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An Empirical Study on the Current State of Internet of Multimedia Things (IoMT)

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Abstract: As the Internet continues to expand, immense people around the globe join the Internet. The Internet of Things (IoT) can be defined as the interconnection of peerless identifiable embedded computing devices within the current Internet infrastructure. This paradigm encompasses an infrastructure of software, hardware, and services that link tangible objects called things to the Internet. In Internet of Things technology, multimedia big data which is said to be the huge amount of data from multimedia devices will be generated with the swiftly rise of the multimedia gadgets and devices. The multimedia devices need higher processing and memory resources to process the obtained multimedia information. The Internet of Things systems are fiasco in realizing the multimedia devices connectivity unless they are able in processing multimedia gadgets and devices at a moment. In this paper, we are introduces a new concept of Internet of Multimedia Things (IoMT) for multimedia communications in Internet of Things (IoT). Internet of Multimedia Things (IoMT) communications play a vital role in Internet of Things (IoT) applications such as traffic control and handling, environmental monitoring, healthcare sector, observation & surveillance, event recognition and house monitoring and automation. In this paper, we present a comprehensive survey of IoMT and future research directions. The Internet of Multimedia Things (IoMT) applications such as real-time multimedia based security and monitoring in smart house, Smart Agriculture, multispecialty hospitals, metropolitan area, and smart transportation handling systems are of the most difficult systems to deploy.

Keywords: Internet of Multimedia Things (IoMT), Cloud Computing, Internet of Thins (IoT), Quality of Things (QoT), Wireless Sensor Network (WSN), Machine to Machine (M2M), Machine to Human (M2H).

1. INTRODUCTION

The Internet of Things (IoT) is a modern concept that has transformed conventional lifestyles into high-tech ones. The rise of intelligent environments [1] means that technologies are becoming more interconnected and that the Internet is being used more. The internet of things (IoT) is rapidly expanding, and the ability to link physical and virtual reality is opening new doors for innovation in almost every field of life [2]. The Internet of Things (IoT) is a set of heterogeneous objects or devices with varying computing and connectivity capabilities that can gather data from the physical world linked by the internet. Machine to machine (M2M) communications, on the other hand, would be the most prevalent technology in IoT concepts [3]. Sensors, actuators, cell phones, home automation systems, and smart grid devices all have the ability to have a huge impact on our lives and how we communicate with them. The Internet of Things (IoT) is a mixture of information technology, computer science, electronics, telecommunications, and other fields [4]. The concept of the Internet of Things (IoT) was introduced by Kevin Ashton in the year 1999.

The Internet of Things (IoT) has shown that computers are not the only devices with Internet connectivity, and that various devices and artefacts have this capability. It has become the most vital research topic in the last 15 years [5], whose objective is based on everyday objects having identification, detection, and interconnection and processing capabilities to communicate with each other and with services via the Internet to unriddle a specific and useful need of people [6]. Internet of Things (IoT) is a broad-spectrum system which includes many integrated system. Wireless sensors in the Internet of Things communicate with one another via short-range wireless communication. A wireless sensor network (WSN) is a set of sensors linked to the Internet through one or more gateways [7]. Single-hop or multi-hop wireless communications can be used to communicate between the sensors and the sensor network's gateways [8].

The Internet of Multimedia Things (IoMT) is a new paradigm created by smart heterogeneous multimedia devices that communicate and cooperate with one another and with other devices through the Internet of Multimedia Things (IoMT). Smart objects in the Internet of

Multimedia Things (IoMT) are usually [9] limited in terms of energy, memory capacity, and processing power. To make the devices smaller, cost effective and energy efficient, sensors are usually designed to be battery operated or solar powered with only a few kilobytes of memory, and limited processing power in megahertz [10]. Multimedia data is a set of unstructured characteristics that includes audio, images, and video. Transmission of such large, unstructured data over a network with limited bandwidth and computing power necessitates an efficient and intelligent network topology. Real-time multimedia contact due to bandwidth constraints and packet loss, IoT applications can experience network delays and congestion, lowering the quality of transmitted multimedia. To fix the aforementioned [11] concerns, multimedia communications in IoT have been proposed in recent years. In most IoMT smart systems, the intelligence generated by Deep learning methods is tightly bound to the application that implements it, restricting the provisioning [12] of that particular intelligence service to other applications, also within the same system domain [13]. For example, in a intelligence university campus scenario, it is reasoning that the same facial recognition system should be applied to register the presence of undergraduate & postgraduate students in the university classroom as well as to unlock a laboratory door for a researcher. This article presents a comprehensive state of the art survey on Internet of Multimedia Things (IoMT) [14]. Multimedia wireless sensor networks which process enormous multimedia traffic in real time IoT applications [15] namely traffic monitoring, remote system monitoring and home security monitoring, smart grid monitoring need huge memory and computational resources and consume more energy differentiate with traditional wireless sensor networks collecting information from the physical environment for example temperature, pressure, and light.

The rest of this paper is organized as follows. The related work is presented in Section II. We describe the Internet of Multimedia Things (IoMT) in Section III and Internet of Multimedia Things (IoMT) architecture in Section IV. In Section V, we present the Internet of Multimedia Things (IoMT) in wireless sensor. We present Internet of Multimedia Things (IoMT) in cloud computing in Section VI. We provide Quality of Things (QoT) for Internet of Multimedia Things (IoMT) in Sections VII. We are discussing Internet of Multimedia Things (IoMT) enabling technologies in Sections VIII. We are widely discussing Internet of Multimedia Things (IoMT) applications in Sections IX. In Section X, we present Internet of Multimedia Things (IoMT) uncovered matter. We conclude this paper in Section XI.

