Optimization of Bandwidth for Ultra-reliable and Low Latency Communication using Compression

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Annex A

THESIS ACCEPTANCE CERTIFICATE

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Date: 15 AUG 2023

This thesis is dedicated to my beloved parents.

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Abstract

4G and 5G are emerging technology that provides high data rates with reliability and optimized latency, as compared to the other (LTE, CDMA, HSPA) technologies. This technology provides three types of services: mMTC (Machine Type communication) which is already been developed as part of 3GPP release 13/14, eMBB(enhanced Mobile Broadband) which provides enhanced bandwidth with moderate latency, and uRLLC(Ultra-reliable and low latency communication) which is introduced in 3GPP-release 15/16 and is still under development. Ultra-reliable and low-latency communication service requires strict latency and reliability. URLLC focuses on applications that expect precise real-time communication for autonomous vehicles, advanced power grids, device communication for accidents and emergencies, industrial communication (e.g., wireless operation of equipment), and health care (e.g. remote operations and monitoring). The proposed research focuses on the efficient utilization of bandwidth at Layer 2 of the protocol stack for ultra-reliable and low-latency applications in 5G/4G or any other RAT (Radio Access Technology) by using a novel header compression approach called "Robust Header Compression" and analysis its impact for network and upper layers header compression for the application of telesurgery. RoHC is implemented and data is simulated. Comparison is made on the bases of the original and compressed header. This compression approach compresses the IP, UDP and RTP header. Multiple compression scenarios have been analyzed and compression ratios are measured for URLLC telesurgery application.

Keywords: *sentiment analysis, Covid-19, tweets, coronavirus, Twitter, machine learning algorithm, deep word embedding, BERT.*

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List of Abbreviations and Symbols

URLLC	Ultra-Reliable and Low Latency Communication
MAC	Medium Access Control
QoS	Quality of Service
SN	Sequence Number
IP	Internet Protocol
UDP	User Datagram Protocol
TCP	Transmission Control Protocol
RTP	Real-Time Protocol
PDCP	Packet Data Convergence Protocol
RoHC	Robust Header Compression
EHC	Ethernet Header Compression
TDD	Time Division DuplexMultiplexing
FDD	Frequency Division Duplex
RLC	Radio link control
RRC	Radio Resource Control

CHAPTER 1: INTRODUCTION

Telecommunication plays a crucial role in healthcare by enabling the exchange of information and delivery of medical services remotely. It allows the healthcare professionals to provide medical services to patients remotely, through video conferencing, telephone calls or secure messaging platform, a branch known as telemedicine provides virtual consultation, diagnoses, and treatment without the need for in-person visits. With the development of modern technologies, it enables remote monitoring of patient's vital signs, chronic conditions, and overall health status. Medical devices and wearable equipment equipped with telecommunication capabilities can transmit data such as blood pressure glucose level, heart rate, and activity levels to healthcare providers, this remote monitoring provides healthcare professionals to track patients' health conditions and identify potential issues.

Remote surgery, also known as telesurgery or robotic surgery, is a surgical procedure performed by a surgeon who is not physically present in the same location as the patient. Instead, the surgeon controls robotic surgical instruments equipped with high-definition cameras remotely through advanced telecommunication technologies. Advanced telecommunication technologies, such as high-speed internet, low-latency networks, and secure data transmission, are essential for remote surgery. These technologies enable real-time communication between the surgeon and the robotic surgical system, ensuring that the surgeon's commands are accurately transmitted to the robotic instruments. Because robotic surgical systems used in remote surgery offer enhanced precision and dexterity compared to traditional surgical techniques and the robotic instruments can replicate the movements of the surgeon's hands with greater precision, allowing for more precise surgical maneuvers. So high speed internet and low-latency networks are particularly important for these procedures. Remote surgery presents several challenges and considerations. One critical aspect is ensuring the reliability and security of the telecommunication infrastructure to maintain uninterrupted and secure communication between the surgeon and the robotic system. Latency or network disruptions could have serious consequences during surgery. Surgeons also need to undergo specialized training to operate robotic systems effectively and adapt to the differences in tactile feedback compared to traditional surgery. It's worth noting that while remote surgery has shown promise and has been successfully performed in certain cases, it is still a developing field. Ongoing advancements in telecommunication technologies, robotic systems, and surgical techniques continue to shape the future of remote surgery, with the potential to transform the way surgical care is delivered.

One of the fundamental requirements for efficient data transmission in healthcare and telesurgery is high-speed internet connectivity. A robust internet connection ensures fast and reliable communication between the surgeon and the robotic surgical system, minimizing delays between commands and system responses. High-speed internet is also essential for transmitting large medical imaging files, patient data, and real-time video feeds during telesurgery. To support efficient data transmission and ensure reliable connectivity, healthcare facilities and telesurgery centers can benefit from establishing a dedicated network infrastructure. This can include dedicated fiber-optic connections, virtual private networks (VPNs), and quality-of-service (QoS) configurations to prioritize critical data traffic. A dedicated network infrastructure helps mitigate the risk of network congestion, provides better control over data transmission, and ensures a secure and efficient communication environment. Efficient data transmission in telesurgery requires prioritization of critical data traffic to maintain low latency and minimize packet loss. QoS mechanisms can be employed to prioritize real-time video streams, surgical commands, and other mission-critical data over less time-sensitive data. By assigning appropriate priority levels to data traffic, QoS ensures that tele surgical instructions are promptly and accurately transmitted to the robotic surgical system, enhancing the overall efficiency and safety of telesurgery procedures.

Optimizing bandwidth usage is crucial to ensure efficient data transmission during telesurgery. Large volumes of data, including high-resolution medical images and real-time video streams, are transmitted during tele surgical procedures. Bandwidth optimization techniques such as data compression and minimizing unnecessary data transfers help reduce the size of data files without compromising their quality. By optimizing bandwidth, network congestion can be minimized, ensuring smooth data transmission, and reducing the risk of delays or interruptions.

Bandwidth optimization plays a crucial role in healthcare and specifically in telesurgery, where efficient data transmission is essential for successful remote surgical procedures. Here are some key reasons: -

1. Real-Time Communication: Telesurgery requires seamless real-time communication between the surgeon and the robotic surgical system. By optimizing bandwidth, data

can be transmitted with minimal delays, ensuring that the surgeon's commands are promptly and accurately received and executed by the robotic instruments. This real-time communication is crucial for maintaining the precision and synchronization required during surgical procedures.

2. Minimizing Latency: Bandwidth optimization helps reduce latency, which is the time it takes for data to travel from the sender to the receiver. In telesurgery, even small delays in data transmission can significantly impact the surgeon's ability to control the robotic surgical system. By minimizing latency through bandwidth optimization, surgeons can have more immediate control over robotic instruments, enhancing their dexterity and precision during surgical procedures.
3. High-Quality Video Transmission: Telesurgery often relies on high-definition video transmission to provide the surgeon with a clear and detailed view of the surgical site. Bandwidth optimization techniques, such as compression algorithms, help reduce the size of video files without compromising their quality. This enables high-quality video transmission over limited bandwidth connections, ensuring that the surgeon has a clear visual representation of the surgical field.
4. Efficient Transmission of Medical Imaging: Telesurgery may require the transmission of medical imaging files, such as X-rays, CT scans, or MRIs, for accurate pre-operative planning and intraoperative guidance. These imaging files can be large and data intensive. Bandwidth optimization techniques help compress and transmit these files efficiently, ensuring that they reach the surgeon in a timely manner without overwhelming the available bandwidth.
5. Minimizing Network Congestion: Bandwidth optimization techniques help minimize network congestion by reducing the amount of data transmitted and prioritizing critical data traffic. In healthcare environments where multiple applications and systems compete for bandwidth, optimization ensures that telesurgery-related data takes precedence. This minimizes the risk of network congestion, improves overall network performance, and prevents delays or interruptions during surgical procedures.
6. Cost-Effectiveness: Bandwidth optimization can lead to cost savings in healthcare and telesurgery. By efficiently utilizing available bandwidth, healthcare organizations can avoid costly network upgrades or investments in additional infrastructure. Bandwidth optimization techniques help maximize the utilization of existing resources, enabling healthcare providers to deliver tele surgical services effectively without incurring

significant expenses.

7. Accessibility and Scalability: Bandwidth optimization allows healthcare organizations to extend tele surgical services to remote or underserved areas where internet connectivity may be limited. By optimizing bandwidth usage, telesurgery can be performed over various network connections, including satellite or cellular networks, expanding access to specialized surgical care. Additionally, bandwidth optimization facilitates the scalability of telesurgery services, accommodating a larger number of procedures and supporting the growth of telemedicine initiatives.

The advent of 5G technology holds significant potential for transforming healthcare in various ways. 5G networks offer exponentially faster speeds and lower latency compared to previous generations of mobile networks. This enables healthcare providers to leverage high-quality video conferencing, telemedicine, and remote patient monitoring solutions with minimal lag or disruptions. The low latency and high bandwidth of 5G networks make it well-suited for telesurgery and remote surgical applications. With 5G, surgeons can remotely control robotic surgical systems in real-time with enhanced precision and minimal delay. This opens opportunities for expert surgeons to perform complex surgeries in remote or underserved areas, improving access to specialized surgical care and reducing the need for patient transportation. The Internet of Medical Things (IoMT), which includes interconnected medical devices and wearables, generates a vast amount of data that needs to be transmitted securely and efficiently. 5G networks provide the necessary capacity and speed to handle this data influx effectively. With 5G, medical devices can communicate seamlessly, enabling efficient data collection, analysis, and integration into electronic health records.

