(FULL) Setting up Wireguard on VPS

Introduction

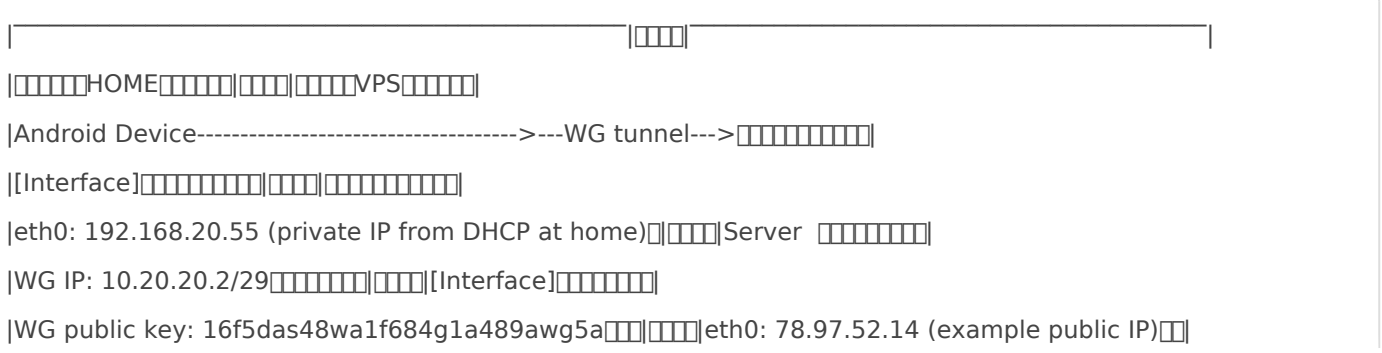
You have one or more services running on a VPS somewhere. Because the VPS is sitting on the internet with a public IP, the easiest way to access it is by exposing a port on that VPS where the service is running. This, however, opens up a load of possible security issues. Because now anyone on the internet can access the service just like you. This is perfectly fine in most cases, I mean, all websites that you browse work this way – they are exposed so that people can access them. You may have some form of 2FA or other application-level security method setup, but that doesn't help mitigate vulnerabilities in the application itself. By limiting access to your application in the first place, you covering a large part of the attack surface. **All of this by leveraging the power of VPN technology.**

Setup Plan

Currently, all services on my VPS are listening on the server's public IP, which is the only network interface together with localhost. Here's what we will do:

1. Install and setup Wireguard interface on the server
2. Setup clients
3. Stop all services and bind them only to the Wireguard interface
4. Adjust firewall rules according to our new setup

> This guide assumes that you will access these services only from a few devices. If, for example, you would like to provide your whole home network with access to the services running on your VPS, you will have to do it a bit differently.



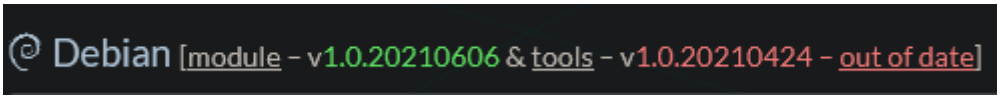
```
|WG private key: gzf74894ger89a46sd14g84r8esg□□|□□□□|WG IP: 10.20.20.1/29□□□□□□|
|□□□□□□□□□□□□□□|□□□□|WG public key: 6t57489hgnufjfiosdjjfp98h□|
|Windows Device--------------------------------------->---WG tunnel--->WG private key: 4gfd89a7g1fd56g848g4fdg41fd|
|[Interface]□□□□□□□□□□|□□□□|□□□□□□□□□□□□|
|eth0: 192.168.20.56 (private IP from DHCP at home)□|□□□□|□□□□□□□□□□□□|
|WG IP: 10.20.20.3/29□□□□□□□□|□□□□|□□□□□□□□□□□□|
|WG public key: fgd489fdsg84168e46g1514ge5g□□□|□□□□|□□□□□□□□□□□□|
|WG private key: iyut789tr496516sh416g4164h6h□□|□□□□|□□□□□□□□□□□□|
|_____|□□□□|_____|
```

**note: don't worry, the public and private keys in the diagram are just random placeholder values*

Installation on the VPS

Since we are running Debian, we can get Wireguard from the official repository. I usually prefer building software from source, but for the sake of this guide, I will go the easier route and simply use the repo version.

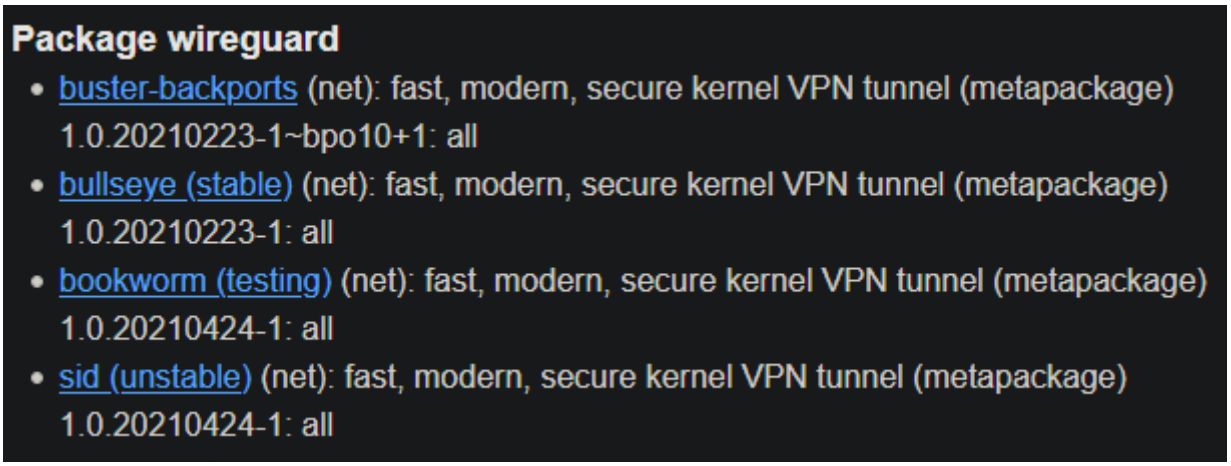
> Note that since it's Debian, the packages are sometimes a bit outdated. At the time of writing, the tools weren't available in the newest version – even in the unstable repo. The default stable repo has even older packages.



The situation around Debian and Wireguard is a bit confusing. Debian is known to be stable but has older packages. If you don't want to worry about anything, just install it from the stable repo:

```
$ sudo apt install wireguard
```

However, if you are on Debian 10, Wireguard still isn't integrated into the 4.19 kernel, which means the installation will bring the wireguard-dkms (Dynamic Kernel Module Support) package as well. On Debian 11, this should not be necessary, because Wireguard is already natively in the 5.10 kernel (which is default for Debian 11). I have it a bit more complicated. I am in fact running Debian 11, but with the 5.4 kernel (backported from Debian 10), which also doesn't have Wireguard natively, but that's just a side note. You can see the version status of the Wireguard package here:



To find out how to add testing or unstable to Debian 11, check out my guide over here.

Configure Wireguard on the server

The main configuration folder is located in `/etc/wireguard`. This directory will contain both configuration and private/public key, therefore it is only accessible with root by default. To get to this directory, you need to elevate privileges.

```
$ sudo su
(root)$ cd /etc/wireguard/
```

Create configuration file for the Wireguard interface

Create a new file in `/etc/wireguard`. The name of the file will also be the name of the interface (like eth0,lo,etc.) + .conf file extension. I like the default naming, so I will use name it `wg0.conf`. Before creating the file, change `umask` to `077`, so that the file is readable only by root. `Umask` controlls what permissions will newly created files and directories have. The default umask is `022`. When we use the `umask` command with a different number, all new files and directories will be created under permissions we have set. This modifies the default `umask` value only for the current sub-shell. To go back to the default `umask`, just logout/login. You can also make the changes permanent if you want. You can read more about `umask` here.

```
(root)$ umask 077


(root)/etc/wireguard$ touch wg0.conf
```

Prepare wg0.conf

Open `wg0.conf` with your favorite editor.

```
(root)$ vi /etc/wireguard/wg0.conf
```

We can slowly start preparing the config file, step by step. Right now, add the `[Interface]` block, which will define properties of the server's Wireguard interface.

- `Address` – The local IP of the server within the Wireguard tunnel and subnet mask in CIDR notation. I know I will only have 3 clients, therefore I picked a small subnet `/29` with only 6 usable hosts. (Basic subnetting knowledge is required).
- `ListenPort` – The port on the server Wireguard will use to communicate with other peers. After everything is set up, this will be the only port exposed to the open internet. If left unspecified, default is `51820`.
- `PrivateKey` – The private key of the server that will be generated in a moment. **This key should never be shared or leave the server. We will only send out the public key** (as the name suggests).

> **Always keep private keys on devices where they were created. They should never be moved accross network or even accross devices.**

The `wg0.conf` file should look like this right now:

```
[Interface]
Address = 10.20.20.1/29
ListenPort = 51895
PrivateKey =
```

Generate server public/private keys

Wireguard is built around the public and private key pairs structure. There is technically no such a thing as *client* or *server* in Wireguard, because everything is a *peer*. We use the *client/server* terminology to help our mind imagine the setup better. Each *peer* will generate its own private and public key. The **private key** will never leave the device where it originated from and should be kept well secured. The **public key** will be copied over to the other peers. In my case, the VPS will become a *peer* to both the Android and Windows device (*clients*). However, Android nor Windows will even know about each other, they will only be aware of the VPS, which will be their only *peer*. Reason for this is that they only need to talk to the VPS, not to each other.

Still as root, with `umask` set to `0077` (check by typing `umask` in the terminal) and in the `/etc/wireguard` directory, create a new subdirectory for the public/private keys and preshared keys (will explain in a second).

```
(root)$ mkdir keys psk
```

Navigate to the `keys` directory and generate the server key pair.

```
(root)$ cd keys
(root)$ wg genkey | tee wg0_private.key | wg pubkey > wg0_public.key
```

The `wg genkey` command generates a random *private* key in base64 and prints it to standard output (terminal). The output is instead redirected to `tee`, which both prints it to stdout (terminal), but also saves it into a file `wg0_private.key`. The private key printed to stdout is then piped (`|` symbol) to `wg pubkey`, which calculates the public key and prints it in base64 to stdout from a corresponding private key (the one we redirected to it with the pipe), lastly redirect the public key from stdout to a file `wg0_public.key`

Now we have two files in the `keys` directory:

```
(root)$ ls


wg0_private.key  wg0_public.key
```

Generate preshared keys

> This option adds an additional layer of symmetric-key cryptography to be mixed into the already existing public-key cryptography, for post-quantum resistance (for paranoid people like me).

From the [Wireguard whitepaper]:

> In order to mitigate any future advances in quantum computing, WireGuard also supports a mode in which any pair of peers might additionally pre-share a single 256-bit symmetric encryption key between themselves, in order to add an additional layer of symmetric encryption. The attack model here is that adversaries may be recording encrypted traffic on a long term basis, in hopes of someday being able to break Curve25519 and decrypt past traffic. While pre-sharing symmetric encryption keys is usually troublesome from a key management perspective and might be more likely stolen, the idea is that by the time quantum computing advances to break Curve25519, this pre-shared symmetric key has been long forgotten. And, more importantly, in the shorter term, if the pre-shared symmetric key is compromised, the Curve25519 keys still provide more than sufficient protection. In lieu of using a completely post-quantum crypto system, which as of writing are not practical for use here, this optional hybrid approach of a pre-shared symmetric key to complement the elliptic curve cryptography provides a sound and acceptable trade-off for the extremely paranoid. Furthermore, it allows for building on top of WireGuard sophisticated key-rotation schemes, in order to achieve varying types of post-

> compromise security.

