Sudan University of Science and Technology

College of Engineering

Electronics Engineering Department

Design and Implementation of a Raspberry Pi Wi-Fi Extender

A Research Submitted in Partial fulfillment for the Requirements of the Degree of B.TECH (Honors) in Electronics Engineering

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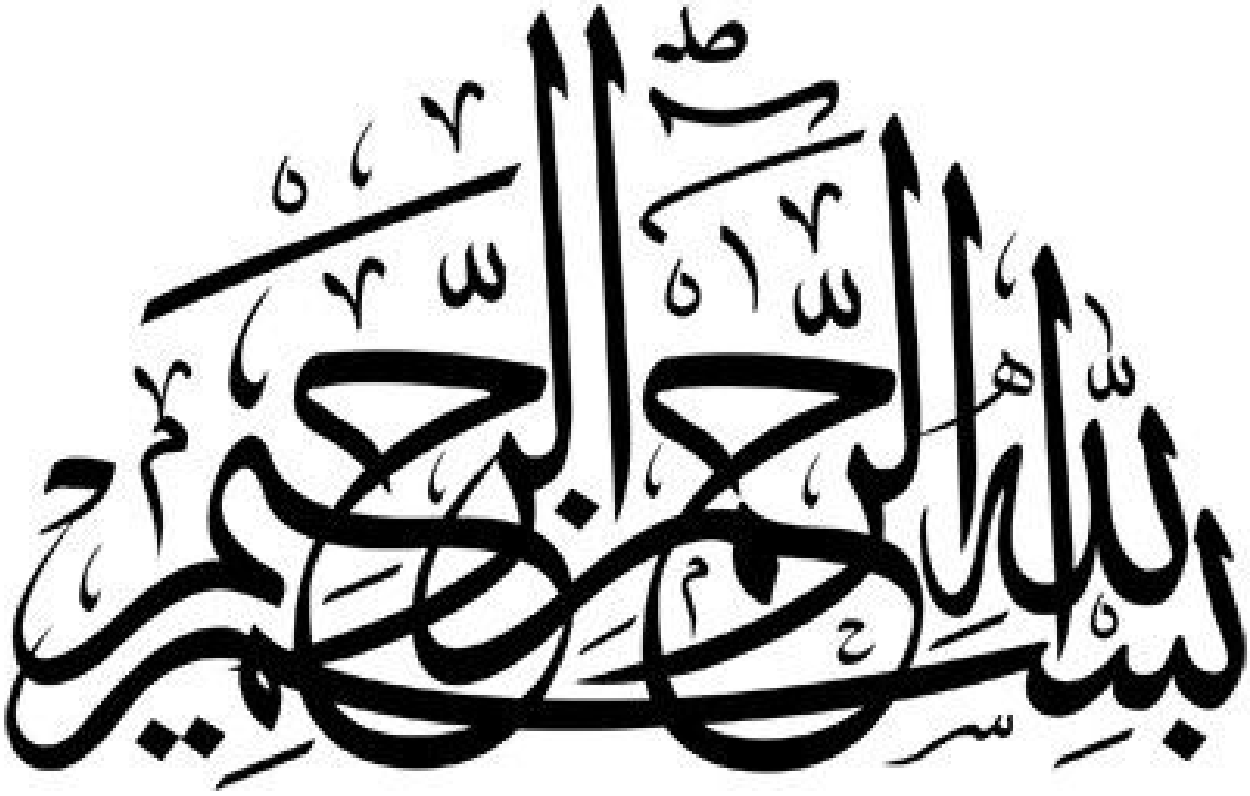
بسم الله الرحمن الرحيم

الآيـــــــــــــــة

قال تعالى:

﴿ يَـٰٓأَيُّهَا ٱلَّذِينَ ءَامَنُوٓاْ إِذَا قِيلَ لَكُمۡ تَفَسَّحُواْ فِي ٱلۡمَجَـٰلِسِ فَٱفۡسَحُواْ يَفۡسَحِ ٱللَّهُ لَكُمۡۖ وَإِذَا قِيلَ ٱنشُزُواْ فَٱنشُزُواْ يَرۡفَعِ ٱللَّهُ ٱلَّذِينَ ءَامَنُواْ مِنكُمۡ وَٱلَّذِينَ أُوتُواْ ٱلۡعِلۡمَ دَرَجَـٰتٖۚ وَٱللَّهُ بِمَا تَعۡمَلُونَ خَبِيرٞ ﴾

صدق الله العظيم

[المُجَادلَةِ: ١١]

Dedication

إلهى لا يطيب الليل إلا بشكرك ولا يطيب النهار إلا بطاعتك .. ولا تطيب اللحظات إلا بذكرك .. ولا تطيب الآخرة إلا بعفوك .. ولا تطيب الجنة إلا برؤيتك

"الله ﷻ"

وأَحسنُ منكَ لم ترَ قطُّ عيني وَأجْمَلُ مِنْكَ لَمْ تَلِدِ النّسَاءُ

خلقتَ مبرأً منْ كلّ عـيبٍ كأنكَ قدْ خلقتَ كما تشاءُ

"سيدنا محمد ﷺ"

إلى قدوتنا الأولى ونبراسنا إلى من أخذوا بيدنا .. إلى من أعطونا بلا حدود .. إلى سندنا في هذه الدنيا .. إلى من كلَّلهم الله بالوقار .. إلى من علمونا العطاء دون انتظار .. إلى من نحمل اسمهم بكل افتخار

"الآبـــاء"

إلى من جعل الله عز وجل الجنة تحت أقدامهن .. إلى القلب الحاني .. إلى الظل الداني .. إلى من كان دعاؤهن سر نجاحانا .. وتيسير أمورنا

"الامهـــات"

إلى من لا غنى عنهم .. إلى من تزدان بهم الدنيا

"إخواننا الأعزاء"

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إلى الشموع التي تحترق لتنير لنا الطريق .. إلى المصابيح المنيرة .. إلى النجوم التي تتلألأ وتتألق دائماً .. إلى كل من علمنا حرفاً

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Abstract

In today's modern life, wireless access to the internet is in many cases a necessity .The purpose of the overall project was to design and build a smart mobile repeater. And how to create a portable Access Point with Wi-Fi repeater capabilities. The repeater will navigate an environment in search of the signal strength from a distant router. After it sufficiently acquires a high level signal, it will act as a relay so that other computers may connect to the router through it.

المستخلص

يعد الوصول الى اللاسلكى فى الحياة العصرية اليوم أمرا ضروريا فى كثير من الحالات..

كان الغرض من المشروع ككل هو تصميم وبناء مكرر محمول ذكي وكيفية إنشاء نقطة وصول محمولة بإمكانيات مكرر Wi-Fi سوف يتنقل المكرر في بيئة بحثًا عن قوة الإشارة من جهاز توجيه بعيد. بعد حصوله على إشارة عالية المستوى بشكل كافٍ ، سيعمل كمرحل حتى تتمكن أجهزة الكمبيوتر الأخرى من الاتصال بالموجه من خلاله.

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List of Abbreviations

1G	**First Generation**
2G	**Second Generation**
3G	**Third Generation**
AP	**Access Point**
ARM	**Advanced RISC Machine**
AVR	**Alf and Vegard's RISC Processor**
CDPD	**Cellular Digital Packet Data**
CMC	**Computer Mediated Communication**
CPU	**Central Processing Unit**
DIP	**Dual Inline Package**
DHCP	**Dynamic Host Configuration Protocol**
DNS	**Domain Name System**
FDR	**Full Duplex Relays**
GPS	**Global Positioning System**
GPU	**Graphics Processing Unit**
HD	**Half Duplex**
HDMI	**High-Definition Multimedia Interface**
HTTP	**Hypertext Transfer Protocol**
IC	**Integrated Circuit**
IEEE	**Institute of Electrical and Electronics Engineers**
IP	**Internet Protocol**
IoT	**Internet-of-Things**

IR	**Infra-Red**
ISP	**Internet Service Provider**
ISDN	**Integrated Services Digital Network**
Li Fi	**Light Fidelity**
NAT	**Network Address Translation**
MAC	**Media Access Control**
MSP	**Mixed Signal Processor**
ML	**Machine Learning**
OS	**Operating System**
PAN	**Personal Area Network**
PC	**Personal Computer**
PDAs	**Personal Digital Assistant**
PIC	**Peripheral Interface Controller**
PHY	**Physical Layer**
PING	**Packet Internet Grouper**
RAM	**Random Access Memory**
RISC	**Reduced Instruction Set Computer**
ROM	**Read Only Memory**
RSSI	**Received Signal Strength Indicator**
SD	**Secure Digital**
SDN	**Software-Defined Networking**
SI	**Self-Interference**
SINR	**Signal to Interference Plus Noise Ratio**
SLIP	**Serial Line Internet Protocol**

STA	**Station**
SSH	**Secure Shell**
UDP	**User Datagram Protocol**
USD	**Universal Serial Bus**
Wi-Fi	**Wireless Fidelity**
WEP	**Wired Equivalent Privacy**
WLANs	**Wireless Local Area Networks**
WMANs	**Wireless Metropolitan Area Networks**
WPA	**Wi-Fi Protected Access**
WPA2	**Wi-Fi Protected Access II**
WPANs	**Wireless Personal Area Networks**
WWANs	**Wireless Wide Area Networks**

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Chapter One

Introduction

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Introduction

1.1 Overview

The wireless access point connects mobile phones or computers in places that do not reach the Internet signal or are weak instead of using wires and cables. In this project we will look for how to design a wireless access point that helps to distribute the Internet and expand the signal range and support the wireless Internet at home or Business offices or cafes [1].

An extender (Wi-Fi range extender) is a device that takes the radio signal of an access point (AP) of Wi-Fi and rebroadcasts it to create a new group of Extended Service Set Identifier. It is useful for extending the range of an AP to where the wired network cannot reach since installation of AP needs both commercial power supply and the wired network line to serve as the last mile of the Internet. Based on our preliminary experiments, although the extender itself offers slower connection compared to the original AP, it could offer more stable connection at hard to reach places. One of the significant factors that affect the internet speed is where the extender is set. Therefore, we investigated extender usage based on the correlation between distance, Received Signal Strength Indicator (RSSI), and the speed of the connection. Through our control experiment for the extender usage, we found that just placing an extender might degrade the performance compared to the direct association to an AP in the service area in the AP. We also found that the optimal position of the extender was not centered equidistant from the AP and the client, but rather shifted toward the AP. [2]

Next-generation Home Wi-Fi networks have to step forward in terms of performance. New applications such as on-line games, virtual reality or high quality video contents will further demand higher throughput levels, as well as low latency. Beyond physical (PHY) and medium access control (MAC) improvements, deploying multiple access points (APs) in a given area may significantly contribute to achieve those performance goals by simply improving average coverage and data rates. However, it opens a new challenge: to determine the best AP for each given station (STA). This article studies the achievable performance gains of using secondary APs, also called Extenders, in Home Wi-Fi networks in terms of throughput and delay. To do that, we introduce a centralized, easily implementable channel load aware selection mechanism for Wi-Fi networks that takes full advantage of IEEE 802.11k/v capabilities to collect at a from STAs, and distribute association decisions accordingly. These decisions are completely computed in the AP (or, alternatively, in an external network controller) based on an AP selection decision metric that, in addition to RSSI, also takes into account the load of both access and backhaul wireless links for each potential STA-AP/Extender connection. Performance evaluation of the proposed channel load aware AP and Extender selection mechanism has been first conducted in a purpose-built simulator, resulting in an overall improvement of the main analyzed metrics (throughput and delay) and the ability to serve, at least, 35% more traffic while keeping the network uncongested when compared to the traditional RSSI-based Wi-Fi association. This trend was confirmed when the channel load aware mechanism was tested in a real deployment, where STAs were associated to the indicated AP/Extender and total throughput was increased by 77.12%.[3]

1.2 Problem Statement

There are many limitations in current Wi-Fi connection, the limited range of the Wi-Fi signal and the number of its users.

1.3 Proposed Solution

Increase the range of the Wi-Fi signal and the number of its users. Possible applications include home, business offices, cafes, airports, public stations and train Stations.

1.4 Methodology

The project relies on research and study in the field of wireless communication and programming, and data collection from references, websites and scientific papers. This project contains two parts, the practical part is the design of the circuit consisting of the microcomputer, the power source, and the Wi-Fi module, and the programmatic part.

In terms of software, Raspberry Pi OS Lite will be the used operating system for this Project

1.5 Objectives

The goal of this project is to solve the coverage problem by using a Raspberry Pi that acts as an expansion point and then transmits this data locally as a router.

1.6 Thesis Layout

Chapter Two provides background and literature review. Chapter Three explains the functional modules and system design. Chapter Four presents the results and the calibration. Chapter Five provides conclusions and recommendations.

Chapter Two

Literature Review

Chapter Two

Literature Review

2.1 Overview

Wi-Fi has been widely adopted in homes, offices, and public hot spots. One challenge that often arises is the range of the network, because Wi-Fi operates under strict transmission power limits, such that nodes on the edge of the network often get degraded or even interrupted service. This problem can be alleviated to a degree by range extenders such as [1], which extend the range of the network by capturing and rebroadcasting the packets .However, it is known that the range extenders may reduce network speed because the node maybe close to the Access Point (AP) and can receive from the AP directly such that rebroadcasting the packets is unnecessary.

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This article studies the achievable performance gains of using secondary APs, also called Extenders, in Home Wi-Fi networks in terms of throughput and delay. To do that, we introduce a centralized, easily implementable channel load aware selection mechanism for Wi-Fi networks that takes full advantage of IEEE 802.11k/v capabilities to collect data from STAs, and distribute association decisions

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2.2 Wireless Networks

Wireless Communication is a method of transmitting information from one point to other, without using any connection like wires, cables or any physical medium. Generally, in a communication system, information is transmitted from transmitter to receiver that are placed over a limited distance. With the help of Wireless Communication, the transmitter and receiver can be placed anywhere between few meters (like a T.V. Remote Control) to few thousand kilometres (Satellite Communication).

A wireless network enables people to communicate and access applications and information without wires. This provides freedom of movement and the ability to extend applications to different parts of a building, city, or nearly anywhere in the world. Wireless networks allow people to interact with e-mail or browse the Internet from a location that they prefer.

Many types of wireless communication systems exist, but a distinguishing attribute of a wireless network is that communication takes place between computer devices. These devices include personal digital assistants (PDAs), laptops, personal computers (PCs), servers, and printers. Computer devices have processors, memory, and a means of interfacing with a particular type of network. Traditional cell phones don't fall within the definition of a computer device; however, newer phones and even audio headsets are beginning to incorporate computing power and network adapters. Eventually, most electronics will offer wireless network connections.

As with networks based on wire, or optical fiber, wireless networks convey information between computer devices. The information can take the form of e-mail messages, web pages, and data base records, streaming video or voice. In most cases, wireless networks transfer data, such as e-mail messages and files, but advancements in the performance of wireless networks is enabling support for video and voice communications as well.

Wireless communication is the transfer of information between two or more points that do not use an electrical conductor as a medium for the transfer. The most common wireless technologies use radio waves. With radio waves, intended distances can be short, such as a few meters for Bluetooth or as far as millions of kilometers for deep-space radio communications. It encompasses various types of fixed, mobile, and portable applications, including two-way radios, cellular telephones, personal digital assistants, and wireless networking. Other examples of applications of radio wireless technology include GPS units, garage door openers, wireless computer mouse, keyboards and headsets, headphones, radio receivers, satellite television, broadcast television and cordless telephones. Somewhat less common methods of achieving wireless communications include the use of other

electromagnetic wireless technologies, such as light, magnetic, or electric fields or the use of sound.

Although it has history of more than a century, wireless transmission has found widespread use in communication systems only in the last 15-20 years. Currently the field of wireless communications is one of the fastest growing segments of the telecommunications industry. Wireless communication systems, such as cellular, cordless and satellite phones as well wireless local area networks (WLANS) have found widespread use and have become an essential tool in many people's every-day life, both professional and personal. To in insight into the wireless market momentum, it is sufficient to mention that it is expected that the number of worldwide wireless subscribers in the years to come will be well over the number of wireline subscribers. This popularity of wireless communication systems is due to its advantages compared to wireline systems. The most important of these advantages are mobility and cost savings. Networkswireless networks are also useful in reducing networking costs in several cases. This stems from the fact that an overall installation of a wireless network requires significantly less cabling than a wired one, or no cabling at all. This fact can be extremely useful: Network deployment in difficult to wire areas. Such is the case for cable placement in rivers, oceans, etc. Another. Example of this situation is the asbestos found in old buildings. Inhalation of asbestos particles is very dangerous and thus either special precaution mustbe taken when deploying cables or the asbestos must be removed. Unfortunately, both solutions increase the total cost of cable deployment. Prohibition of cable deployment. This is the situation in network deployment in several cases, such as historical buildings.

Deployment of a temporary network. In this case, cable deployment does not make sense, since the network will be used for a short time period. Deployment of a

wireless solution, such as a WLAN, is an extremely cost-efficient solution for the scenarios described above. Furthermore, deployment of a wireless network takes significantly less time compared to the deployment of a wired one. The reason is the same: no cable is installed. In this introductory chapter we briefly overview the evolution of wireless networks, from the early days pioneers like Samuel Morse and Guglie Marconi to the big family of today's wireless communications systems. We then proceed to briefly highlight the major technical challenges in implementing wireless networks and conclude with an overview of the subjects described in the book.

Wireless transmission dates back into the history of mankind. Even in ancient times, people used primitive communication systems, which can be categorized as wireless. Examples are smoke signals, flashing mirrors, flags, fires, etc. It is reported that the ancient Greeks utilized a communication system comprising a collection of observation stations on hilltops, with each station visible from its neighboring one. Upon receiving a message from a neighboring station, the station personnel repeated the message in order to relay it to the next neighboring station. Using this system messages were exchanged between pairs of stations far apart from one another. Such systems were also employed by other civilizations. However, it is more logical to assume that the origin of wireless networks, as we under- stand them today, starts with the first radio transmission. This took place in 1895, a few years after another major breakthrough: the invention of the telephone. In this year, Guglie Marconi demonstrated the first radio-based wireless transmission between the Isle of Wight and a tugboat 18 years later. Marconi successfully transmitted a radio signal across the Atlantic Ocean from Comwall to Newfoundland and in 1902 the first bidirectional communication across the Atlantic Ocean was established. Over the years that followed Marconi's pioneering activities, radio-based transmission continued to evolve. The origins of radio-based

telephony date back to 1915. When the first radio-based conversation established between ships.

2.3 Types of Wireless Networks

2.3.1 Wireless Local Area Networks (WLANS)

WLANS allow users in a local area, such as a university campus or library, to form a network or gain access to the internet. A temporary network can be formed by a small number of users without the need of an access point; given that they do not need access to network resources.

Wi-Fi is a WLAN technology used to connect computers, tablets, smartphones and other devices to the internet. A Wi-Fi network is simply an internet connection that's shared with multiple devices in home or business via a wireless router. The router is connected directly to the internet modem and acts as a hub to broadcast the internet signal to all your Wi-Fi enabled devices this gives the flexibility to stay connected to the internet as long as it's in the network coverage area.

2.3.2 Wireless Personal Area Networks (WPANS)

The two current technologies for wireless personal area networks are Infra-Red (IR) and Bluetooth (IEEE 802.15). These will allow the connectivity of personal devices within an area of about 30 feet. However, IR requires a direct line of site and the range is less.

2.3.3 Wireless Metropolitan Area Networks (WMANS)

This technology allows the connection of multiple networks in a metropolitan area such as different buildings in a city, which can be an alternative or backup to laying copper or fiber cabling.

2.3.4 Wireless Wide Area Networks (WWANS)

These types of networks can be maintained over large areas, such as cities or countries, via multiple satellite systems or antenna sites looked after by an ISP. These types of systems are referred to as 2G (2nd Generation) systems.