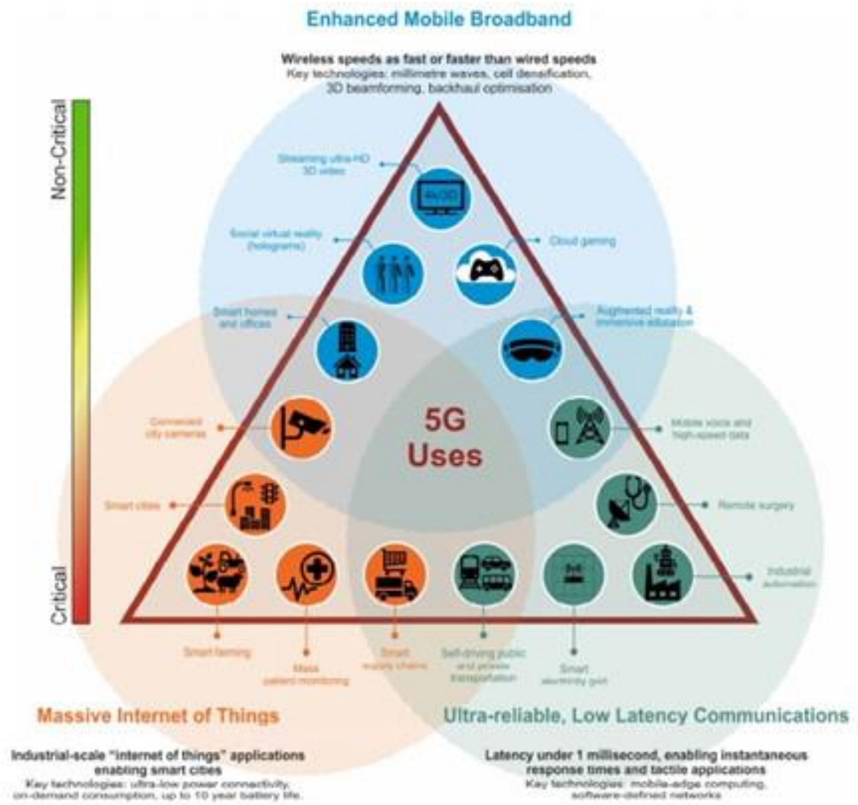

Figure 1: 5G Applications

Figure 1 illustrates, 5G technology offers a range of services and capabilities that have the potential to transform various industries, including healthcare.

1. Enhanced Mobile Broadband (eMBB)
2. Ultra-reliable and Low Latency Communication (URLLC)
3. Massive Machine-Type Communications (mMTC)

5G provides significantly faster speeds and higher capacity compared to previous generations of mobile networks. This enables users to experience enhanced mobile broadband services, such as ultra-high-definition video streaming, seamless video conferencing, and fast file downloads. 5G technology provides ultra-reliable and low-latency communications, making it suitable for mission-critical applications. Industries such as public safety, emergency services, and transportation can benefit from 5G's ability to support critical communications with high reliability, fast response times, and uninterrupted connectivity. This ensures reliable and efficient communication in situations that require immediate action. 5G facilitates the connection of a massive number of devices in a single area, enabling machine-type communications. This is particularly relevant for applications like smart cities, smart grids, industrial automation, and environmental monitoring. 5G introduces the concept of network slicing, where a single physical network infrastructure is partitioned into multiple virtual networks to cater to different use cases and requirements. This allows for customized service offerings and optimized resource allocation for specific applications. In healthcare, network slicing can be leveraged to provide dedicated and secure connectivity for critical medical applications, telemedicine services, and IoT devices.

As we know, the population of the world is growing fast and so are diseases, due to limited resources it very important to optimize the utilization of resources. In the sector of telecommunication, bandwidth is one of the most important resources, with the increase in population, usage of telecommunication in electronic devices has been increased and that usage is growing rapidly faster than we imagined. According to the standard ITU-R M.2410-0 the minimum requirement of device density is 1000000 devices per km2. Despite the dedicated bandwidth for ultra-reliable and low latency communication service, there are a huge number of users and services to use URLLC and it has been discussed earlier how bandwidth impact the network and health sector. data compression, prioritization, and selective transmission, data aggregation, defining QoS rules, based network structure, local caching, and offline storage. Besides critical data, there is a network overhead with every data packet. The reduction in network overhead plays a significant role in optimizing bandwidth for healthcare, especially telesurgery. Robust Header Compression (RoHC) is a technique to optimize the network header by compressing the information. This thesis focuses on the implementation of RoHC for URLLC at the network layer, how it reduces the network overhead for multiple type of network traffic in multiple scenarios, and its effect on ultra-reliable and low-latency communication service.

CHAPTER 2: PROBLEM FORMULATION

In this chapter, we will be discussing the main problem that this research will be addressing. Also, the challenges that researchers faced during the work, and the components of solutions to the problem are also discussed here.

Medical sciences made tremendous progress in the 21st century, cures to many diseases have been discovered, new technologies play a vital role in this development. Whereas in recent years communication has become the backbone of almost every technology and field of life. Communication opens up a new era of advancement by introducing the 5th generation of

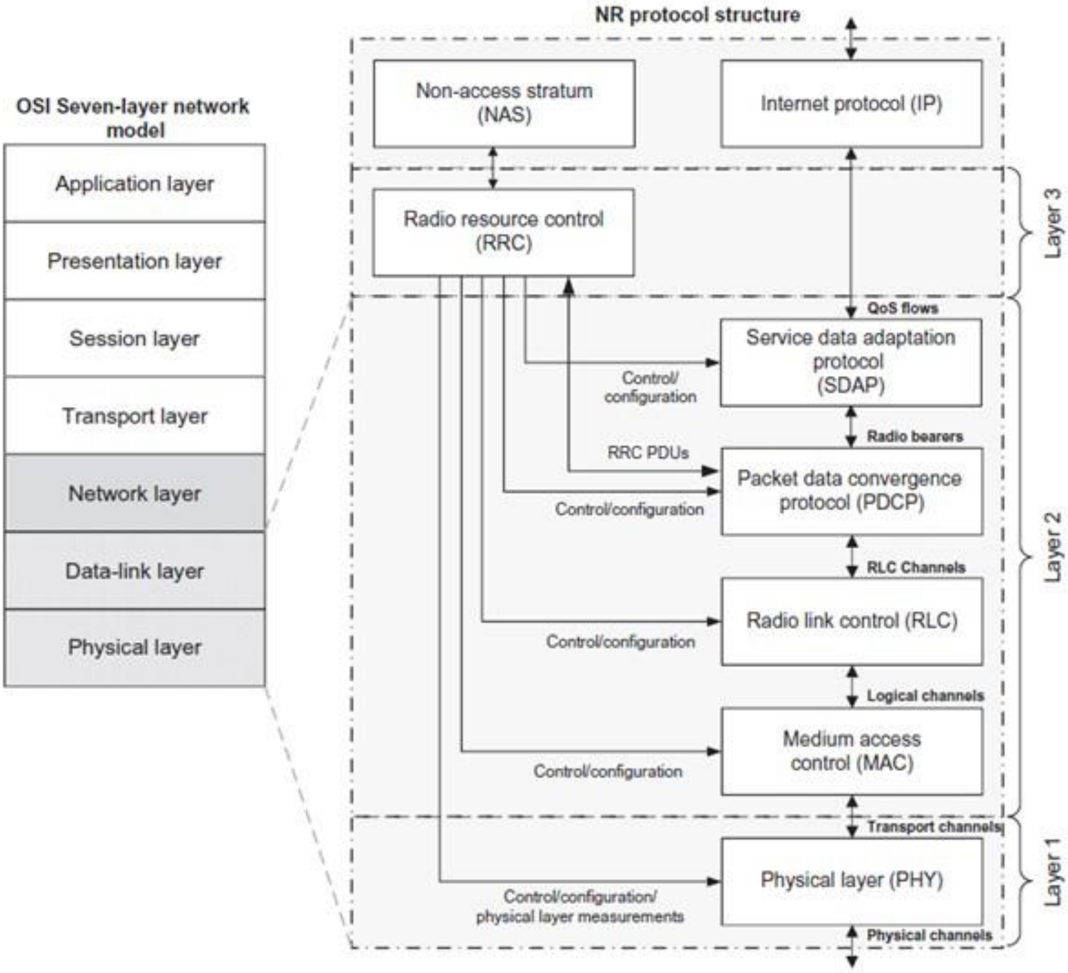

Figure 2: 5G NR Protocol Structure Mapping to OSI Seven-layer Model

networks also known as 5G, It has been deployed at some places and enhancements are under process as well, whereas the 6G networks study is under process and research is on the way. These new enhancements enabled a lot of opportunities in many filed of science where communication is the bottleneck, Now, 5G data rates can be delivered up to 20 Gbps and on average 100Mbps which is much faster than 4G. In 5G three new types of applications or we can say services are introduced eMBB, eMTC, and URLLC. The scope of these services has been described in 1st chapter of this thesis.