RELATED WORK

Through numerous applications, the Internet of Things (IoT) has changed the use of the Internet in recent years. The internet-of-things (IoT) paradigm is one of the next evolutionary steps in internet-based computing, and it is already having a positive effect in a wide range of application domains, such as smart cities, sustainable living, healthcare, manufacturing, and more [16[. The foundation of IoT is served by integration of RFID tags, actuators, sensors etc and defines the communication between physical objects through internet and reaches common goals [17]. The various areas of Industry got affected by emergence of IoT and has many projects associated with it such as agriculture, food processing etc industry, security surveillance, environment monitoring etc.[18]. Yusuf Perwej et al. provide a technical overview of Internet of Things protection in multimedia data. Because, the protection was a major concern when just two devices were coupled [19]. Furthermore, multimedia data differs from scalar data in that it imposes quality-of-service criteria on green communications IoT [20]. Physical devices layer, network layer, mixture layer, and background layer are the four layers proposed for the multimedia IoT in [21]. In [22], image and video frames were divided into important premium blocks and unimportant regular blocks to save energy on IoT devices and provide high QoE to end users. Many Cross layer protocols have been proposed in recent past [23] for WSN and they have optimized the various parameters of the layers. But these protocols require to be enhanced by the optimization model for multimedia IoT as proposed (IoMT) in this paper. IoMT services are real-time in nature and need to provide guaranteed quality and performance [24].

The first research to present the vision and standardisation of the Internet of Multimedia Things (IoMT) [25]. The paper introduces the "IoMT" paradigm, which allows multimedia objects to communicate with one another and connects to the Internet of Things to enable multimedia-based services while keeping applications and users in the loop. Based on the use of multimedia content as IoT input and output, multimedia as IoT input, and multimedia as IoT output, the authors specified IoMT in three scenarios [26]. The paper suggested a layered QoE model for IoMT applications, presented a use case involving remote monitoring driving activities, and performed subjective QoE evaluations. It introduces architecture for IoMT and presented its possible use-cases and applications. Existing hardware and communication protocol layer technologies reviewed in paper [27]. Perera et al. [28] proposed an IoT middleware solution that can work on resource constrained mobile devices allowing them to collect and process data from sensors easily. Mobile sinks and mobile relays have been suggested for improving the performance of data collection in WSNs.

The survey [29] includes the most important work in the area of multimedia stream processing. In this paper develops a detailed taxonomy for multimedia big data (MMBD) computing in the context of the Internet of Things. It also looked at the literature on issues including scalability, usability, data durability, and heterogeneity. Bisnik et al. [30] studied the problem of providing quality coverage using mobile sensors and analyzed the effect of controlled mobility on the fraction of events captured. The existing survey on energy-efficient IoMT is presented in [31]. This study explains the working of each layer of the traditional IoT architecture; however, the intrinsic nature of multimedia data is not considered in any aspect. Xu et al. [32] further studied delay tolerant event collection in sensor networks with mobile sink which considers the spatial-temporal correlation of events in the sensing field. Kaaradi et al. [33] have presented the concept of Quality of Things (QoT) for IoMT. He et al. [34] analyzed the performance of data collection theoretically to evaluate service disciplines of MEs through a queuing model. Thiyagarajan et al. [35] have proposed a secure video transmission energy-aware encryption scheme for IoMT. Singh and Al Turjman [36] studied the use of heuristically accelerated learning techniques for improving the data delivery success rate in information-centric sensor networks. It examined the performance in terms of influence on the network lifetime, average good outcome and bad outcome rates, energy consumption, and the QoI at the accomplishment.

INTERNET OF MULTIMEDIA THINGS (IoMT)

The Internet of Things (IoT) is a term used to describe a system of interconnected, internet-connected devices that can capture and transmit data over a wireless network without the need for human interaction. Devices embedded with internet connectivity, sensors, and other hardware enable communication and control through the web in the Internet of Things (IoT) [37]. IoT has become one of the most important technologies of the 21st century. Now that we can connect everyday objects kitchen appliances, cars, thermostats, baby monitors to the internet via embedded devices, seamless communication is possible between people, processes, and things. IoT systems cannot successfully realize the notion of ubiquitous connectivity of everything [38] if they are not capable to truly include ’multimedia things’. We will show some glims of Multimedia before launching the Internet of Multimedia Things (IoMT).

Multimedia is a concept that combines the words multi and media. The term media (medium) has a double meaning: it refers to a device that stores data on a disc, CD, tape, semiconductor memory, and other devices. Second is the transmission of information carriers, such as numbers, text, sound, graphics and so on. Therefore, the corresponding term and multimedia is a single media, literally, the media is compounded by a single media. Multimedia is anything and everything that you watch and listen. It is graphics, audio, sound, text and many. This is usually recorded and played, displayed or accessed by information content processing devices such as computerized and electronic devices.

Multimedia includes everything you see and hear in the form of text, images, audio, video, and other formats [39]. Information content processing systems, such as computerized and electronic devices, typically recode and play, view, or access this. We may use multimedia in the workplace, schools, residences, public spaces, and virtual reality. These have many functions to do many things and have made the things to more mobile. Multimedia enhanced simple, text-only computer interface and production acquisition and holding of attention and interest in measurable benefits. In short, is to improve multimedia information retention. When it’s properly constructed, can be profound and useful multimedia entertainment. Multimedia can be use in many way are business, school, home, public places and virtual reality. The Internet of Multimedia Things (IoMT) can be described as a “network of interconnected objects capable of acquiring multimedia contents from the real world and presenting information in a multimedia way” [40] by including multimedia content. The idea of combining multimedia and IoT is relatively new. The word "Internet of Multimedia Things" (IoMT) was recently coined to describe IoT-based multimedia communications. Multimedia objects, on the other hand, can be described as "objects capable of acquiring multimedia contents from the physical world while being equipped with multimedia devices". Processing of multimedia events and their execution environments are essential in IoMT for analyzing the huge amount of unstructured data generated in smart cities [41].

IoMT is described as the addition of IoT challenges, such as protection, routing, quality of service (QoS) and quality of experience (QoE) issues, heterogeneity of multimedia sensors, and so on [42]. IoMT devices need higher bandwidth, bulky memory resources, and higher computational power to analyze and process the procured multimedia data[43]. The traditional multimedia application involves the data transmission of multipoint-to-point communication for example the surveillance system of the entire smart metropolitan area and multipoint-to-multipoint scenarios. The table 1 represents a comparison of IoMT and IoT based technologies.

