DIOPS Wi-Fi Package
(PC APP: Wireshark; C/C++ dev package: pcap; Terminal tool: tcpdump)

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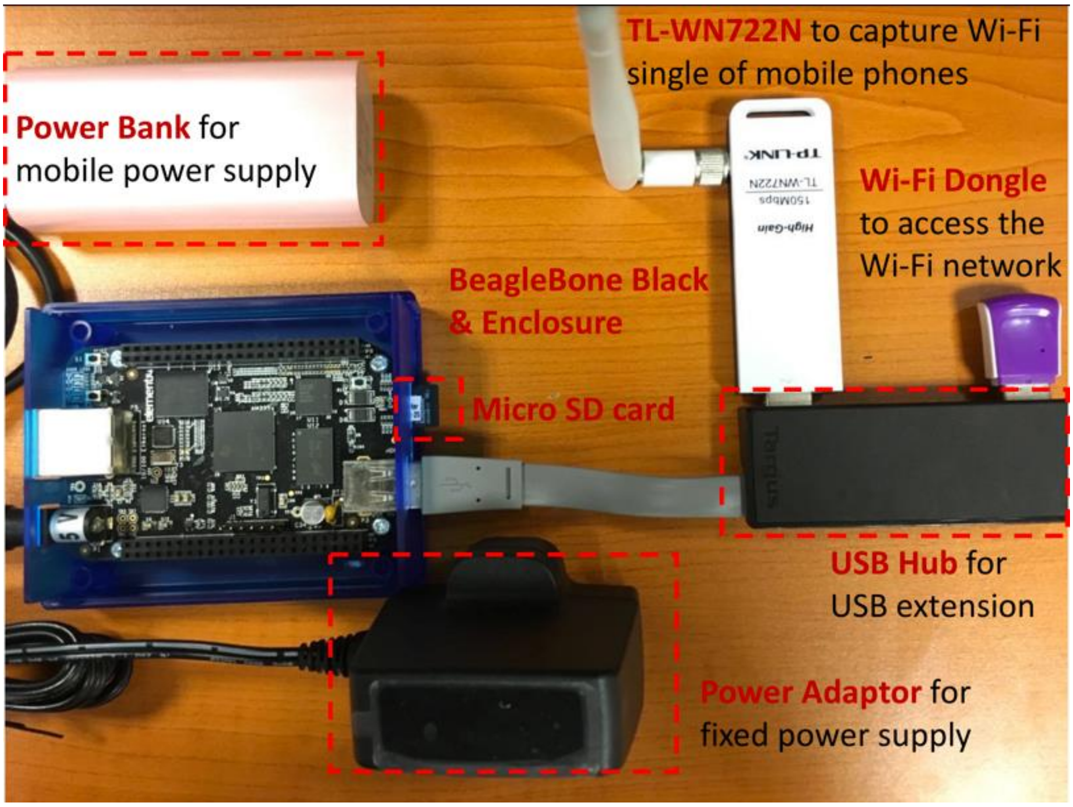
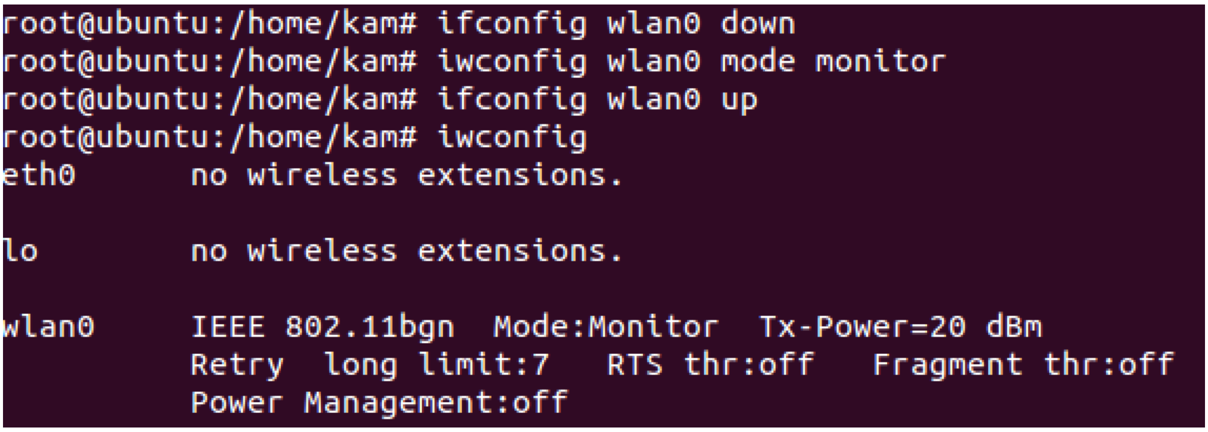
1. Smart Gateway Components



TL-WN722N to capture Wi-Fi single of mobile phones
Power Bank for mobile power supply
TP-LINK
TL-WN722N
150Mbps
High-Gain
Wi-Fi Dongle to access the Wi-Fi network
BeagleBone Black & Enclosure
Micro SD card
USB Hub for USB extension
Power Adaptor for fixed power supply

1) **BeagleBone Black & Enclosure**
   works as the basic platform for the system.
2) **Micro SD card**
   stores the source for system booting and works as a local database.
3) **Wi-Fi Dongle**
   enables the network accessibility.
4) **TL-WN722N**
   performs as Wi-Fi sensor for Wi-Fi signal strength capturing. They are both connected to smart gateway with USB interfaces. Since only 1 USB interface is available on BeagleBone Black.
5) **USB Hub**
   is required here for USB extension since only 1 USB port on the board.
6) **Power Bank**
   can work as mobile power supply.
7) **Power Adapter**
   is for fixed permanent power supply.
8) **Settings**

to enable Wi-Fi signal sensing, TL-WN722N should work in monitor mode. The following figure shows the procedures to do the configuration on Ubuntu.

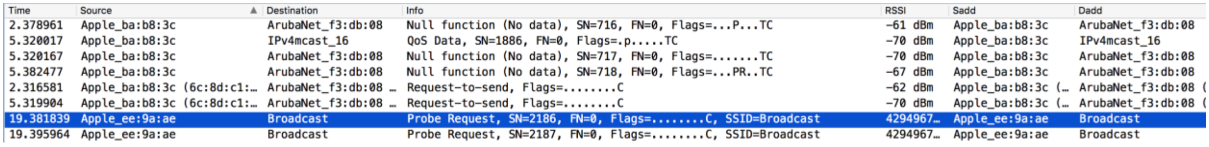


```
root@ubuntu:/home/kam# ifconfig wlan0 down
root@ubuntu:/home/kam# iwconfig wlan0 mode monitor
root@ubuntu:/home/kam# ifconfig wlan0 up
root@ubuntu:/home/kam# iwconfig
eth0      no wireless extensions.

lo        no wireless extensions.

wlan0     IEEE 802.11bgn  Mode:Monitor  Tx-Power=20 dBm
          Retry  long limit:7   RTS thr:off   Fragment thr:off
          Power Management:off
```