Table 2.1: Comparison of Wireless Network Types

Type	Coverage	Performance	Standards	Applications
WPAN	Within reach of a person	Moderate	Wireless PAN Within reach of a person Moderate Bluetooth, IEEE 802.15, and IrDA Cable replacement for peripherals	Cable replacement for peripherals
WLAN	Within a building or campus	High	IEEE 802.11, Wi-Fi, and HiperLAN	Mobile extension of wired networks
WMAN	Within a city	High	Proprietary, IEEE 802.16, and WIMAX	Fixed wireless between homes and businesses and the Internet
WWAN	Worldwide	Low	CDPD and Cellular 2G, 2.5G, and 3G	Mobile access to the Internet from outdoor areas

2.4 Wi-Fi Extenders

2.4.1 L2 Relay Extender

The study in [] proposed L2Relay, a novel packet relay protocol for Wi-Fi networks that can improve the performance and extend the range of the network. A device running L2Relay is referred to as a relayer, which overhears the packet

transmissions and retransmits a packet on behalf of the Access Point (AP) or the node if no ACK is overheard. One important feature of L2Relay is its ubiquitous compatibility, i.e., it is compatible with any Wi-Fi devices, such that one or multiple relayers can be installed in any network easily without any modification to the AP or the nodes .L2Relay is a layer-2 solution that exploits many layer 2 functional it is such as carrier sense. It encompasses unique solutions to link quality measurement, rate adaptation, and relayer selection. We implement L2Relay in the Open FWWF platform and compare it against the baseline network without a relayer as well as a popular commercial Wi-Fi range extender. Our results show that L2Relay achieves overall better performance than both compared schemes.

2.4.2 Channel load AP

In presence of multiple AP/Extenders, a new challenge appears: how to determine the best AP/Extender for each given STA. According to the default Wi-Fi AP selection mechanism, an STA that receives beacons from several AP/Extenders will initiate the association process with the AP/Extender with the highest received signal strength indicator (RSSI) value. Though simple and easy to implement, this mechanism omits any influence of traffic load and, consequently, can lead to network congestion and low throughput in scenarios with a high number of STAs [7].

Many research activities have already widely tackled the APs election process in an area commonly referred to as load balancing, whose goal is to distribute more efficiently STAs among the available AP/Extenders in a WLAN. Although multiple effective strategies have been proposed in the literature, most of them lack the prospect of real implementation, as they require changes in the existing IEEE 802.11 standards and/or in STAs' wireless cards.

2.4.3 Full Duplex Relays

An existing Wi-Fi network is a common solution when wireless coverage extension is required in the absence of a connection to the backbone network. Half-duplex (HD) Wi-Fi relays employ two different frequencies, time slots, or orthogonal spreading codes to prevent the transmitted signal from interfering with its own receiver. In contrast full-duplex relays (FDR) utilize wireless resources more efficiently by transmitting and receiving simultaneously on the same frequency band, creating the potential of doubling the system throughput, when compared to their Half Duplex (HD) counter parts [1].Although FDR has higher transmission efficiency, it suffers from Self Interference (SI) since the transmitted signal by the FDR is received as an in-band blocker by its own receiver. The SI signal results in system instability, and poor signal to interference plus noise ratio (SINR) of the signal that is intended to be relayed [2]. In order to use a FDR for higher efficiency, SI must be coherently cancelled in order to provide stability and a satisfactory level of SINR of the received signal, before amplifying and forwarding it. To achieve sufficient SI suppression FDR relies on cancellation across multiple domains (spatial, analog and digital cancellation.

The inefficiency of the RSSI-based AP selection mechanism has motivated the emergence of alternative methods that take into account other metrics than solely the RSSI .The most representative examples are classified according to three different criteria: the AP selection mode, the architecture employed, and the selected decision metric.

In the active AP selection, the STA considers all potential Aps and gathers information regarding one or more performance metrics to make a decision. In [15], the STA scans for all available APs, quickly associates to each, and even runs a set of tests to estimate Internet connection quality. On the contrary

The passive APs election is based on the information that the STA directly extracts from beacon frames or de duce's from their physical features, such as the experienced delay in [3]. Lastly, in the hybrid AP selection, the network makes use of the information shared by the STA to give advice on the best possible potential AP.

In [9], for instance, clients automatically submit reports on the Aps that they use with regard to estimated backhaul capacity, ports blocked, and connectivity failures. Architecture: This category splits the different mechanisms into decentralized and centralized. Decentralized mechanisms are those in which the STA selects its AP based on its available information (even combining cross-layer information, as in [8]). On the other hand, centralized mechanisms imply a certain degree of coordination between different APs thanks to a central entity (that may well be an SDN controller, as in [13] intended to balance overall network load. Decision metric: The AP selection metric can be determined by a single parameter (e.g., AP load in [12] or a weighted combination of some of them (e.g. Throughput and channel occupancy rate in [3]. Apart from RSSI, there exists a vast quantity of available magnitudes for this purpose; however, the most common ones in the reviewed literature are throughput, load, and delay. Furthermore, there exist some novel approaches that have introduced machine learning (ML) techniques into the AP selection process. For instance, in [14] a decentralized cognitive engine based on a neural network trained on past link conditions and throughput performance drives the AP selection process.

Likewise, a decentralized approach based on the exploration-exploitation trade-off from Reinforcement Learning algorithms is used in [14], [12]. Under that system, STAs learn the network conditions and associate to the AP that maximizes their throughput. In consequence, STAs stop its exploration, which is only resumed

when there is a change in network's topology. Another decentralized ML-based approach is proposed in [13], where the AP selection mechanism is formulated as a non-cooperative game in which each STA tries to maximize its throughput. Then, an adaptive algorithm based on no-regret learning makes the system converge to an equilibrium state.

2.4.4 AP/Extender Selection Mechanisms

A review of the currently existing AP/Extender selection mechanisms along with the description of the Wi-Fi scanning modes that enable them are explained as follows.

Wi-Fi scanning modes in the IEEE 802.11 standard defines two different scanning modes: passive and active [16]. In passive scanning, for each available radio channel, the STA listens to beacons sent by APs for a dwell time .As be a cons are usually broadcast by the AP every 100 ms, channel dwell time is typically set to 100-200 ms to guarantee beacon reception [17], [18]. In active scanning, the STA starts broadcasting a probe request frame on one channel and sets a probe timer. If no probe response is received before the probe timer reaches Min Channel Time, the STA assumes that no AP is working in that channel and scans another channel alternatively.

Otherwise, if the STA does receive a probe response, it will further wait for responses from other working APs until Max Channel Time is reached by the probe timer. Min Channel Time and Max Channel Time values are vendor-specific, as they are not specified by the IEEE 802.11 standard. Indeed, using optimum values to minimize the active scanning phase have attracted research attention. In [18], for instance, the author sets these values as low as 6-7 ms and 10-15 ms, respectively. Since passive scanning always has longer latency than active

scanning, wireless cards tend to use the latter to rapidly find nearby APs [12]. However, active scanning has three disadvantages:

a) it consumes significant more energy than passive scanning,
b) it is unable to discover networks that do not broadcast their SSID, and
c) it may result in shorter scan ranges because of the lower power level of STAs.

It is also usual that mobile STAs periodically perform active background scanning to discover available APs, and then accelerate an eventual roaming operation [11]. In this case, the STA (already associated to an AP and exchanging data) goes periodically off-channel and sends probe requests across other channels. On the other hand, the active on-roam scanning only occurs after the STA determines a roam is necessary.

The default Wi-Fi AP selection mechanism regardless the scanning mode used by an STA to complete its own list of available APs, and the final purpose of this scanning (i.e., the initial association after the STA start-up or a roaming operation), the STA executes the default Wi-Fi AP selection mechanism (from now on also named RSSI-based) by choosing the AP of the previous list with the strongest RSSI. This is the approach followed by common APs and available multi-AP commercial solutions, like Google Wi-Fi [12] or Links develop [13], which are especially indicated for homes with coverage problems and few users. In addition, these two solutions also integrate the IEEE 802.11k/v amendments but only to provide faster and seamless roaming. The strongest RSSI might indicate the best channel condition between the STA and the AP. However, only relying on this criteria is not always the best choice, as it can lead to imbalanced loads between APs, inefficient rate selection, and selection of APs with poor throughput.

2.5Computer and Microcomputer

• A Microcomputer is a type of computers is an integrated system of computer components capable of a wide variety of applications (general purposes).

A microcomputer typically contains:

- Microprocessor at the heart of the system
- Data storage ICs RAM, ROM
- Mass storage elements External Drives, Hard Drives, …
- Standard I/O devices monitor, keyboard, mouse, printer,…

On the other hand, advantages of microcomputers, (as opposed to microcontrollers) are that they have (are): – higher computing capabilities – General purposes and reprogrammable – More user friendly: • Have Operating systems • Easier in Inputs and outputs • More suitable for user needs and applications

2.6 Raspberry Pi

Raspberry Pi is a series of small, single-board computers developed to teach computer science basics to school students and other people in low-income countries. It became a popular and easy to experiment tool to develop school projects, hardware programming, robotics, basic automated machines, circuits, etc. The Uses of Raspberry Pi is a small, quite affordable, and very much capable hardware device called a credit card size computer. A Raspberry Pi has the following types

- Raspberry Pi 1 model B
- Raspberry Pi 1 model A
- Raspberry Pi 1 model B+
- Raspberry Pi 1model A+

- Raspberry Pi Zero
- Raspberry Pi 2
- Raspberry Pi 3 model B
- Raspberry Pi Zero W

2.6.1 Raspberry Pi 3 Model B

The Raspberry Pi3 B is a single-board computer that can connect to a TV and keyboard. It has Wi-Fi and Bluetooth connectivity. It boots from the micro-SD card and runs on Linux OS or Windows 10 IoT. It boots from the micro-SD card and runs on Linux OS or Windows 10 IoT. It is supplied without housing, power supply, keyboard, screen and mouse in order to reduce the cost and promote the use of recovery equipment.

Version 3 is based on a quad-core 64-bit ARM Cortex-A53 processor at 1.2 GHz (about 10x faster than the Pi1 and 50% more capable than the Pi2 model) and has 1 GB of RAM memory.

The Raspberry Pi3 B model has Wi-Fi and Bluetooth connectivity, has 4 USB ports, a micro-SD port, a 40-pin I/O connector and an HDMI port. Version 3 is physically identical to the Pi 2 version making it compatible with the cases and other accessories of the Pi 2 version.

This board is based on an ARM processor and allows the running of the GNU/Linux/Windows 10 IoT operating system and compatible software. The Raspberry Pi can perform tasks from a desktop PC (spreadsheets, word processing, games). It can also stream videos in high definition thanks to its Broadcom Video core IV circuit (allows the decoding of full HD Blu-ray streams).

The Raspberry P3 requires an SD card with an OS, a power supply, a USB keyboard, a USB mouse, a case and cables. To prepare a bootable SD card, you need to have a PC with a card reader.

2.6.2 Characteristics of the Raspberry Pi 3 B

- **Power supply to be provided**: 5 V dc/max 2.5 A* via micro-USB socket (* maximum current if all functions are used).
- **CPU**: Quad-core ARM Cortex-A53 1.2 GHz (Broadcom BCM2837)
- **GPU**: Dual Core Video Core IV Multimedia Co-Processor
- **Wi-Fi**: 2.4GHz, 802.11n (Broadcom BCM43438)
- **Bluetooth**: 4.1 (Broadcom BCM43438)
- **Memory**: 1 GB LPDDR2 (1024 MB)
- **USB**: 4 USB 2.0 ports
- **Ethernet**: 10/100 base T Ethernet port: RJ45
- **Bus**: SPI, I2C, series
- **Card holder:** micro-SD
- **Audio outputs**: HDMI and 3.5mm jack
- **Video outputs**: HDMI
- **Support for distributions**: dedicated based on **Linux** and **Windows 10**
- **Dimensions**: 88 x 58 mm

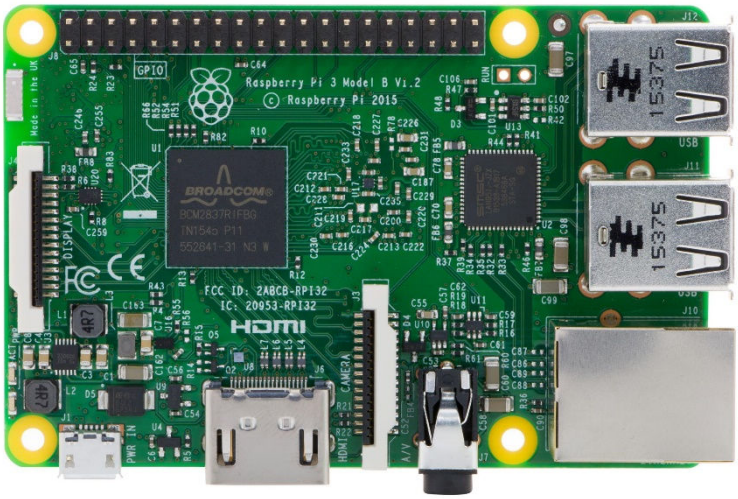


Figure 2.1 Raspberry Pi 3

Chapter Three

Wi-Fi Extender Design Method

Chapter Three

Wi-Fi Extender Design Method

3.1 System Design Elements

The simple Raspberry Pi Wi-Fi extender is a good concept in which we can create a new hotspot to increase the number of Internet users Design the proposed system it consists of hardware and software design as shown in Figure 3.1

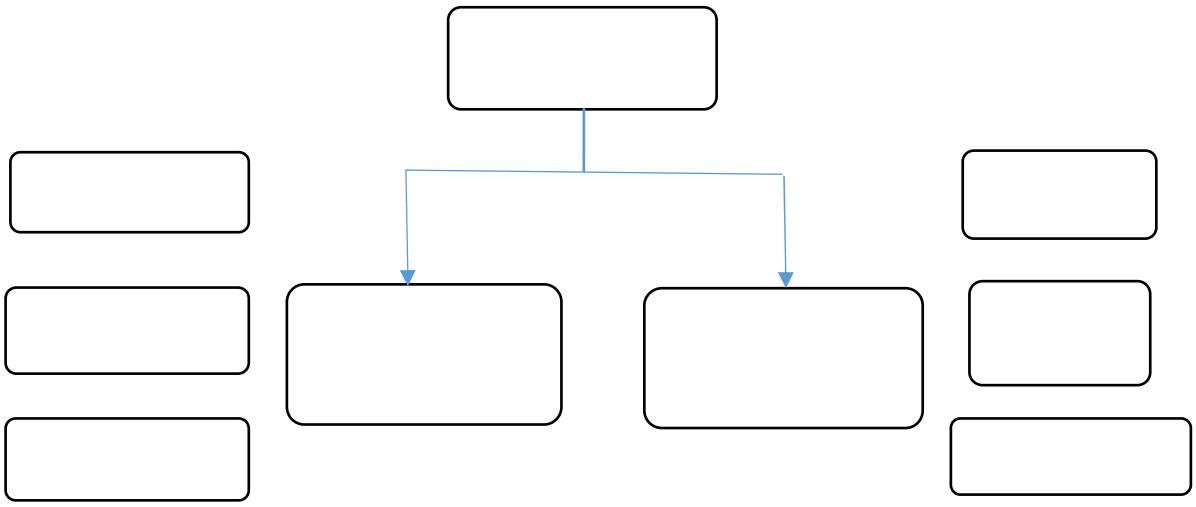


Figure 3.1: Design Process of simple Raspberry Pi Wi-Fi extender

3.2 Hardware Part

Here are all the parts and pieces we used for the Raspberry Pi Wi-Fi Extender research project, we will need 2 Wi-Fi dongles to be able to complete this research, to work as an access point, a Raspberry Pi 3, a Micro SD card, a 5V2A power supply, a router, Raspberry Pi Case

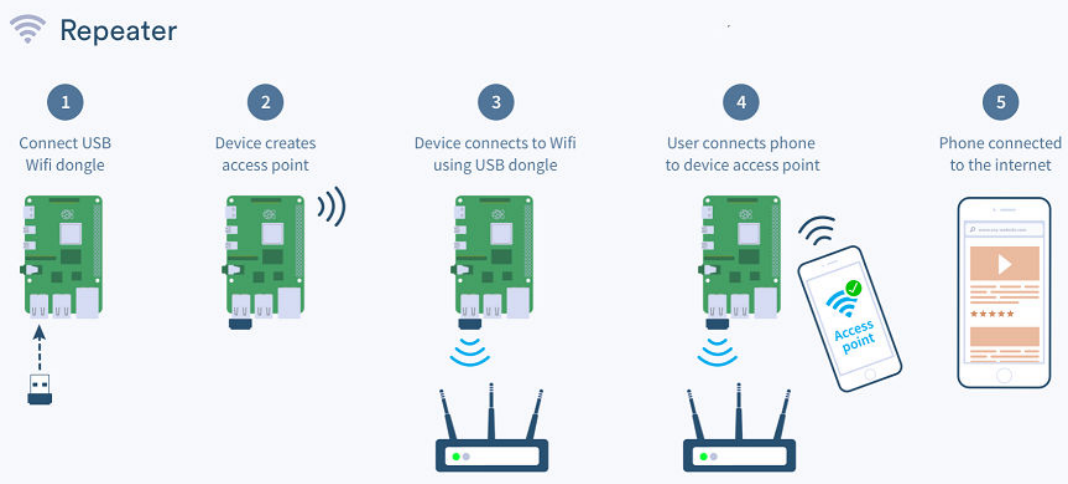


Figure 3.2: Simple Raspberry Pi Wi-Fi extender

Figure 3.3 shows building a network using Raspberry Pi and Wi-Fi dongles to create a connected access point for the purpose of increasing the number of Internet users.

Figure 3.3: Hardware Elements

3.3 System Design Components Description

3.3.1 Raspberry Pi 3 model B

One of the most popular Raspberry Pi boards is the Raspberry pi 3 model B. While it was not actually the first board to be released, it remains to be the most actively used. Models made in UK Raspberry Pi 3 B+ (B Plus) with 1.4 GHz 64-bit quad-Core processor, 1GB RAM dual band 2.4GHz and 5GHz IEEE 802.11.b/g/n/ac wireless LAN, enhanced Ethernet performance 32GB Samsung EVO+ micro SD card (Class 10) Pre-loaded with NOOBS, USB Micro SD Card Reader Cana Kit 2.5A USB Power Supply with Micro USB Cable and Noise Filter, specially designed for the Raspberry Pi 3 B+ (UL Listed) Premium Raspberry Pi 3

B+ Case, High Quality HDMI Cable, 2 x Heat Sinks, GPIO Quick Reference Card, Cana Kit Full Color Quick-Start Guide.

