User-Friendly Android-Based Home Control System For Individuals With Mobility Disabilities

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Abstract. The increasing adoption of smart devices worldwide brings promises of enhanced living standards, but for marginalized communities, cost and accessibility remain significant barriers. Conventional home assistants are expensive, require constant internet connectivity, and are designed without consideration for low-income users in developing countries. This paper proposes a low-cost alternative to conventional home assistants that addresses these limitations. Our model supports voice commands in both English and Bangla and includes an application for offline system management. By developing this system with affordable hardware and local production, we contribute to bridging the digital divide and providing sustainable, inclusive technological solutions for underserved communities. This model will help marginalized communities and people with disabilities, making technology affordable, inclusive and accessible for everyone.

Keywords: *Low-cost home assistants, sustainable technology, smart devices, digital divice, localized solutions, developing countries*

1. Introduction

Smart devices, which connect wirelessly and operate autonomously, are increasingly prevalent globally, especially in emerging markets. The global smartphone market is projected to reach $15.3 billion by 2025, driven by rapid adoption in countries like Bangladesh, where smartphone penetration has accelerated due to the pandemic, with 55.89% of people using mobile phones and 30.68% accessing the internet [1]. However, many smart devices remain out of reach for marginalized groups in developing countries due to their high cost, energy consumption, and reliance on stable internet connections. Additionally, individuals with mobility disabilities often face the challenge of not having tailored smart home assistants that meet their specific needs. This paper proposes a low-cost alternative to conventional home assistants, focusing on making smart devices more affordable, user-friendly and energy-efficient, while ensuring compatibility with low-bandwidth requirements for people with mobility disabilities and marginalized groups. This proposed model goes beyond just technology. It is designed to be user-friendly for people with disabilities, making daily tasks easier and more accessible. By offering affordable, inclusive solutions, it empowers individuals with disabilities, helps bridge the technology gap and creates a future where everyone, regardless of ability, can benefit from and participate in the digital world. This solution can significantly impact by increasing accessibility for people with mobility disabilities and marginalized groups. It empowers users with greater independence, improves inclusivity, and reduces economic barriers to technology. Additionally, local production of these devices can boost the economy, while energy-efficient features contribute to sustainability. Overall, it promotes social equity, self-reliance, and environmental benefits. These home assistants can control other devices, play music, answer questions, set reminders, and order products, providing significant value in diverse sectors such as education, healthcare, and agriculture. The proposed solution is to use low-cost home assistants as an accessible gateway to these technologies, incorporating voice and text interfaces, local languages, and offline databases to better serve farmers in low-connectivity, low-income contexts. This system aims to empower farmers by giving them access to smart farming tools that can enhance productivity, profitability, and sustainability. Beyond agriculture, the work expands the understanding of smart devices in low-income settings, offering a novel, practical framework for evaluating the performance, impact, and user satisfaction of these low-cost devices. This research aspires to inspire further innovation in the development of smart devices that can improve the quality of life of marginalized communities globally, democratizing access to smart technologies and contributing to a more inclusive digital future.

A study examines the barriers and enablers of smartphone adoption among rural women in India, recommending strategies like cost reduction, improved usability, and training support to overcome them [2]. Another research explores the role of smart devices in disaster management in Indonesia and proposes a framework integrating smart devices with cloud computing and social media to enhance disaster response and recovery [3]. An analysis of the impact of smart devices on the digital divide in Africa argues that while they reduce gaps in access, skills, and usage, they also introduce new forms of inequality and exclusion [4]. A systematic literature review of ethical concerns surrounding voice assistants identifies nine areas of concern, including privacy, autonomy, transparency, social order, and conflict of interest [5]. Research on home assistants among older adults finds that these devices improve social connectedness and reduce loneliness but also raise privacy concerns and ethical issues [6]. A security and privacy review of home assistants highlights threats such as eavesdropping, spoofing, phishing, and data leakage, and suggests countermeasures and best practices to mitigate these risks [7].

The main objectives of our work are as follows,

a. To control the system not only in English but also in the Bangla language.

b. To design a user-friendly system with features that accommodate users with disabilities.

c. To make the device accessible for uneducated and low-income workers by simplifying the interface and decreasing the cost.

Overall, to produce low-cost alternatives to home assistants.