2. Raw Packets Captured by TL-WN722N

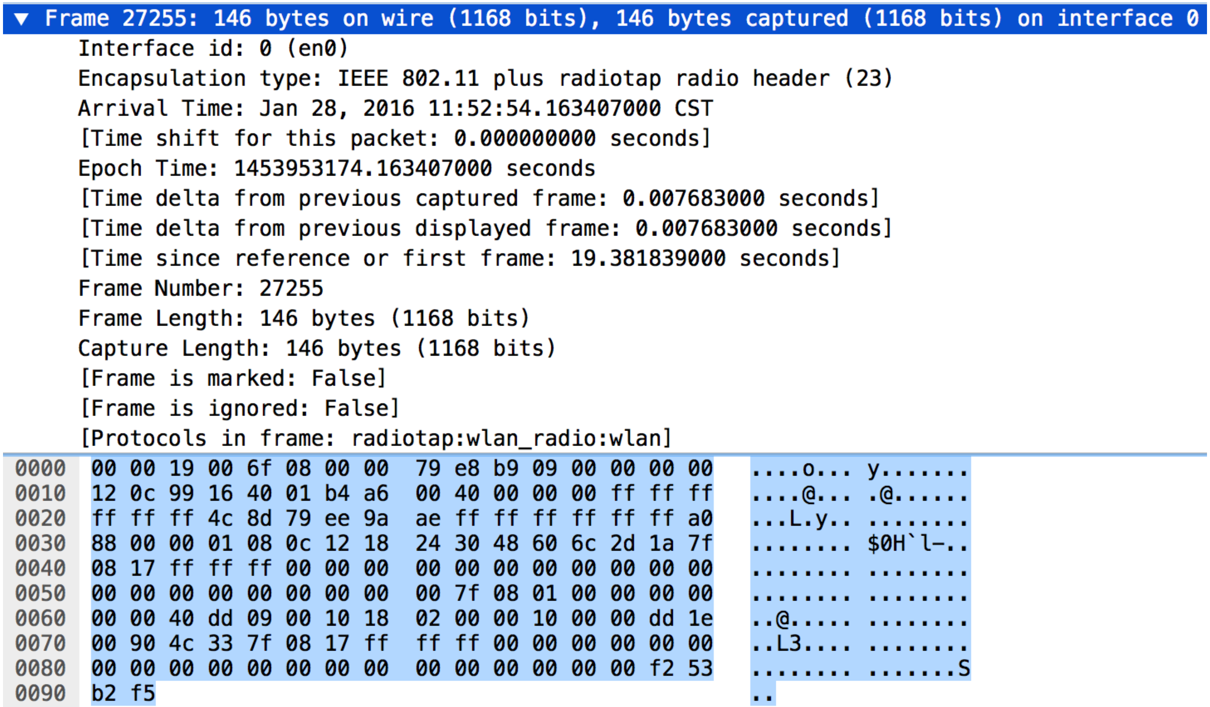
(This part is demonstrated with Wireshark GUI, where we analyze Wi-Fi packet structure. The same theory is applicable to tcpdump and pcap)

Information in captured packets: including MAC address of source, RSSI values



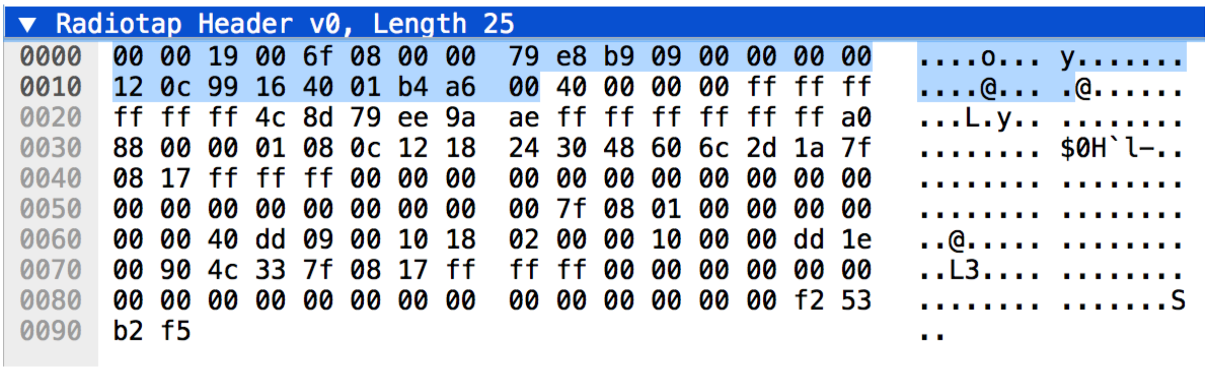
Time	Source	Destination	Info	RSSI	Sadd	Dadd
2.378961	Apple_ba:b8:3c	ArubaNet_f3:db:08	Null function (No data), SN=716, FN=0, Flags=...P...TC	-61 dBm	Apple_ba:b8:3c	ArubaNet_f3:db:08
5.320017	Apple_ba:b8:3c	IPv4mcast_16	QoS Data, SN=1886, FN=0, Flags=.p.....TC	-70 dBm	Apple_ba:b8:3c	IPv4mcast_16
5.320167	Apple_ba:b8:3c	ArubaNet_f3:db:08	Null function (No data), SN=717, FN=0, Flags=.......TC	-70 dBm	Apple_ba:b8:3c	ArubaNet_f3:db:08
5.382477	Apple_ba:b8:3c	ArubaNet_f3:db:08	Null function (No data), SN=718, FN=0, Flags=...PR..TC	-67 dBm	Apple_ba:b8:3c	ArubaNet_f3:db:08
2.316581	Apple_ba:b8:3c (6c:8d:c1:…	ArubaNet_f3:db:08 …	Request-to-send, Flags=........C	-62 dBm	Apple_ba:b8:3c (…	ArubaNet_f3:db:08 (
5.319904	Apple_ba:b8:3c (6c:8d:c1:…	ArubaNet_f3:db:08 …	Request-to-send, Flags=........C	-70 dBm	Apple_ba:b8:3c (…	ArubaNet_f3:db:08 (
19.381839	Apple_ee:9a:ae	Broadcast	Probe Request, SN=2186, FN=0, Flags=........C, SSID=Broadcast	4294967…	Apple_ee:9a:ae	Broadcast
19.395964	Apple_ee:9a:ae	Broadcast	Probe Request, SN=2187, FN=0, Flags=........C, SSID=Broadcast	4294967…	Apple_ee:9a:ae	Broadcast

Details for the selected highlighted packet shown above



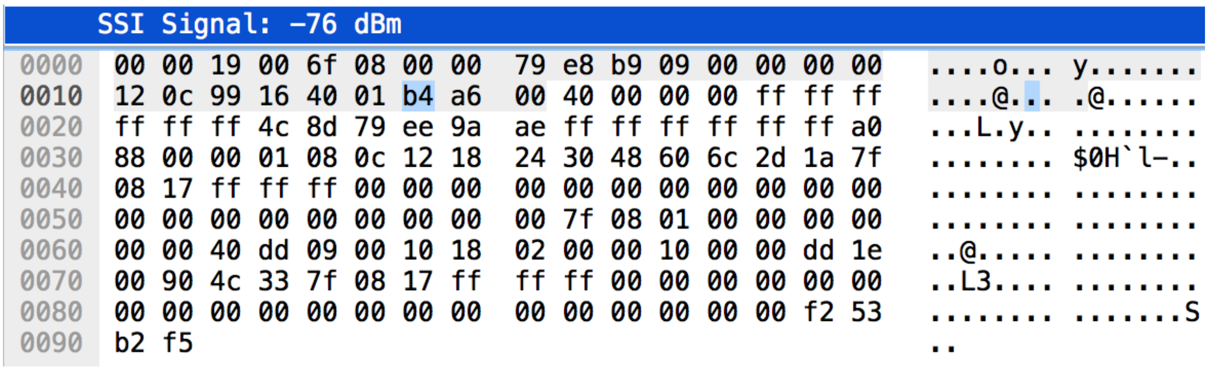
```
▼ Frame 27255: 146 bytes on wire (1168 bits), 146 bytes captured (1168 bits) on interface 0
      Interface id: 0 (en0)
      Encapsulation type: IEEE 802.11 plus radiotap radio header (23)
      Arrival Time: Jan 28, 2016 11:52:54.163407000 CST
      [Time shift for this packet: 0.000000000 seconds]
      Epoch Time: 1453953174.163407000 seconds
      [Time delta from previous captured frame: 0.007683000 seconds]
      [Time delta from previous displayed frame: 0.007683000 seconds]
      [Time since reference or first frame: 19.381839000 seconds]
      Frame Number: 27255
      Frame Length: 146 bytes (1168 bits)
      Capture Length: 146 bytes (1168 bits)
      [Frame is marked: False]
      [Frame is ignored: False]
      [Protocols in frame: radiotap:wlan_radio:wlan]
0000  00 00 19 00 6f 08 00 00  79 e8 b9 09 00 00 00 00   ....o... y.......
0010  12 0c 99 16 40 01 b4 a6  00 40 00 00 00 ff ff ff   ....@... .@......
0020  ff ff ff 4c 8d 79 ee 9a  ae ff ff ff ff ff ff a0   ...L.y.. ........
0030  88 00 00 01 08 0c 12 18  24 30 48 60 6c 2d 1a 7f   ........ $0H`l-..
0040  08 17 ff ff ff 00 00 00  00 00 00 00 00 00 00 00   ........ ........
0050  00 00 00 00 00 00 00 00  00 7f 08 01 00 00 00 00   ........ ........
0060  00 00 40 dd 09 00 10 18  02 00 00 10 00 00 dd 1e   ..@..... ........
0070  00 90 4c 33 7f 08 17 ff  ff ff 00 00 00 00 00 00   ..L3.... ........
0080  00 00 00 00 00 00 00 00  00 00 00 00 00 00 f2 53   ........ .......S
0090  b2 f5                                              ..
```

