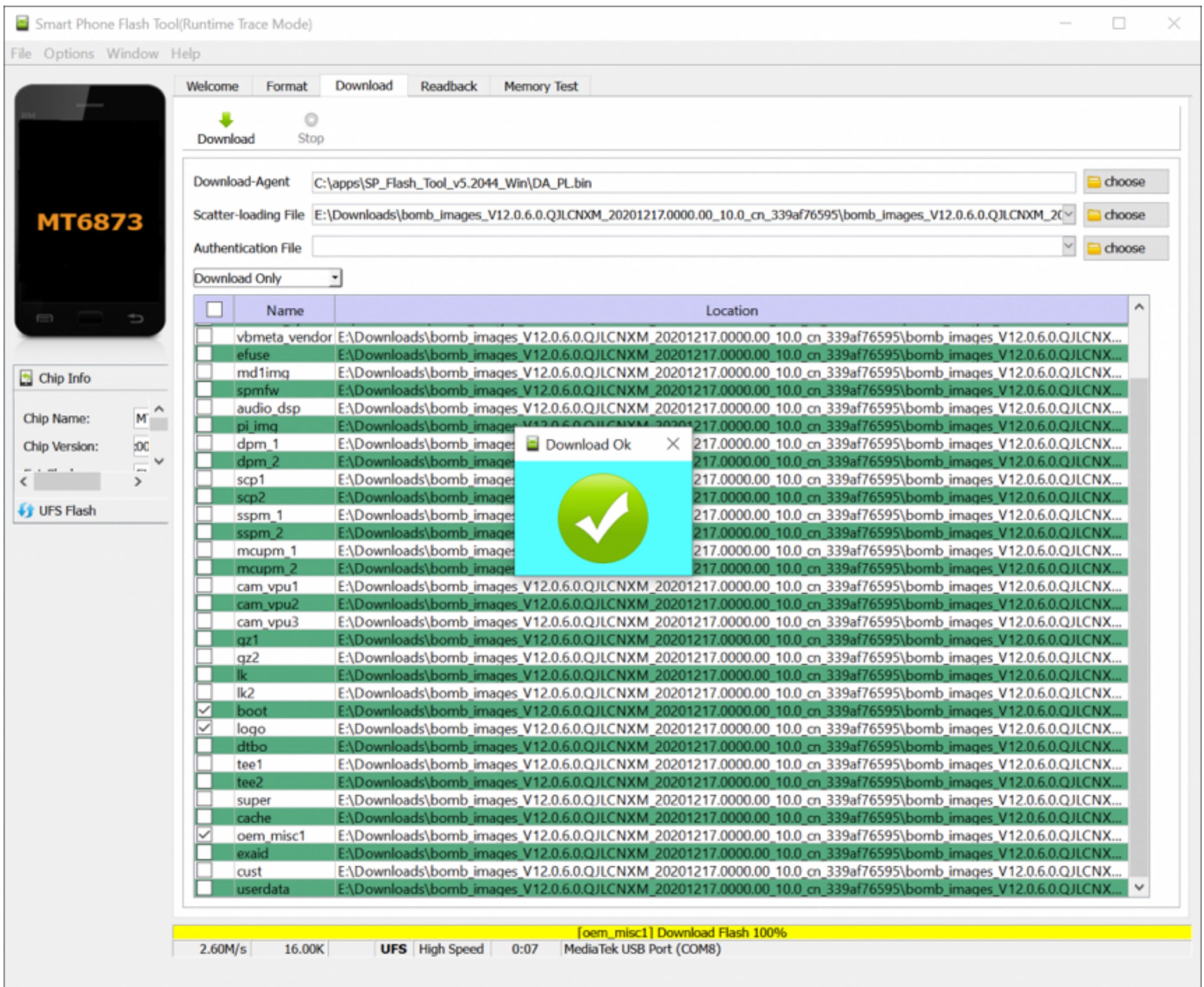
Dissecting a MediaTek BootROM exploit

A bricked Xiaomi phone led me to discover a project in Github that uses a MediaTek BootROM exploit that was undocumented. The exploit was found by Xyz, and implemented by Chaosmaster. The initial exploit was already available for quite a while. Since I have managed to revive my phone, I am documenting my journey to revive it and also explains how the exploit works. This exploit allows unsigned code execution, which in turn allows us to read/write any data from our phone.

For professionals: you can just skip to how the BootROM exploit works (spoiler: it is very simple). This guide will try to guide beginners so they can add support for their own phones. I want to show everything but it will violate MediaTek copyright, so I will only snippets of decompilation of the boot ROM.



