L. Gondim, (2016) [12] bring to the surface many important points. The dramatic increase of mobile users and the possible 5G solutions are evaluated and requirements of such networks such as security, reliability, low latency, improved QoS, improved QoE and the idea of faster more scalable mobile networks are presented. The paper also makes references to the works of Amitabh Mishra & Dharma P. Agriwal (2015), specifically a paper titled *'5G for telemedicine that uses cognitive networks and multiple-input/multiple-output MIMO technology'* [13]. Amitabh et al discusses various concepts and presents *the 'proposition of a new architecture for continuously sending physiological data with low consumption'.*

[2.2] LITERATURE CRITIQUE

This section is a review of the strengths and weaknesses from the point of view of the hypothesis.

Paper Title	Strength	Weakness
5G-air-simulator: an open-source tool modelling the 5G air interface.	The paper builds upon state-of-the-art methods and use of the simulator can be used for existing and novel research.	There have been occasions where the simulator has been used in some research papers, however, use of the simulator is not widespread.
	The paper has been referenced in various scholarly publications which were only made possible by using this simulator.	The technical terms and phrases used in the document means that the paper may not be accessible to an individual who has no knowledge in the field.
	The paper provides an in-depth description of the simulation environment. The paper also provides a summary of the main use cases that could possibly arise and a complete breakdown of the high-level functionalities.	
Performance analysis of medical video streaming over 4G and beyond small cells for indoor and moving vehicle (ambulance) scenarios.	State-of-the-art technologies including small cell technology are discussed in the paper.	The age of the paper can be criticised as the paper was published in 2014 which is over six years ago. There have been major advances, so a more recent analysis is needed.

	The results and analysis section are excellent, and the findings are very detailed with the addition of graphical visualizations which can be interpreted easy, these visualizations are supported by textual descriptions.	There is a lack of emphasis on security for the use cases mentioned in this research paper. Security is crucial to consider because if such systems were to fail, there could be fatal consequences to the patient. Security must be addressed because according to an article by the BBC, more than half of British firms report cyber-attacks in 2019. [16]
	The use case in the paper is supported by the 5G air simulator which clearly shows one the results of deploying such technologies.	The paper does not map m-QoE to m-QoS although, in the future work section, the paper mentions that possible future work aims to deal with this along with the benefits of cross-layer design.
	The paper gives detailed use cases and provides a feasibility analysis of deploying small cell heterogeneous networks in m-health.	
Small cell-based ambulance scenario for medical video streaming: A 5G-Health use case.	The paper provides feasibility analysis when deploying small cell networks in m-health.	There is a lack of emphasis on security of the small cell based 5G technology mentioned in the paper.

	All research which supports this paper is from academic sources which were up to date at time of publication and verified by accredited organizations.	The paper fails to map m-QoS, m-QoE when transmitting medical ultrasound videos in the uplink direction
	This paper provides a more recent analysis that builds upon the previous works of Dr Ikram, specifically the paper *"Performance analysis of medical video streaming over 4G and beyond small cells for indoor and moving vehicle (ambulance) scenarios'.* An updated use case for 5G networks is presented for transmission of ultrasound video files between hospitals in the uplink direction while in moving scenarios.	The paper is very complex and technical, therefore may not be understood by an individual who does not have previous experience in the field.
5G Mobile System for Healthcare.	Many state-of-the-art technologies such as Wireless Tele Surgery (WTS) and Wireless Service Robots (WSR) are discussed.	The age of the paper can be criticised as it was published in 2017 which is over three years ago. 5G technology has been advancing at a fast pace so possibly a more recent analysis would be beneficial.

	The paper in question presents two use cases for the deployment of ultra-reliable robotics platforms for low latency 5G mobile systems. both containing high detail	A possible limitation could be that the paper only considers the use of two mobile systems in healthcare however, this could be a positive for someone who was looking for specific information relating to these technologies.
	The paper highlights the benefits for adopting such technologies for businesses and provides analysis for connectivity provider and for care providers.	
Health Solutions Using 5G Networks and M2M Communications.	The paper consolidates research between the field of 5G, m-Health and M2M communications. It also explores the potential of the technologies mentioned and aims to deal with various challenges associated with them. Many key areas relating to 5G such as increased security measures needing to be put in place, extended battery life, low latency, increased bandwidth, and scalability are addressed in the paper. There are many relevant, up to date statistics used throughout the paper to support the research.	Such basic explanations such as 'What is 5G?' may not be necessary because the individuals seeking this information should already have knowledge on this topic if they are searching for such a paper. Publication of this paper was back in 2016, this is over four year ago hence a more recent analysis may be beneficial [17].

Table 2: *Literature Critique Table.*

[2.3] 5G APPLICATION IN THE MEDICAL SECTOR

It is important for one to understand some real-life applications of 5G within the medical sector to understand the possible potential of such technology. Section [3.2] provides two examples of deployment of 5G in the healthcare industry which are easy to understand and contain examples of possible real-life dialogue between healthcare professionals.

[2.3.1] SHANGHAI TENTH PEOPLE'S HOSPITAL

Shanghai's Tenth people's hospital is at the cutting edge of 5G technology and have been able to monitor the whole operation of conducting a biopsy to collect hydrops in order make better treatment decisions at a later stage was carried out via the 5G network. The patient in this scenario was diagnosed with abnormal cervical lymph nodes after two thyroid cancer surgeries [27].

Communication will be available between medical experts during the surgery. A proposed dialogue for the conversation could include the following.

Surgeon Located at facility: "Is this the correct lymph node?"
Surgeon not located at facility: "Yes, on the left side, check the size."
Surgeon Located at facility: "Ok, 4 millimetres."
Surgeon not located at facility: "Puncturing be ready."
Surgeon Located at facility: "3, 2, 1, go."

Figure 1: *Ultrasound Image Transmitted over 5G, Shanghai.*

Figure (1) shows the ultrasound image being transmitted via the 5G network and on the right-hand side, the healthcare professionals can converse in a video conference environment. This type of technology can allow for many healthcare professionals to assess the image without having the be in the same room or even the same country.

After the above procedure, a second procedure was demonstrated with a patient who was situated thousands of miles away from the Shanghai medical centre. The patient was undergoing an ultrasound scan, medical experts then discussed the patients case and were able to recommend a treatment plan based on the ultrasonic image they were able to see within a short time frame.

The issue with 4G networks is that when dealing with image transmission there is a time lag so to watch the needle movement without latency issues is important. The recent emergence of 5G technology has improved things and clear verbal communications can be accompanied by high-definition low-latency video while easing the imbalance of domestic medical resources.

The system in place at Shanghai Tenth People's Hospital has been accessed by various medical institutions in many different cities across china.

The 5G infrastructure is 100 times faster than the current 4G infrastructure and for example, it is possible to download a two-hour film in approximately 3.6 seconds whereas when using a 4G connection, this would take roughly six minutes. This mass increase in speed has brought new possibilities to china's medical industry.

[2.3.2] 5G-BASED REMOTE SURGERY ON HUMAN BRAIN.

The Chinese PLA General Hospital (PLAGH) in association with China mobile and Huawei 5G technology conducted an operation which was carried out by Ling Zhipei the chief physician of the First Medical Centre of the Beijing-based PLAGH and Department of Neurosurgery of PLAGH's Hainan hospital which lasted three hours [28].

The patient was suffering from Parkinson's disease so was unable to fly from Beijing to Hainan. According the local media, China's first 5G-based remote surgery with a deep brain stimulation (DBS) implant was carried out by Ling at 9:00 am in Sanva City, Ling was able to manipulate the surgical implements from around 3,000 kilometres away in Beijing with micron precision on a computer via a 5G network. Ling successfully implanted the DBS at the optimal target site and the patient 'Felt good' after the surgery.

Figure 2: *Remote surgery powered by 5G technology.*

The success of such technology in china has led to breakthroughs in telemedicine and the nearly real-time operation allows for improved remote observations, consultations, and guidance during operations. It is predicted that in the near future, high-quality experts from renowned hospitals will have the ability to operate remotely and directly on patients who are located in remote areas through the use of remote surgery and will be able to complete surgical operations and procedures which were previously difficult to finish at 'grassroots-level hospitals'.

