iJRASET
International Journal For Research in Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 9 **Issue:** VII **Month of publication:** July 2021

DOI: https://doi.org/10.22214/ijraset.2021.36403

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue VII July 2021- Available at www.ijraset.com

Surgical Telementoring and Surginars with Added Virtual Layer using 5G Network

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Abstract: ***Healthcare sector has always been a key sector for social and economic well-being of any nation and since COVID-19 pandemic it has gained a center stage. Human resources are at the core of health care system. However, there is an acute shortage of doctors, nurses, and other health care workers. Brunt of scarce human resource is starker at specialization level. 5G network may provide a solution to this problem by human resource capacity building in some of the most complex areas of medical science. It may also provide an access to surgical expertise distributed globally. The low latency, high volume and high-speed data transfer allows sharing live surgical feed which may enhance the learning and assistance process. Hence, a synergy is achieved of physical and virtual world and a potential business model can be developed in such ecosystem. This work explores the requirements, architecture, implementation strategy, roles, and responsibilities of various stakeholders etc. to provide surgical expertise on a 5G network.***

Keywords: 5G, surgery, Tele-mentoring, Human Capacity Building, Surginars

I. INTRODUCTION

Healthcare sector is one of the most essential sectors for well-being of any nation. At the core of healthcare sector lies the human resources which includes medical and paramedical staffs such as medical practitioner, surgeon, nurses, and laboratory technicians. Shortage of quality human resource in healthcare sector is a major challenge for low- and middle-income countries. Approximately, 48% of global population resides in Low and Middle-Income Countries which is catered by 19% of surgeons present globally.[1] African and Asian countries are particularly underserved. Sub Saharan Africa has 11% of the global population with 24% of global disease burden but only 3% of the healthcare workforce.[2] This shortage is more alarming in case of specialist workforce. Only 12% of the surgical, anesthesia and obstetrical specialist workforce practices where one-third of the population lives.[3] The problem further aggravates in rural and remote areas.

According to a study, more than 1,00,000 surgeons will be required by 2030 in USA which will require $2 Billion annually.[4] With growing incidence of diseases and deteriorating environment, upskilling of medical human resource will be a key concern in coming times. Hence, we have a supply side shortage and demand side necessity for upskilling of medical human resource.

Telemedicine has greatly improved the accessibility of medical care to patients during these covid times. It has also provided good medical assistance to local medical practitioners in rural and remote regions via tele-assistance by specialist doctors. However, similar approach in case of surgical activities is marred with challenges like lack of necessary skill, required bandwidth, latency in data transmission etc.

Under such circumstances, Surgical Tele-mentoring and Surginars on a 5G network provides a solution for remote surgical assistance and upskilling of human resources, especially surgeons.

These applications were of limited utility earlier because of high bandwidth requirement and latency in data transmission. With advent of 5G network which provides Ultra-reliable Low Latency Communication (ULLLC), Massive Machine Type Communication (mMTC) and Enhanced Mobile Broadband, such applications are feasible. Surginar is portmanteau of “Surgery” and “Webinar”. It provides for a wider access, enhanced learning experience and quality content for training and educational purposes through live streaming. On the other hand, Surgical Tele-mentoring is remote surgical guidance, and assistance in decision making process through expert surgeons who are geographically separated. Other than transmission, display is also critical for Surginars and Surgical Tele-mentoring. Here, use of virtual technology i.e., Telestration can further enhance learning experience. In spite of such far-reaching ramifications, there are infrastructural, legal, ethical, and economic issues which require further discussions.

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II. LITERATURE REVIEW

Tele-mentoring and Surginars are based on the Halstedian Model of training i.e. "see one-do one-teach one".[5]Surgical Tele-mentoring involves the usage of advance Information and Communication Technology to provide Real-Time guidance and technical assistance in performing surgical procedures from an expert surgeon in a different geographical location.[6] Surgical Tele-mentoring provides certain benefits, which include: (i) Providing high-quality surgery to rural and remote regions (ii) Delivering surgical feedbacks to geographically distant doctors on real-time basis and receive inputs (iii) Facilitate collaboration of surgeons (iv) Logistically convenient and less expensive for patient and (v) Easy pre-operative evaluation and post-operative follow-ups. Surgical Tele-mentoring earlier efforts were limited by low bandwidth availability and high latency in data transmission.

