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ORIGINAL CONTRIBUTION

Metaverse Technology to Empower Students Literacy Rate Using Modern Educational Resources in Kanchipuram District

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Abstract The COVID-19 pandemic hastened the worldwide transition to online education, revealing both prospects and obstacles in digital learning environments. The Kanchipuram district includes both urban centers and distant rural communities, making it perfect for studying disparities in digital accessibility. Although urban regions are experiencing improvements in infrastructure (4G/5G), numerous rural areas continue to depend on restricted 3G access or lack any connectivity altogether. Although Tamil Nadu boasts a high overall literacy rate, the rural areas of Kanchipuram experience significant learning loss and increased dropout rates, particularly in the aftermath of COVID-19. Initiatives such as "Illam Thedi Kalvi" (Education at the Doorstep) and "Ennum Ezhuthum" (Number and Writing) have been launched here to close the gap demonstrating government involvement and local enthusiasm. Kanchipuram, a district located in Tamil Nadu, provides a strategically significant and illustrative case study for exploring the adoption of Metaverse-driven education and hybrid communication technologies such as 5G and LoRaWAN. Kanchipuram lies within the Tamil-speaking region, where AI platforms such as Duolingo in local languages could significantly improve literacy, especially among young learners. Although technological advancements, especially in Metaverse settings, offer fresh opportunities for engaging and inclusive education, notable inequalities persist, particularly for learners in rural and developing regions. This study explores how metaverse technology can help close the Digital divide, emphasizing affordable and low-energy communication tools like LoRaWAN combined with 5G networks. Moreover, the research examines the incorporation of AI-driven tools such as Duolingo and gesture-based authentication systems to improve the security and customization of online learning platforms. This research tackles the gaps in accessibility, performance, and infrastructure that impede fair online education by utilizing enhanced supervised machine learning algorithms. The results seek to guide efficient technology strategies and enhance secure, verified, and engaging learning experiences for marginalized groups. This research encompasses an analysis of current digital education projects, a suggested framework for Metaverse-oriented learning, and an assessment of its effects on enhancing literacy via pilot programs in chosen schools.

Keywords Online education · Metaverse · Digital divide · LoRaWAN · 5G · Duolingo · Gesture-based authentication systems

Introduction

The Government of Tamil Nadu launched new initiatives such as the "Illam Thedi Kalvi" (Education at the Doorstep) and "Ennum Ezhuthum" (Number and Writing) via the School Education Department beginning in 2021 to address the learning loss and gaps experienced by children in Government schools due to the COVID-19 pandemic [1].

Illam Thedi Kalvi: This program aims to guarantee that children keep learning even when they cannot attend school consistently.

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Ennum Ezhuthum: This initiative was introduced to enhance the fundamental reading, writing, and arithmetic abilities of students in government and assisted schools.

This technology can be an efficient tool for online and collaborative education. It helps to stabilize and make a fruitful relationship between educationalists and students, which involves education and collaboration to rebuild our methods and techniques where to meet the needs of all pupils [9]. Educationalists should be aware of generating training experiences that deliver the precise tools and helps for all beginners to succeed. However, educators need to use technology effectively in our education system and provide security and authentic learning experiences with their practice. Education participants should involve to collaborate together to use Metaverse technology and improvise online tutoring. In this research, 5G technology acts as a backload for LoRaWAN. 5G enabled as a gateway or ethernet to 5G router. However in this research Metaverse Technology is used only for authenticated users. Focussing mainly on lack of online educators in Kanchipuram districts.

The Metaverse is an immersive, virtual digital space where users engage through avatars in real-time. It integrates technologies such as virtual reality (VR), augmented reality (AR), and 3D simulations to produce captivating, interactive experiences. In an academic setting, the Metaverse provides virtual classrooms, interactive simulations, and gamified learning experiences that can enhance student engagement in their studies. In districts such as Kanchipuram, where conventional resources might be scarce, the Metaverse can deliver top-notch educational experiences straight to students through digital devices. 5G represents the newest generation of wireless technology, providing faster internet, reduced latency, and enhanced connectivity over earlier networks. 5G facilitates effortless access to Metaverse platforms by offering speedy and dependable internet connections. This is essential for instantaneous interactions, seamless streaming of learning material, and minimal lag in VR experiences, particularly in the rural or semi-urban regions of Kanchipuram. LoRaWAN is a wireless communication protocol with low power consumption and long-range capability, aimed at IoT (Internet of Things) applications. It enables data transfer across vast distances while using very little energy. LoRaWAN can connect affordable educational tools (such as sensors, attendance monitors, e-learning stations) in schools with inadequate internet infrastructure. It can assist in overseeing student involvement, record attendance, or deliver educational materials in real-time, even in distant areas of the district where broadband or 5G might not yet be fully established. Teachers, researchers, students and the policy makers are the stakeholders.

Teachers

Benefits

Improved Teaching Resources: Availability of immersive materials (e.g., 3D narratives, interactive virtual labs) that make lessons more captivating and simpler to present.

Professional Growth: Chances to enhance skills in digital and immersive teaching methods, transforming them into more effective and future-ready instructors.

Lowered Burnout: The automation of routine tasks (such as assessments or attendance using avatars/AI tools) enables educators to concentrate on advanced teaching methods.

Contributions

Curriculum Customization: Modifying conventional curricula into VR/AR-oriented units in the local language (e.g., Tamil).

Feedback Cycle: Offering insights to developers and policymakers regarding what is effective or requires enhancement in the virtual learning environment.

Mentorship: Assisting fellow educators in adjusting to new technology via peer assistance and training.

Students

Benefits

Immersive Education: Captivating, gamified, and hands-on lessons that foster profound comprehension and memory, particularly for learners with scarce conventional resources.

Equal Opportunity: Students from rural and financially disadvantaged backgrounds can access high-quality education comparable to their urban peers.