CHAPTER 3

[3.1] METHODOLOGY

A customised diagram has been created for this dissertation and it provides a theoretical structure for how one intends to test the aims of the project have been met. The diagram below is a five-step methodology to ensure completion of objectives in the correct order.

The diagram below contains five sections which are labelled from [1] to [5]. Each section has a relevant 'Objective' and 'Result' for that section.

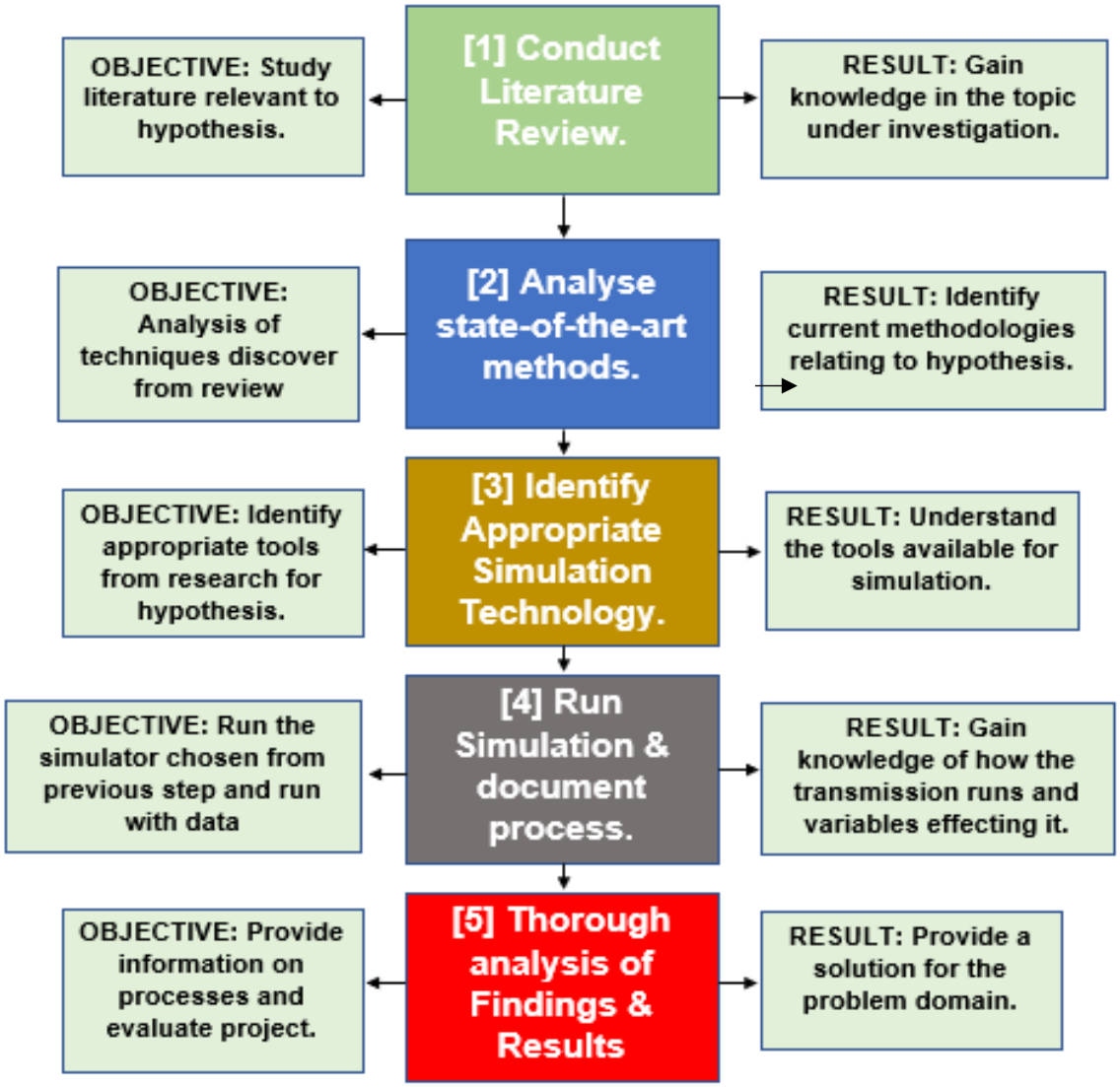

Figure 3: *Diagram Highlighting 5-Step Methodology.*

The diagram is split up into five different sections which need to be executed sequentially starting at **Step [1]** before progressing sequentially towards **Step [5].**

Step [1]: An extensive literature review of the proposed topic area. The aim of the review is to study literature relevant to the hypothesis and the objective which is shown to the left of the green rectangle, one hopes to gain knowledge in the topic under investigation. The result which is predicted from **Step [1]** is shown to the right of the green rectangle.

Step [2]: Conduct a thorough, in-depth analysis of the current state-of-the-art techniques and methodologies relating to the hypothesis. The main goal of such an analysis is to discover techniques and methodologies which were uncovered in the previous **Step [1]**. The objective of the analysis is clearly shown to the left of the blue rectangle, one hopes to identify the current methodologies at play in the subject area and the predicted result is clearly shown in the box to the right of the blue rectangle.

Step [3]: Where one identifies the most suitable technologies discussed in **Step [2]** for the application relating to the hypothesis of such a dissertation. The goal of this step is to identify the simulation tool/tools which are most appropriate when dealing with 5G and the transmission of ultrasound files via 5G networks. This is clearly labelled to the left of the golden rectangle; one hopes to gain a more depth and thorough understanding of the requirements of such a research project and what tools can accommodate such requirements. The predicted outcome is clearly described on the right of the golden rectangle.

Step [4]: This is the penultimate step which needs to be executed. The simulation technology which has been adopted based on the previous section needs to be analysed, the full simulation process must also be recorded and documented, making sure that all relevant information is correctly stored. The main aim of **Step [4]** is to successfully explore the simulator with test data, this is clearly shown to the left of the grey rectangle. One hopes to gain hands-on experience and knowledge with the chosen simulation tools and variables which affect the transmission process. The predicted results are shown to the right of the grey rectangle.

Step [5]: This step is the final step in the five-step methodology proposed for the research project and includes the process of providing a thorough analysis of all research and simulations done during the project. This step aims to tie together all parts of the dissertation into one neat report and

the objective of such a step is to uncover novel information related to the subject field and evaluate the topic. The objective of the step is clearly shown to the left of the red rectangle. The results of following **Step [5]** is to hopefully uncover novel information relating to the field which will benefit further research and fill a gap in current research, this is indicated to the right of the red rectangle.

[3.2] FEMTOCELLS

An important concept which needs to be understood is that of femtocells. This concept aims to combine fixed-line broadband access with cellular telephone using the deployment of ultra-low cost, low-power base stations (BSs) that can be installed in the individual or organizations premises [18] for example, installing such devices in hospitals can improve coverage and throughput of users while reducing the cost of implementation [19].

Femtocells can cover hundreds of meters and they work by connecting to the network of the service provider usually via a cable. There are two current design types, one which support 4-8 active mobile devices in a residential environment and two, which can support 8-16 mobile devices in an enterprise environment however, this is heavily dependent on femtocell hardware and versions. Due to the proximity of BSs, the transmission power of user equipment is saved resulting in extended battery life [20] and network coverage in areas where signal to main network may be weak for example, a large hospital environment.

There are various security issues associated with femtocells that need to be considered if they were to be used in a situation where data security is crucial such as a healthcare environment. The black hat hacker conference in las Vegas, Nevada demonstrated that they could clone a mobile phone that runs on a CDMA network by collecting the ID number through the use of a femtocell [21], the researchers were also able to intercept data, SMS, and voice calls. Over recent years femtocells have gained more popularity however, it is important that the security vulnerabilities are addressed before use in a healthcare environment.