1) Radiotap Header: including RSSI value (signal strength indicator)



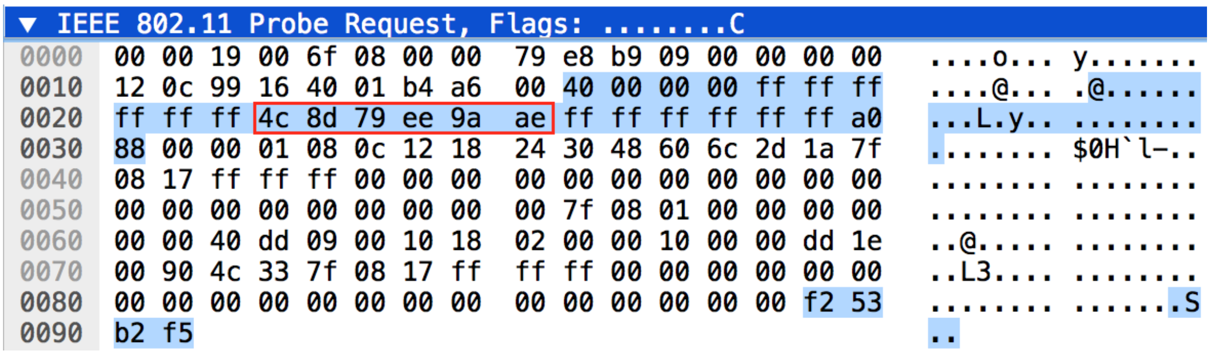
```
▼ Radiotap Header v0, Length 25
0000  00 00 19 00 6f 08 00 00  79 e8 b9 09 00 00 00 00   ....o... y.......
0010  12 0c 99 16 40 01 b4 a6  00 40 00 00 00 ff ff ff   ....@... .@......
0020  ff ff ff 4c 8d 79 ee 9a  ae ff ff ff ff ff ff a0   ...L.y.. ........
0030  88 00 00 01 08 0c 12 18  24 30 48 60 6c 2d 1a 7f   ........ $0H`l-..
0040  08 17 ff ff ff 00 00 00  00 00 00 00 00 00 00 00   ........ ........
0050  00 00 00 00 00 00 00 00  00 7f 08 01 00 00 00 00   ........ ........
0060  00 00 40 dd 09 00 10 18  02 00 00 10 00 00 dd 1e   ..@..... ........
0070  00 90 4c 33 7f 08 17 ff  ff ff 00 00 00 00 00 00   ..L3.... ........
0080  00 00 00 00 00 00 00 00  00 00 00 00 00 00 f2 53   ........ .......S
0090  b2 f5                                              ..
```

SSI Signal is the information we need from this part



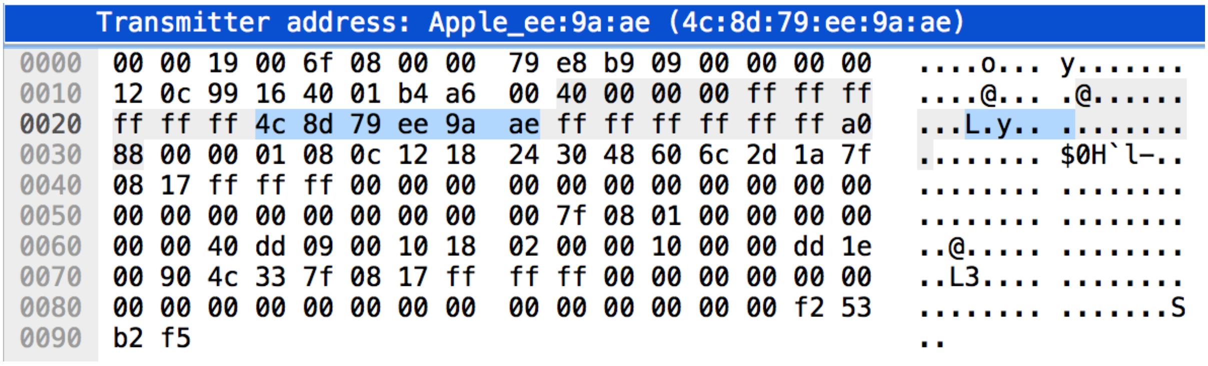
```
SSI Signal: -76 dBm
0000  00 00 19 00 6f 08 00 00  79 e8 b9 09 00 00 00 00   ....o... y.......
0010  12 0c 99 16 40 01 b4 a6  00 40 00 00 00 ff ff ff   ....@... .@......
0020  ff ff ff 4c 8d 79 ee 9a  ae ff ff ff ff ff ff a0   ...L.y.. ........
0030  88 00 00 01 08 0c 12 18  24 30 48 60 6c 2d 1a 7f   ........ $0H`l-..
0040  08 17 ff ff ff 00 00 00  00 00 00 00 00 00 00 00   ........ ........
0050  00 00 00 00 00 00 00 00  00 7f 08 01 00 00 00 00   ........ ........
0060  00 00 40 dd 09 00 10 18  02 00 00 10 00 00 dd 1e   ..@..... ........
0070  00 90 4c 33 7f 08 17 ff  ff ff 00 00 00 00 00 00   ..L3.... ........
0080  00 00 00 00 00 00 00 00  00 00 00 00 00 00 f2 53   ........ .......S
0090  b2 f5                                              ..
```

2) Wi-Fi packet: including MAC address of source (utilized as user ID)