Language and Contextual Learning: Assistance in regional languages and culturally appropriate material improve understanding.

Contributions

Engaged Involvement: Through their interactions in the Metaverse, students create usage data that aids in improving educational resources and customizing learning experiences.

Collaborative Learning: Engaging in online group environments promotes cooperation and leadership skills.

Expansion of Digital Literacy: By engaging with the platform, students inherently develop technological skills in addition to their academic knowledge.

Policymakers and Government Agencies

Benefits

Insight from Data: Real-time analytics and evaluation tools offer quantifiable insights into advancements in literacy and the efficacy of resources.

Scalability: After being successfully tested in Kanchipuram, the model can be effectively rolled out to other districts and states.

Policy Innovation: Enhances government initiatives such as Digital India, NEP 2020, and Samagra Shiksha through the incorporation of advanced technology in education.

Contributions

Financial Support and Resources: Ensuring budget provisions for VR equipment, 5G connectivity, and educator training.

Policy Assistance: Establishing regulations and guidelines to guarantee ethical, inclusive, and secure use of Metaverse tools.

Public–Private Partnerships (PPP): Facilitating cooperation between EdTech firms and educational institutions for developing content and maintaining platforms.

Background

Through interactive proof of learning progress and the provision of visions to teachers, administrators, and students, technology-enabled assessments improve learning and teaching. To minimise breaks in learning time, these assessments may be integrated into digital learning activities [10]. Interactive learning tools, digital learning materials, software, or simulations that include students in academic material and provide them access to internet databases and other primary sources are all examples of digital learning. Technology-enabled learning, teaching, and evaluation call for a strong infrastructure. High-speed connection and gadgets that are accessible to instructors and learners are important components of this infrastructure. A complete learning infrastructure goes beyond cables and hardware to incorporate digital learning materials, additional resources, including professional development for teachers and school leaders.

5G has more dimensions and faster than 4G. The 4G mobile technologies and other digital devices will always be vulnerable to technical complications or network disaster and also the ease of accessing the others information which leads to impersonation [22]. Learning via experience is made easier by the Metaverse. Lessons that would be unfeasible or impractical in a traditional classroom can be completed virtually by students through role-plays, experiments, and partnerships. They can travel the solar system, investigate the deep sea, or model chemical interactions in a secure virtual setting. Students are better prepared for the future as a result of this, which develops their creativity, critical thinking, and problem-solving abilities [4, 16]. In this paper, Metaverse Technology plays a vital role in login phase providing safe and security learning experience to prevent unauthorised access.

Challenges

In emerging nations and low-income areas in particular, millions of youngsters still do not have access to an online education. Underprivileged populations cannot access education because of inadequate infrastructure, including schools, transportation, and internet connectivity [2]. However, 2G,3G and 4G technology have their limitations. The next stage of the internet's progression is the metaverse, while remote learning technologies kept the educational system running during the pandemic [3, 17]. Accessibility will be evaluated by monitoring the rise in student enrolment and steady engagement in online learning sessions conducted through low-power LoRaWAN and devices integrated with 5G. Improved security will be assessed by implementing gesture-based authentication systems, with effectiveness gauged by a decrease in unauthorized access cases and increased user satisfaction concerning data privacy. Improved learning engagement will be assessed through AI-based tools like Duolingo, monitoring factors such as time dedicated to activities, completion percentages of interactive sections, and feedback from learners.

Objectives

The Internet has become a crucial part of life. Accessing the internet plays a vital role in humanoid lifespan and also in educational arena because it is capable to deliver information and outright the given tasks while we are doing some other work. Some rural areas the school-going children could not able to continue their studies due to their financial, technological resources and family crisis [13]. In this paper, a model and implementation of Automation and controlling several devices with LoRaWAN technology are established. This could be very beneficial and cost effective for rural area students who wants to enlighten their talents and skills to get benefits in online education.

LoRaWAN aids to provide a long distance communication and long battery life but it has low data rates. In this research, the proposed scheme is enabling LoRaWAN 5G gateway or ethernet to 5G router we can achieve the better data rates upto 1 Gbps. Both Metaverse and LoRaWAN applications ensures the security to protect the confidential data from the unauthorized users in online education.

Therefore, Fig. 1 illustrates the cycle of Leadership → Teaching → Assessment → Learning, encompassed by vital infrastructure, which aligns seamlessly with the integration of the metaverse into education. It highlights a student-focused, vision-driven, technology-enhanced environment where immersive learning serves not only as a tool but as a transformative journey.

In Fig. 2, it illustrates that students can participate in virtual conferences, seminars, and Q&A sessions with specialists in a communal 3D setting. Conventional online courses transform into engaging 3D educational environments featuring interactive boards, virtual laboratories, and instant avatar interaction. Learners can navigate online campuses, join club gatherings, connect with classmates, and engage in collaborative activities. The metaverse facilitates experiential education via simulations, virtual experiments, and role-playing activities.

