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PiWall as a home traffic controller: enabling parental control and monitoring

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ABSTRACT

The movement control order (MCO) has led to a surge in internet usage among children, becoming the new normal. Most countries heavily rely on online platforms for education, granting children more freedom to explore the internet using electronic devices. Yet, it is challenging for parents to monitor their online activities. Children may stumble upon unsuitable content such as pornography or get redirected to harmful websites through pop-up advertising. To address these concerns, this study proposes PiWall, a home traffic controller. PiWall aims to block undesirable websites and filter out advertisements to help parents manage their home network. Testing shows that PiWall significantly improves the internet browsing experience by reducing website loading times and network traffic, hence offering protection against inappropriate content and malicious attacks. Implementing PiWall as a home traffic controller is a viable alternative to traditional parental controls in creating a safer internet environment for children.

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1. INTRODUCTION

The concerns surrounding children's excessive internet usage were already gaining traction before the onset of the COVID-19 outbreak in 2019. In today's digital age, children are constantly exposed to online risks and potential harm. With the advent of the COVID-19 pandemic, many countries implemented movement control order (MCO) to curb the spread of the virus. Consequently, schools shifted to virtual learning, leading to a heavy reliance on electronic devices for internet access among students. Parents now find themselves grappling with the dilemma of allowing their children to use computers, smartphones, and tablets for educational purposes while navigating the potential negative impacts of internet overuse.

Unsupervised internet access exposes children to inappropriate content and increases the risk of cyberbullying and victimization. Unfortunately, some parents struggle to monitor their children's online activities, including internet surfing [1], [2]. For instance, in Saudi Arabia, over half of teenagers engage in problematic internet use (PUI), surpassing the global average. This highlights the importance of active parental supervision [3]. The accessibility of inappropriate content, such as pornography, poses significant dangers to children and adolescents [4]. The Malaysia communications and multimedia commission (MCMC) has taken steps to address this issue by blocking 2921 pornographic websites since September 2018 to safeguard local internet users [5].

Encountering pornographic content can occur accidentally or intentionally, with adolescents often stumbling upon such material through mistyped website addresses, search engine results, or pop-up ads. The prevalence of this exposure varies across countries; for instance, around 84% of Australian adolescents aged 16 to 17 have encountered pornographic websites [6]. Exposure to pornography on social media is particularly concerning for children and adolescents due to their psychological development and hormonal changes [7]. It can impact adolescent health [8], leading to addiction, hindering learning and character development [9], [10], and have detrimental effects on mental health and academic performance, as well as perpetuating violence against women [11], [12]. Therefore, it is essential to engage in open discussion with children and adolescents about the dangers of pornography [13]. Comprehensive programs should be developed to help adolescents navigate the internet safely and enhance their media literacy skills. Accidental exposure to inappropriate content can also occur through clicking on pop-up ads while browsing the internet, highlighting the importance of proactive measures to protect children online. Some pop-up ads are scams or fraudulent and are becoming more common [14], [15]. Clicking on these ads can redirect users to other pages that generate money for scammers [16] and disrupt online experiences. They also contribute to slower website loading times and decreased network traffic [17], [18].

Installing and utilizing a home traffic control system provides an effective means of restricting and blocking access to certain websites and applications. Integrating such a system with smart home technology enables automatic and secure management of vehicle entry, enhancing convenience and safety on the premises [19]. The controller of the smart home system can be operated via a web browser and can manage devices manually or automatically [20]. While past research has explored smart home control systems, such as fuzzy logic-based fire notifications in homes [21] and kitchen automation systems for improved convenience, efficiency, and sustainability in food preparation, storage, and consumption [22], involving teenage users specifically necessitates incorporating web applications. It is essential to strike a balance between monitoring and respecting privacy when involving teenagers in the use of smart home technology. Open communication about the reasons behind these controls and involving teenagers in setting boundaries can foster a cooperative and understanding environment. Smart home technology should prioritize enhancing safety and responsibility over strict surveillance. Such systems have shown significant reductions in the frequency of pornography access and substantial improvements in parental monitoring of online activities [23]. Filters can be implemented through various methods, including software on personal computers or network infrastructure such as proxy servers, domain name system (DNS) servers, or firewalls that allow internet access [24].