Bricking my Phone and understanding SP Flash Tool

I like to use Xiaomi phones because it's relatively cheap, has an easy way to unlock the bootloader, and the phone is easy to find here in Thailand. With an unlocked bootloader, I have never got into an unrecoverable boot loop, because I can usually boot into fastboot mode and just reflash with the original ROM. I usually buy a phone with Qualcomm SOC, but this time I bought Redmi 10X Pro 5G with MediaTek SOC (MT6873 also known as Dimensity 800). But it turns out: you can get bricked without the possibility to enter fastboot mode.

A few years ago, it was easy to reflash a Mediatek phone: enter BROM mode

(usually by holding the volume up button and plugging the USB when the phone is off), and use SP Flash Tool to overwrite everything (including boot/recovery partition). It works this way: we enter BROM mode, the SP Flash Tool will upload DA (download agent) to the phone, and SP Flash Tool will communicate with the DA to perform actions (erase flash, format data, write data, etc).

But they have added more security now: when I tried flashing my phone, it displays an authentication dialog. It turns out that this is not your ordinary Mi Account dialog, but you need to be an Authorized Mi Account holder (usually from a service center). It turns out that just flashing a Mediatek phone may enter a boot loop without the possibility of entering fastboot mode. Quoting from an XDA article:

> *The developers who have been developing for the Redmi Note 8 Pro have found that the device tends to get bricked for a fair few reasons. Some have had their phone bricked when they were flashing to the recovery partition from within the recovery, while others have found that installing a stock ROM through fastboot on an unlocked bootloader also bricks the device*
>
> — Xiaomi needs a better way to unbrick its devices instead of Authorized Mi Accounts

I found one of the ROM modders that had to deal with a shady person on the Internet using remote Team Viewer to revive his phone. He has some explanation about the MTK BootROM security. To summarize: BROM can have SLA (Serial Link Authorization), DAA (Download Agent Authorization), or both. SLA prevents loading DA if we are not authorized. And DA can present another type of authentication. Using custom DA, we can bypass the DA security, assuming we can bypass SLA to allow loading the DA.

When I read those article I decided to give up. I was ready to let go of my data.

MTK Bypass

By a stroke of luck, I found a bypass for various MTK devices was published just two days after I bricked my Phone. Unfortunately: MT6873 is not yet supported. To support a device, you just need to edit one file (`device.c`), which contains some addresses. Some of these addresses can be found from external sources (such as from the published Linux kernel for that SOC), but most can't be found without access to the BootROM itself. I tried reading as much as possible about the BROM protocol. Some of the documentation that I found:

- MediaTek details: SoC startup: has a link to BROM documentation
- Support for Mediatek Devices in Oxygen Forensic® Detective (Explains about BROM protection)

Another luck came in a few days later: Chaosmaster published a generic payload to dump the BootROM. I got lucky: the generic payload works immediately on the first try on my phone and I got my Boot ROM dump. Now we need to figure out what addresses to fill in. At this point, I don't have another ROM to compare, so I need to be clever in figuring out these addresses. We need to find the following:

- `send_usb_response`
- `usbdl_put_dword`
- `usbdl_put_data`
- `usbdl_get_data`
- `uart_reg0`
- `uart_reg1`
- `sla_passed`
- `skip_auth_1`
- `skip_auth_2`

From the main file that uses those addresses we can see that:

- `uart_reg0` and `uart_reg1` are required for proper handshake to work. These addresses can be found on public Linux kernel sources.
- `usbdl_put_dword` and `usbdl_put_data` is used to send data to our computer
- `usbdl_get_data` is used to read data from computer
- `sla_passed`, `skip_auth_1` and `skip_auth_2`, are the main variables that we need to overwrite so we can bypass the authentication

We can start disassembling the firmware that we obtain fro the generic dumper. We need to load this to address 0x0. Not many strings are available to cross-reference so we need to get creative.

Somehow `generic_dump_payload` can find the address for `usb_put_data` to send dumped bytes to the Python script. How does it know that? The source for `generic_dump_payload` is is available in ChaosMaster's repository. But I didn't find that information sooner so I just disassembled the file. This is a small binary, so we can reverse engineer it easily using binary ninja. It turns out that it does some pattern matching to find the prolog of the function: `2d e9 f8 4f 80 46 8a 46`. Actually, it searches for the second function that has that prolog.

Pattern finder in generic_dump_payload

Now that we find the `send_word` function we can see how sending works. It turns out that it sends a 32-bit value by sending it one byte at a time. Note: I tried continuing with Binary Ninja, but it was not easy to find cross-references to memory addresses on a raw binary, so I switched to Ghidra. After cleaning up the code a bit, it will look something like this:

What generic_dump_payload found

Now we just need to find the reference to `function_pointers` and we can find the real address for `sendbyte`. By looking at related functions I was able to find the addresses for: `usbdl_put_dword`, `usbdl_put_data`, `usbdl_get_data`. Note that the exploit can be simplified a bit, by replacing `usbdl_put_dword` by a call to `usbdl_put_data` so we get 1 less address to worry about.