Medical services are a critical type of service that lies under the umbrella of URLLC. URLLC deals with the critical type of information transmission, and it makes sure the communication latency must be minimum and data reliability must be maximum. According to 3GPP specification, the latency requirement is 1 millisecond and for this purpose, they introduced an advanced TDD and FDD structure at the physical layer. While layer two offers integrity, security, and management of data packets. At layer two, a new sublayer SDAP is introduced to manage the QoS flow, which can be seen in the figure \ref{fig:2}. The figure represents the mapping of the 5G NR protocol structure to the OSI seven-layer model, It can be seen NR protocol structure replaces the datalink and physical layer, while the network layer connects with the NR SDAP layer. Currently, compression is not an essential component of the protocol structure, but it supports EHC and RoHC.

The network and upper layers have a lot of redundant information that transmits in every packet. The size of this information varies from 28 to 60 bytes based on the used protocol. Normally, this is not a big issue over traditional networks, but when it comes to critical time-sensitive information which uses time-sensitive networks it becomes a big overhead. URLLC is designed to address time-sensitive communication in 5G and on-word networks. Telesurgery is one of the applications that use time-sensitive networks. This thesis focuses on the analysis of how much Robust Header Compression – RoHC can contribute to the optimization of bandwidth by compressing network and upper layer headers. RoHC usually offers multiple profiles for different protocols. RFC 3095 is used for the implementation of RoHC. The RFC offers compression of IP, UDP and RTP protocols. These protocols used in real time audio and video streaming and can be used for machine operation for telesurgery. RoHC will be the part of packet data convergence protocol (PDCP).

CHAPTER 3: LITERATURE REVIEW

5G technology has been transforming the health sector for years due to its potential to bring forth advance and more reliable solutions. It has introduced multiple solutions that enable the healthcare industry to perform tasks faster with more reliable communication, advanced data transfer, and improved connectivity. 5G technology has offered significantly increased data transfer speeds and reduced latency to the domain of telemedicine. The comparison of the speeds proved that 5G enables solutions to run up to 100 times faster than 4G while enabling seamless and high-quality video sessions between doctors and patients [1]. Moreover, where 4G and 3G faces interruptions in the network, 5G offers a smooth connection while eliminating disruptions, which leads to improved patient satisfaction and accurate diagnoses [2]. Another study used remote acoustic field testing along with telerehabilitation powered by 5G to check the response of doctors and patients. Remote ultrasound and physical activities were performed by the patient and monitored by the doctor via 5G connection. The study found that the transmission was faster and offered lesser delays giving doctors a chance to provide real-time diagnosis with accuracy [3].

5G technology can also be seen gaining attention in the field of medical devices and wearables. This technology has been enabling the production of connected medical devices and wearables including smartwatches, fitness trackers, and remote monitoring devices [4]. During the last few years, the number of medical wearables has increased in the market given their increased usage mostly by the elderly in the society [5]. Majority of these devices are designed to collect and transfer health-related data to healthcare professionals like doctors and nurses in real time. The real-time transmission of data has proven to be helpful in continuously monitoring patients for early detection of abnormalities or any health issues [6]. This has also aided in providing necessary medical care to the patients and design solutions for them in advance. Research comparing the benefits of medical devices running on 5G with the devices running on its alternatives proved that 5G wearables are securer, offers to connect an increased number of connected devices per square KMs, better service reliability, and mobility [7].

A huge issue faced with the medical wearables today is their security as they are always at the risk of getting hacked by hackers. This raises issues in authentication and identity management for many people. The solutions of IoT in the healthcare wearables merged with

5G offer a better chance at having a secure and protected experience due to its ability to provide a smooth experience even when moving around and fast data transmission [8]. Since these wearables are also connected with devices like mobile phones, once hacked, the hacker can easily access other data stored in the phone as well. This can become a major concern for privacy as well [9]. A study presented a model for healthcare wearables powered by IoT and 5G promising faster communication, better security, stricter authentication, privacy, and good identity management [10].

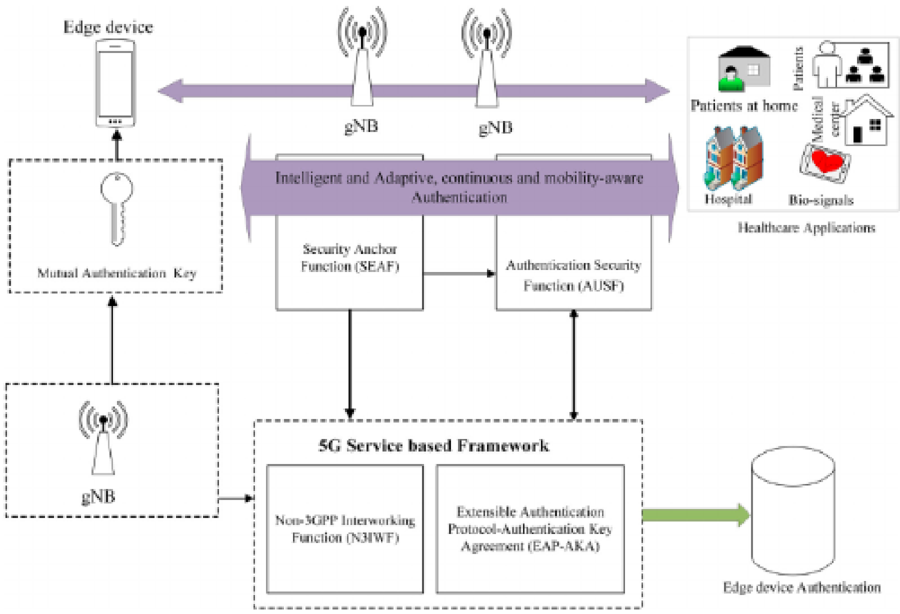

Figure 3: Authentication model for IoT-based 5G healthcare wearables

Since the world is moving towards experiences empowered by artificial intelligence, Augmented Reality and Virtual Reality in healthcare domain are becoming rapidly famous. This has led into the development of various medical solutions designed around AR and VR. One of the biggest benefits of 5G is its ultra-low latency and high bandwidth capabilities that has supported AR and VR in healthcare in delivering seamless and immersive experiences to prepare medical professionals for providing guidance and care [11]. This has also empowered patients to get real-time interactions, precise surgical guidance, remote collaboration among doctors, and enhanced training simulations [12]. Moreover, it has also been successful in providing surgeons with real-time supervision in operation room during complex procedures. Due to its ability to provide stable and fast transmissions, surgeons can visualize critical information like patient-specific anatomical data, medical imaging overlays, and instructions related to a procedure within their field of view increasing surgical precision, reduction in errors, and better surgical outcomes [13].

5G technology is also powering remote medical training and education by providing immersive virtual reality experiences. It enables medical students and professionals to take a part in virtual simulations, realistic surgical training, and interactive educational modules, regardless of their physical location [14]. It prepares them to be able to stand in the operation room and navigate through the complex structure of human body and perform successful surgeries [15]. The high bandwidth capabilities of 5G guarantee the smooth transmission of high-definition Virtual Reality content, resulting in an engaging and highly effective learning environment [16]. The integration of 5G with augmented reality and VR also opens up numerous possibilities for therapeutic interventions. Patients suffering from chronic pain, anxiety disorders, or phobias experience significant benefits through immersive VR experiences tailored to alleviate their symptoms and enhance their overall well-being [17]. Therapists despite being physically distant can remotely guide patients through virtual setups, offering exposure therapy, relaxation techniques, and cognitive-behavioral interventions [18].

5G technology is playing a pivotal role in revolutionizing medical imaging and collaboration among healthcare professionals as well. It has transformed the healthcare landscape and improved patient outcomes. The high bandwidth and low latency offered by 5G networks supports the seamless transmission of large medical files like CT scans, MRIs, and 3D reconstructions [19]. This enables doctors to access and analyze complex imaging data remotely to provide early diagnosis and plan treatment accordingly. Additionally, Augmented Reality powered by 5G technology can overlay imaging data onto patients in real time, promising continuous visualization and enhancing surgical precision [20]. Moreover, 5G supports healthcare professionals to collaborate with each other whenever needed without the hassle of delays and lags. Surgeons can use 5G to consult with remote specialists, get second opinions, and livestream real-time surgical procedures to seek guidance or for educational purposes. The immersive nature of Augmented Reality and Virtual Reality enables remote teams to seek each other’s opinions and have discussions on treatment plans, perform research, and innovate new solutions for the betterment of patients. It has also proven to be beneficial during emergencies and natural disasters [21]. It enables healthcare professionals, emergency responders, and authorities in having reliable and fast communication. Sharing of data in real-time, including patient information, test results, imaging results, and logistical coordination, has significantly improved emergency response times and the efficiency of medical interventions [21].

5G technology has branched into two main categories based on its architecture. The first category is called Non-Standalone or NSA 5G. This category is mostly used in the initial phase of 5G deployment. Networks based on NSA 5G rely on the existing infrastructure of 4G LTE as an anchor to control the signaling and management functions. In-depth study of this architecture reveals that in it the 5G radio access network is connected to the 4G core network, called EPC - Evolved Packet Core, which allows devices to stay connected to both 4G and 5G networks at the same time [22]. The most quoted benefit of NSA 5G is the faster data speeds and lower latency than 4G, however, on the downside, it doesn't leverage the progressive abilities and power of 5G to their full potential [23]. The second category is known as Standalone 5G architecture that represents the complete application of 5G technology. SA 5G operates without depending on the 4G infrastructure. In place of 4G infrastructure, it utilizes a new core network called the 5G Core commonly known as 5GC. Standalone 5G enables end-to-end 5G connectivity along with the advanced features such as network slicing, edge computing, and ultra-low latency [24]. It utilizes 5G infrastructure to its best with making 5G specifications the base for signaling and management promising improved performance, low latency, and the ability to fully utilize the unique capabilities of 5G [25]. A good number of people like to design solutions that are based on the NSA 5G architecture and then slowly shift on the SA 5G, however, the advancements in the domain of 5G is making it easy for people to fully trust 5G and start with SA 5G architecture in the first place.