This study introduces PiWall, a home traffic controller designed to assist parents in supervising and monitoring website access. The study investigates the response time for implementing PiWall into an existing network and provides insights into its effectiveness. The paper is organized as follows: section 2 outlines the method, section 3 presents the findings and evaluations, section 4 provides a comprehensive discussion of the results, and section 5 concludes the study with definitive insights.

2. METHOD

2.1. Hardware and software requirements

The main requirement for PiWall installation is compatibility with the Ubuntu operating system to run the DNS server. Given the widespread use of Raspberry Pi in enhancing security and privacy within local area network (LAN) [25]-[28], this study opts for the Raspberry Pi 3 model B, recognized as the latest and most powerful iteration among Raspberry Pi models [28], [29]. In terms of processing hardware, the model features a quad-core 1.2 GHz Broadcom BCM2837 64-bit CPU and 1 GB of RAM, meeting the minimum specifications for running the server. The mainboard includes BCM43438 wireless LAN and onboard Ethernet, tailored for network connectivity. Additionally, it boasts a Micro SD port with a minimum of 32 GB for loading the operating system and storing data. This system is built with the Raspbian operating system used for configuring, modifying, and testing commands for errors to ensure compliance with requirements before hardware installation. The Raspbian operating system is available for free download from Raspberry Pi’s official website.

2.2. System overview

PiWall is a home traffic controller with a primary focus on enhancing user safety during internet browsing. This study specifically delves into its implementation within private networks, particularly home networks. The objective is to facilitate parental control and monitoring of children's internet activities, thus mitigating risks associated with inappropriate searches and content as well as harmful website redirection. Instead of requiring constant parental supervision, PiWall automates the process of blocking unauthorized websites and monitoring network traffic.

Essentially, PiWall scrutinizes traffic based on IP addresses specified in the configuration file to ascertain network entry permissions. If an IP address is unauthorized, access is promptly denied. The implementation of PiWall follows a star topology, as depicted in Figure 1. This topology was chosen for its suitability in a home network LAN setup, where each node connects to a central connection point.