Figure 3.4: Raspberry Pi 3 model B

Table 3.1: Characteristics of Raspberry Pi 3 Model B

Board	Raspberry Pi 3 Model B
Processor	Broadcom BCM2837
CPU Core	Quad core ARM Cortex-A53, 64Bit
Clock Speed	1.2GHz (Roughly 50% faster than Pi2)
RAM	1 GB
GPU	400 MHz Video Core IV®
Network Connectivity	1 x 10 / 100 Ethernet (RJ45Port)
Wireless Connectivity	802.11n wireless LAN (Wi-Fi) &

	Bluetooth 4.1
USB Ports	4 x USB 2.0
GPIOs	2 x 20 Pin Header
Camera Interface	15-pin MIPI
Display Interface	DSI 15 Pin / HDMI Out /Composite RCA
Power Supply (Current Capacity)	2.5 A

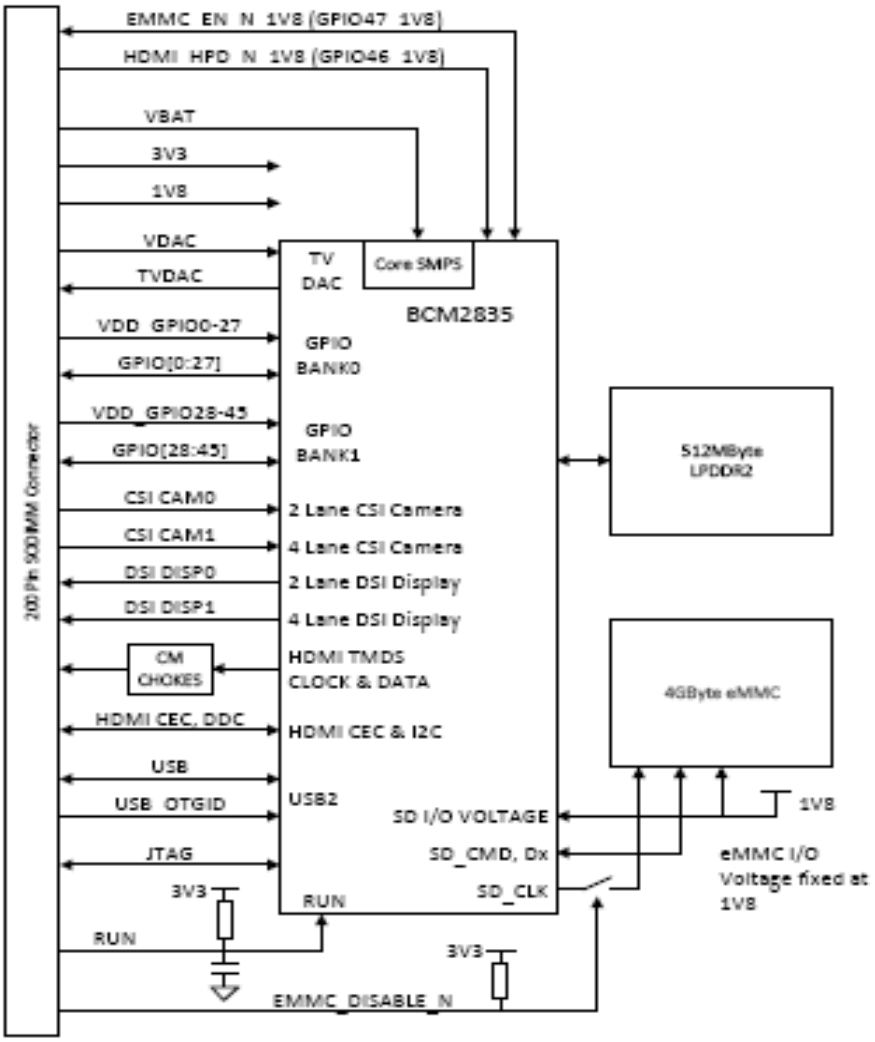


Figure 3.5: Block Diagram of Raspberry Pi

Figure 3.6: Power Supply Utilities

3.3.2 Micro SD Card

Ideal for Android Smartphones and Tablets, and MIL Cameras Capacities up to 512GB (1GB=1,000,000,000 bytes; Actual user storage less) to store even more hours of Full HD video (Approximations; Results and Full HD (1920x1080) video support may vary based on host device, file attributes and other factors) Up to 98MB/s transfer read speed (Based on internal testing; Performance may be lower depending on host device, interface, usage conditions and other factors) lets you move up to 1000 photos in a minute (Based on 4.1GB transfer of photos (avg. file 3.5MB) with USB 3.0 reader; Results may vary based on host device, file attributes and other factors) Load apps faster with A1 rated performance (A1 Performance is 1500 read IOPS, 500 write IOPS; Based on internal testing; Results may vary based on host device, app type and other factors) Class 10 for Full HD

video recording and playback (Full HD (1920x1080) video support may vary based upon host device, file attributes, and other factors)

Figure 3.7: block diagram of Micro SD Card

Table 3.2: Characteristics of Micro SD Card

Brand	SanDisk
Flash Memory Type	Micro SD
Hardware Interface	Micro SD HC
Secure Digital Association Speed Class	Class 10
Memory Storage Capacity	16 GB

3.3.2Huawei E5180

Huawei E5180 is a new home wireless router for 4G LTE Network, with a special design. Made in China and designed by Huawei, E5180 LTE router is capable of 2G, 3G and 4G LTE wireless technologies. Huawei E5180 Router could support both FDD and TDD networks on band 1,3,7 and 20 in FDD and band 38 in TDD. Huawei E5180 supports up to 32 wireless terminals to access internet.

Figure 3.8: block diagram of **Huawei Wi-Fi Cube E5180** 4G Router

Table 3.3: Huawei Wi-Fi Cube E5180 4G Router Technical Specifications:

Category 4	LTE Cat4 Router
Huawei E5180s-22	4G LTE Band 1/3/7/20/38 (FDD 800/1800/2100/2600 MHz and TDD 2600MHz)
Huawei E5180s-610	4G LTE Band 3/7 (FDD 850/1800/2600MHz)
FDD Download speed	150 mbps and upload speed to 50 Mbps
TDD Download speed	112mbps and upload speed to 10Mbps
Wifi Signal band	Wi-Fi 802.11 b/g/n, 2.4G
RAM	2 X 2 MIMO
Support up to	32 Wireless users
Port	One RJ-45 port (or with one RJ-11)
SIM type	micro SIM
Wifi antenna	Two connectors for external antenna (E5180s-610)

3.3.3 Wi-Fi Dongle Linksys WUSB600N-CA Wireless Adapter

Otherwise known as a wi-fi dongle, wi-fi stick, internet stick or USB network adaptor, a dongle is a small modem that allows you to access 3G, 4G or 5G data (depending on your dongle plan) by plugging it into a USB port on the device you're using.

Figure 3.9: Wi-Fi dongle Linksys WUSB600N-CA

The USB300WN2X2C USB Wireless Network Adapter lets you add 300 Mbps Wireless-N connectivity to your desktop or laptop system through USB 2.0. With a compact, lightweight design, the adapter is extremely portable, and is unobtrusive when connected to your system - you can even leave it connected to your laptop when in a carrying bag, without worrying about damaging the adapter or the host

port while on the move. The USB wireless adapter is capable of data transfer rates up to 300Mbps over a 2.4GHz 802.11n WiFi network (backward compatible with 802.11b/g), through a 2 Transmitter / 2 Receiver antenna design. The adapter also supports security options such as WEP, WPA or WPA2, as well as quick device connection through Wireless Protected Setup (WPS), for a reliable and secure connection. Backed by a StarTech.com 2-year warranty and free lifetime technical support.

3.3.3.1 Applications

- Add wireless networking capabilities, without having to open up your computer case.
- Replace or upgrade an existing Wi-Fi connection to IEEE 802.11n standards.
- Connect to a wireless-N network in remote locations where wired connections are unavailable.
- Add high-speed Wi-Fi connectivity to support demanding applications such as streaming video, VoIP and network backups.

3.3.3.2 Features

- Extremely compact and lightweight design.
- 2 Transmitter/2 Receiver (2x2:2) antenna configuration.
- Compliant with IEEE 802.11n standards, with data rates up to -300Mbps.
- Backward compatible with 802.11b/g (11/54Mbps respectively).
- Supports WEP (64-128-bit), WPA and WPA2 wireless security.
- Supports WMM Quality of Servic.

Table 3.4: Wi-Fi dongle Linksys WUSB600N-CATechnical Specifications

Brand	Linksys
Hardware Interface	USB
Operating System	Windows XP Professional
Compatible Devices	Desktop
Item Dimensions LxWxH	2 x 9 x 6 inches
Data Link Protocol	USB
Data Transfer Rate	300 Megabits Per Second
Item Weight	0.35 Pounds

3.3.4Wi-Fi dongle TP-Link TL-WN725N 150Mbps Wireless N Nano USB Adapter

3.3.4.1 TP-Link TL-WN725N Overview

With its miniature design the TL-WN725N 150Mbps Wireless N Nano USB Adapter from TP-Link is not only small but extremely light allowing you to plug it in and forget it. This versatile wireless adapter allows you to connect to802.11b/g/n networks, giving you the ability to get online virtually anywhere there is an available Wi-Fi signal.

Once connected, you can then browse the web, stream video, and download files at ultra-fast data speeds of up to 150Mbps. The internal antenna found in the TL-WN725N allows you to connect through frequencies ranging from 2.400-2.4835GHz, giving you even more flexibility with regards to connecting to available wireless networks. With Ad-Hoc and infrastructure modes you can directly connect to an access point through infrastructure mode or create your own temporary network utilizing the Ad-Hoc functionality.

Setup and security of your new wireless adapter is a breeze with the bundled CD providing a utility available in 14 languages. This utility helps with everything from installation to wireless network settings and even security configurations. Security configuration also comes in a variety of encryption standards including

WPA and WPA2, made accessible from the integrated WPS (Wi-Fi Protected Setup) button located on the adapter.

Miniature Design
With its miniature size and sleek design, you can connect the nano adapter to any USB port and leave it there. With the tiny device flush against the USB port, there's no need to worry about blocking adjacent USB interfaces, or that the adapter may fall out when moving a connected laptop from A to B.

Stable Wireless Signals
With transmission data rates of up to 150Mbps, the TL-WN725N complies with wireless 802.11b/g/n standards, enabling fast wireless connections for lag-free online gaming and video streaming.

Advanced Security
The integrated WPA/WPA2 encryptions found on the TL-WN725N are standards developed by the Wi-Fi Alliance to promote security for WLANs. The security features found on the USB network adapter provide a more advanced layer of security when compared to traditional WEP encryptions standards.

Bundled CD for Easy Operation
The TL-WN725N comes with a 14-language utility located on its bundled CD that helps users complete the software installation and wireless network settings, including security configurations and wireless connection, quickly and easily, even for novice users new to wireless networking.

Features

- Speed Fast Wi-Fi – Great for surfing, emailing and posting social media
- Design Sleek miniature design – The adapter is so small that once plugged in, can be left in a computer’s USB port
- Ease of Use Backward Compatibility – Supports routers utilizing 802.11b and 802.11g Wi-Fi standards
- Security · Active Defense – WPA/WPA2 encryption provides your Wi-Fi network with advanced protection against security threats

Specifications

Wireless

- Wireless Standard: IEEE 802.11b/g/n ·

- Frequency: 2.4GHz ·
- Wireless Mode: Ad-Hoc / Infrastructure Mode ·
- Wireless Security: WEP, WPA/WPA2, WPA-PSK/ WPA2-PSK ·
- Modulation Technology: DBPSK, DQPSK, CCK, OFDM, 16-QAM, 64-QAM.

Hardware

- Interface: USB 2.0 ·
- Antenna: Internal antenna ·
- LED: Status ·
- Dimensions: 0.73 × 0.59 × 0.28 in (18.6 × 15 × 7.1 mm)

Figure 3.10: Wi-Fi dongle TL-WN725N

Package Contents	150Mbps Wireless N Nano USB Adapter TL-WN725N Quick Installation Guide Resource CD
Certification	FCC, CE, RoHS
System Requirements	Windows10/8.1/8/7/XP/Vista, Mac OS X 10.9-10.13, Linux
Environment	Operating Temperature: 0℃~40℃ (32℉ ~104℉) Storage Temperature: -40℃~70℃ (-40℉ ~158℉) Operating Humidity: 10%~90% non-condensing Storage Humidity: 5%~90% non-condensing

3.4 Software Configuration and Programming Steps

3.4.1 Raspberry Pi OS Lite and Required Packages

This will be the used operating system for this Project. You can get the latest version from official Raspberry Pi Website. We would like to point out that since the Raspberry Pi is Linux based anduses wpa_supplicant as the accompanying package, we don't need a hostapd (a Host Access Point Daemon which allows your host device, in this case the Raspberry Pi module, to become an Access Point or AP) as the computer itself becomes the Access Point for your Wi-Fi.

Table 3.5: Packages and 3rd Party Applications

Packages to use	wpa_supplicant systemd-networkd	
Packages to stop	Dhcpd	
3rd Party Applications	BalenaEtcher	Flashing the image onto the SD card

3.4.2 Programming Prerequisite Steps

From the website mentioned above, download the .iso file from the Raspberry Pi Website. Then once downloaded on your PC or Laptop, insert the SD card into your computer. Using Balena-Ether flash the ISO image in SD-Card and then wait till it is done (the process can take a while to be completed). After this step close the Balena-Ether application. Then, open the boot partition (which is basically your SD card, which will be in a separate drive in your PC), and then create a blank text file and name it SSH (with no extension).

Next, create another text file called wpa_supplicant.conf in the same drive and paste the following. This is used to connect to the Wi-Fi for the first time.

```
Ctrl_interface=DIR=/var/run/wpa_supplicant
GROUP=netdev<br>update_config=1
country=US
network={
ssid=”mywifissid”
psk=”mywifipassword”
key_mgmt=WPA-PSK
}
```

Note that here, just write the country to be your own country of residence. The ‘mywifissid’ is the name of your Wi-Fi device, and ‘mywifipassword’ the password for your Wi-Fi device. The **key_mgmt** should be set to **None** if you don’t have a password for your Wi-Fi.

Then, open your computer terminal and then go to the directory where your Raspberry Pi OS Lite is installed. Then simply use

```
ssh pi@raspberrypi.local
```

after which you’ll be prompted to connect or not, for which you type in ‘yes’. Then you’ll be prompted for the password, and the default password is raspberry.

After the Completion of Above Steps. You should have a fully functional Raspberry Pi running Raspbian OS, Connected to your Home Wi-Fi Network.

3.4.3 Upgrading the Raspbian OS

Now you finally would want to update your package list and upgrade the packages and then reboot Pi. For this, just enter the commands given below, wait for them to process and then use the following commands

```
sudo apt update -y
sudo apt upgrade -y
sudo reboot
```

3.4.4 Setting Up “System –Network”

Before we begin this step, “system -network is a system daemon that manages network configurations. It detects and configures network devices as they appear; it can also create virtual network devices.”

Now usually in many builds, we use a software to provide a Domain Name System (DNS) caching and dynamic host configuration protocol (DHCP) for smaller networks. This basically allows us to assign IP addresses to devices connecting to the AP and the DNS then maps host names to the IP addresses. To do so, we need to assign a static IP address to the DHCP and configure it.

But in our case, the networked is already built into the **init** system. Therefore, we don’t need to configure the DHCP or the **dhcpd** configuration step. This is especially useful which helps us minimize the need of additional packages. We are basically using the **system-network** instead of the **hostapd**. So now, moving on to further steps.

3.4.4.1 Prevent the use of dhcpd

Note thatit is required that you run this step as a root

```
sudo su
```

In this step, we are first masking the dhcp and networking services through the first command. Then we are removing the networking interfaces like wlan0 in the next line of code. Finally we are replacing the text in the codes which are present in the resolve conf file of the system.

Copy the lines of code one by one from the following, wait for the processes to happen and proceed to the next step.

```
sudo systemctl mask networking.service dhcpcd.service
```

```
sudo mv /etc/network/interfaces /etc/network/interfaces~
sudo sed -I ‘1i resolvconf=NO’ /etc/resolvconf.conf
```

3.4.4.2 Use the inbuilt “systemd-networkd”

In this step, there are two commands to run on terminal. First run the system-networked command which helps run the package. The next command then helps set up a network and then we can proceed onwards towards the third step.

As always, wait for the program to finish the particular line of code, and once you’ve confirmed that the setup is finished, you can move ahead.

```
sudo systemctl enable systemd-networkd.service system-resolved.service
sudo ln -sf /run/systemd/resolve/resolv.conf /etc/resolv.conf
```

3.4.4 Configuring “wpa-supplicant” (wlan0 as client)

A.1 First of all, take note that in the following steps, wlan0 is the Wi-Fi carrier (AP). wlan0 is the default Wi-Fi Ethernet port of Raspberry Pi. A simple ‘*ifconfig*‘ will list down all the ethernet interfaces.

A.2 wlan1 Wi-Fi port belongs to USB adapter. We are now going to create a wpa-supplicant for both of them separately.

A.3 Recall that initially we had created a wpa-supplicant conf file. Now we will create 2 conf files so that one will connect to our access point and the other will connect to the Wi-Fi. First we will configure the on-board Wi-Fi. This is used to create an AP.

A.4 Create a new file

• Use the command given below to create a new file. Once this command is successfully executed, you will be taken to the file, after which you should look at the step below.

```
sudo nano /etc/wpa_supplicant/wpa_supplicant-wlan0.conf
```

3.4.4.1 Modify wpa_supplicant-wlan0.conf

• Add the following content from below in the created file, and then press Ctrl X,Y and Enter. Note that you can change the country in the given text to the country of your residence. It isn't required to be changed as such, only in cases where there are different channels used perhaps should you pay attention to this. SSID can be any name that you choose to keep, in our case, we have gone with the name 'Extender'. The psk field is the password field, which also can be set to whatever meets your needs. In our case, we have set it to '12345678'. Usually, it is seen that people keep the same password for the extender as their Wi-Fi's, but it is totally up to you!

```
country=IN
ctrl_interface=DIR=/var/run/wpa_supplicant GROUP=netdev
update_config=1
network={
ssid="Extender"
mode=2
key_mgmt=WPA-PSK
psk="12345678"
frequency=2412
}
```

• The frequency to be used can also be set to either a 5Ghz or a 2.4Ghz value, and this depends on whatever your Wi-Fi's frequency channel is. We have set it to 2.4 as an example in this case.

• Remember, this configuration is to be used for the onboard wifi Adapter wlan0 which will be used to create a wireless access point.

A.6 Give users permissions to read and write to the file

• Copy the following line of code. Once confirmed, move onto the next step.

```
sudo chmod 600 /etc/wpa_supplicant/wpa_supplicant-wlan0.conf
```

3.4.A.7 Here, first we disable and then enable the service. We can directly use reload, but sometimes the changes are not reflected – so the old method is better.

```
sudo systemctl disable wpa_supplicant.service
sudo systemctl enable wpa_supplicant@wlan0.service
```

3.4.5 Configuring wpa-supplicant (wlan1 USB WiFi Module)

•Same procedure as the previous step, in this, we are just setting the wpa-supplicant file for the USB adapter that will be connected to the client.

3.4.B.1 Create a new file

• Use the command below to create a new file, to which you'll be taken to upon execution

```
sudo nano /etc/wpa_supplicant/wpa_supplicant-wlan1.conf
```

• Add the following content in the file and then press Ctrl X,Y and Enter

```
country=US
ctrl_interface=DIR=/var/run/wpa_supplicant GROUP=netdev
update_config=1
network={
ssid="RouterSSID"
psk="12345678"
```

```
}
```

• Change the SSID and psk to your Router SSID and password. This should be the SSID and password of the device you want your extender to connect to.

3.4.B.2 Give user permissions to read and write to the file

• Copy the given line of code

```
sudo chmod 600 /etc/wpa_supplicant-wlan1.conf
```

3.4.B.3 Restart wpa-supplicant service

• Disable and Enable, just like before.

```
sudo systemctl disable wpa_supplicant.service
sudo systemctl enable wpa_supplicant@wlan1.service
```

3.4.C STEPS 5 Configuring Interfaces

- Create a new file
- Add the content given below
- Create a new file
- Add the following content
- Reboot Raspberry Pi

3.4.D Configuring Interfaces

• These are some of the properties that the Wi-Fi card will use. First for the on-board Wi-Fi, then for the router.

3.4.D.1 Create a new file

- Copy this line of code to your terminal

```
sudo nano /etc/systemd/network/08-wlan0.network
```

3.4.D.2 Add the following content

• Copy this content in the file and save the file by Ctrl X,Y and Enter

```
[Match]
Name=wlan0
```

```
[Network]
Adress=192.168.7.1/24
IPMasquerade=yes
IPForward=yes
DHCPServer=yes
[DHCPServer]
DNS=1.1.1.1
```

• You can change the DNS to whatever DNS you want. Keep the rest same

D.3 Create a new file

• This is for the client you will be connecting to

```
sudo nano /etc/systemd/network/12-wlan1.network
```

D.4 Add the following content

• Copy this content in the file and save the file by **Ctrl X,Y** and Enter

```
[Match]
Name=wlan1
[Network]
DHCP=yes
```

D.5 Reboot Raspberry Pi

• Use the following command to reboot

```
sudo reboot
```

Chapter Four

Results and Discussion

Chapter Four

Results and Discussion

4.1 Introduction

This chapter explains the design of the circuit combined by the software and Hardware. The software includes balena program loaded to the Raspberry pi board that embedded in the hardware design.