Move to the `psk` directory and generate preshared keys for each of the clients. The preshared key will then be part of both the server and client configuration file.

```
(root)$ cd /etc/wireguard/psk
(root)$ wg genpsk > android_client.psk
(root)$ wg genpsk > windows10_client.psk
```

Again, there should be 2 files in the directory, one for each client.

```
(root)$ ls


android_client.psk  windows10_client.psk
```

Edit wg0.conf

Open the config file again and fill in some of the remaining information:

```
[Interface]
Address = 10.20.20.1/29
ListenPort = 51895
PrivateKey = your_private_key

[Peer]
PublicKey =
PresharedKey = your_preshared_key_for_this_client
AllowedIPs = 10.20.20.2/32

[Peer]
PublicKey =
PresharedKey = your_preshared_key_for_this_client
AllowedIPs = 10.20.20.3/32
```

> Open two terminals – one with `wg0.conf` in editor and the other in `/etc/wireguard/` directory. Now use `cat` to print contents of your newly generated key files to the terminal and simply copy and paste them to the editor.

`AllowedIPs` – IP address within the Wireguard tunnel for each peer in CIDR notation. Wireguard will accept only packets coming from these specific IP ranges or from a single IP of the client when

used with `/32`.

This is it for now, we will come back to the config file in a moment.

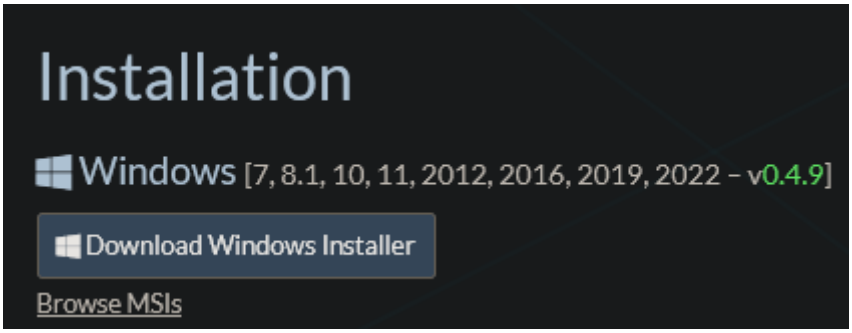
> Remember which peer is which. The first one is for the Android device, while the second one is for the Windows client.

Setting up the clients

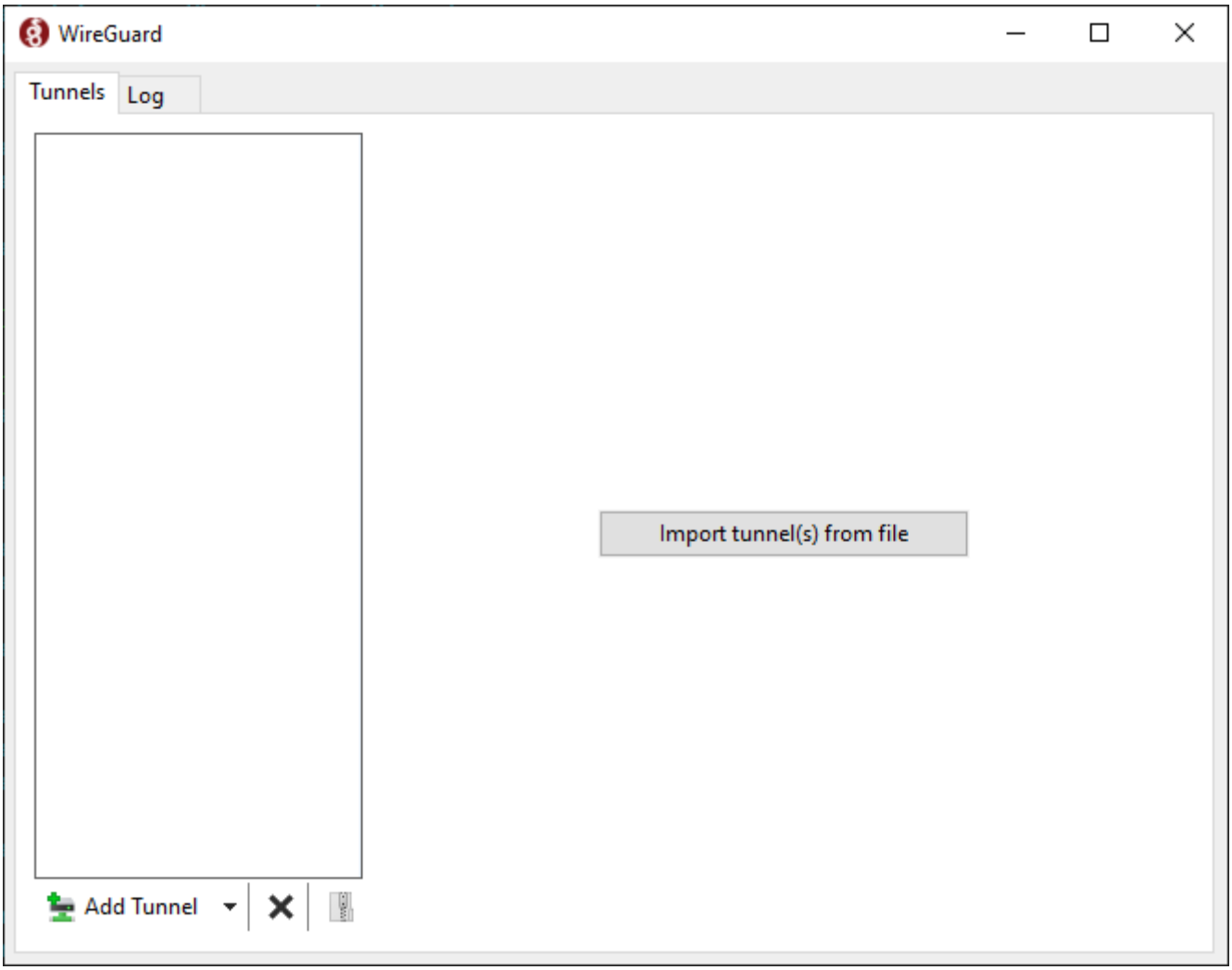
1. Windows

Download and install Wireguard

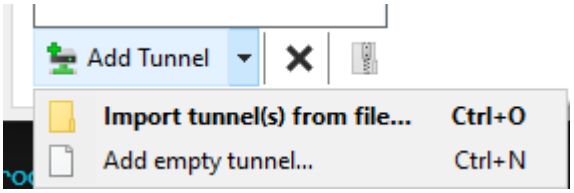
Download the Windows Installer from the official Wireguard website.



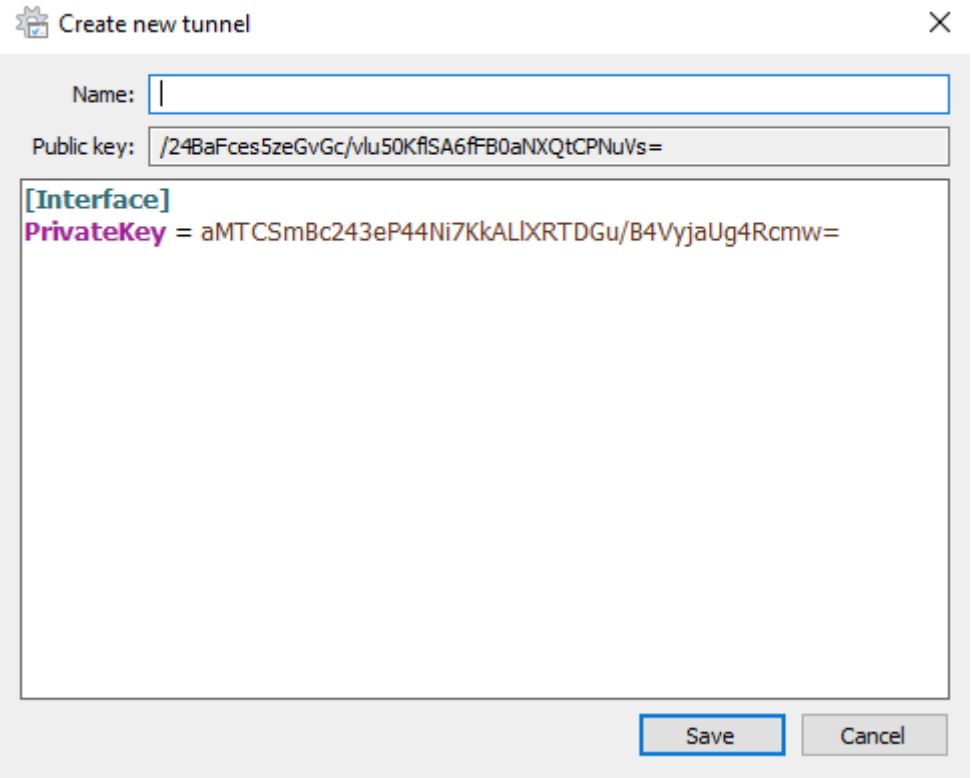
Run the `wireguard-installer.exe` and after a few moments, this window should appear:



Click the arrow next to `Add Tunnel` and select `Add empty tunnel...`



Wireguard will automatically generate a private and public key for this client.



**note: all keys shown will be destroyed afterwards and are only used for demonstration purposes*

Pick a name for the new tunnel, can be anything without spaces. Fill in the client config like I did:

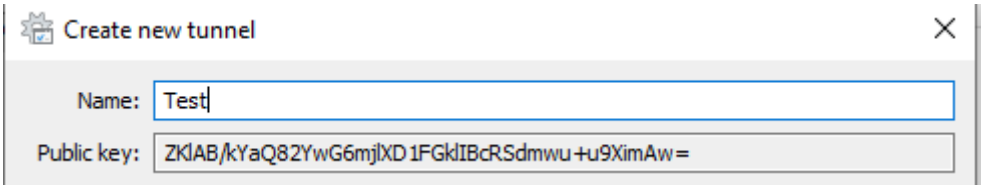
```
[Interface]
PrivateKey = your_private_key
Address = 10.20.20.3/29

[Peer]
PublicKey = public_key_of_the_server
PresharedKey = preshared_key_from_server
AllowedIPs = 10.20.20.1/32
Endpoint = public_server_ip:51895
```

- `PrivateKey` – Private key of the client that it just generated
- `Address` – Client's IP within the Wireguard tunnel
- `[Peer]` – Configuration block with information about the VPS (the other end of the Wireguard tunnel)
- `PublicKey` – The public key of the server. Use cat to print the file `/etc/wireguard/keys/wg0_public.key` to the terminal and copy & paste it here.
- `PresharedKey` – Preshared key generated on the server to the `psk` directory, named `windows10_client.psk`.
- `AllowedIPs` – Only traffic destined for the `10.20.20.1/32` network will go through the Wireguard tunnel (32 is only 1 host). To make all traffic go through the tunnel, put `0.0.0.0/0` to the same field.