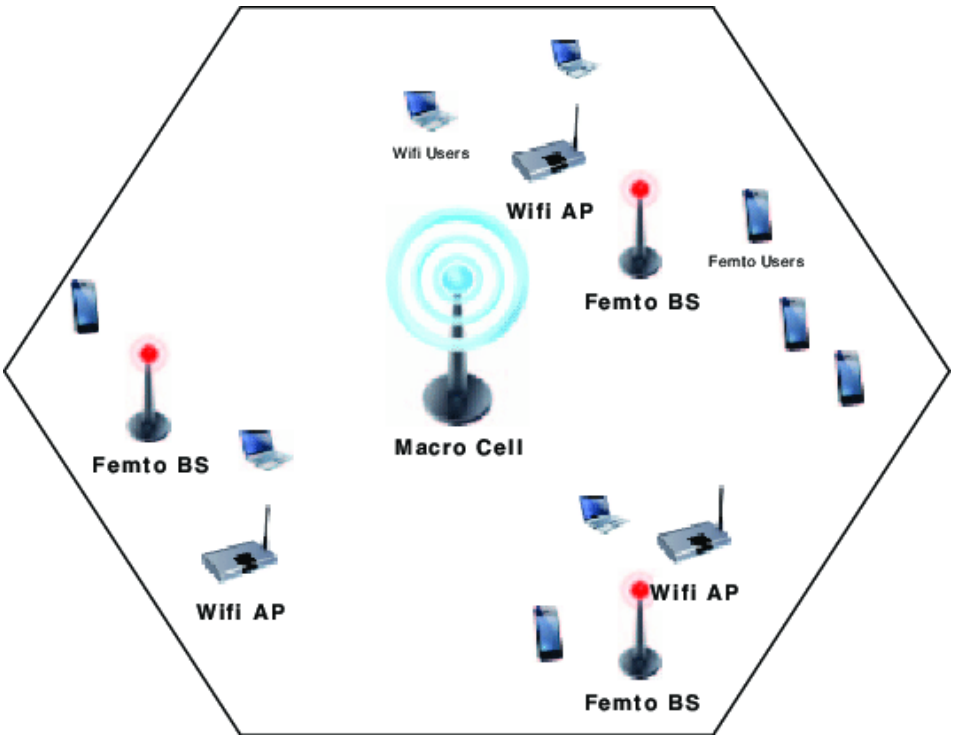

Figure 4: *Macrocell-Femtocell-Wi-Fi Network.[22]*

[3.3] MOBILE FEMTOCELLS

The concept of mobile femtocells (Mobile-Femto) (Mfemto) is a relatively new idea. Mobile computing is becoming a vital part of everyday life in which User Equipment (UE) demand being reachable anywhere at any time and many individuals travel from place to place via the use of public transport or vehicle. Sometimes coverage while travelling is intermittent and providing coverage via outdoor base stations (BSs) is often not adequate, this could be improved by the installation of more BSs however, this has massive financial implications for Internet Service Providers (ISPs) and is not an ideal solution. [23]. Mobile Femtocell technology can be the solution to this issue and significantly improve vehicular UEs performance in LTE networks.

MFemto is a combination of mobile relays and femtocells [24]. The main benefit is that mobile femtocells can move around and dynamically connect to the operators core network within proximity. All users of the MFemto are addressed as one and Mobile-Femto can be installed in many different scenarios including public transport, moving vehicles and specifically medical vehicles which greatly improves the efficiency of existing network infrastructures. A proposed use case mentioned in [7] suggests that by making the ambulance vehicle a mobile femtocells, the UE is connected via an internal access point via the femtocell rather than that of the microcellular network hence, signal penetration is greatly reduced as the signal does not have to travel through the metal surface of the vehicle.

After thorough analysis of literature relating to mobile femtocells, it was found that deployment of such technologies to improve internet coverage while travelling in trains, mobile femtocells have been installed [25]. Another piece of literature which is relevant to the concept of mobile femtocells is the work conducted in [24]. The paper investigates the advantages of using mobile femtocells in vehicles while in [26] the authors investigate the integration of wireless body and ambient sensors into a hybrid femtocell network for home monitoring.

[3.4] MOBILE SMALL CELLS

The concept of a mobile small cell is relatively new and is comprised from small cells and multiple mobile relays which allow the individual to move around while connecting to service operators in close proximity and does this with the use of standard radio interface techniques to connect with existing base stations [7]. Installation can be done in various types of vehicles such as an ambulance and is addressed as a single unit which improves the spectral efficiency, throughput and signal quality as well as reducing the signalling overhead and reducing handover activities by addressing all operations as a single handover [29].

Users within a moving vehicle encounter several issues:

- Low Signal-to Interference-Noise-Ratio (SINR).
- Lower Throughput.
- Poor Signal Quality.
- Multiple handovers = reduced connection due to the mobility of the vehicle.

The concept of small cells have the potential to completely eradicate these issues by making the vehicle itself a moving vehicle and connecting the UE to small cell BSs instead of outdoor Macrocell BSs which hence, improves signal quality and avoids penetration loss from vehicle surfaces [30].

[3.5] ULTRASOUND

An ultrasound scan, otherwise known as **(Sonogram, Sonography, Ultrasonography),** is a procedure that uses high frequency sound waves to create an image of part of the inside of the body including tendons, joints, muscles, blood vessels and internal organs., one common use for an ultrasound scan would be to monitor an unborn baby, diagnose a certain condition or to guide a surgeon during a procedure [31].

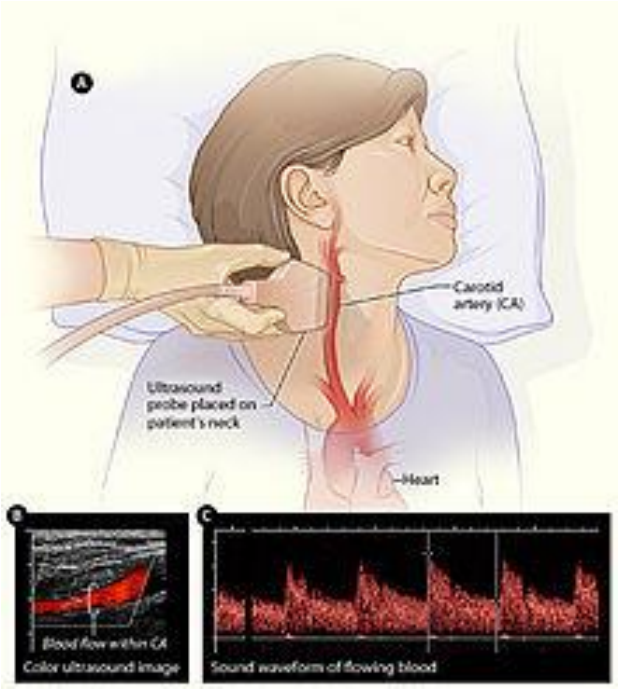

Figure 5: *Ultrasound of carotid artery.*

Most ultrasounds only last between 13-45 minutes and usually take place in a radiology department and are performed by radiologists or a sonographer. Ultrasounds are sound waves with a frequency which is greater than 20,000 Hz which humans cannot hear. Ultrasonic images otherwise known as sonograms are created by sending pulses of ultrasound into tissue with the use of a probe and the

pulses echo off tissue with different properties which are recorded and then displayed as an image.

There are three main types of ultrasound scans:

- **[1] Internal Ultrasound Scan** – A probe is inserted into the body.

- **[2] Endoscopic Ultrasound Scan** – A probe is attached to a long, thin flexible tube called an endoscope and passed further into the body.

- **[3] External Ultrasound Scan** – The probe is moved over the skin.

[3.6] 3D ULTRASOUND

Three-dimensional (3D) ultrasound is a technique used to convert standard 2D grayscale ultrasound images into a volumetric dataset. The 3d image can then be reviewed retrospectively. The technique was developed for problem-solving (particularly in obstetric/gynaecologic exams) and to potentially reduce the operators dependence of ultrasound imaging [32].

There are four main ways of capturing data for 3D ultrasounds, using a probe freehand and recording each slice, mechanically by using an internal linear probe which is tilted using a motor inside the probe or by using a endoprobe which works by inserting the probe and then removing the transducer in a controlled way. The final approach is the matrix array transducer which makes use of beam steering to sample point through a pyramid shaped volume. 3D ultrasound simply refers to the volume rendering of the ultrasound data and is also known as 4D (3-spatial dimensions plus 1-time dimension) when a series of 3D volumes are collected over time [33].

Figure 6: *3D Fetal Ultrasound Image.*

[3.7] SYSTEM MODEL – ULTRASOUND MOVING SCENARIO

This section discusses the system model provided in [7] for the deployment of the femtocellular network from inside an ambulance.

[1] The Femotcellular base station (FBS) is situated inside the ambulance.

[2] A transceiver is installed on the roof of the ambulance which is used to transmit and receive data to/from the backhaul macrocellular network.