In 2019, Society of American Gastrointestinal and Endoscopic Surgeons (SAGES), in its technology working group defined the technological requirement for Surgical Tele-mentoring. It assessed the technical requirement of tele-mentoring devices (Display and transmission) on parameters like safety and reliability, transmission quality, ease of use and cost. For live tele-mentoring application, it recommended minimum latency of 450 ms and transmission quality of HD 1080p (1920 x 1080p) at 30 frame per second (transport bandwith requirement for uncompressed transmission is 1.5Gbps).[7] A German study showed that 5G meets the criteria in terms of data volume, speed and latency for Telesurgery.[8] 5G stands for Fifth Generation broadband cellular network and is an upgrade on 4G in terms of mean/peak data transmission speed, bandwidth availability in high-frequency bandwidth availability, device centric mobility via beamforming and lower latency.[9] Comparison between 4G/LTE and 5G is shown below.[10]

Table 1. 4G/LTE Vs 5G

Characteristics	4G/LTE	5G
Data Rate	0.01-1 Gbps	0.1-20 Gbps
Latency	10 ms	1 ms
Mobility	~360 km/h	~500 km/h
Energy Efficiency	0.1 mJ per 100 bit	0.1 µJ per 100 bit

5G can operate in 3 frequency bands (Low, Medium also known as Sub-6 and High or mmWave) which is shown below:

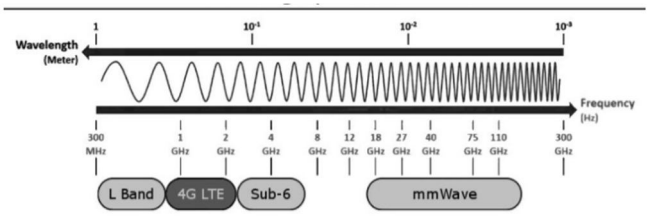


Fig 1: Network Spectrum Bands[10]

mmWave frequency band (~17-100 GHz) is considered to be the fastest and most suitable range to provide speed in Gbps. However, this is very short-range wave resulting in very limited cell size and application only in highly dense region and for applications which requires bandwidth boast.

In 2019, during Mobile World Congress, Laparoscopic Surgeries accompanied by Tele-mentoring were demonstrated on a 5G network. During the transmission, the mean data upload/download speed was symmetrical at 98 (range 95–102) MB/s. There was no significant signal loss, so there was no image buffering or pixelation. Latency time was 202 ms. The mean rating of image quality by all surgeons was 9·67 of 10.[11] In one study, Transurethral Enucleation of the Benign prostrate (TUEB) using bipolar energy was performed. In this, an Endourologist (Novice to TUEB) was guided by an Experienced one, in ten prospective cases of TUEB. It was concluded that, in spite of some delay in transmission and quality for couple of cases, Tele-mentoring application for TUEB is promising.[12] Sleeve Gastrectomy, a relatively new surgery was performed by using surgical Tele-mentoring application. Both Mentor and Mentee showed considerable satisfaction towards the procedure and also considered that Tele-mentoring can smoothen the learning curve.[13]

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With advancement of technology, technologies like virtual reality, Augmented Reality, AI etc are revolutionizing different sectors like entertainment, video experience etc. Tools like telestration (virtually writing on live image of host screen for better communication) facilitate faster and more unambiguous instructions from mentor to mentee.[14] An additional visual guidance on top of audio support, adds a new perspective to mentor's directions. Telestration has been considered as an essential functionality for Tele-mentoring application.[15]