Table 1. The Comparison of IoMT and IoT Based Technologies

No.	Features	Internet of Multimedia Things (IoMT)	Internet of Thins (IoT)
1	Data Size	Megabytes to Gigabytes	Bytes to Kilobytes
2	Resources	High Energy Consumption	Low Energy Consumption
3	Deployment	Audio and Video Sensors	RFID Tags
4	Bandwidth	Megabytes	Kilobytes
5	Quality of Service	High Bandwidth	Low Bandwidth
6	Storage	Gigabytes	Kilobytes to Megabytes
7	Data Heterogeneity	Diversified Multimedia Data	Limited Heterogeneity
8	Delay Sensitivity	High	Low
9	Data Signal Processing	Multimedia Data Analytics	Structured Data Analytics
10	Processing	Megahertz to Gigahertz	Kilohertz to Megahertz
11	Service Compositions	Not Available Specialized	SOA Based
12	Memory	Megabytes to Gigabytes	Kilobytes to Megabytes
13	Communication Protocols	None Standardized	Standardized

Around the globe multimedia systems have been employed a wide range of applications [44], including emergency response systems, traffic monitoring, medical Applications (for patient or child monitoring), crime inspection, smart cities, smart homes, smart hospitals, smart agriculture, video-surveillance devices might be deployed in various scenarios, such as within public transport management systems (managing buses, airplanes or road traffic), Internet of bodies (IoB), image processing, mobile computing [45], Industrial IoT (IIoT), smart systems, personal asset protection (within homes or construction sites) and many other applications [46]. Multimedia communication in the IoT faces enormous challenges due to dynamic networks, heterogeneous devices and data, strict QoS, and delay sensitivity and reliability requirements over resource-constrained IoMT [47]. The goal is to make these devices smart by allowing them to communicate with one another, effectively turning them into smart objects.

INTERNET OF MULTIMEDIA THINGS (IoMT) ARCHITECTURE

The orchestration of the Internet of Multimedia Things allows systems, apps, the cloud, and smart sensors to be integrated into a single platform. The IoMT works for both scalar and multimedia data [48]. The timely and efficient delivery of data is the most important feature of IoMT. As a result, stringent quality of service (QoS) standards is imposed, as well as effective network architecture. The rapid growth of multimedia traffic in IoT has led the way to innovating new techniques to meet its requirements [49]. The novel Internet of Multimedia Things (IoMT) architectures are presented in this section shown in figure 1. Multimedia traffic has drastically grown in the last few years.

The robust increase in multimedia traffic necessitates an efficient network traffic management system. Rego *et al.* [50] propose an intelligent network management system for the IoT video surveillance system based on SDN and Artificial Intelligence [51]. SDN (Software Defined Networking) emerged as a technique for increasing network functionality while lowering costs, simplifying hardware, and encouraging groundbreaking research. Software specified networks (SDNs) enhance network management capabilities. Artificial intelligence, when combined with SDN, can provide network solutions based on classification and estimation techniques [52]. Artificial intelligence helps to manage resources and network traffic dynamically. Using AI to study the traffic of the network, we can discover the different types of flow that are being transmitted. Thus, traffic patterns can be obtained, which can then be applied in SDN decision making.

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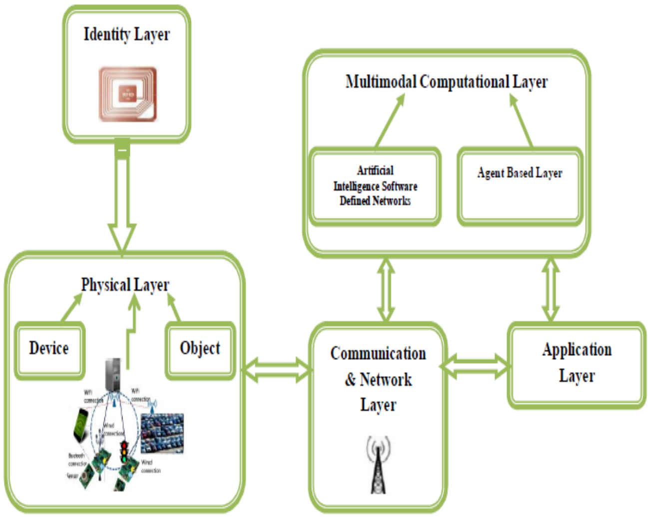

Fig. 1 Internet of Multimedia Things (IoMT) Architecture

Integrate artificial intelligence techniques with SDN, adaptive behaviors are achieved in order to improve the performance of the network. The Multi agent cloud computing-based architecture for multimedia communication in IoT due to the bulky and unstructured nature of multimedia content. Multimedia sensing, monitoring, and addressability, multimedia aware cloud, and multi-agent systems are the four key parts of this architecture. Kaeri *et al.* [53] further enhance the multi agent IoMT architecture to make it more practical by proposing and implementing the five layer architecture.

An innovative agent based architecture for systems supporting remote collaboration based on an IoMT approach. Basic IoT elements and instruments, such as cameras, microphones, sensors, and multimedia communication lines, are used in these applications. This architecture is divided into five layers applications, service execution agents, resource connectors, IoMT services & resources, and IoMT devices & communications. Each interface and communication, such as touch screens, synchronous and asynchronous communication lines, and cloud storage, are represented by the bottom three layers. Parallel channels necessitate the simultaneous use of several graphical user interfaces and, more critically, a display surface.

Those channels can be incorporated into applications dynamically by users to enhance the expandability of the IoMT system. Rahman et al. [54] propose a context-aware fog cloud hybrid based framework that integrates spatio temporal multimedia data from IoT mobile and stationary nodes for the massive ad-hoc crowd. In this article [55], a three-tier architecture mobile client tier, fog node tier, and remote cloud tier, is presented. The authors aim to optimize energy resource utilization and reduce end-to-end delay for the massive crowd in the smart city. The mobile client tier includes service consumers. Fog nodes tier comprises Smartphone's and other IoT fog nodes distributed in the city to assist in real-time processing of spatio-temporal collective or individual queries. To analytical compute, store, and process offline queries, the cloud tier is made up of IP-based massive big data architecture. A sustainability and energy efficiency model, as well as huge geo-tagged, multimedia big data architecture, are included in the communication architecture between mobile users and fog nodes, as well as between fog nodes and the cloud.

