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Integration of VoIP and IoT to Modernize Healthcare System

Nimra Akram[1], M. Junaid Arshad[2]

[1,2]Department of Computer Science, University of Engineering and Technology, Lahore, Pakistan

***Abstract*– Over the past few years, telemedicine research outputs have surged due to the COVID-19 epidemic. According to published research, one way to combat the COVID-19 epidemic is to use telemedicine to get medical care from a distance. In this survey paper, we examine a number of articles on telemedicine and eHealth, focusing on the topics included in the articles, among other things i.e. wireless technologies and architectures in eHealth, communication protocols, quality of services and experience standards. For those who are unfamiliar with telemedicine, we also include an introductory overview. This survey examines a number of telecom technologies that are currently being considered, as well as the requirements and difficulties associated with them. Generally speaking, a thorough overview of the advancements in telemedicine standards, protocols, and technology is discussed, introducing scholars to a number of unresolved challenges. The most cutting-edge specialized application areas are highlighted in particular. We offer significant research issues and prospective future directions in the field of telemedicine technology as we wrap up the survey report.**

***Index Terms*– VoIP, eHealth, Internet of Things, Communication Protocols and COVID-19**

I. INTRODUCTION

TELEMEDICINE refers to providing medical services via information and communication technology, regardless of the geographical distance between patients and physicians. Since the early 1900s, telemedicine has facilitated remote clinical interactions. Recent research has focused on wireless communication technology, which ensures efficient and reliable medical services, especially in emergencies. Various communication technologies have been implemented to offer patients easy access to professional medical care without the need for in-person visits. This approach has reduced the cost of medical diagnoses and eliminated the need for long-distance travel for consultations. However, current research on VoIP (Voice over Internet Protocol) in telemedicine highlights several challenges that need ongoing attention for optimal benefits. While VoIP cannot entirely replace traditional physical examinations, it can significantly reduce hospital traffic and prevent the spread of contagious diseases. The COVID-19 pandemic has underscored the importance of leveraging VoIP and eHealth. Studies comparing VoIP and in-person care, such as in pediatric clinical genetics, have shown VoIP to be a viable alternative for routine evaluations. In the post-COVID-19 era, there is a need to review telecommunication technology to develop fully functional VoIP services, as many studies advocate for its increased use.

This survey summarizes earlier studies on the various communication technologies used in VoIP, conducted by other researchers. Internet and wireless technologies for digital data transfer, wireless design, WBAN, satellite-based communication, mobile VoIP, and cellular technologies—including the use of infrared links—are some of these technologies.

- *Applying infrared connections:* Below figure provides a broad summary of VoIP systems. Communications in VoIP applications fall into one of the following categories:
- *Body Area Communication:* the exchange of information between patients and wearable sensors or other telemedical devices
- *Remote connections:* satellite, internet, GSM, and WAN connections between the telemedical devices and distant servers.
- Communication according to application domain, such as video conferencing, medical picture transmission, and emergency VoIP communication.

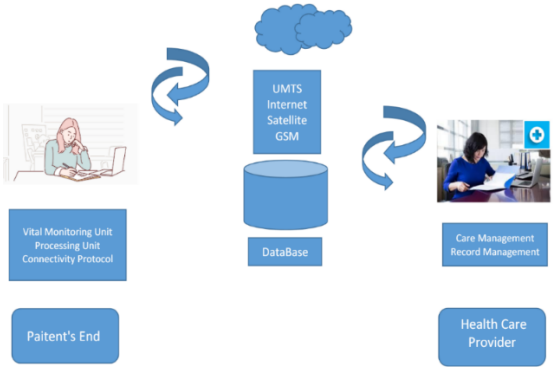

Fig. 1: IoT Application Overview

This research reviews communication technologies used in VoIP implementations, the associated challenges, and the need

for standardization. Despite various efforts, no standard format exists for medical data communication in VoIP, hindering smooth deployment. Key issues include data security, privacy, patient safety with wearable devices, and QoS requirements. Addressing these areas is crucial to meet the increasing demand and reduce medication costs. The specific contributions of this work include:

- An overview of VoIP and the evolution of telecommunications technology.
- A review of the various standards and protocols present in VoIP, with a focus on the current trends.
- Identification of several deployment challenges along with the state-of-the-art in this research area.