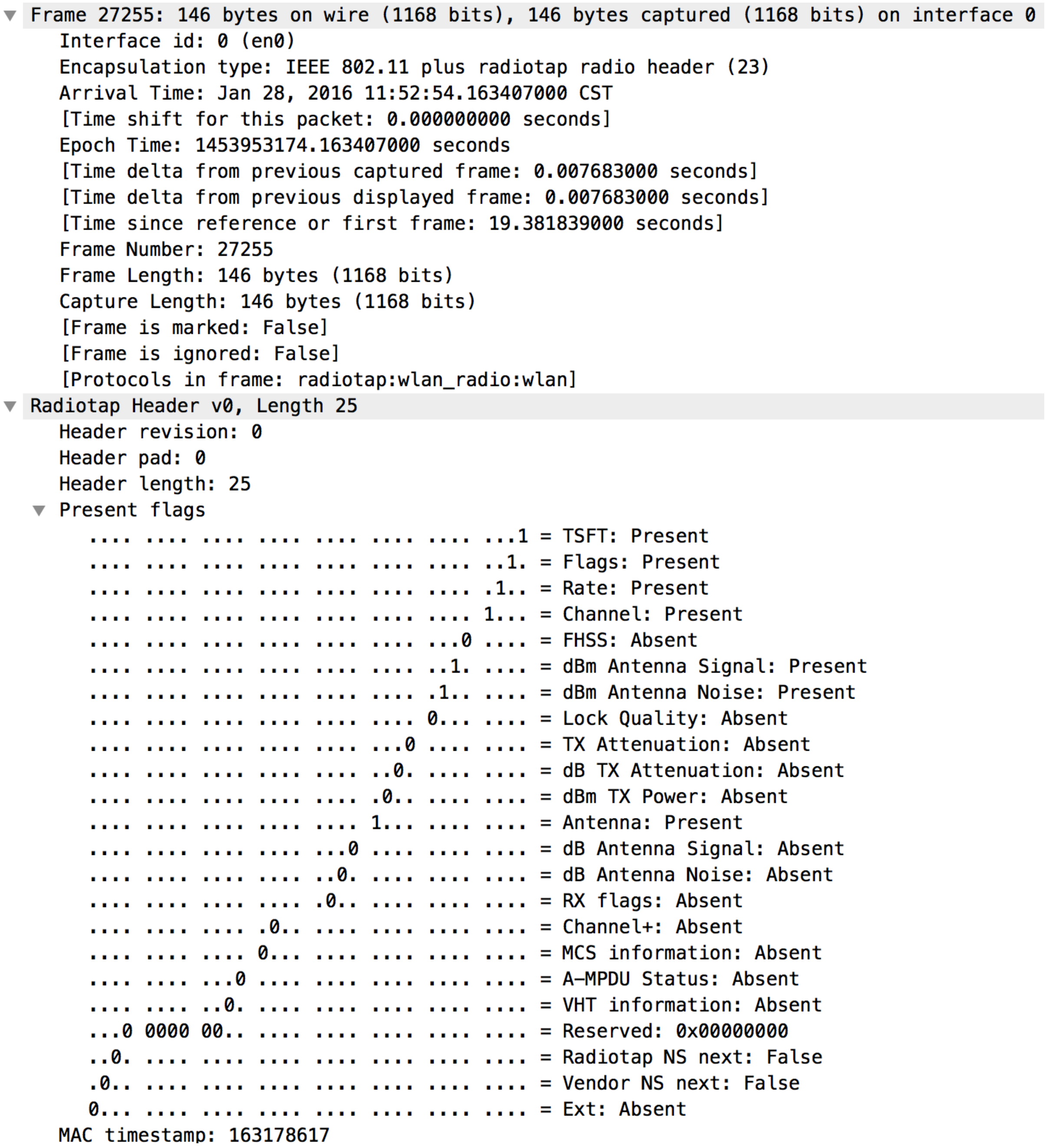
```
▼ IEEE 802.11 Probe Request, Flags: ........C
0000  00 00 19 00 6f 08 00 00  79 e8 b9 09 00 00 00 00   ....o... y.......
0010  12 0c 99 16 40 01 b4 a6  00 40 00 00 00 ff ff ff   ....@... .@......
0020  ff ff ff 4c 8d 79 ee 9a  ae ff ff ff ff ff ff a0   ...L.y.. ........
0030  88 00 00 01 08 0c 12 18  24 30 48 60 6c 2d 1a 7f   ........ $0H`l-..
0040  08 17 ff ff ff 00 00 00  00 00 00 00 00 00 00 00   ........ ........
0050  00 00 00 00 00 00 00 00  00 7f 08 01 00 00 00 00   ........ ........
0060  00 00 40 dd 09 00 10 18  02 00 00 10 00 00 dd 1e   ..@..... ........
0070  00 90 4c 33 7f 08 17 ff  ff ff 00 00 00 00 00 00   ..L3.... ........
0080  00 00 00 00 00 00 00 00  00 00 00 00 00 00 f2 53   ........ .......S
0090  b2 f5                                              ..
```

Transmitter address is the information we need from this part

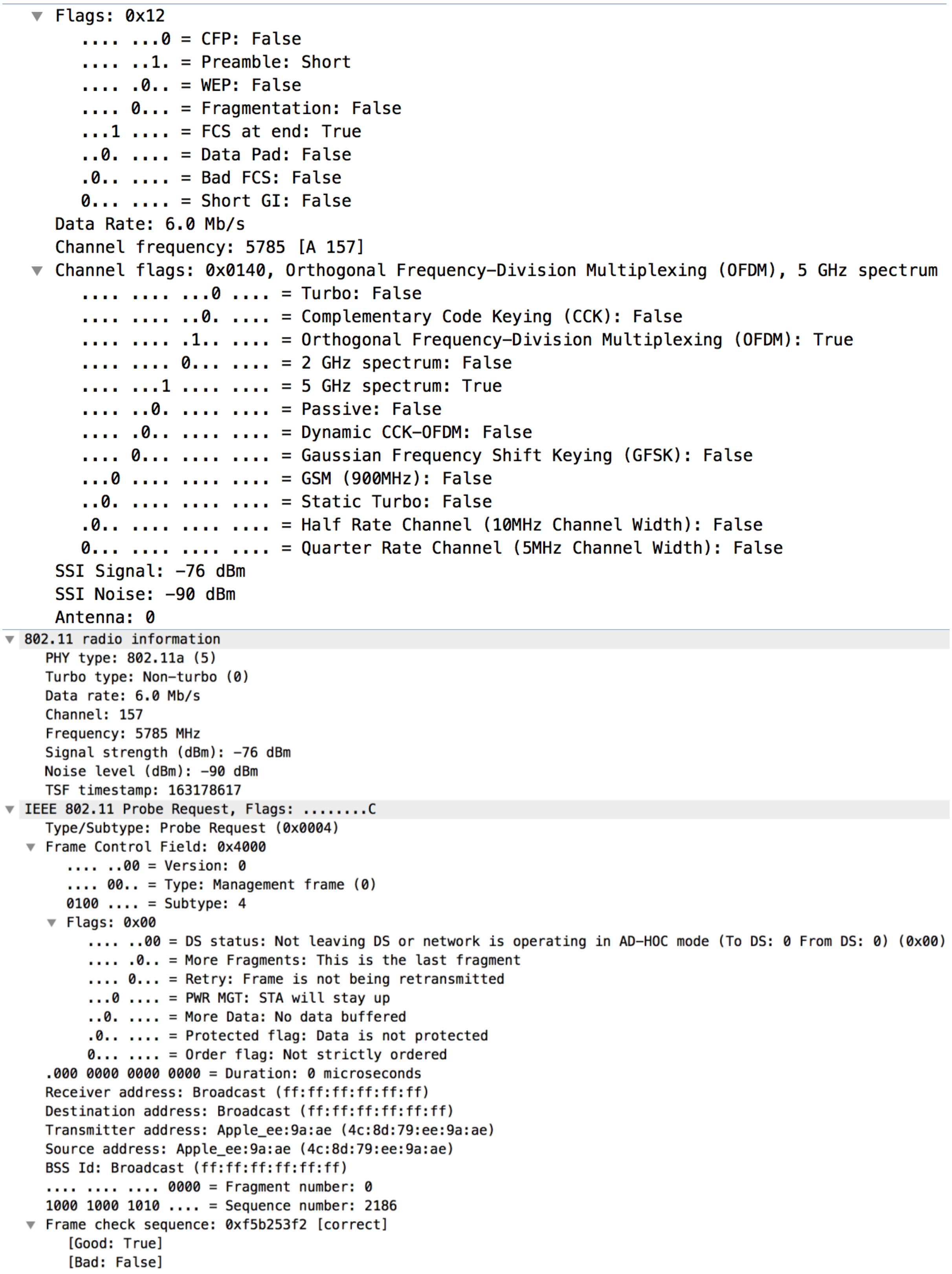


```
Transmitter address: Apple_ee:9a:ae (4c:8d:79:ee:9a:ae)
0000  00 00 19 00 6f 08 00 00  79 e8 b9 09 00 00 00 00   ....o... y.......
0010  12 0c 99 16 40 01 b4 a6  00 40 00 00 00 ff ff ff   ....@... .@......
0020  ff ff ff 4c 8d 79 ee 9a  ae ff ff ff ff ff ff a0   ...L.y.. ........
0030  88 00 00 01 08 0c 12 18  24 30 48 60 6c 2d 1a 7f   ........ $0H`l-..
0040  08 17 ff ff ff 00 00 00  00 00 00 00 00 00 00 00   ........ ........
0050  00 00 00 00 00 00 00 00  00 7f 08 01 00 00 00 00   ........ ........
0060  00 00 40 dd 09 00 10 18  02 00 00 10 00 00 dd 1e   ..@..... ........
0070  00 90 4c 33 7f 08 17 ff  ff ff 00 00 00 00 00 00   ..L3.... ........
0080  00 00 00 00 00 00 00 00  00 00 00 00 00 00 f2 53   ........ .......S
0090  b2 f5                                              ..
```