An in-depth study of 5GC architecture shows the network functions and entities it is made up of. These entities include Access and Mobility Management Function (AMF), User Plane Function (UPF), Session Management Function (SMF), Policy Control Function (PCF), Authentication Server Function (AUSF), Unified Data Management (UDM), Network Repository Function (NRF), and Network Slice Selection Function (NSSF). The management for mobility of user equipment (UE) and access-related procedures is taken care by the Access and Mobility Management Function. AMF manages the connection and authentication of user equipment and mobility management functions like handover and roaming. The UPF takes care of the user plane traffic in the 5G network like packet routing, packet forwarding, traffic management, and quality of service enforcement. It ensures efficient data transfer between the UE and external networks. In the 5G network, the SMF controls session creation, modification, and termination. It manages routing, control, and policies pertaining to sessions, as well as the assignment of network slices for various service needs. The PCF is in charge of controlling and enforcing policies. It controls access control, traffic management, billing, and QoS policy rules. It makes sure the network runs in accordance with the established policies and offers the necessary level of service quality. Similarly, the AUSF is in charge of security and authentication-related tasks. It offers security parameters, authenticates UEs, and guarantees secure connection between the UE and the network. In the 5G network, the UDM is in charge of managing user-related data. User profiles, authentication details, subscription information, and other pertinent data needed for user services and functions are all stored and managed by it. The NRF performs service discovery and registration tasks. In order to facilitate effective communication and coordination between various entities, it stores information about the network functions and services that are offered. Network slices must be chosen and assigned by the NSSF depending on service requirements. It chooses the best network slice based on the latency, bandwidth, and QoS needs of a specific service or application.

The services provided by 5G solutions can be divided into multiple categories based on the architecture. SA 5G infrastructure empowers services including Enhanced Mobile Broadband (eMBB), Ultra-Reliable-Low-Latency-Communications (URLLC), and Massive Machine-Type Communications (mMTC). These services are built on the same 5G Core architecture, which makes them flexible and scalable to provide services to complex applications and solutions. Enhanced Mobile Broadband focuses on delivering high-speed, high-capacity mobile broadband services for an enhanced user experience for apps like 4K/8K video streaming, online immersive gaming, virtual reality (VR), augmented reality (AR), and multimedia content. The 5GC architecture ensures competent data transmission and management to meet the requirements of eMBB services. With eMBB, users can experience ultra-fast download and upload speeds, high-quality streaming of multimedia content, and seamless connectivity in crowded areas. It is believed that eMBB will transform the industry of media in the years to come. eMBB is used to enable seamless video conferencing and high-quality audiovisual communication between various healthcare providers and patients. It empowers solutions to allow remote consultations, diagnosis, and monitoring of patients possible, eradicating the need for in-person visits in some cases and intensifying access to healthcare services, especially in remote areas. Its high bandwidth facilitated the transmission of large medical imaging files like CT scans, MRIs, and ultrasounds, in real-time without any lags. This helps radiologists and other healthcare professionals to gain remote access to imaging data, analyze it, collaborate with specialists, and make more accurate and timely diagnoses. It also supports the development and use of mHealth apps, including health monitoring, wellness tracking, and medication management. These apps rely on high-speed connectivity for transmitting data from wearable devices and sensors to doctors or cloud-based platforms for further analysis and monitoring.

The focus of mMTC is on supporting massive-scale machine communication, aiding the connection of a huge number of devices and sensors essential for apps in the Internet of Things (IoT), smart cities, smart agriculture, industrial IoT, environmental monitoring, and asset tracking. The architecture of 5GC gives the necessary scalability, proficiency, and resource management abilities to take care of the massive number of connected devices and their communication needs [26]. It supports the deployment of a large-scale network of sensors, smart devices, and IoT applications that require long battery life, low power consumption, and efficient use of network resources. The applications of mMTC are getting famous in different domains of real-life. In smart city programs, mMTC is used to manage resources effectively, monitor infrastructure, and enhance resident quality of life. It enables the placement of various sensors and gadgets all around the city to gather information on trash management, energy usage, traffic movement, and other topics [27]. It is essential to industrial automation because it enables the connection and communication of many different machines, sensors, and devices in production facilities. Real-time monitoring, proactive maintenance, process improvement, and overall operational effectiveness are made possible [28]. Large-scale sensor networks can be deployed in the agricultural industry to keep an eye on crop health, irrigation efficiency, and soil conditions. Farmers may apply precision agriculture, boost crop yields, and optimise resource use with the aid of this data-driven strategy. It makes it possible to track and monitor products in real time throughout the supply chain. It enables effective inventory management, asset tracking, shipment monitoring, and predictive analytics, enhancing the visibility and responsiveness of the entire supply chain [29]. By enabling wearable technology, telemedicine, and remote patient monitoring, it is revolutionising healthcare. It enables ongoing patient care, real-time data transmission, and remote consultations, which improve patient outcomes by lowering hospital admissions and improving patient care.

URLLC, on the contrary, is designed to give ultra-reliable and low-latency communication for apps requiring real-time, near-zero latency, and mission-critical services like autonomous vehicles, industrial automation, real-time monitoring, and remote surgery. It enables real-time data transmission, quick response times, and ensures a highly reliable and robust network connection, making it suitable for scenarios where even milliseconds of delay can have significant consequences [30]. The 5GC architecture makes sure that the network meets the stringent reliability, latency, and availability requirements of URLLC services. Like eMBB and mMTC, URLLC is also famous in the medical industry for various reasons. It has proven its worth in emergency situations by offering solutions that offer establishment of a stable communication channel between medical professionals, emergency responders, and authorities involved in the rescue missions [31]. Solutions designed on URLLC enable humans to have a high-reliability communication aiding in swift decision-making, exchange of necessary information, and coordination of rescue efforts. These solutions have helped in providing efficient emergency response and improving patient outcomes. It also facilitates real-time monitoring of patients through smart wearable devices and sensors embedded in them [32]. These devices and sensors enable seamless transmission of crucial healthcare data, such as heart rate, body temperature, blood pressure, or glucose levels, with minimal latency. This fast and seamless connection enables healthcare providers to monitor patients' health conditions remotely in real time aiding in early detection of abnormalities and timely interventions.

Another major role played by URLLC in the medical industry is enabling connected ambulances and mobile clinics to have reliable and low-latency communication [33]. These solutions offer real-time transfer of health data like temperature, blood pressure, and sugar level from connected ambulances and mobile clinics to medical professionals in the hospitals ensuring that they have access to the necessary information to give immediate and appropriate care and guidance during transit or in remote locations [34]. A study presented an efficient design and prototype capable of enabling eHealth use case in a 5G (URLLC) network slicing environment. The authors suggested the usage of network slicing for connecting an ambulance to a remote physician to guide the emergency attendants for any necessary prehospital treatment to provide medical care to the patient for avoiding any severity in symptoms [35]. Another study presented a framework based on real-time adaptive video encoding capable of ensuring fine-tuned medical video streaming in a video communication system that is wireless by nature. The authors suggested linear regression models for the presented encoding method while making sure the presence of minimum bitrate requirements and high video quality [36].

Solutions revolving around remote surgery and teleoperations are also using URLLC at its core structure. When the basics of telesurgery are observed, four major elements are found playing a crucial role. These elements include robots performing surgery, the video feedback system, the haptic feedback system, and the network connection among all the previous elements connecting them for a seamless communication [37]. This process expands the geographical coverage of experienced and competent medical personnel in remote areas and increases the usage efficiency of the medical infrastructure. However, one element that plays are breaking or making role is the network connection that has to be of exemplary quality. The system that provides haptic feedback captures and transmits both tactile and kinaesthetic feedback to the surgeon, going beyond a video-only feedback system. This haptic feedback enhances the surgeon's experience in handling virtual objects and provides additional sensory information. A remote surgery operation necessitates two network links: a forward link for transmitting commands from the surgeon's location to the remote unit, including robot control, surgeon voice data, and communication with multiple surgeon units. The feedback link involves transmitting data from the remote location to the control unit, which may include 3D video recording, haptic feedback, and voice data from the remote surgical team [8]. Moreover, haptic feedback requires a maximum latency of 19ms end-to-end [38]. Thus, an ultra-low latency and highly reliable channel are crucial for facilitating teleoperation.

Many countries like the UK, Singapore, and South Korea have already come up with solutions that offered them the ability to perform telesurgeries, however, most of these solutions lacked efficient latency and fast transfer rates. These issues can easily be tackled with the help of 5G and better solutions can be provided to people to ensure better healthcare facilities to residents of remote areas [6]. In a remote surgery experiment conducted in Canada in 2003, more than 20 common surgeries were performed over a distance of 250 miles [5]. The round-trip (RT) delay time was 15ms in a privately hired network channel, with video encoding taking over 120ms. However, advancements in computational processing have significantly reduced the video coding time over the past decades. This has made the quality of solutions offered much better, faster, more efficient, and more beneficial for the residents of remote areas. The high data rates produced, such as 1.7Mbps for uncompressed 4K video, and the stringent real-time (RT) latency requirements impose a burden on the network aspect [39].

