REVISTA INGENIO

Desarrollo de una herramienta educativa inalámbrica basada en Raspberry Pi

Development of a Raspberry Pi-based wireless educational tool

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RESUMEN

El siguiente documento presenta un dispositivo de conectividad inalámbrica diseñado específicamente para el sector educativo, que emplea tecnología IoT y Raspberry Pi. Su objetivo principal es ofrecer a las instituciones educativas una solución asequible que permita realizar presentaciones en el aula sin problemas y sin comprometer la calidad ni la facilidad de uso. Utilizando una metodología experimental, configuramos un ordenador monoplaca Raspberry Pi, transformando este dispositivo en una alternativa práctica a un ordenador de sobremesa tradicional. Esta configuración permite la reproducción de varios tipos de documentos, incluidos Word, Excel, PowerPoint y Publisher, ofreciendo a educadores y estudiantes una herramienta versátil para satisfacer sus necesidades académicas. La solución propuesta funciona a la perfección: mediante el uso de una aplicación móvil gratuita, los contenidos pueden transmitirse sin esfuerzo a dispositivos externos, como proyectores, televisores y monitores. De este modo se aborda un problema educativo cuyo principal inconveniente radica en el coste de los equipos. En última instancia, el objetivo no es solo superar las barreras financieras en la educación, sino también impulsar la exploración innovadora para mejorar la conectividad y la automatización en diversos entornos.

ABSTRACT

The following document introduces a wireless connectivity device specifically designed for the educational sector, employing IoT technology and Raspberry Pi. Its primary objective is to offer educational institutions an affordable solution that enables seamless classroom presentations without compromising on quality and user-friendliness. Using an experimental methodology, we configure a Raspberry Pi single-board computer, transforming this device into a practical alternative to a traditional desktop computer. This setup enables the playback of various document types, including Word, Excel, PowerPoint, and Publisher, offering educators and students a versatile tool to meet their academic requirements. The proposed solution operates seamlessly: through the use of a free mobile application, content can be effortlessly streamed to external devices, such as projectors, televisions, and monitors. This addresses an educational issue where the primary drawback lies in the cost of the equipment. Ultimately, the aim is not only to overcome financial barriers in education but also to ignite innovative exploration in enhancing connectivity and automation across diverse settings.

I. Introduction

The internet has gained immense significance and has become indispensable in various domains, including education, employment, communication, entertainment, and more. A vast portion of the global population now enjoys access to a pervasive system of information and connectivity [1]. The public's growing demand for increased advancements, innovations, and assistance through this expansive platform in their daily lives has driven extensive research in science and technology. These efforts have yielded remarkable achievements, such as the emergence of the Internet of Things (IoT) [2].

IoT involves the interconnection of physical-world objects via the internet, equipped with sensors, actuators, and communication technology. The primary objective of this technology is to develop practical, groundbreaking applications while enhancing existing ones [3].

Hence, in accordance with the previously mentioned objectives, this endeavor is focused on creating a wireless connectivity apparatus tailored specifically for the educational sector [4]. It leverages IoT technology and the Raspberry Pi to furnish educational institutions with a cost-effective solution. This solution enables the seamless display of presentations in classrooms without sacrificing quality or user-friendliness. Moreover, through the utilization of a complimentary mobile application, content can be effortlessly transmitted to external devices such as projectors, televisions, and monitors [5].

Modern educational approaches have evolved significantly over time. While traditional tools like books, blackboards, and flipcharts remain relevant, technology and the internet have emerged as indispensable resources. This is primarily due to the vast wealth of bibliographic sources available and the inclusion of visual aids, which greatly enhance the quality of contemporary education and facilitate more engaging and effective learning experiences across age groups [6]. In fact, these resources have become integral components of essential educational tools for institutions today [7].

1.1. ELABORATED UPON SPECIFIC COMPONENTS.

Projector

This device plays a crucial role in receiving video signals and displaying images on a surface. Its significance is particularly pronounced in educational contexts, where its utilization is geared towards enhancing the educational experience, fostering interactive and engaging teaching methods.

Raspberry Pi 4 model B

The Raspberry Pi represents a family of single-board computers (SBCs) initiated by the Raspberry Pi Foundation, aimed at promoting affordable computer science and electronics education. Since its introduction in 2012, the Raspberry Pi has left a profound mark across diverse domains, including education, research, DIY project development, and the creation of inventive technology solutions [8] [9] (see Figure 1).