The authors [56] suggested a six-layered IoMT architecture focused on big data aggregation, computation, and multimedia content extraction. Instead of using the word media, the writers used the term modal, which explains how data is perceived to convey meaning. Moreover, they have listed three main problems associated with multimodal big data computation that is to compute the huge amount of data, to detect and extract meaningful information and the current limitation of big data processing platforms for multimedia [57]. The six layers proposed in IoMT architecture. Moreover, the article presents a unique and efficient technique that is Divide and Conquers Principal Component Analysis (DC-PCA) to reduce the dimensions, subdivides the data, process the subdivided data in parallel fashion, and fuse the final parallel processed data to extract the features.

Mediaware Traffic Protection Architecture (MTSA) for IoMT was developed by Zhou and Chao [58] and consists of four key components. Key management, which involves service control, user control, flow control, scalable, and non-scalable schemes [59], is one of these elements. Watermarking is used to identify the origin of multimedia content, trace illegal distribution [60], and block unauthorized access by embedding a unique watermark into multimedia content [61]. Security is of critical importance for various multimedia applications in IoT. The media-aware traffic security architecture (MTSA) is applied to obtain satisfying traffic management based on the given media-aware traffic classification and analysis. MTSA is one of the first security-aware traffic manage- ment strategies for multimedia applications running over the IoT. For facilitating various multimedia applications in the Internet of Things, the author proposed an efficient [62] media-aware security system. This system of multimedia traffic classification and analysis is designed to deal with the heterogeneity of various applications. To support multimedia content in various IoT applications, a standardized IoMT architecture is required.

INTERNET OF MULTIMEDIA THINGS (IoMT) IN WIRELESS SENSOR

The IoMT is an extension of the IoT, with one of its primary goals being to support video streaming as part of IoT implementation. In the Internet of Things, resource-constrained low-cost, low-power heterogeneous multimedia devices can communicate with one another and be globally accessible via unique IP addresses, in the same way as computers and other networking devices connected via the Internet can. IoMT faces similar challenges to IoT, such as dealing with large quantities of data, requests, and computation, as well as some unique requirements. The multimedia devices in IoMT-based wireless multimedia networks [63] are expected to be small artefacts with a limited amount of power resources, which they must effectively use to extend network life time.

Multimedia communication in the Internet of Things (IoT) can potentially reach into a vast array of areas and touch people’s lives in profound and different ways. For example, real For example, governments can allow its citizens to upload real-time multimedia data using some Smartphone applications to report about the road and traffic conditions within the cities. The real-time multimedia streaming information can be applied to the current emergency response services, e.g., 112 in Lucknow and 1090 in Lucknow woman helpline. It will allow an emergency response service to provide accurate information about the nature or seriousness of an incident, such as a robbery, accident, or domestic abuse, if the caller may send video or photographs of the incident or the incident location. The current trend is for devices and things to migrate away from non-multimedia data support and toward multimedia streaming, especially video streaming. Here upon, it is important to have an understanding of multimedia streaming and the sensor embedded in these devices, multimedia sensor nodes in this case.

IoT technology enables massive data collection, which leads to the emergence of a large number of sensor-based applications. Wireless Sensor Networks (WSNs) have become the most common IoT-based data collection platforms. In Wireless Sensor Networks (WSNs), data collection is one of the most important operations [64]. In view of the characteristics of these data, we believe that very large-scale and heterogeneous WSNs can be very useful for collecting and processing these Big Data [65]. WSNs (Wireless Sensor Networks) have exploded in popularity over the last decade. In traditional WMS and WMSN, the sensors are constrained devices in terms of their energy, processing and computational resources. WMSN is a network of interconnected sensor nodes that sense the environment, and retrieve multimedia and ordinary data ubiquitously from the physical environment [66] shown in figure 2. Multimedia data include still images, audios, and videos and even live media streams that are supported by sensor nodes with installed cameras and microphones.

At the multimedia unit, the massive amount of multimedia data acquired is compressed using various pre-transmission processing procedures such as transformation, quantization, estimation, entropy coding, and so on, in order to minimize bandwidth requirements during transmission [67]. These processes are computationally complex and consume significant amount of energy. IoMT devices exhibit limited bandwidth capacity, but enabling a good video quality needs high compression that is infeasible due to high energy consumption. Wireless Multimedia Sensor Networks are a special type of Wireless Sensor Network (WSN) where huge amounts of multimedia data are transmitted over networks composed of low power devices [68].

The majority of wireless multimedia devices are supposed to run on batteries. Since multimedia retrieval and processing are both energy-intensive processes. Multimedia data processing is a computationally intensive task. Local multimedia processing necessitates the temporary storage of data during sensing and manipulation. The volume of data in WMSNs is much bigger as compared to WSNs primarily due to the use of video and audio streaming. IoMT based multimedia devices have limited energy and processing capability, so the complexity should be shifted to the cloud. Intelligent traffic control systems, military software, security

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systems, and wildlife monitoring are only a few of the areas where WMSNs have found use. Since they require both non-multimedia and multimedia knowledge, all of these applications are heterogeneous in nature [64].

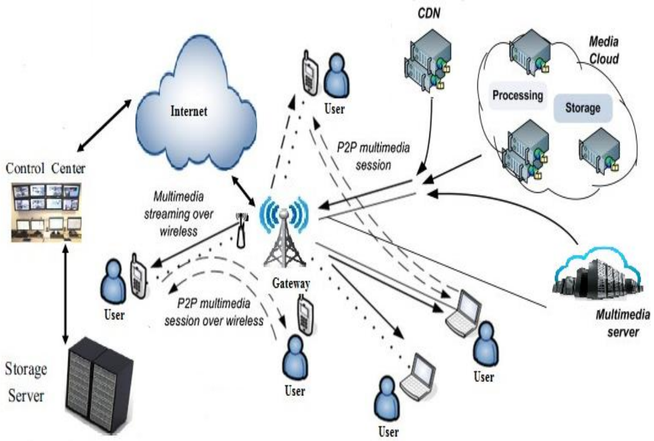

Fig. 2 Internet of Multimedia Things (IoMT) Wireless Communication

The ultra-wideband (UWB) is normally used as a short-range, wireless communication standard for sending and receiving multimedia information data and that operates through radio waves. Ultra-wideband is used for a bandwidth (BW) that is larger or equal to 500 MHz or a fractional bandwidth (FBW) greater than 20% where $FBW = BW/fc$, where fc is the center frequency. In contrast, various WPAN standards such as, Zigbee, Bluetooth [69], IEEE 802:15:4. ZigBee has been adopted for IoT due to its energy efficient operation. Multimedia sensing demands high processing and continuous data acquisition, which results in higher energy consumption. Since, the IoMT devices are expected to be operated on batteries that may not last longer due to demanding nature of multimedia data [70]. Thus, efficient energy harvesting procedures need to be devised to energize sensors and prolong the network lifetime.

