Android Exploits 101

Maddie Stone
@maddiestone

whoami - Maddie Stone (she/her)

- Security researcher at Project Zero
  - Focused on 0-day exploits actively used in the wild

Goal

- Understand the “shape” of modern 0-day exploits for Android
- Foundation of current exploit threats to Android users to inform investments in defenses and detection
- Join the exploits fun! :)

In-the-wild 0-day exploits

- Goal: Learn from 0-days exploited in-the-wild to make 0-day hard.

- Tracking spreadsheet of known itw 0-days
- Root cause analyses: https://googleprojectzero.github.io/0days-in-the-wild/rca.html
- Year-in-review reports: 2020, 2019
- A World Where 0-day is Hard keynote [video]

0-day exploit:
an exploit defenders don’t yet know about

CVE-2021-1905: Qualcomm Adreno GPU memory mapping use-after-free

Ben Hawkes, Project Zero

The Basics

Disclosure or Patch Date: 1 May 2021

Product: Qualcomm Adreno GPU

Advisory: https://www.qualcomm.com/company/product-security/bulletins/may-2021-bulletin

Affected Versions: Prior to Android 2021-05-01 security patch level

Note: the Qualcomm Adreno GPU kernel driver may be used in other platforms aside from Android, but the following analysis was performed with Android in mind, since Android is a high priority area of interest for Project Zero.

First Patched Version: Android 2021-05-01 security patch level

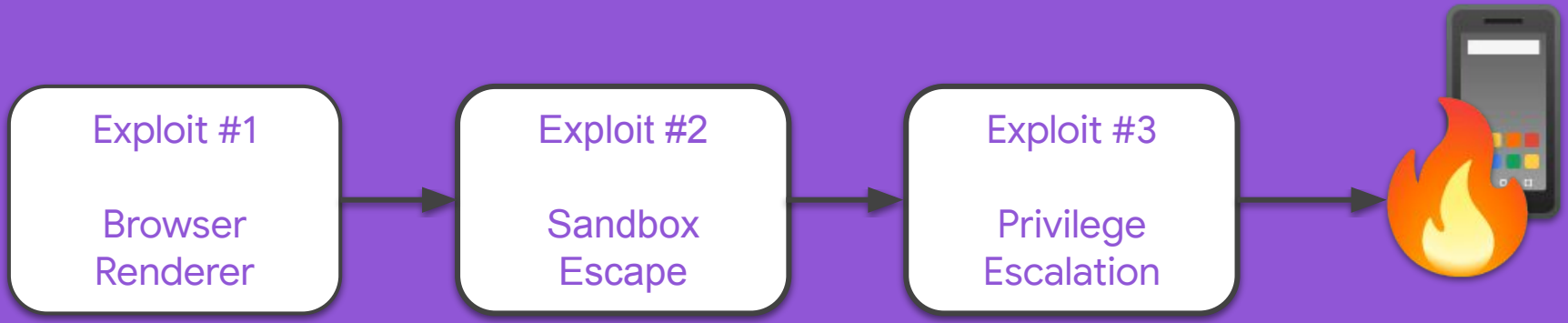
Issue/Bug Report: N/A

Patch CL:
https://source.codeaurora.org/quic/la/kernel/msm-4.9/commit/?id=d236d315145f8250523ce9e14897d62e5d6639fc
https://source.codeaurora.org/quic/la/kernel/msm-4.9/commit/?id=ec3c8cf016991818ca286c4fd92255393c211405

Bug-Introducing CL: N/A

Reporter(s): N/A

https://googleprojectzero.github.io/0days-in-the-wild/0day-RCAs/2021/CVE-2021-1905.html


Exploit #1
Browser Renderer
Exploit #2
Sandbox Escape
Exploit #3
Privilege Escalation

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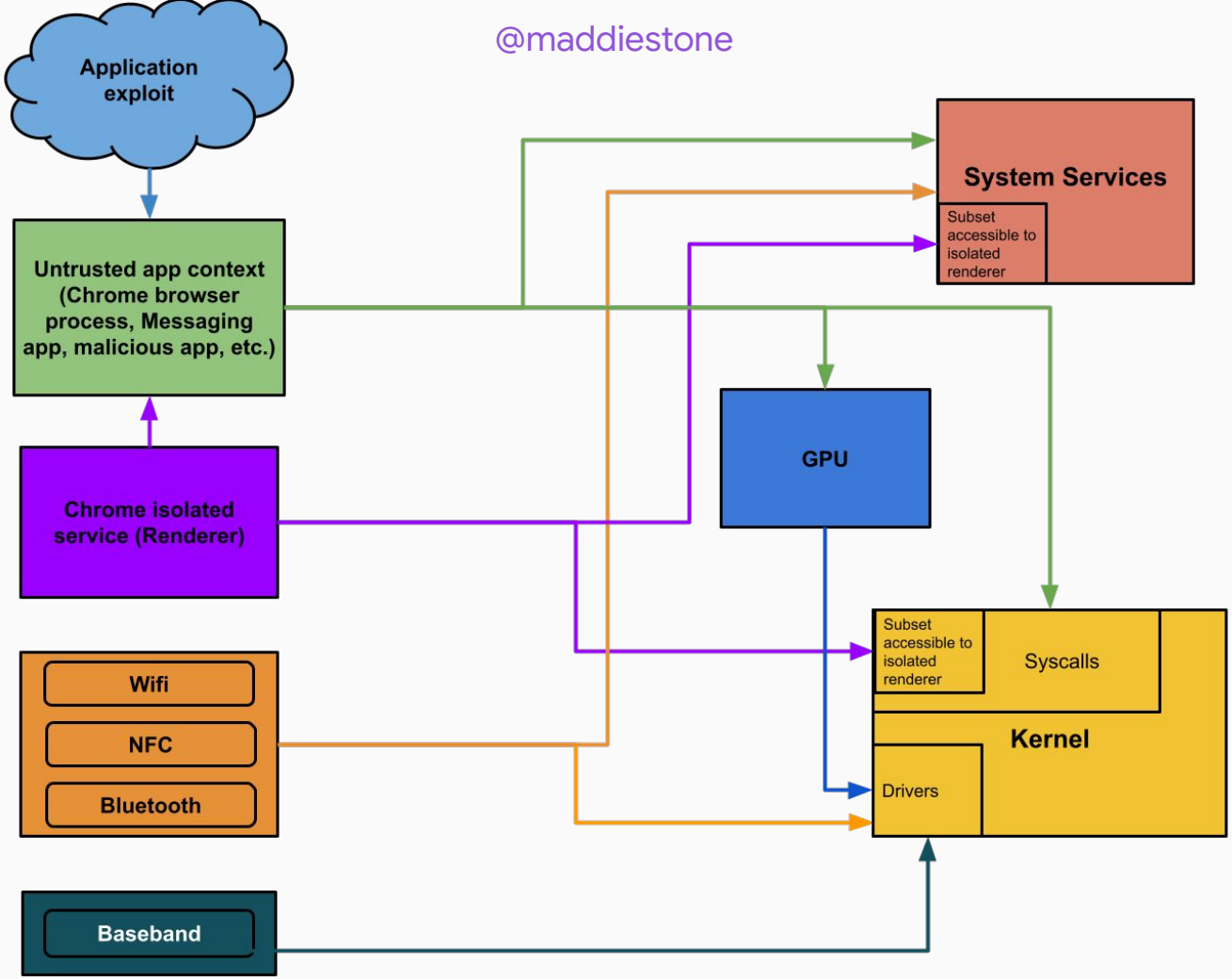