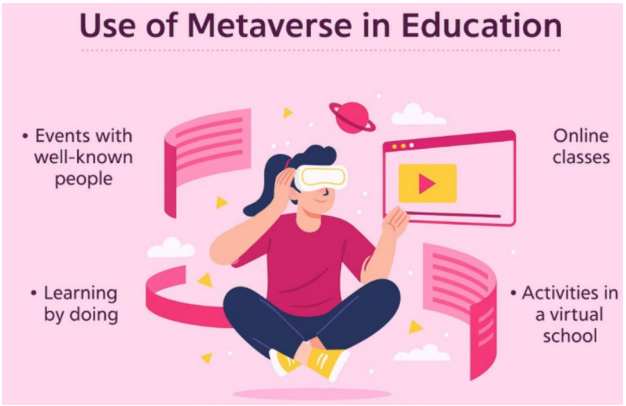

Fig. 2 Metaverse in online education

Fig. 1 Online and collaborative learning Infrastructure

Related Work

LoRaWAN

In Fig. 3, Represents the LoRaWAN is used as a Wi-Fi technology. LoRa provides for long-range communications which covers between 15 and 20 km. The proposed system of networking consists of a hardware system and software interface. In the hardware system, the integration of LoRaWAN Wi-Fi technology for controlling, monitoring the hand-held devices and an application is provided for automating and governing the several users of internet access, with smart phones, tablets, and laptops [11]. LoRa devices communicates with the Network Server through the GateWay(GW). This arrangement tends to be the better method for monitoring the several users devices with ease. The internet access will be centrally monitored by the administrator to facilitate internet access to the different users. This system restricts the unauthorized websites for the safekeeping and wellbeing purpose through the internet as long as it exists on Wi-Fi network coverage. It focuses that the system is reliable, affordable and also fulfil the needs of non-network coverage user [12].

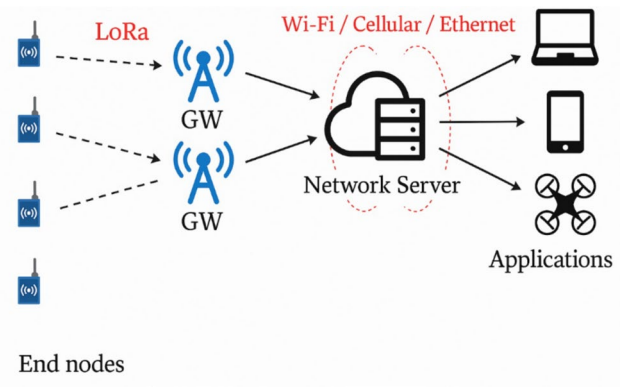

Fig. 3 Structure of LoRaWAN

Gesture Recognition Technology

The proposed system includes the authentication system using gesture recognition method in Fig. 4. The mathematical explanation of a humanoid gesture by a calculating equipment is known as gesture recognition. Gesture recognition is one of the features of what programmers refer to as facial recognition, voice recognition, eye tracking, and lip movement recognition in addition to a perceptual user interface [5]. Computers can now recognise and understand human movements as commands thanks to perceptual computing user interfaces (PUI). In this paper, presents the Hand Gesture Recognition for authentication purpose. It is a sign language recognition. Using the Capacitive proximity sensors can be used discretely to provide covert gesture-based interfaces that don't require contact by detecting the presence of the human body across a distance.

Mobile Spyware

Mobile spyware is an arrangement of software package that governs and records information about an end user's actions. Mobile spyware can be adopted by the uMobix Android Tracker. In Fig. 5, Explains the Proposed technology for Communication and it is a smartphone surveillance software. It could be mounted onto your devices to track data such as calls, text messages, emails, location,