Specifications of the Raspberry Pi 4 model B are:

· System-on-a-chip: Broadcom BCM2711
· CPU: 1.5 GHZ quad-core processor with Cortex-A72 arm
· GPU: Video Core VI
· Memory: 1/2/4 GB LPDDR4 RAM

· Connectivity: 802.11ac Wi-Fi / Bluetooth 5.0, Gigabit Ethernet
· Video & Sound: 2 x micro-HDMI ports supporting 4K@60Hz displays via HDMI 2.0, MIPI DSI display port, MIPI CSI camera port, 4-pole stereo output and composite video port.
· Ports: 2 x USB 3.0, 2 x USB 2.0
· Power: 5V/3A via USB-C, 5V via GPIO header
· Expansion: 40-pin GPIO header

VNC (Virtual Network Computing)

VNC is a remote desktop system that relies on the RFB (remote frame buffer) protocol, facilitating the remote control of a computer system [10].

· Facilitates screen sharing among users
· Enables cross-platform compatibility
· Utilizes lightweight protocols
· Operates as a standalone platform

Its architectural structure, is rooted in a client-server model, where the computer running the client application assumes control over the computer running the server application [11].

vnc utilizes a dedicated frame buffer aligned with the rfb protocol to manage client requests [12].

Once it receives a request for a screen refresh, the server captures the screen content from the frame buffer.

The server processes and transmits the captured screen image data, along with frame buffer update details, to the client. Subsequently, the user decodes and updates the bitstream accordingly [13].

RFB (Remote Frame Buffer)

The communication protocol designed for remote access to a basic user interface represents a technology enabling users to establish remote connections to and manage a system or application. Its architecture is rooted in the «frame buffer» class, making it especially well-suited for the efficient transmission of graphical data [13].

This protocol functions within a client-server framework [14]. The RFB client is the computer or any compatible device establishing a connection with the RFB server. Once the connection is established, the user gains access to the window system and applications hosted on the server (see Figure 2).

Figura 1.
Raspberry Pi 4 model b

Note: https://www.raspberrypi.com/products/raspberry-pi-4-model-b/

Figura 2.
Client-server model
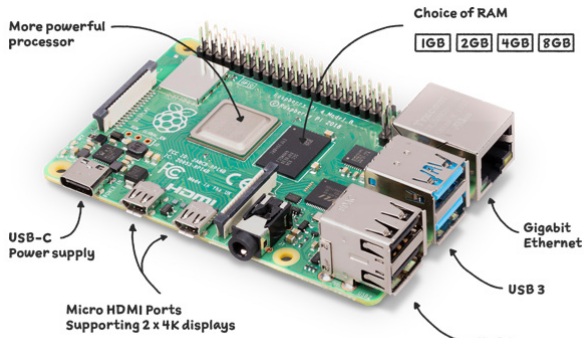
Debian

This is an open-source software initiative that continues to be actively maintained, even though it has been around for a while. Some users may find it a bit challenging, leading to misconceptions that it is primarily used by hackers, but this perception is entirely inaccurate. [15] Debian offers highly user-friendly tools designed for both system administrators and regular users. One notable advantage is its unwavering commitment to being entirely free [16].
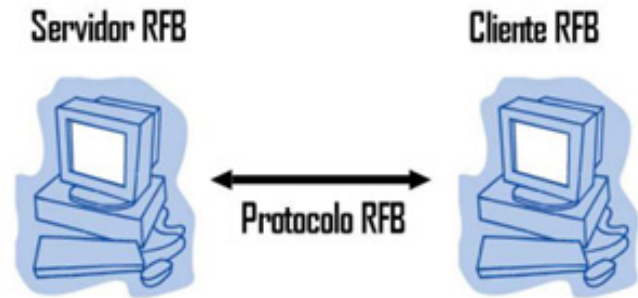
TCP (transmission control protocol)

This protocol is universally recognized by all devices [17]. It is designed to establish a dependable connection, accepting a data stream within local processes, breaking it down into segments not exceeding 64 Kbytes, and transmitting each segment as a separate IP datagram. Upon reception, the data is then reconstructed [18].