INTERNET OF MULTIMEDIA THINGS (IoMT) IN CLOUD COMPUTING

Cloud computing is a new IT technology that is being used in computation today. Previously, we stored our data on hard drives in computers. Hard drive technology has been replaced by cloud storage services. Cloud computing is defined as the delivery of resources such as storage, databases, servers, networking, and software over the Internet. It is a green technology that allows users to access, compute, and store resources over the internet without having to physically acquire them [71]. Cloud computing generally includes Infrastructure as a service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). Reduce the computation time and to overcome the storage space shortage issues, most of the organizations nowadays shifting to cloud computing from the traditional process of computation. It manly focuses on distributing data and computations over a scalable data centers of network. Nowadays users can easily access the multimedia content over the internet at any time. Here the user can efficiently store the multimedia content of any type and of any size in the cloud after subscribing it with no difficulties.

The cloud provides a stable environment in which data can be accessed, stored, and processed in a transparent manner. Users have higher expectations when it comes to multi-screen applications. Users can access the cloud's multimedia content through multiple devices, with a wide range of video, audio codecs, aspect ratios, and screen sizes supported on a live or pay-per-use basis. In addition, the Cloud multimedia has to provide application & service specific QoS adaptation, in terms of bandwidth and delay while performing tasks such as storage, delivery, sharing, submission, and retrieval, for enormous number of heterogeneous end-user devices [73].

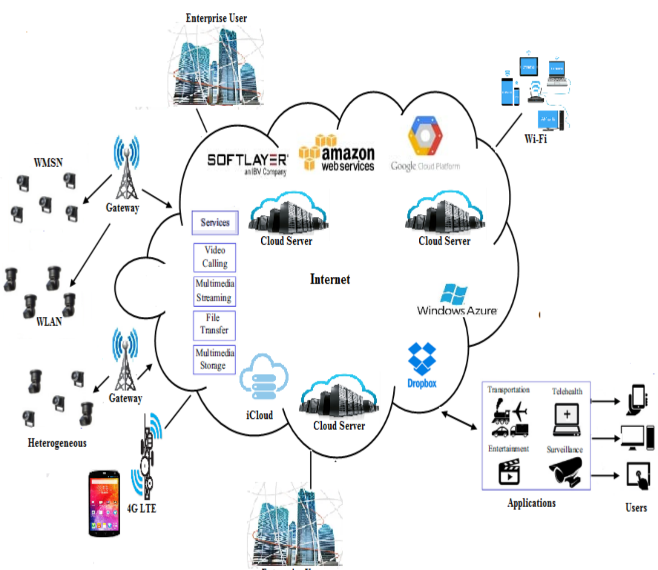

Fig. 3 Internet of Multimedia Things (IoMT) in Cloud's

Cloud multimedia computing provides cost-effective services to service providers by efficiently multiplexing media contents such as audio, video, and image by offering a common infrastructure, using the server, optimization, virtualization, accessibility, and automatic processing [74] as shown in figure 3. The use of Blockchain technology in IoMT may have a number of advantages [75]. Blockchain is a cutting-edge technology that has been employed to security via data access management, tamper proof recording [76], transparency, support for smart contracts, and trustless consensus properties, which indicates it has the potential to be utilized to protect service discovery for IoMT [77].

However, integrating a cloud platform into IoMT and IoT systems is a difficult task that comes with numerous challenges, including management, synchronization, reliability, and enhancement. For real-time multimedia services, Video Service Providers (VSPs) are shifting their infrastructures to public clouds [78]. The integration of cloud computing with IoMT & IoT enables the user to access their desired data anywhere and anytime. If the services and applications are properly managed on cloud platforms, users will not only be able to access the data but, will control their systems too. For example, the users can be enabled to ubiquitously access the sensor data from remote sensor devices as a Sensing as a Service (SaaS) [79], rule engines can be implemented to control the actuators operation automatically from the cloud as a Sensing and Actuation as a Service (SAaaS) [80], providing control to identity and policy management systems Identity and Policy Management as a Service (IPMaaS) [81], enabling access to video analyses and streaming of recorded video content in the cloud video surveillance as a service (VSaaS) [82]. The IoMT & IoT are multi-layer technologies that are used to control and automate connected devices. To put it another way, this aids you in getting physical objects online. This platform will give you the tools you need to attach devices for machine-to-machine communication.