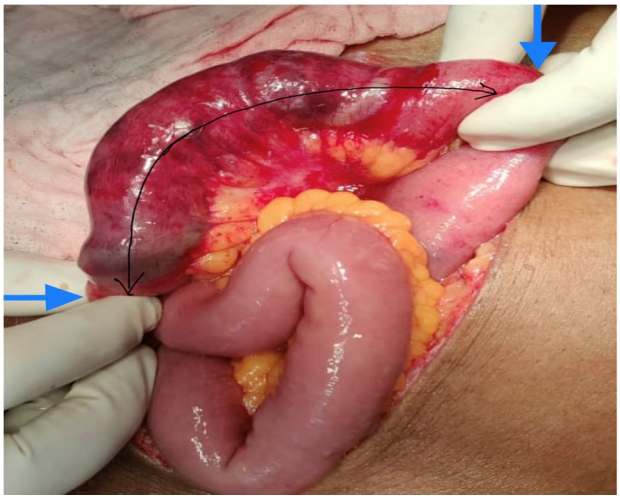


Figure 2: Surgical Telestration

III. METHOD

Here it is attempted to explain the network architecture, hardware/software requirements and business case for the current proposal. Schematic of the network is shown is Figure 3. Various component of the architecture are as follows:

A. Host Side

1) *Screen:* To project the live feed of primary surgical camera, and is shared between host and remote surgeon.
2) *Video Encoder:* Converts the raw inputs from camera into streamable video format.
3) *Surgical Camera:* Main camera to record surgery. It provides the input feed to video encoder.
4) *General View Camera:* Secondary camera to record the proceedings of Host surgeon and store the same in cloud to maintain activity log.
5) Surgeon's Headset

B. Remote Side

1) *Screen:* Screen to project share live feed from primary surgical camera.
2) *General View Camera:* Secondary camera to record the proceedings of remote surgeon and store the same in cloud to maintain activity log.
3) Surgeon's Headset

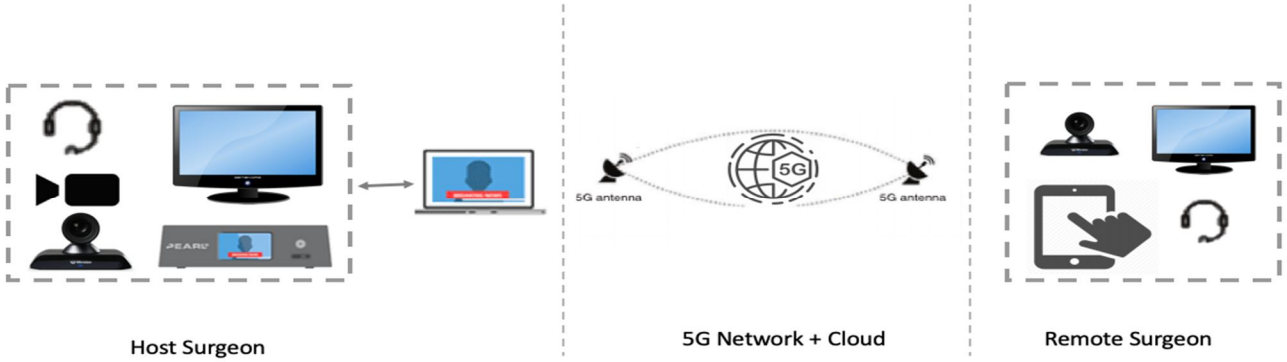


Figure 3: Network Architecture for Telementoring

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In addition to above hardware requirement, an intermediate web application is needed for following purpose:

a) Video Conferencing: Feed from both general view camera and surgical camera of host and remote side.
b) Connectivity: Maintaining audio and network connectivity all the time.
c) Telestration: In-built telestration capability for enabling annotation on live feed.
d) Profiles/Events: Maintaining profile of surgeons and log of events.
e) Misc: Authentication, medical meetups, etc.