URLLC enables remote surgical procedures through establishing an ultra-low latency communication between the surgeon present at a faraway location and the robotic surgical system present near the patient. URLLC's basic features like high reliability and low latency enable doctors to use these solutions for precise control of the robotic system and making sure that real-time feedback is shared to minimize any delays in surgical actions [40]. Solutions like this have opened up opportunities for remote surgeries, giving expert surgeons the ability and liberty to operate on patients located in remote or underserved areas using their knowledge and experience. Even though telesurgery with URLLC shows a lot of potential for a brighter future, it still has a few issues to tackle first before making it commercial. According to a research, the biggest hindrance in telesurgery becoming global is the low-latency rate and issue depending on the local internet solutions. Since telesurgery requires a high-latency and stable internet connection, the demand for a faster and more reliable connection is fair. Even though this issue can easily be resolved with 5G, it has been difficult to implement it well enough [41]. Another question that is usually asked when it comes to successful implementation of telesurgery is the ways to reduce the network overhead. This involves optimization of data transmission, implementing ways to minimize unnecessary protocol overhead, and improving network efficiency. One way to reduce network overhead is through devising various data compression techniques and reduce bandwidth usage along with lowering network overhead. These algorithms include gzip, zlib, or LZ77 (Lempel-Ziv-Markov chain). Another technique used is called caching where accessed information is stored frequently closer to the end-users reducing the repeated data transmission over the network. This results in lesser long trips for data transmission reducing overhead and making response times better. Content Delivery Networks (CDNs) are mostly used for this purpose. Some networks use data deduplication to reduce network overhead whereby identifying and eliminating duplicate data before transmission. These techniques compare arriving data with current data and transmit only the unique information, dropping redundant data transmission and preserving network resources. Protocol Optimization is also used for the same purpose where communication protocols are reviewed and optimized to eliminate unnecessary protocol layers, decrease header sizes, and minimize protocol signaling overhead. Similarly, Quality of Service (QoS) Prioritization implements QoS mechanisms for prioritizing critical traffic over non-critical traffic. It assigns appropriate priorities or weights so the network resources can be allocated efficiently, minimizing congestion and making overall network performance better than ever.

Even though these techniques have proven to be quite beneficial in many network-related solutions but the design of 5G requires techniques that are more robust and flexible. In this scenario, another technique that has been helping compressing information to reduce network overhead is known as Robust Header Compression (RoHC). RoHC is a network protocol technique widely used to optimize the network header by compressing the information. It has been used to reduce the overhead of Internet Protocol headers in packet transmissions by compressing the IP, User Datagram Protocol (UDP), and Real-time Transport Protocol (RTP) headers [42].

RoHC works by first compressing the IP, UDP, and RTP headers through deleting redundant information. The compression techniques used include header dictionaries, static compression, and dynamic compression to reduce the header size while retaining all the essential information [43]. Secondly, it performs context-based compression, where the compressor and decompressor share a context for compression and decompression of the header. The shared context includes data about previously transmitted headers, enabling the decompressor to rebuild the original headers accurately [44]. It also achieves high compression efficiency by recognizing common patterns and recurrent information in the headers and replacing redundant fields with references to minimize the overall header size. It also adapts the compression algorithm on the basis of the characteristics of the network traffic to optimize compression performance in different situations. It is also known for its error resilience where it uses mechanisms to ensure to reduce transmission errors. It uses checksums and error detection methods to confirm the accuracy of compressed headers. In case of errors, it has the ability to recover and synchronize the decompressor with the compressor to maintain the compression state and minimize the influence of errors on the decompressed headers [45]. RoHC reduces the size of IP, UDP, and RTP headers to conserve bandwidth and allow more data transmission within the available network resources.

A study evaluated the real-time transmission of GSM encoded voice and H.26L encoded video with ROHC over a wireless link. For voice transmission, the effect of ROHC on bandwidth consumption, voice quality, and delay jitter was investigated. The findings indicated that ROHC generally reduces the bandwidth needed for the transmission of GSM encoded voice in half for a wide range of error probabilities on the wireless link. Additionally, when compared to transmissions without ROHC, voice quality is enhanced, particularly for wireless links with high bit error probability. The study looked at how ROHC affected the amount of bandwidth used for video transmission. Results showed that in common cases, the bandwidth savings using ROHC range between 5 and 40% and depend on the quantization scale chosen for the video encoding and the video content [46]. Another study found that the usage of RoHC can also help manage and utilize the bandwidth of a satellite in a much better way [47]. A study found that RoHC when used to its full potential can reduce the headers of network layers efficiently resulting significant reduction of network overhead and saving bandwidth [48].

CHAPTER 4: IMPLEMENTATION OF BANDWIDTH OPTIMIZATION TECHNIQUE

Since we have seen how important is to optimize the bandwidth. There are multiple ways to optimize it, and the compression method is proposed here to optimize the bandwidth. Compression is a technique to reduce the amount of data that needs to be transmitted while keeping all the content. Here, the compression is applied not on the data but on the network headers. This thesis focuses on how network headers can be compressed and utilized for ultra-reliable and low-latency communication in time-sensitive networks. There are a number of scenarios where the efficiency of compression varies. Robust header compression is a technique to compress the network header. This technique has been implemented and simulation has been run for different scenarios of compression.

4.1 Robust Header Compression-RoHC

Internet protocol has a header of 20 bytes of minimum without options. And transport layer uses TCP and UDP protocols encapsulated as data in the network layer. TCP has a header of 20 bytes with mandatory fields and 40 bytes for optional fields. While UDP has a header of 8 bytes. The application layer uses RTP and RTCP for real-time videos and audio streaming. The RTP and RTCP has a header of 12 and 8 bytes respectively. In all these headers there is redundant information which can be known as static information which doesn’t change for a session. While there is dynamic information that changes continuously. The transmission of static information redundantly is a waste of resources.

In the case of telesurgery/health care where information is time-critical and resources are very limited, reducing the transmission of redundant information is not an option. Robust header compression also known as RoHC introduced schemes in RFCs to optimize the network and transport layer headers along with real-time protocol. In telesurgery, there are two main types of information one is known as visual information like a video camera and the other is control information used to operate the surgical equipment. This type of information uses time-sensitive networks, it can be on wifi, Lora, 4G/5G cellular. As the network layer is generic to all types of IP-based networks, RoHC can be used with any type of underlying technology.

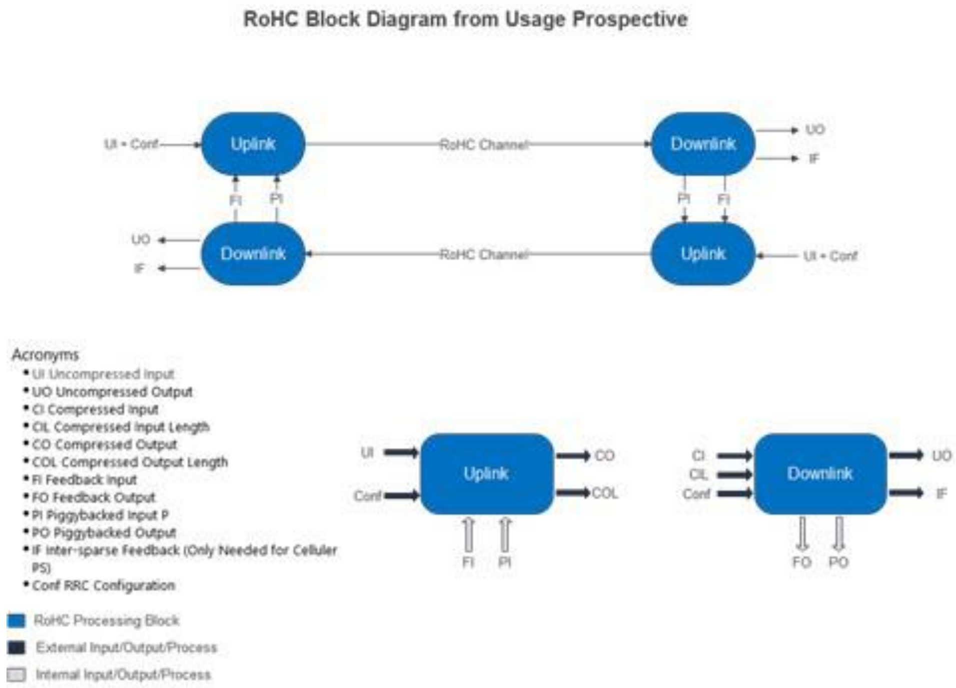

Figure 4: RoHC Block Diagram based on entities

RoHC is implemented and simulated in a C environment using the visual studio community version. The main components of RoHC are the compressor and decompressor as illustrated in figure 4, these components normally exist in pairs, but they can exist individually as well. While compressor and decompressor have their own independent context which includes the information to compress and decompress the network headers respectively

4.2 RoHC states and compression process

A compressor in RoHC has 3 states IR, FO, and SO. IR stands for initialization and refreshes in this stage there is no compression and information related to context is transmitted to the decompressor. FO – First Order is the second stage of compression where compression is partially working. The dynamic context is transferred in this stage; it is not a compulsory stage. The third one is SO stands for second order, in this stage completely compressed packet is transferred. The transition between states is based on feedback and an optimistic approach, it depends upon the type of mode.