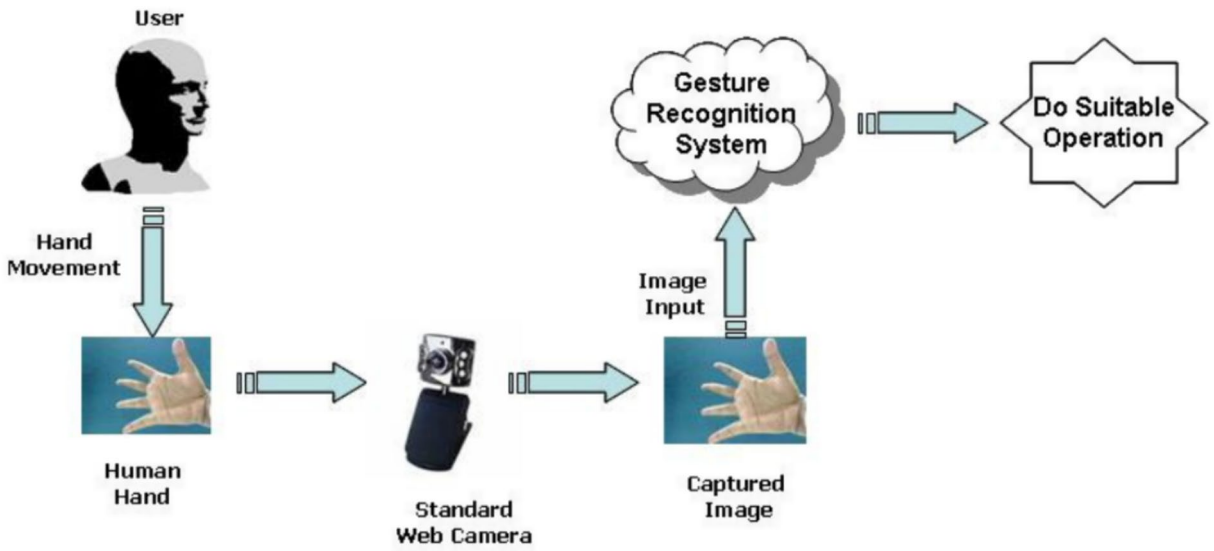

Fig. 4 Gesture recognition method

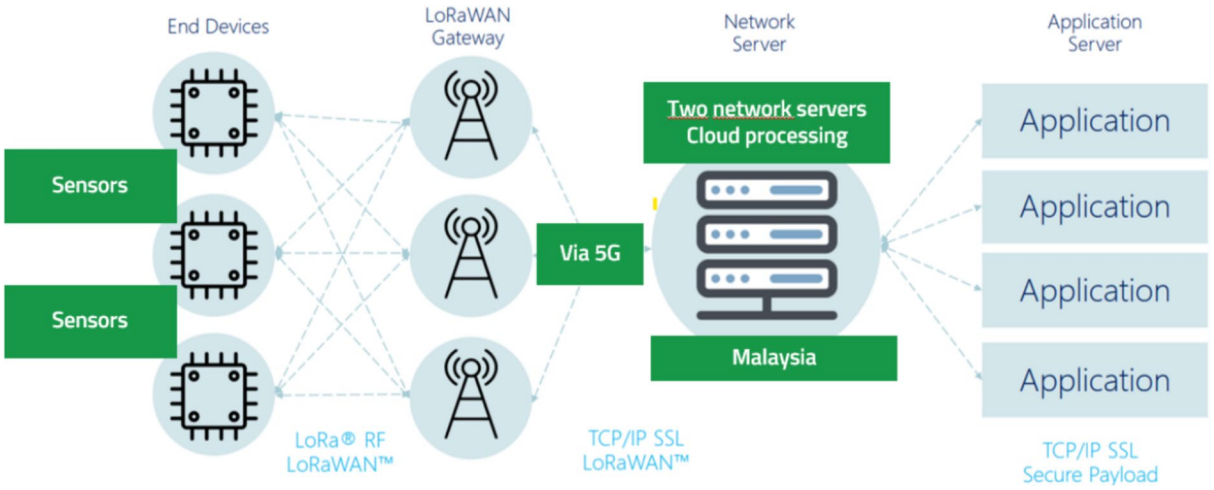

Fig. 5 5G Enabled LoRaWAN implementation

photos, and browsing history [6]. uMobix is a parental control app that will give you important information regarding the end users activities online and even offline. An essential tool for the administrator and the internet service provider who want to keep tabs on user's social interactions, track incoming, outgoing, missed, and even deleted phone calls with all details. With uMobix, you can keep an eye on anything from social media activity to call and message logs.

Proposed LoRaWAN Technology

5G allows a new kind of network that is designed to connect together including machines, objects and devices. From the Fig. 5, LoRaWAN gateway connected through 5G and share the resources and applications through network server.

In the Fig. 6, provides the Proposed Technology of LoRaWAN implementation which opens up the hands-on devices along with the internet access to the rural area school students those who are affected with poor network facility and non-network coverage areas. Especially in Pandemic,

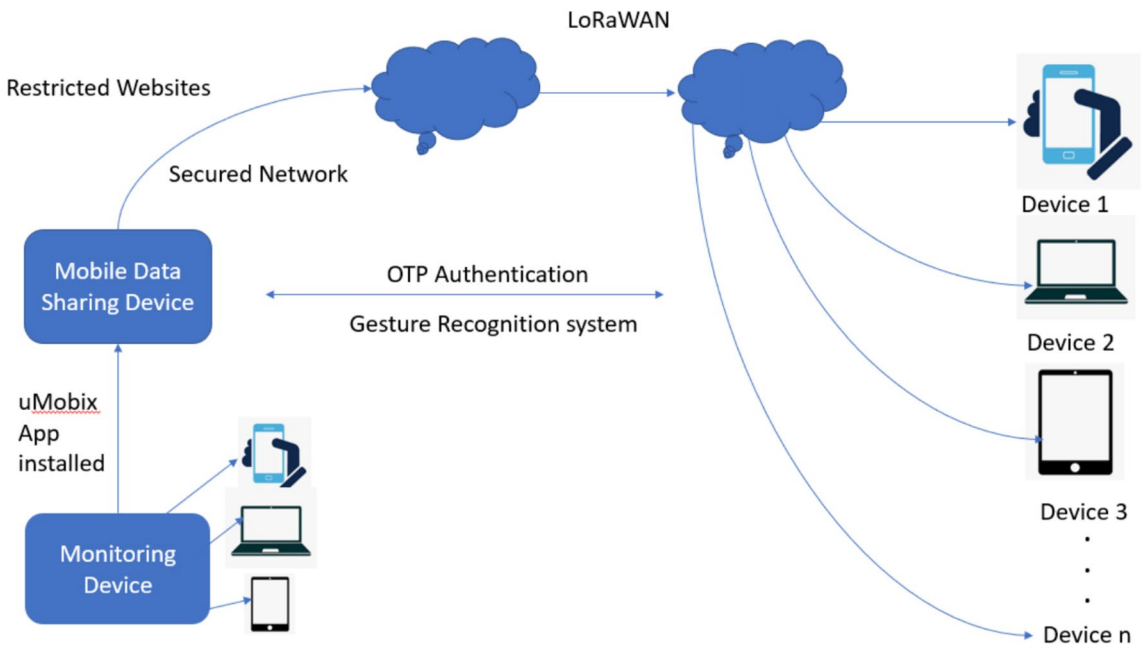

Fig. 6 Proposed technology of LoRaWAN for communication

this method tends to be very helpful and effective way for online and collaborative learning.

The source device will share the mobile data through 5G enabled LoRaWAN and also monitor and tracks the several target devices which is paired with source device using uMobix mobile spyware software package to prevent from unauthorized websites. The target devices can be enabled only the access given by the source device using Gesture recognition method. Based on this method, several number of rural area students can get more benefits and improvise the literacy rate in their education through online.

Duolingo Tool

In Fig. 7, Represents the Duolingo Tool with enabled Metaverse Technology which is a range of beneficial programmes and online learning platforms are included in the category of virtual learning aids for instructors. Learning can be effective and fun even when done on the road thanks to applications like Duolingo and systems like Zoom or Google Classroom [7].For the pupils in remote areas, the Duolingo programme serves as a cosy and very engaging interface. After the users are authenticated by the login phase of Metaverse and Gesture Recognition technology, the Duolingo tool is activated.