- `Endpoint` – The public IP address and port on your Wireguard server. Run `ip a` on the server to get it.

Add Windows client public key to the server config

Copy this public key and paste it into `wg0.conf` on the server to the `PublicKey` line in the corresponding (second) `[Peer]` block.



Server `/etc/wireguard/wg0.conf`

```
[Interface]
Address = 10.20.20.1/29
ListenPort = 51895
PrivateKey = your_private_key

[Peer]
PublicKey =
PresharedKey = your_preshared_key_for_this_client
AllowedIPs = 10.20.20.2/32

[Peer]
PublicKey = public_key_from_the_windows_client
PresharedKey = your_preshared_key_for_this_client
AllowedIPs = 10.20.20.3/32
```

> Windows client should now be set up, before testing, make sure you have completed the following:

- **On the Windows client:**
  - `Address` in the `[Interface]` block is correct and same as `AllowedIPs` in `[Peer]` block on the server (expect the number after /, that can be different)
  - `PublicKey` is filled with the key from `/etc/wireguard/keys/wg0_public.key` from the server.
  - `PresharedKey` is filled with the key from `/etc/wireguard/psk/windows10_client.psk`.
  - `AllowedIPs` is set to the Wireguard local IP of the server with `/32` subnet mask.
  - `Endpoint` has the public IP of the server with the correct port.
- **On the server:**
  - `PublicKey` in the `[Peer]` block is copied from the Windows client.
  - `PresharedKey` is the same as on the client.

- `AllowedIPs` corresponds to the `Address` field on the client (expect the number after /, that can be different).

Test the Windows–Server connection

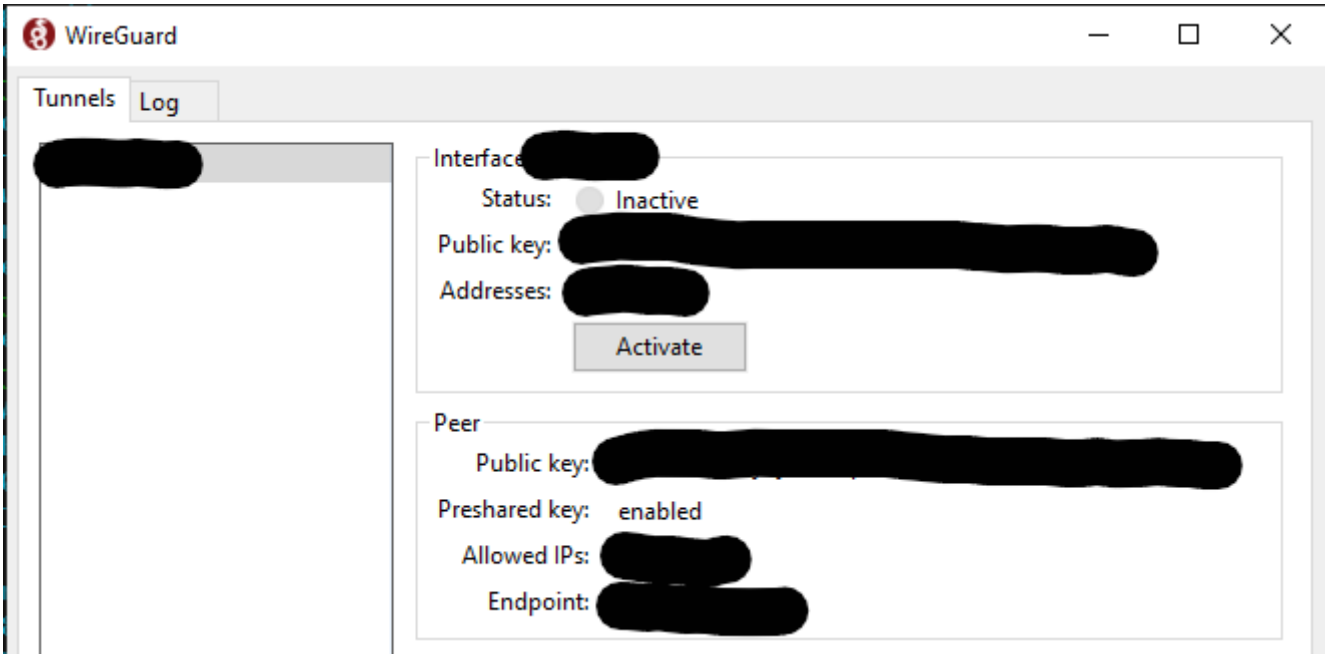
Make sure the firewall is set to allow communication on port `51895` on the server and comment out the other peer in `wg0.conf` like this:

```
[Interface]
Address = 10.20.20.1/29
ListenPort = 51895
PrivateKey = your_private_key

# [Peer]
# PublicKey =
# PresharedKey = your_preshared_key_for_this_client
# AllowedIPs = 10.20.20.2/32

[Peer]
PublicKey = public_key_from_the_windows_client
PresharedKey = your_preshared_key_for_this_client
AllowedIPs = 10.20.20.3/32
```

Start Wireguard interface on the server:

```
$ wg-quick up wg0

[#] ip link add wg0 type wireguard
[#] wg setconf wg0 /dev/fd/63
[#] ip -4 address add 10.20.20.1/29 dev wg0
[#] ip link set mtu 8920 up dev wg0
```

Start Wireguard tunnel on the Windows client by clicking *Activate:*



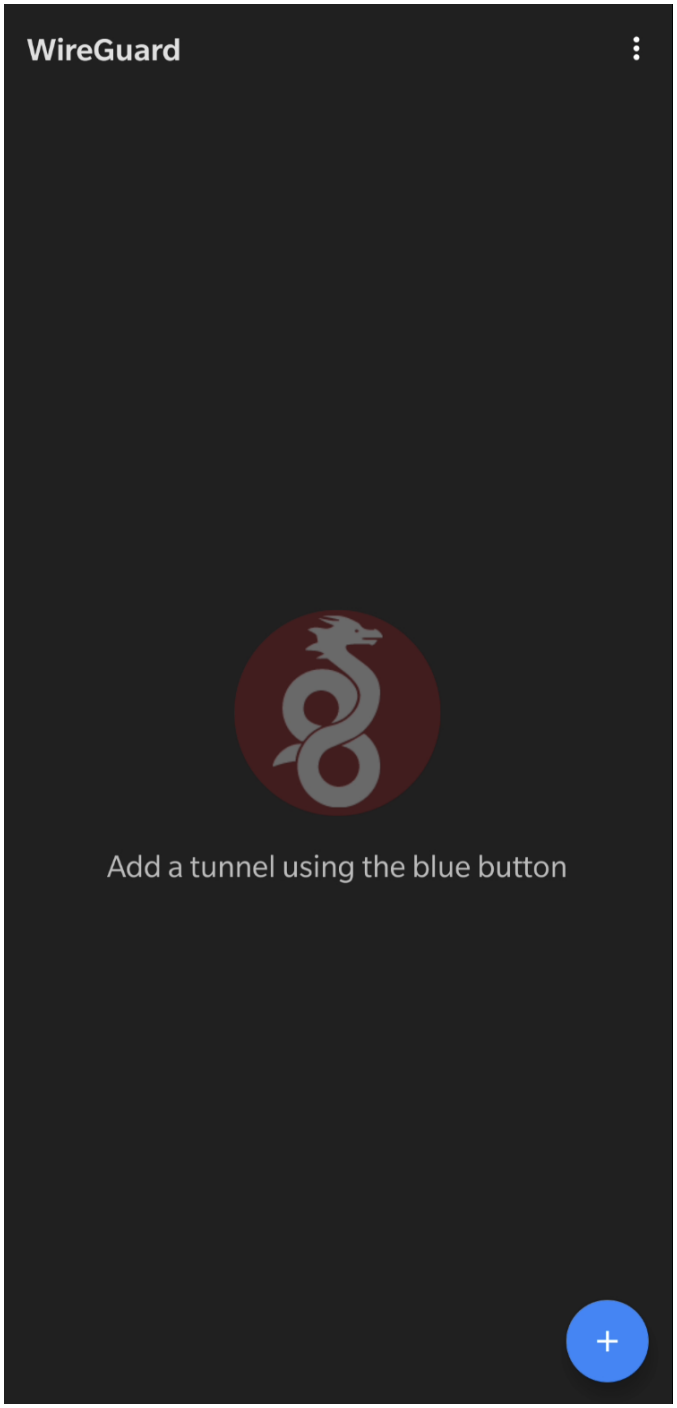
> The tunnel is now established, use ping from both devices to test connectivity.

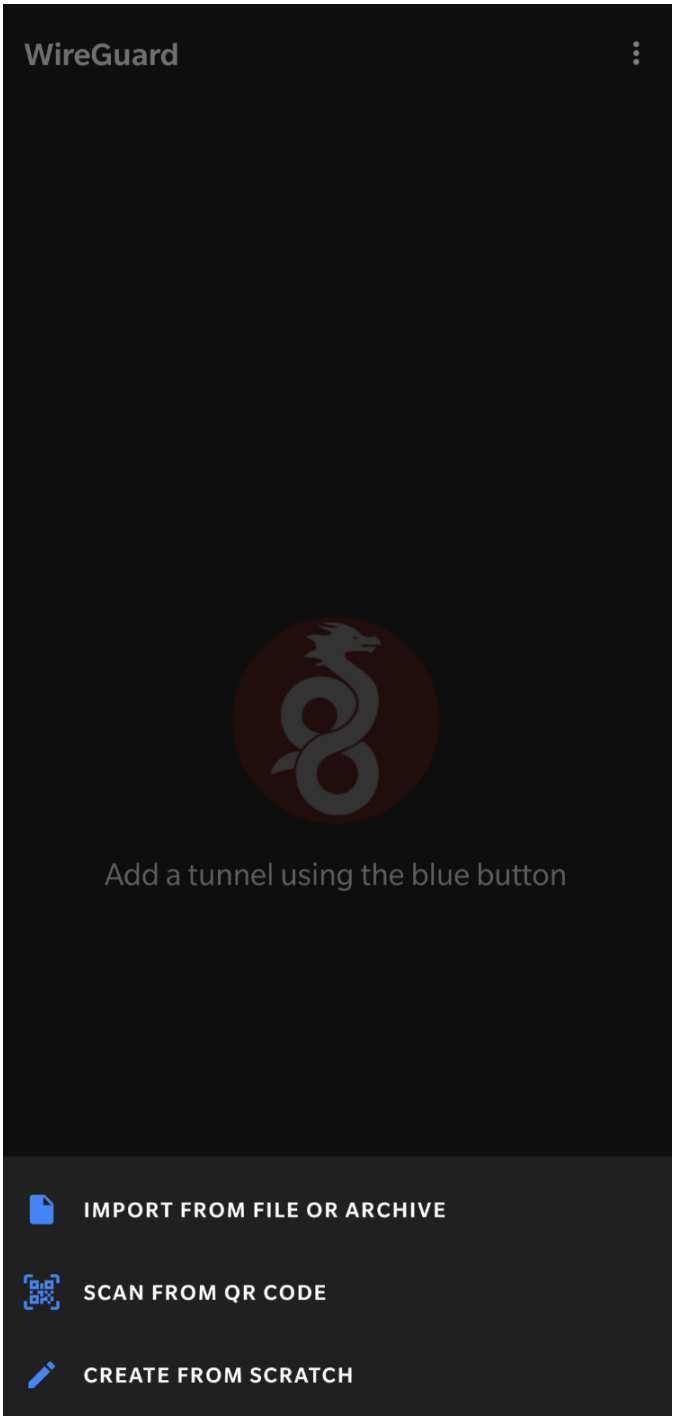
2. Android

Leave the Windows client for a while, we will come back to it later to finish some things.