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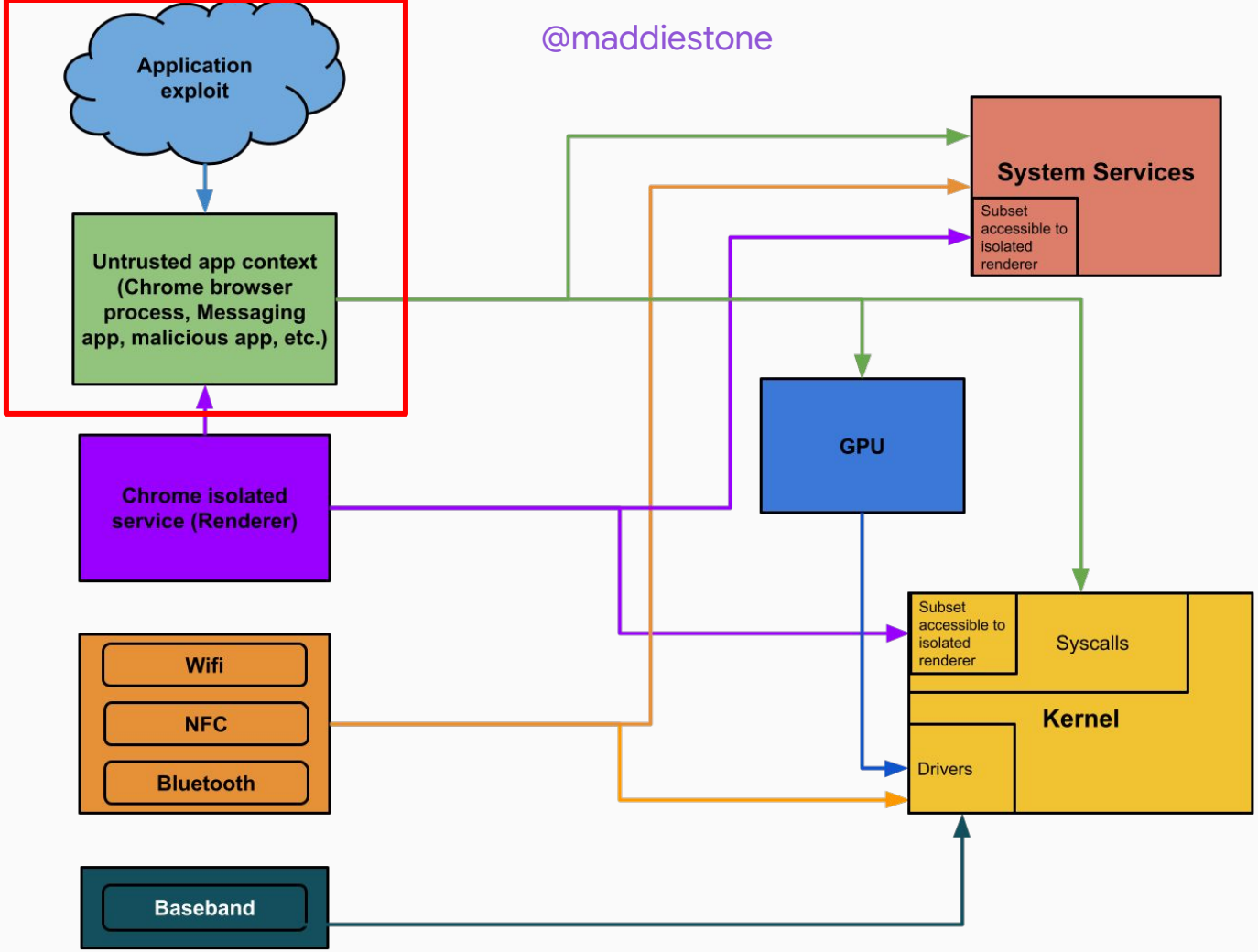
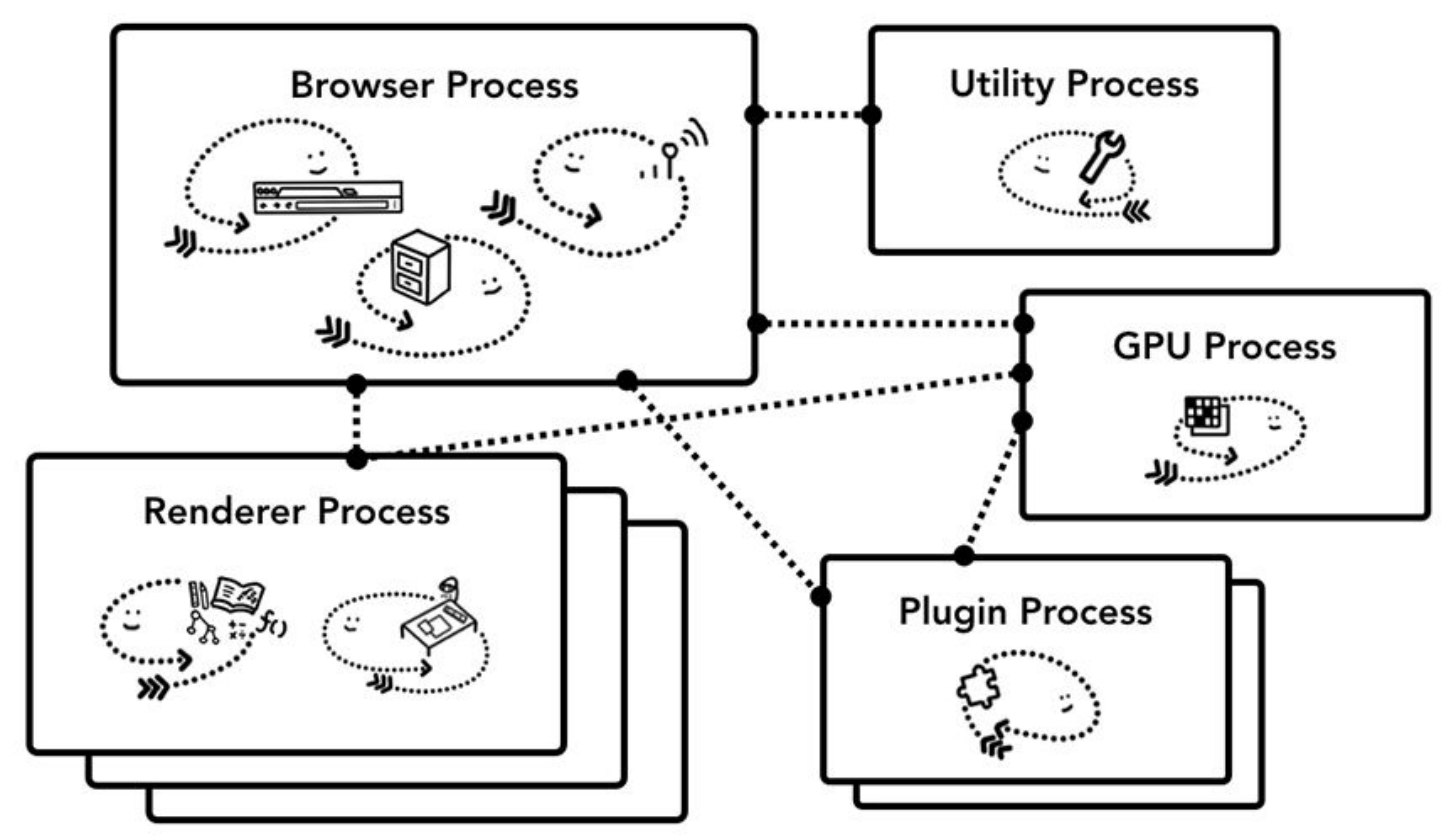


Application Exploit - Messaging/Video Conferencing

- Good 0-click attack surface
- For video/audio conferencing, WebRTC is a common library
  - Most android apps will have their conferencing & messaging code in a native library
- Lots of options:
  - Android messages, Duo, WhatsApp, Signal, Telegram, WeChat, and more...
- Examples:
  - WhatsApp 0-day CVE-2019-3568 [Checkpoint blog, P0 slides, P0 recording]
  - Exploiting Android Messengers
  - Detailed series on exploit chain for Samsung via MMS

Chrome (and other browsers)



https://developers.google.com/web/updates/2018/09/inside-browser-part1

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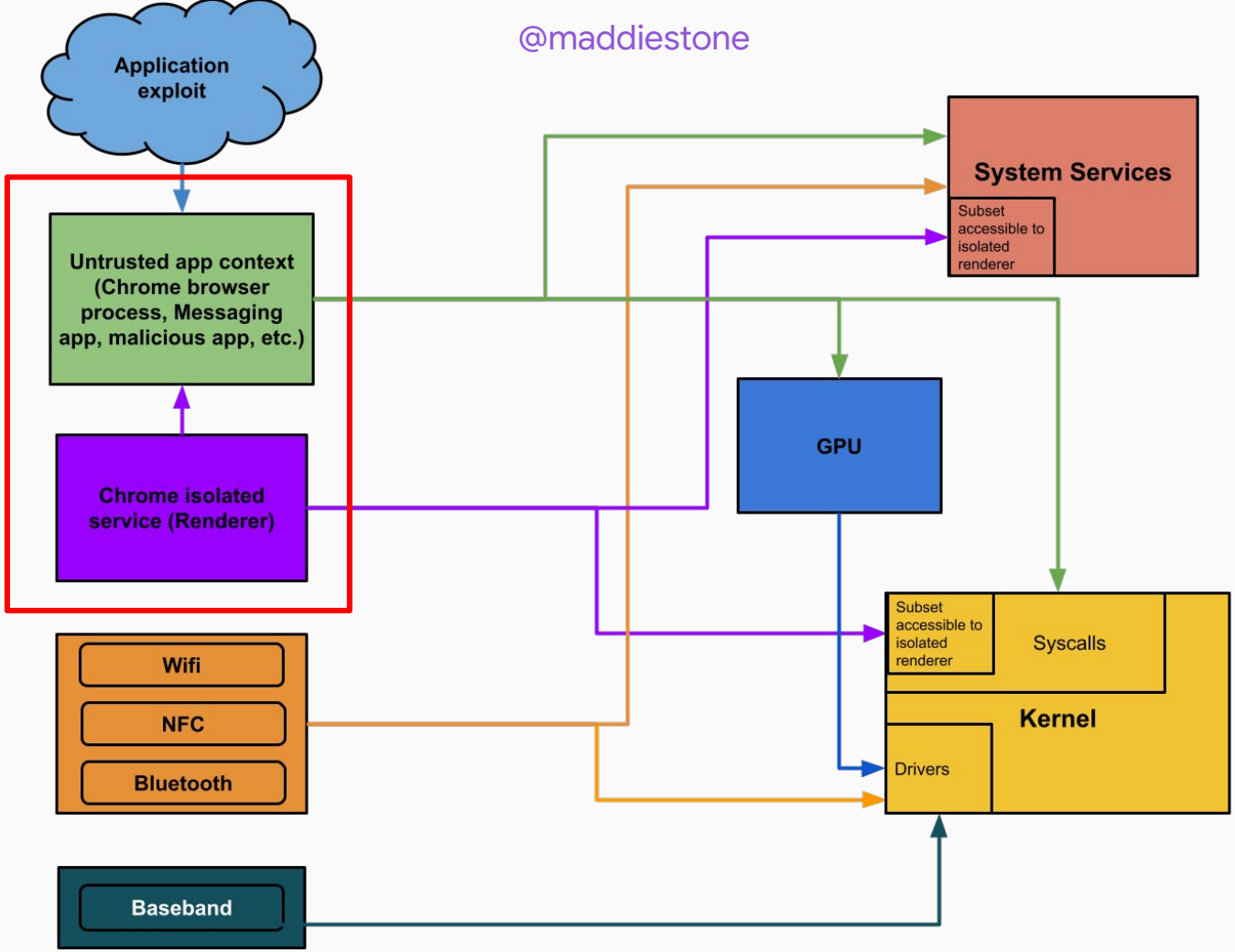