4.2 Setup balena software

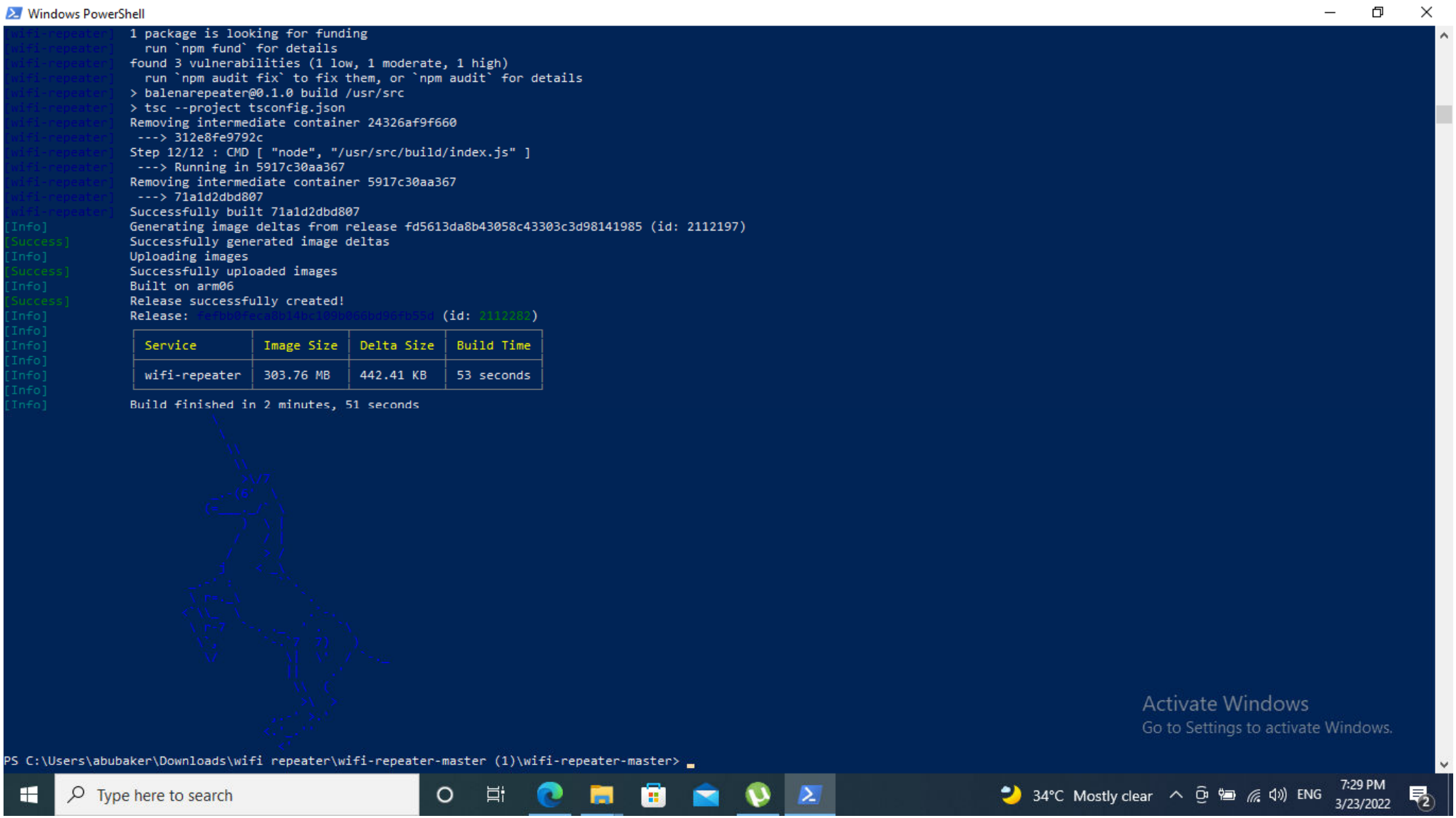


Figure 4.1 program uploading

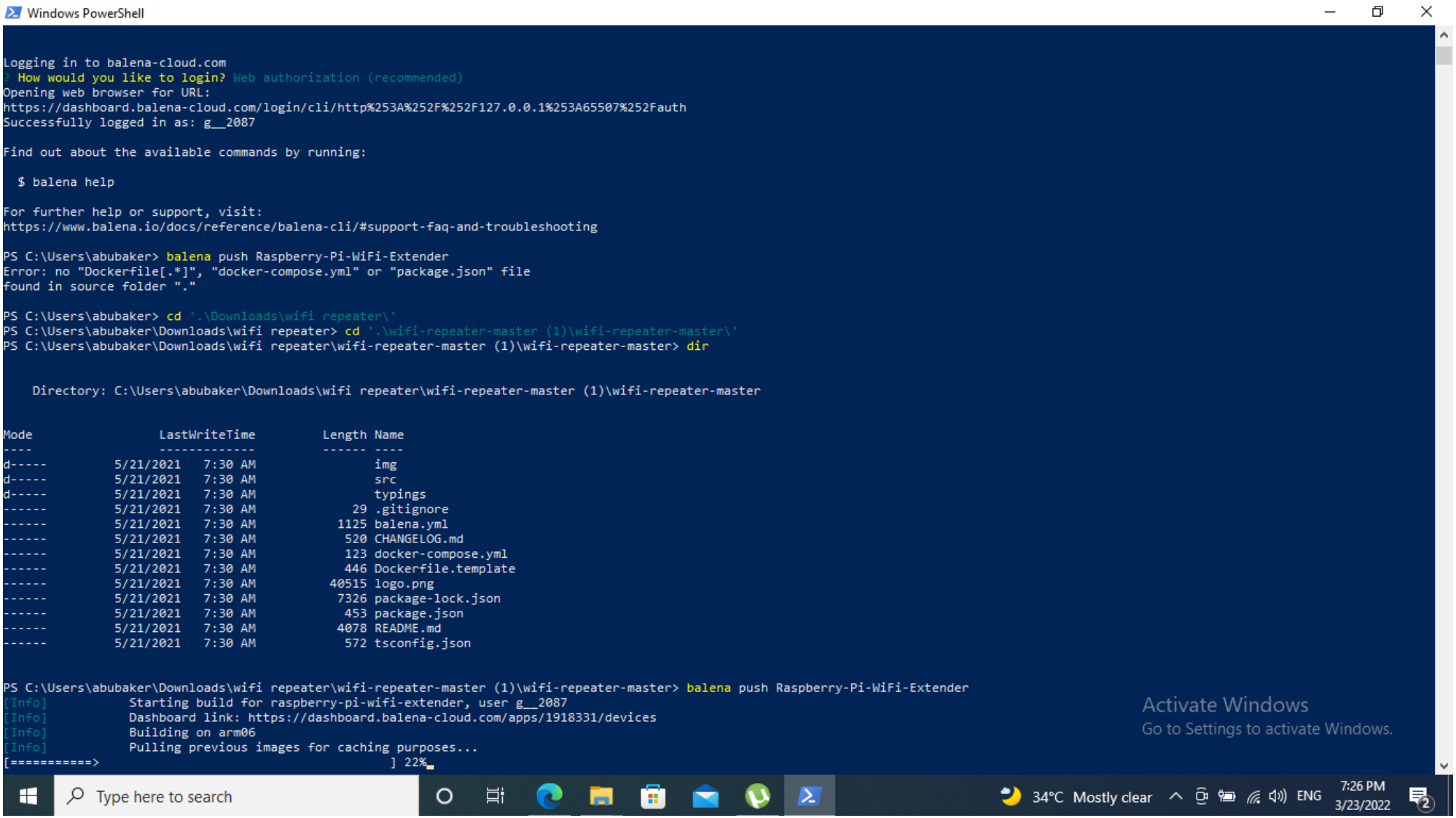


Figure 4.2 balena code uploading

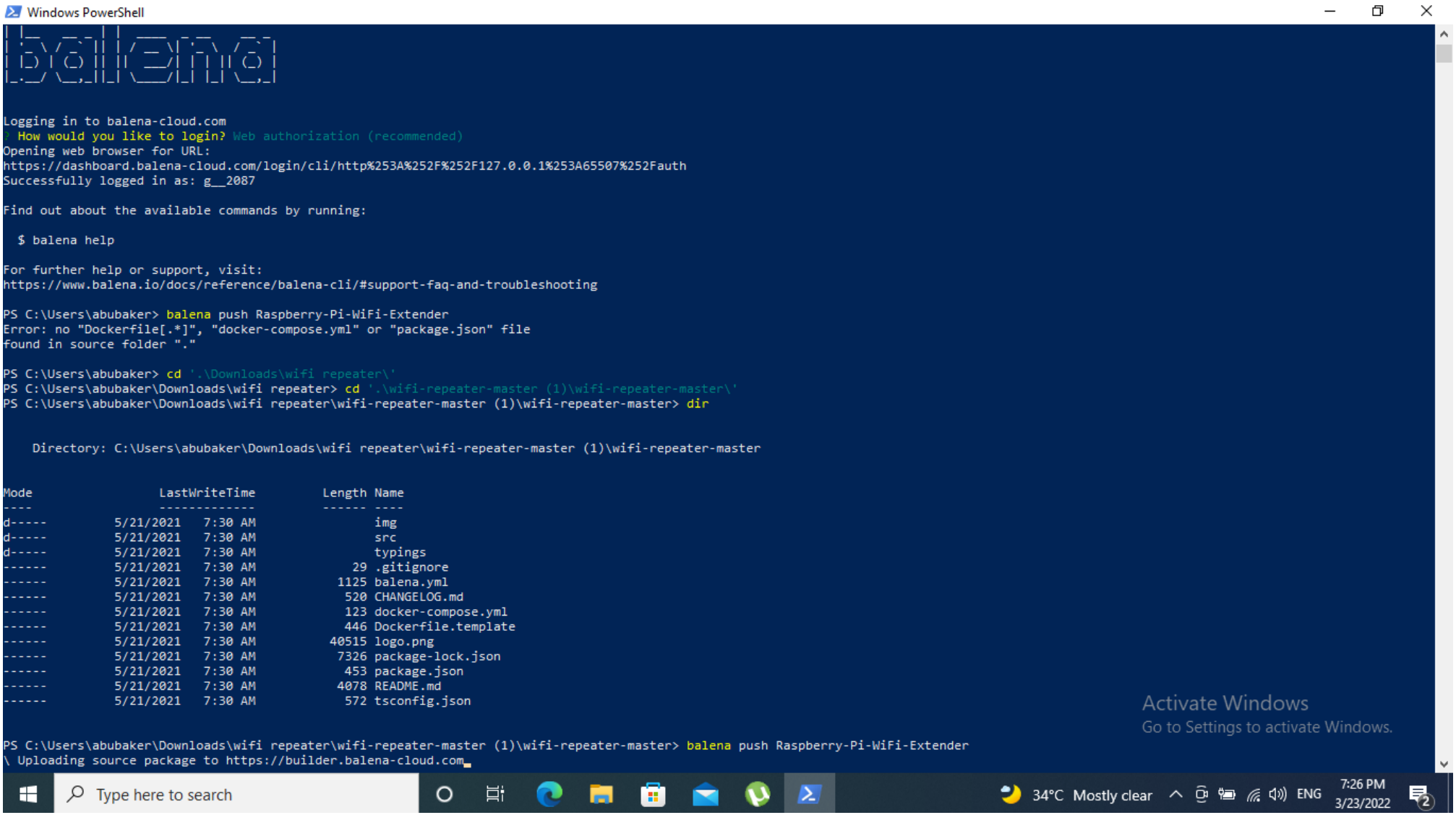


Figure 4.3balena code uploading

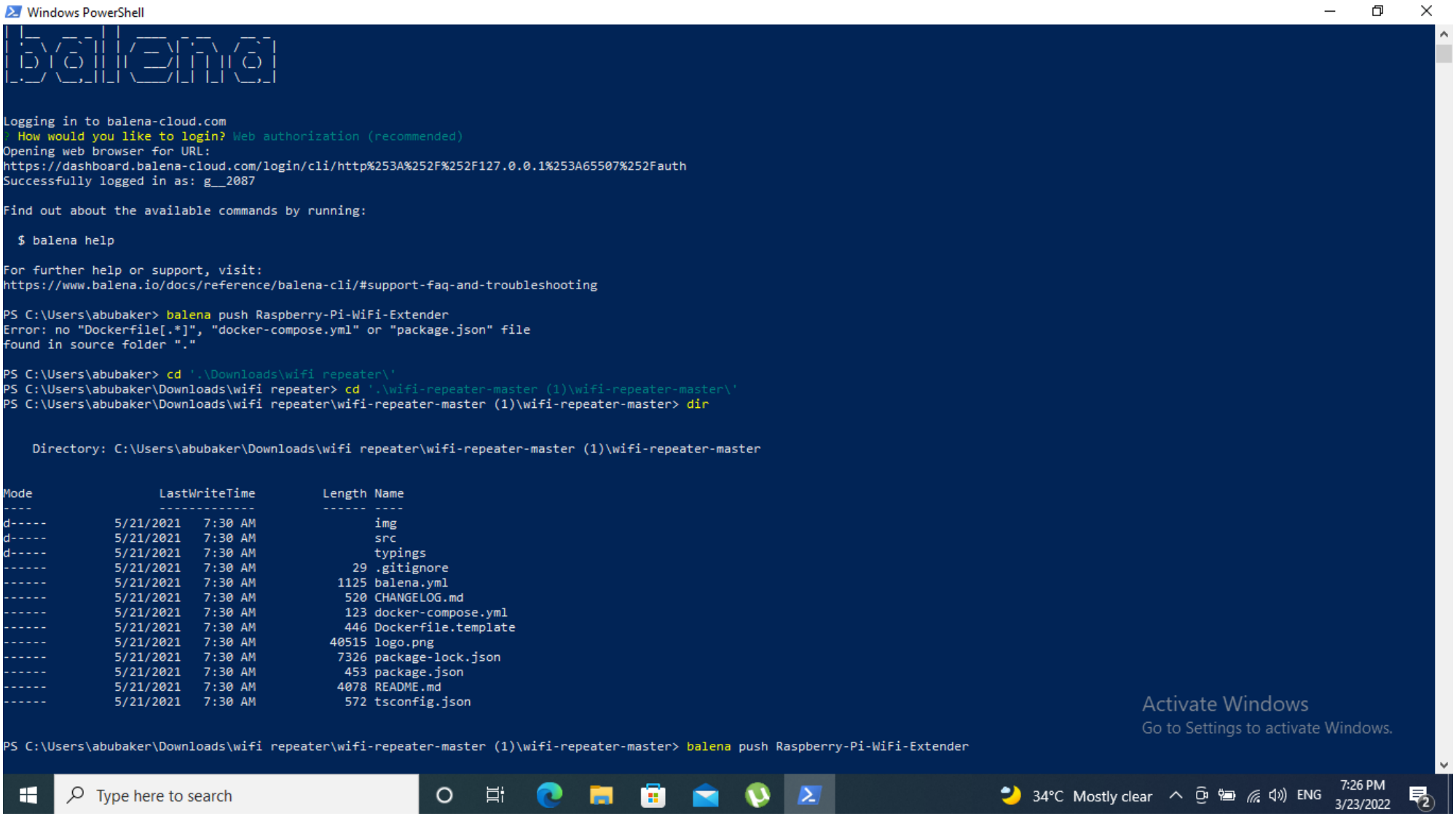
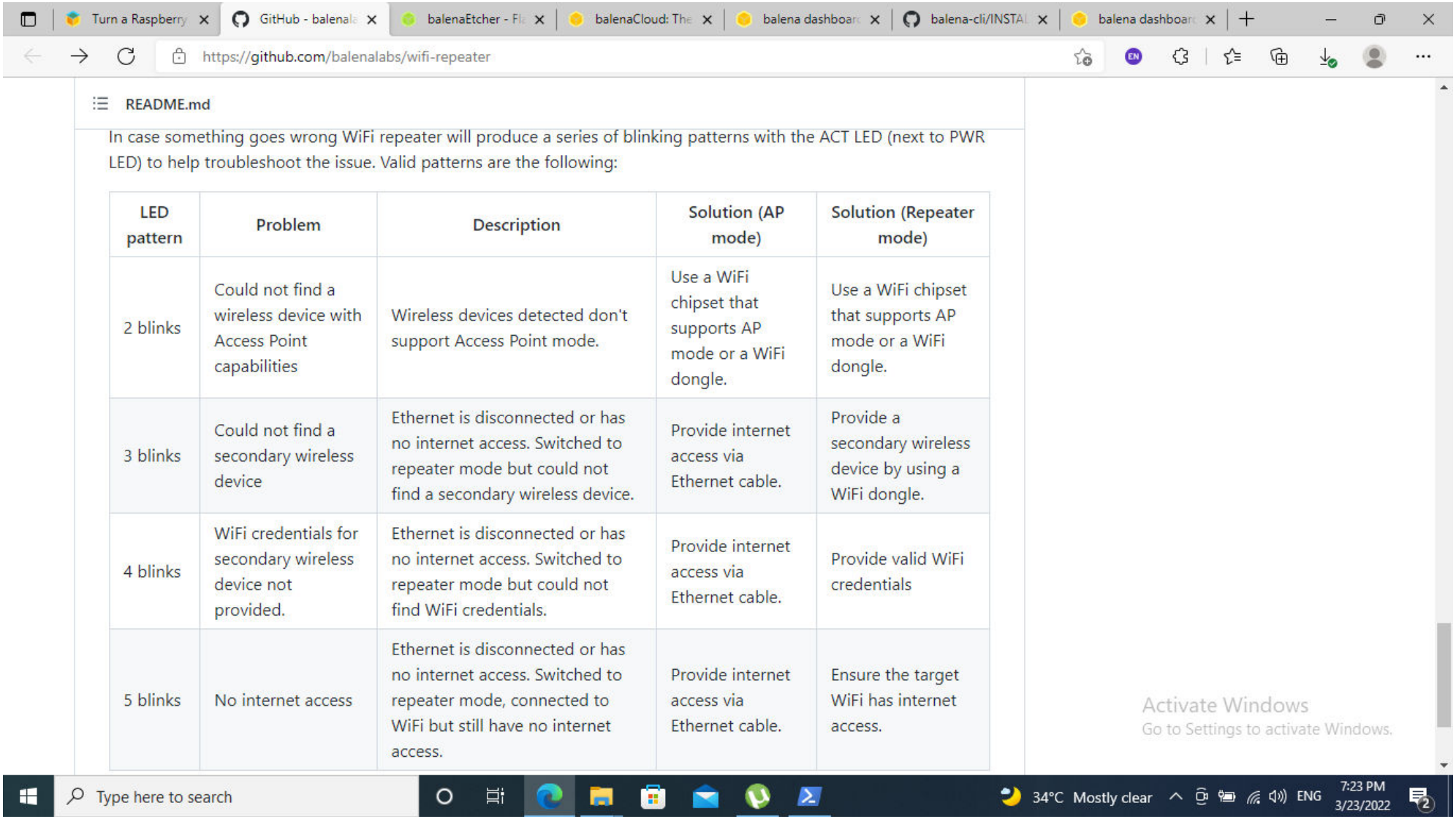


Figure 4.4balena code uploading



README.md

In case something goes wrong WiFi repeater will produce a series of blinking patterns with the ACT LED (next to PWR LED) to help troubleshoot the issue. Valid patterns are the following:

LED pattern	Problem	Description	Solution (AP mode)	Solution (Repeater mode)
2 blinks	Could not find a wireless device with Access Point capabilities	Wireless devices detected don't support Access Point mode.	Use a WiFi chipset that supports AP mode or a WiFi dongle.	Use a WiFi chipset that supports AP mode or a WiFi dongle.
3 blinks	Could not find a secondary wireless device	Ethernet is disconnected or has no internet access. Switched to repeater mode but could not find a secondary wireless device.	Provide internet access via Ethernet cable.	Provide a secondary wireless device by using a WiFi dongle.
4 blinks	WiFi credentials for secondary wireless device not provided.	Ethernet is disconnected or has no internet access. Switched to repeater mode but could not find WiFi credentials.	Provide internet access via Ethernet cable.	Provide valid WiFi credentials
5 blinks	No internet access	Ethernet is disconnected or has no internet access. Switched to repeater mode, connected to WiFi but still have no internet access.	Provide internet access via Ethernet cable.	Ensure the target WiFi has internet access.