[3] The FBS installed inside the ambulance establishes the wireless connection between the paramedics inside the ambulance and the Femto Access Point (FAP).

[4] The FAP and the transceiver are connected via the wired network.

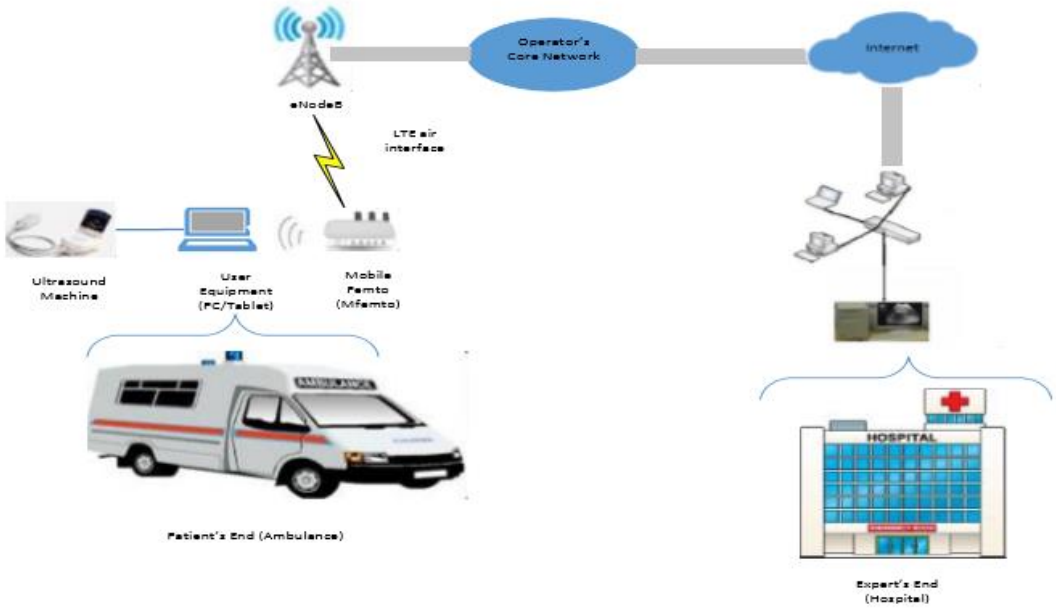

Figure 7: *Moving vehicle (Ambulance) scenario for ultrasound.*

[3.8] SIMULATION 1

This section provides a complete breakdown and analysis of the performance of the simulation provided in [7].

The simulation in the paper provides a performance analysis of small cell (Femto) network communication between Femto BSs (HeNB) and the user. The paper makes use of a single cell and several femtocells which are randomly distributed. The mobile femtocell will be addressed as a fixed femtocell for the individuals using the connection in the vehicle which creates an indoor environment.

A sample of Ultrasound video was used from Cardiff University Hospital. The Ultrasound video sequence was at 25 frames/second with a resolution of 640x480 and was in the YUV format and has been compressed using H.264 at 128Kbps.

The LTE-Sim Simulator technology was used in the paper to perform the analysis [35] and the QoS analysis has been analysed with reference to the packet loss ratio, delay, and throughput.

Results of the simulation showed that by using femtocells in the m-health field, performance was improved significantly than that of the conventional microcellular network.

SIMULATION PARAMETERS

Parameter Values:

- Bandwidth = 1.4 MHz
- Simulation Duration = 100s
- Frame structure = FDD
- Maximum delay = 100ms
- Macro BS TX power = 43dBm
- Femto BS TX power = 20dBm
- Maximum Delay = 100ms
- Video Bitrate = 129Kbps
- Number of users per femtocell = 1-8
- Scheduling Algorithm = FME

Results of running the simulation showed that there was a significant performance improvement when using femtocells in the m-health field.

[3.9] SIMULATION 2

This section provides a complete breakdown and analysis of the performance of the simulation provided in [8].

The paper proposes two scenarios.

[1] Paramedics and staff inside the ambulance are connected to the outside microcell bass station with the use of mobile small cells.

[2] Paramedics and staff inside the ambulance are connected to the small cell base station inside the ambulance which then connects to the microcell base station.

The paper explains that it is critical during the patients journey to the hospital that the paramedics can transmit large high-resolution medical data to and from various locations. Due to the ambulance always moving, there are various issues involved which effects the QoS. The paper explains that there has been previous work conducted on moving vehicles and transmission of data [36][37] however, the QoS often causes issues for the technology which needs to be overcome.

A sample of Ultrasound video was used from Cardiff University Hospital. The Ultrasound video sequence was at 25 frame/second with a resolution of 640x480 and was in for YUV format and has been compressed using H.264 at 128Kbps is used for the simulation as seen in [7].

The system model is the same of that in Figure 7 and the process is explained below.

- **[1]** The Femotcellular base station (FBS) is situated inside the ambulance.
- **[2]** A transceiver is installed on the roof of the ambulance which is used to transmit and receive data to/from the backhaul macrocellular network. The transceiver is stronger than the one contained in the UE so therefore there is increased signal quality, capacity, throughput, and delay which can significantly enhance the QoS.

- **[3]** The FBS installed inside the ambulance establishes the wireless connection between the paramedics inside the ambulance and the Femto Access Point (FAP).
- **[4]** The FAP and the transceiver are connected via the wired network.

SIMULATION ENVIRONMENT

To simulate the communication between the small cell network and the small cell base station (HeNB) and paramedics situated inside the ambulance. the LTE-Sim Simulator technology was used in the paper to perform the analysis of the m-QoS [35]**.** A small cell network was set up inside the vehicle and is addressed as a single mobile small cell, the speed of the vehicle was set to 120kmph. Each small cell has the potential to accommodate several users from 1 to 10. The radius is set to 10m and is moving at a constant speed inside a microcell radius of 1km. Background internet traffic is added during the simulation to assess how both the mobile small cell and microcell perform in a congested environments within a vehicle and the streaming of the ultrasound video is done in the uplink direction between the hospital and the ambulance. FME (First Maximum Expansion) scheduler is an algorithm which was selected and work as an uplink scheduling algorithm which can be used to maximise throughput of the network under assessment.

SIMULATION PARAMETERS FOR PROPOSED AMBULANCE SCENARIO

Parameter Values:

- Bandwidth = 1.4 MHz
- Macrocell radius = 1 Km
- Mobile small cell radius = 10m
- Frame structure = FDD
- Maximum delay = 100ms
- Video bitrate = 200 kbps
- Scheduler type = FME
- Video duration = 20 sec
- Simulation time = 30 sec
- UE speed 1 = 20 km/h Path loss/ channel model
- Vehicular propagation model
- Simulation repetitions = 10

CHAPTER 4

[4.1] SECURITY MEASURES RELATING TO 5G

This research paper focuses heavily on the cyber security issues relating to the transmission of data over 5G networks. The current security measures in place need to be drastically improved to avoid the risk of the many cyber-attacks that can be deployed. The risk of a cyber-attack dramatically increases the risk to businesses, governments and more importantly, the healthcare industry [34].

A few of the main issues when looking at 5G and cyber security are listed in the table below.

Security Issue	Description
[4.1.1] IoT devices manufactured with a lack of security.	Due to low-end smart devices in mass production, manufactures may not prioritize cyber security issues relating to these devices. As more devices connect to networks many billions of devices with different levels of security such as door locks, Smart TV's and sensors like thermometers mean that there are many points which are vulnerable hence a possible breach in security could happen. This lack of consideration for the security of low-end devices with 5G capabilities mean that cyber-attacks and hacking may become a big issue.
[4.1.2] Increased bandwidth will put a strain current security monitoring.	The current limitations of the 4G infrastructure has made the job of the network manager who monitors the network easier. The huge increase in size of the of 5G networks being introduced brings with it the threat of many cyber-attacks. These threats will need to be dealt with by creating new methods and systems to deal with the increased speeds and increased volume of data.

[4.1.3] There is a lack of encryption early in connection process	Device information (Vehicle model, Smartphone Model, Operating System) can be used to help hackers to target specific devices and help them understand which devices are connected to a certain network which can mean that hackers can then use this information to plan a further attack if it is not properly encrypted.
[4.1.4] Decentralized security	The introduction of 5G has also brought with it more software-based systems. Previous 4G networks had fewer traffic points-of-contact whereas these new systems have more traffic routing points [34]. These increased amount of points means that security checks are harder to conduct, and any unsecured areas may compromise different parts of the network.