3) Other related information from Wi-Fi packets we captured



```
▼ Frame 27255: 146 bytes on wire (1168 bits), 146 bytes captured (1168 bits) on interface 0
    Interface id: 0 (en0)
    Encapsulation type: IEEE 802.11 plus radiotap radio header (23)
    Arrival Time: Jan 28, 2016 11:52:54.163407000 CST
    [Time shift for this packet: 0.000000000 seconds]
    Epoch Time: 1453953174.163407000 seconds
    [Time delta from previous captured frame: 0.007683000 seconds]
    [Time delta from previous displayed frame: 0.007683000 seconds]
    [Time since reference or first frame: 19.381839000 seconds]
    Frame Number: 27255
    Frame Length: 146 bytes (1168 bits)
    Capture Length: 146 bytes (1168 bits)
    [Frame is marked: False]
    [Frame is ignored: False]
    [Protocols in frame: radiotap:wlan_radio:wlan]
▼ Radiotap Header v0, Length 25
    Header revision: 0
    Header pad: 0
    Header length: 25
  ▼ Present flags
      .... .... .... .... .... .... .... ...1 = TSFT: Present
      .... .... .... .... .... .... .... ..1. = Flags: Present
      .... .... .... .... .... .... .... .1.. = Rate: Present
      .... .... .... .... .... .... .... 1... = Channel: Present
      .... .... .... .... .... .... ...0 .... = FHSS: Absent
      .... .... .... .... .... .... ..1. .... = dBm Antenna Signal: Present
      .... .... .... .... .... .... .1.. .... = dBm Antenna Noise: Present
      .... .... .... .... .... .... 0... .... = Lock Quality: Absent
      .... .... .... .... .... ...0 .... .... = TX Attenuation: Absent
      .... .... .... .... .... ..0. .... .... = dB TX Attenuation: Absent
      .... .... .... .... .... .0.. .... .... = dBm TX Power: Absent
      .... .... .... .... .... 1... .... .... = Antenna: Present
      .... .... .... .... ...0 .... .... .... = dB Antenna Signal: Absent
      .... .... .... .... ..0. .... .... .... = dB Antenna Noise: Absent
      .... .... .... .... .0.. .... .... .... = RX flags: Absent
      .... .... .... .0.. .... .... .... .... = Channel+: Absent
      .... .... .... 0... .... .... .... .... = MCS information: Absent
      .... .... ...0 .... .... .... .... .... = A-MPDU Status: Absent
      .... .... ..0. .... .... .... .... .... = VHT information: Absent
      ...0 0000 00.. .... .... .... .... .... = Reserved: 0x00000000
      ..0. .... .... .... .... .... .... .... = Radiotap NS next: False
      .0.. .... .... .... .... .... .... .... = Vendor NS next: False
      0... .... .... .... .... .... .... .... = Ext: Absent
    MAC timestamp: 163178617
```



```
▼ Flags: 0x12
    .... ...0 = CFP: False
    .... ..1. = Preamble: Short
    .... .0.. = WEP: False
    .... 0... = Fragmentation: False
    ...1 .... = FCS at end: True
    ..0. .... = Data Pad: False
    .0.. .... = Bad FCS: False
    0... .... = Short GI: False
  Data Rate: 6.0 Mb/s
  Channel frequency: 5785 [A 157]
▼ Channel flags: 0x0140, Orthogonal Frequency-Division Multiplexing (OFDM), 5 GHz spectrum
    .... .... ...0 .... = Turbo: False
    .... .... ..0. .... = Complementary Code Keying (CCK): False
    .... .... .1.. .... = Orthogonal Frequency-Division Multiplexing (OFDM): True
    .... .... 0... .... = 2 GHz spectrum: False
    .... ...1 .... .... = 5 GHz spectrum: True
    .... ..0. .... .... = Passive: False
    .... .0.. .... .... = Dynamic CCK-OFDM: False
    .... 0... .... .... = Gaussian Frequency Shift Keying (GFSK): False
    ...0 .... .... .... = GSM (900MHz): False
    ..0. .... .... .... = Static Turbo: False
    .0.. .... .... .... = Half Rate Channel (10MHz Channel Width): False
    0... .... .... .... = Quarter Rate Channel (5MHz Channel Width): False
  SSI Signal: -76 dBm
  SSI Noise: -90 dBm
  Antenna: 0
▼ 802.11 radio information
    PHY type: 802.11a (5)
    Turbo type: Non-turbo (0)
    Data rate: 6.0 Mb/s
    Channel: 157
    Frequency: 5785 MHz
    Signal strength (dBm): -76 dBm
    Noise level (dBm): -90 dBm
    TSF timestamp: 163178617
▼ IEEE 802.11 Probe Request, Flags: ........C
    Type/Subtype: Probe Request (0x0004)
  ▼ Frame Control Field: 0x4000
      .... ..00 = Version: 0
      .... 00.. = Type: Management frame (0)
      0100 .... = Subtype: 4
    ▼ Flags: 0x00
        .... ..00 = DS status: Not leaving DS or network is operating in AD-HOC mode (To DS: 0 From DS: 0) (0x00)
        .... .0.. = More Fragments: This is the last fragment
        .... 0... = Retry: Frame is not being retransmitted
        ...0 .... = PWR MGT: STA will stay up
        ..0. .... = More Data: No data buffered
        .0.. .... = Protected flag: Data is not protected
        0... .... = Order flag: Not strictly ordered
    .000 0000 0000 0000 = Duration: 0 microseconds
    Receiver address: Broadcast (ff:ff:ff:ff:ff:ff)
    Destination address: Broadcast (ff:ff:ff:ff:ff:ff)
    Transmitter address: Apple_ee:9a:ae (4c:8d:79:ee:9a:ae)
    Source address: Apple_ee:9a:ae (4c:8d:79:ee:9a:ae)
    BSS Id: Broadcast (ff:ff:ff:ff:ff:ff)
    .... .... .... 0000 = Fragment number: 0
    1000 1000 1010 .... = Sequence number: 2186
  ▼ Frame check sequence: 0xf5b253f2 [correct]
      [Good: True]
      [Bad: False]
```

3. Data Processing on Gateways to Get MAC Address and RSSI

1) C struct data type for valid Wi-Fi packets

```
struct radiotap_header
{
    unsigned char hd_rv[1];
    unsigned char hd_pad[1];
    unsigned char hd_len[2];
    unsigned char prst_flg[4];
    unsigned char mac_tstp[8];
    unsigned char flg[1];
    unsigned char dt_rt[1];
    unsigned char chnl_frq[2];
    unsigned char chnl_type[2];
    signed char ssi_sgn[1];
    unsigned char atn[1];
    unsigned char rx_flg[2];
};

struct wifi_header
{
    unsigned char frame_ctrl[2];
    unsigned char duration[2];
    unsigned char rx_add[6];
    unsigned char tx_add[6];
};
```

2) Processing on gateways to filter invalid packets and parse out valid MAC Address and RSSI

```
// Data stored in database: data->tx_add, double(head->ssi_sgn[0])
/*-----------Get the Net Packets Sniffered from Wireless Card-------------*/
/*-----------Exclude Invalid MAC Address----------------------------------*/
void Sniffer::GetPacket(u_char *args, const struct pcap_pkthdr *header, const
u_char *packet)
{
        // declare pointers to packet headers
        const struct radiotap_header *head;   /* The raidotap header*/
        const struct wifi_header *data;       /* The wifi data header */

        // define raidotap header
```