2. METHOD

Employing an experimental approach, we undertake the configuration of a Raspberry Pi single-board computer, effectively converting it into a pragmatic substitute for conventional desktop computers. This reconfiguration empowers the device to support the playback of an array of document formats, encompassing Word, Excel, PowerPoint, and Publisher. As a result, educators and students gain access to a versatile tool tailored to fulfill their diverse academic needs. The proposed solution seamlessly operates through the utilization of a cost-free mobile application, allowing for effortless content streaming to external devices like projectors, televisions, and monitors.

This innovative solution directly addresses a prevalent issue within the realm of education, primarily characterized by the formidable cost of requisite equipment. By simplifying the transition to Raspberry Pi-based systems and their compatibility with the Raspberry Pi single-board computer, this initiative aims to bridge the financial gap and facilitate more accessible and interactive learning environments. It paves the way for affordable, high-quality classroom presentations, ushering in an era of heightened connectivity, automation, and learning enhancement across various educational settings.

The suggested system has been meticulously planned and organized into a framework consisting of three core components (see Figure 3).

1. Raspberry Pi Connectivity.
2. HDMI facilitates the high-quality transmission of data for audio and video, ensuring exceptional clarity.
3. Internet Access.
4. This involves utilizing either a wireless connection or an Ethernet connection to establish network connectivity. Enabling WIFI on the Raspberry Pi can be achieved by following the specified procedure, enabling the transfer of files to the Pi.
5. Application Management.
6. The installed operating system provides the ability to navigate and control various applications seamlessly.

Raspberry Pi HDMI connectivity

To implement the proposed system, Raspberry Pi provides 2 micro-HDMI ports for connecting to a projector. In cases where the projector lacks an HDMI port, an HDMI to VGA converter can be used.

Installation of the operating system

The process of installing the operating system on a Raspberry Pi is made effortless with the Raspberry Pi Imager. This powerful tool streamlines the formatting of the SD

Figura 3.
Architecture of the proposed system
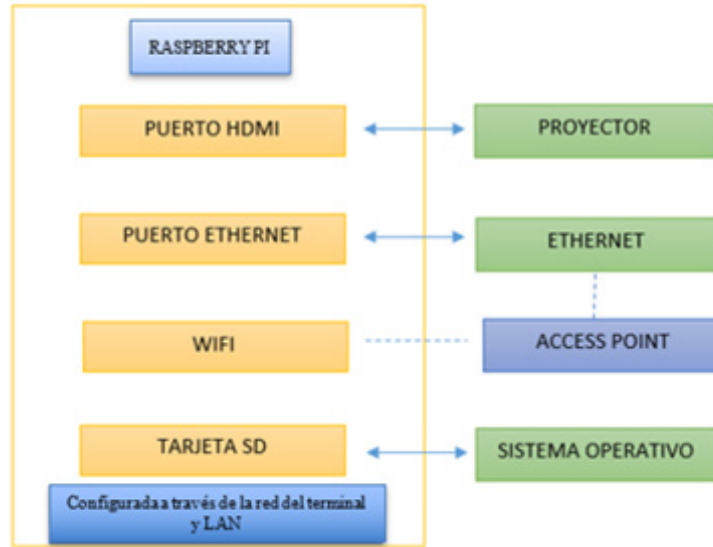
card and the loading of the latest OS version, significantly expediting the entire procedure [19].

Network connectivity and power supply

The system is equipped with a 5V to 3A power supply featuring a USB type-C connector and an Ethernet input for establishing an internet connection through an Ethernet cable. Furthermore, it offers the flexibility of connecting via WIFI, as this model includes WIFI capabilities [9].

Operating system update

To perform a system update, two commands are necessary:

· Utilize 'sudo apt-get update'
· Execute 'sudo apt-get upgrade'

Establishing a connection between a mobile device/laptop and Raspberry Pi

VNC is a pre-installed program, and to activate it, you can run the command 'sudo raspi-config'. Navigate to «Interfacing Options», locate and select «VNC-Yes». To view your smartphone's screen, you'll need to enable USB debugging on your mobile device. In this process, access your Android device's settings, search for «additional settings», and choose «developer options». In that menu, enable «USB debugging».

SCRCPY Installation

Install SCRCPY to mirror your cellphone's screen by connecting the mobile device to the Raspberry Pi using a USB cable. Once connected, you can take full control of the Android device using your keyboard and mouse [20].