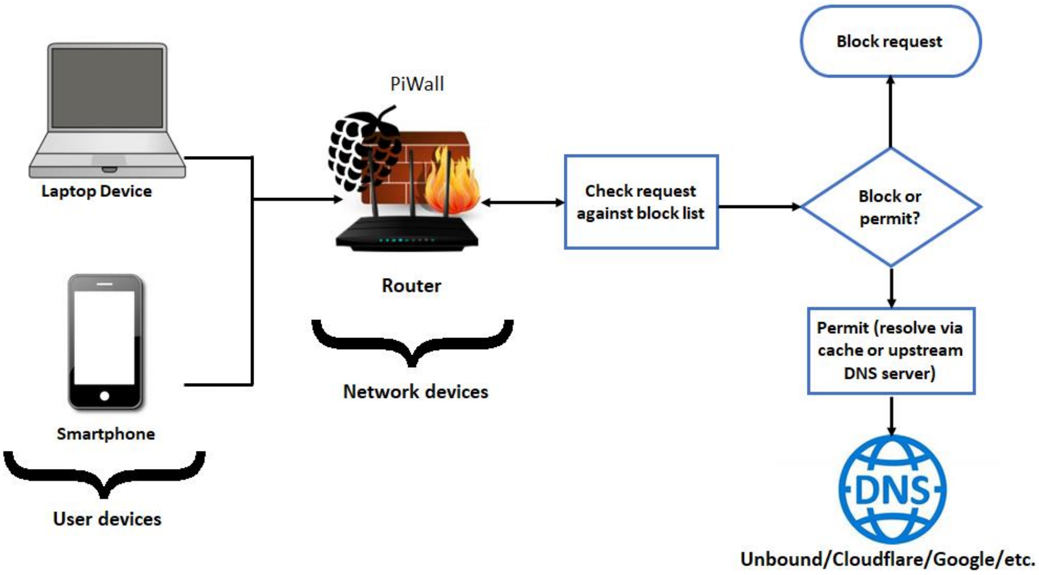

Laptop Device
Smartphone
User devices
PiWall
Router
Network devices
Check request against block list
Block or permit?
Block request
Permit (resolve via cache or upstream DNS server)
DNS
Unbound/Cloudflare/Google/etc.

Figure 1. The architecture of PiWall

The PiWall process begins when a user connects to the network. Upon connection, the user's query is directed to PiWall, for evaluation. If the query is not found on the blocklist, PiWall grants access to the server. The Raspberry Pi device is configured as a PiWall, and the server undergoes testing to ensure seamless connectivity and accessibility to prevent failures. Subsequently, PiWall is configured to filter out undesired website URLs and IP addresses according to user-defined criteria.

2.3. Implementation

The implementation phase is a critical stage where PiWall is brought to life and deployed, requiring meticulous consideration of all technical details. The implementation follows the architecture outlined in Figure 1. PiWall involves setting up and configuring the Raspberry Pi model B board. The process involved in the implementation stage is detailed below.

2.3.1. Configuration environment server in oracle virtualBox

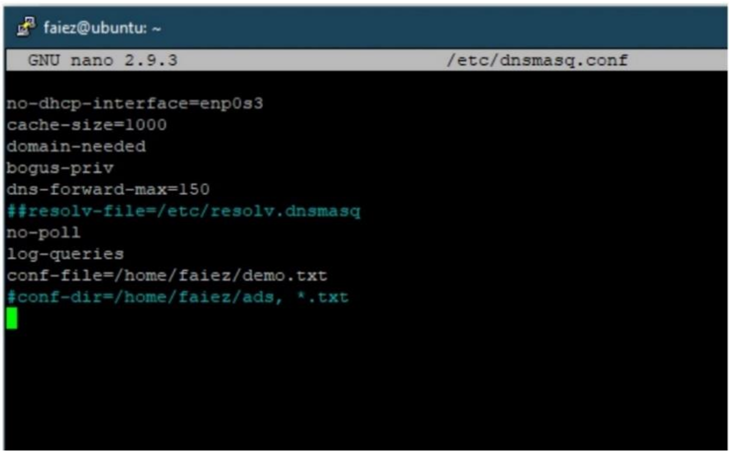
A virtual box is used to set up the servers. In this setup, the DNS acts as the internet's phone book, translating domain names such as 'google.com' into corresponding IP addresses when users input them into web browsers. Browsers then use these addresses to communicate with origin servers to access website data [30]. This study employs dnsmasq, a free software that provides DNS caching, dynamic host configuration protocol (DHCP) server, router advertisement capabilities, and network boot capabilities for small-scale computer networks. Its small size and lightweight nature make it suitable for routers and firewalls with limited resources.

2.3.2. List of blocked IP addresses

Addresses containing suspicious and malicious websites and advertisements are listed in [31], [32]. These references are commonly used in ad-blocking applications. These lists are updated daily to ensure no new addresses are overlooked. Daily updates are essential because publishers frequently create new addresses to promote their advertisements and increase the success of their attacks. This study requires dnsmasq query addresses, as it employs dnsmasq blocking [31]. The standard format for dnsmasq is also available in [32]. Subsequently, the addresses need to be modified to point to the address 0.0.0.0. In the dnsmasq format, hundreds of thousands of domain names need to be modified, a task facilitated using Microsoft Excel.