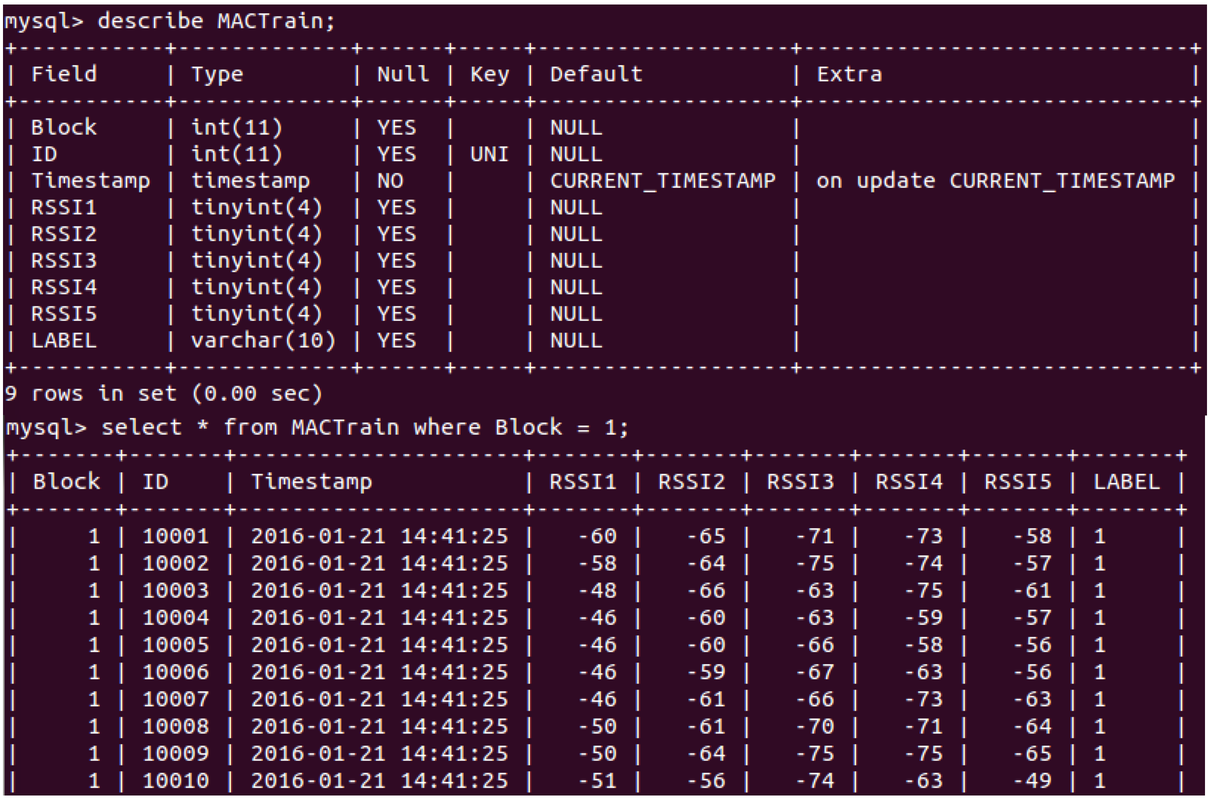
```
head = (struct radiotap_header*)(packet);

// define/compute wifi data offset
data = (struct wifi_header*)(packet + (head->hd_len[0]));

/*------------------Invalid From Head Inform-----------------------*/
// Struct not as defined:TSFT Flags Rate Channel dB_Antenna_Signal
if((head->prst_flg[0] & 0x3f) != 0x2f)
{
        return;
}
//.... 1... = Fragmentation: True
if((head->flg[0] & 0x08) == 0x08)
{
        return;
}
// ...1 .... = FCS at end: false
if((head->flg[0] & 0x10) == 0x00)
{
        return;
}
// .1.. .... = Bad FCS: True
if((head->flg[0] & 0x40) == 0x40)
{
        return;
}

/*------------------Invalid From Data Inform-----------------------*/
// Reserved Type: 11 return
if (((data->frame_ctrl[0]) & 0x0c) == 0x0c)
{
        return;
}
// Reserved in Management Frames
if (((data->frame_ctrl[0]) & 0x6c) == 0x60)
{
        return;
}
// Reserved in Control Frames
if (((data->frame_ctrl[0]) & 0x8c) == 0x04)
```

```
    {
        return;
    }
    // Reserved in Data Frames
    if (((data->frame_ctrl[0]) & 0xfc) == 0xd8)
    {
        return;
    }
    // CTS frame, no tx add, return
    if ((data->frame_ctrl[0] == 0xc4))
    {
        return;
    }
    // ACK frame, no tx add, return
    if ((data->frame_ctrl[0] == 0xd4))
    {
        return;
    }
    // Beacon frame/Reassociation request/Association response, tx is an AP
    if (((data->frame_ctrl[0]& 0xfc) == 0x80) || ((data->frame_ctrl[0]& 0xfc)
== 0x30) || ((data->frame_ctrl[0]& 0xfc) == 0x10))
    {
        //SetRecordStatic(data->tx_add, head->ssi_sgn[0]);
        AddStaticRecord(data->tx_add, (double)head->ssi_sgn[0]);
        return;
    }
    // Type/Subtype: Null function (No data) (0x24)
    if ((data->frame_ctrl[0]& 0xfc) == 0x48)
    {
        return;
    }
    // Type/Subtype: ATIM (0x09)
    if ((data->frame_ctrl[0]& 0xfc) == 0x90)
    {
        return;
    }
    // To DS: 0 From DS: 0(Not leaving DS or network is operating in AD-HOC
mode)
    if(((data->frame_ctrl[1]) & 0x03) == 0x00)
    {
        // Not probe request
        if(((data->frame_ctrl[0]) & 0xfc) != 0x40)
        {
            return;
        }
        //return;
    }
    // To DS: 1 From DS: 1(Frame part of WDS from one AP to another AP)
    if(((data->frame_ctrl[1]) & 0x03) == 0x03)
    {
        return;
    }
    // no valid rssi,return
    // revised by xhang 2016-01-08 [add contrains that return when ssi less
than -75]
    // if (head->ssi_sgn[0] > 0)
    if (head->ssi_sgn[0] > 0 || head->ssi_sgn[0] < -75)
    {
        return;
    }

    Sniffer::AddNewMacRecord(data->tx_add, double(head->ssi_sgn[0]));

    return;
}
```