Figure 4.5 blinking patterns troubleshooting

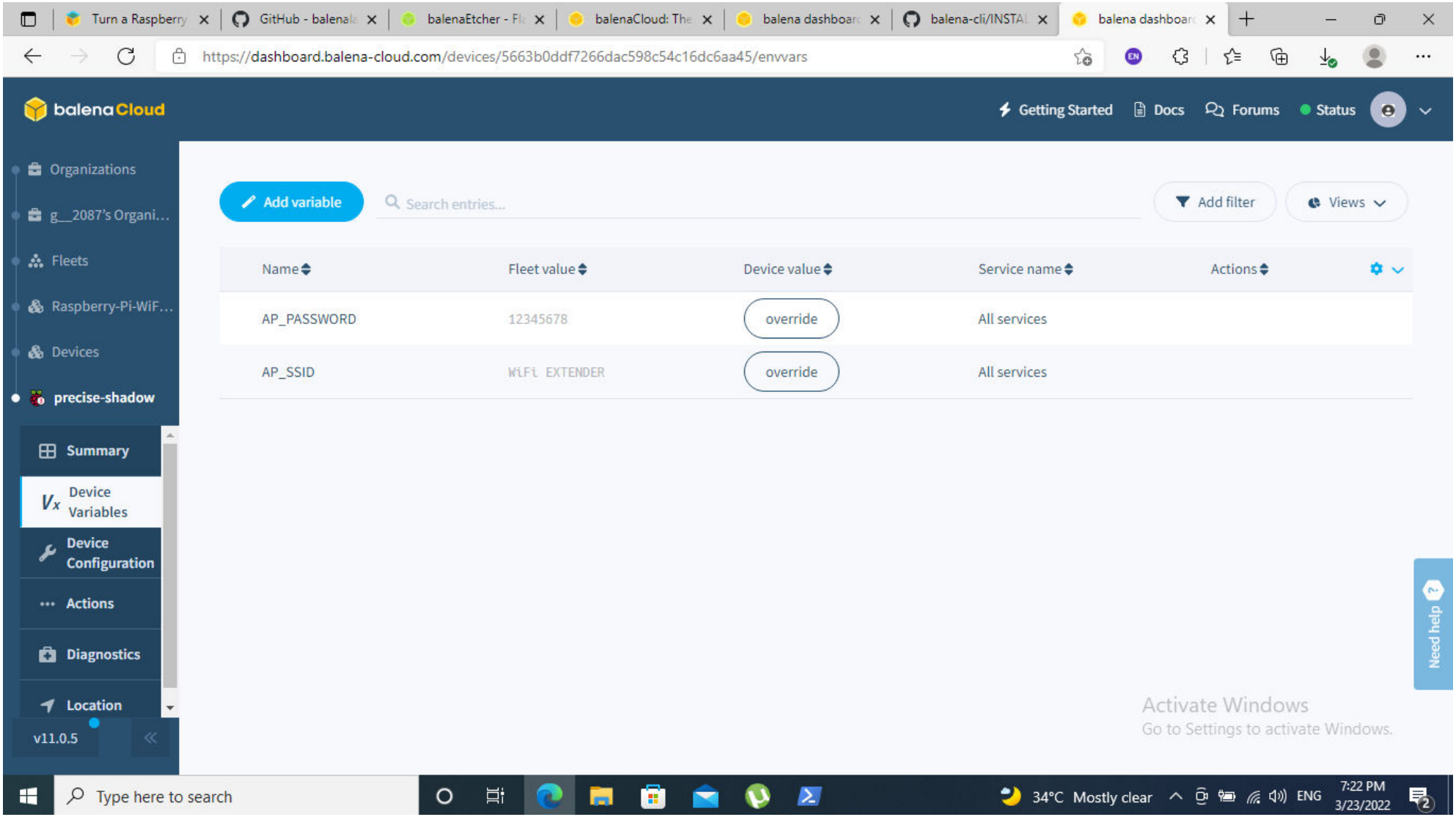


Figure 4.6 balena cloud

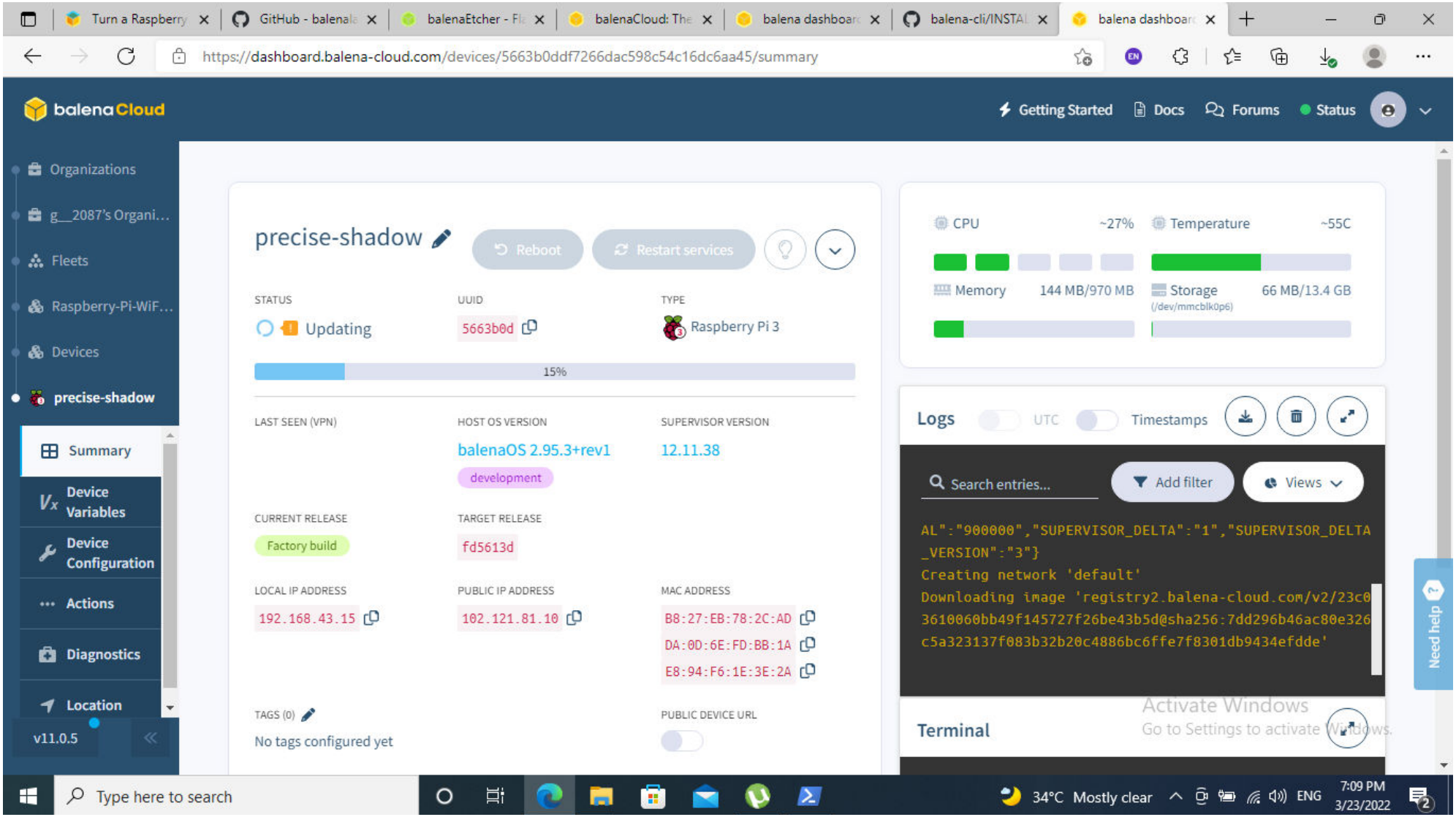


Figure 4.7balena cloud precise-shadow

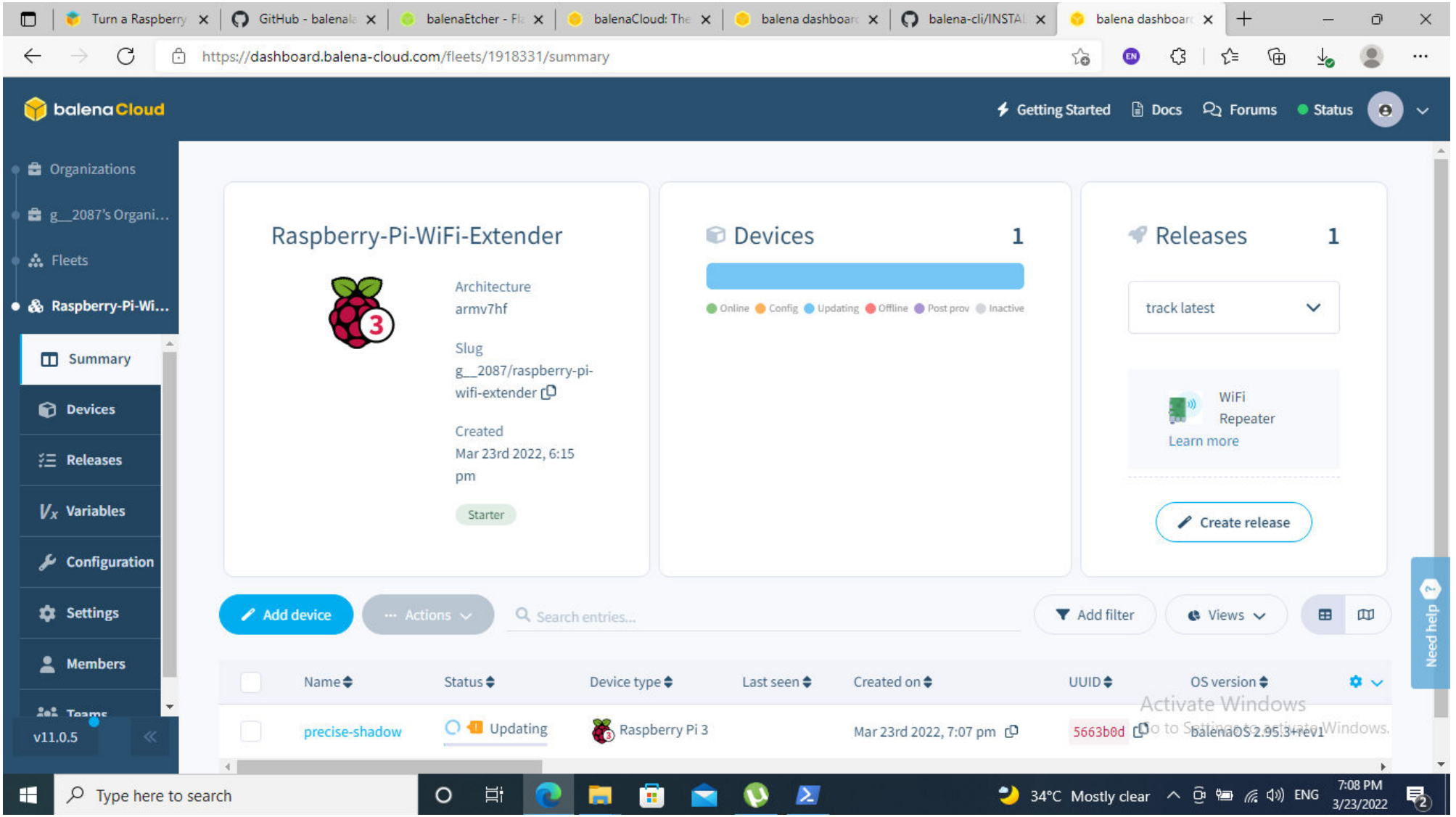


Figure 4.8balena cloud summary

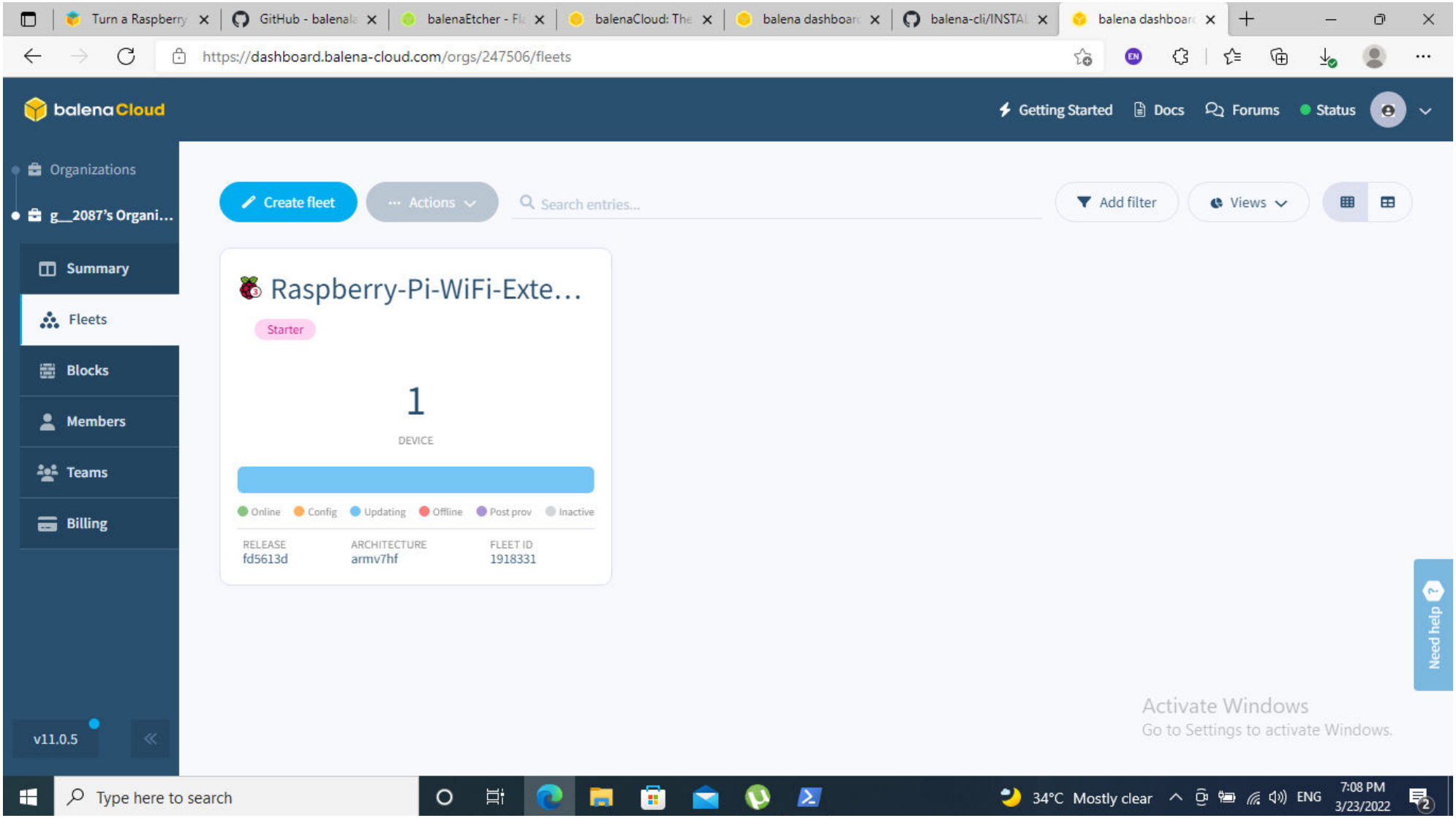


Figure 4.9balena cloud fleets

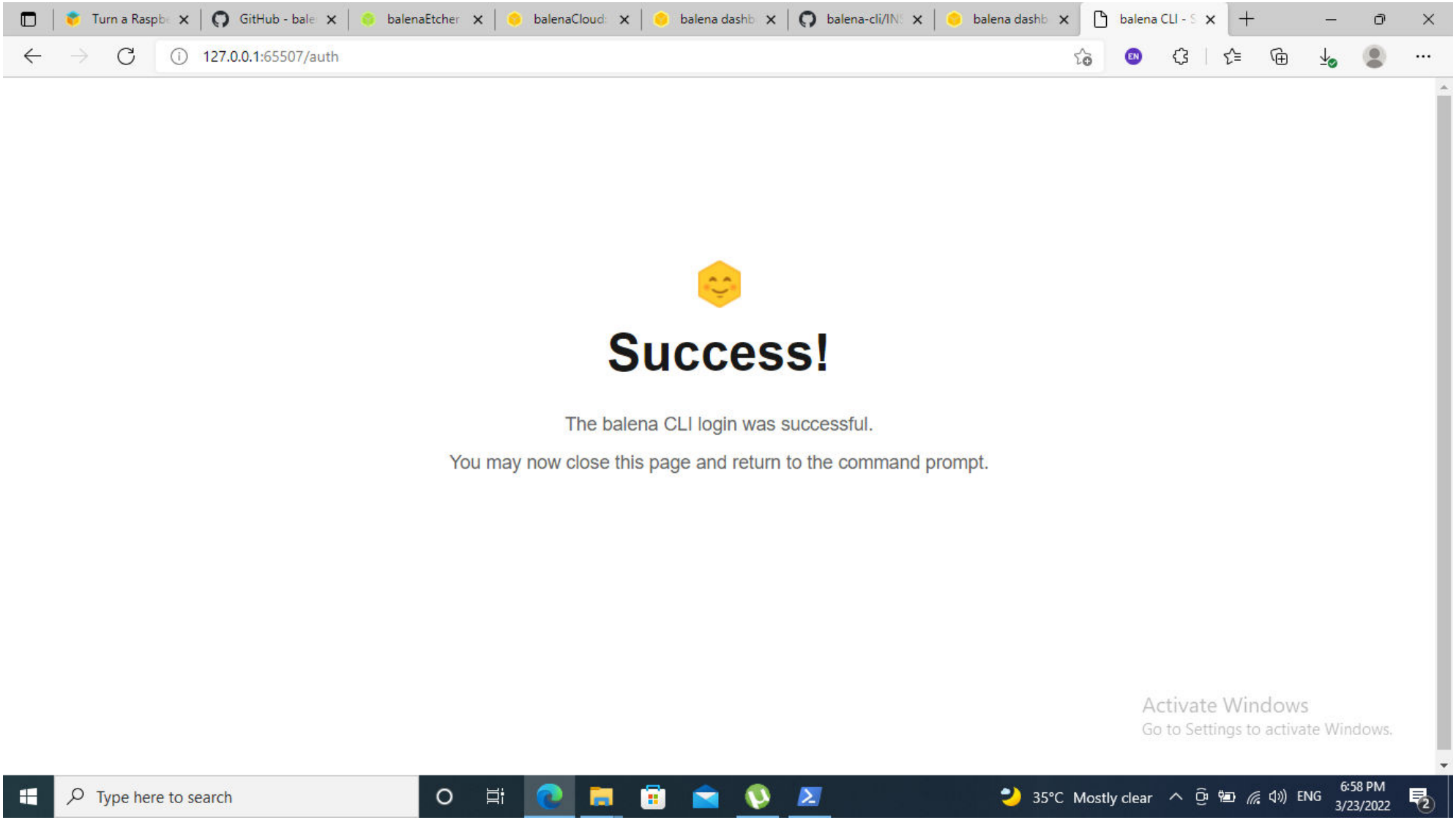


Figure 4.10 balena CLI loging

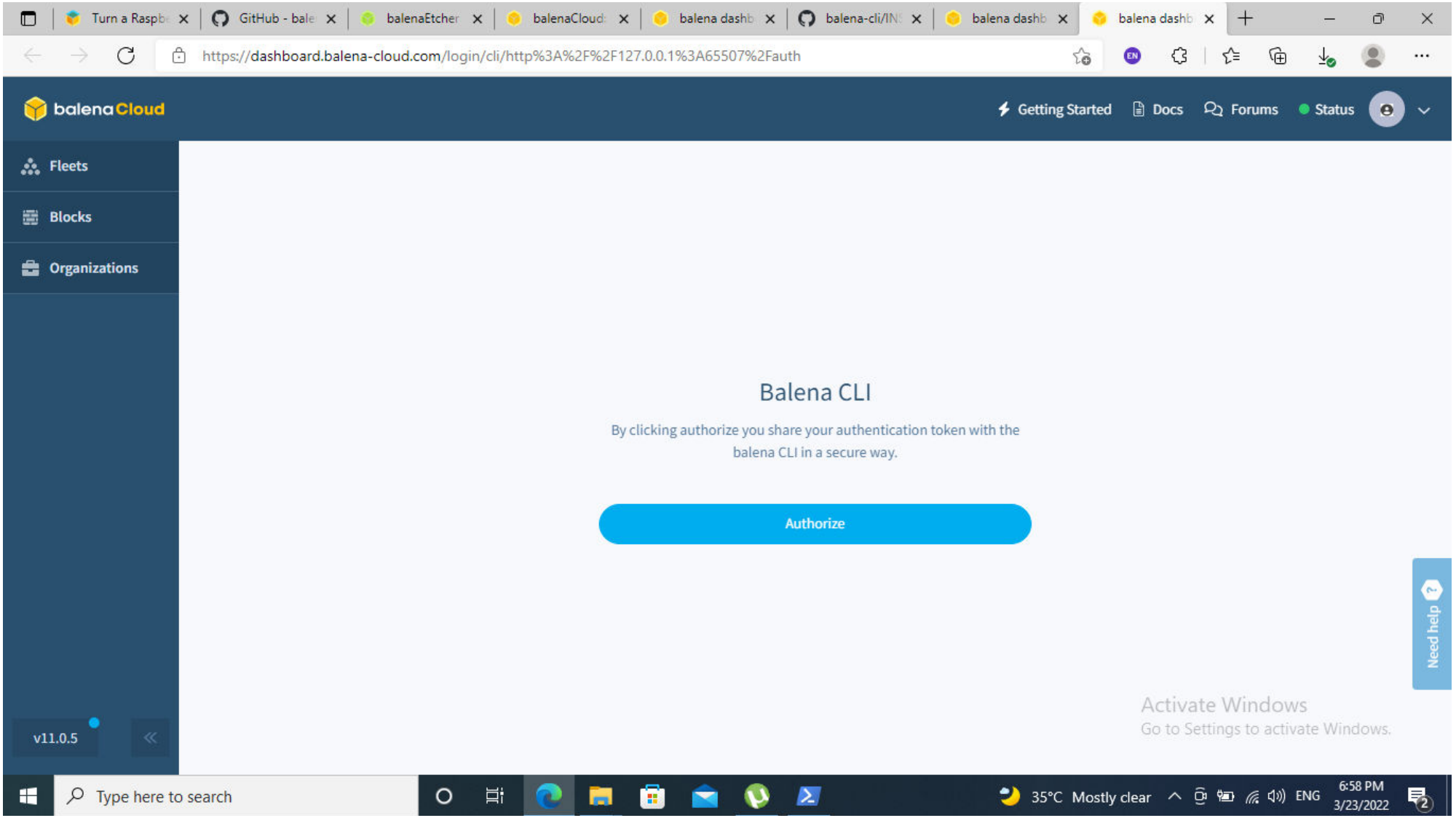


Figure 4.11balena CLI loging

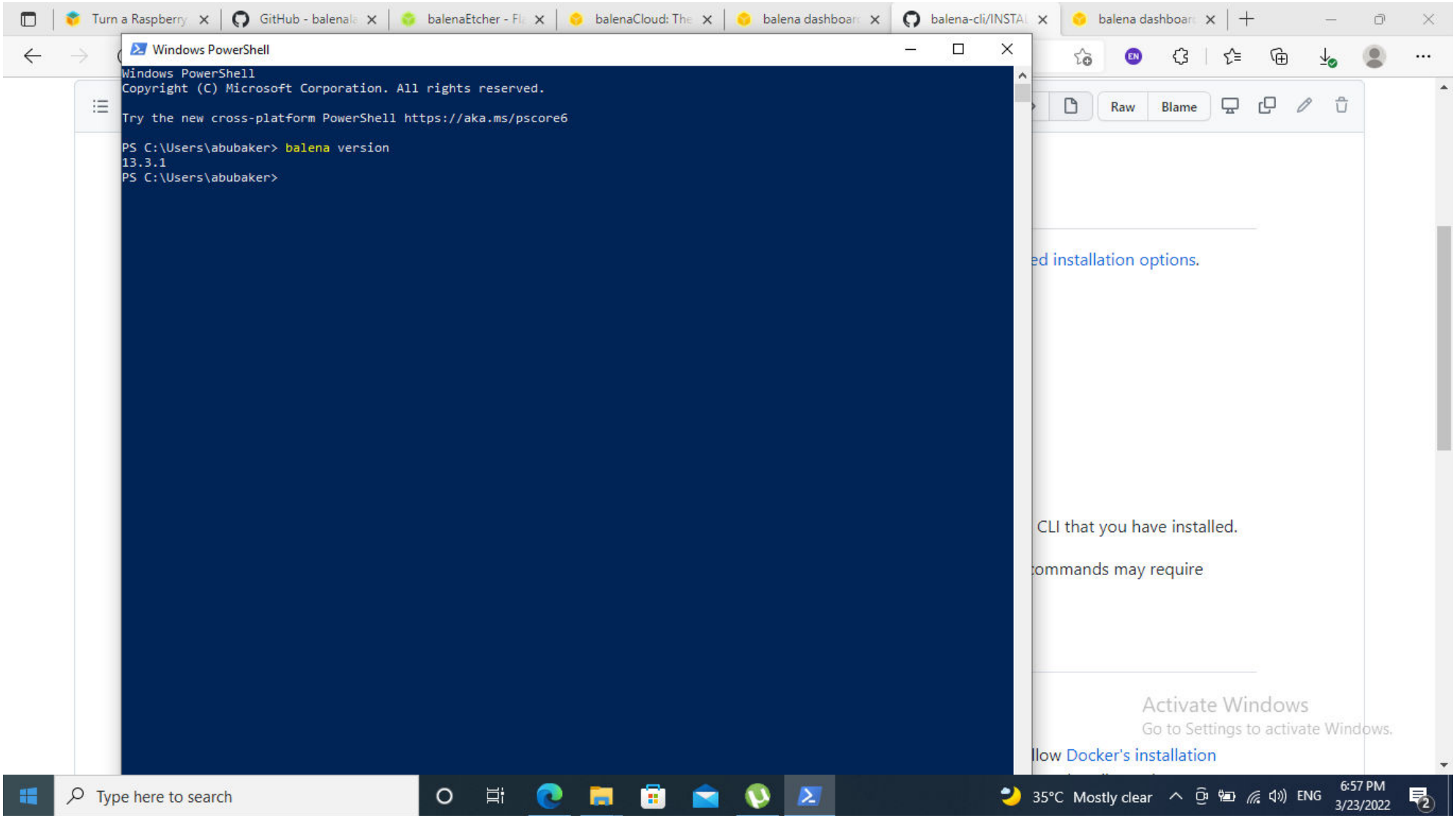


Figure 4.12balena code uploading

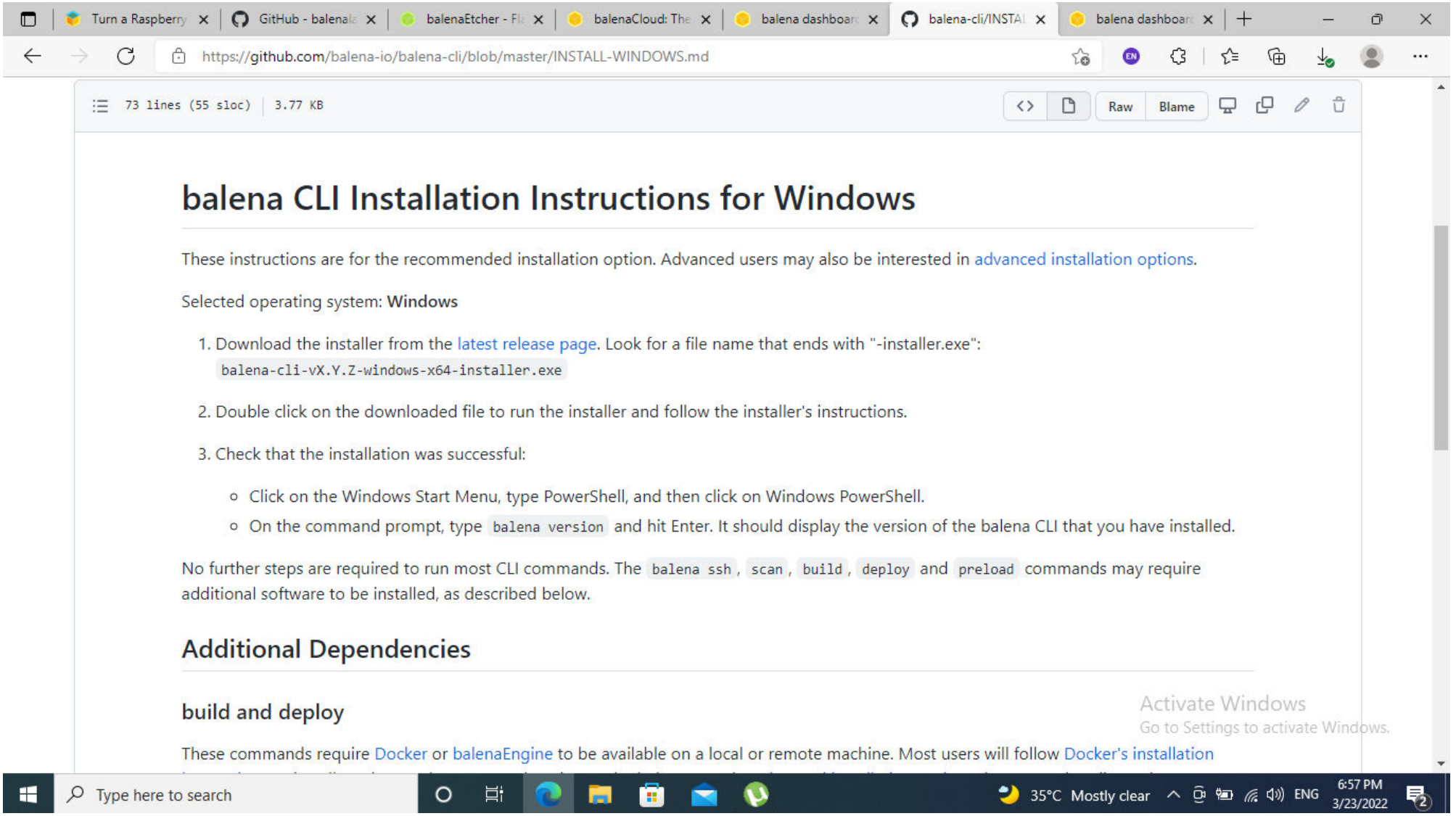


Figure 4.13 balena CLI Installation Instructions for Windows

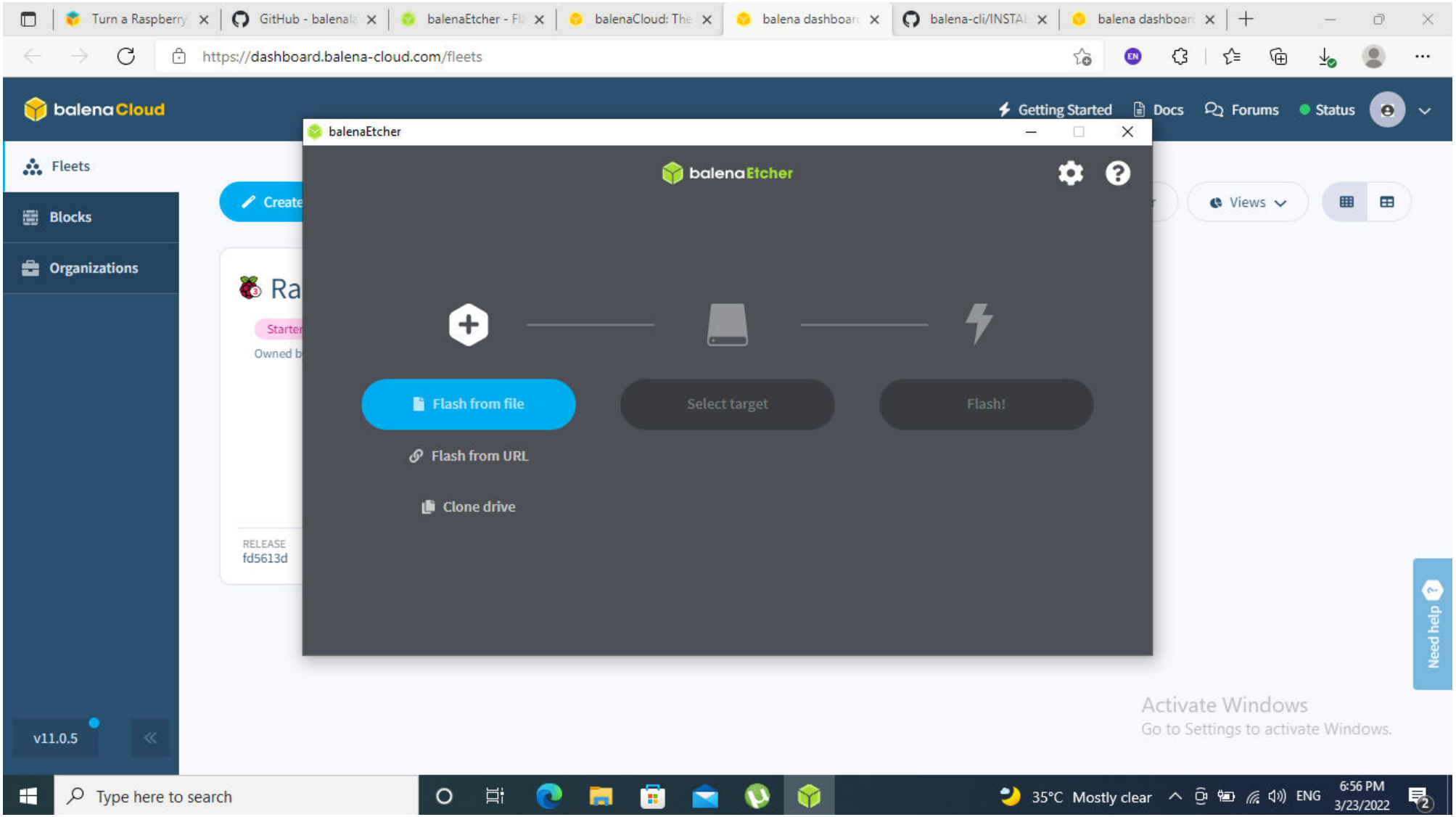


Figure 4.14 balena software loder

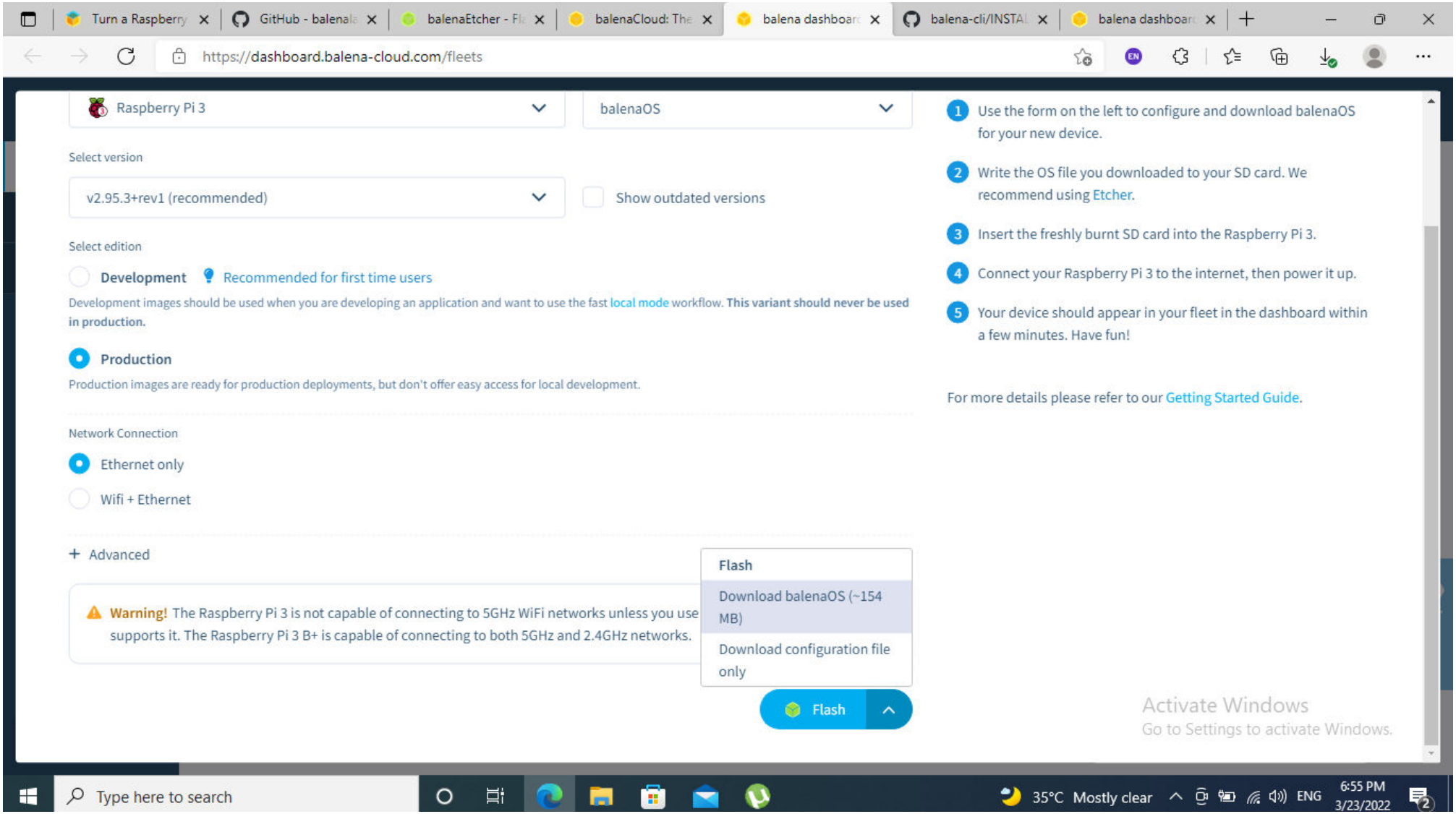


Figure 4.15 balena dashboard

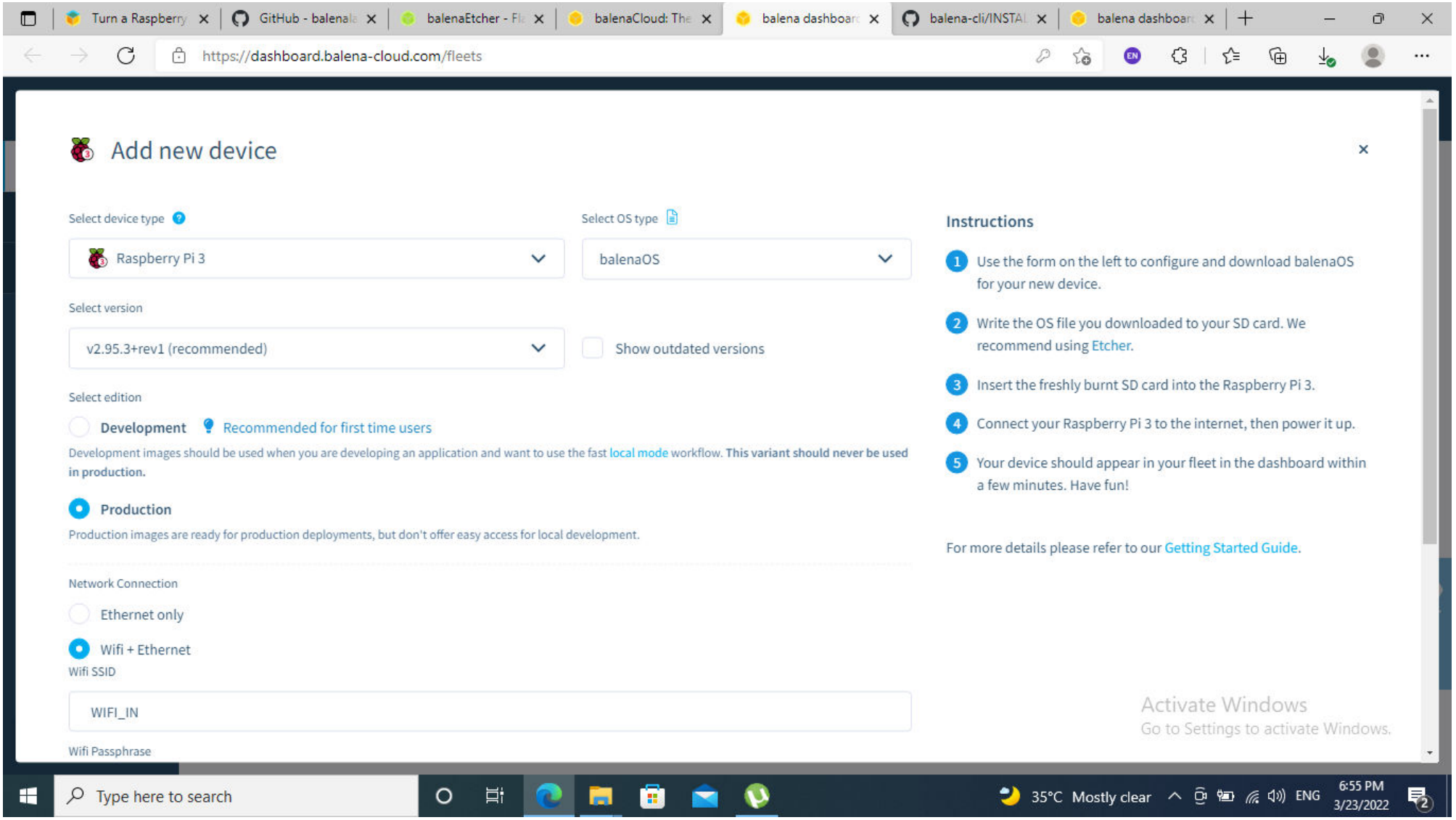


Figure 4.16 balena setup

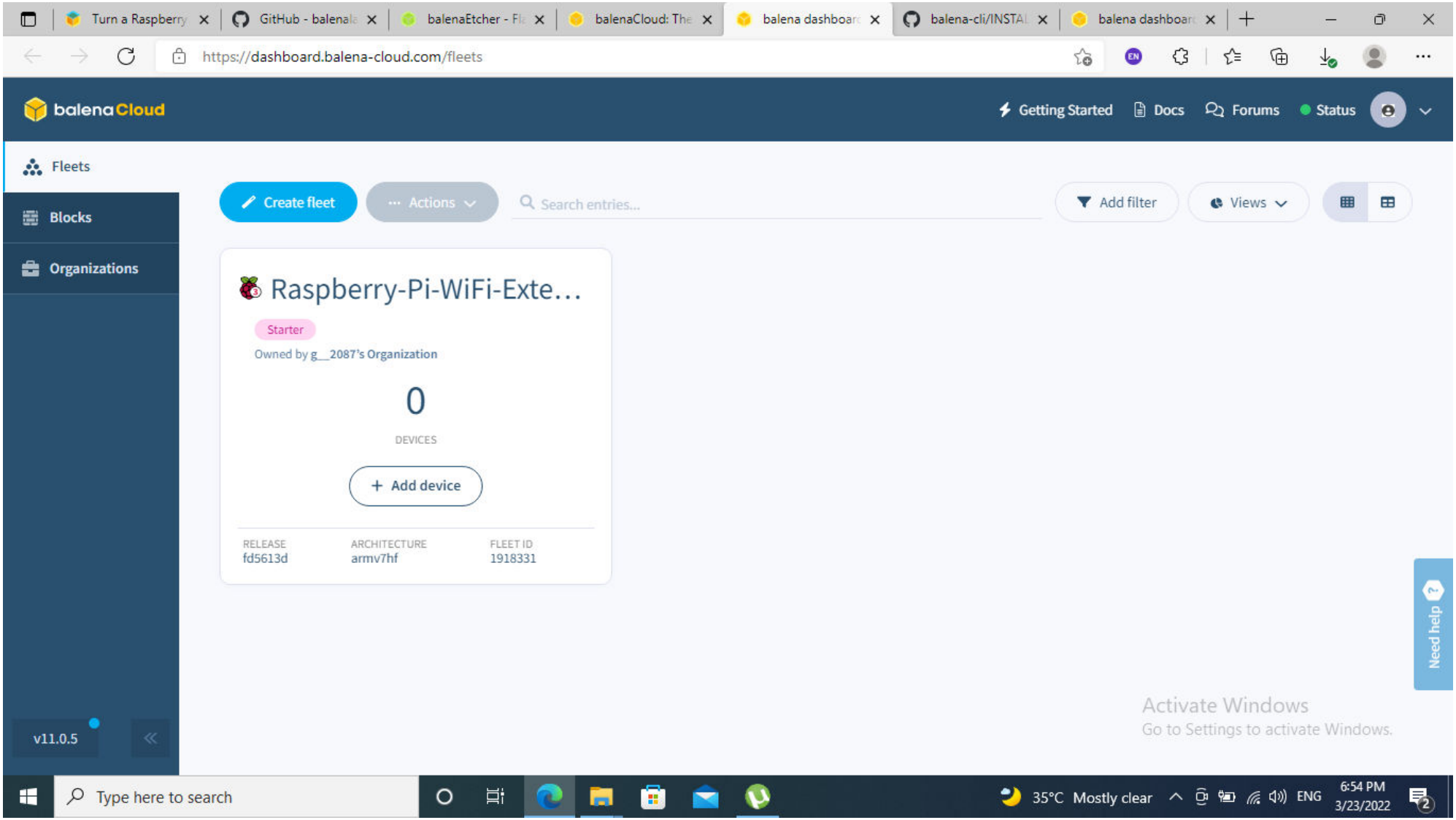


Figure 4.17 balena cloud

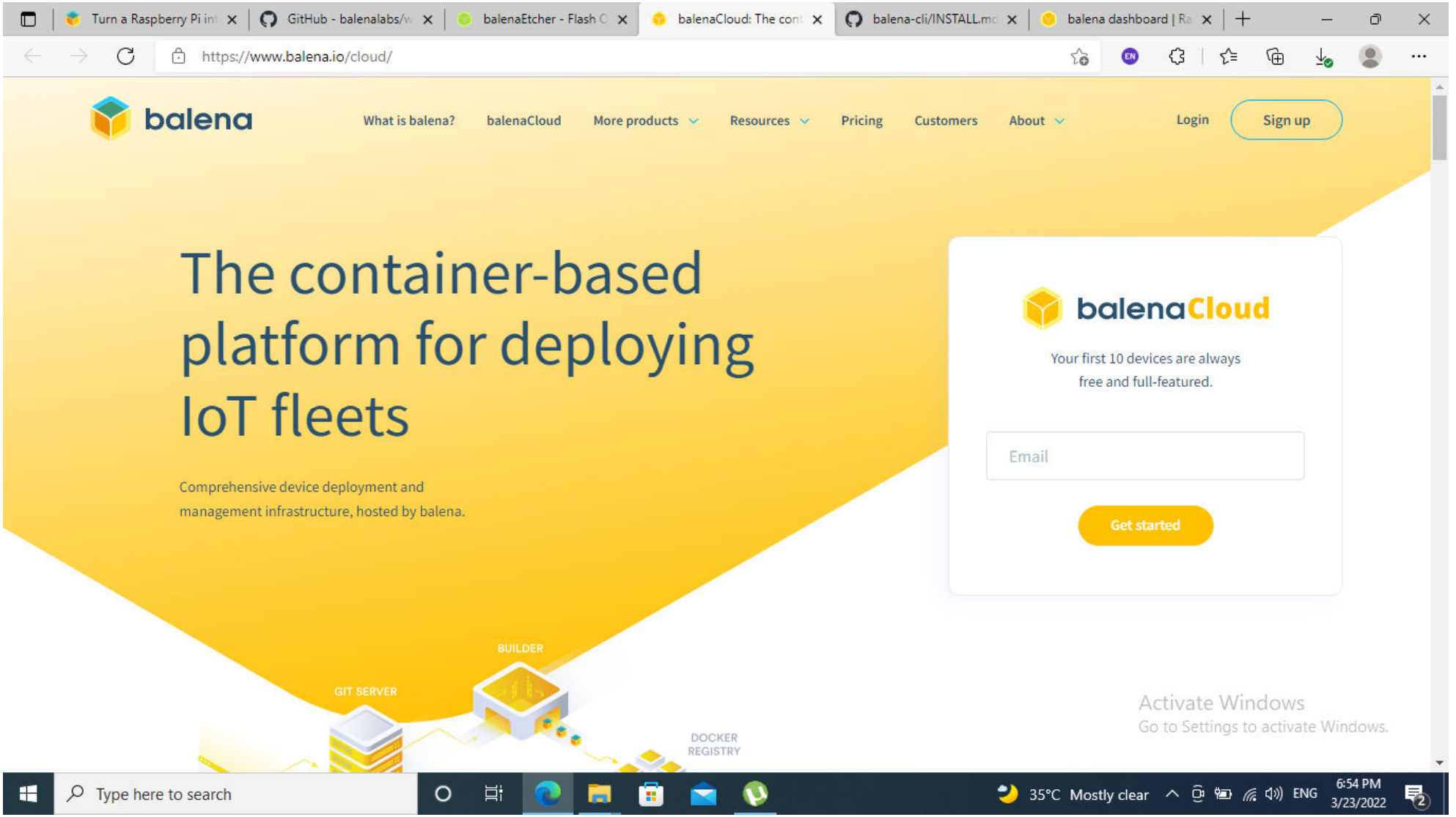


Figure 4.18 balena cloud

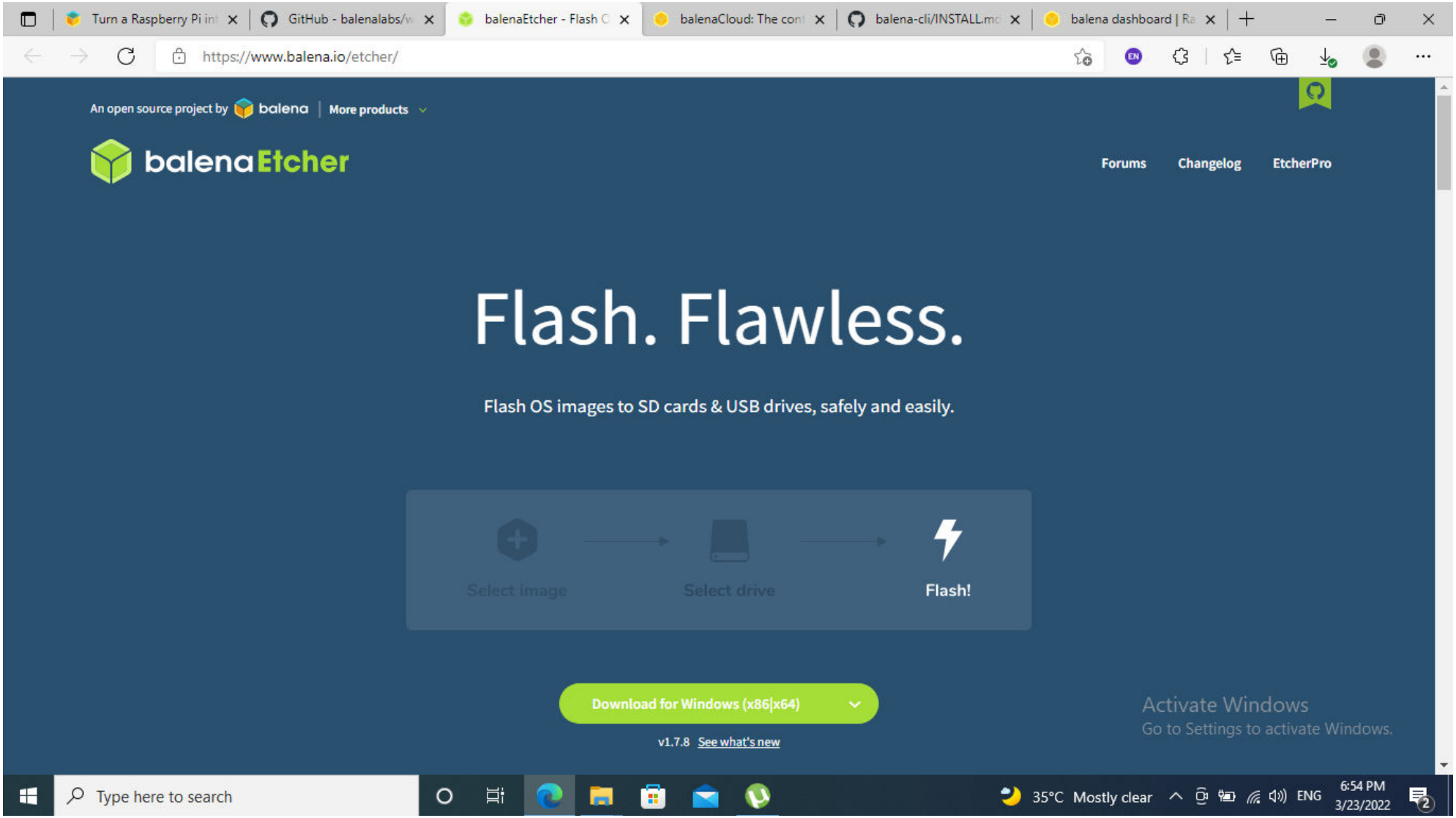


Figure 4.19 balena software loder

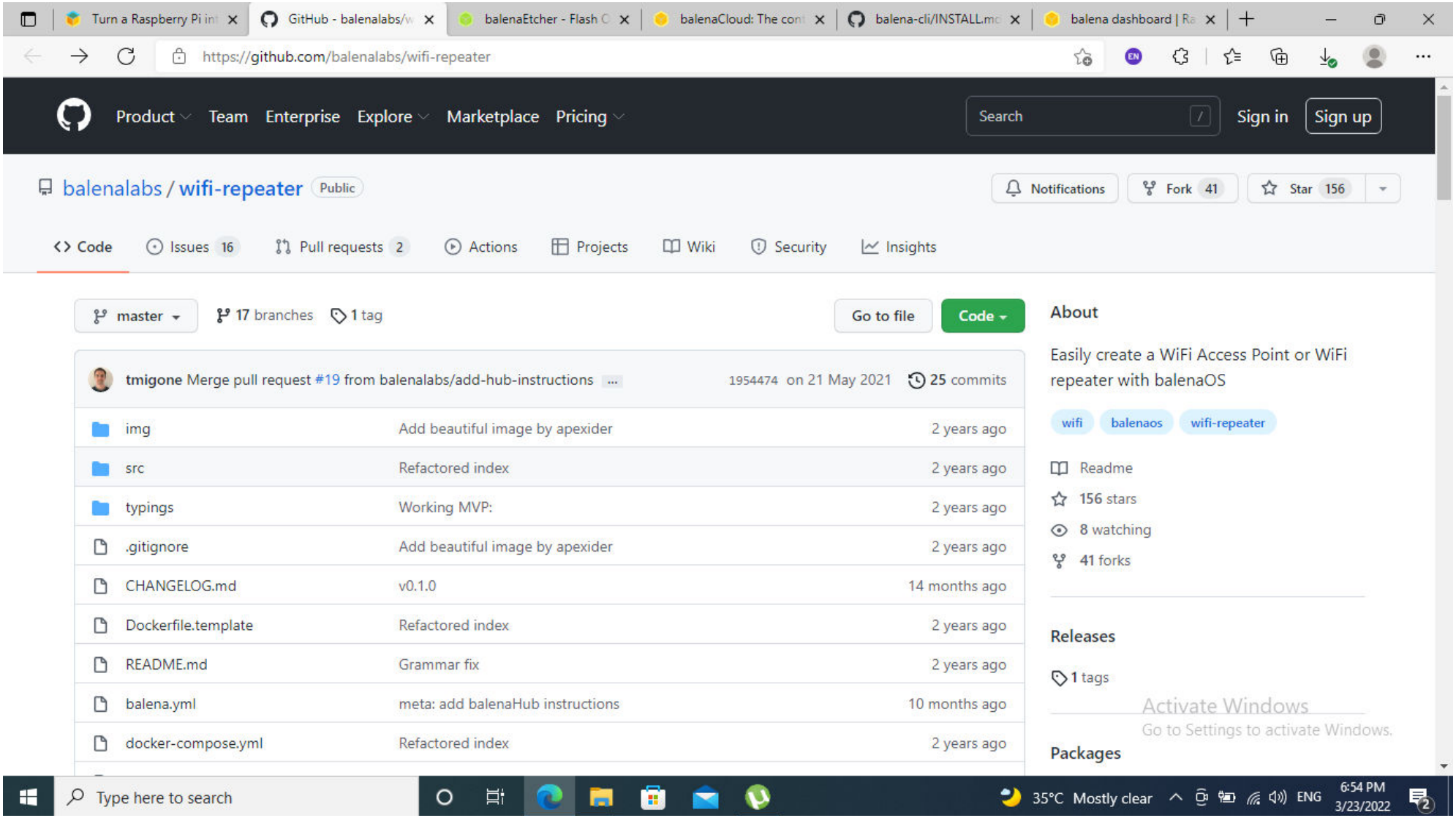


Figure 4.20 balena router code

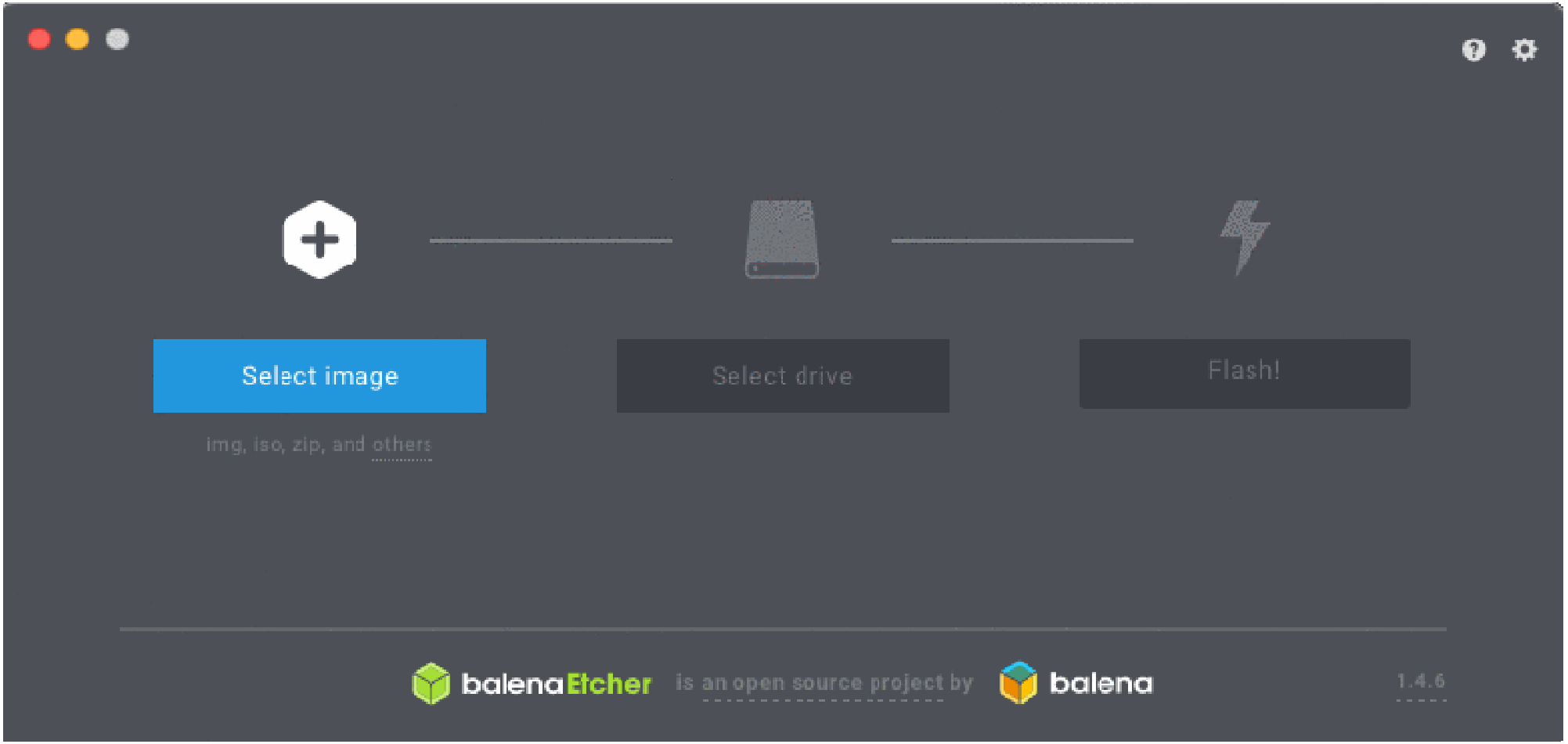


Figure 4.21balena software loder

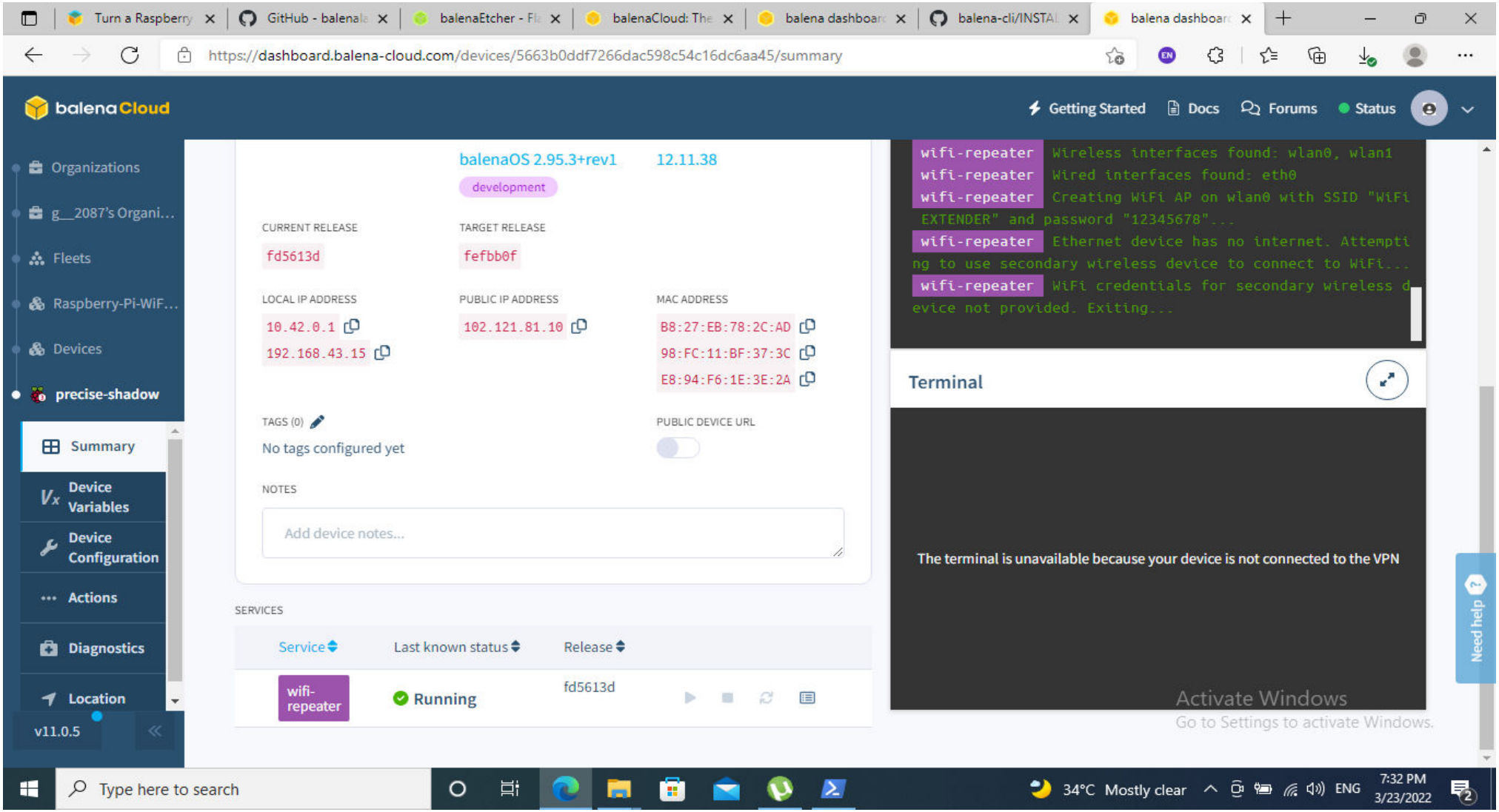


Figure 4.22 router setting

Chapter Five

Conclusions and Recommendations

Chapter Five

Conclusions and Recommendations

5.1 Conclusion

Navigating through the various networking devices can be a daunting task at first. Most of the devices you see in the networking field look similar but perform differently. Each device has its own personal function which can range from necessary to make your network work to a device that acts more like an accessory to your network. One of these devices which can help your network is a wireless repeater. Making the decision to use a wireless repeater can come to a couple different reasons. Mostly importantly is that you are looking to increase range in your network. Maybe the network signal just isn't strong enough in your home or office. You'll search for ways to improve on this and you come across a wireless repeater. Some of the things that can be improved using a wireless repeater is extending that network to places that are lacking signal strength, have many users on the same network or you even want some access outside. A repeater is a viable option for many but real world performance might not be what you're looking for. Wi-Fi repeater are really just a quick fix to a lack lustre network signal that can't be reached via hard wiring. This is why we always recommend to hard wire with Bulk Ethernet Cable when you can.

5.2 Recommendations

1. Decide where you want to install the wireless repeater. Keeping it a reasonable amount of distance from the first router or wireless access point can help with performance. Common places for this can be another floor or in the basement. Keep in mind that concrete can have an effect on performance so keeping it on a wooden wall can give a benefit.
2. Find the most accessible AC power outlet in your location you have chosen. Make sure there isn't anything obstructing it such as other cables.
3. In future research our recommendations to use smart signal search.