Wireless connection

To establish a wireless connection, execute commands that activate the TCP/IP protocol on the device. Open the console terminal and enable the TCP/IP port with the command «adb tcpip 5555». Then, execute the command «adb connect 192.168.xx.xx:5555» to connect to the Android device. Upon execution, you will see the message «already connected».

EQUATIONS FOR CALCULATING SYSTEM BANDWIDTH

Equation 1:
    Bandwidth utilization = Data transfer rate × Transfer duration   (1)
    The volume of data transferred is measured in various units, including bits, kilobits, or megabits.
    The time elapsed is expressed in seconds, minutes, or hours, depending on the required level of precision.
    The formulas outlined in the paper titled «Assessing average throughput for data stream quantity in an NDN rendezvous server» provide a comprehensive method for computing the average throughput of packets transmitted within a system [21]. This calculation approach is straightforward and effective in estimating bandwidth utilization within a system operating at a specific data transfer rate over a defined time interval.
    The system's transmission rate exhibits a direct correlation and is based on an optimal route forwarding strategy, taking into account factors such as the speed of interest, data rates (250 m/s), and data mobility. This

strategy is applied in the context of data content streams, with lengths ranging from 100 to 1500 bytes [22].

$$DIFS=SIFS+(2*RT) \qquad (2)$$

$$TME=\frac{VGM}{2}*RT \qquad (3)$$

$$MPDU=1400+UDP+NDN\ header+MAC\ header \quad (4)$$

$$TTP = expenses\ generated\ by\ physical\ layer+\\ MPDU/(Data\ Rate) \qquad (5)$$

$$Expenses\ generated\ physical\ layer+\frac{ACK\ packet\ size}{ACK\ transmission\ rate} \quad (6)$$

$$ATC=TS_{ACK}+TSC+ABT+DIFS \qquad (7)$$

$$Average\ Throughput = \frac{Application\ Load}{Average\ Time\ Per\ Content} \qquad (8)$$

Where:

- *RT*, Time slot (μs).
- *DIFS*, space distributed between frames (μs).
- *VMG*, Minimum congestion window (slots).
- *TME*, Average waiting time (μs).
- *MPDU*, Maximum size of a data packet unit (*bytes*).
- *TTP* packet transmission time (μs).
- *TS_{ACK}, Tiempo de tansmisión ACK*, measured in (μs).
- *TSC*, Content send time, refers to the period of time it takes to transmit data or information from a source to a destination over a communication network.
- *ABT,* Mean wait time, refers to the average time a message, signal or data packet must wait on a network before being transmitted or delivered to its destination.
- *ACK* packet size, the size of the ACK packet can be quite small, typically measured in bytes.
- Average throughput, refers to the average throughput over a given time interval.
- Application load, refers to the amount of network traffic generated or received by the application.
- *ATC*, Average time per content measured in (μs).

INSTALLING RASPBERRY PI OS USING RASPBERRY PI IMAGER

The Raspberry Pi, being an integrated computer with limited memory, necessitates the use of a storage device, such as an SD card, to install an operating system that aligns with the hardware's functional specifications, for instance, Raspbian.

RASPBERRY PI IMAGER

Raspberry Pi imager stands as a robust tool meticulously designed to simplify the process of installing an operating system on a Raspberry Pi. This user-friendly application facilitates both the formatting of the SD card and the seamless loading of the latest OS version, significantly expediting the entire setup.

To get started, you can easily download the Raspberry Pi imager from the official website and proceed with its installation. Subsequently, connect an SD card reader to your computer, select the desired card for the OS installation, and you'll be up and running with your Raspberry Pi promptly, all without unnecessary complications or concerns regarding the intricacies of OS installation. [23]

Once the OS is successfully installed on the SD card, the initial configuration process will commence (see Figure 4). During this configuration, you can enable various settings at the time of installation, including:

HOSTNAME: PI. ENABLE SSH

Configure the username and password (pi user by default), configure the Wi-Fi (SSD: TelecoTT1 Password: xxxxxxxxx). Configure local (Europe/Madrid and keyboard: es).

After installation, you'll need to identify the IP address of the Raspberry Pi for establishing a connection. To accomplish this task, IpScan is employed (see Figure 5).