2.3.3. Server configuration

In this phase, dnsmasq is configured as a caching DNS server on RaspiOS (also known as Raspbian). Once the DNS server is installed, the configuration file must be edited to ensure it properly reads the listed addresses. Figure 2 illustrates an example of a DNS server configuration file, with the “conf-file=/home/faiez/demo.txt” line indicating the location of the text file containing the listed addresses.



```
  GNU nano 2.9.3                                /etc/dnsmasq.conf

no-dhcp-interface=enp0s3
cache-size=1000
domain-needed
bogus-priv
dns-forward-max=150
##resolv-file=/etc/resolv.dnsmasq
no-poll
log-queries
conf-file=/home/faiez/demo.txt
#conf-dir=/home/faiez/ads, *.txt
```

Figure 2. Raspberry Pi 3 model B board

The “no-dhcp-interface=eth0” line is used to turn off the DHCP server. Following this, the “ifconfig” or “ip addr” command is executed to verify that the ethernet adapter is named “eth0”. To reduce latency for subsequent lookups, the DNS server may cache requests, with the "cache-size=1000" setting limiting the cache to 1000 items. The “dns-forward-max=150” line restricts the number of simultaneous DNS requests a network can perform. Normally, RaspiOS looks up DNS entries from the “resolv” file at “/etc/resolv.conf” to instruct dnsmasq to use a separate file containing the “upstream” DNS servers, as indicated by the “resolv- file=/etc/resolv.dnsmasq” line. Enabling log queries is an optional setting. By using the command "DNS lookups," users can benefit from seeing the reply and query from their end.

2.3.4. PiWall’s IP address

The PiWall’s IP address can be easily determined using Fing, a mobile application developed for discovering devices connected to the same network. Fing provides a comprehensive list of all devices within the network, along with their corresponding IP addresses, facilitating seamless configuration and management of the PiWall.