Install Wireguard for Android

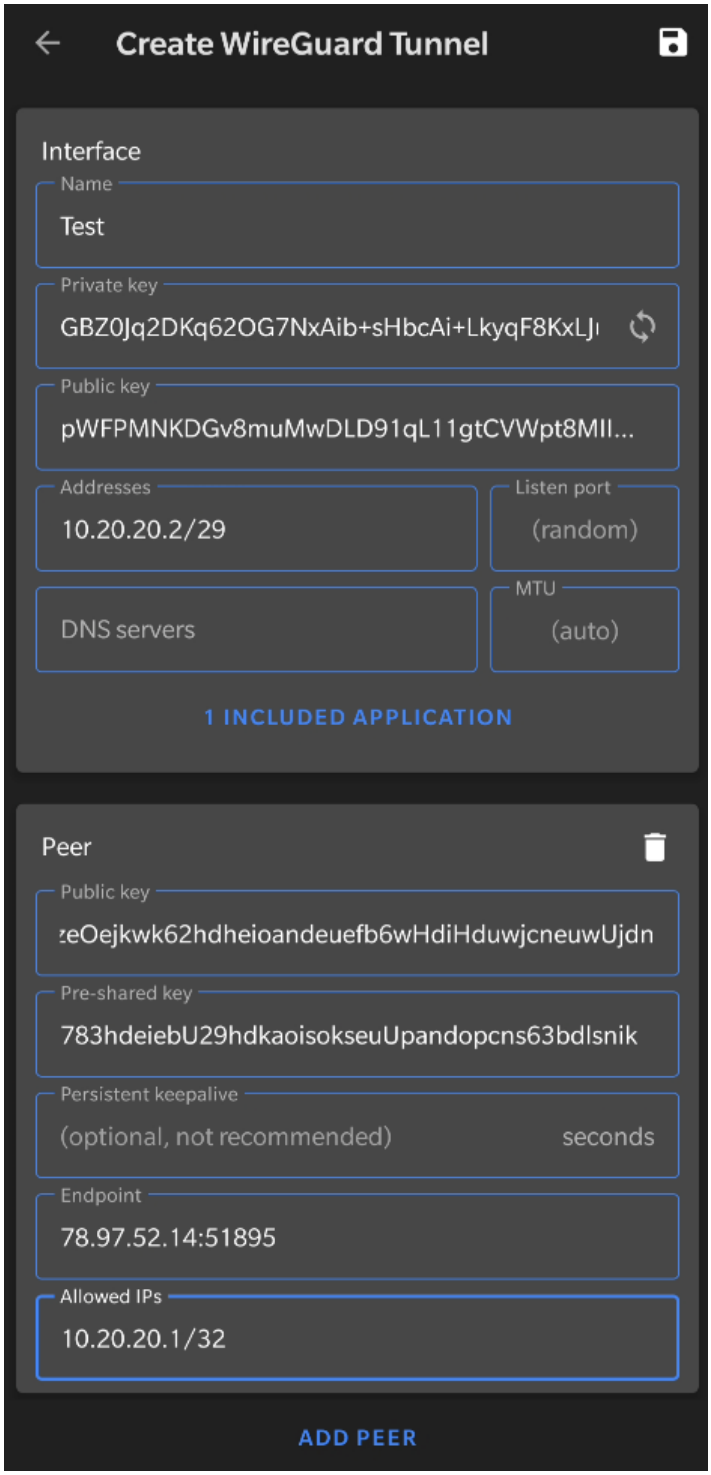
Wireguard can be installed from Google Play Store or preferably from F-Droid. Use option which suits you the best.





Wireguard allows you to create tunnels in 3 ways – import from file, scan QR code or create from scratch. The first two options are more convenient, however they require additional setup that we will leave for another blog post. I will use the third option now.

Configure Wireguard tunnel



`Interface`

- `Name` – Name for the interface
- `Private key` – Will be generated on the device and hidden by default, keep it secret
- `Public key` – Derived from the Private key, will be shared with the server
- `Addresses` – IP address of this device within the Wireguard tunnel in `/29` subnet

`Peer`

- `Public key` – Public key of the server (`/etc/wireguard/keys/wg0_public.key`)
- `Pre-shared key` – Pre-shared key generated on the server (`/etc/wireguard/psk/android_client.psk`)
- `Endpoint` – Public IP address of the server with appropriate port (look into `/etc/wireguard/wg0.conf`, value of `ListenPort`)
- `Allowed IPs` – Wireguard IP of the server in `/32` subnet (only that IP), check `Address` field in `wg0.conf` on the server. To route everything through the VPN, use `0.0.0.0/0`

Additionally, if you want to restrict some apps from using the Wireguard interface, you can do so by clicking `All Applications` and either excluding or including some apps. I will only be using my web browser with the Wireguard tunnel to access my websites, therefore I include `Bromite` only (one of the best Android web browsers).

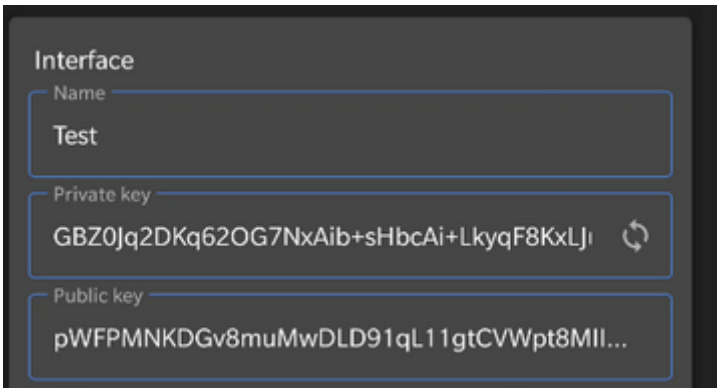
Click the save icon in the top right corner and you should see the name of the interface in the main menu. Toggle it on by clicking the button next to it or edit by clicking on the name.

Add Android client to the server config

The Android client should be fully set up for now. Go back to the server and fill appropriate part of `wg0.conf`. Focus on the part we have commented out while testing the Windows client:

```
# [Peer]
# PublicKey =
# PresharedKey = your_android_preshared_key
# AllowedIPs = 10.20.20.2/32
```

Remove the hashtags (#) and fill in `PublicKey` with the Android's Public key from here:



> Either come up with a way to copy the public key over to the server or just carefully type it in manually.

Restart server interface

After editing the config, bring the Wireguard interface down and up again to reload the configuration.

```
$ sudo wg-quick down wg0
[#] ip link delete dev wg0


$ sudo wg-quick up wg0
[#] ip link add wg0 type wireguard
[#] wg setconf wg0 /dev/fd/63
[#] ip -4 address add 10.20.20.1/29 dev wg0
[#] ip link set mtu 8920 up dev wg0
```

Test the Android–Server connection

Make sure the server Wireguard interface is up and click the button next to the name of the Wireguard interface on Android. Android might ask you to confirm starting a VPN service and a little key icon will appear in the notification bar.

Try accessing `10.20.20.1` in you Android browser or ping it with Termux or other application.

> If you've done everything correctly, you should be able to ping the server from your client. For troubleshooting, try removing the pre-shared keys or check if you have copied all the keys correctly or if the firewall is not preventing communication on the Wireguard port.

Android – restricting apps

When configuring the Android client, we have restricted all apps, except for our web browser, from accessing the Wireguard tunnel. Therefore we aren't able to use ping in app like Termux to test connecitivity to the server. You can temporarily include all apps and save the configuration or navigate to `10.20.20.1` in the browser to perform a handshake with the server.

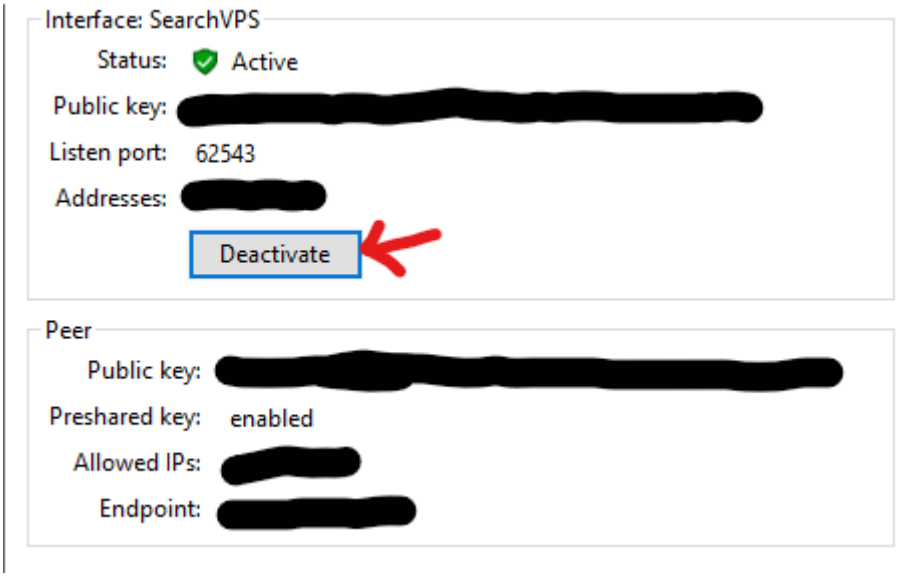
Wireguard and NAT

Wireguard is by design a very quiet protocol. If there's nothing to talk about then there's no data going through the tunnel. Communication only takes place when peers have some data to send. When there's no real data exchange happening, it seems like there is no tunnel at all. This works perfectly fine in configurations where all peers are reachable through a public IP address, because they can be reached at any moment by anyone. Peer 1 wants to talk to Peer 2? No problem. After 5 minutes, Peer 2 suddenly wants to send something to Peer 1? Totally okay, they can all reach each other.

But what if Peer 2 was instead hidden behind NAT? This is very common in consumer-grade internet connections or in mobile networks. They don't have public IPv4 addresses, simply because they don't need them. Now Peer 1 wants to talk to Peer 2, but how to get to it? There's no public IPv4 address and the firewalls between Peer 1 and Peer 2 have already forgot any previously established connections. You can test this yourself and see what happens. First of all, turn off all tunnels and wait a few moments.

Pinging server and clients

```
$ sudo wg-quick down wg0


[#] ip link delete dev wg0
```



Now bring both peers up again:

```
$ sudo wg-quick up wg0


[#] ip link add wg0 type wireguard
[#] wg setconf wg0 /dev/fd/63
[#] ip -4 address add 10.20.20.1/29 dev wg0
[#] ip link set mtu 8920 up dev wg0
```

Click `Activate` in Windows.