Establish a SSH connection using PuTTY over port 22 with the following credentials (see Figure 6).
Username: pi
Password: passwd (default)

Afterward, you will be prompted to update the password.

Upon successfully connecting to the system, perform the following updates:

- sudo apt-get update
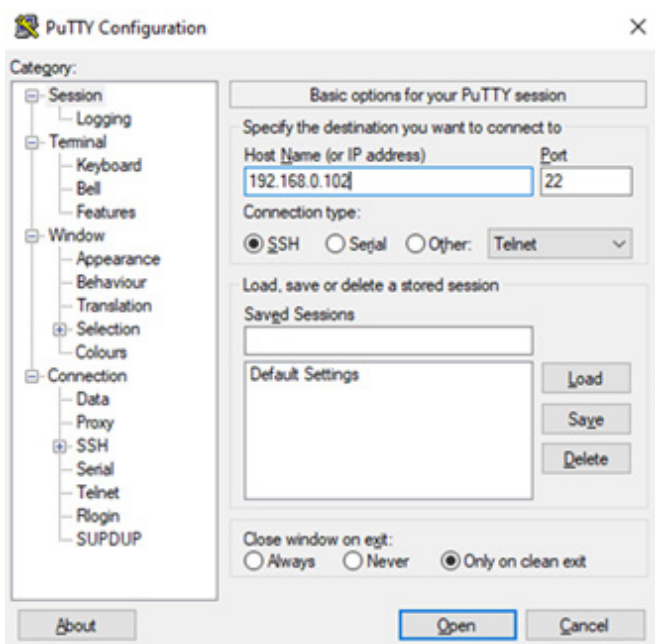- sudo apt-get upgrade

INSTALLATION OF VNC

While in the console, you should enable VNC (which comes pre-installed) to connect to the desktop and proceed with the installation from the remote desktop. To do this, run the command: sudo raspi-config, navigate to Interfacing Options, and locate VNC. Then, select 'Yes' to enable it (see Figure 7).

Download and install VNC Viewer on your device and connect it to the Raspberry Pi.

Figura 4.
Menú selección SO

Figura 5.
IpScan detecting Wifi equipment

Figura 6.
PuTTY Menu

Figura 7.
VNC Viewer interface

In the accompanying illustrations, you can observe the login process for accessing the Raspberry Pi through VNC, allowing you to view the desktop and access its various options.

INSTALLATION OF PIKISS

Execute the following command: curl -sSL https://git.io/JfAPE | bash

Upon completion of the installation, you will find the launcher available in the System Tools menu (see Figure 8).

3. RESULTS AND DISCUSSION

Launch the PiKISS application to access the menu. From there, navigate to the «Others» category, and select the option for «Display and control of connected Android devices» (see Figure 9).
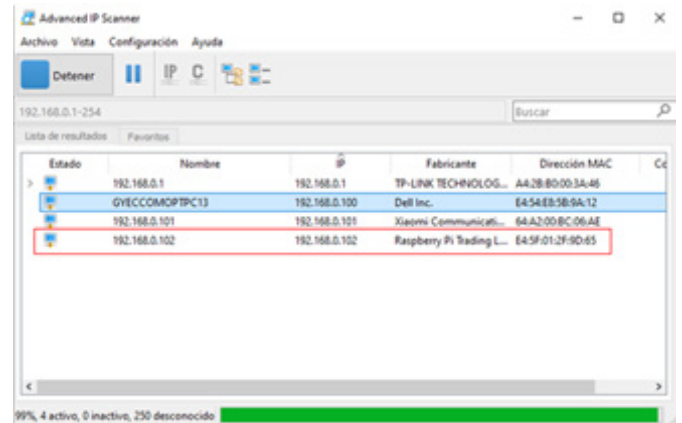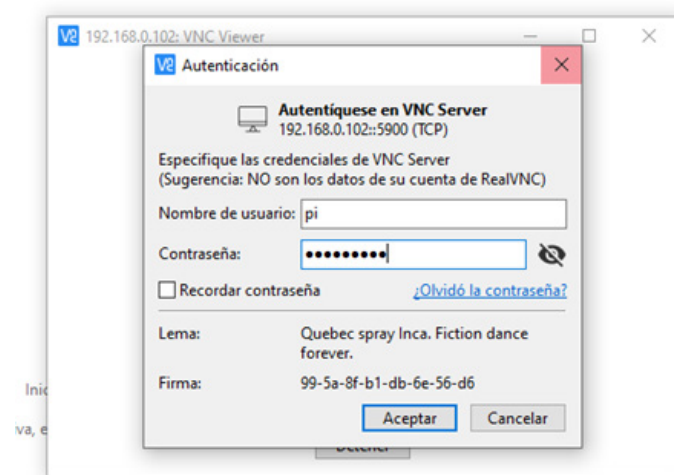
To view your mobile screen, you need to enable USB debugging on your phone. In this process, you access the settings of your Android device, look for the additional settings option, and select the developer options. In that menu, you choose USB debugging.