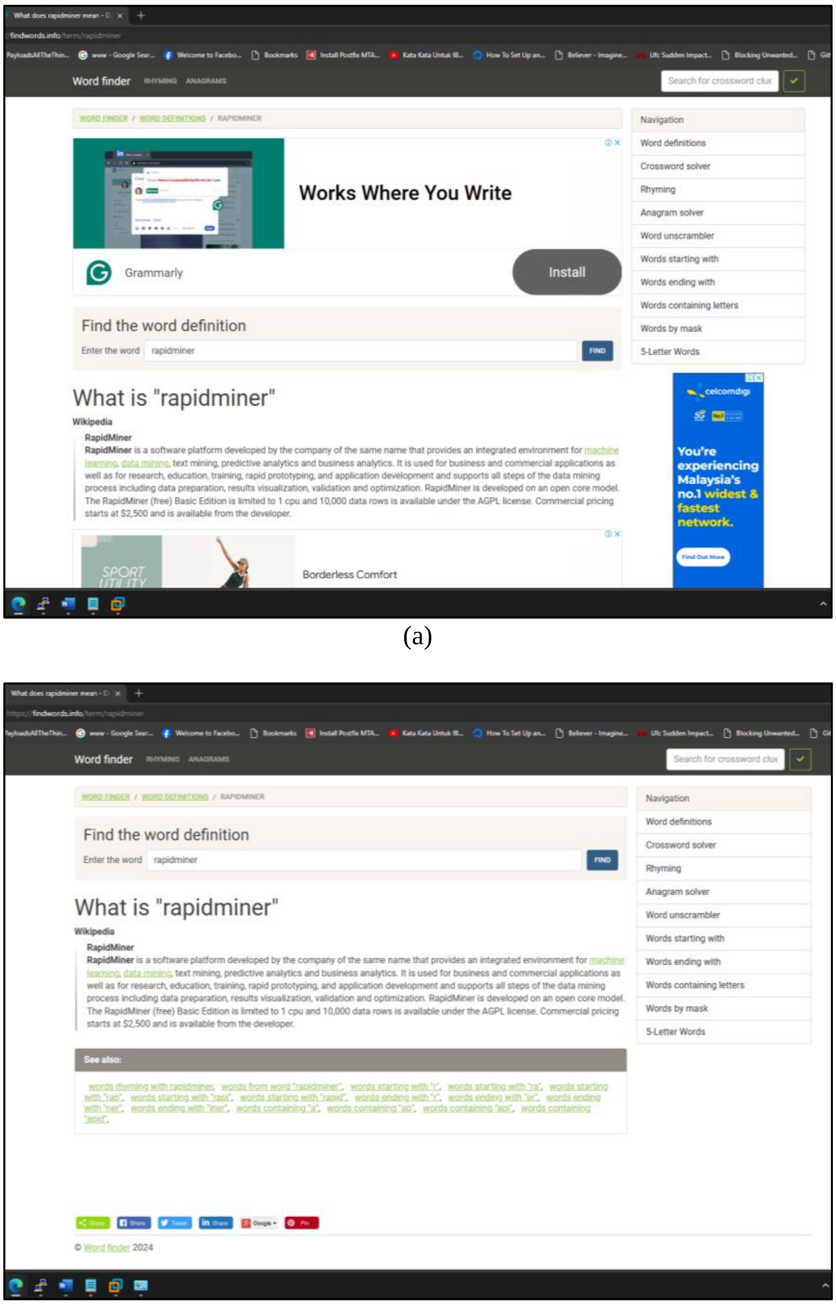
3. RESULTS AND DISCUSSION

3.1. Testing

The PiWall underwent testing in two scenarios: on a personal computer and on a smartphone. The main objective was to assess PiWall's effectiveness in blocking pop-up advertisements on specific websites. Figures 3(a) and (b) display a website on a personal computer with and without PiWall, respectively. Figure 3(a) shows the original website with pop-up ads, while Figure 3(b) illustrates PiWall’s success in blocking these advertisements. Similarly, Figures 4(a) and (b) display the testing on a mobile phone. Figure 4(a) displays the original website, while Figure 4(b) demonstrates PiWall’s success in blocking these pop-up advertisements. Overall, these findings confirm the successful accomplishment of the study’s objective.

3.2. Response time

To test the response time of websites with and without PiWall, measurements were taken during two sessions: from 8:00 a.m. to 9:00 a.m. and from 8:00 p.m. to 9:00 p.m. These sessions were selected for their potential impact on PiWall's response due to varying user numbers. As internet speed increases, website loading becomes almost instantaneous due to the millisecond response time of the DNS server. PiWall's response time to filtered websites has minimal impact on user loading time. The negligible difference in response time with and without PiWall is detailed in Table 1. It's important to note that the speed of the internet connection mainly influences this factor. Therefore, implementing PiWall as a home traffic controller is able to speed up the response time. This indicates that the use of PiWall does not significantly affect user loading time.



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Word finder RHYMING ANAGRAMS
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(a)

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See also:

words rhyming with rapidminer, words from word "rapidminer", words starting with "r", words starting with "ra", words starting with "rap", words starting with "rapi", words starting with "rapid", words ending with "r", words ending with "er", words ending with "ner", words ending with "iner", words containing "a", words containing "ap", words containing "api", words containing "apid",

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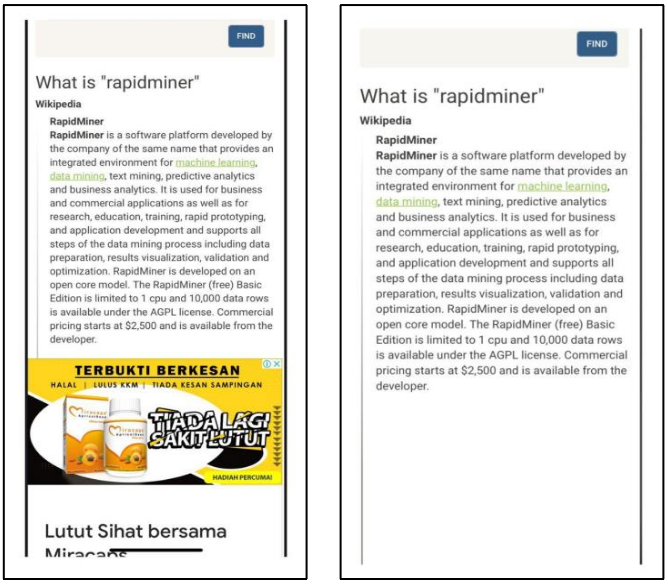
(b)