First of all, try pinging the client from the server. The server is `10.20.20.1` and client `10.20.20.3`

```
$ ping 10.20.20.3
PING 10.20.20.3 (10.20.20.3) 56(84) bytes of data.
From 10.20.20.3 icmp_seq=1 Destination Host Unreachable
ping: sendmsg: Destination address required
From 10.20.20.3 icmp_seq=2 Destination Host Unreachable
ping: sendmsg: Destination address required
From 10.20.20.3 icmp_seq=3 Destination Host Unreachable
ping: sendmsg: Destination address required
From 10.20.20.3 icmp_seq=4 Destination Host Unreachable
ping: sendmsg: Destination address required
From 10.20.20.3 icmp_seq=5 Destination Host Unreachable
ping: sendmsg: Destination address required
```

Wait...why? Both clients are running and have the Wireguard interface active, right? Well, because the client (`10.20.20.3`) is behind NAT and it hasn't contacted the server yet, the server doesn't know where to send the data.

Now ping the server (`10.20.20.1`) from the client (`10.20.20.3`). This works because the server (`10.20.20.1`) has a public IP and we can route the data to it this way.

```
PS C:\Users\Marek> ping 10.20.20.1


Pinging 10.20.20.1 with 32 bytes of data:
Reply from 10.20.20.1: bytes=32 time=87ms TTL=64
Reply from 10.20.20.1: bytes=32 time=42ms TTL=64
Reply from 10.20.20.1: bytes=32 time=42ms TTL=64
Reply from 10.20.20.1: bytes=32 time=42ms TTL=64

Ping statistics for 10.20.20.1:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
```

```
Approximate round trip times in milli-seconds:
    Minimum = 42ms, Maximum = 87ms, Average = 53ms
```

Quickly go back to the server and ping the client (`10.20.20.3`) again:

```
$ ping 10.20.20.3
PING 10.20.20.3 (10.20.20.3) 56(84) bytes of data.
64 bytes from 10.20.20.3: icmp_seq=1 ttl=128 time=42.7 ms
64 bytes from 10.20.20.3: icmp_seq=2 ttl=128 time=42.8 ms
64 bytes from 10.20.20.3: icmp_seq=3 ttl=128 time=42.5 ms
```

Why is it working now? It is because the client established the connection first and now for a while, the server will be able to reach the client until this connection gets lost. There are two ways to prevent this behavior (client having to send data first)

1. Setup *Persistent keepalive* to keep the connection *alive* behind NAT or stateful firewalls, disabled by default.
2. Always initiate connection from the client first.

In our case (connecting to a web server to access a service), the server doesn't need to communicate with us unless we want it to. When accessing a website on the server, we know that we (the client) will always initiate the connection first. However, if it causes issues within your setup, configure *Persistent keepalive.*

Moving network services to the WG interface

In order to move our network services to another interface, we first need to find out what exactly is running on the server. We are interested in services and their listening ports. There are a few commands to achieve this, e.g `netstat`, `lsof`, `ss` and `nmap`. Pick the one that works on your server, so you don't have to install anything additional just for one command.

```
$ netstat -tulpn
```

I will run netstat with a couple of flags grouped together, definitely easier than writing `netstat -t -u -l -p -n`

- `-t` lists TCP
- `-u` lists UDP
- `-l` shows only listening ports (omitted by default)
- `-p` shows what program/service is running on each port
- `-n` doesn't resolve IPs and hosts

```
$ sudo netstat -tulpn
```

```
Active Internet connections (only servers)
Proto Recv-Q Send-Q Local Address           Foreign Address         State       PID/Program name
tcp        0      0 127.0.0.53:53           0.0.0.0:*               LISTEN      72/systemd-resolved
tcp        0      0 127.0.0.1:8888          0.0.0.0:*               LISTEN      205/uwsgi
tcp        0      0 0.0.0.0:443             0.0.0.0:*               LISTEN      98/nginx: master pr
tcp        0      0 127.0.0.1:4004          0.0.0.0:*               LISTEN      82/filtron
tcp        0      0 127.0.0.1:4005          0.0.0.0:*               LISTEN      82/filtron
tcp        0      0 127.0.0.1:5000          0.0.0.0:*               LISTEN      77/python3
tcp        0      0 78.97.52.14:7985        0.0.0.0:*               LISTEN      107/sshd: /usr/sbin
tcp        0      0 0.0.0.0:80              0.0.0.0:*               LISTEN      98/nginx: master pr
udp        0      0 127.0.0.53:53           0.0.0.0:*                           72/systemd-resolved
udp        0      0 0.0.0.0:51895           0.0.0.0:*                           -
udp6       0      0 :::51895                :::*                                -
```

We can see a few services running on localhost (`127.0.0.1`), systemd-resolve localhost address (`127.0.0.53`), example public IP (`78.97.52.14`) or on all interfaces (`0.0.0.0`). The only one that we will care about now are `0.0.0.0` and `78.97.52.14`. From now on, everything will be very setup specific, so I might even change the way I write, from *we* to *me.*

Binding Nginx to wg0 interface

The main service I want to move is Nginx. It runs all my websites on this server, so it would make sense to migrate it first. Right now, it binds itself to all interfaces (`0.0.0.0`), so the websites should technically be already accessible on the Wireguard IP of the server (`10.20.20.1`), but I want them to be ONLY accessible on that interface.

Edit `/etc/nginx/conf.d/name_of_config.conf` and add the Wireguard IP address in front of ports in `server` config block on the `listen` line, like this:

```
server {
    listen 443 ssl http2;
    server_name youwebsite.com
    ...
    ...

to

server {
    listen 10.20.20.1:443 ssl http2;
    server_name youwebsite.com
    ...
    ...
```

Before reloading or restarting Nginx, make sure Wireguard is running and the interface is up, otherwise you will run into errors.

```
$ sudo wg-quick up wg0
```

Reload Nginx to cause least interruption to the service.

```
$ sudo systemctl reload nginx
```

Run netstat again to check if Nginx rebinded like I wanted:

```
$ sudo netstat -tulpn

Active Internet connections (only servers)
Proto Recv-Q Send-Q Local Address           Foreign Address         State       PID/Program name
tcp        0      0 127.0.0.53:53           0.0.0.0:*               LISTEN      72/systemd-resolved
tcp        0      0 127.0.0.1:8888          0.0.0.0:*               LISTEN      205/uwsgi
tcp        0      0 10.20.20.1:443          0.0.0.0:*               LISTEN      23281/nginx: master
tcp        0      0 127.0.0.1:4004          0.0.0.0:*               LISTEN      82/filtron
tcp        0      0 127.0.0.1:4005          0.0.0.0:*               LISTEN      82/filtron
tcp        0      0 127.0.0.1:5000          0.0.0.0:*               LISTEN      77/python3
tcp        0      0 78.97.52.14:7985        0.0.0.0:*               LISTEN      107/sshd: /usr/sbin
tcp        0      0 10.20.20.1:80           0.0.0.0:*               LISTEN      23281/nginx: master
udp        0      0 127.0.0.53:53           0.0.0.0:*                           72/systemd-resolved
udp        0      0 0.0.0.0:51895           0.0.0.0:*                           -
udp6       0      0 :::51895                :::*                                -
```

When I try to access my websites now, it....doesn't work. But at least I perfectly know why and how to fix it. Before, when I wanted to access `mysite.com`, I typed in `mysite.com` into the browser address bar and my device requested a DNS record for `mysite.com`, which turned out to be a public IP address of my server, or something else (depending on what I had set on my domain's registrar website.) The DNS records still points to the public IP of my server, but Nginx isn't serving the websites on that public IP anymore, but on the Wireguard one. How do I fix this?

Remove old DNS records

First of all, I will remove the old DNS A records with my registrar so that I don't forget. This varies vastly from registrar to registrar, so you will have to figure it our on your own.

Point new DNS records to Wireguard

The problem is that I cannot just create new A records with the Wireguard IP (`10.20.20.1`), because that's a reserved private IP, it wouldn't route anywhere. There are couple of ways to solve this:

1. Fill in the `DNS Server` field on both clients with a DNS server that will be able to provide resolution for the private IP `10.20.20.1`. It could even be the `10.20.20.1` server itself, but that means I would have to setup a DNS service on the server
2. Point clients (using the `DNS Server` field) to your local DNS server on your home network and create the A records there. This method, however, will not work for roaming clients if they connect to a different network (like mobile data).
3. Since it's just one server with two websites and two clients (this method wouldn't make sense in larger deployments), I could just edit local DNS entries (hosts file) to avoid having to configure a whole new DNS server, just for this single purpose.

I might look into a more sophisticated solution for DNS with split tunnel VPN later on, but for now I will use the third method.

Editing hosts file on Windows

Navigate to `C:\Windows\System32\drivers\etc` in the Windows Explorer and open the file named `hosts` in Notepad and add the following lines into the file:

```
10.20.20.1□□mysite.com
10.20.20.1□□mysite2.com
```

You might need to flush your DNS cache, but after saving the file, those two sites should now resolve correctly, because Windows checks the local hosts file first by default.

Editing hosts file on Android

With Android, it's a little more complicated. Since its a mobile operating system designed to keep the user away from all advanced configuration (but still better than iPhone in this regard), we cannot simply open the hosts file and edit it. On a rooted phone you can, but on a regular one you can't. We have basically two options

1. Use a pseudo-VPN app to re-route all traffic locally through a filter that allows you to add custom DNS entries (I think Blokada can do that, apart from other things), except we can't, because `There can be only one VPN connection running at the same time. The existing interface is deactivated when a new one is created.` – developer.android.com Judging by one comment on Reddit "*I'm not entirely sure if this is how it works but using wireguard on a rooted phone and a compatible kernel let's wireguard interact directly through the kernel. It doesn't show up as an active VPN through android. So it may be possible to use that and a conventional VPN approach to have two at once?*" If this actually works, it should theoretically be possible, but you need a rooted phone and it's probably in early stages.
2. Use the VPN server as a DNS server, since it's a roaming device anyway.

3. ~~Use `adb` to pull the hosts file to PC, edit it and push it back to your Android device. That's what I'll do.~~

~~How to get `abd` up and running is outside of this guide, there might be a guide for that on this site at some point, but until then, refer to the internet.~~

~~Enable USB debugging in Android settings and connect it using a cable to you PC. Allow USB debugging for this specific device and check that it's recongnized.~~

```
$ .\adb.exe devices
List of devices attached
215e29da        device
```

~~Transfer the hosts file from Android to your device:~~

```
.\adb.exe pull /system/etc/hosts C:\Users\Marek\Desktop
```

~~Open it with Notepad and add new lines containing IP and hostname in this format:~~

```
10.20.20.1□□mysite.com
10.20.20.1□□mysite2.com
```

> Nope, this didn't work because pushing the file to a read-only file system doesn't work. Christ, I have to root my phone as soon as I can...

Setup basic DNS server on Linux

So I will eventually have to setup a DNS server on the Wireguard server, but just a simple one. No need to use `bind`, but simply `DNSmasq`.