Table 3: *Security Issues for 5G Networks Table.*

[4.2] CYBER THREATS TO 5G NETWORKS.

There are a variety of different attacks which a 5G network may be susceptible to. The vulnerabilities present in a network can be exploited to take advantage or gain unauthorised access to the device/system. Some of the most common cyber-threats relating to 5G include:

Cyber Threat	Description
[4.2.1] DDoS (Distributed denial-of-service) attack.	This type of attack is when a hacker floods a network or webpage to take it offline.
[4.2.2] MiTM (Man-in-the-Middle) attack.	The hacker manages to intercept the communications between two parties over a network. He then has the potential to eavesdrop on the communication or change the communication data.
[4.2.3] Botnet attack.	The hacker takes control of a network of connected devices, who then uses these connected devices to launch a huge cyber-attack.
[4.2.4] Intercepting Calls.	If the hacker knows any information about the broadcast paging protocols, the two adjacent attacks are possible.
[4.2.5] Location Tracking.	

Table 4: *Common Cyber Threat for 5G Networks Table.*

[4.2.1] INTERNET OF THINGS

The Internet of Things (IoT) is the concept of connecting any device which has an on/off switch to the internet and to other connected devices. The IoT is a large interconnected network of people and things and all of which share and collect data about the way they are used and about the environment around them [55] many different varieties of objects in various sizes and shapes will be included in the IoT such as smart microwaves, self-driving cars and wearable smart health tracking devices.

The emerging 5G technology will cause innovation across many different industries and be able to provide a platform enabling these emergent technologies such as IoT to become an integral part of our lives. The full potential of IoT has still not been met and 5G, being commercially available in 2020, the industry is developing new global standards and pre 5G products to benefits many different industries, not just that of the healthcare industry [56].

According to a recent report by Ericsson, there is estimated to be 550 million 5G subscriptions in 2022 and Asia Pacific will be the second fastest growing region with 10% of all subscriptions being 5G in 2020.

The IoT has opened new doors in the healthcare industry and has allowed for IoT-Enabled devices to make remote monitoring of patients in the healthcare sector possible which has the potential to keep the patient safe and healthy and empowers physicians to deliver the highest level of care possible [57]. This remote monitoring with the use of IoT-Enabled devices has improved patient engagement and satisfactions levels, it allows for the interaction between patient and doctor to be conducted a lot easier and efficiently. A further important point to mention is that by remote monitoring of patients health can reduce the amount of time the patient has to spend in hospital and also prevents re-admission to hospitals because the amount of patient/doctor engagement is increased. IoT has great potential in the healthcare industry and has the potential to reduce costs and improve treatments.

[4.3] 5G AND CYBER SECURITY FUTURE WORK

As seen in the previous section there are many different types of attacks and many factors which cause weaknesses in these 5G networks. Security measures need to be improved and during the early stages of deployment, real-world results can be used to develop these security technologies. A few key considerations need to be made when deploying 5G technologies:

[4.3.1] Security Incentive.

Organizations and manufacturers who oversee these 5G technologies need to focus on cyber-security. Especially in low-end products such as sensors, monitors and smartwatches. A possible benefit system could be put in play so that the manufacturer/organization can offset their losses which would then boost consumer protection.

[4.3.2] Consumer Education

Consumers of such technologies will need to be educated and learn how to safely interact with IoT devices. Consumers need to understand the importance of securing all their devices connected to the network and putting measures in place to enforce the security of their network and user equipment connected to these networks.

[4.3.3] Security Foundations Must be established.

Providers of the network need to focus on the software-based protection to deal with the risks associated with 5G networks. These large organization need to join forces with cyber security companies to deal with the associated risks, monitor the network and encrypt all communications which take place over the network.

[4.3.4] Install Antivirus & Malware Protection on all 5G enabled devices.

Antivirus software is used to prevent devices from becoming infected with viruses of malware. Some pieces of software are available free to download however, others require a license to use.

[4.3.5] VPN (Virtual Proxy Network)

A VPN can be used to stop hackers accessing your data and tracking you online.

[4.3.6] Enforce Strong Password Security Protocols.

Secure protocols must be established to make passwords strong enough not to be cracked. The use of many different character, letters and numbers can make it more difficult for hackers to find out your password via dictionary and brute force attacks and a policy should be put in place to enforce this password protocol.

[4.3.7] Keep all devices updated with the latest software update

All devices that are connected to the network should be updated with the latest security patch. This makes sure that the device is ready for all the new security threats. An example of these devices includes all mobile devices and operating systems that connect to the 5G network.

[4.3.8] Effective Security Policies

Policies need to be defined for users of the system to avoid possible security breaches such as unauthorised access. Authorisation policies can be used to define what users can do and cannot do within the system in question. It is also important that obligation policies are implemented correctly because in the situation where there is a security breach, all individuals already know what steps they need to take in order to keep the system working and deal with the security breach.

CHAPTER 5

[5.1] RESULTS ANALYSIS

This section presents a detailed description and analyses of the findings in the context of this research dissertation. All aspects and methodologies currently used in the 5G infrastructure specifically during the transmission of ultrasound files which are discussed in this research dissertation will be analysed against the aims of the dissertation and presented in an appropriate format. A complete overview of the QoS and QoE is provided and accurate prediction of the expected speeds of the transmission of ultrasound while using 5G and 4G in both mobile and static scenarios will be given in the conclusion section.

[5.2] SIMULATION ANALYSIS RESULTS

This section provides an overview of the simulation technologies discussed previously and new simulation environments which are available for the simulation of 5G networks.

The table below provides a summary of the main simulation technologies such as 'LTE-SIM' and '5G K-Sim & K-SimPlatform' along with others. Many characteristics of the technology are described in the table such as the code or environment needed to be able to run the software, software cost and accessibility methods are described to name a few.

	Developer	Simulator	Characteristics					
			Code	Cost	User Manual	Platform	Cloud Computing	Accessibility (download/install)
Vienna 5G Simulators	TUW	5G simulator (LLS, SLS)	Open (MATLAB)	Free	○	X	X	△
NYUSIM	NYU	5G channel model	Open (MATLAB)	Free	○	○ (exe file)	X	△
LTE-SIM	POLIBA	LTE simulator	Open (C++)	Free	△	X	X	△
5G Library for LTE System Toolbox	MathWorks	5G PHY library + LTE LLS Simulator = 5G LLS	Open (MATLAB)	Charged	○	X	X	○ (web-based)
5G K-Sim. & K-SimPlatform	5G WISE	5G LLS, SLS, NS	Open (C++)	Free	○	○ (web-based)	○	○ (web-based)

Table 5: *Existing 5G Simulators & Characteristics.*

After analysis of the findings from the research conducted in this paper, one would **recommend** the **5G k-sim & K-sim platform [45]** to any researcher who is looking to simulate a 5G network who does not have the funds to pay for a license or additional software such as MATLAB [46]. The simulator has been used in many research papers [7] [8] [38] and has proved to be reliable.

The 5G K-SimPlatform has many differences when compared with existing simulators such as the ones mentioned above. The simulator is built upon the concepts of object-oriented programming (OOP), this greatly improves the speed of the simulator and enhances the development possibilities and modularity. The simulator is also open source and allows one to use detailed functions based on the standard specification and system model which means that it is interoperable and has the ability to integrate between link level, system level and network simulation which allows for highly accurate simulation.

A final crucial point to mention is that through the use of modularization, the development of the simulator environment has the ability to be applied to many different environments and channel quality information (CQI) and various traffic measurement techniques are used to provide the right quality of service the various users in the network require.

[5.3] QUALITY OF EXPERIENCE ANALYSIS

The research project has revealed many factors and environmental variables which affect the Quality of Experience. This section aims to address the main issues which affect the quality of experience of the transmission of ultrasound videos over 5G networks.

[5.3.1] COST

There are many financial factors that affect the QoE. The cost of setting up the increased amount of base stations is great and the engineers who install these base stations need to be trained to set them up which again has a financial implication on the companies who employ these individuals.