We have seen it numerous times in movies or shows, how a surgeon is surrounded by residents/ medical students and the difficulties faced in such surgical learning. Surginars is a form of massive open online course where live surgeries can be taken up to teach the nuances of surgical procedure in more real-time situation. Similarly, with advent of 5G ultra-fast, reliable, and instant network, Surgical Tele-mentoring in pre-operative evaluation, during surgical procedure and post-operative follow-up can provide knowledge of experts to any geographical location and bridging this knowledge gap accompanied by improvement in decision-making process. For Surginars and surgical Tele-mentoring, in the above network architecture, the roles and responsibilities of various stakeholders is show in in Table 2.:

Table 2. Stakeholder's Roles and Responsibility Matrix

S.No.	Application / Stakeholder	Surginars	Surgical Tele-mentoring
1.	Host Surgeon	Expert Surgeon performing surgery in OT and may explain simultaneously	Novice Surgeon performing surgery
2.	Remote Surgeon	-	Expert Surgeon providing guidance
3.	Audience	Paramedical Staff in two-way communication	Paramedical Staff

IV. DISCUSSION

Present day network like 4G-LTE/unlicensed Wi Fi band has limitations of bandwidth availability, number of devices connected simultaneously, latency etc. With 5G comes the promise of a fast, instant, and reliable network. 5G can bridge the knowledge gap globally as well as domestically. But as we have observed that there is a shortage of empirical studies which utilized Tele-mentoring to a considerable extent. Hence, the adaption of Surgical Tele-mentoring needs to follow a course so that it can instill necessary confidence and trust in various stakeholders. Surginars provide a good starting point for it. Surginars can be a very productive application of reliable network for healthcare capacity building. It can be very much fruitful for multidisciplinary surgical work which requires collaborative work approach. It can be used for upskilling not only for budding surgeons but also for paramedic staffs, managers etc. This provides a dynamic platform where an expert surgeon shares his knowledge to a relatively less experienced audience in a two-way communication setup. Adopting Surginars in an early stage may allow for course correction which may help in smooth implementation of Surgical Tele-mentoring.

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As we already know that there is limited empirical study done on surgical tele-mentoring in recent times. Based on the maturity of 5G network and lessons learnt from Surginars implementation, it can pave the way for surgical Tele-mentoring. Short course apprenticeship of novice surgeons followed by Surgical Tele-mentoring assistance can go a long way for remote population in economically constrained low- and middle-income countries. However, implementation is not without challenges. But following a piecemeal approach in which initial implementation in form of Surginars followed by introduction of Surgical Tele-mentoring will help in its acceptance and building trust in the system of Tele-mentoring and Surginars. Such system can bring paradigm shift in providing surgical care in less accessible areas like war zones, rural regions, calamity-affected regions etc. In addition to that, in long run, it may also improve YLL, DALY and mortality rate by decreasing the global burden of surgical disease.

Certain level of confidence and trust is very much essential to develop a mentor-mentee relation while performing a surgical procedure. There can be various ways to achieve this. One of the methods can be the piecemeal approach i.e., initial implementation followed by short course apprenticeship then performing surgeries using Tele-mentoring assistance. This approach helps not only in building the confidence of novice surgeon with time but also develop a level of trust and confidence in the system of Surgical Tele-mentoring. Other methods can be attending Surginars, medical meetups etc.

Even though Surgical Tele-mentoring provides for multiple facilities of expert opinion without any significant additional cost, the comfort and satisfaction of patient like data security of patient, redundancy plan etc is of prime importance is this whole setup. Data protection and security of identity of patient which are handled by medical devices and internet- based applications need to be established at both ends. Some ways of achieving this is using WPA2 protected wireless devices, using VPN or end-to-end dedicated secure channel, encryption, authentication protocol etc. Lack of surgical tele-mentoring regulatory frameworks creates an impediment for the adoption of such applications.

In spite of its far-reaching ramifications, Surgical Tele-mentoring and Surginars may face infrastructural, legal, ethical and regulatory challenges especially because of its international implications which requires considerations and deliberations in international bodies like International Telecommunication Union, World Health Organization etc. Second major challenge is lack of empirical evidence to truly understand the challenges and potential of such applications. Third challenge is of fixing a risk matrix etc.

V. CONCLUSION

According to a study, approx. a quarter of global disease burden is surgical in nature. Approximately 25.3% mortality and 28.0% Disability Adjusted Life years (DALY) lost are because of delay in timely surgical intervention.[16] Discussion under this work provides a scalable method to fill-up the human capacity gaps present in healthcare sector. This hypothesis provides for the network architecture, implementation approach, stakeholder's roles, and responsibilities. Even though these applications are not without challenges, but if achieved, it has the potential to make surgical care universal. It provides a solution to scale-up existing functional surgical system that can have a beneficial impact of unserved and underserved population.