Install DNSmasq

```
$ sudo apt install dnsmasq


Unpacking dnsmasq-base (2.85-1) ...
Selecting previously unselected package dnsmasq.
Preparing to unpack .../dnsmasq_2.85-1_all.deb ...
Unpacking dnsmasq (2.85-1) ...
Setting up dnsmasq-base (2.85-1) ...
Setting up dns-root-data (2021011101) ...
Setting up dnsmasq (2.85-1) ...
Created symlink /etc/systemd/system/multi-user.target.wants/dnsmasq.service →
```

```
/lib/systemd/system/dnsmasq.service.
Job for dnsmasq.service failed because the control process exited with error code.
See "systemctl status dnsmasq.service" and "journalctl -xe" for details.
invoke-rc.d: initscript dnsmasq, action "start" failed.
● dnsmasq.service - dnsmasq - A lightweight DHCP and caching DNS server
   Loaded: loaded (/lib/systemd/system/dnsmasq.service; enabled; vendor preset: enabled)
   Active: failed (Result: exit-code) since Mon 2021-09-20 00:43:35 CEST; 18ms ago
  Process: 23908 ExecStartPre=/etc/init.d/dnsmasq checkconfig (code=exited, status=0/SUCCESS)
  Process: 23915 ExecStart=/etc/init.d/dnsmasq systemd-exec (code=exited, status=2)
     CPU: 55ms

Sep 20 00:43:35 hostname systemd[1]: Starting dnsmasq - A lightweight DHCP and caching DNS server...
Sep 20 00:43:35 hostname dnsmasq[23915]: dnsmasq: failed to create listening socket for port 53: Address
already in use
Sep 20 00:43:35 hostname dnsmasq[23915]: failed to create listening socket for port 53: Address already in use
Sep 20 00:43:35 hostname systemd[1]: dnsmasq.service: Control process exited, code=exited,
status=2/INVALIDARGUMENT
Sep 20 00:43:35 hostname dnsmasq[23915]: FAILED to start up
Sep 20 00:43:35 hostname systemd[1]: dnsmasq.service: Failed with result 'exit-code'.
Sep 20 00:43:35 hostname systemd[1]: Failed to start dnsmasq - A lightweight DHCP and caching DNS server.
Processing triggers for dbus (1.12.20-2) ...
```

Run DNSmasq at startup:

```
$ sudo systemctl enable dnsmasq
```

The problem is that DNSmasq tries to bind to port `53`, which on my system is already occupied by `systemd-resolved`. I need to figure out how to make these two work together or disable systemd-resolved.

> Heads up – Skip to ***Final configuration for server*** to see the final configuration files. The following is mostly me trying to figure out how to do this properly. If you enjoy reading about others suffering, go ahead.

Edit /etc/systemd/resolved.conf

DNS configuration is usually managed by `/etc/resolv.conf` file, however, if you open the file, it states the following – `# This file is managed by man:systemd-resolved(8). Do not edit.`

Therefore use `/etc/systemd/resolved.conf` to perform any configuration regarding DNS. We are interested mainly in the `DNSStubListener` line, which we have to uncomment and set to `no`. That disables systemd-resolved from binding to `127.0.0.53:53`. I would also advise to disable `LLMNR` and

`MulticastDNS`, do some research about these two yourself to figure if you need them. The file should now look like this:

```
[Resolve]
DNS=your_DNS_server
#FallbackDNS=
#Domains=
LLMNR=no
MulticastDNS=no
#DNSSEC=allow-downgrade
#DNSOverTLS=no
#Cache=yes
DNSStubListener=no
#ReadEtcHosts=yes
```

Restart systemd-resolved. Be aware that you might lose DNS connectivity until you start DNSmasq. I won't do that right now, because I still need to change a few things:

```
$ sudo systemctl restart systemd-resolved
```

Running `systemd-resolve` to check it's status reveals that some settings aren't still how I wanted. I have managed to change the Global configuration, but not settings for individual interfaces.

```
$ sudo systemd-resolve --status

Global
       Protocols: -LLMNR -mDNS -DNSOverTLS DNSSEC=no/unsupported
resolv.conf mode: uplink
     DNS Servers: my_prefered_DNS_server

Link 15 (wg0)
Current Scopes: none
     Protocols: -DefaultRoute +LLMNR -mDNS -DNSOverTLS DNSSEC=no/unsupported

Link 19 (eth0)
Current Scopes: DNS
     Protocols: +DefaultRoute +LLMNR -mDNS -DNSOverTLS DNSSEC=no/unsupported
   DNS Servers: DNS_server_i_dont_like
```

I haven't find another config file to add these values into, so just change them using the `systemd-resolve` command.

```
$ sudo systemd-resolve --interface eth0 --set-dns my_prefered_DNS_server
$ sudo systemd-resolve --interface eth0 --set-llmnr no
$ sudo systemd-resolve --interface wg0 --set-llmnr no
```

Again, confirm that everything is set to your liking with `systemd-resolve --status`

```
$ systemd-resolve --status
Global
         Protocols: -LLMNR -mDNS -DNSOverTLS DNSSEC=no/unsupported
  resolv.conf mode: uplink
Current DNS Server: my_prefered_DNS_server
       DNS Servers: my_prefered_DNS_server

Link 15 (wg0)
Current Scopes: none
     Protocols: -DefaultRoute -LLMNR -mDNS -DNSOverTLS DNSSEC=no/unsupported

Link 19 (eth0)
    Current Scopes: DNS
         Protocols: +DefaultRoute -LLMNR -mDNS -DNSOverTLS DNSSEC=no/unsupported
Current DNS Server: my_prefered_DNS_server
       DNS Servers: my_prefered_DNS_server
```

Edit /etc/dnsmasq.d

By default, the file is full of commented out lines with all kinds of configuration settings. In fact, it's so long that it's better to back it up and write just the options you want into an empty one.

```
$ sudo cp /etc/dnsmasq.conf /etc/dnsmasq.conf.default
```

Delete everything in `/etc/dnsmasq.conf` with `vi` and `1000dd`.

```
$ sudo vi /etc/dnsmasq.conf
```

Add the following lines to the config:

```
interface=lo,wg0
bind-interfaces
```

Restart DNSmasq and check if it binded to the right interfaces (localhost and Wireguard)

```
$ sudo systemctl restart dnsmasq


$ sudo netstat -tulpn | grep 53
tcp        0      0 127.0.0.1:53            0.0.0.0:*               LISTEN      25764/dnsmasq
tcp        0      0 10.20.20.1:53           0.0.0.0:*               LISTEN      25764/dnsmasq
udp        0      0 127.0.0.1:53            0.0.0.0:*                           25764/dnsmasq
udp        0      0 10.20.20.1:53           0.0.0.0:*                           25764/dnsmasq
```

All looks great, however, trying multiple pings to common websites reveal random DNS issues:

```
$ ping google.com
ping: google.com: Temporary failure in name resolution
```

> At this point, I have spent a few hours researching how name resolution works on Linux machines. It got a little more complicated with systemd-resolved. I won't explain the whole proccess or what I did, just show you the final configuration files and try to explain how the name resolution works as of now.

Previous plan

I'm currently trying to figure out how to get DNS resolution working on the server itself (so that the server can resolve names with `DNSmasq` and `systemd-resolved` combined). My previous plan was:

- Disable `systemd-resolved` binding to `127.0.0.53` with `DNSStubListener=no` in `/etc/systemd/resolved.conf`
- Set DNS on all interfaces with systemd-resolved to `127.0.0.1` (this also changes nameserver in `/etc/resolv.conf` to `127.0.0.1`)
- Run DNSmasq on `127.0.0.1` (for the server itelf) and on `10.20.20.1` (for the Android Wireguard client).
- Set DNS server in DNSmasq (`/etc/dnsmasq.conf`) to a public DNS of choice for regular name resolution.

Thanks to this, when the server wants to perform a DNS query, this happens *(as far as I understand, don't @ me and kindly let me know if I'm wrong):*

1. It first looks into `/etc/nsswitch.conf` and looks onto the `hosts` line, which says `files dns`.
2. Because of `files`, it looks into `/etc/hosts` first, to see if the address isn't hard-coded this way.
3. Then because of `dns`, it looks into `/etc/resolv.conf`, which is managed by systemd-resolved. This file will only contain `127.0.0.1`, which points to DNSmasq running on that interface on port `53`. The reason why it points to `127.0.0.1` is because we have set DNS to `127.0.0.1` globally in `/etc/systemd/resolved.conf`.

4. DNSmasq will take that query and forward it to our prefered public DNS server configured in `/etc/dnsmasq.conf` with the `server` line.

Unfortunately, this **does not work**, or at least I was unable to make it work this way. The outcome of this is a broken name resolution that sometimes works and sometimes doesn't.

Current plan

To fix my server's DNS resolution, I came up with a reversed setup plan. Instead of everything pointing to DNSmasq for name resolution, I will point DNSmasq to the other side, which is systemd-resolved – **this turned out to produce the same behavior.**

After thorough examination, I decided to completely throw systemd-resolved out the window by stopping the service and disabling it.

```
$ sudo systemctl stop systemd-resolved
$ sudo systemctl disable systemd-resolved
```

Try the good old way of editing `/etc/resolv.conf` and add your DNS server. After adding different upstream DNS servers, I'm slowly starting to realize that the entire issue might have been actually caused by the upstream server and not my local configuration. The DNS I used before is extremely fast (+-2 ms response times), but sometimes just stops responding completely. It might have something to do with reverse lookup and I might somehow fix it later, but for now, I have decided to opt for the slower, but more reliable upstream DNS server.

Final configuration for server

There might actually be a way to do it! Go back to my reversed setup plan, because this time it works.

Enable and start systemd-resolved again:

```
$ sudo systemctl enable systemd-resolved
$ sudo sytemctl start systemd-resolved
```

Look into `/etc/resolv.conf`. Because we have started systemd-resolved, it had already probably overwrote `/etc/resolv.conf` with the following, which is alright:

```
nameserver 127.0.0.53
options edns0 trust-ad
search .
```

Open `/etc/systemd/resolve.conf` and make it look like this:

```
[Resolve]
DNS=my_prefered_DNS_server
FallbackDNS=secondary_DNS_server
#Domains=
LLMNR=no
MulticastDNS=no
#DNSSEC=allow-downgrade
#DNSOverTLS=no
#Cache=yes
DNSStubListener=yes
#ReadEtcHosts=yes
```

Check status of systemd-resolve and edit DNS server for `eth0` if it still has a wrong value

```
$ systemd-resolve --status

Global
          Protocols: -LLMNR -mDNS -DNSOverTLS DNSSEC=no/unsupported
   resolv.conf mode: stub
 Current DNS Server: my_prefered_DNS_server
        DNS Servers: my_prefered_DNS_server
Fallback DNS Servers: secondary_DNS_server

Link 15 (wg0)
Current Scopes: none
     Protocols: -DefaultRoute -LLMNR -mDNS -DNSOverTLS DNSSEC=no/unsupported

Link 19 (eth0)
   Current Scopes: DNS
        Protocols: +DefaultRoute -LLMNR -mDNS -DNSOverTLS DNSSEC=no/unsupported
Current DNS Server: my_prefered_DNS_server
       DNS Servers: my_prefered_DNS_server
```

Your `/etc/dnsmasq.conf` should look like this. We want to run DNSmasq only on the Wireguard interface, but interface also automatically adds loopback to the list. Use `except-interface` to disable binding to localhost.

```
interface=wg0
except-interface=lo
bind-interfaces
```

```
server=127.0.0.53
```

Start DNSmasq

```
# sudo systemctl start dnsmasq
```

You can tell by the output of `systemctl status dnsmasq`, that it's using `127.0.0.53` as it's DNS server.

```
...
using nameserver 127.0.0.53#53
reading /etc/resolv.conf
...
```

Recap what we know about name resolution on the server now. When the server makes a DNS query, this happens (probably):

- Debian consults `/etc/nsswitch.conf`, reads `/etc/hosts` due to `files` option specified at the `hosts:` line, then goes for the DNS server.
- DNS server in `/etc/resolv.conf` points to `127.0.0.53`, which is `systemd-resolv DNSStubListener`.
- `systemd-resolved` is set up to use a prefered public DNS server.