The following segments explain Related Works, System Modeling and Methodology, Proposed System and Voice recognition.

2. Related Works

Home assistants are a type of smart device that can perform various tasks and services for users, such as controlling other smart devices, playing music, answering questions, setting reminders, and ordering products. Home assistants are usually activated by voice commands and use natural language processing and artificial intelligence to understand and respond to the user's requests. Some examples of home assistants are Amazon Echo, Google Nest, and Apple Home Pod.

Home assistants are becoming more popular and widespread in the market, as they offer a convenient and natural way of interacting with technology and accessing information and services. According to a report by Juniper Research, the number of voice assistant devices in use is expected to reach 8.4 billion by 2024, exceeding the world's population. The report also predicts that the smart home will be the fastest growing segment for voice assistants, with a 25.4% annual growth rate [8].

However, home assistants also raise some ethical, social, and technical issues, such as privacy, security, trust, accountability, and usability. These issues are addressed in the literature from different perspectives and disciplines. For example, [5] conducts a systematic literature review of ethical concerns with voice assistants, and identifies nine areas of concern, such as privacy, agency, autonomy, social order, accountability, transparency, conflict of interest, datification, and social interaction. The systematic review of ethical concerns with voice assistants may not capture emerging issues as technology and societal norms evolve. [6] examines the use and perception of home assistants among older adults, and finds that home assistants are perceived as companions and improve social connectedness and reduce loneliness, but also pose some privacy concerns and ethical issues. Research on home assistants for older adults might not consider the wide variability in individual needs and preferences across different age groups and cultures. [7] provides a security and privacy review of home assistants, and analyzes the threats and vulnerabilities of home assistants, such as eavesdropping, spoofing, phishing, and data leakage, and suggests some countermeasures and best practices to mitigate them. This review of security and privacy risks for home assistants could be limited by the rapidly changing nature of threats and the constant evolution of security technologies.

By providing automation and remote-control functions, smart home technology comprises an interconnected network of appliances, systems, and gadgets that improve convenience, efficiency, security, and overall quality of life. Owners of homes acquire the capacity to effectively oversee and control their living space [9], [10]. This technology creates a coherent and responsive smart home environment by fusing sensors, Wi-Fi, and artificial intelligence (AI) to enable seamless device interaction [11]. Security systems, lighting controllers, temperature regulators, and automated kitchen systems are just a few of the gadgets that help create an automated house [12]. Sensors and actuators are used by home automation systems to track environmental variables, evaluate data, and send information via wireless networks to a central server that handles vital user functions. Actuators trigger appropriate responses in emergency situations, such as fires or burglaries [13]. Furthermore, radio-frequency identification (RFID) technology is essential to smart homes because it makes identifying and tracking processes more effective, improving automation and security [14]. In daily activities, it optimizes resource use, enhances user interactions, and provides individualized experiences [15]. The deployment of RFID technology has also opened the door for novel uses, such smart watches for those with visual impairments. In order to facilitate effective household management, a master-slave RFID system was devised, in which slave readers installed in appliances communicate with mobile readers and a master reader connected to a smart home server [16]. These kinds of systems maintain track of basic home inventory and create shopping lists automatically based on the availability of specific items [17]. In addition, contemporary residences equipped with sensor-based technologies cater to the requirements of individuals with disabilities, thereby fostering social integration and augmenting self-sufficiency [18]. Two approaches are used in smart homes to accommodate people with disabilities; building assistive aids that are specifically designed for them and designing bespoke interfaces for seamless device usage [12]. In contrast to generic Human-Machine Interfaces (HMIs), tailored HMIs offer specific functions that are tailored to the specific needs of specific sectors and user groups [19], [20]. Retinal prosthesis are one alternative that improves accessibility even further for those with vision impairments [21]. Another way to let your home devices operate independently is with voice-controlled interfaces. Head-tracking devices provide accurate control via lateral movements, rotation, and forward-backward tilting for people with severe paralysis [22]. Furthermore, sophisticated interfaces that make use of gesture-based controls, brain-computer interactions, and facial recognition greatly enhance usability for individuals with disabilities [23].