Chrome processes on Android

Browser process:

```
u:r:untrusted_app:s0:c216,c256,c512,c768  u0_a216    com.android.chrome
```

App zygote process (manages the isolated/renderer processes):

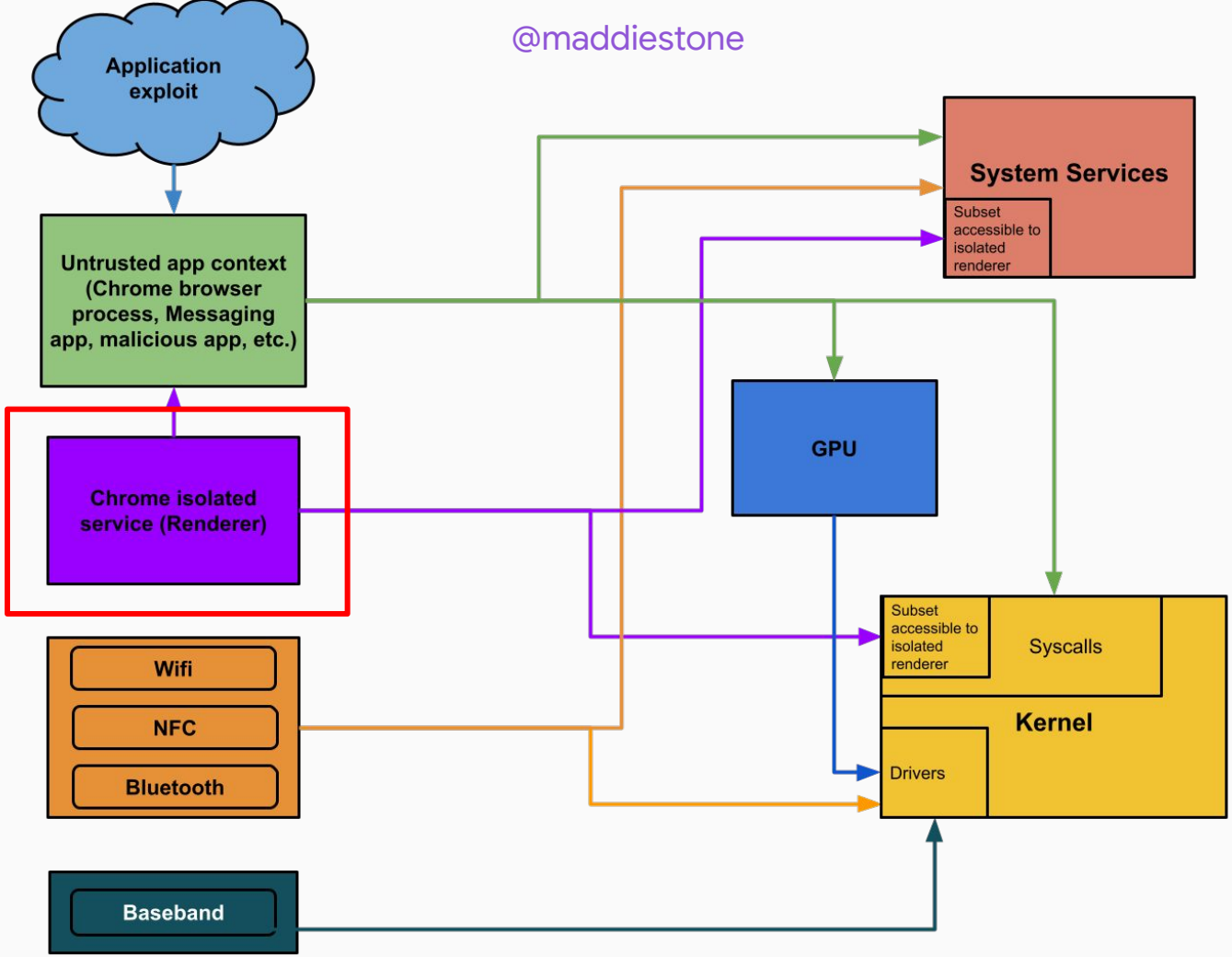
```
u:r:app_zygote:s0:c512,c768               u0_a216      com.android.chrome_zygote
```

GPU process:

```
u:r:untrusted_app:s0:c216,c256,c512,c768  u0_a216    com.android.chrome:privileged_process0
```

Isolated/renderer process[es]:

```
u:r:isolated_app:s0:c512,c768             u0_i9
com.android.chrome:sandboxed_process0:org.chromium.content.app.SandboxedProcessService0:9
```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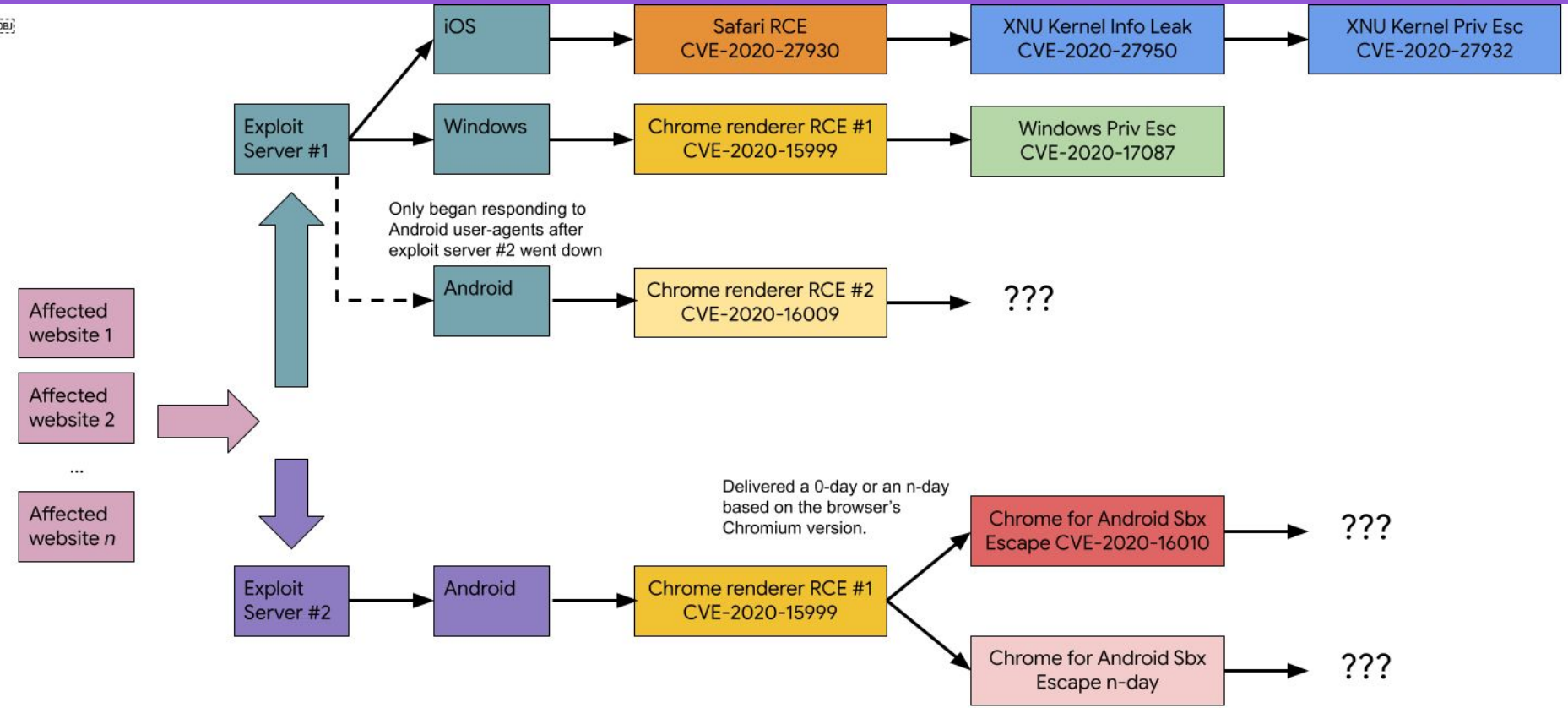
Browser Exploits - Renderer Remote Code Execution

- Chrome uses a multi-process architecture
  - Gaining remote code execution in the renderer process is usually the first step
  - Renderer exploits tend to be usable across
- Common renderer exploit targets
  - V8 (Javascript engine)
  - Blink / DOM
  - Fonts
- Still mostly memory corruption
- Examples:
  - CVE-2020-6418: Incorrect side-effect modelling issue in TurboFan leading to type confusions
  - CVE-2020-15999: FreeType Heap Buffer Overflow in Load_SBit_Png
  - CVE-2021-30551: Type confusion in v8



https://googleprojectzero.blogspot.com/2021/03/in-wild-series-october-2020-0-day.html