Table 2. The IoMT & IoT Cloud Platforms Characteristics

No.	Platform	Gateway	Provision	Assurance	Billing	Protocol					
						DDS	REST	Z-Wave	CoAP	XMPP	MQTT
1	OpenRemote	Yes	No	Yes	No	No	No	Yes	No	No	No
2	Arkessa	No	Yes	Yes	No	Yes	Yes	No	No	No	Yes
4	Axeda	Yes	Yes	Yes	Yes	No	Yes	No	No	No	No
4	IRI Voracity	Yes	No	Yes	Yes	No	No	No	No	No	Yes
5	Etherios	Yes	Yes	Yes	No	No	Yes	No	No	No	No
6	LittleBits	No	No	No	No	Yes	Yes	Yes	No	No	No
7	NanoService	Yes	Yes	Yes	No	No	Yes	No	Yes	No	No
8	Particle	Yes	No	Yes	Yes	No	Yes	No	Yes	No	No
9	Nimbits	No	No	No	No	Yes	Yes	Yes	No	Yes	No
10	Ninja Blocks	Yes	No	No	No	No	Yes	No	No	No	No
11	Fogwing	Yes	No	No	Yes	Yes	Yes	No	Yes	No	No
12	OnePlatform	Yes	Yes	Yes	No	No	Yes	No	Yes	Yes	No
13	RealTime.io	Yes	Yes	No	No	Yes	Yes	No	No	No	No
14	SensorCloud	Yes	Yes	No	No	No	Yes	Yes	No	No	No
15	Altair SmartWorks	Yes	No	Yes	No	No	Yes	Yes	No	No	Yes
16	SmartThings	Yes	Yes	No	No	No	Yes	No	No	No	No
17	TempoDB	No	No	No	No	No	Yes	No	No	No	No
18	SiteWhere	Yes	No	Yes	Yes	No	Yes	No	Yes	No	Yes
19	Thingworx	No	Yes	Yes	No	No	Yes	No	No	No	Yes
20	Watson IoT	Yes	Yes	No	Yes	No	Yes	No	No	No	Yes
21	Xively	Yes	Yes	Yes	Yes	No	Yes	No	No	No	Yes
22	ThingsBoard	Yes	Yes	No	Yes	No	Yes	No	Yes	No	Yes

The IoMT & IoT is software that connects the edge hardware, access points, and data networks to the other end which is usually the end user application. The Z-Wave has demonstrated acceptable performance and despite being somehow more expensive than ZigBee, it has been used widely in smart home applications. Furthermore, Z-Wave applications can benefit from the flexibility and security of this protocol. For real-time M2M communications, the Data Distribution Service (DDS) is a published subscribes protocol. Data Distribution Service (DDS) has 23 QoS policies that cover a broad range of communication criteria such as security, urgency, priority, durability, and reliability, among others. At this time numerous cloud platforms are available in market and these cloud platforms are designed to support different applications and organizational requirements. The table 2 provides a summary of cloud platforms currently available for IoMT & IoT [83]. These services include, support for WAN via gateways, configuration support, delivery and billing of services provided by various application layer protocols and in this table yes stands for support and no stands for lack of support shown in table 2.

QUALITY OF THINGS (QoT) FOR INTERNET OF MULTIMEDIA THINGS (IoMT)

Multimedia communications in real time IoT applications may experience network delay and congestions due to bandwidth constraints and packet loss, which have an adverse impact on the delivered multimedia quality [84].

Millions of users connect, store, share, edit, compute, and transmit multimedia data over the internet, which has strict QoS and QoE specifications in terms of bandwidth, latency, and jitter, which would be a bottleneck for ordinary cloud providers [85]. As a result, general purpose cloud providers face unsatisfied users in terms of media traffic Quality-of-Service (QoS) and Quality-of-Experience (QoE) [86]. In order to fulfill these needs cloud providers requires huge storage capacity, faster graphical processing units (GPUs), strong security aids, high speed network connectivity, and longer battery life.

Non-functional properties of objects are captured by a QoT model. These characteristics apply to the ability of things to perform tasks such as detecting, actuating, and communicating. It is important to design and build a quality aware IoT architecture to ensure the quality of multimedia content such as audio, video, and image to be received, processed, and distributed in IoMT applications. However, M2M communications will be the dominant applications in IoT. The concept of QoT comes into consideration for M2M communications in IoMT [87]. In general, QoT stands for Quality of Things, and it refers to the smooth operation of an IoT device. In an IoT setting, it focuses on the quality of multimedia data to be recorded, processed, and delivered between two or more devices and objects.

The aim of the QoT is for an IoT object to meet the minimum quality requirement of an IoT application. It focuses on the minimum quality of multimedia data captured by the camera node to be processed and delivered by edge and cloud nodes. As a result, the edge and cloud nodes will process and deliver appropriate QoE for multimedia data. The Quality of Things metrics are critical for improving device-to-device or machine-to-machine communication. For machine to human communications such as E-health monitoring and navigation systems, it takes the QoE metrics into consideration such as end-user devices, preferences, satisfaction, and background. The main QoT factors for IoMT applications that can affect service & application performance which includes monitoring, data collection, processing, and delivery [88]. These factors are described as follows.

A. Ecosystem Influence

In this situation, QoT specifications on ecosystems such as physical location, temperature, and time accuracy for IoT applications can be impacted. For example, the information or data collected by multimedia devices and sent to the network gateway must be accurate enough to be used for further processing, such as physical location, time, and temperature.

B. Device Influence

In an IoT platform, real-time multimedia monitoring can result in high energy consumption. As a result, system influences such as device type, device transmission, and battery may affect the device's life time based on its current state.

C. Network Influence

The network efficiency is affected by network influences such as packet loss and jitter. For example, packet loss would result in data loss, lowering the quality of data transmission.

D. Application Influence

To meet the requirements of an IoMT device, application impact such as application and codec types are oriented. For example, instead of H264, a codec like H265 may be used to save network bandwidth while still delivering high-quality video transmission.

INTERNET OF MULTIMEDIA THINGS (IoMT) ENABLING TECHNOLOGIES

IoMT is enabled by several technologies including wireless sensor networks, cloud computing, communication protocols, Machine to Machine (M2M), and Machine to Human (M2H). In this section, we are discussing five enabling technologies towards IoMT shown in figure 4.

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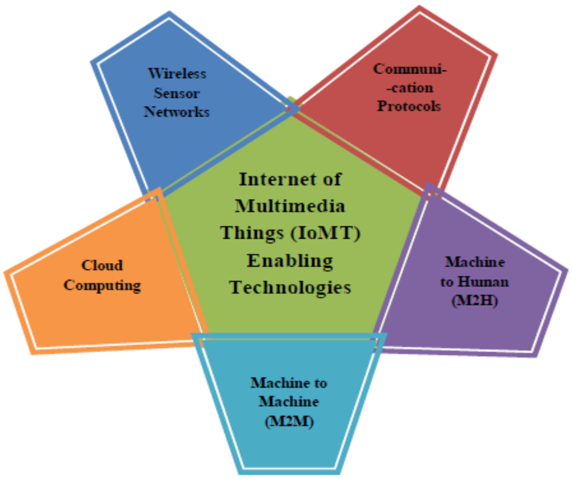