Now onto the main reason why I did this whole thing. Provide a simple DNS server for my Android client.

Setup DNS for client name resolution

Edit /etc/hosts

Add the websites you want to resolve to `/etc/hosts`. That way, when clients queries DNSmasq listening on `10.20.20.1`, it forwards the query to `127.0.0.53`, which also reads `/etc/hosts`, resolving the IP correctly.

```
10.20.20.1      mysite.com
10.20.20.1      mysite2.com
```

Add DNS to Android config

Edit the config by adding `10.20.20.1` to `DNS servers`.

Adjust Firewall for testing

In order for the Android device to be able to use the DNS server on `10.20.20.1`, I need to adjust `iptables` to allow traffic on port 53 on the Wireguard interface. Add this to your iptables configuration file and apply with `iptables-restore`.

```
# Allow DNS queries on the Wireguard interface
-A INPUT -p udp -m udp --dport 53 -i wg0 -j ACCEPT
```

```
$ sudo iptables-restore /etc/iptables/rules.v4
```

> Now access your websites from the Android client and it should resolve correctly to the server's Wireguard IP.

The only "problem" right now is that the Android client will most likely use the Wireguard server IP `10.20.20.1` for all name resolution while it's connected to the VPN. This is not a huge deal since the queries are pretty fast, but might be a deal breaker for some.

Adjusting Firewall rules

Everything regarding the Wireguard VPN should be configured:

- Wireguard tunnel between a server and 2 peers (clients)
- Services running on the Wireguard interface only (Nginx)
- Correct DNS resolving for both the server and Android client

Now it's time to fix the Firewall, so what are our goals here?

- DROP everything except:
  - HTTP/S and DNS on Wireguard interface
  - Ping on all interfaces
  - SSH on Wireguard interface only (later, since SSH is our only access to the VPS and breaking it would cause immense headache)

I am using very powerful `iptables` with `iptables-restore` utility to write my rules to a config file instead to the command line. The config file is located in `/etc/iptables/rules.v4` (may be different in your case).

Open the file and edit it. Everything will be explained in the following code block behind #. For easier reading, I have divided it into parts:

Setup the 3 main chains – `INPUT`, `OUTPUT` and `FORWARD`. It is recommended to always set `INPUT` as implicit `DENY` and only whitelist approved services and ports.

```
*filter
# CONFIGURE INPUT, OUTPUT AND FORWARD CHAINS
# Drop forwarded traffic, we don't need that since we are not acting as a router
:FORWARD DROP [0:0]
```

```
# Accept all outgoing connections
:OUTPUT ACCEPT [0:0]

# Block all incoming traffic (default DENY)
:INPUT DROP [0:0]
```

When everything is blocked by default, these rules have to exist to allow communication on localhost and any established connections (when you initiace connection from the server)

```
# BASIC RULES FOR THINGS TO WORK WITH DEFAULT DENY ON INPUT CHAIN
# Do not block localhost traffic to itself
-A INPUT -i lo -j ACCEPT

# Allow established and related incoming connections
-A INPUT -m conntrack --ctstate ESTABLISHED,RELATED -j ACCEPT
```

Rules to allow devices within the Wireguard tunnel to access web services (ports `80` and `443`) + `53` for DNS.

```
# WIREGUARD INTERFACE CONFIG
# Allow web traffic for my search engine (only on the Wireguard interface)
-A INPUT -p tcp -m tcp --dport 80 -i wg0 -j ACCEPT
-A INPUT -p tcp -m tcp --dport 443 -i wg0 -j ACCEPT

# Allow DNS queries on the Wireguard interface
-A INPUT -p udp -m udp --dport 53 -i wg0 -j ACCEPT
```

Rules for the public IP of the server. The only thing that needs to be open is the Wireguard port. You can also configure the server to accept `ICMP` ping requests for easier troubleshooting. Without this rule, the server won't be "pingable" even if it's up.

```
# PUBLIC IP RULES
# Allow ICMP pings on all interfaces (for easier troubleshooting)
-A INPUT -p icmp --icmp-type echo-request -j ACCEPT

# Allow Wireguard on the public IP
-A INPUT -p udp -m udp --dport 51895 -i eth0 -j ACCEPT
```

`SSH` is the most critical service and therefore will still be available on all interface and I will move it to the Wireguard interface after testing.

```
# SSH
# Allow SSH on the port that it's running on
-A INPUT -p tcp -m tcp --dport 7985 -j ACCEPT

# Commit rules
COMMIT
```

The entire config looks like this:

```
*filter
# CONFIGURE INPUT, OUTPUT AND FORWARD CHAINS
# Drop forwarded traffic, we don't need that since we are not acting as a router
:FORWARD DROP [0:0]

# Accept all outgoing connections
:OUTPUT ACCEPT [0:0]

# Block all incoming traffic (default DENY)
:INPUT DROP [0:0]

# BASIC RULES FOR THINGS TO WORK WITH DEFAULT DENY ON INPUT CHAIN
# Do not block localhost traffic to itself
-A INPUT -i lo -j ACCEPT

# Allow established and related incoming connections
-A INPUT -m conntrack --ctstate ESTABLISHED,RELATED -j ACCEPT

# WIREGUARD INTERFACE CONFIG
# Allow web traffic for my websites (only on the Wireguard interface)
-A INPUT -p tcp -m tcp --dport 80 -i wg0 -j ACCEPT
-A INPUT -p tcp -m tcp --dport 443 -i wg0 -j ACCEPT

# Allow DNS queries on the Wireguard interface
-A INPUT -p udp -m udp --dport 53 -i wg0 -j ACCEPT

# PUBLIC IP RULES
# Allow ICMP pings on all interfaces (for easier troubleshooting)
-A INPUT -p icmp --icmp-type echo-request -j ACCEPT

# Allow Wireguard on the public IP
```

```
-A INPUT -p udp -m udp --dport 51895 -j ACCEPT

# SSH
# Allow SSH on the port that it's running on
-A INPUT -p tcp -m tcp --dport 7985 -j ACCEPT

# Commit rules
COMMIT
```

Apply the configuration with `iptables-restore`. First make sure all rules make sense to you.

```
$ sudo iptables-restore /etc/iptables/rules.v4
```

List and check the rules (`-n` to not resolve DNS and `-v` for verbose output)

```
$ sudo iptables -L -nv

Chain INPUT (policy DROP 32 packets, 1941 bytes)
 pkts bytes target     prot opt in     out     source               destination
    0     0 ACCEPT     all  --  lo     *       0.0.0.0/0            0.0.0.0/0
   47  2876 ACCEPT     all  --  *      *       0.0.0.0/0            0.0.0.0/0           ctstate RELATED,ESTABLISHED
    0     0 ACCEPT     tcp  --  wg0    *       0.0.0.0/0            0.0.0.0/0           tcp dpt:80
    0     0 ACCEPT     tcp  --  wg0    *       0.0.0.0/0            0.0.0.0/0           tcp dpt:443
    0     0 ACCEPT     udp  --  wg0    *       0.0.0.0/0            0.0.0.0/0           udp dpt:53
    2   168 ACCEPT     icmp --  *      *       0.0.0.0/0            0.0.0.0/0           icmptype 8
    0     0 ACCEPT     udp  --  *      *       0.0.0.0/0            0.0.0.0/0           udp dpt:51895
    0     0 ACCEPT     tcp  --  *      *       0.0.0.0/0            0.0.0.0/0           tcp dpt:7985

Chain FORWARD (policy DROP 0 packets, 0 bytes)
 pkts bytes target     prot opt in     out     source               destination

Chain OUTPUT (policy ACCEPT 34 packets, 5056 bytes)
 pkts bytes target     prot opt in     out     source               destination
```

Enable Wireguard on startup

If we are going to move SSH into the Wireguard tunnel only, we need to make sure that the interface is active even (or especially) after the server restarts. For that, we need to enable Wireguard with systemd (or other init service). Fortunately it's pretty easy.

```
$ sudo systemctl enable wg-quick@wg0.service
$ sudo systemctl daemon-reload
$ sudo wg-quick down wg0
$ sudo systemctl start wg-quick@wg0
```

It's time to test all of our efforts – reboot the server and hope all configuration stays correct afterwards. I like to do this, even though it's not neccessary, to save myself from unnecessary headaches when the server unexpectedly restarts and it turns out that the configuration wouldn't survive a schedules restart anyway.

Troubleshooting post-reboot

First thing I noticed is that Nginx was unable to start. Wireguard interface started up fine, but the webserver didn't, even after manual service restart. Turns out Apache2 was starting as a service and occupying port 80. I am too scared to completely purge Apache2 from the system, so I will just stop and disable the service.

```
$ sudo systemctl stop apache2
$ sudo systemctl disable apache2
```

Time for another reboot. This time, Nginx failed to start again, but manual restart of the serviced fixed it. This leads me to the idea, that Nginx is trying to start sooner than Wireguard and is unable to bind to the Wireguard interface, because it does not exist yet.

Edit the `nginx.service` systemd file to make sure it starts after Wireguard had already brought up the interface. You can either directly edit `/lib/systemd/system/nginx.service` file, but that is a bad practice, because the file is usually overwritten with updates. The correct way to do this should be use `sudo systemctl edit --full nginx.service`. Add `wg-quick@wg0.service` to the line end of the line with `After=` and add a new line `Requires=wg-quick@wg0.service` before the previous one.