CVE-2020-15999

```
Load_SBit_Png( ... ) {
[...]
  png_get_IHDR( png, info,
                &imgWidth, &imgHeight,
                &bitdepth, &color_type, &interlace,
                NULL, NULL ); // *** 1 ***
[...]
  if ( populate_map_and_metrics )   {
    metrics->width  = (FT_UShort)imgWidth; // *** 2 ***
    metrics->height = (FT_UShort)imgHeight;
    map->width      = metrics->width;
    map->rows       = metrics->height;
    map->pixel_mode = FT_PIXEL_MODE_BGRA;
    map->pitch      = (int)( map->width * 4 );
[...]
  if ( populate_map_and_metrics ) {
    /* this doesn't overflow: 0x7FFF * 0x7FFF * 4 < 2^32 */
    FT_ULong  size = map->rows * (FT_ULong)map->pitch; // *** 3 ***
    error = ft_glyphslot_alloc_bitmap( slot, size ); // *** 4 ***
    if ( error )
      goto DestroyExit;  }
[...]
  png_read_image( png, rows ); // *** 5 ***
```

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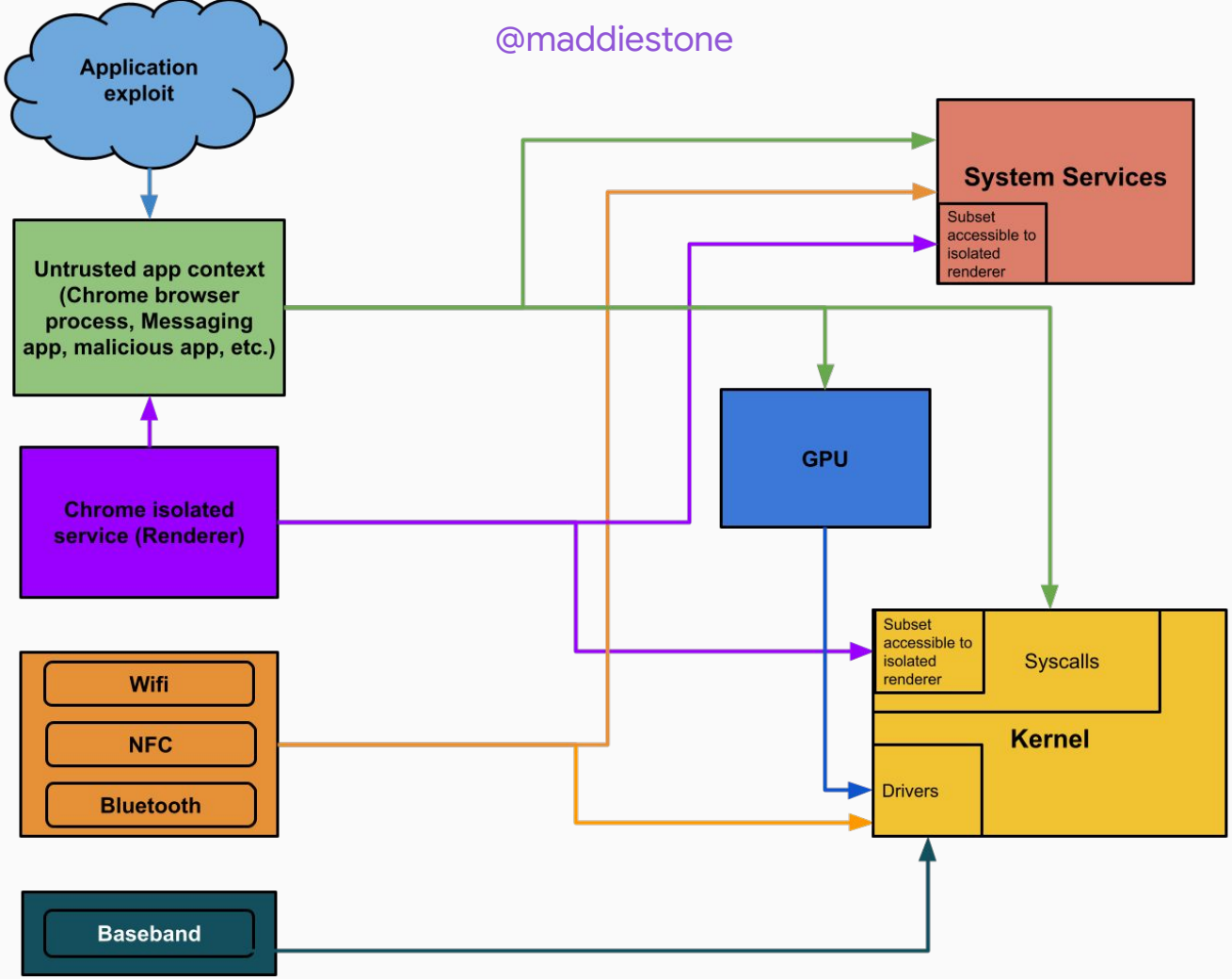