4. Data Stored in MySQL Database

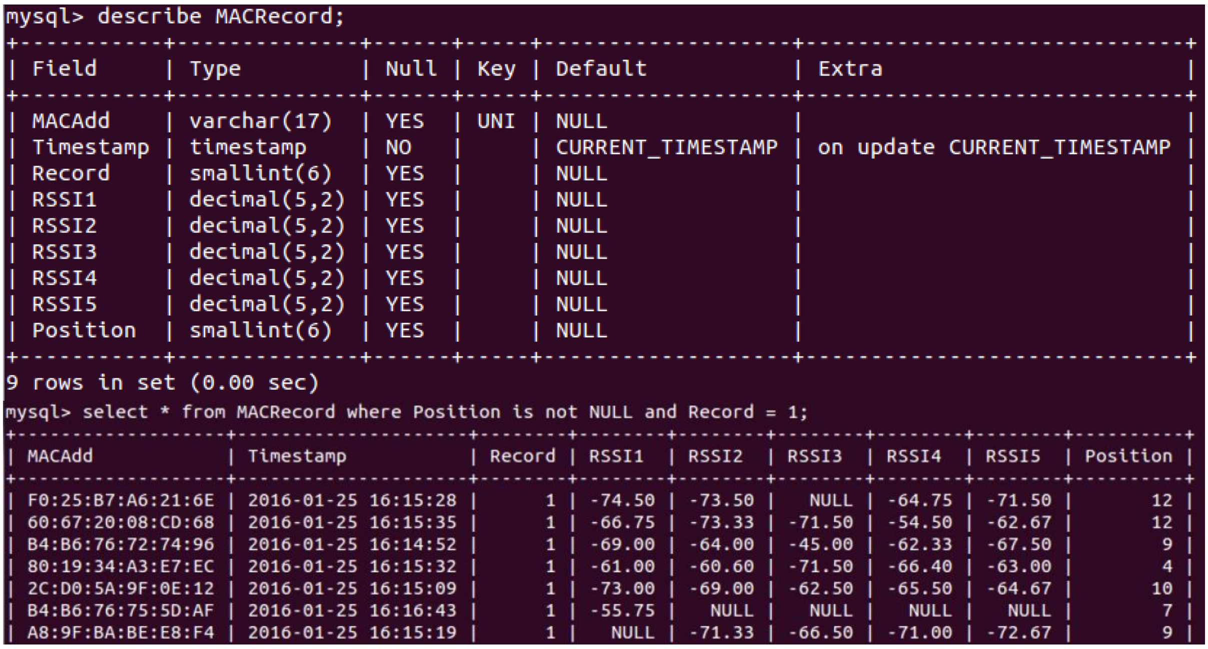
Two tables: MACTrain; MACRecord

1) MACTrain



```
mysql> describe MACTrain;
+-----------+-------------+------+-----+-------------------+-----------------------------+
| Field     | Type        | Null | Key | Default           | Extra                       |
+-----------+-------------+------+-----+-------------------+-----------------------------+
| Block     | int(11)     | YES  |     | NULL              |                             |
| ID        | int(11)     | YES  | UNI | NULL              |                             |
| Timestamp | timestamp   | NO   |     | CURRENT_TIMESTAMP | on update CURRENT_TIMESTAMP |
| RSSI1     | tinyint(4)  | YES  |     | NULL              |                             |
| RSSI2     | tinyint(4)  | YES  |     | NULL              |                             |
| RSSI3     | tinyint(4)  | YES  |     | NULL              |                             |
| RSSI4     | tinyint(4)  | YES  |     | NULL              |                             |
| RSSI5     | tinyint(4)  | YES  |     | NULL              |                             |
| LABEL     | varchar(10) | YES  |     | NULL              |                             |
+-----------+-------------+------+-----+-------------------+-----------------------------+
9 rows in set (0.00 sec)
mysql> select * from MACTrain where Block = 1;
+-------+-------+---------------------+-------+-------+-------+-------+-------+-------+
| Block | ID    | Timestamp           | RSSI1 | RSSI2 | RSSI3 | RSSI4 | RSSI5 | LABEL |
+-------+-------+---------------------+-------+-------+-------+-------+-------+-------+
|     1 | 10001 | 2016-01-21 14:41:25 |   -60 |   -65 |   -71 |   -73 |   -58 | 1     |
|     1 | 10002 | 2016-01-21 14:41:25 |   -58 |   -64 |   -75 |   -74 |   -57 | 1     |
|     1 | 10003 | 2016-01-21 14:41:25 |   -48 |   -66 |   -63 |   -75 |   -61 | 1     |
|     1 | 10004 | 2016-01-21 14:41:25 |   -46 |   -60 |   -63 |   -59 |   -57 | 1     |
|     1 | 10005 | 2016-01-21 14:41:25 |   -46 |   -60 |   -66 |   -58 |   -56 | 1     |
|     1 | 10006 | 2016-01-21 14:41:25 |   -46 |   -59 |   -67 |   -63 |   -56 | 1     |
|     1 | 10007 | 2016-01-21 14:41:25 |   -46 |   -61 |   -66 |   -73 |   -63 | 1     |
|     1 | 10008 | 2016-01-21 14:41:25 |   -50 |   -61 |   -70 |   -71 |   -64 | 1     |
|     1 | 10009 | 2016-01-21 14:41:25 |   -50 |   -64 |   -75 |   -75 |   -65 | 1     |
|     1 | 10010 | 2016-01-21 14:41:25 |   -51 |   -56 |   -74 |   -63 |   -49 | 1     |
```

2) MACRecord

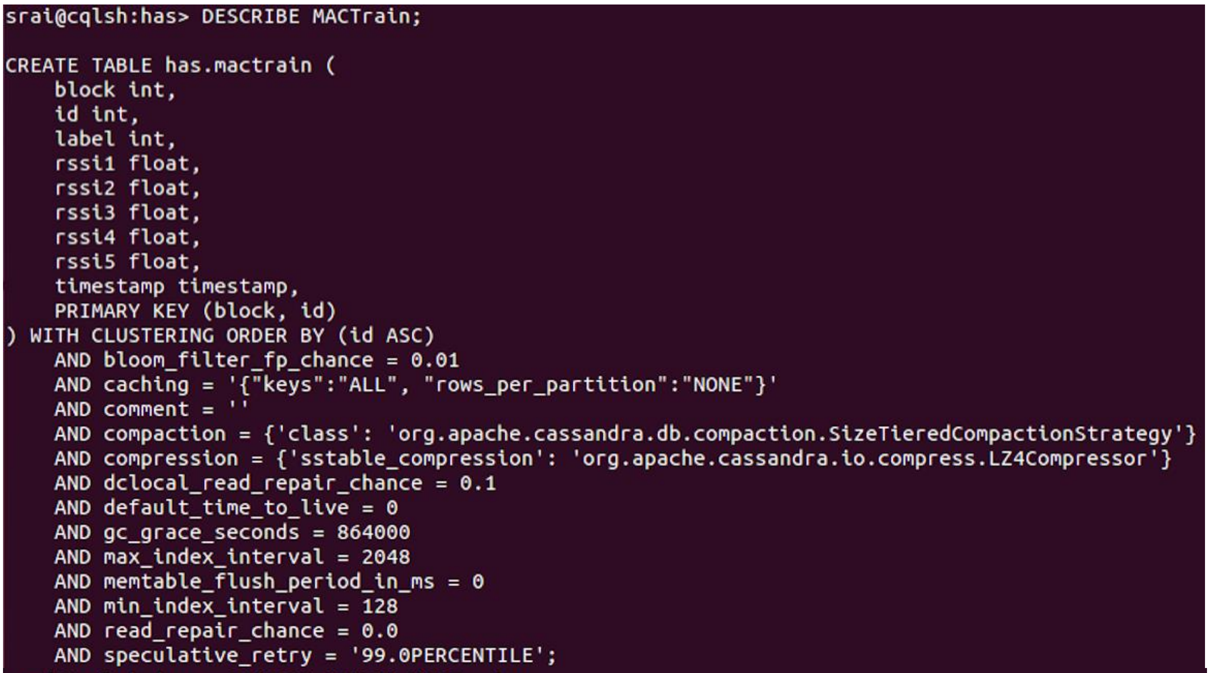


```
mysql> describe MACRecord;
+-----------+--------------+------+-----+-------------------+-----------------------------+
| Field     | Type         | Null | Key | Default           | Extra                       |
+-----------+--------------+------+-----+-------------------+-----------------------------+
| MACAdd    | varchar(17)  | YES  | UNI | NULL              |                             |
| Timestamp | timestamp    | NO   |     | CURRENT_TIMESTAMP | on update CURRENT_TIMESTAMP |
| Record    | smallint(6)  | YES  |     | NULL              |                             |
| RSSI1     | decimal(5,2) | YES  |     | NULL              |                             |
| RSSI2     | decimal(5,2) | YES  |     | NULL              |                             |
| RSSI3     | decimal(5,2) | YES  |     | NULL              |                             |
| RSSI4     | decimal(5,2) | YES  |     | NULL              |                             |
| RSSI5     | decimal(5,2) | YES  |     | NULL              |                             |
| Position  | smallint(6)  | YES  |     | NULL              |                             |
+-----------+--------------+------+-----+-------------------+-----------------------------+
9 rows in set (0.00 sec)
mysql> select * from MACRecord where Position is not NULL and Record = 1;
+-------------------+---------------------+--------+--------+--------+--------+--------+--------+----------+
| MACAdd            | Timestamp           | Record | RSSI1  | RSSI2  | RSSI3  | RSSI4  | RSSI5  | Position |
+-------------------+---------------------+--------+--------+--------+--------+--------+--------+----------+
| F0:25:B7:A6:21:6E | 2016-01-25 16:15:28 |      1 | -74.50 | -73.50 |   NULL | -64.75 | -71.50 |       12 |
| 60:67:20:08:CD:68 | 2016-01-25 16:15:35 |      1 | -66.75 | -73.33 | -71.50 | -54.50 | -62.67 |       12 |
| B4:B6:76:72:74:96 | 2016-01-25 16:14:52 |      1 | -69.00 | -64.00 | -45.00 | -62.33 | -67.50 |        9 |
| 80:19:34:A3:E7:EC | 2016-01-25 16:15:32 |      1 | -61.00 | -60.60 | -71.50 | -66.40 | -63.00 |        4 |
| 2C:D0:5A:9F:0E:12 | 2016-01-25 16:15:09 |      1 | -73.00 | -69.00 | -62.50 | -65.50 | -64.67 |       10 |
| B4:B6:76:75:5D:AF | 2016-01-25 16:16:43 |      1 | -55.75 |   NULL |   NULL |   NULL |   NULL |        7 |
| A8:9F:BA:BE:E8:F4 | 2016-01-25 16:15:19 |      1 |   NULL | -71.33 | -66.50 | -71.00 | -72.67 |        9 |
```