Fig. 4 Internet of Multimedia Things (IoMT) Enabling Technologies

A. Wireless Sensor Networks (WSN)

A wireless sensor network is made up of sensors that are spread across the network and are used to detect environmental and physical conditions. A WSN is made up of several end-nodes, routers, and a coordinator. End Nodes are equipped with a number of sensors and can also serve as routers. The data packets are routed via routers from end-nodes to the coordinator. The coordinator collects the data from all the nodes [89]. Coordinator also acts as a gateway that connects the WSN to the internet. Deploying WSN for IoMT applications is gaining attraction from the both academia and the industry in areas such as home & building energy monitoring and environment monitoring. Using WSN including camera sensors and actuator sensors that can sense scalar data such as temperature, pressure, humidity, and multimedia information from the surrounding environment can improve the efficiency, reliability, and safety of an IoMT application. For example wireless multimedia sensors are able to monitor the renewable energy sources such as sun & wind intensity and direction, and predict the information. Also real-time multimedia monitoring system such as CCTV can be used to monitor critical aspects [90].

B. Cloud Computing

Cloud computing is a transformative computing paradigm that entails distributing software and services over the internet. It entails provisioning of computing, networking, and storage resources on demand and offering these resources to users as metered services in a "pay as you go" model [91]. Cloud computing is a service that is PaaS (Platform as a Service), IaaS (Infrastructure as a service) and SaaS (Software as a service). Cloud computing provides a variety of capabilities, such as flexible computing and storage space. Devices can be monitored and controlled at any time and from any place. Fog & edge computing has recently become a common method for dealing with delay-sensitive IoMT applications [92]. The provisioning of resources is a completely automated operation. Cloud computing resources can be accessed over the network using standard access mechanisms that provide platform independent access through the use of heterogeneous client platforms such as the workstations, laptops, tablets, and Smartphone's.

C. Communication Protocols

Communication protocols act as the foundation of IoT and IoMT systems, allowing for network connectivity and device coupling. Devices can share data over a network using communication protocols [93]. Multiple protocols are sometimes used to denote various aspects of a single communication. A group of protocols designed to work together are known as a protocol suite, when implemented in software they are a protocol stack. The Voice packets and the Video packet are transmitted in the existing infrastructure using the Voice over Internet Protocol (VoIP). VoIP (Voice over IP, VoIP and IP telephony) has become more popular in the recent years due to its advantage of low-priced calls than to the existing Public Switch Telephone Network [94].

D. Machine to Machine (M2M)

M2M (machine-to-machine) communication is a promising technology for next-generation communication systems. M2M, or machine-to-machine communication, is just what it sounds like: two machines "communicating," or exchanging data, without the need for human interaction [95]. Without any human contact, this refers to multimedia communication between two or more devices. For example in traffic control system there are camera sensors used to monitor variables such as traffic speed, accidents, and road congestions. There is detection software used to send all the information across the computers that controls the traffic by showing traffic lights and signs.

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E. Machine to Human (M2H)

Machine to human interaction is a form of communication in which humans collaborate with AI systems and other machines rather than using them as tools or devices. The aim of this human-machine partnership is to leverage each other's strengths, physical abilities, and weaknesses. Multimedia contact between computers and humans is referred to as this.

The most popular M2H application is E-health monitoring, which is an application and service that allows doctors to monitor patients remotely. Smart sensors capture patient data and display it in a multimedia format so that doctors can learn more about the patient's health. Another application of M2H is navigation system, which is a service where roads equipped with camera sensors provide accurate information (such as traffic delays) to the end-user, so that the user could select a better route.

INTERNET OF MULTIMEDIA THINGS (IoMT) APPLICATIONS

The Internet of Multimedia Things (IoMT) infrastructure opens up a slew of possibilities for bettering services and applications by maximizing the use of multimedia data. Multimedia data is jam-packed with useful details. The multimedia content in the IoMT app is used to display a geographical region, which can be both outdoor and indoor. In this section, we are talk about the Internet of Multimedia Things (IoMT) applications.

A. Real Time Multimedia in IoMT

The Web is the most widely used system for transmitting multimedia documents, which include text, audio, video (natural or synthetic), and other types of information. Multimedia data are fundamentally continuous, heterogeneous, and isochronous, three characteristics that when combined have significant real-time implications. Multimedia services, like video-on-demand or distributed simulation, are real-time applications with sophisticated temporal functionalities in their user interface. Real time multimedia will be very demanding is terms of bandwidth.

B. Traffic Monitoring in IoMT

One of the big problems in the smart city is effective traffic management and regulation. There are various solutions based on infrared detectors, magnetic loops, and microwave radars to deal with this issue. These traditional methods have high installation and maintenance costs, as well as a lack of precision. The researcher put forward IoMT based techniques to effectively detect and identify the volume of traffic and predict the reason for a traffic jam.

C. Behavioral Interpretation in IoMT

Behavioral analytics focused on multimedia content has recently emerged as a useful tool. Unusual activity in video streams can be detected automatically, and autonomous reactive measures, such as alerts, can be initiated. A truck with prohibited dimensions or a vehicle going in the wrong direction, for example, may be detected and warnings issued. Multimedia networks the behavioral analytics can be done at smart camera nodes to interpret the event and appropriate reactive approaches can be executed such as reporting to a public safety department, triggering alarms to notify the responsible personnel, calling for medical or other types of assistance.

D. Crime Detection in IoMT

In this paper authors is [97] presented a novel concept of IoMT based crime detection in a smart city by analyzing human emotions and CCTV videos. After detection and identification of crime, it is stored in the database and visualized using a Geographic Information System (GIS).

E. Surveillance in IoMT

Until now, the authentication scheme relied on the use of passwords. However, to close security gaps, the researcher has suggested a variety of IoT security and surveillance systems based on multimedia data, such as retina scanning, biometric scanning, voice recognition, and video surveillance systems. IoMT can tremendously enhance the capabilities of the traditional surveillance and security systems.

F. Telemedicine in IoMT

The IoMT paradigm has the potential to improve the applicability of telemedicine and bring significant advancements in tele-healthcare technology, especially in rural areas. IoMT's technical solutions have the potential to be particularly beneficial to developing countries. The patients under observation in a hospital can be examined by doctors from a remote location via multimedia devices.