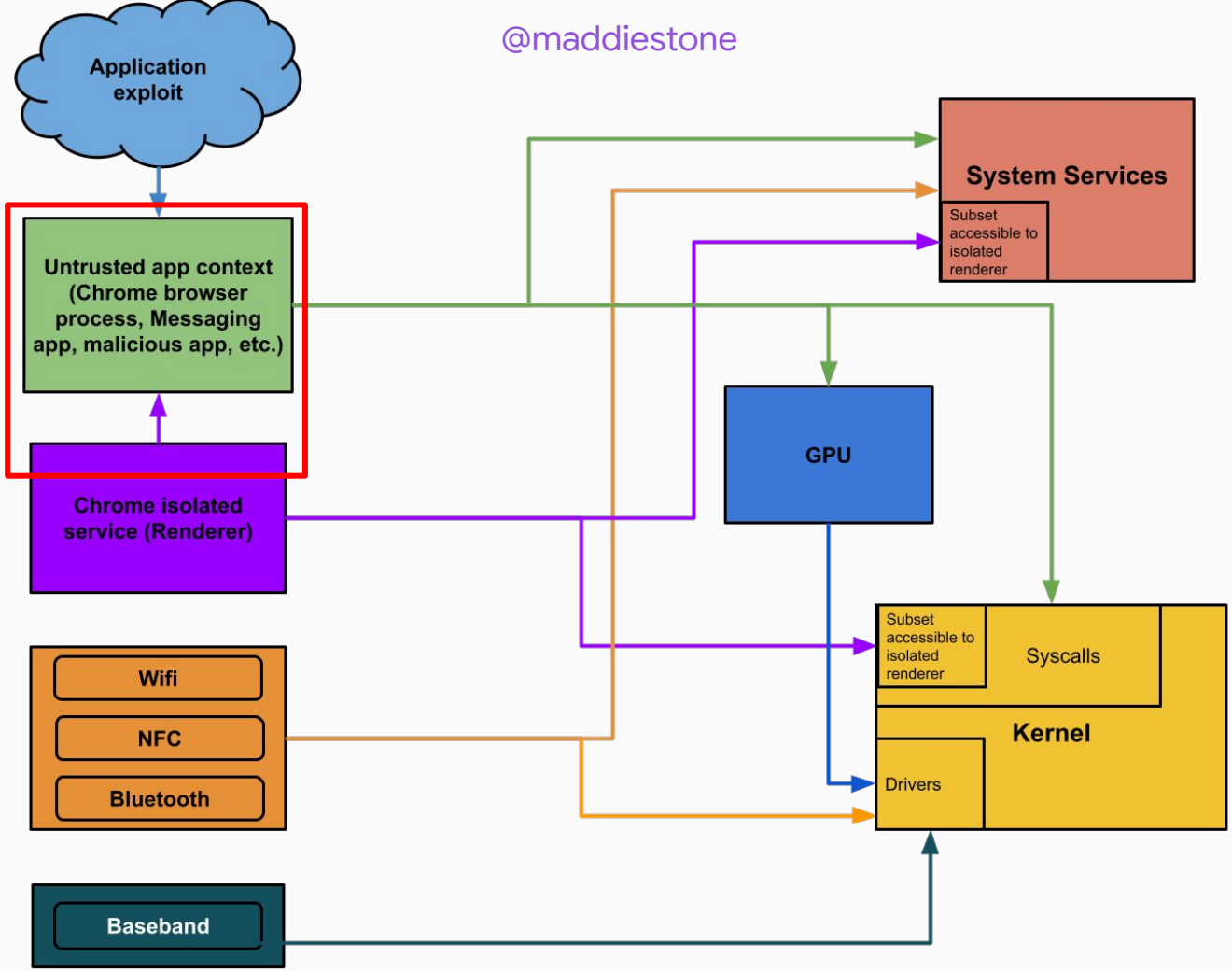
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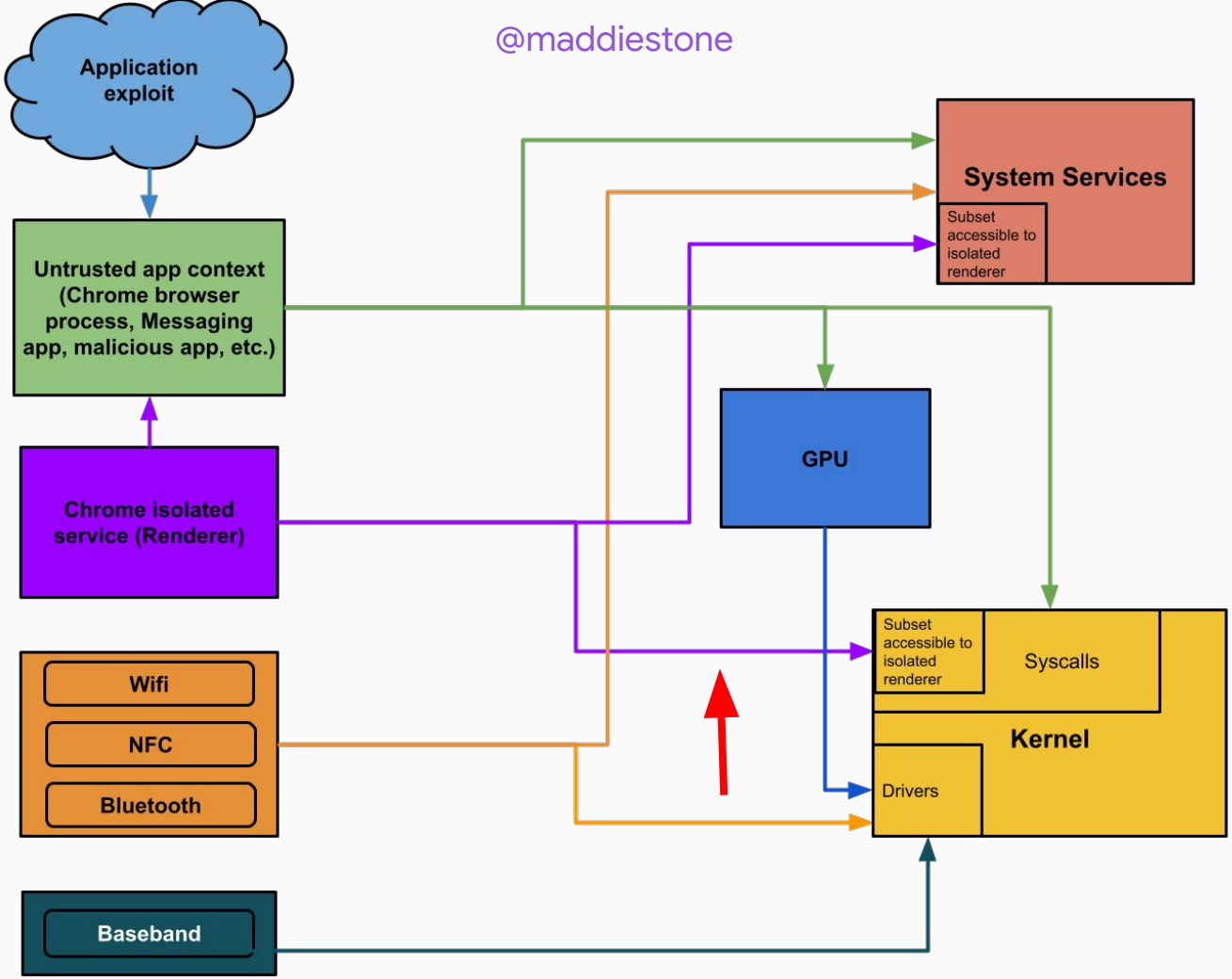
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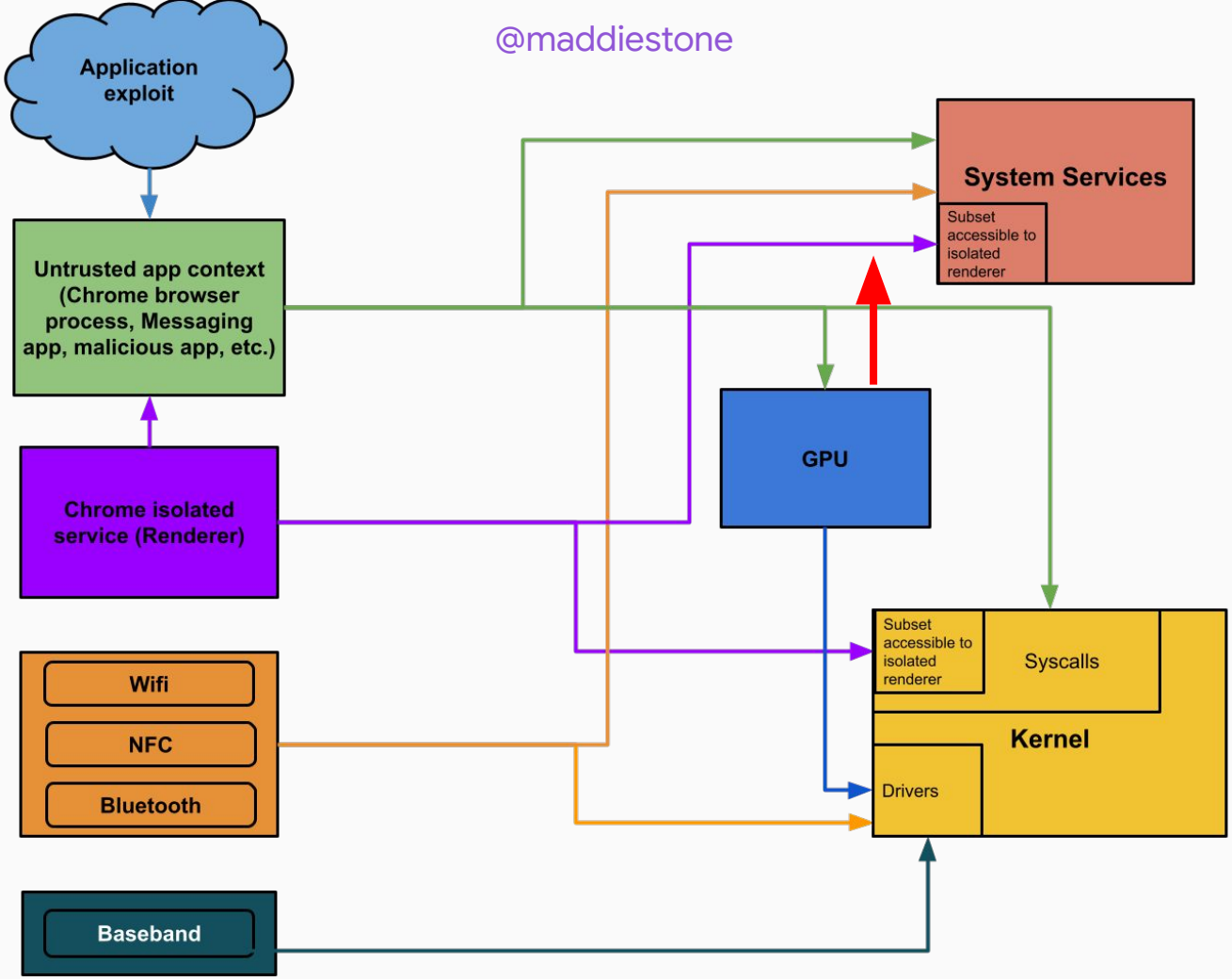


Browser Exploits - Sandbox Escape

- In this case, “sandbox escape” means escaping the Chrome sandbox, not the application sandbox
- With renderer RCE, the options to escape the sbx are:
  - Renderer (isolated_app) → Browser process (untrusted_app) [Purple to Green]
  - Renderer (isolated_app) → Chrome GPU process [Purple to Green]
  - Renderer (isolated_app) → Kernel (Binder) [Purple to Yellow]
  - Renderer (isolated_app) → System services [Purple to Red]
- Examples:
  - CVE-2020-6572: Chrome MediaCodecAudioDecoder Sandbox escape
    - (and CVE-2019-5870 and CVE-2019-13695)
  - CVE-2020-16010: Sandbox escape to Chrome GPU Process
  - CVE-2020-16045: Sandbox escape via Payment Processing Code