4. In future researches our recommendations to use gun antenna to increase signal density.

References

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[3] W, E., 2021. Wifi Extender. [Online] Available at: www.mywifiext-helpnumber.com [Accessed 11 September 2021].

[4] file:///C:/Users/ahmed/Desktop/Proposal/1-s2.0-S1876610217364329-main.pdf

[5] file:///C:/Users/ahmed/Desktop/Proposal/27_turk.pdf

[6] file:///C:/Users/ahmed/Desktop/Proposal/SCIENCE_and_TECHNOLOGY_The _Development_o.pdf

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[12] Dione Gardner-Stephen Serval Project Inc. Adelaide, Australia Matthew Lloyd New Zealand Red Cross Wellington, New Zealand Wireless Communication: Introduction, Types and Applications (electronicshub.org).

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APPENDEX

Wi-Fi Extender CLICommands

[Info] Starting build for raspberry-pi-wifi-extender, user g__2087

[Info] Dashboard link: https://dashboard.balena-cloud.com/apps/1918331/devices

[Info] Building on arm06

[Info] Pulling previous images for caching purposes...

[Success] Successfully pulled cache images

[wifi-repeater] Step 1/12 : FROM balenalib/raspberrypi3-node:12-build as builder

[wifi-repeater] ---> 4cd3c3d751b3

[wifi-repeater] Step 2/12 : WORKDIR /usr/src

[wifi-repeater] Using cache

[wifi-repeater] ---> a7b9fd5547ee

[wifi-repeater] Step 3/12 : RUN install_packages python

[wifi-repeater] Using cache

[wifi-repeater] ---> ac141b070f52

[wifi-repeater] Step 4/12 : RUN npm install blinking

[wifi-repeater] Using cache

[wifi-repeater] ---> 4ae8c4a5e822

[wifi-repeater] Step 5/12 : FROM balenalib/raspberrypi3-node:12-run

[wifi-repeater] ---> 47fddc7f5a45

[wifi-repeater] Step 6/12 : ENV DBUS_SYSTEM_BUS_ADDRESS=unix:path=/host/run/dbus/system_bus_socket

[wifi-repeater] Using cache

[wifi-repeater] ---> 4d03e866d948

[wifi-repeater] Step 7/12 : RUN install_packages dbus

[wifi-repeater] Using cache

[wifi-repeater] ---> 745b3b906622

[wifi-repeater] Step 8/12 : WORKDIR /usr/src

[wifi-repeater] Using cache

[wifi-repeater] ---> 0a591d7f87ef

[wifi-repeater] Step 9/12 : COPY . .

[wifi-repeater] ---> acbdc79ebb17

[wifi-repeater] Step 10/12 : COPY --from=builder /usr/src .

[wifi-repeater] ---> 7b77f7edbd66

[wifi-repeater] Step 11/12 : RUN npm install && npm run build

[wifi-repeater] ---> Running in 24326af9f660

[wifi-repeater] > abstract-socket@2.1.1 install /usr/src/node_modules/abstract-socket

[wifi-repeater] > node-gyp rebuild

[wifi-repeater] gyp

[wifi-repeater] ERR!

[wifi-repeater]

[wifi-repeater] find Python

[wifi-repeater]

[wifi-repeater] gyp

[wifi-repeater]

[wifi-repeater] ERR!

[wifi-repeater] find Python

[wifi-repeater] Python is not set from command line or npm configuration

[wifi-repeater] gyp

[wifi-repeater] ERR!

[wifi-repeater] find Python Python is not set from environment variable PYTHON

[wifi-repeater]

[wifi-repeater] gyp

[wifi-repeater] ERR!

[wifi-repeater] find Python checking if "python" can be used

[wifi-repeater]

[wifi-repeater] gyp

[wifi-repeater] ERR!

[wifi-repeater] find Python - "python" is not in PATH or produced an error

[wifi-repeater] gyp

[wifi-repeater] ERR!

[wifi-repeater] find Python checking if "python2" can be used

[wifi-repeater]

[wifi-repeater] gyp