An inventive wheelchair system that could navigate using facial inclination and stop in response to mouth shape was shown in an assistive technologies study [24]. For those with restricted mobility, the system's voice-guided navigation and obstacle detection provide useful options [25]. In addition, specific lifting equipment is made to help people move from wheelchairs to beds [26]. Rehabilitation robots help people with disabilities become more independent by making tasks like sitting and manipulating objects easier [27]. A robotic suit that helps with bathing was proposed by Satoh et al. [27]. It integrates with HMIs to guarantee smooth operation. Conventional classrooms have been transformed into interactive spaces furnished with linked gadgets through the integration of the Internet of Things (IoT) in education. Personalized learning experiences are made possible by these tools, which include interactive whiteboards and tablets [28], [29]. Beyond classrooms, IoT helps with administrative duties like energy management and campus security [30]. IoT also helps educational institutions with resource optimization, attendance tracking, and remote learning [31]. To safeguard stakeholders, IoT use in education necessitates close consideration of data security and privacy [32]. Additionally, RFID technology is essential in educational settings. It is utilized to design interactive play spaces for young children, fostering communication abilities in kids with various difficulties [11]. For instance, RFID-tagged toys help deaf children learn sign language by connecting objects with related animations and visuals, which speeds up language acquisition [33]. Through animations with human avatars, these systems introduce kids to many object variants through audio-visual stimuli [34]. The Louisiana School for the Deaf has produced noteworthy results by showcasing the value of bilingual education with RFID-enabled devices in its early childhood curriculum [35]. Furthermore,

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studies show that RFID-based systems are more affordable and useful in learning contexts than conventional barcode-based ones [36].

3. System Model and Methodology

A. Proposed System

This block diagram has the following components and connections. Power Supply (12 V) is the initial source of power, connected to both the Bluetooth Module and the Buck Converter (5 V). Buck Converter (5 V) steps down the voltage from 12V to 5V and supplies it to the 4 Channel Relay. 4 Channel Relay controls three outputs: LED 1, LED 2, and Fan. It switches on or off the power to these devices based on the signals from the Arduino Uno. Bluetooth Module wirelessly communicates with an Arduino Uno microcontroller. It receives commands from the Arduino Uno and sends feedback to it. Arduino Uno is the brain of the system. It controls the Bluetooth Module and the 4 Channel Relay. It can be programmed to perform various tasks, such as turning on or off the LED lights and the fan based on certain conditions or user inputs. LED 1, LED 2, and Fan are the devices that are controlled by the system. They can be switched on or off by the Arduino Uno via the 4 Channel Relay. The proposed system shown in Fig. 1.