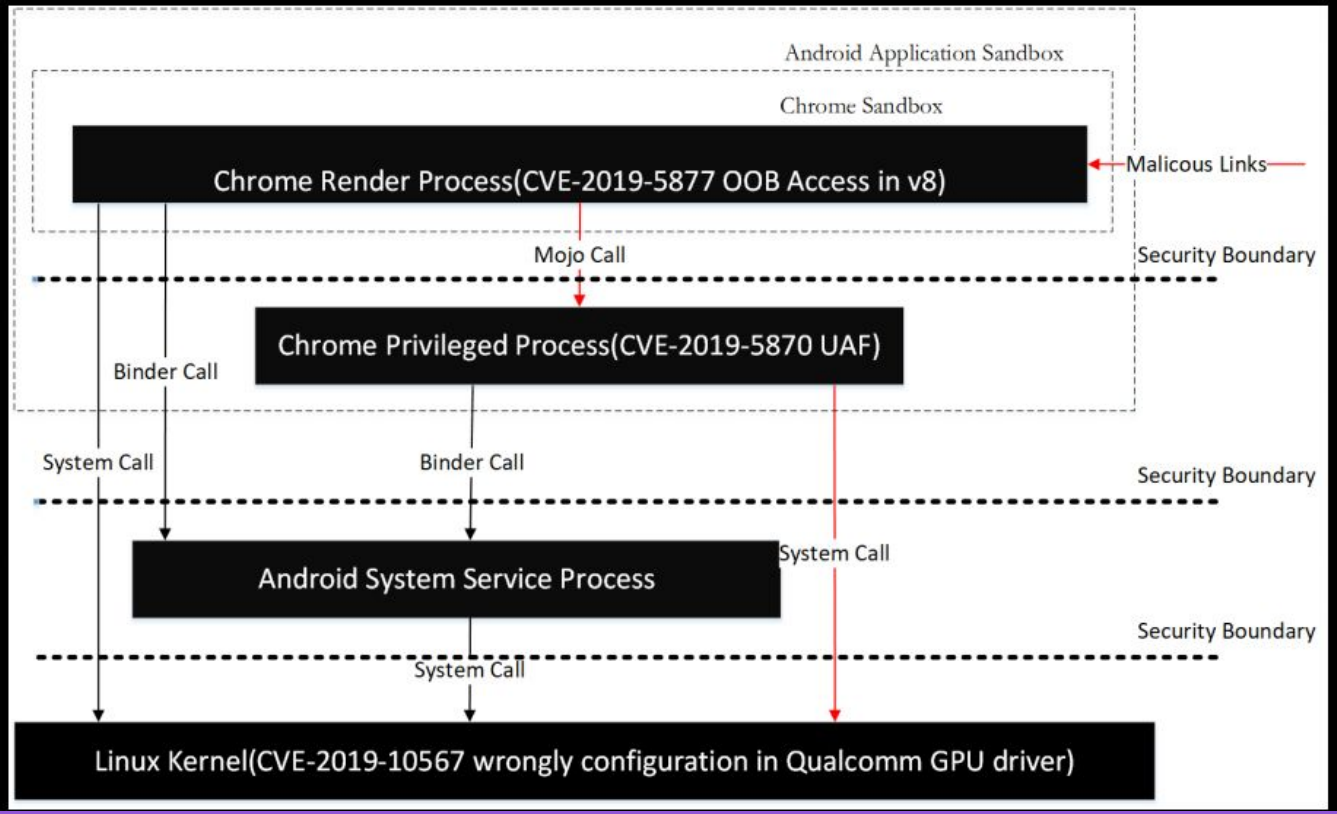
CVE-2020-6572

- Use-after-free in `MediaCodecAudioDecoder::~MediaCodecAudioDecoder()`
  - Android-specific code that uses Android's media decoding APIs to support playback of DRM-protected media on Android
  - Runs in the Chrome GPU process (`privilegedprocess`)
- A `unique_ptr` is assigned to another, going out of scope which means it can be deleted, while at the same time a raw pointer from the originally referenced object isn't updated

Example Chrome for Android Chains

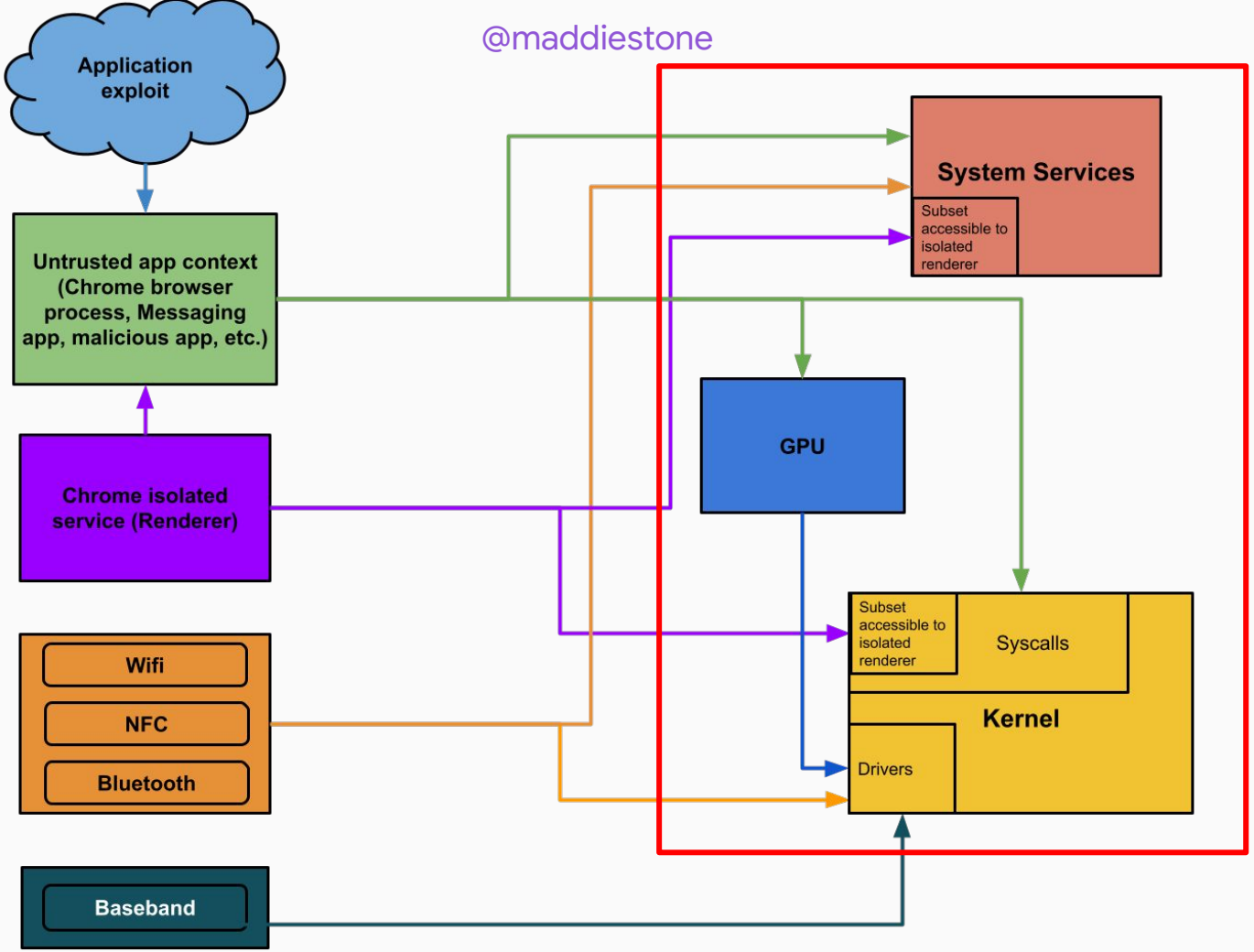
- 3-part blog series by Man Yue Mo
  - CVE-2020-15972 (Chrome webaudio) → CVE-2020-16045 (Chrome payment processing) → CVE-2020-11239 (Qualcomm GPU)
- Oct 2020 in-the-wild exploits
  - CVE-2020-15999 (Freetype) → CVE-2020-16010 (Chrome for Android) → ???
- TiYunZong

The Exploit Chain(TiYunZong)



Blackhat 2020: TiYunZong Pixel full chain exploit [slides, video]

Local Privilege Escalations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Android LPE Attack Surfaces

From an attacker's perspective, maintaining an Android exploit capability is a question of covering the widest possible range of the Android ecosystem in the most cost-effective way possible.

- ***Tier*: Ubiquitous**

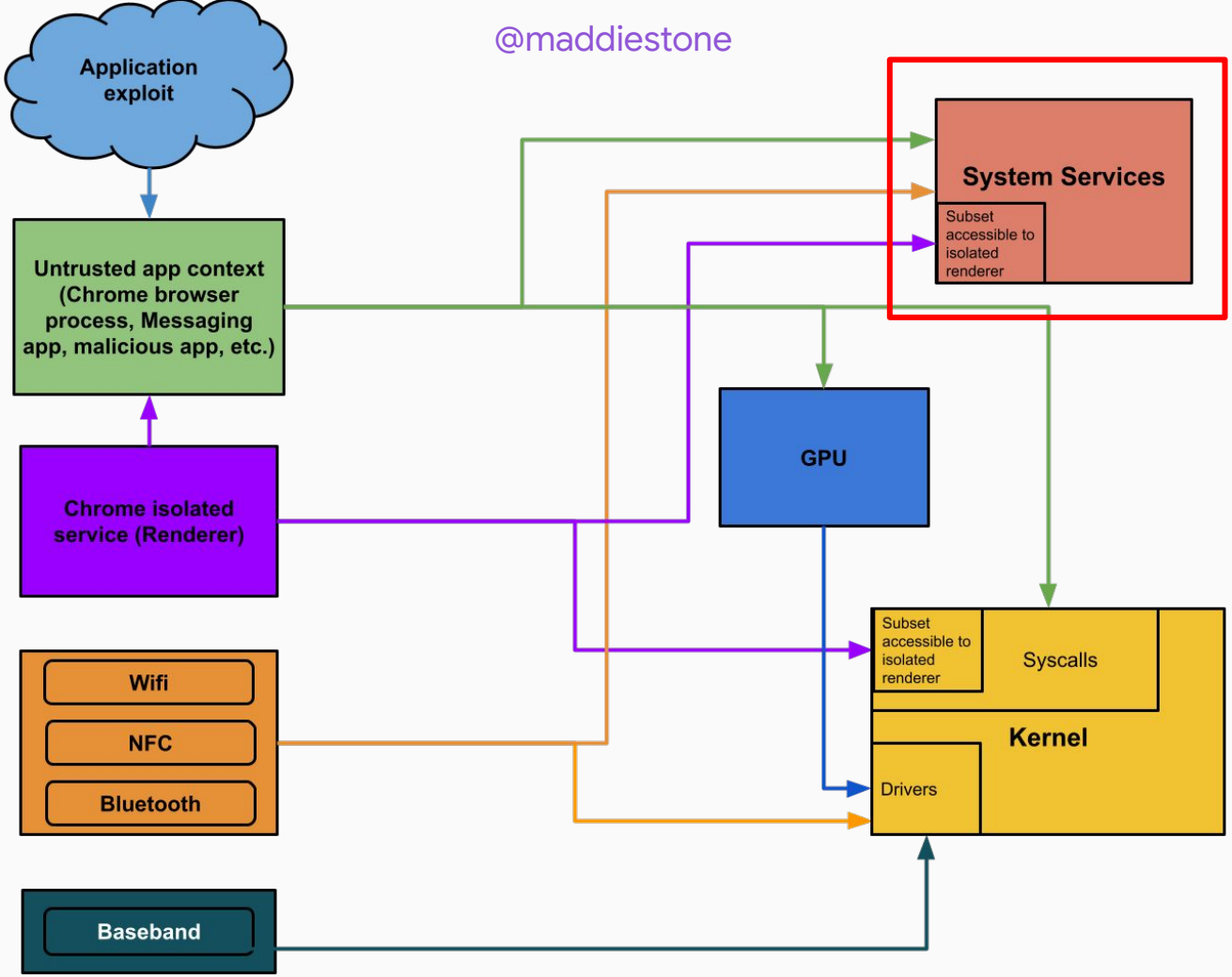
  Description: Issues that affect all devices in the Android ecosystem.
  Example: Core Linux kernel bugs like Dirty COW, or vulnerabilities in standard system services.
- ***Tier*: Chipset**