The cost implications for setting up these 5G networks in rural areas is a major factor and needs to be considered. The infrastructure would need to be fully upgraded which means that a large amount of cables would have to be installed which brings with it the issue of where to run the cables as some rural areas are protected by projects such as the natural trust. An article which discusses the rollout implications of the 5G infrastructure in Britain says that '90% of the population will have 5G coverage by the year 2027, but coverage is unlikely to reach the final 10% due to the exponentially increasing costs'. [39] The article suggests that this final 10% is likely to be in hard to reach rural areas which do not have any current infrastructure in place and these rural areas could include hospitals which would mean the access to such technologies such as transmission of ultrasound files and remote tele-surgery would not be possible.

[5.3.2] RELIABILITY

A crucial factor which impacts the QoE is the reliability of the network. In such crucial scenarios such as mobile ultrasound scanning it is key that the network is reliable because if connection was to be lost at such an important time, the patients' health may suffer. The rollout of 5G promises massive speed increases and low latency however, this is no use if the network is not reliable.

Many different companies who provide these services have been coming up with more and more solutions to improve the reliability of these networks. The notion of 5G relying on the high-band spectrum has been challenged by T-Mobile who have managed to achieve a 'nationwide 5G network because, rather than using high-band spectrum, T-Mobile has used mostly lower frequency airwaves to build its network' [40]. The use of lower frequencies mean that the signals generated can travel a greater distance and are more efficient when travelling through objects such as through walls of buildings (hospitals) and the metal structure of vehicles (ambulances) however, these low frequency signals do not bring the dramatic benefits that 5G promises so in future it is thought that 5G will combines these low and high frequencies to enhance the reliability of the network and provide the most coverage possible.

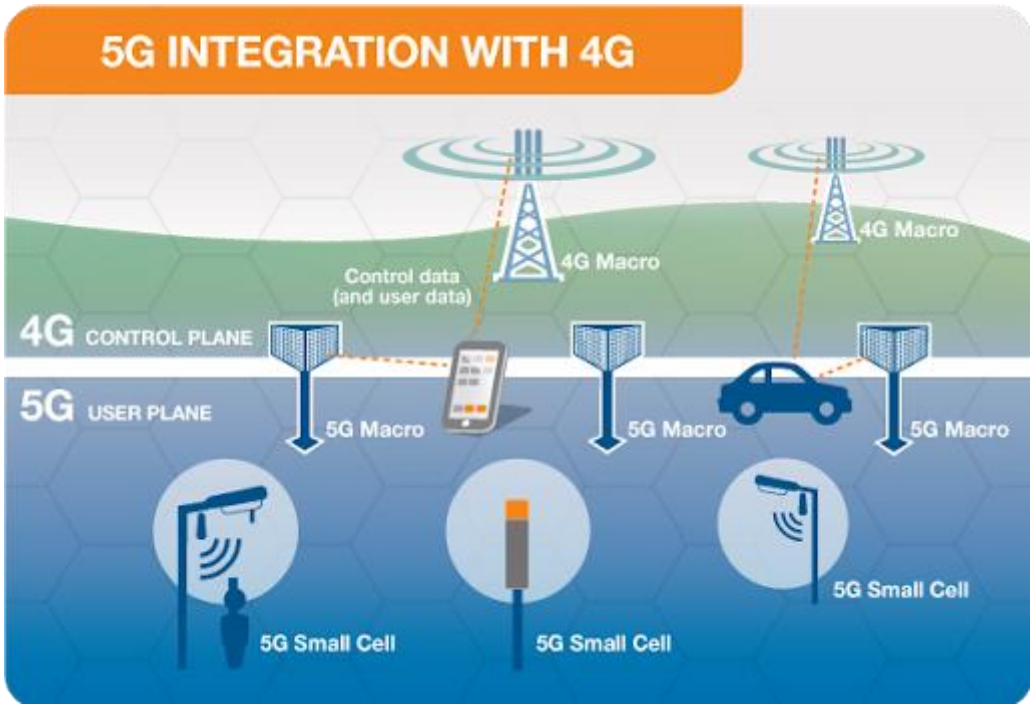

Figure 8: *5G Integration with 4G.*

[5.3.3] EFFICIENCY

The efficiency of a network is important, during the implementation and rollout of 5G technology, efficiency mechanisms need to be considered at the design level stage before implementation. Factors including environmental and social issues and that relating to energy consumption are being concentrated on and it is thought that through the correct implementation and design of efficiency mechanisms that future 5G networks can reduce energy consumption up to a factor of 20 when compared with 4G networks hence improving the overall efficiency of the network [41] which is seen as a benefit in many ways such as reducing average energy costs to organizations using the technology and also reducing the environmental impact the technology has on the environment.

There has been major development concerning the creation of Massive Multiple-Input Multiple-Output (mMIMO) antennas. These antennas work by transmitting signals only in the direction of the UE, these signals are referred to as beams. In the current 4G technology, these beams are sent over a wide area. By directing these beams, the overall throughput is improved as multiple beams can be projected at once and each beam is able to recycle the cells frequencies making them more efficient than the current 4G solution. A recent statement made by Orange labs says that 'While 5G antennas consume three times more energy than that of a 4G antenna however, by the year 2021 the ratio is expected to drop by 50% and then by another 25% in the year 2022'. Improvements in these antennas means that they will be able to transmit data at a rate of around five times faster than 4G antennas as well as delivering higher throughput which means that more users can be served simultaneously which again improves the efficiency which is crucial in the transmission of large ultrasound files.

[5.3.4] PRIVACY & SECURITY

The 5G infrastructure uses encryption a lot more than previous generations. This is an advantage and reduces the amount of attacks such as data interception [4.2.4] and location tracking [4.2.5] which is important because if medical information was transmitted and intercepted and altered before re-transmission then the information would be incorrect and may lead to the wrong medical decisions being made which could possibly be fatal to the patient.

The fact that the technology is a lot more software/cloud based than previous generations can only be a benefit. Monitoring these networks and analysing them for threats can be done a lot easier than that of the previous generations and the process of 'network slicing' allows the network to be broken down into various segments all of which can be treated individually which could for example be used in a medical environment where the network could be sliced in many sections and

the sections allocated to the departments who are conducting crucial operations such as ultrasound transmission via the network can then be given the right amount of resources to that segment of the network.

Although the introduction of 5G brings with it enhanced security, the issues mentioned [Table 4] still apply and adequate protection mechanisms still need to be put in place to deal these issues. By working closely with cyber security firms one can ensure that there is an adequate Security operations and assurance SOA plan in place that covers all eventualities and possible breaches of security. Researchers have recently pointed out a flaw in the 5G infrastructure and these networks are vulnerable to the "'Downgrade" attacks which involve manipulating the targets phone connection and downgrading it to a 3G or 4G service' [42]. This means that hackers can then exploit the unresolved flaws of these networks and carry out the many possible attacks.

[5.3.5] USER EXPERIENCE & USER CONFIDENCE

The optimisation of wireless services for customers is key to a good user experience (Ux) and is an important thing to consider when analysing the QoE of a network. The term UX refers to the individuals emotions and viewpoint of the system in place, in this scenario the way in which the user feels during the transmission of ultrasound over 5G networks. It is key that developers of such technologies and applications consider the UX at the design level stage before implementation occurs to provide the optimum user experience. Some factors which affect the UX include the usability, accessibility, and user interface.

By having an adequate UX by optimising the right design procedures, we can ensure that there is a good level of user confidence in these 5G systems. By increasing the user confidence, the user of the system can feel confident when using and interacting with the systems which in turn increases the sales for the companies pushing the technology while also increasing the user base [44].

By the use of user testing before deployment of the medical systems we can ensure that the product is fit for purpose and is not constantly throwing errors and crashing, such events can reduce the users confidence and respect for a technology. Overall, the 5G infrastructure should greatly improve the UX which in turn improves the user confidence when compared with previous generations such as 4G and 3G. The increase in speed and reduction in latency should theoretically improve the transmission of ultrasound videos therefore the QoE will be significantly improved.

[5.3.6] ENIRONMENTAL VARIABLES

The environment plays a big role in the QoE of the transmission of ultrasound video files. Many environmental variables are out of our control and these variables could impact the QoE of the transmission. This section aims to discuss these variables and the potential impact they could have on the QoE.

[5.3.7] FIXED VS MOBILE 5G NETWORKS

Whether or not the user is mobile or in a fixed location is likely to affect the QoE of the ultrasound transmission process. As previously mentioned in [3.2].