Metaverse with Current Technology

Through Metaverse, educators can build classrooms which needed for educational purposes. In Fig. 8, depicts the Metaverse Technology which helps in many ways for online education [14]. Different ways of Avatar can be created. It also displays 3D illustrations which can help students to understand how a certain piece of machinery (machines) works or a mathematical concept looks like in real life scenarios [18]. Provides a new avenues for self-expression, communication, and exploration. With the ability to improve and simplify our daily lives, this digitally connected environment holds great potential. There is still a need for many individuals to comprehend the Metaverse and its practical applications, despite its promising future [8].

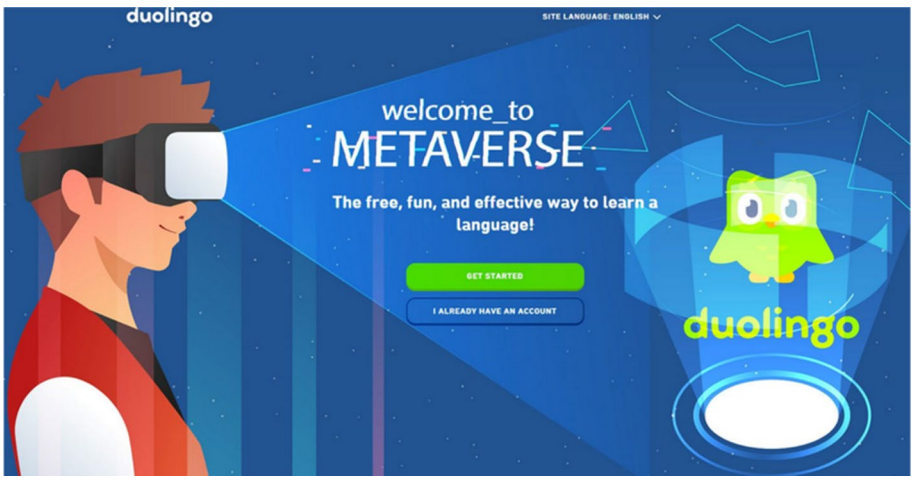

Fig. 7 Duolingo tool on metaverse technology

Fig. 8 Online education with metaverse technology

Communication between the end users can be done to the help of Metaverse technology where user1 can communicate with user2 by 3D Visualization and online Avatar can be created for live class demonstration [15]. Avatar can communicate with each other with the tutor and students where the effective live communication can be implemented using this Metaverse Technology. This could be a future scenario for effective classroom teaching via online [13].

In order to improve the user authentication Metaverse technology to be implemented. In this paper, adopted the Metaverse concept is exclusively for security, verification and Authentication purposes. In Fig. 9, explains the login phase for online education via Metaverse.

After the user is authenticated by Gesture Recognition technology for the extra protection the Metaverse technology is implemented at the login phase. At User Setup Phase, Unique Identifier creates by the user, Certificate Authority (CA) verifies the user credentials and stores the user information to the Service Provider. After Service Provider verifies the user credentials then the user's avatar is created in the virtual space [19]. Avatar's will be created for each authenticated users, so the stakeholders can access the online education anywhere at anytime.

Implementation and Methodology

The study materials were included students data from the Elementary school education, Secondary school education and higher education collected from Kanchipuram District. Out of 160 schools were analysed in Kanchipuram District and randomly selected few students data were collected from these schools. With these data Improved Supervised Machine Learning Algorithm used for analysing with successful literacy rate percentage through the Decision Tree Algorithm with enabled 5G enabled LoRaWAN along with Metaverse Technology in Login Phase for authentication Purpose. In Fig. 10, Represents the results of the graph are shown below for the literacy rate of Kanchipuram Districts from the year 2001–2024.

As per 2011 census, Literacy rate is less in rural areas of Kancheepuram district is 75.95% when compared to rural areas where as 89.39%. Datasets and literacy rate were collected from the Kanchipuram districts during the period between 2001 and 2011. https://www.census2011.co.in/census/district/22-kancheepuram.html

In the Fig. 9, Represents the sample of the students data has been selected randomly from 160 schools. Among 160 schools, it is noticed that High literacy level has been achieved the samples of 108 schools by adopting 5G enabled LoRaWAN services using Improved Supervised Machine Learning Algorithm and the literacy level is less in 52 schools. Again, the evaluation to be continued among 108 schools and the literacy rate is achieved on 71 samples of schools with enabled 5G LoRaWAN services and the literacy level is less in 37 schools and so on. Hence the comparison shows that the 5G enabled LoRaWAN services is adopted where the target level is achieved to the above level whereas the target level is below by using 3G and 4G networks.