Data collected from these patients can enable doctors to identify any indication of upcoming severe event so that necessary action may be taken pre-determinedly.

G. Public Warning in IoMT

When a disaster strikes and local or national authorities need to warn residents to take precautions, IoMT devices such as bus stop displays, connected billboards or road displays, and even displays within buses and connected cars may help disseminate reliable and timely information to those in the affected area, whether on a local or national scale.

H. Retina Authentication in IoMT

The researcher proposes different strategies for implementing retina scanning and iris recognition to further improve the protection level of IoT using multimedia communication [98] describes a retina-based face recognition authentication method. In this article, retina modeling is improved by accurate truncation adaption, illumination classification, and lighting estimation. Yale B database is utilized to validate their model.

I. Multimedia Security in IoMT

A type of content-based defense is multimedia security. Content alludes to a higher level representation or semantics of the data in the sense of knowledge generation, processing, transmission, and storage [99]. Digital watermarking, data encryption, multimedia authentication, digital rights management, and other security issues are addressed by IoMT security. Network security does not sufficiently address the needs of content security because they often process information at the bit-level which does not allow appropriate consideration of the semantics of the information.

J. Societal Interaction in IoMT

In the presence of IoMT multimedia devices, the concepts of smart societies and social interactions, which are currently a hot topic in science, can be given a new dimension. The societal and communal impact of the multimedia devices is huge and the increase in offered functionalities enabled by multimedia sensor devices is reshaping people-to-people interaction, people-to-device interaction and inter-devices interaction.

K. Smart Agriculture in IoMT

Another important industrial field is agriculture. Researchers are attempting to use IoMT to revolutionize the agriculture sector and increase productivity. Authors is [100] present automatic irrigation and an infected area monitoring system using a wireless camera in the crop field to aid farmers.

l. Health Monitoring in IoMT

Multimedia data provides the medium to communicate, monitor, and cooperate with various aspects of daily life at numerous levels of granularity across various applications, which in terms of health is known as personal health media. Zafra *et al.* [101] addressed the issue of coexistence wearable devices for e-health with traditional three-layered IoT architecture and proposed a pervasive layered architecture to integrate M2M communication between e-health wearable and IoT devices.

J. Recommendation Systems in IoMT

In IoMT scenarios, a large number of services and applications are created, making it difficult for users to identify the most applicable ones. In this context, recommendation systems [102] are important enablers that allow for the identification of suitable resources and applications [103]. Recommendation systems suggest items of relevance examples of such recommendations [104] in IoMT scenarios are apps to be installed on a gateway, additional devices to be deployed and managed by a gateway. Further applications of recommendation technologies in the IoT context are the recommendation of health monitoring, traffic monitoring, smart agriculture, multimedia security prediction etc.

UNCOVERED MATTER IN THE INTERNET OF MULTIMEDIA THINGS (IoMT)

The IoMT technology creates large amounts of multimedia data. IoMT technology faces a difficult challenge in managing large amounts of multimedia data. It's difficult to keep produced big multimedia data consistent, reusable, and reconcilable without proper management. Low-cost and small IoMT multimedia devices with limited memory resources are required [105]. Thus, efficient data acquisition methodologies should be developed which can alleviate the burden on memory resources. The need for higher data rates in the IoT communication stack to enable multimedia communication is one of the most important challenges. Since IEEE 802.15.4 was never designed to handle multimedia traffic [106], IoMT can rely on unlicensed wireless technology with higher data rates, such as Wi-Fi. Video is the element most often associated with the term multimedia. The communications channel capacity and storage requirements for transmitting and storing digital video are the most demanding of the multimedia elements. One minute of high-quality uncompressed video can consume 500 megabytes (MB) of storage space. Since the processing power of IoMT multimedia devices is restricted, existing multimedia encoding schemes cannot be used on these devices. As a result, less computationally complex encoding techniques are required; compressive sensing-based encoding techniques appear to be a promising technology in this regard. The multimedia streaming support of end-user devices can vary dramatically, from a mobile phone with minimal cellular bandwidth to a high end desktop computer with high-speed broadband Internet access. Therefore, real time streaming protocols are required to initialize sessions and retrieve multimedia content from servers, considering the processing capability and the Internet bandwidth of the user device. Higher compression of acquired multimedia raw data needs higher processing resources as a result the transmission bandwidth requirement is relaxed and vice versa. Therefore, it is a trade off between the level of compression achieved and the bandwidth requirement. To reduce the processing and energy consumption overheads from the multimedia sensing devices in the IoMT system, the acquired multimedia video must be encoded using low complexity encoders. Due to the demanding nature of multimedia data, IoMT devices are required to run on batteries that may not last very long [107]. Thus, efficient energy harvesting procedures need to be devised to energize sensors and prolong the network lifetime.

CONCLUSION

The world is undergoing a choreographic rapid change from isolated systems to widespread Internet based enabled 'things' competent of interacting each other and generating data that can be analyzed to bring out valuable information. This highly linked worldwide network structure known as Internet of Things (IoT) will enrich everybody existence. The smart distinct multimedia devices that interact and cooperate with one another and with other devices via the Internet create a new emerging paradigm called the Internet of Multimedia Things (IoMT). The Internet of Multimedia Things (IoMT) devices are totally distinct from IoT devices. The Multimedia Internet of Things (IoT) is the collection of interfaces, protocols, and allied multimedia associated information representations that enable advanced services and applications based on human to device and device to device interlink in naturalistic and virtual environments. It needs large memory, higher computational power, and more power peckish with higher bandwidth. The Internet of Multimedia Things (IoMT) orchestration enables the unification of systems, software, cloud, and smart sensors device into a solitary platform. In this paper, we present an extensive review of Internet of Multimedia Things (IoMT) and enabling technologies. We have also discussed some of the architectures of IoMT environment along with their applications and the future research challenges. Ultimately, novel solutions for multimedia data processing and management in the IoMT ecosystem can renovate comfortably quality of life, metropolitan environment, and smart city administration. Finally, this paper points out the open and prospective research areas that need to be solved in future Internet of Multimedia Things systems.

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