If the user is mobile while transmitting data via the 5G network, then the QoE is dramatically altered. A full breakdown of this is shown [3.3] [3.4] and the findings show that the increased number of BSs will significantly improve the experience when compared with previous generations.

[5.3.8] EFFECTS OF BUILDINGS ON 5G TRANSMISSION

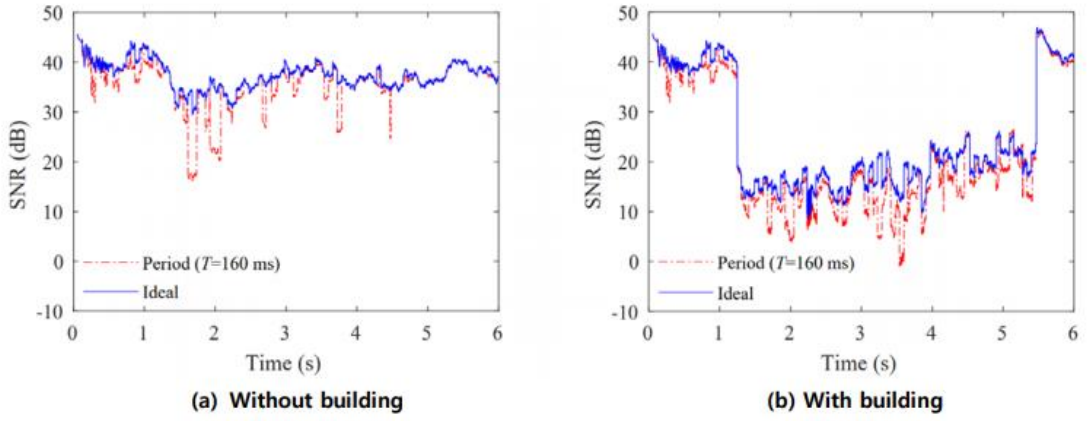

Figure 9: *Effects of a Building on Transmission.*

The creators of the 5G-KSimPlatform '5G Wise' have conducted a simulation which is shown in figure X. The graphs provided outline the SNR values of the Transport Blocks (TBs) that are received when the building exists and when the building does not exist [45].

When the channel matrix is known, the highest SNR values are obtained by the best analogue beamforming vectors which are set to an update period of T = 160ms to reflect the tracking procedure of the beam. The SNR produced during the simulation are significantly lower than that of the ideal case where the channel matrix is known. The reason for this is that the gNB and the UE use previous channel information to transmit and receive data via the use of analogue beamforming vectors.

In the second graph (b), the SNR values of the received TBs are shown when the building is present. The graph clearly shows that the SNR rapidly decreases when the channel condition is changed to the non-line-of-sight (NLOS) due to the presence of the building. Graph (b) does not represent minus infinity values because when T is applied and if the channel condition is changed for example from LOS to NLOS, the SNR value becomes 0.

[5.3.9] APPLICATION AREA

Different parts of networks have different priorities, for example a medical tele-surgery department may have the need for a large amount of resources in order to function whereas the wireless network in the coffee department of the hospital would need significantly less resources. This application area in which the 5G network is being used greatly effects the QoE. Many factors such as the hardware being used or the effect of mobility [4.3.7] can influence the QoE.

Critical applications such as the transmission of large medical files and videoconferencing will be allocated the resources they need via 'network slicing' and the other departments such as the coffee department will be allocated the amount of resources they need to operate, all of which can be monitored. This allocation means the system is more efficient and the resources are only being used where they are needed the most hence providing an improved QoE when compared to previous generations.

[5.4] QUALITY OF SERVICE ANALYSIS

One must assess the quality of service QoS to fully understand the impact 5G will have on the medical sector. QoS refers to the ability to be able to prioritise the various segments of the users, this includes but is not limited to users and data. By prioritising these different segments one can ensure that the performance is always maintained at the correct level for the application.

The need for the optimum bit error rates, delay variation and packet loss can be guaranteed by prioritising segments of the network and in crucial scenarios such as that of the streaming of medical ultrasound videos of 5G networks, the QoS is very important especially when live streaming these ultrasound videos [47].

A recent study was conducted by RootMetrics [48] and it highlighted the maximum download speeds for some of the major cities on the 'EE' network within the UK. In London, a maximum download speed of 327.1Mbps was recorded. In Birmingham, the maximum speed was 450.9Mbps and In Cardiff, 339.4Mbps. The study is also compared with that of another major provider 'Vodafone' who managed to achieve a maximum download speed of 314.8Mbps in London, 345.9Mbps in Cardiff and 366.9Mbps in Birmingham. Which is a significant improvement from previous generations of cellular technology. This data clearly shows that the QoS will be significantly improved in the cities mentioned in the study however, rural areas may struggle as they do not have the underlying hardware for the installation of these networks as mentioned in [4.3.1].

[5.5] SECURITY ANALYSIS

This section aims to look give an analysis of the current state of security when it comes to the transmission of ultrasound files over 5G networks.

There are many bugs still present in the 5G infrastructure and these bugs have the potential to be exploited by individuals who want to gain unauthorised access to systems or cause malicious damage by various means which is highlighted in [4.2]. In order to avoid these malicious attacks, healthcare organizations need to work closely with specialized Cyber-security firms and professionals to ensure that all the vulnerabilities of the system have been patched and that the systems are under constant monitoring in order to detect the signs of attacks for example, spike in network traffic.

[5.6[SECURITY POLICIES

This section aims to describe a policy-based approach to cover all possible vulnerabilities in such 5G transmission system over heterogeneous networks. these systems are very complexed and often incorporate wired and wireless technologies into the network, this can make network management a challenge. The use of policy-based management systems has proved to be a promising solution for the problem of controlling and monitoring such critical 5G networks [49]. Such policies support the behaviour change of systems without needing to halt the network and is suitable for heterogeneous networks which, in the scenario of the transmission of ultrasound of 5G networks, should be available at all times without sudden halts or reconfigurations.

These policies define the behaviour of the network or system and defines all the rules associated with the use of such services. A policy based management system can help to define and enforce rules and provides better security because it incorporates many resources into the core network and these crucial resources must be protected from malicious attacks, possibly by authorised users who could potentially exploit these resources by misusing their allocated network privileges. A few of the many policies that could possibly apply to the research hypothesis are described overleaf:

Authorisation Polices – A Authorisation policy specifies which activities a certain user can or cannot perform in the system in question. Positive authorisation means that the user has access to a system or resource. A negative authorisation policy prohibits the user from performing certain actions which involve objects in the system [50].

Obligation Policies – A Obligation policy specifies what the subject in the system must do in the case that a certain even was to occur. This means that pre-defined events hence trigger the security policies to perform certain actions. These type of policies have a number of applications specifically a lot to deal with security violations and what to do if a violation occur and what set of actions will be taken to protect the network and is based on the event condition action (ECA) rules [50].

Ponder2 – A type of policy which is appropriate across many applications and environments is the Ponder2 policy system. This system has a good level of extensibility and allows for greater flexibility, it also provides interactivity which is more engaging for users. Ponder2 is flexible and can function on various hardware and software setups such as that of distributed systems, Local area Networks (LANs) and Wide area Networks (WANs) [53].

International Telecommunication Union – The ITU offers various guidelines on what to do if a certain malicious events were to occur and contains information of what to do when these events happen. The ITU explains security management should follow a certain set of procedures if an attack was to happen [49].

Table (6) has been created below and highlights the three most common attacks in terms of the transmission of ultrasound data over 5G networks. The table contains three columns including name of attack, description of attack, security mechanism to avoid the attack, and the likelihood of the attack happening.

Name of Attack	**Description**	**Security Mechanism**	**Likelihood (1-5)**
MiTM (Man-in-the-Middle) attack.	The hacker manages to intercept the communications between two parties over a network. He then has the potential to eavesdrop on the communication or change the communication data [4.2.2].	To prevent such an attack, it is important to use a VPN to encrypt all traffic and data transmission over the network. This reduces the attackers ability to read/modify the data. Also, secure incident response plans and intrusion detection systems are required [51].	4/5
Intercepting Calls/ Location Tracking	If the hacker knows any information about the broadcast paging protocols, the two adjacent attacks are possible [4.2.4] [4.2.5].	The 5G network is more intrusive than previous generations, exact locations can be more precise than that of 4G networks hence a VPN could make this information encrypted.	2/5
DDoS (Distributed denial-of-service) attack.	This type of attack is when a hacker floods a network or webpage to take it offline [4.2.1].	A good DDoS response plan can be used to enforce a defence strategy and by monitoring the network for unusual activity can help spot and deal with a DDoS attack [50].	2/5

Table 6: *Ultrasound Transmission Possible Attacks.*

[5.7] CONCLUSION

It is clear to see that the aims and objectives of the research project have been met.