Connect your mobile device to the Raspberry Pi using a USB cable. Once the connection is established, you can have complete control over the Android device using the keyboard and mouse.

On the Android device, access the Wi-Fi settings and choose the network you are connected to while verifying the IP address. Execute the command «adb connect 192.168.65.191:5555» to establish a connection with the Android device. Once executed, it will confirm the connection with the message «already connected».

To establish a wireless connection, execute the commands to enable the TCP/IP protocol on the device. Open the console terminal and activate the TCP/IP port using the command: «adb tcpip 5555».
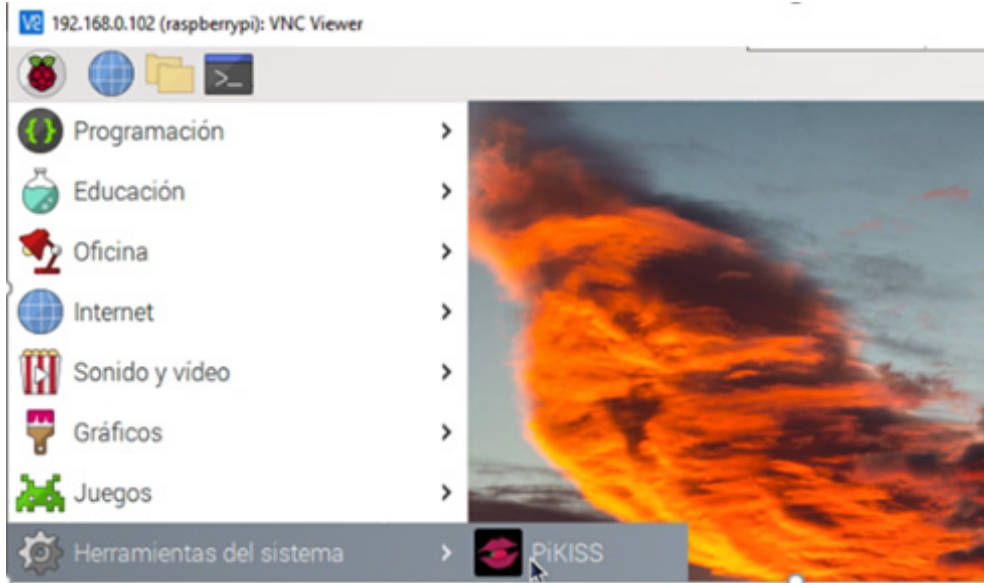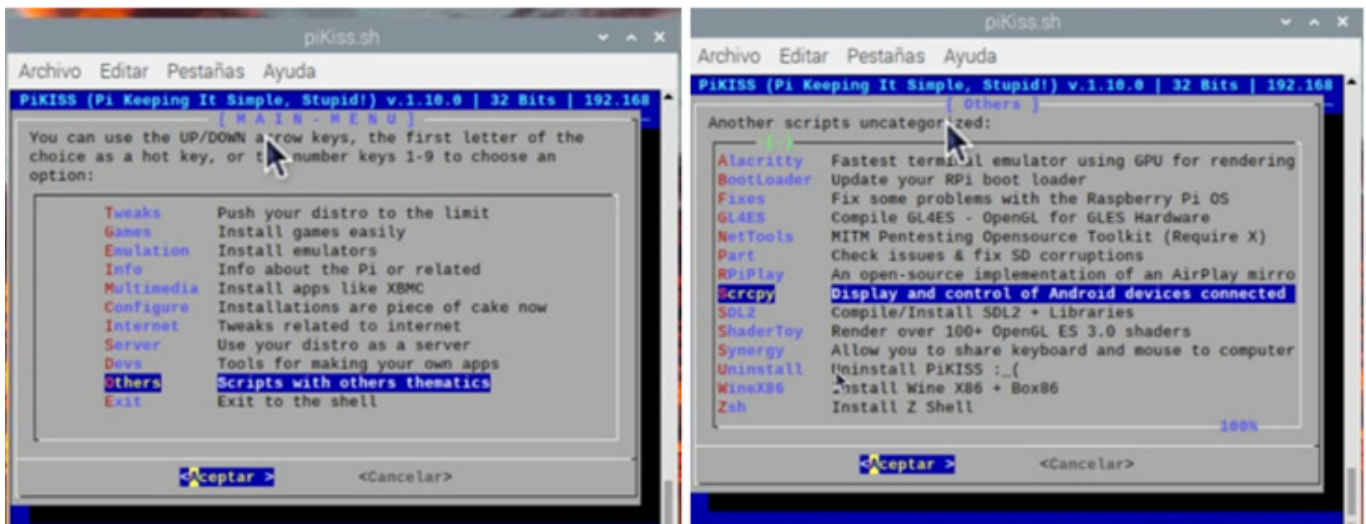
Figura 8.
PiKISS installed