  Description: Issues that affect a substantial portion of the Android ecosystem, based on which type of hardware is used by various OEM vendors.
  Example: Snapdragon SoC perf counter vulnerability, or Broadcom WiFi firmware stack overflow.
- ***Tier*: Vendor**

  Description: Issues that affect most or all devices from a particular Android OEM vendor
  Example: Samsung kernel driver vulnerabilities
- ***Tier*: Device**

  Description: Issues that affect a particular device model from an Android OEM vendor
  Example: Pixel 4 face unlock "attention aware" vulnerability

https://googleprojectzero.blogspot.com/2020/09/attacking-qualcomm-adreno-gpu.html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System Services

- System services are services that run in the system_server process (UID: system)
  - These services are a part of the “Android Framework”: core services for the functionality of the phone written in Java.
    - Include services like Telephony, PackageManager, ActivityManager, PowerManager, etc.
  - https://android.googlesource.com/platform/frameworks/base/+/master/services/java/com/android/server/SystemServer.java
- Example
  - CVE-2018-9411 - https://blog.zimperium.com/cve-2018-9411-new-critical-vulnerability-multiple-high-privileged-android-services/
  - Deserialization Vulnerabilities

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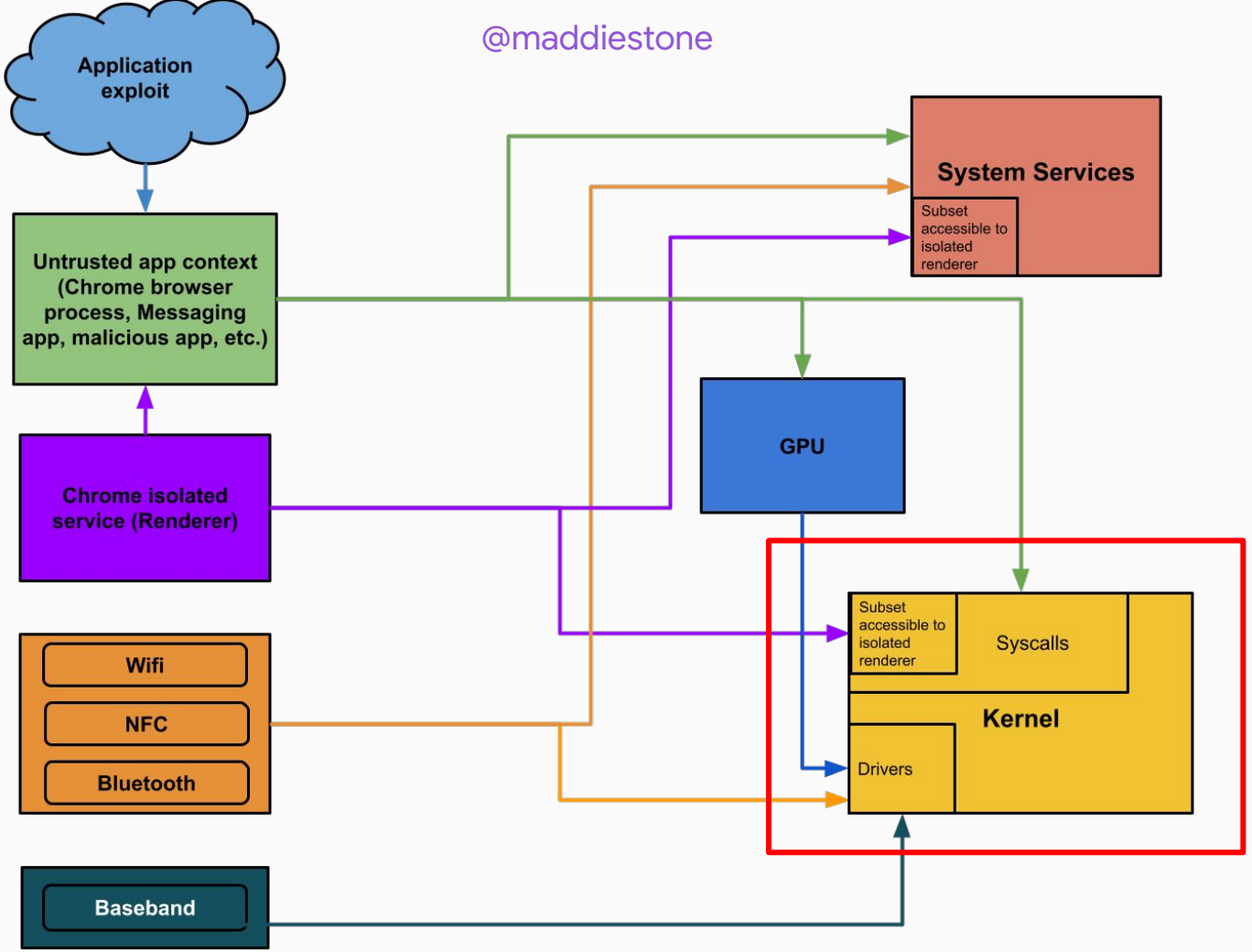

Kernel Priv Escs

- Survey of n-days used in-the-wild
- Kernel drivers
- Syscalls
- Binder (Inter-Process Communication)
  - Accessible from Chrome renderer (isolated_app)
  - Examples:
    - CVE-2019-2215: “Bad Binder” [blog, video]
    - CVE-2020-0041: Using the same Binder bug to both escape the Chrome sandbox and escalate to root