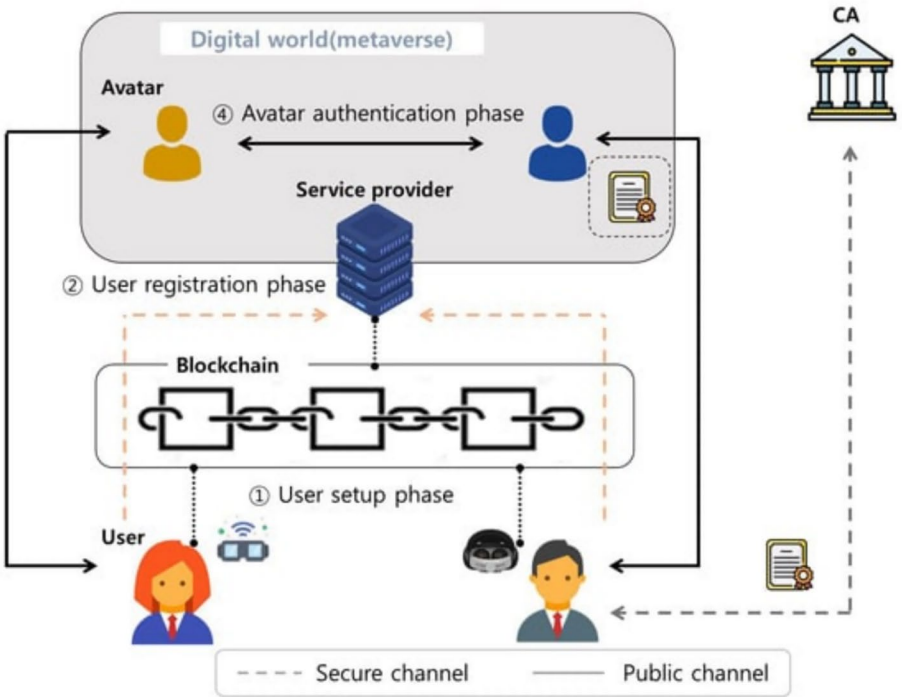

Fig. 9 User authentication and login phase in metaverse technology

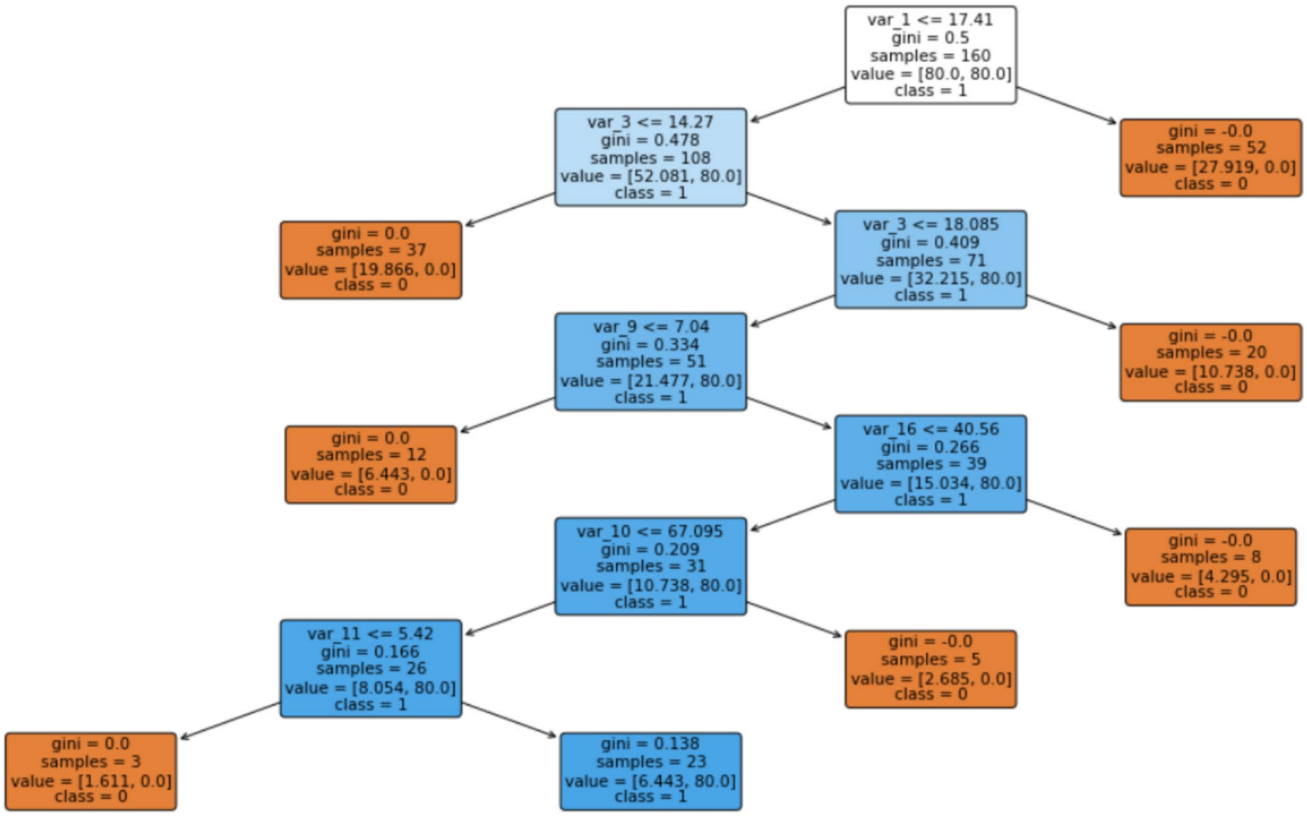

Fig. 10 Decision tree samples for the literacy rate

```
df_train.groupby('target').size()

target
0    52
1    108
dtype: int64
```

Based on the data collected, the sample data is fed into Improved Supervised Machine Learning Algorithm Decision Tree. The incorporation of Decision Tree samples in this research aims to offer a data-driven method for comprehending the primary factors affecting literacy rates among students in Kanchipuram. Decision Trees, functioning as a supervised machine learning method, provide a visual and understandable approach to represent decisions influenced by factors like infrastructure, teacher quality, digital access, socioeconomic status, and types of interventions (e.g., education based in the Metaverse). The node recognizes critical factors of literacy that aid focused interventions and models the effects of technology adoption. In Fig. 10. The Orange Colour node represents below the target level and blue colour node represents above the target level. For the above said, 160 samples of the schools in the Kanchipuram Districts from the year 2001 to 2024 and the decision tree is built in the Fig. 10. Shown below. So, the decision tree approach Enhances Policy Decision-Making.

```
#Create the figure
plt.figure(figsize=(20,10))
#Create the tree plot
plot_tree(model_tree,
          feature_names = var_columns, #Feature names
          class_names = ["0","1"], #Class names
          rounded = True,
          filled = True)
plt.show()
```

From the Fig. 11. Statistical analysis, it is observed the literacy rate of.

i) 2001 is 78.83%
ii) 2011 is 84.49%
iii) In current Scenario, it is expecting at 2024 is 90.10% with empowered 5G Enabled LoRaWAN Technology