Figure 3. The testing of PiWall on the website display on; (a) a personal computer without PiWall and (b) a personal computer with PiWall



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(b)

Figure 4. The testing of PiWall on the mobile phone interface website display on; (a) a mobile phone without PiWall and (b) a mobile phone with PiWall

Table 1. Response time of PiWall filtered traffic

Website	Time/ms			
	8.00–9.00 am		8.00–9.00 pm	
	Without PiWall	With PiWall	Without PiWall	With PiWall
www.facebook.com	0.025	0.015	0.055	0.013
www.youtube.com	0.022	0.014	0.041	0.016
www.instagram.com	0.039	0.016	0.044	0.021
twitter.com	0.030	0.016	0.079	0.012
shoppee.com.my	0.018	0.013	0.057	0.017
Average	0.0268	0.0148	0.0552	0.0158

3.3. Discussion

The development of PiWall using Raspberry Pi has successfully achieved its main objective of providing a secure online environment, especially for children. Setting up PiWall involves manual configuration, including the installation of PuTTy for access. Notably, PiWall does not require complex infrastructure, making it suitable for home networks. With PiWall, traffic management on the home network becomes automated, provided it has access to the server's IP address or URL and requires filtering for its information. Testing the response time with PiWall reveals a noticeable reduction in traffic delays when accessing websites, all without compromising data transfer speed or latency.

One of PiWall's notable advantages is its empowerment of users, especially parents, to take charge of their network by integrating it with their home router. This allows users to selectively block websites, without any limitations on the volume of filtered traffic. Therefore, parents can monitor their children's online activities, ensuring they stay away from inappropriate content and browse safely without malware risks. However, PiWall's dependency on the home router may lead to failures if the network experiences issues. Additionally, certain websites, especially those relying heavily on ads, may cease to function as PiWall filters them out.

PiWall shares similar objectives with existing parental control solutions such as Safe Eyes, KidsWatch, Net Nanny, and Kidsafe [31]. Safe Eyes includes time limits, tracks browsing history, and helps parents monitor online activities. KidsWatch tracks and blocks contents from the owner's computer and manages children's screen time. Net Nanny can dynamically filter and scan pages to determine suitability for children. Kidsafe enables parents to control website access. These tools are known as parental control apps and services. Meanwhile, PiWall operates differently by interfacing directly with the router. Therefore, the children are unaware that the website has already been filtered. Further investigation is needed to assess the PiWall's effectiveness as a router management interface and its potential as an alternative method for creating a safer online environment for children.

4. CONCLUSION

This study introduces PiWall as a practical solution for parents seeking to establish a safer online environment for their children. Built using a Raspberry Pi 3 model B, PiWall functions as a traffic controller within the home networks. Its setup involves manual configuration, including the installation of PuTTy for external access. PiWall effectively manages network traffic by filtering and blocking data based on user-defined parameters, accessible via the server's IP or URL. It offers user-friendly controls, granting users full authority over their home network traffic.

Future research endeavors could focus on enhancing PiWall's functionality by enabling direct URL restriction and safe-listing via a mobile platform. Such advancements would strengthen online safety measures for children and adolescents, enabling the restriction of access to inappropriate apps or online services, and fostering trust and communication between parents and children. Furthermore, PiWall is poised to complement existing smart home security systems, promising further enhancements in digital security and parental control capabilities.

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