Figure 5 demonstrate the case of U-mode where no feedback exists, each packet has a duplicate to make it resilient, and state transition is based on a timer. The compressor and decompressor both know the mode of operation and their states are compatible to the previous one with certain limitations.

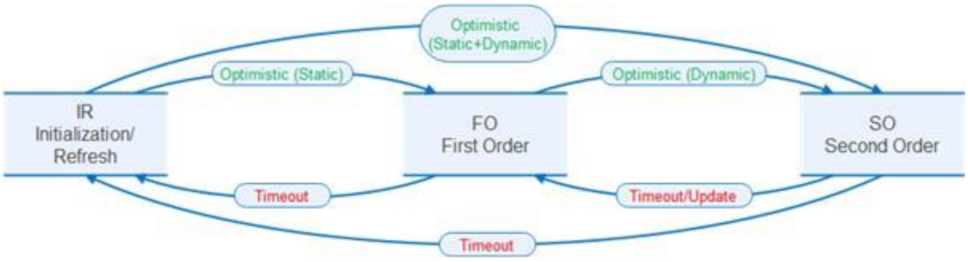

Figure 5: Compressor State Transition in U Mode

Similarly, figure 6 represents the case of O-mode, where an optimistic approach and feedback both exist for state transition. State transition towards higher compression is based on a timer and towards lower compression is based on (S)NACK. As it is mentioned earlier R-mode is completely based on feedback, so all the mode transition occurs based on ACK and (S)NACK.

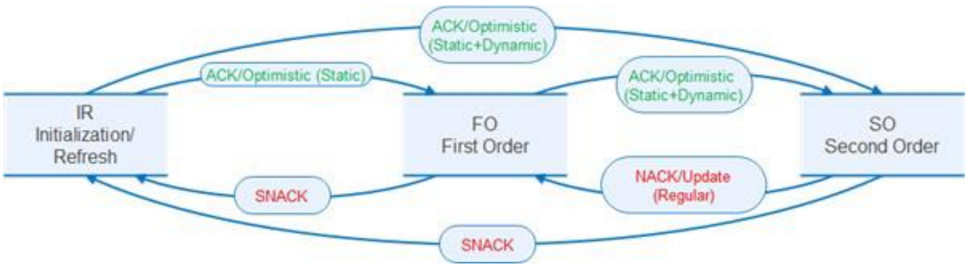

Figure 6: Compressor State Transition in O/R Mode

4.3 Mode Transition and Packet loses.

The change in mode is based on connection stability, and that transition is informed to the decompressor by the compressor. The compressor determines the connection stability by the feedback sent from the decompressor. R mode has a different packet structure as compared to U/O mode in the SO state of the compressor. Therefore, it is essential for the compressor to inform the decompressor about the mode switch to R-mode or vice versa.

Figure 7 illustrates the process of mode transition in RoHC. RoHC usually starts with U-mode, but it can be started from O-Mode and then gradually it moves to R-mode. This transition occurs via feedback packets, and during the transition, RoHC uses UOR type-2 packets which are common for all modes, and usually of size 8-10 bytes. Once the transition is done, RoHC moves to type-0 packets of its respective mode. The type-0 packet has a size of 1 byte. In case of packet losses or decompression failure, the decompressor generates feedback NACK of SNACK. NACK is sent when the decompressor is FC state and it considers a dynamic context regeneration failure, which results in requiring complete dynamic context. SNACK represents static context regeneration failure. This results in moving the compressor to IR state and the decompressor reacquires the complete context of network header. If the connection is stable RoHC entity can jump directly from U-mode to R-mode and the same is valid for instability in connection with reverse mode transition.

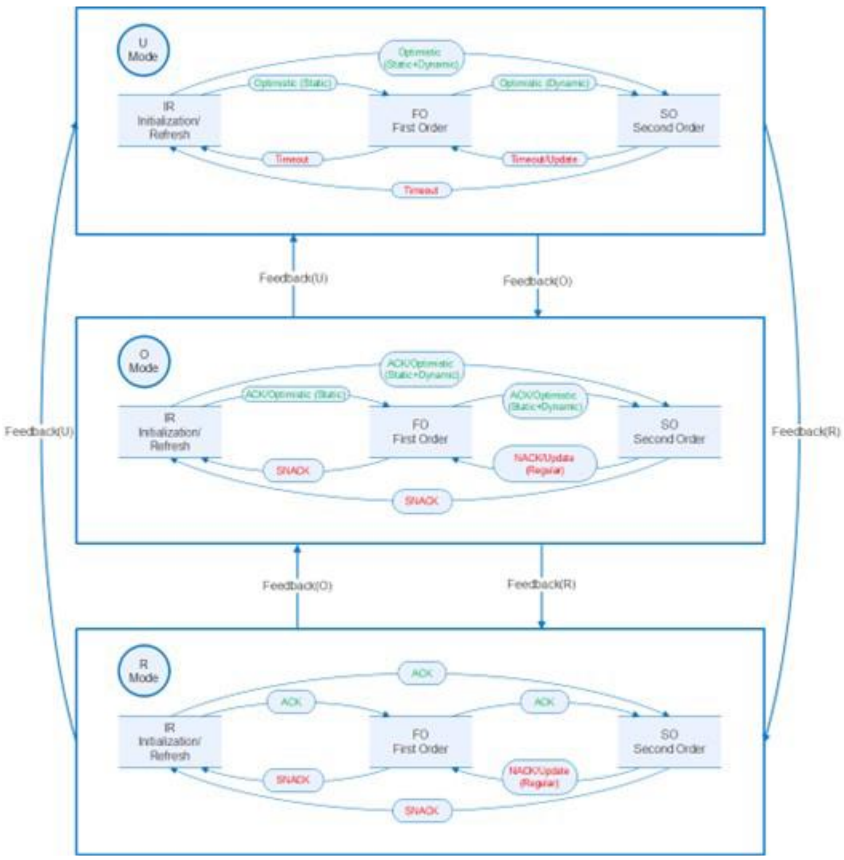

Figure 7: RoHC Compressor State and Mode Transition

4.4 RoHC Decompression States

RoHC decompressor has three states as well, and these states are independent of mode.

1. NC – No context
2. SC – Static Context
3. FC – Full Context

Figure 8: RoHC Decompressor State

Figure 8 depicts the decompress states and how the transition happens. NC is a state with no context when the static context has been established yet. After receiving the IR packets from the compressor, decompress and establish the context. Once the context has been established decompressor can move to SC or FC depending upon the type of context it has established. If the decompressor is in FC and decompression fails, it attempts for recovery internally, if it fails again, it moves to SC and sends NACK to the compressor. This NACK informs the compressor that the decompressor needs uncompressed dynamic context. After receiving this dynamic context, if the decompressor still fails to decompress it moves to NC state and sends SNACK which shows the decompressor needs full context that includes static and dynamic context. As we know RoHC has multiple profiles for multiple types of protocols. The protocol that could be used for telesurgery is RTP/UDP/IP and UDP/IP. The integrity of data is an important part of real-time communication. It is handled by layer 2 and layer 1.

4.4 RoHC Decompression States

RoHC is implemented as a standalone component and tested independently as well as with the protocol stack. When the system starts it configures RoHC configuration which includes the active profiles, the number of sessions, and the maximum number for context identity. Implementation is based on need-based memory allocation to optimize memory usage. So, when data starts, the following steps are performed:

1. Detects the packet type
   (a) If packet type matches with any active profile and Check for an already existing context.

i. If it exists process, it as per the defined process.

(b) if the context does not exist

i. It creates an entity for this packet.

ii. Establish the context

iii. Allocate memory

iv. Assign context identity and store it in list

Figure 9 illustrates the process of uplink and compression. The left side of the figure shows the developed API usage in simulation and the right side of the figure demonstrates the compression process. RoHC has 4 categories of packets.