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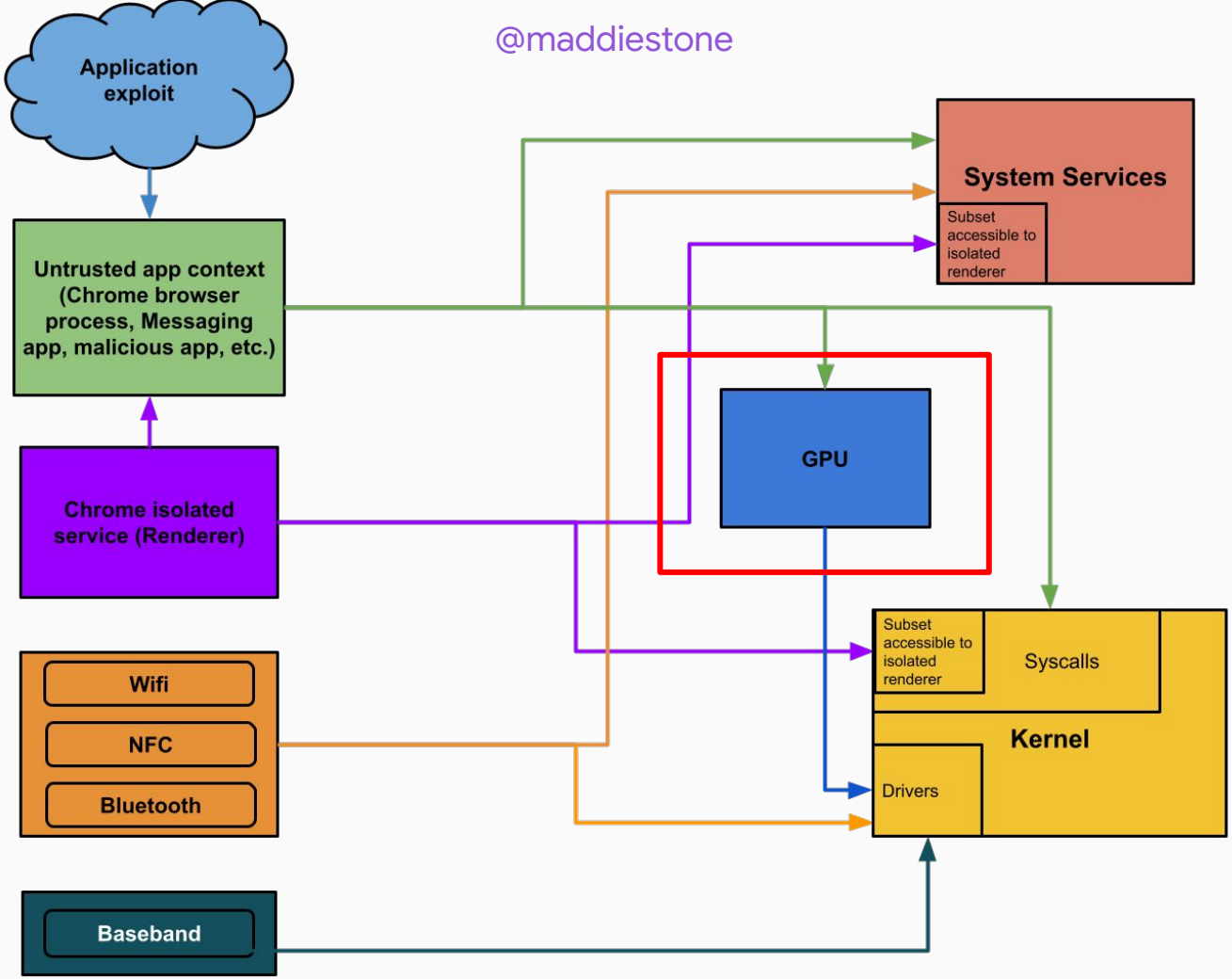
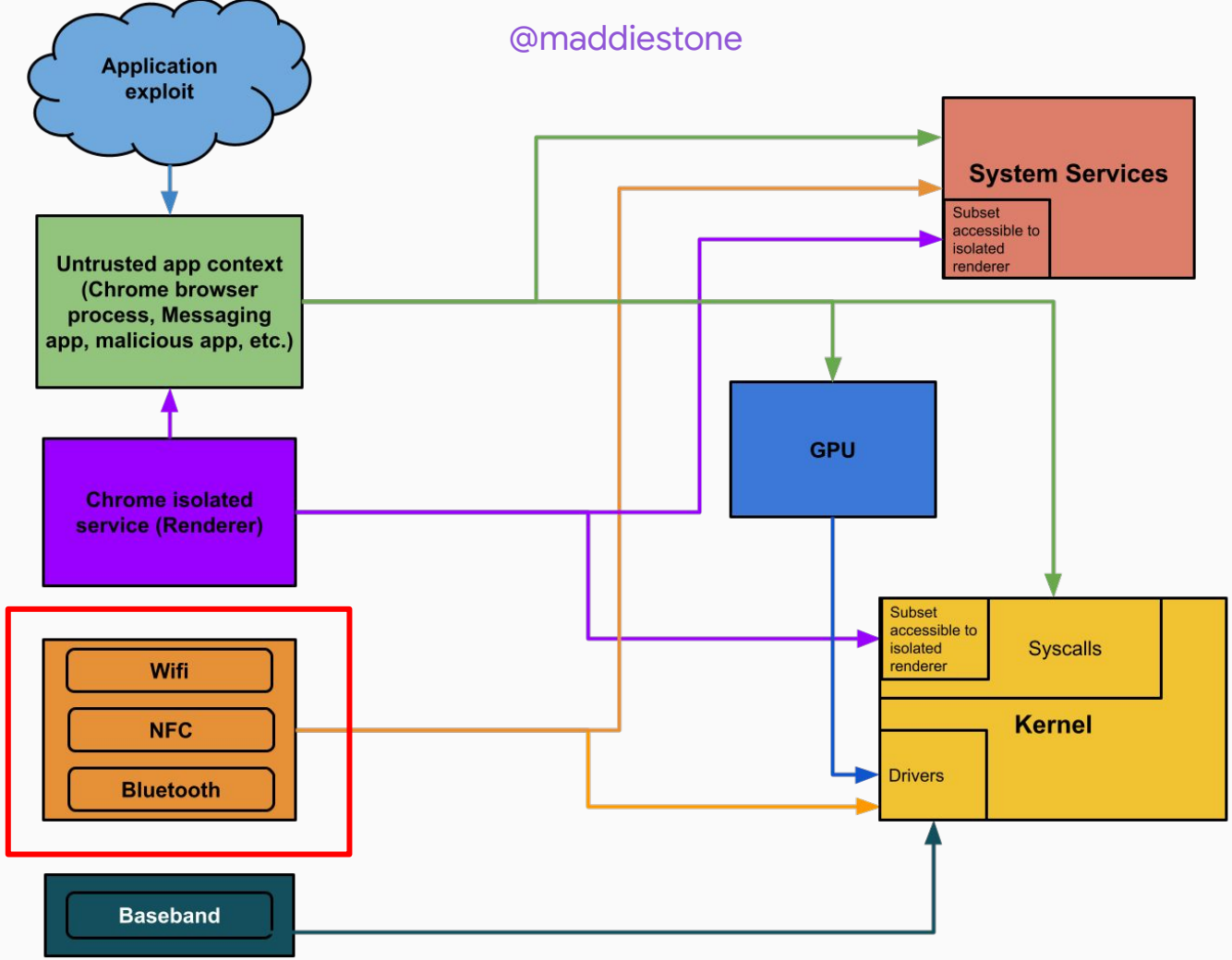


GPU

- Large number of full-chains we're seeing in the last two years target the GPU for the LPE (5 itw bugs this year)

- Qualcomm Adreno & ARM Mali
- Examples:
  - CVE-2021-1905: Qualcomm Adreno GPU memory mapping use-after-free
  - PZ blog post by Ben Hawkes: Attacking the Qualcomm Adreno
  - Blackhat 2020: TiYunZong Pixel full chain exploit [slides, video, whitepaper]
  - Blackhat 2016: GPU-Security-Exposed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WiFi, NFC, & Bluetooth

- Multiple options for exploitation routes
  - Usermode on component chip
  - Kernel mode on component chip
  - Usermode on application processor
  - Kernel on application processor
- Examples:
  - An-android-8-0-9-0-bluetooth-zero-click-rce

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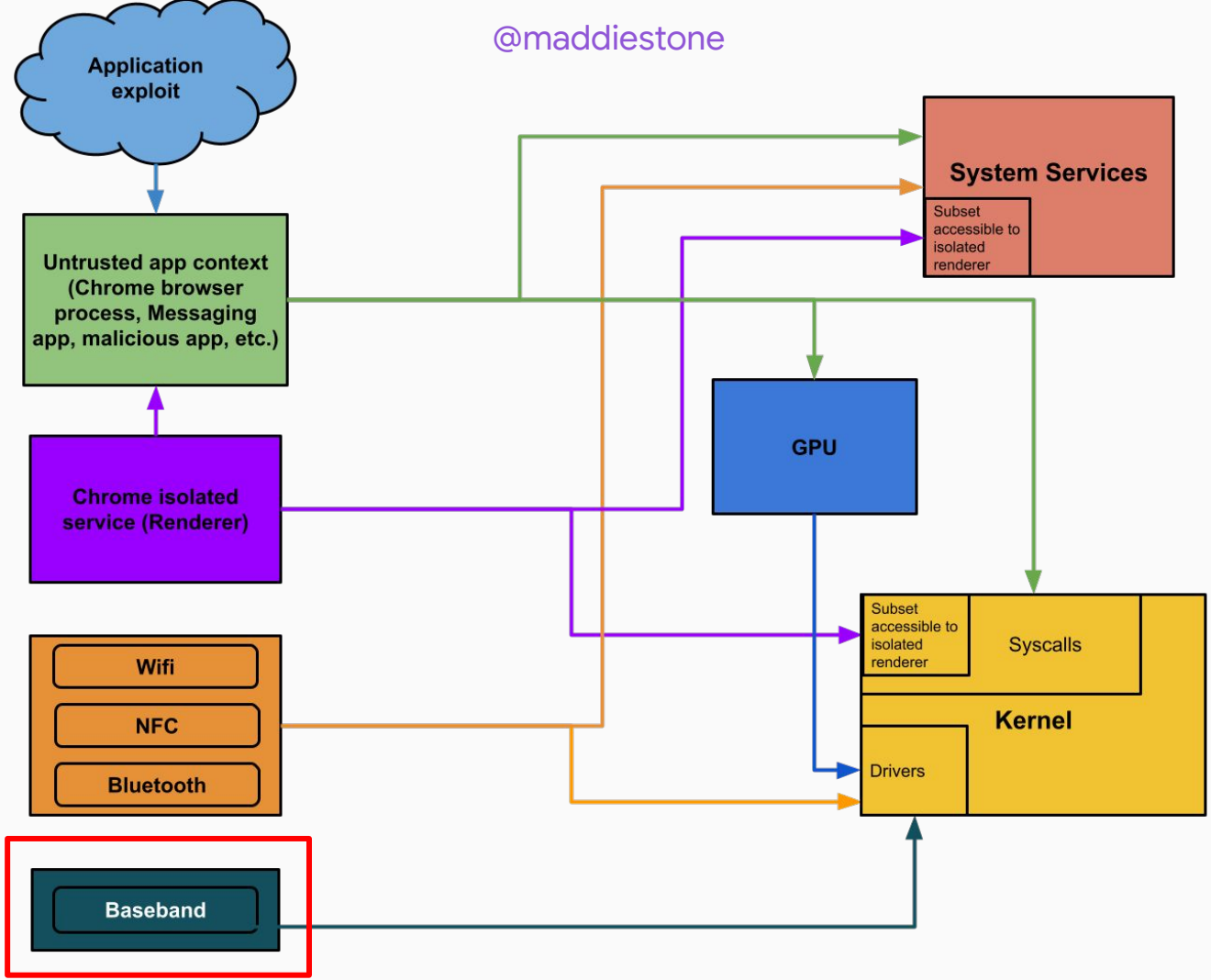

Baseband

- Flow is usually get code execution on baseband processor and then escape to the application processor, usually via the kernel interface

- Examples:
  - Blackhat 2018: Exploitation of a Modern Smartphone Baseband [paper, video]
  - OffensiveCon 2020: Exploring the MediaTek Baseband
  - Walkthrough of a pwn2own baseband exploit

Common mitigations that have to be bypassed

- SELinux [both mitigation & general access control]
- Privileged Access Never (PAN) [1, 2]
- Knox (Samsung)
  - Real-time Kernel Protection (RKP) [1, 2, 3]
- User Access Override (UAO)
- Huawei Kernel Integrity Protection (HKIP)

Plenty of work to do! All are welcome :)