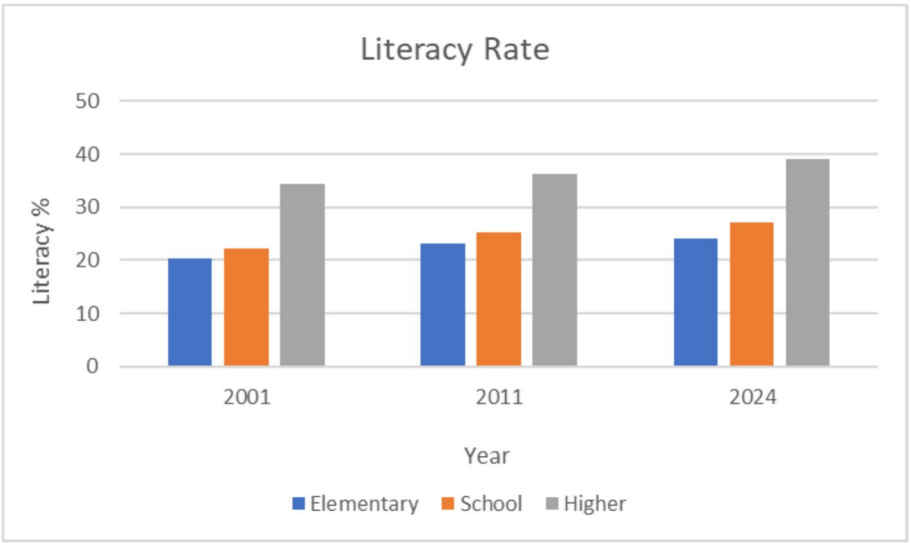

Fig. 11 Statistical analysis of the literacy rate

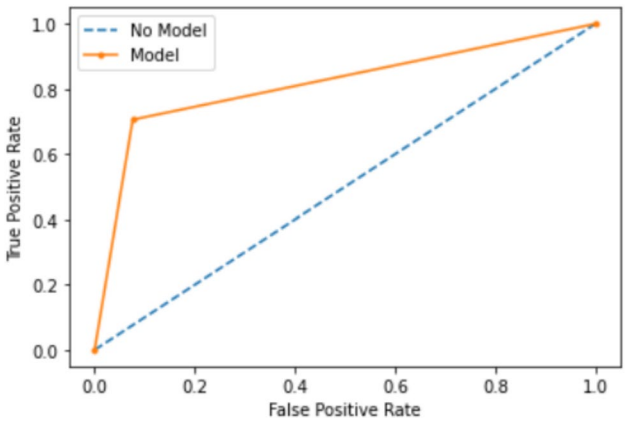

Fig. 12 Target level achieved for the random samples

along with Metaverse concept for authenticated Online Learning experience.

The Fig. 12, shows the ROC Curve for the performance of target level achieved for random samples of schools and it is found that higher education which represents the Model attribute there is a predominant increase by enhancing and equipping the Metaverse technology when compared to elementary and school education which represents the No model attribute in a graph. Thus the results shown the differences between with or without 5G enabled LoRaWAN services.

To estimate the confusion matrix from the ROC curve shown in the Fig. 12. We must make a few assumptions based on the shape of the curve and the information typically associated with such curves. Given that the curve reflects true positive rate (TPR) and false positive rate (FPR) at various thresholds, we can make some reasonable assumptions about the confusion matrix based on specific points on the curve.

From the graph,

- TPR (True positive rate) is equivalent to sensitivity, calculated as $\frac{TP}{TP+FN}$
- FPR (False positive rate) is calculated as $\frac{FP}{FP+TN}$

Let's estimate the confusion matrix:

1. *True Positives (TP)*: The TPR seems to be about 0.7 at a certain threshold, indicating that 70% of actual positives are correctly classified as positives.
2. *False Positives (TP)*: The FPR appears to be about 0.2 at a same threshold, meaning that 20% of actual negatives are incorrectly classified as positives.

Assume we have a balanced dataset of 100 samples (50 positives and 50 negatives)

$$\text{TP (True Positives)} = 70\% \text{ of } 50 = 35$$

$$\text{FN (False Negatives)} = 50 - \text{TP} = 50 - 35 = 15$$

$$\text{FP (False Positives)} = 20\% \text{ of } 50 = 10$$

$$\text{TN (True Negatives)} = 50 - \text{FP} = 50 - 10 = 40$$

Thus, the confusion matrix based on the graph would look like:

35(TP)	15(FN)
10(FP)	40(TN)

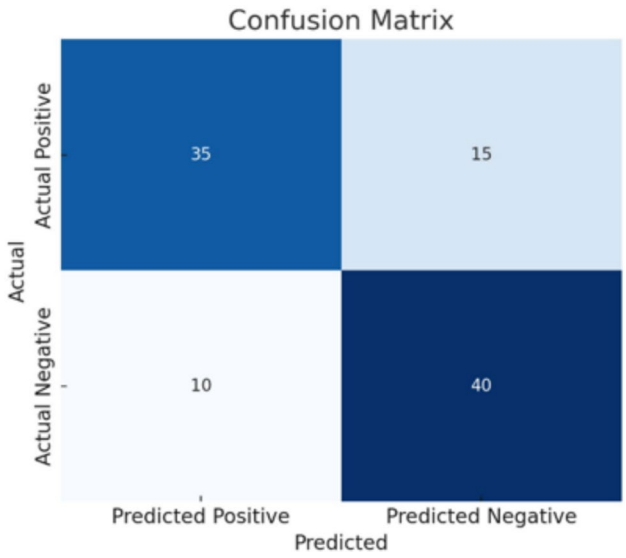

Fig. 13 Confusion matrix for the literacy rate

Thus the Fig. 13 shows the confusion matrix for the Literacy rate as per the census from the year 2001–2024.