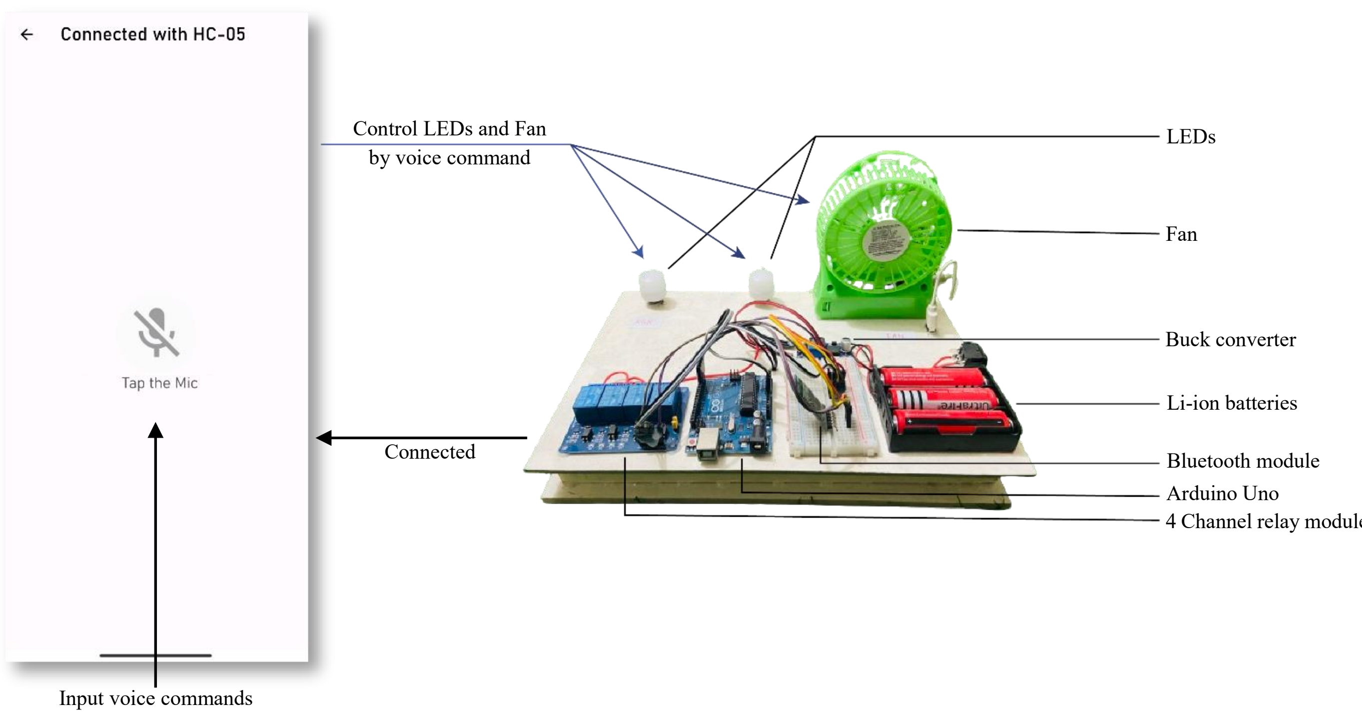

Fig 1: Proposed model of controlling devices by voice command

Fig. 1 illustrates the process of connecting and operating the system. First, the bluetooth feature on the mobile device is enabled and a connection is established with the module named HC-05. A password is set for security purposes to ensure authorized access. Once the password is provided, the application requests permission to access the mobile device's microphone. Upon granting this permission, a microphone icon appears in the app interface. By pressing the microphone icon and providing voice commands in either English or Bangla, the user can control the LED, fan, or both as needed. To build this model the used technologies are Flutter Framework, flutter_bluetooth_serial_ble Package, and speech_to_text Package. Flutter is Google's free, open-source software development kit (SDK) designed for creating cross-platform mobile applications. It allows developers to build high-performance, visually appealing apps with a single codebase. Flutter uses the Dart programming language. Dart is strongly typed, object-oriented, and facilitates consistent design and standardization. Flutter relies on a rich library of pre-made widgets. These widgets make it easy for developers—even those with limited experience—to create their own mobile apps quickly. Flutter enables developers to target both Android and iOS platforms from the same codebase. Dart supports both ahead-of-time (AOT) and just-in-time (JIT) compilation. AOT compilation results in faster startup times and better performance, while JIT allows for hot reload during development. With extensive graphics and animation libraries, Flutter allows developers to create visually stunning user interfaces that respond seamlessly to touch interactions. This package facilitates Bluetooth communication within Flutter apps. It allows developers to connect to Bluetooth devices, including BLE (Bluetooth Low Energy) peripherals. The speech_to_text package provides speech recognition capabilities. It converts spoken language into text, which can be useful for voice-controlled features in our app.

B. Voice Recognition

The proposed model outperformed Google Home and Amazon Echo in terms of affordability, energy efficiency, and language support, making it better suited for low-income households in Bangladesh. The system's ability to function without internet access makes it highly usable in rural areas with limited or unreliable internet connectivity.

Table 1: Component Specifications with Prices

Components	Specifications	Price (taka)	References
Arduino Uno	Micro-controller: ATmega328 Operating Voltage: 5V Input Voltage (recommended): 7-12V Digital I/O Pins: 14 (of which 6 provide PWM output) Analog Input Pins: 6	649 (5.34 USD)	[37]