Figura 9.
PiKISS options

Open Scrcpy as usual without requiring the use of a USB cable, and you will be able to view the screen of the device (see Figure 10).

The research project represents a significant step towards addressing the educational disparities that exist in underprivileged schools and institutions. Education is a fundamental right, and access to quality educational tools should not be limited by economic constraints. By focusing on the development of a Raspberry Pi-based wireless educational tool, this project seeks to democratize access to technology-enhanced learning experiences.

The creation of a customized application designed to facilitate seamless connections and content sharing across multiple mobile devices is a pivotal aspect of this initiative. The goal is to empower educators and students with a user-friendly platform that enables them to collaborate, share resources, and engage in interactive learning activities. Such an application can bridge the digital divide,

making advanced educational tools accessible to even the most resource-constrained environments.

However, as this research project progresses towards implementation, one crucial consideration is the existing network infrastructure's ability to handle the anticipated surge in data traffic. The deployment of this application will likely lead to increased demands on the network, requiring a thorough evaluation of its capacity. In cases where the current infrastructure falls short, proactive steps must be taken to enhance it. This could involve upgrading network hardware, expanding bandwidth, or implementing quality of service measures to ensure uninterrupted data flow.

In essence, this research project not only embodies the spirit of technological innovation but also emphasizes the importance of equitable educational opportunities. By providing a cost-effective and scalable solution for underprivileged schools and institutions, it aims to pave the

Figura 10.
Wireless connection working

way for a more inclusive and enriching learning experience, ultimately contributing to narrowing the educational gap and fostering a brighter future for all.

The Raspberry Pi operates on a 5V and 3A power supply, which furnishes the required energy for its smooth operation and execution of tasks. It's worth emphasizing that an alternative power source, like a portable battery, can also be used, provided that it aligns with the specific device requirements. The article titled «Power consumption of the Raspberry Pi: a comparative analysis» [23] offers a comprehensive response to the intriguing question regarding the power consumption of Raspberry Pi. The study outlines various scenarios and conducts an intricate examination of power usage in each scenario. As detailed in figure 11, the research concludes that the average power consumption of Raspberry Pi devices stands at 3.5 watts. Furthermore, the study undertakes a comparative assessment between Raspberry Pi and other devices, such as desktop computers and laptops, enabling an evaluation of the advantages that Raspberry Pi presents when compared to these alternative solutions (see Figure 11).

Table 1 exhibits a dataset that has been generated from a sample of 22 observations. These observations were collected over a time span starting from time t=0 seconds and concluding at t=0.12 seconds. Throughout this timeframe, there was an exchange of data packets occurring between devices, specifically between Raspberry Pi and an Android device, and vice versa. These exchanges were executed using the transmission control protocol (TCP). The recorded values represent the sizes of these transmitted packets, ranging from 0 to 1514 bytes. Even

when considering the original byte values, it is noteworthy that the size of these packets remains within a range that is well within the typical capabilities of network connections. This suggests that the existing network infrastructure is more than capable of efficiently managing the volume of data transmitted during each exchange, which is crucial for ensuring a seamless and uninterrupted communication experience (see Table 1).