This article reviews major research areas to identify state-of-the-art VoIP technologies and implementation constraints. It covers the evolution of communication technologies for VoIP, using cases, types of transmitted information, standards, and protocols. The article concludes with current research challenges and future directions for developing robust, secure, and efficient VoIP systems.

II. RELATED WORK

Many surveys and studies have been conducted regarding the modernization of the healthcare system, the summary to which is presented in Table I:

Table I: Related Work

References	Name	Limitations	Evaluation Matrix
1	Yamin, M.A.Y.; Alyoubi, B.A. Adoption of telemedicine applications among Saudi citizens during COVID-19 pandemic: An alternative health delivery system. J. Infect. Public Health 2020, 13, 1845–1855.	Limited geographical scope; potential bias due to specific population studied.	Provides insights into the adoption of telemedicine during the COVID-19 pandemic, valuable for understanding its impact on healthcare delivery.
3	Lukas, H.; Xu, C.; Yu, Y.; Gao, W. Emerging Telemedicine Tools for Remote COVID-19 Diagnosis, Monitoring, and Management. ACS Nano 2020, 14, 16180–16193.	Reliance on emerging technologies may pose implementation challenges; generalizability of findings may be limited.	Offers a glimpse into the potential of telemedicine tools for managing and monitoring COVID-19 remotely, highlighting their role in public health crises.
4	Portnoy, J.M.; Pandya, A.; Waller, M.; Elliott, T. Telemedicine and emerging technologies for health care in allergy/immunology. J. Allergy Clin. Immunol. 2020, 145, 445–454.	Potential biases in patient selection; limited discussion on barriers to implementation.	Provides valuable insights into the application of telemedicine and emerging technologies in allergy/immunology, offering opportunities for improved healthcare delivery.
5	Hur, J.; Chang, M.C. Usefulness of an Online Preliminary Questionnaire under the COVID-19 Pandemic. Nat. Public Health Emerg. Collect. 2020, 44, 116.	Relies on self-reported data; may not capture diverse perspectives.	Highlights the utility of online preliminary questionnaires during the COVID-19 pandemic, offering insights into optimizing telemedicine services for public health emergencies.
6	Kannampallil, T.; Ma, J. Digital Translucence: Adapting Telemedicine Delivery Post-COVID-19. Telemed. e-Health 2020, 26, 1120–1122.	Limited discussion on long-term sustainability; potential overlook of ethical considerations.	Explores the concept of digital translucence in adapting telemedicine delivery post-COVID-19, providing a framework for enhancing transparency and trust in telemedicine interactions.
7	Xu, C.; Yang, Y.; Gao, W. Skin-Interfaced Sensors in Digital Medicine: From Materials to Applications. Matter 2020, 2, 1414–1445.	Emphasis on technical aspects; may lack insights into user experience and acceptability.	Explores the use of skin-interfaced sensors in digital medicine, offering a technological perspective on advancing telemedicine applications for improved healthcare outcomes.
8	Yadav, A.; Singh, V.K.; Bhoi, A.K.; Marques, G.; Garcia-Zapirain, B.; Díez, I.d.l.T. Wireless body area networks: UWB wearable textile antenna for telemedicine and mobile health systems. Micromachines 2020, 11, 558.	Focuses on specific technical innovations; may overlook broader implications and challenges.	Introduces wireless body area networks and wearable textile antennas for telemedicine and mobile health systems, highlighting potential advancements in remote healthcare monitoring.
14	Latifi, R.; Doarn, C.R.; Merrell, R.C. Telemedicine, Telehealth and Telepresence; Springer International Publishing: Cham, Switzerland, 2021.	Comprehensive overview of telemedicine concepts; potential lack of depth in specific technological advancements.	Offers a comprehensive overview of telemedicine, telehealth, and telepresence, serving as a foundational resource for understanding the broader landscape of remote healthcare delivery.
20	Muschol, J.; Heinrich, M.; Heiss, C.; Knapp, G.; Repp, H.; Schneider, H.; Thormann, U.; Uhlar, J.; Unzeitig, K.; Gissel, C. Assessing Telemedicine Efficiency in German Follow-up Care With Video Consultations for Patients in Orthopedic and Trauma Surgery: A	Limited to a specific geographic region; may not generalize to other healthcare contexts.	Evaluates telemedicine efficiency in German follow-up care, providing insights into the effectiveness of video consultations for patients in orthopedic and trauma surgery within a specific healthcare system.