The main aim of the research project was to *'Provide a contribution to the future development and research of 5G technology specifically when streaming large ultrasound video files over 5G networks'*. this aim was then broken down into four distinct objectives.

The first objective states that upon completion of the dissertation, one *will 'be able to provide an analysis of the Quality of Services (QoS) when transmitting large ultrasound video files over 5G networks.'* Section [5.4] deals with this objective and the findings from the research suggests that the QoS will be significantly improved in the cities mentioned in the RootMetrics [48] study however, rural areas may struggle because they do not have the underlying hardware for the installation of these networks which was analysed in detail in section [4.3.1].

The second objectives states that one should be able to *'Provide an analysis of the Quality of Experience (QoE) when transmitting large ultrasound files over 5G networks.'* upon completion of such a research paper. Section [5.3] deals with this objective and contains an in-depth analysis of the main factors which could impact the QoE when transmitting ultrasound video files over 5G networks. Many factors such as Cost, Reliability, Efficiency, Privacy, Security, User Experience (UX), User confidence and Environmental variables such as the Application for which the 5G network is being deployed and the influence of fixed and mobile networks have been found to greatly influence the QoE. It is important to consider these factors when deploying a 5G network in a medical environment, if these factors and variables are controlled and setup correctly, it is predicted that 5G technology will allow for faster data access speeds, faster download speeds and streaming of content via the network. 5G networks claim to offer almost instantaneous connection speeds, lower latency and advanced antenna technology which allows for the process of beam steering which greatly improves the transmission of ultrasound videos over 5G networks both in fixed and mobile scenarios.

The third objective which states that one must '*Conduct a thorough evaluation of the security risks involved with transmitting such data and discuss possible cyber-attacks and preventative measures*

to deal with these attacks.' Has been completed successfully. Section [5.3.4] and section [5.5] deal these security risks. Section [5.3.4[] highlights the relationship between the privacy and security of a network and its implication on the QoE and discusses the potential for new types of attacks on these networks which we have not seen before such as that of the 'downgrade attacks'. Section [5.5] gives an overall summary of the findings in terms of security and refers to section [4.2] which highlights all the most common cyber threats that 5G networks are prone to and contains a detailed breakdown of the preventative measures that can be put in place such as VPNs and network monitoring to avoid some of these malicious attacks and improve the security of the transmission of data via 5G networks.

For assurance that the network is secure, all eventualities need to be covered and effective security policies need to be defined.' Section [5.6] explains what policy-based security involves and contains a brief overview of a few of the most relevant policies relating the hypothesis such as authorisation policies and obligation policies.

The fourth and final objective of this dissertation says that one should *'Overall, explain why adopting such technologies would be beneficial and propose possible future research in the area'.* Chapter [5] contains an analysis of the findings of the literature review and research conducted. Many different concepts such as simulation of networks, factors effecting the QoS and QoE as well as some consideration on the security of such systems are discussed and it is clear to see that the findings suggest that 5G technologies are beneficial in the field of 5G transmission, various reasons for why this technology is better than previous generations were uncovered such as increased data transmission speeds and low latency communications to name a few however, it has to be noted that many things effect the successful deployment of such technologies such as cost and environmental factors such as fixed and mobile location need to be considered and all security vulnerabilities covered in order for the successful deployment of such networks and for them to be able to be operating at the optimum service level which is important in crucial applications such as that of medical ultrasound streaming/transmission can be improved by the use of such technologies such as mobile, fixed femtocells and network slicing. It is predicted that 5G should excel when compared to its predecessors and section [2.3] proves that this type of technology is already being used and is bringing with it massive benefits for patients and healthcare professionals alike.

According to recent findings by Oracle*, 'During retrieval the system streams data from the database to the client at a rate that saturates the network hence the speed is as fast the current hardware will allow. Cardiac CT images, which were specifically requested were retrieved at the rate at an average rate of 852 images/second for approximately 1497 Cardiac CT studies/hour. There is a variation in retrieval rates among the different modalities due to the variation in image sizes. On a two-node RAC cluster, 2768 Cardiac CT studies were retrieved per hour at an average rate of 1575 images/sec. the data volume metric of the two-node RAC cluster was measured at a sustained rate of 1 GB/sec. 970 new Cardiac CT studies per hour were written to the database at an average rate of 554 images/sec. During simultaneous retrieval and writing of Cardiac CT images, over 1200 Cardiac CT studies were retrieved per hour and 760 new studies were written into the database* [54]. The findings from Oracle show that the theoretical 4G data limit has already been achieved which means that it is impossible to transmit and write these complex images and videos any faster due to the limit of the current infrastructure. With 5G technology, 10Gbps maximum download speeds are claimed to be available which would allow for great amounts of data to be transmitted in a small amount of time, improved QoS, QoE and security.

For one to fully understand to what extent 5G will benefit the healthcare industry, the approximate speed for the transmission of ultrasound videos via the use of 4G networks is given in the table below:

Modality	Average Image Size (MB) READ.	Average Image Size (MB) WRITE.	Reading Images (MB/SEC)	Writing Images (MB/SEC)
ULTRASOUND	**27.5**	**26.1**	**458**	**391**

Table 7: *Ultrasound Transmission Theoretical Speed (4G).*

The estimated speed for the transmission of ultrasound videos over 5G networks is predicted to be approximately 10x faster than that of the 4G infrastructure, the approximate speed for the transmission of ultrasound videos via the use of 5G networks is given in the table below:

Modality	Average Image Size (MB) READ.	Average Image Size (MB) WRITE.	Reading Images (MB/SEC)	Writing Images (MB/SEC)
ULTRASOUND	**275**	**261**	**4,580**	**3,910**

Table 8: *Ultrasound Transmission Theoretical Speed (5G).*

[5.8] FUTURE CONSIDERATIONS

It is clear to see that this research paper opens the door to many avenues of novel research. The amount of research conducted in the field of 5G transmission is sparse and there are various gaps which need to be filled to evolve to the next stage of understanding. This section presents three possible future research opportunities that need further exploration.

- *Optimisation of 5G networks for improved transmission speed.*

This is a crucial research area which will bring benefits to many different subject fields. The aim of such a research paper would be to investigate the transmission of data across 5G networks and find out what variables affect the transmission. The cutting-edge technologies will also be investigated and a complete breakdown of all factors which effect transmission will be presented before predicting the best solution to improve the overall transmission speed.

- *Vulnerabilities of 5G small cell and mobile small cell networks.*

This research paper is more fitted to one who is pursuing the fields of cyber security. The main aim of the paper is to investigate the different vulnerabilities that are common on both small cell networks and mobile small cell networks. this research paper will analyse all possible attacks and points where the 5G infrastructure could be breached and presents the solution to avoid these attacks and how to deal with such attacks if they were to occur. The paper would consider all the latest research which is relevant and provide a complete breakdown and analysis of the tools which could be used to exploit such networks and tools which can prevent such breaches of security.

- *Health implications of 5G waves on human biology.*

Recently, there has been a lot of stigma attached to 5G technology and many individuals believe that 5G waves have the potential to cause damage to the immune system hence, increasing the human beings chances of getting ill. One would provide a complete breakdown of all factors and academic research linking this theory and providing evidence of how this technology works and the possible side effects of this technology based on scientific and academic information.

- *Possible Security Risks Associated with the increasing IoT.*

The increasing amount of data which is generated by these IoT solutions contain a large amount of data which gives insights on how individuals live and the way we work. Although there is a lot of benefits of the IoT, privacy and security are an area which needs more research. One would conduct research into the modern IoT ecosystem and understand how data is sent via cellular networks and cloud applications to understand the potential security risks associated with the IoT and be able to provide a full breakdown of the most common security threats associated with these systems and give potential solutions and mechanisms to avoid/counteract these threats.

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TABLE OF TABLES

TABLE OF FIGURES