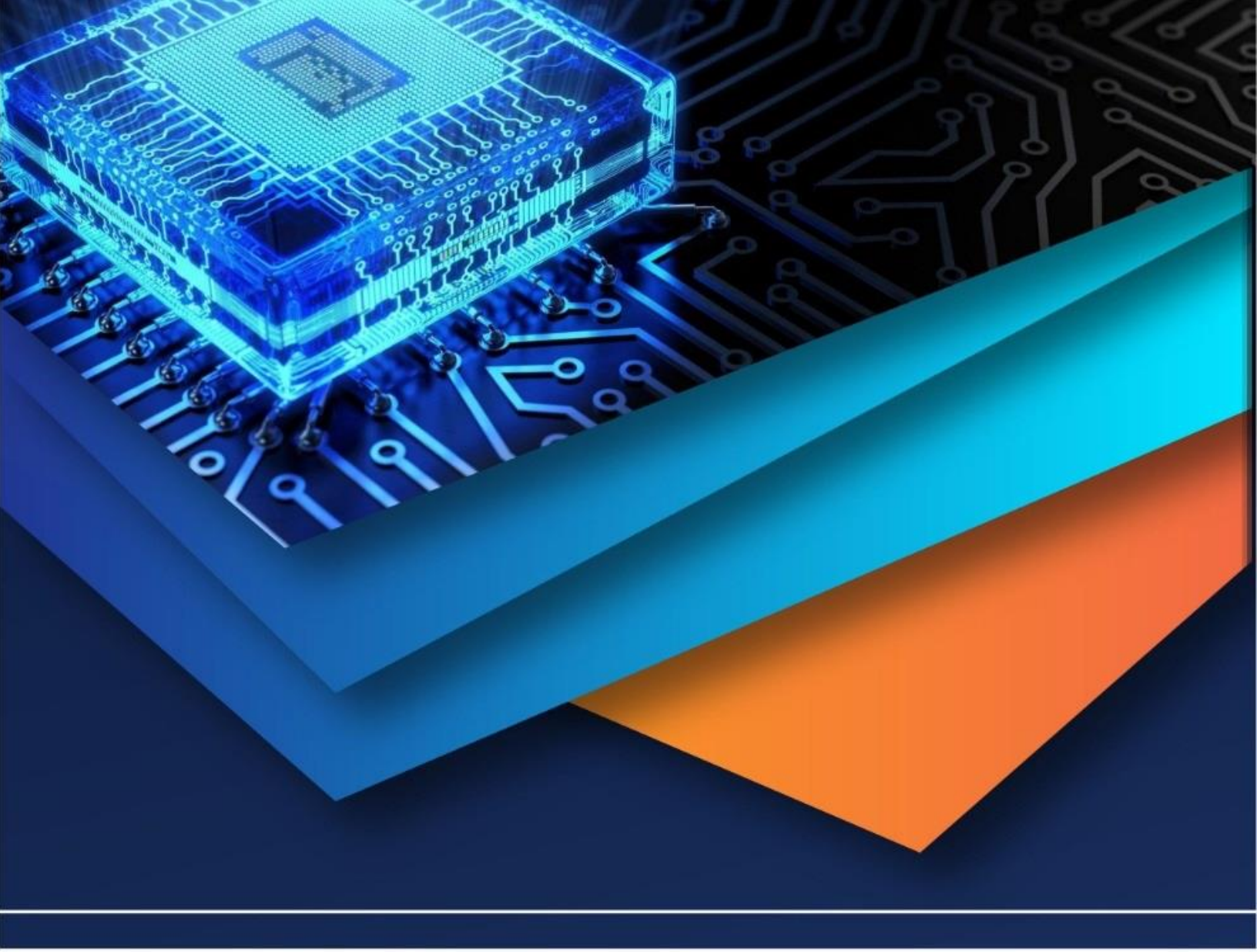
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