	Randomized Controlled Trial. J. Med. Internet Res. 2022, 24.		
21	Giansanti, D.; Morone, G.; Loreti, A.; Germanotta, M.; Aprile, I. A Narrative Review of the Launch and the Deployment of Telemedicine in Italy during the COVID-19 Pandemic. Healthcare 2022, 10, 415.	Focuses on Italy-specific context; potential overlook of broader international perspectives.	Focuses on Italy-specific context; potential overlook of broader international perspectives.
9	Kayyali, S. Resource Management and Quality of Service Provisioning in 5G Cellular Networks. arXiv 2020, arXiv:2008.09601	Theoretical nature may lack practical insights; may not address specific telemedicine applications.	Discusses resource management and quality of service provisioning in 5G cellular networks, offering theoretical foundations for optimizing telemedicine services in future network environments.

III. OVERVIEW OF TELEMEDICINE

Major Before providing distant medical assistance, the physical distance between the patient and the provider must be considered, as different technologies and protocols are needed for short-range versus long-range communication. Short-range communication technologies include Bluetooth, ZigBee, and Wi-Fi, while long-range communication uses LoRaWAN, internet, GSM, 3G, 4G, LTE, and 5G. Environmental sensors, such as thermometers, accelerometers, and motion detectors, provide various data like location, movement, and temperature. Recent advancements include nano-engineered electrochemical sensors for COVID-19 diagnosis and management.

- Field Effect Transistor-based (FET-based) sensors; these are ultrasensitive and are used to detect Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) antigens.
- Laser-engraved graphene-based immune sensors, which are used to obtain a diagnosis from saliva.
- Laser-engraved graphene-based immunosensors, which are used to obtain a diagnosis from saliva.
- Other sensors used in VoIP includes
  i. PPG, or photoplethysmography.
  ii. For eye diagnosis, an electrooculogram (EOG) is used.
  iii. Diet sensors, which track eating habits and evaluate coronary heart disease and Type II diabetes.
  iv. The GSR, or galvanic skin response.

A) Evolution of Communications Technologies for VoIP

VoIP communication technologies enable the transmission of data from body sensors, forming sensor network systems. The advancement of VoIP has greatly benefited from telecommunication developments, tracing back to the electrical telegraph and Plain Old Telephone Service (POTS). Initially used by the military, the telegraph allowed faster medical data transmission, teleconsultations, and medical supply orders compared to traditional mail.

Communication Network Links for VoIP:

Technological developments such as high-speed internet connections enable digital connections between patients in remote rural areas and healthcare providers at large hospitals. The widespread availability of affordable high-speed internet allows remote patients to access VoIP services. This subsection covers the two communication network links—point-to-point and point-to-multipoint—that support VoIP.

Point-to-Point Links:

Point-to-point connections and high-speed internet allow larger medical facilities to connect with smaller rural health centers, enabling remote specialist consultations and patient referrals. This is particularly useful for teleconsultations, telepsychiatry, teleradiology, and remote monitoring of elderly patients receiving palliative care at home.

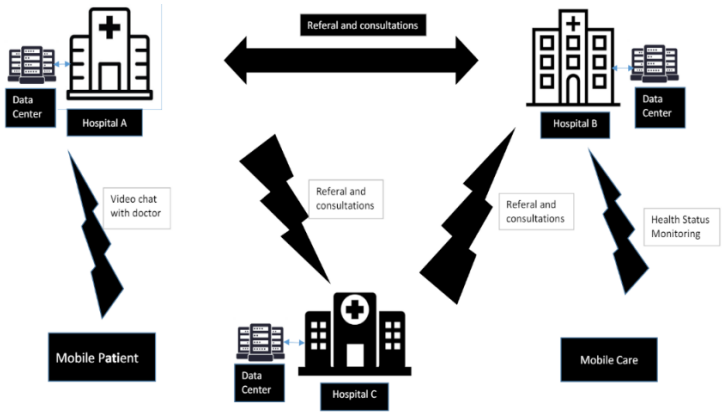

Fig. 2: Point to point links

Point-to-Multipoint Links:

This type of connection requires very high-speed internet with extensive coverage, as multiple patients connect simultaneously to healthcare providers. Ensuring data security, privacy, and proper information sharing is a significant challenge due to the large volume of shared data.