After another reboot, Nginx started on its own successfully. List systemd services to check if there are any other issues.

```
$ systemctl list-units --type=service

  UNIT                      LOAD   ACTIVE SUB     DESCRIPTION
  console-getty.service           loaded active running Console Getty
  dbus.service                    loaded active running D-Bus System Message Bus
● dnsmasq.service                 loaded failed failed  dnsmasq - A lightweight DHCP and caching DNS server
  filtron.service                 loaded active running filtron
  ifupdown-pre.service            loaded active exited  Helper to synchronize boot up for ifupdown
  networking.service              loaded active exited  Raise network interfaces
  nginx.service                   loaded active running nginx - high performance web server
```

```
  ssh.service                    loaded active running OpenBSD Secure Shell server
  systemd-journal-flush.service  loaded active exited  Flush Journal to Persistent Storage
  systemd-journald.service       loaded active running Journal Service
  systemd-logind.service         loaded active running User Login Management
  systemd-modules-load.service   loaded active exited  Load Kernel Modules
  systemd-networkd.service       loaded active running Network Service
  systemd-remount-fs.service     loaded active exited  Remount Root and Kernel File Systems
  systemd-resolved.service       loaded active running Network Name Resolution
  systemd-sysctl.service         loaded active exited  Apply Kernel Variables
  systemd-sysusers.service       loaded active exited  Create System Users
  systemd-tmpfiles-setup-dev.service loaded active exited  Create Static Device Nodes in /dev
  systemd-tmpfiles-setup.service loaded active exited  Create Volatile Files and Directories
● systemd-udev-trigger.service   loaded failed failed  Coldplug All udev Devices
  systemd-udevd.service          loaded active running Rule-based Manager for Device Events and Files
  systemd-update-utmp.service    loaded active exited  Update UTMP about System Boot/Shutdown
  systemd-user-sessions.service  loaded active exited  Permit User Sessions
  user-runtime-dir@1000.service  loaded active exited  User Runtime Directory /run/user/1000
  user@1000.service              loaded active running User Manager for UID 1000
  uwsgi.service                  loaded active running LSB: Start/stop uWSGI server instance(s)
  wg-quick@wg0.service           loaded active exited  WireGuard via wg-quick(8) for wg0
  whoogle.service                loaded active running Whoogle

LOAD   = Reflects whether the unit definition was properly loaded.
ACTIVE = The high-level unit activation state, i.e. generalization of SUB.
SUB    = The low-level unit activation state, values depend on unit type.
28 loaded units listed. Pass --all to see loaded but inactive units, too.
To show all installed unit files use 'systemctl list-unit-files'.
```

It seems that dnsmasq also failed to start and I assume it was due to the same issue. Edit dnsmasq with systemd again:

```
$ sudo systemctl edit --full dnsmasq.service
```

Both lines `Requires` and `After` already exist, so just add wg-quick@wg0.service on each of these line:

```
[Unit]
Description=dnsmasq - A lightweight DHCP and caching DNS server
Requires=network.target wg-quick@wg0.service
Wants=nss-lookup.target
```

```
Before=nss-lookup.target
After=network.target wg-quick@wg0.service
```

This howerver, creates a paradox. DNSmasq **requires** `wg-quick` and **starts after** `wg-quick`, but also **before** `nss-lookup.target`

Now examine `wg-quick` (`systemctl cat wg-quick@wg0`)

```
...
After=network-online.target nss-lookup.target
Wants=network-online.target nss-lookup.target
...
```

According to this configuraion – `wg-quick` starts **after** `nss-lookup.target` when `DNSmasq` has to start **before** `nss-lookup.target`, while also starting **after** `wg-quick`, which has to start **after** `nss-lookup.target`.....and we got a loop. My solution to this is to simply comment out the `DNSmasq` dependency of starting before `nss-lookup.target`.

```
$ sudo systemctl edit --full dnsmasq.service
```

```
[Unit]
Description=dnsmasq - A lightweight DHCP and caching DNS server
Requires=network.target wg-quick@wg0.service
Wants=nss-lookup.target
# Before=nss-lookup.target
After=network.target wg-quick@wg0.service
```

This shouldn't break anything. Here's a sidenote about what `nss-lookup.target` even is:

A target that should be used as synchronization point for all host/network name service lookups. Note that this is independent of UNIX user/group name lookups for which nss-user-lookup.target should be used. All services for which the availability of full host/network name resolution is essential should be ordered after this target, but not pull it in. systemd automatically adds dependencies of type After= for this target unit to all SysV init script service units with an LSB header referring to the "$named" facility.

The only thing that's left is to restore iptables at boot according to the config.

Setup iptables-persistent

There are multiple ways to make iptables rules persist accross reboots, but this seems to be the prefered way.

Install `iptables-persistent`. It will ask you to save the current configuration to a file. We already have a config file present and this would only overwrite our file, so say no.

```
$ sudo apt install iptables-persistent
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
The following additional packages will be installed:
  netfilter-persistent
The following NEW packages will be installed:
  iptables-persistent netfilter-persistent
0 upgraded, 2 newly installed, 0 to remove and 0 not upgraded.
Need to get 23.4 kB of archives.
After this operation, 91.1 kB of additional disk space will be used.
Do you want to continue? [Y/n] y
```

Try rebooting and checking with `sudo iptables -L -nv` if the rules have been applied.

Migrate SSH to Wireguard interface

> Notice that I am running SSH on a non-standard port. The default is 22 and is often changed to reduce the number of bots spamming it on public servers. When running over VPN, it is safe to return back to the default 22 for simpler configuration.

Configure SSH on all interfaces

Currently my `iptables` firewall accepts SSH traffic on all interfaces on the correct port. SSH server configuration resides in `/etc/ssh/ssdh_config`. In this file `ListenAddress` is currently pointed to the public IP only. To bind both the public and Wireguard IP, replace the old value of `ListenAddress` with `0.0.0.0` and restart the service (your SSH connection won't be droped)

```
....
Port 7985
#AddressFamily any,inet
ListenAddress 0.0.0.0
#ListenAddress ::
....
```

```
$ sudo systemctl restart sshd
```

```
$ systemctl status sshd


sudo systemctl status sshd
● ssh.service - OpenBSD Secure Shell server
     Loaded: loaded (/lib/systemd/system/ssh.service; enabled; vendor preset: enabled)
     Active: active (running) since Tue 2021-09-21 20:02:01 CEST; 4s ago
       Docs: man:sshd(8)
             man:sshd_config(5)
    Process: 3503 ExecStartPre=/usr/sbin/sshd -t (code=exited, status=0/SUCCESS)
   Main PID: 3504 (sshd)
        CPU: 55ms
     CGroup: /system.slice/ssh.service
             └─3504 sshd: /usr/sbin/sshd -D [listener] 0 of 10-100 startups

Sep 21 20:02:00 hostname systemd[1]: ssh.service: Succeeded.
Sep 21 20:02:00 hostname systemd[1]: Stopped OpenBSD Secure Shell server.
Sep 21 20:02:00 hostname systemd[1]: Starting OpenBSD Secure Shell server...
Sep 21 20:02:01 hostname sshd[3504]: Server listening on 0.0.0.0 port 7985.
Sep 21 20:02:01 hostname systemd[1]: Started OpenBSD Secure Shell server.
```

Connect SSH using the Wireguard server IP

Open another terminal windows on the machine that you use to connect to the server (Windows clients in my case):

```
> ssh username@10.20.20.1 -p 7985
```

It will give you the classic warning about unknown ECDSA fingerprint, type `yes` to procceed.

```
The authenticity of host '[10.20.20.1]:7985 ([10.20.20.1]:7985)' can't be established.
ECDSA key fingerprint is SHA256:&UIhigdanUYdfs/wF56atgafd851jL4w9uT564sg6133.
Are you sure you want to continue connecting (yes/no/[fingerprint])? yes
Warning: Permanently added '[10.20.20.1]:7985' (ECDSA) to the list of known hosts.
```

Voila...you should be in. Before binding SSH to the Wireguard interface only, **edit SSHd service to start after wg-quick.** Currently, SSHd doesn't care if wg-quick already started or not and might try to bind to an interface that doesn't exist yet. See the config now:

```
$ sudo systemctl cat sshd


[Unit]
```

```
Description=OpenBSD Secure Shell server
Documentation=man:sshd(8) man:sshd_config(5)
After=network.target auditd.service
ConditionPathExists=!/etc/ssh/sshd_not_to_be_run

[Service]
EnvironmentFile=-/etc/default/ssh
ExecStartPre=/usr/sbin/sshd -t
ExecStart=/usr/sbin/sshd -D $SSHD_OPTS
ExecReload=/usr/sbin/sshd -t
ExecReload=/bin/kill -HUP $MAINPID
KillMode=process
Restart=on-failure
RestartPreventExitStatus=255
Type=notify
RuntimeDirectory=sshd
RuntimeDirectoryMode=0755

[Install]
WantedBy=multi-user.target
Alias=sshd.service
```

Edit the config like this: (changes on the `Requires` and `After` line)

```
$ sudo systemctl edit --full sshd

[Unit]
Description=OpenBSD Secure Shell server
Documentation=man:sshd(8) man:sshd_config(5)
Requires=wg-quick@wg0.service
After=network.target auditd.service wg-quick@wg0.service
ConditionPathExists=!/etc/ssh/sshd_not_to_be_run

[Service]
EnvironmentFile=-/etc/default/ssh
ExecStartPre=/usr/sbin/sshd -t
ExecStart=/usr/sbin/sshd -D $SSHD_OPTS
ExecReload=/usr/sbin/sshd -t
ExecReload=/bin/kill -HUP $MAINPID
KillMode=process
```

```
Restart=on-failure
RestartPreventExitStatus=255
Type=notify
RuntimeDirectory=sshd
RuntimeDirectoryMode=0755

[Install]
WantedBy=multi-user.target
Alias=sshd.service
```

Reload systemctl daemon to make the new configuration active:

```
$ sudo systemctl daemon-reload
```

I am now going to reboot the server for the last time I hope to see whether all services started up in a correct order and everything works. Surprise, surprise – it does.

Limit SSH to the Wireguard interface only

Go back to the sshd config file in `/etc/ssh/sshd_config` and set the `ListenAddress` field to `10.20.20.1`. Restart `sshd` to apply.

```
$ sudo systemctl restart sshd
```

Notice `sshd` binding to the Wireguard interface.

```
$ systemctl status sshd
...
Sep 21 22:53:20 hostname sshd[301]: Server listening on 10.20.20.1 port 7985.
...
```

Check `netstat` to confirm that everything is running on the Wireguard interface:

```
$sudo netstat -tulpn

Active Internet connections (only servers)
Proto Recv-Q Send-Q Local Address           Foreign Address         State       PID/Program name
tcp        0      0 127.0.0.1:5000          0.0.0.0:*               LISTEN      76/python3
tcp        0      0 10.20.20.1:7985         0.0.0.0:*               LISTEN      301/sshd: /usr/sbin
tcp        0      0 10.20.20.1:80           0.0.0.0:*               LISTEN      149/nginx: master p
tcp        0      0 127.0.0.53:53           0.0.0.0:*               LISTEN      71/systemd-resolved
tcp        0      0 127.0.0.1:8888          0.0.0.0:*               LISTEN      230/uwsgi
```

```
tcp        0      0 10.20.20.1:443          0.0.0.0:*               LISTEN      149/nginx: master p
tcp        0      0 127.0.0.1:4004          0.0.0.0:*               LISTEN      80/filtron
tcp        0      0 127.0.0.1:4005          0.0.0.0:*               LISTEN      80/filtron
udp        0      0 127.0.0.53:53           0.0.0.0:*                           71/systemd-resolved
udp        0      0 0.0.0.0:51895           0.0.0.0:*                           -
udp6       0      0 :::51895                :::*                                -
```

Adjust iptables

Make a last slight change to the iptables configuration in `/etc/iptables/rules.v4` by restricting SSH to the `wg0` interface

Replace the line

```
-A INPUT -p tcp -m tcp --dport 7985 -j ACCEPT
```

with

```
-A INPUT -i wg0 -p tcp -m tcp --dport 7985 -j ACCEPT
```

Apply `iptables` using `iptables-restore`

```
$ sudo iptables-restore /etc/iptables/rules.v4
```

> This should be it. Turned out to be way more complicated than expected, but that's exactly how it usually works, but unexpected things occur :)

Recap what we have managed to do today:

- Setup Wireguard with 3 peers (Linux server, Windows and Android client)
- Setup web services and SSH on correct interfaces
- Setup a DNS server for our clients
- Adjust network firewall and make it persistent

Doesn't seems like a lot, though when you look through this entire article, it's clear that it took some serious research and troubleshooting (just like any other IT thing, right?).

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