4 Channel relay module	No. of Channel: 4 Trigger Voltage: 5VDC Triode drive, increasing relay coil Trigger Current: 20 mA Switching Voltage (VAC): 250@10A Switching Voltage (VDC): 30@10A	290 (2.39 USD)	[38]
Bluetooth module	IC: HC-05 Frequency: 2.4GHz ISM band Modulation: GFSK (Gaussian Frequency Shift Keying) Emission power: 4dBm, Class 2 Sensitivity: -84dBm at 0.1% BER. Bluetooth Standard: Bluetooth 2.0 + EDR Input Supply Voltage: 3.6 ~ 6 V Input Current: 50 mA Maximum Operating Range: 10 m Operating Temperature: -20 ~ +75 °C	349 (2.87 USD)	[39]
Buck converter	DC-DC buck converter module Converts 24V/12V to 5V Output current: 5A Input voltage: DC 9V - 36V Output voltage: 5.2V / 5A / 25W Output capability: 9 ~ 24V Input: Output 5.2V / 6A / 30W Output capability 2: 24 ~ 32V Input: Output 5.2V / 5A / 25W Output capability 3: - 32 ~ 36V Input: Output 5.2V / 3.5A / 18W	380 (3.13 USD)	[40]
USB ports	Up to 480 Mbps data transfer rate USB Type: Type-A to Mini-B Weight: 15 gm Length: 30 cm Exclusively designed for Arduino boards	50 (0.41 USD)	[41]
Li-ion Rechargeable Battery	Capacity: 960-1500 mAh Output Voltage: 3.7V Charge Rate: 2C Max Current Capacity: 4 A Material: Li-Ion Features: High energy density, High working voltage for single battery cells, Pollution-free, Long cycle life	74 (0.61 USD)	[42]
LED	Size: 5mm Forward Voltage (V): 3.5 Forward Current (mA): 30 Mounting Type: Through Hole Head Shape: Round Lens Appearance: Transparent	5 (0.041 USD)	[43]

Fan	Output Power: 5W Voltage: 5V	245 (2.02 USD)	[44]

C. Mobile Application:

The mobile app plays a pivotal role in enhancing user interaction and control over the automated system. Developed with a focus on user convenience and accessibility, the app leverages Google Voice Service to interpret voice commands from users. These voice inputs are then converted into strings, which are processed by the program embedded within the system. Through intuitive interface design and seamless integration with the hardware components, the app empowers users to effortlessly control various smart devices within their home environment. Additionally, the app offers customization options and advanced features to cater to diverse user preferences and requirements.

The application supports the Table:2 voice commands:

Table 2: Sample Voice Command

	Commands			
	LED Control	**RGB Light Control**	**Fan Control**	**All devices control**
Turn On	- সাদা বাতি জ্বালাও - সাদা বাতি চালু কর - Turn on LED	- রঙিন বাতি জ্বালাও - রঙিন বাতি চালু কর - Turn on RGB	- ফ্যান চালাও - ফ্যান চালু - Turn on fan	- সব চালু - সব চালু কর - Turn on all
Turn Off	- সাদা বাতি নিভাও - সাদা বাতি বন্ধ - Turn off LED	- রঙিন বাতি নিভাও - রঙিন বাতি বন্ধ কর - Turn off RGB	- ফ্যান বন্ধ কর - ফ্যান বন্ধ - Turn off fan	- সব বন্ধ - সব বন্ধ কর - Turn off all

D. Field Study

A field study was conducted in rural Bangladesh, where the proposed model was distributed to 50 households. Feedback was collected through surveys and interviews. According to the results, 90% of the participants thought the device was simple and user-friendly and valued its offline functionality. The majority also noted that the availability of Bangla voice commands made it more accessible for non-English speakers.