B) Use case of VoIP

Depending on the requirement and need of the patients, the following two units are covering the tele-medication to get maximum possible benefits:

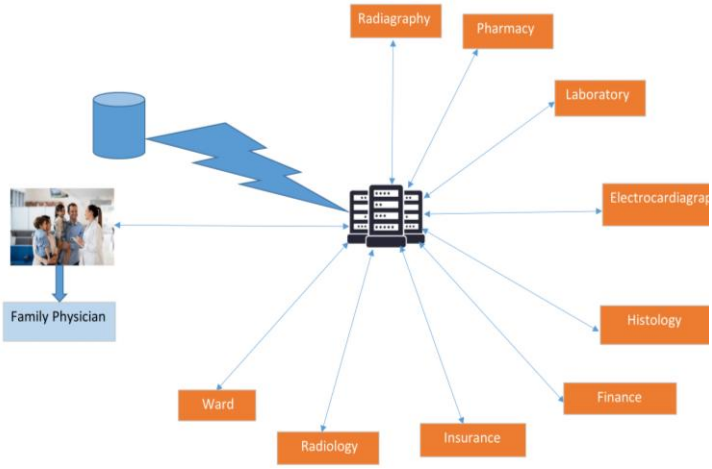

Fig. 3: VoIP application overview

Remote Medical Server Unit: In this setup, expert physicians access patient services remotely. Patient data from the Patient WBAN is transmitted through a communication unit and stored in a database. Physicians, with proper authentication, can access this information for diagnosis, often using videoconferencing with compatible cameras, microphones, and other devices to assess patient EHRs.

Medical Professional Unit: This unit refers to the personnel that provide the medical or caregiving services remotely, who may include physicians, hospital facilities staff who carry out data interpretation, ambulance staff, nurses, and other healthcare professionals.

Types of information transmitted using Specialist Application of VoIP: VoIP is VoIP is increasingly integral in medical settings for remote consultations and addressing care provider shortages. Early adopters in specific medical sub-specialties have propelled tailored VoIP solutions forward.

- Telepsychiatry: Telepsychiatry expands mental health care access by allowing experienced psychiatrists to remotely treat patients, addressing shortages in psychiatry and circumventing the need for extensive physical exams.
- Tele-dermatology: Tele-dermatology empowers primary care physicians to remotely diagnose skin conditions, utilizing high-resolution cameras to coordinate patient care efficiently and determine the need for further examinations.
- Teleophthalmology: Using teleophthalmology technology, eye doctors can remotely monitor therapy progress and conduct examinations on patients.
- Tele-nephrology: Tele-nephrology refers to the practice of remotely consulting a nephrologist; an example of an inter-professional application of tele-nephrology solutions is the case of a family doctor who requires a specialist opinion concerning a patient who has kidney disease.
- Tele-obstetrics: Through tele-obstetrics, gynecologists can provide prenatal care to expectant mothers; as an example, a doctor at one facility could film an ultrasound of a baby's heart and send it to an obstetrician in another location for analysis.
- Tele-oncology: With the goal of making cancer treatment more accessible, tele-oncology has grown rapidly in recent years; among the different tele-oncology technologies are store-and-forward mechanisms that transmit images for diagnosis and real-time video platforms that enable oncologists to consult with patients.
- Telepathology: Through the use of telepathology technologies, pathologists are able to collaborate remotely on pathology cases for the purposes of diagnosis, study, and instruction; many telepathology solutions are "save and forward" systems that let pathologists send and receive high-resolution images and videos.
- Telerehabilitation: VoIP allows healthcare providers to remotely provide rehabilitation treatments such as physical therapy to those who need them.