[wifi-repeater] ERR!

[wifi-repeater] find Python - "python2" is not in PATH or produced an error

[wifi-repeater]

[wifi-repeater] gyp

[wifi-repeater] ERR!

[wifi-repeater] find Python

[wifi-repeater] checking if "python3" can be used

[wifi-repeater] gyp

[wifi-repeater] ERR!

[wifi-repeater] find Python - "python3" is not in PATH or produced an error

[Wifi-repeater]

[wifi-repeater] gyp ERR!

[wifi-repeater] find Python

[wifi-repeater]

[wifi-repeater] gyp

[wifi-repeater] ERR! find Python

[wifi-repeater]

****

[wifi-repeater] gyp

[wifi-repeater] ERR! find Python You need to install the latest version of Python.

[wifi-repeater]

[wifi-repeater] gyp

[wifi-repeater] ERR!

[wifi-repeater] find Python

[wifi-repeater] Node-gyp should be able to find and use Python. If not,

[wifi-repeater] gyp ERR! find Python

[wifi-repeater] you can try one of the following options:

[wifi-repeater] gyp

[wifi-repeater] ERR! find Python

[wifi-repeater] - Use the switch --python="/path/to/pythonexecutable"

[wifi-repeater]

[wifi-repeater] gyp

[wifi-repeater] ERR! find Python

[wifi-repeater] (accepted by both node-gyp and npm)

[wifi-repeater] gyp

[wifi-repeater] ERR! find Python

[wifi-repeater] - Set the environment variable PYTHON

[wifi-repeater] gyp

[wifi-repeater] ERR! find Python

[wifi-repeater] - Set the npm configuration variable python:

[wifi-repeater]

[wifi-repeater] gyp ERR!

[wifi-repeater] find Python npm config set python "/path/to/pythonexecutable"

[wifi-repeater] gyp

[wifi-repeater]

[wifi-repeater] ERR!

[wifi-repeater] find Python For more information consult the documentation at:

[wifi-repeater] gyp

[wifi-repeater]

[wifi-repeater] ERR!

[wifi-repeater]

[wifi-repeater] find Python

[wifi-repeater] https://github.com/nodejs/node-gyp#installation

[wifi-repeater] gyp

[wifi-repeater] ERR!

[wifi-repeater] find Python

****

[wifi-repeater] gyp

[wifi-repeater] ERR!

[wifi-repeater] find Python

[wifi-repeater]

[wifi-repeater] gyp

[wifi-repeater] ERR!

[wifi-repeater] configure error

[wifi-repeater]

[wifi-repeater] gyp ERR!

[wifi-repeater] stack

[wifi-repeater] Error: Could not find any Python installation to use

[wifi-repeater] gyp

[wifi-repeater] ERR! stack

[wifi-repeater] at PythonFinder.fail (/usr/local/lib/node_modules/npm/node_modules/node-gyp/lib/find-python.js:307:47)

[wifi-repeater] gyp

[wifi-repeater] ERR! stack

[wifi-repeater] at PythonFinder.runChecks (/usr/local/lib/node_modules/npm/node_modules/node-gyp/lib/find-python.js:136:21)

[wifi-repeater]

[wifi-repeater] gyp

[wifi-repeater] ERR!

[wifi-repeater] stack at PythonFinder.<anonymous> (/usr/local/lib/node_modules/npm/node_modules/node-gyp/lib/find-python.js:179:16)

[wifi-repeater] gyp

[wifi-repeater]

[wifi-repeater] ERR!

[wifi-repeater]   stack

[wifi-repeater]   at PythonFinder.execFileCallback (/usr/local/lib/node_modules/npm/node_modules/node-gyp/lib/find-python.js:271:16)

[wifi-repeater] gyp

[wifi-repeater] ERR!

[wifi-repeater] stack   at exithandler (child_process.js:315:5)

[wifi-repeater]

[wifi-repeater] gyp ERR!

[wifi-repeater] stack   at ChildProcess.errorhandler (child_process.js:327:5)

[wifi-repeater] gyp

[wifi-repeater]   ERR!

[wifi-repeater]

[wifi-repeater] stack