1. IR and IR-DYN
2. Type-2 UOR
3. Type-1 UO,R
4. Type-0 UO,R

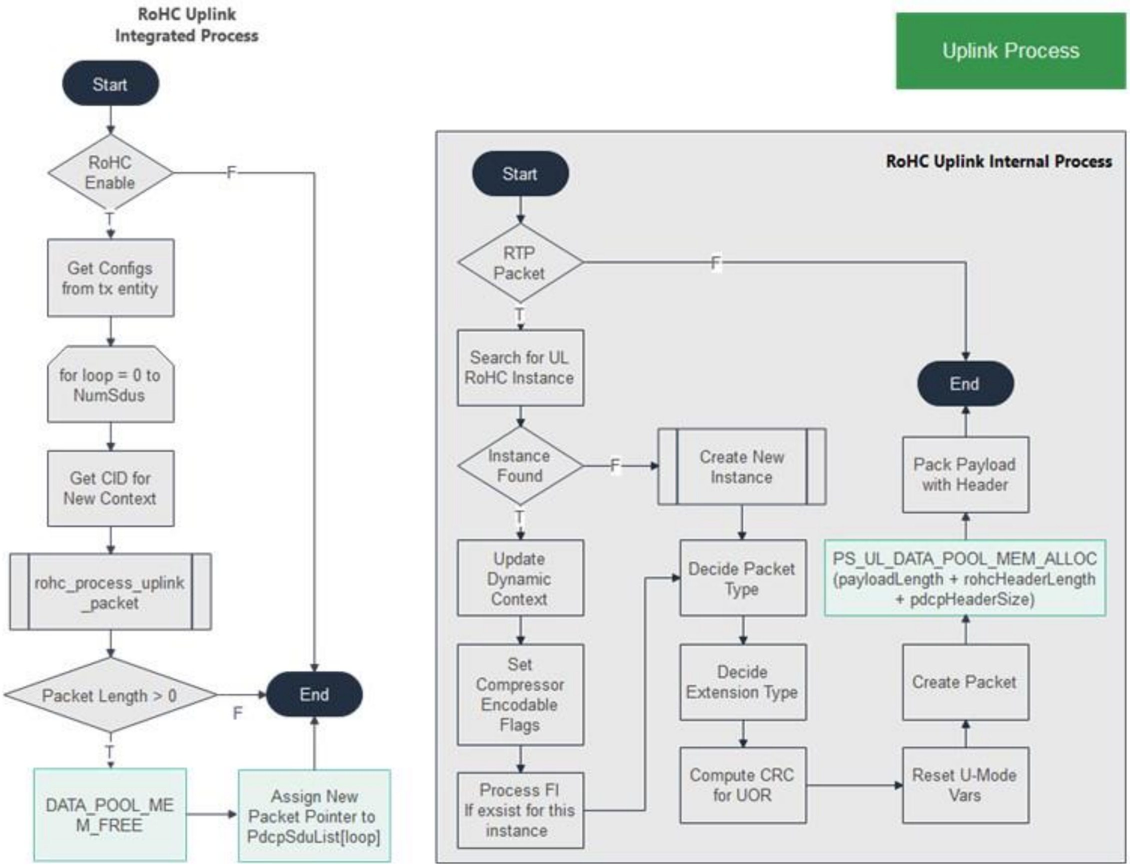

Figure 9: RoHC Uplink Process

These packet types are selected by the compressor based on its state. In IR state IR or IR–DYN packets are used, in the case of the FO state IR – Dynamic and Packet Type–2 can be used based on decompressor feedback both used to update dynamic and semi-static context.IR, IR-DYN and Type-2 packets are common for UOR mode, whereas Type-1 and Type-0 has common formate for UO mode and different format for R mode. While Packet Type – 1 and 0 are used in the case of SO state, their selection is defined by decompressor feedback, the details can be seen in RFC 3095.

4.4 RoHC Decompression States

In the downlink process, an entity is created upon reception of IR packets only if the context is new otherwise existing context is searched and decompress the packet. The process of downlink is shown in figure 10. The decompressor, process the received feedback for associated compressor and send desired information to the compressor. It also generates feedback based on decompression of packet with three possible options ACK, NACK, SNACK.

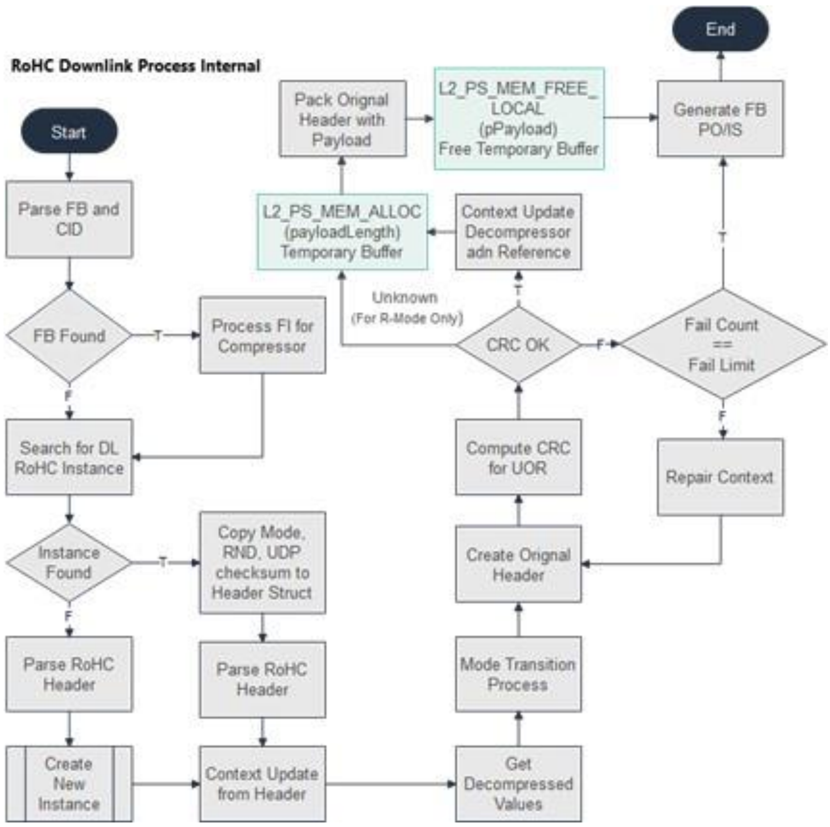

Figure 10: RoHC Downlink Process

ACK helps compressor to improve compression state and the operation mode. It is an indication of stable connection. NACK is negative acknowledgment, which indicates failure of dynamic context decompression. It is an indication of instability of connection which may result in degradation of the compression state. SNACK stands for static negative acknowledgment. It represents a failure of static context decompression or there is loss of synchronization between compressor and decompressor. In this case compressor moves to IR state and send IR packets to restore the context on decompressor. The decompressed validation is check by CRC send in type-0 packets. In case of O mode only (S)NACK is enough because it moves up due to optimistic approach while (S)NACK can only move compressor to down state.

This figure 11 shows the process of creating new instance of RoHC which also includes the wlsb window and configuration of compressor and de-compressor. This configuration includes RoHC version, maximum CID value it enables RoHC entity to determine the type of CID large or small. If the value is less than or equal to 15 it shows small CID and otherwise large CID, and the number of sessions that can be established.

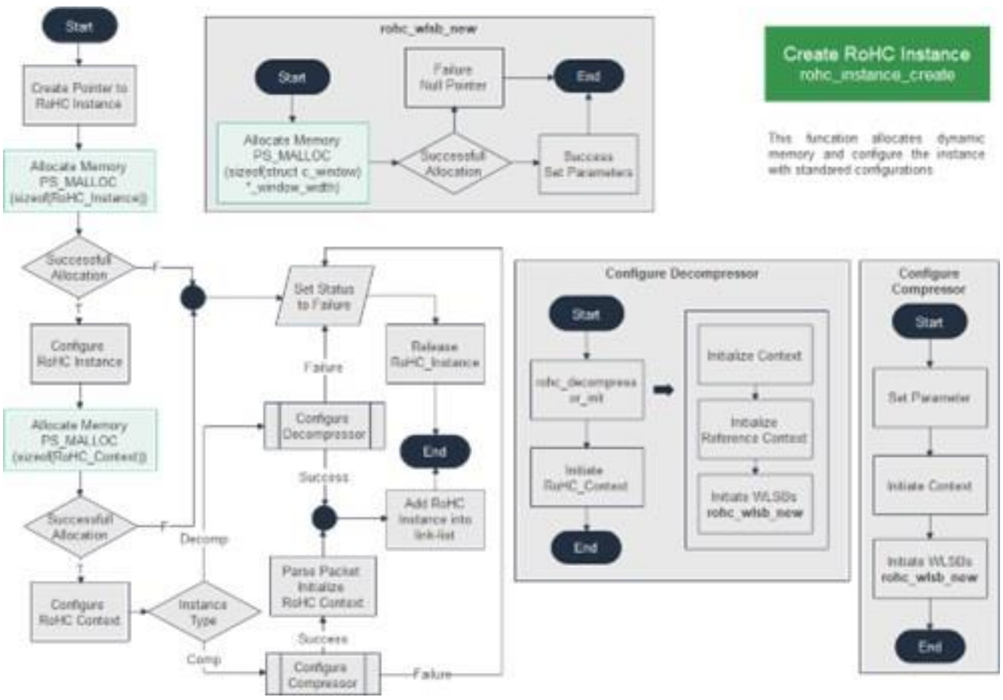

Figure 11: RoHC Instance Creation Process

CHAPTER 5: EXAMPLE AND ANALYSIS OF SIMULATED HEADER COMPRESSION

In this chapter, we will analyze and assess the improvements in the efficiency of the network with this new approach. The simulated environment consists of a laptop and simulation software. The RoHC is implemented using C language and according to the defined RFC3095. The data is generated using an open-source tool. RoHC compresses the header up to 3 bytes based on the scenario. In this simulation, multiple scenarios have been executed and analysis is made based on how much efficiency can be gained in different cases of compression.