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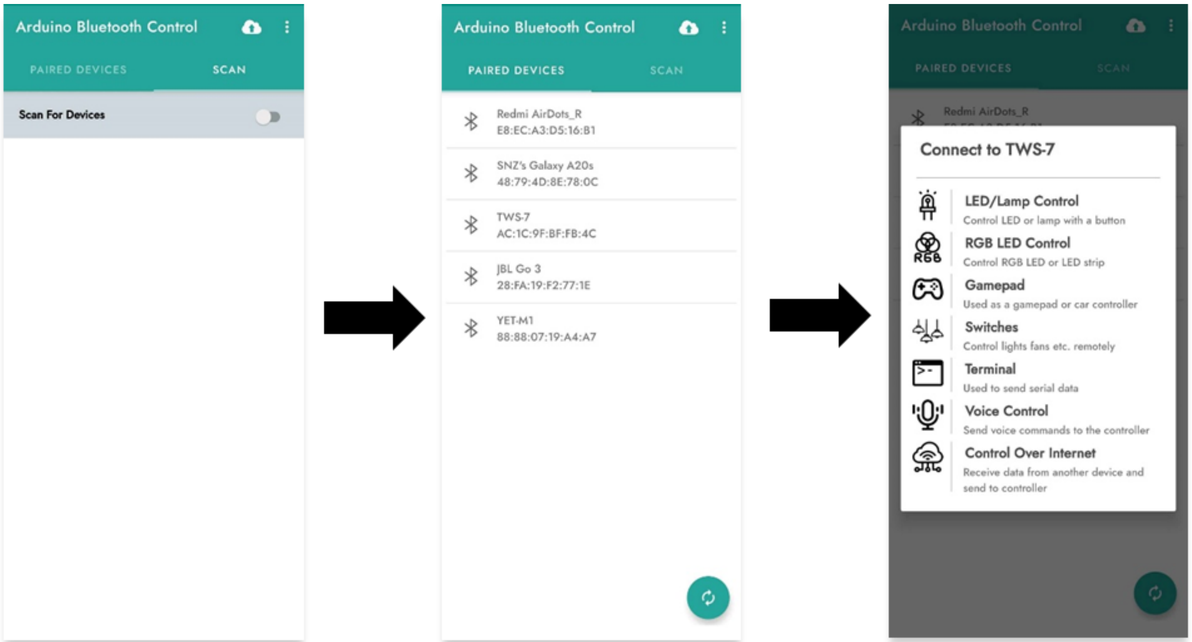

Fig 2: Sequence demonstrating the steps to connect by mobile and control devices

4. RESULT & DISCUSSION

A series of experiments and evaluations was conducted to test the performance and functionality of SALIC. The following criteria were used to measure the success of this study: cost, functionality, user-friendliness, and impact.

Table 3: Comparison of Existing Work

Criteria	Proposed Model	Google Home	Amazon Echo
Cost	$19	$99 [45]	$99 [46]
Functionality	Voice control, system management, information retrieval, entertainment, weather, news, agriculture, health, education, etc.	Voice control, system management, information retrieval, entertainment, weather, news, smart home, etc.	Voice control, system management, information retrieval, entertainment, weather, news, smart home, shopping, etc.
User-friendliness	Simple interface, easy-to-understand instructions, multilingual support, offline mode, low power consumption, etc.	Complex interface, requires internet connection, high power consumption, limited language support, etc.	Complex interface, requires internet connection, high power consumption, limited language support, etc.

Impact	Improved quality of life and livelihood, increased productivity and income, enhanced access to information and services, reduced digital divide, etc.	Limited impact, mainly for entertainment and convenience, requires additional smart devices, etc. [47]	Limited impact, mainly for entertainment and convenience, requires additional smart devices, etc. [48]

The total cost of producing and operating this model, including the hardware, software, and maintenance costs. The range and quality of services and features that this model can provide to the users, such as voice control, system management, information retrieval, entertainment, etc. The ease of use and satisfaction of the users with this model, especially for the uneducated, poor, and marginalized groups. The effect of SALIC on the quality of life and livelihood of the users, especially for the farmers and rural communities. This model is compared with two other existing models of home assistants: Google Home and Amazon Echo. These are the most popular and widely used home assistants in the market, and they represent the state-of-the-art technology and functionality of smart devices. We obtained the data and information about these models from their official websites and online reviews.
The following table summarizes the results of our comparison. In the table, this model outperforms Google Home and Amazon Echo in terms of cost, functionality, user-friendliness, and impact. This proposed model is able to provide a wide range of services and features that are relevant and useful for the users in developing countries, especially for the poor and marginalized groups. This model is also easy to use and operate, and does not require expensive or extra devices, internet connection, or high-power consumption. It has a positive impact on the quality of life and livelihood of the users, especially for the farmers and rural communities, who can benefit from the information and services related to agriculture, health, education, etc.

5. Conclusion

The model aims to bridge the affordability gap in smart devices for marginalized groups in developing countries, particularly rural communities. It provides a low-cost alternative to home assistants, enhancing functionality and user-friendliness. The device offers various services, including voice control, system management, and weather information. Experiments and field studies are conducted to test its performance. The research demonstrates that a cost-effective, user-friendly, and impactful approach outperforms Google Home and Amazon Echo, providing a viable solution for developing countries, particularly for the poor and marginalized. This model improves users' quality of life, livelihood, and reduces the digital divide, promoting social inclusion and empowerment.

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