[wifi-repeater]   at ChildProcess.emit (events.js:314:20)

[wifi-repeater] gyp

[wifi-repeater] ERR! stack

[wifi-repeater]   at Process.ChildProcess._handle.onexit (internal/child_process.js:274:12)

[wifi-repeater] gyp

[wifi-repeater]   ERR!

[wifi-repeater]   stack

[wifi-repeater]   at onErrorNT (internal/child_process.js:470:16)

[wifi-repeater] gyp

[wifi-repeater] ERR!

[wifi-repeater] stack at processTicksAndRejections (internal/process/task_queues.js:84:21)

[wifi-repeater]

[wifi-repeater] gyp ERR!

[wifi-repeater]

[wifi-repeater] System Linux 5.4.0-72-generic

[wifi-repeater]

[wifi-repeater] gyp ERR!

[wifi-repeater] command "/usr/local/bin/node" "/usr/local/lib/node_modules/npm/node_modules/node-gyp/bin/node-gyp.js" "rebuild"

[wifi-repeater]

[wifi-repeater] gyp ERR!

[wifi-repeater] cwd

[wifi-repeater] /usr/src/node_modules/abstract-socket

[wifi-repeater]

[wifi-repeater] gyp ERR!

[wifi-repeater] node -v v12.22.9

[wifi-repeater]

[wifi-repeater] gyp ERR!

[wifi-repeater] node-gyp -v v5.1.0

[wifi-repeater]

[wifi-repeater] gyp ERR!

[wifi-repeater] not ok

[wifi-repeater]

[wifi-repeater]

[wifi-repeater] npm WARN

[wifi-repeater]   balenarepeater@0.1.0 No repository field.

[wifi-repeater]

[wifi-repeater] npm WARN optional

[wifi-repeater]   SKIPPING OPTIONAL DEPENDENCY: abstract-socket@2.1.1 (node_modules/abstract-socket):

[wifi-repeater]

[wifi-repeater] npm

[wifi-repeater] WARN

[wifi-repeater]   optional

[wifi-repeater]   SKIPPING OPTIONAL DEPENDENCY: abstract-socket@2.1.1 install: `node-gyp rebuild`

[wifi-repeater] npm

[wifi-repeater]   WARN

[wifi-repeater]

[wifi-repeater] optional

[wifi-repeater]   SKIPPING OPTIONAL DEPENDENCY: Exit status 1

[wifi-repeater]

[wifi-repeater]

[wifi-repeater]

[wifi-repeater] added 21 packages from 97 contributors, removed 1 package, updated 1 package and audited 28 packages in 3.915s

[wifi-repeater] 1 package is looking for funding

[wifi-repeater]   run `npm fund` for details

[wifi-repeater] found 3 vulnerabilities (1 low, 1 moderate, 1 high)

[wifi-repeater] run `npm audit fix` to fix them, or `npm audit` for details

[wifi-repeater] > balenarepeater@0.1.0 build /usr/src

[wifi-repeater] > tsc --project tsconfig.json

[wifi-repeater] Removing intermediate container 24326af9f660

[wifi-repeater] ---> 312e8fe9792c

[wifi-repeater] Step 12/12 : CMD ["node", "/usr/src/build/index.js"]

[wifi-repeater] ---> Running in 5917c30aa367

[wifi-repeater] Removing intermediate container 5917c30aa367

[wifi-repeater] ---> 71a1d2dbd807

[wifi-repeater] Successfully built 71a1d2dbd807

[Info] Generating image deltas from release fd5613da8b43058c43303c3d98141985 (id: 2112197)

[Success] Successfully generated image deltas

[Info] Uploading images

[Success] Successfully uploaded images

[Info] Built on arm06

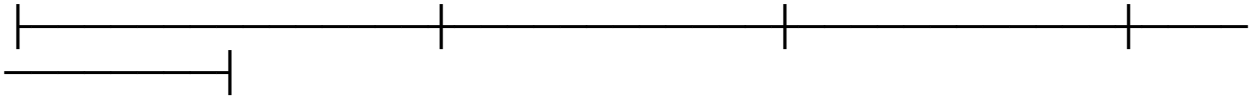
[Success] Release successfully created!

[Info] Release: fefbb0feca8b14bc109b066bd96fb55d (id: 2112282)

[Info]

[Info] │ Service │ Image Size │ Delta Size │ Build Time │

[Info]



[Info] │ wifi-repeater │ 303.76 MB │ 442.41 KB │ 53 seconds │

[Info] ┗━━━━━━━━━━━━━━━━━━━━┻━━━━━━━━━━━━━━━━━━━━┻━━━━━━━━━━━━━━━━━━━━┻━━━━━━
━━━━━━━━┛

[Info] Build finished in 2 minutes, 51 seconds

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