The hardest part for me was to find `send_usb_response` to prevent a timeout. From the main file, I know that it takes 3 numeric parameters (not pointers), and this must be called somewhere before we send data via USB. This narrows it down quite a lot and I can find the correct function.

Now to the global variables: `sla_passed`, `skip_auth_1`, and `skip_auth_2`. When we look at the main exploit in Python, one of the first things that it does is to read the status of the current configuration. This is done by doing a handshake then retrieve the target config.

Target config

There must be a big "switch" statement in the boot ROM that handles all of these commands. We can find the handshake bytes (`A0 0A 50 05`) to find the reference to the handshake routine (actually found two of them, one for USB and one for UART). From there we can find the reference to the big switch statement.

The handshake

You should be able to find something like this: after handshake it starts to handle commands

And the big switch should be clearly visible.

Switch to handle various commands

Now that we found the switch, we can find the handler for command 0xd8 (get target config). Notice in python, the code is like this:

Notice the bit mask

By looking at the bitmask, we can conclude the name of the functions that construct the value of the config. E.g: we can name the function that sets the secure boot to is `bit_is_secure_boot`. Knowing this, we can inspect each `bit_is_sla` and `bit_is_daa`

we can name the functions from the bit that it sets

For SLA: we need to find cross-references that call `bit_is_sla`, and we can see that another variable is always consulted. If SLA is not set, or SLA is already passed, we are allowed to perform the next action.

finding sla_passed

Now we need to find two more variables for passing DAA. Looking at `bit_is_daa`, we found that at the end of this function, it calls a routine that checks if we have passed it. These are the last two variables that we are looking for.

How the BootROM Exploit Works

The exploit turns out very simple.

1. We are allowed to upload data to a certain memory space
2. The handler for USB control transfer blindly index a function pointer table

Basically it something like this: `handler_array[value*13]();`

But there are actually some problems:

- The value for this array is unknown, but we know that most devices will have 0x100a00 as one of the elements
- We can brute force the value for USB control transfer to invoke the payload
- We may also need to experiment with different addresses (since not all device has 0x100a00 as an element that can be used)

Another payload is also provided to just restart the device. This will make it easy to find the correct address and control value.

Closing Remarks

Although I was very upset when my phone got bricked, the experience in solving this problem has been very exciting. Thank you to Xyz for finding this exploit, and ChaosMaster for implementing it, simplifying it, and also for answering my questions and reviewing this post.

admin / January 31, 2021 / hacks, hardware, reverse-engineering, security, writeup

12 thoughts on "Dissecting a MediaTek BootROM exploit"

Irwansyah

February 1, 2021 at 1:23 am

"... it does some pattern matching to find the prolog of the function" <- does this pattern matching things is the same concept as pattern matching in functional programming? And what are the benefits of using pattern matching compare to other techniques?

Erjey

February 4, 2021 at 8:50 pm

so did you unbrick your redmi 10x?

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admin

February 23, 2021 at 2:37 am

yes

Joh Doe

March 28, 2021 at 8:58 am

Hi! Can you tell me how to get to edl mode on xiaomi redmi note 9? I cant. If I press volume – key it takes me to fastboot, and if press + it takes me to recovery -but not edl, I think- mode.

Xenador77

January 18, 2024 at 7:49 pm

EDL is for Qualcomm based devices

MediaWreck

March 2, 2021 at 7:11 am

Can you point me to the location of chaosmaster's BROM dumping utility? I didn't find an exact match in his github repository list but I am unsure what keywords to be looking for.

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admin

March 6, 2021 at 1:05 pm

Its called generic_dump.c

https://github.com/chaosmaster/bypass_payloads/blob/master/generic_dump.c

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Jay

March 1, 2022 at 3:34 pm

Can you please help me? Ihave this same issue and it happened to me when i picked Format All + Download in spflashtool. Im willing to pay if you can help me revive my device please.

Jay

March 1, 2022 at 3:35 pm

I have a device which is a realme gt neo. SOC is dimensity 1200. Thank you i really hope that you can help me.

John

November 5, 2022 at 6:26 pm

Hello. I've stumbled upon this post while trying to unbrick my Poco m5 powered by mt6789(closest payload is mt6785).
Is it possible to recreate all the steps? I mean I've got a bit exprience in programming but defenitely not in reverse engineering, which is bummer. I've read this blog post like 20 times, but it feels like many steps to follow aren't there and it's hard to go along for newbie. Can you maybe give some advice?

Avi

December 13, 2023 at 11:04 am

Hi , thanks for the article it was really aducated
as for the "How the BootROM Exploit Works"
i don't understand this section.
I thought that after you have found all the nessessary addresses
you just need to reedit the device.c file with the addresses you've found and then to run the exploit
so the last part "How the BootROM Exploit Works" is not clear.

Avi

December 13, 2023 at 11:07 am

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can you please explain the connection to this part?