The following picture will explain how benefits we can get using these techniques:

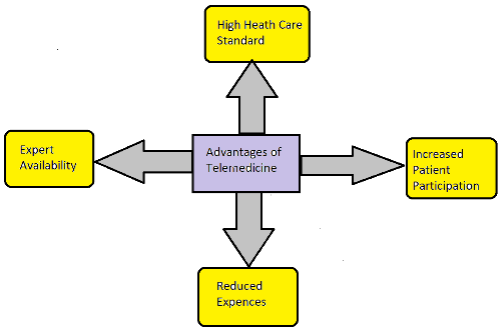

Fig. 3: Advantages of Telemedicine

IV. COMMUNICATION STANDARD AND PROTOCOLS

Communication Standards and Protocols ensure consistency and universality for successful message transmission between communication devices. They encompass authentication, Error Detection and Correction (EDC), signaling, modulation, and demodulation techniques, with common protocols including:

- Bluetooth stack of protocols
- Zigbee stack of protocols
- Wireless Application Protocol (WAP)
- File Transfer Protocol (FTP)
- Hypertext Transfer Protocol (HTTP)
- TCP/IP
- UDP

Connectivity protocols/standards required for communications technologies in VoIP consist of ZigBee/IEEE 802.15.4, Bluetooth/IEEE 802.15.1, WiMAX/IEEE Broadband Wireless Access (BWA) 802.16, Wi-Fi/WLAN/IEEE 802.11, User Datagram Protocol (UDP), Real-Time Protocol (RTP), and Real-Time Transport Control Protocol (RTCP) and TCP/IP.

ZigBee:

The strengths of ZigBee technology include:

- Low latency
- High data security
- Collision avoidance and retransmission, ensuring more reliable data transmission
- Support for multiple network topologies, such as point-to-point, star, and mesh topologies
- Support for unlimited nodes in a network
- Scalability
- Low energy consumption
- Ease of implementation
- 128-bit AES encryption ensures data security.

Classification of Research Challenges in VoIP:

- *Cost of Deployment and Legal Framework:* Using VoIP offers enhanced access to quality healthcare, yet implementation challenges, like costly communication infrastructures, hinder accessibility, especially in developing regions. The high deployment costs often lead to limited services for end consumers, exacerbated by inadequate legal frameworks.
- *Network Coverage, Capacity and Mobility:* Strong network coverage is essential for seamless VoIP app functionality, requiring network providers to ensure efficient data flow between local patient sites and physician locations, particularly crucial for real-time medical services.
- Quality and Integrity of Data for ML Algorithms: To train machine learning algorithms, high-quality datasets must be easily accessible. Reliable models that are tailored to the specific area of a research challenge require high-integrity data to extract the necessary features.
- *Energy Efficiency:* Wearable technology often demands high power for data measurement and transmission, necessitating compact yet energy-efficient battery designs, crucial for optimizing wearable VoIP gadgets.

V. CONCLUSIONS

This review covers the development of VoIP systems and various communication technologies used, including telemedical applications like BAN. It examines remote communication with telemedical servers via internet, satellite, WAN, and GSM. The selection of communication technologies depends on infrastructure availability, application nature, and cost considerations, with protocols tailored to specific data transmission needs. ML algorithms are proposed for VoIP enhancement, aiming to address implementation challenges and unmet research needs. Future VoIP designs should focus on integrating wireless networks for QoS and mobility, standardizing medical data transfer formats, ensuring data security, and optimizing energy efficiency for wearable medical devices.

Further research is needed in areas such as blockchain, mobile edge computing, and cloud computing for secure data transfer in VoIP applications. Study topics should include resource allocation in emergency VoIP, utilizing vertical handoff algorithms, and effective media compression techniques. Future VoIP designs must consider factors like open standards, gateways, and scalability of communication technologies. Future research should integrate current VoIP technologies with emerging concepts like IoMT, W-IoT, and H-IoT to enhance remote health monitoring and network compatibility, alongside addressing obstacles like legal issues and. technology accessibility.

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