Comparison of 3G and 4G

The Fig. 14 shows that the lower literacy rate of 3G and 4G networks due to the signal may be disrupted and uncountable problem. Due to the network failures or other issues, it may lead to data leakage from the unauthorized users. The Fig. 13 shows that the maximum users are accessing 3G services due to the cost of 4G or 5G services or network coverage problem [23]. Even accessing Facebook, twitter or any other social websites it shows less availability power of 4G networks. Though the users can access 3G services with 75% the speed of 3G has 0.2 to 2 Mbps whereas 5G has 100 Mbps to 1 Gbps. The Fig. 10 shows the findings of the target level achieved by enabling 5G Gateway of LoRaWAN which exceed more than 78% of success rate of Literacy in the Kanchipuram districts.

Results and Discussion

In this Digital world, where technology evolves fast. 5G enabled LoRaWAN came as a solution for the issues and causes shown in 3G and 4G. 5G has lower latency rate than 3G and 4G and the internet speed is achieved than 3G and 4G. Highest Literacy rate is achieved by 5G enabled LoRaWAN when compared to 3G and 4G [23]. The literacy rate of Kanchipuram districts is improved more than 78% from the Fig. 11. The fruitful online education to be done not only the non-interrupted services but also should have the authenticated online learning experience. Hence the Metaverse plays a vital role in login phase of online education. Thus, the results shows that the LoRaWAN with 5G services provides

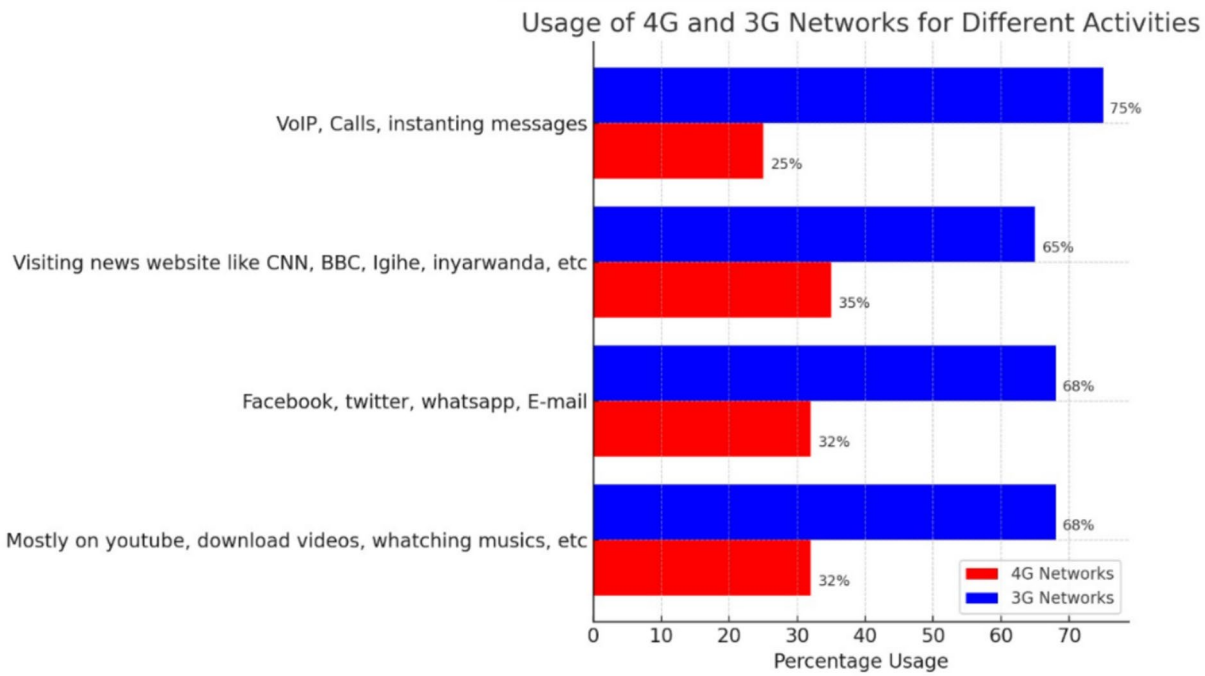

Fig. 14 3G and 4G services for the online educators

the low-power, long-distance communication and high data transfer rates in the rural areas of Kanchipuram Districts.

Conclusion

From the above study, it is found that literacy rate is improved only through higher education by using Improved Supervised Machine Learning Algorithm. So, it is recommended to implement 10 year plan based on increasing literacy rate for both men and women by effective classroom teaching in online. In this Research, Metaverse Technology plays a crucial role in login phase for authentication purposes. By this method, Students can access the study materials and which is shared by the tutors and also they can create, distribute and submit the assignments through the effective Duolingo tool [20] by using cost effective Technology (LoRaWAN). LoRaWAN is essential for providing affordable, long-distance connectivity to rural educational settings, promoting both digital inclusion and the secure, reliable distribution of educational materials. Its incorporation with gesture-based authentication additionally guarantees secure access to educational platforms, fostering literacy and tailored education even in marginalized communities. LoRaWAN improves rural education by closing the digital divide through cost-effective, long-distance connectivity, facilitating offline-first, secure, tailored learning experiences and aiding the implementation of scalable literacy tools in line with government initiatives such as "Illam Thedi Kalvi" and "Ennum Ezhuthum". Since it provides only restricted websites through secured network using Metaverse Technology [21], students could not misuse the network facilities in a wrong way by browsing unwanted websites and impersonation. In this paper, adopted the login phase of Metaverse Technology for better security and authentication purpose. In future, We can establish the Registration Phase and Avatar Authentication phase for more Authentication users with enabling an efficient Metaverse Technology.

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Declarations

Conflict of interest The authors have not disclosed any competing interests.

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