4. CONCLUSIONS

The proposed system represents a valuable solution for enhancing the efficiency of knowledge transmission within educational settings. It achieves this by replacing traditional computers with a Raspberry Pi while harnessing wireless technologies like SCRCPY, thereby creating an effective tool that optimizes teaching delivery in classrooms.

Moreover, it facilitates the seamless presentation of various content types, such as text, PDF files, presentations, and even videos, in an efficient and fluid manner. The incorporation of SCRCPY activates a TCP/IP protocol that simplifies the display of mobile device screens on the Raspberry Pi, ensuring a smooth and high-quality transmission. This functionality grants educators the flexibility to wirelessly share content with students, eliminating the need for cables or physical connections.

The proposed design offers versatility by allowing the use of a USB cable to connect the Raspberry Pi to the projector when Wi-Fi connectivity is unavailable. This guarantees reliable transmission, even in environments with limited wireless network infrastructure.

Tabla 1.
Data transmission sampling while watching a YouTube video

N.º	Time	Source	Destination	Protocol	Length
1	0.000000	192.168.200.10	192.168.200.20	TCP	54
2	0.014968	192.168.200.20	192.168.200.10	VNC	83
3	0.015039	192.168.200.10	192.168.200.20	TCP	54
4	0.054056	192.168.200.10	192.168.200.20	VNC	1514
5	0.054077	192.168.200.10	192.168.200.20	VNC	1514
6	0.054080	192.168.200.10	192.168.200.20	VNC	1514
7	0.054083	192.168.200.10	192.168.200.20	VNC	165
8	0.057637	192.168.200.20	192.168.200.10	TCP	60
9	0.057735	192.168.200.20	192.168.200.10	TCP	60
10	0.058951	192.168.200.20	192.168.200.10	VNC	86
11	0.058972	192.168.200.10	192.168.200.20	TCP	54
12	0.071930	192.168.200.10	192.168.200.5	TCP	90
13	0.109987	192.168.200.5	192.168.200.10	TCP	1034
14	0.110007	192.168.200.10	192.168.200.5	TCP	78
15	0.116741	192.168.200.5	192.168.200.10	TCP	90

Figura 11.
Comparative chart of average power consumption among various devices
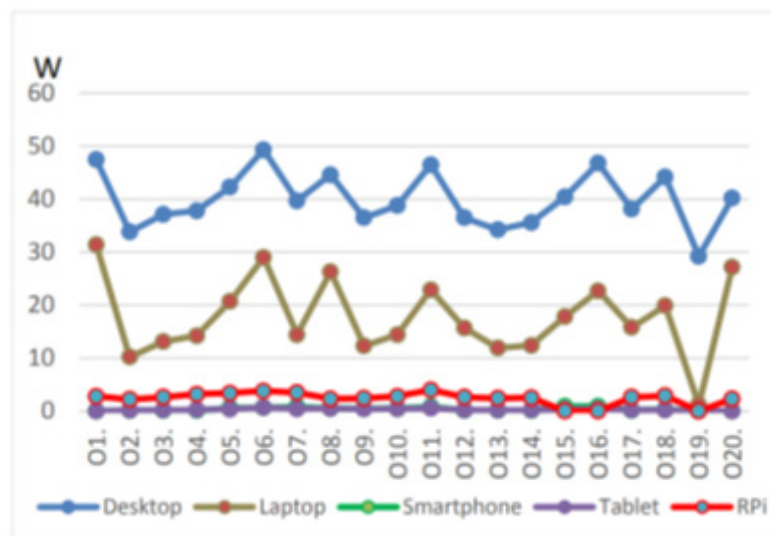
Furthermore, the proposed system not only benefits economically disadvantaged educational institutions but also provides an accessible solution for households lacking access to computers, offering an alternative solution within their homes. By overcoming budget constraints and limited access to advanced technology, it creates a pathway for effective knowledge transmission both within classrooms and households.

Finally, demonstrations through bandwidth consumption confirm that the Raspberry Pi and Android system combination is an optimal design. It exhibits qualities and capabilities comparable to those of a conventional computer, all without the need for substantial expenditure. These findings also lay the foundation for future research aimed at further enhancing this innovative design.

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