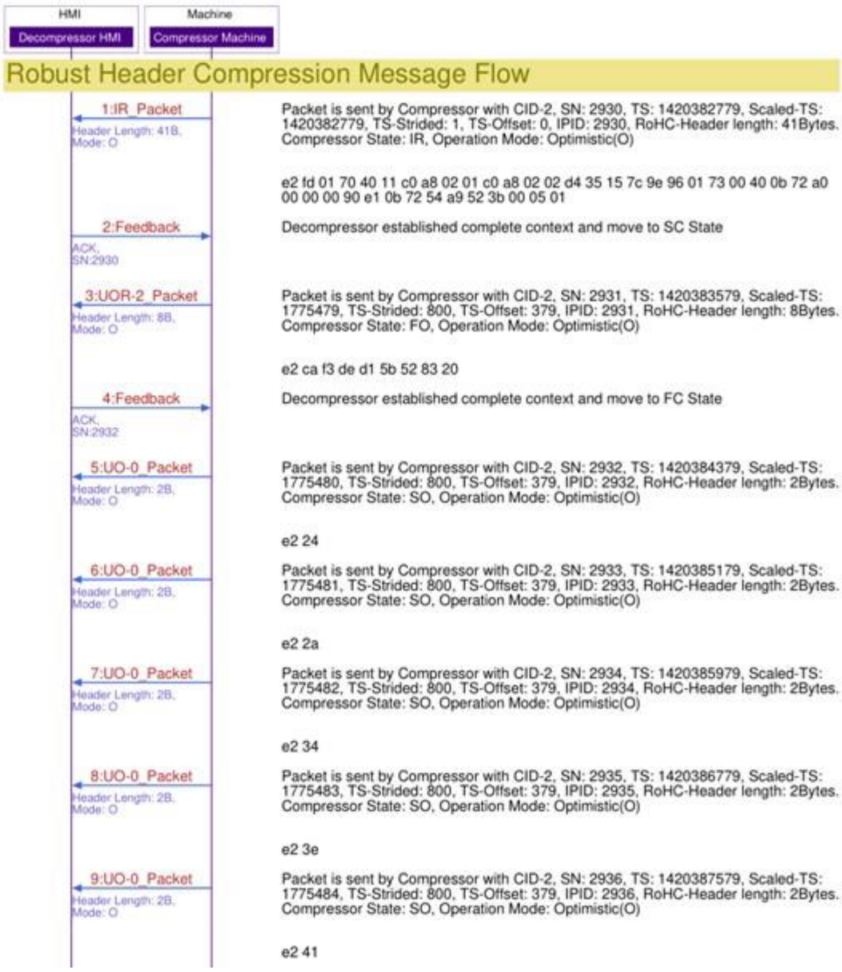

Figure 12: RoHC Example of Packet Flow

This figure 12 shows a standard scenario in which RoHC compressor starts with IR packet and smoothly without any hurdle reach in SO state. On start the header size is 41 bytes which is 1 byte more than actual IPv4 header. Later, it transmits an 8-byte header and finally, it sends a 2-byte header compared to 40 bytes IPv4 header. So, for 100 IPv4 packets with a size of 40 bytes each, the compressor achieves a compression ratio of 93.875\%. but this ratio slightly moves down when we see multiple scenarios in real-time.

5.1 Simulated Scenarios

The scenarios are listed below:

1. UDP Checksum Behavior
2. ID Value and Type
3. IPID random behavior

UDP Checksum Behavior: There are two possibilities in UDP checksum, either applicable or not. It is recognized by the value of the checksum an applicable value is any number other than zero and when the value is zero it represents UDP checksum is not applicable to this packet. So, if there is a non-zero value in the UDP checksum it increases the 2 bytes in compressed packet size, and the change in the UDP checksum behavior is communicated by the IR-DYN packet.

It is observed that the system starts with UDP checksum zero. After, 5 packets UDP checksum becomes applicable and communicated via IR-DYN packet afterward the size of the UO-0 packet increased by 2 bytes. The compression ratio for this case:

$$compression\,ratio = \frac{100 * 40 - (41 + 9 + 3 * 2 + 21 + 4 * 94)}{40} = 88.7\% \rightarrow \text{Eq 5.1}$$

CID Value and Type: The RoHC context is identified by context identity – CID. There are two types of CIDs small and large. Small CID takes 4 bits while large CID takes a maximum of 2 bytes, the size of large CID depends upon the variable length encoding, this scheme is defined in RFC 3095. In the case of small CID, size is fixed to 4 bits for non-zero numbers, and it is zero bits if the small CID value is zero. So, a small CID with a non-zero value adds 1 byte in compressed packet size while a large CID adds 1 to 2 bytes based on the value, a large CID is compressed using variable encoded length. For Large CID

$$compression\,ratio = \frac{100 * 40 - (42 + 10 + 3 * 98)}{40} = 88.7\% \rightarrow Eq\ 5.2$$

In above mention equation, there are 100 packets in the stream, and each packet has a header of size 40 bytes. The first packet is IR of size 42 bytes, and the next won is UOR-2 of size 9 bytes, rest of the packets are type-0 packets of size 3 bytes each. For Small CID

$$compression\,ratio\ =\ \frac{100\ *\ 40\ -\ (41\ +\ 9\ +\ 2\ *\ 98)}{40} =\ 93.875 \rightarrow Eq\ 5.3$$

In the case of small CID, compressed packet size increased by 1 byte compared to the ideal case while reduced by 1 byte compared to large CID. So, it has an efficiency of up to 93.875\% as compared to 88.7\% which is 5\% improvement over large CID. Normally, it is observed that there are no more than 15 sessions on a device which results in configuring a small CID by the network. In equation 3, the IR packet has a size of 41 bytes, UOR-2 has 9 bytes of size and the rest of the packets are type-0 packets of size 2 bytes each.

IPID random and sequential behavior: The IP header has a field called "Identifier", it is a 2-byte value and has two types of behaviors random and sequential. In random behavior, it has a random nonpredictable value, and it cannot be used to develop a relationship with the sequence number sent in RoHC packets, it can be compressed using variable-length encoding but it cannot guarantee the compression. While in the case of sequential behavior, IPID has a relationship with the sequence number and can be derived from a sequence number, if a change appears in the relationship between IPID and sequence number it is informed by the compressor to decompressor. A random IPID increases the size of the compressed packet to 2 bytes.

$$compression\,ratio\ =\ \frac{100\ *\ 40\ -\ (41\ +\ 11\ +\ 4\ *\ 98)}{40} = 93.875\% \rightarrow Eq\ 5.4$$

In Equation 5.4, the IR packet has a size of 41 bytes, and UOR-2 has a size of 11 bytes due to the addition of IPID and the rest of the packets are type-0 packets with a size of 4 bytes each.

Worst Case Scenario w.r.t maximum overhead: In the worst case, all the possible overhead could be present which includes large CID, UDP applicable, and IPID with random behavior, which adds additional bytes in the header. The compression ratio for this case is

$$compression\,ratio\ =\ \frac{100\ *\ 40\ -\ (42\ +\ 13\ +\ 7\ *\ 98)}{40} = 81.475\% \rightarrow Eq\ 5.5$$

Equation 5.5 demonstrate the scenario, in which maximum overhead is present which adds up 6 bytes in compressed packet of type 2,1,0. So in this case IR has size of 42 bytes, UOR-2 has size of 13 bytes and type-0 packets have size of 7 bytes each. Which leads up to 81.475% of compression ratio.

Table 1: Comparison of Compression Scenarios

Sr.	Scenario	Additional Bytes	Head Size (B)	Compression Ratio
1	Ideal Case	0	1	96.375
2	UDP Checksum Present	2	3	88.7
3	Small CID	1	2	93.875
4	Large CID	2	3	91.4
5	IPID Random Value	2	3	91.4
6	Worst	6	7	81.475
7	Common	3	4	91.375

CHAPTER 6: CONCLUSION

In the world of limited resources optimization is a necessity. It is observed that during transmission on the network, redundant information is transferred in each packet. This thing causes a waste of resources. In the era of 5G in the deployment stage and 6G under process, communication technology has become an essential component of every field of life. Medical science is one of the most important fields and communication has revolutionized this branch of science. Remote health procedure specially telesurgery which has been performed as the prototype, would be remarkable development in medical science. Researchers are working on transforming this dream into reality and communication is the backbone of this transformation. This thesis focused on the problem of redundant information transfer in network headers and implemented Robust Header Compression according to RFC3095 and analyzed how much it can be helpful in optimizing the network header. Different cases and scenarios are simulated along with the network cellular protocol stack. It is assumed that URLLC is applicable on lower layers. The simulation run for 100 packets in each defined case. These cases are behaviors of network and application header which affects the compression.

It is observed that the network header in case of video/audio transmission can be compressed up to 93.375%, ideally, it may go up to 96% but in standard cases, the compression ratio is up to 90%. This compression does not include the packet data, it only includes the packet header. In the IP header, IPID is the only non-static information, while UDP has been checksum as a random value and RTP has SN as non-static information. SN of RTP and IPID of IP have a relation and one can be derived from the other. Therefore, IPID only transmits when needed otherwise it is always derived from SN. So, the usual transmission as result of compression is only two bytes instead of forty bytes of header. It also play an important role when machine operating instruction issued from HMI to Machine, for UDP protocol, RoHC compresses 28 bytes into upto 4 bytes.

Similarly, RoHC have profiles for other types of protocols. Those can be implemented and analyzed for their respective scenarios. Ethernet Header compression protocol can be used at layer 2 to compress ethernet headers in same as RoHC does on Network layer. It is suggested that this theses protocols should be essential part of Protocol Stack for URLLC and other IoT based communication. In IoT the data size is usually less than the header size and header overhead can be reduced using RoHC profiles up to 90%. Bandwidth will become one of crucial resource in near future once the 5G deployment will complete and world moves toward IoT in every aspect of life. The resultant would be billion of devices on the earth. We should take measures to optimize the resources and RoHC is one of the ways to optimize the Network header's overhead.

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