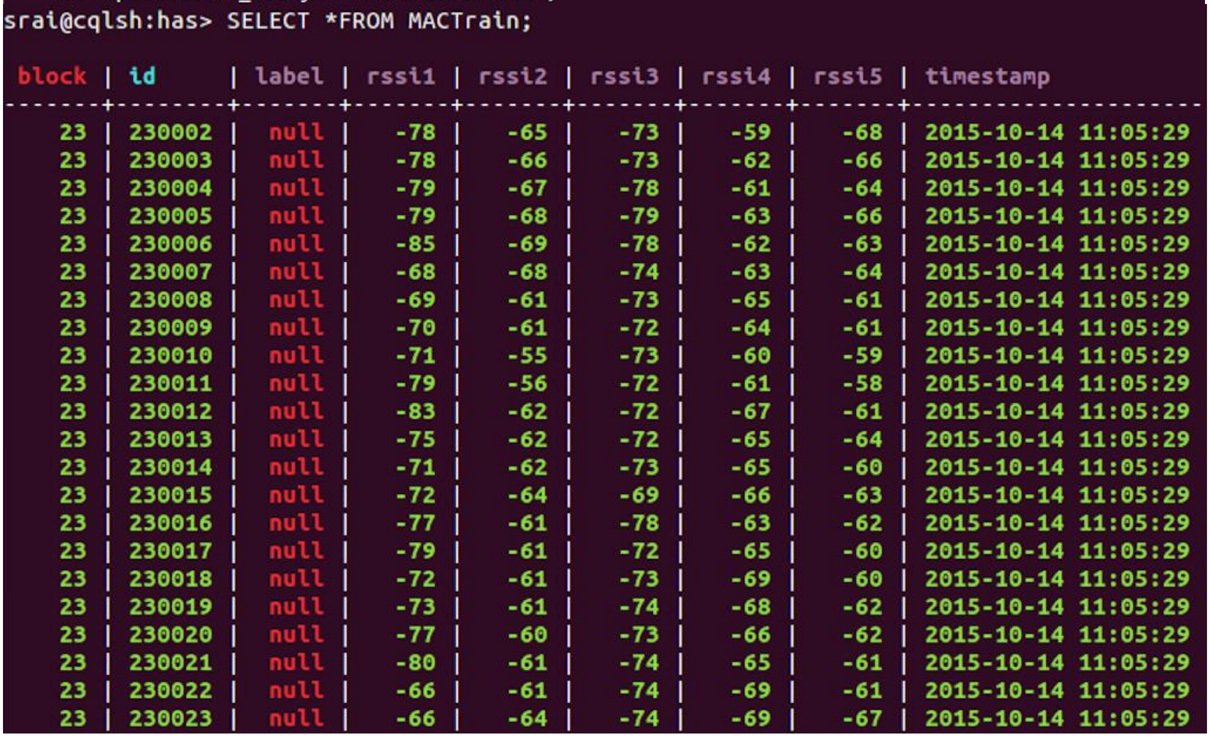
5. Data Stored in Cassandra Database

Two tables: MACTrain; MACRecord

1) MACTrain

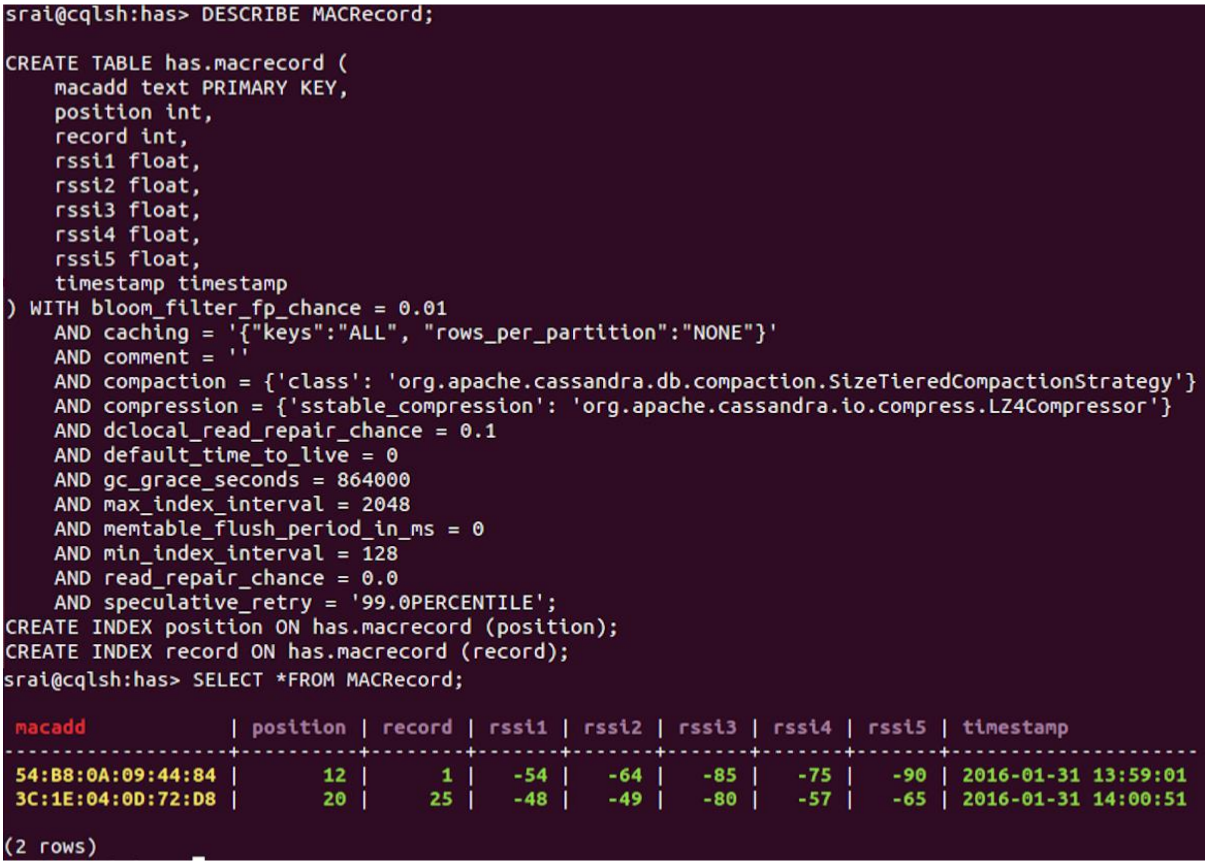


```
srai@cqlsh:has> DESCRIBE MACTrain;

CREATE TABLE has.mactrain (
    block int,
    id int,
    label int,
    rssi1 float,
    rssi2 float,
    rssi3 float,
    rssi4 float,
    rssi5 float,
    timestamp timestamp,
    PRIMARY KEY (block, id)
) WITH CLUSTERING ORDER BY (id ASC)
    AND bloom_filter_fp_chance = 0.01
    AND caching = '{"keys":"ALL", "rows_per_partition":"NONE"}'
    AND comment = ''
    AND compaction = {'class': 'org.apache.cassandra.db.compaction.SizeTieredCompactionStrategy'}
    AND compression = {'sstable_compression': 'org.apache.cassandra.io.compress.LZ4Compressor'}
    AND dclocal_read_repair_chance = 0.1
    AND default_time_to_live = 0
    AND gc_grace_seconds = 864000
    AND max_index_interval = 2048
    AND memtable_flush_period_in_ms = 0
    AND min_index_interval = 128
    AND read_repair_chance = 0.0
    AND speculative_retry = '99.0PERCENTILE';
```



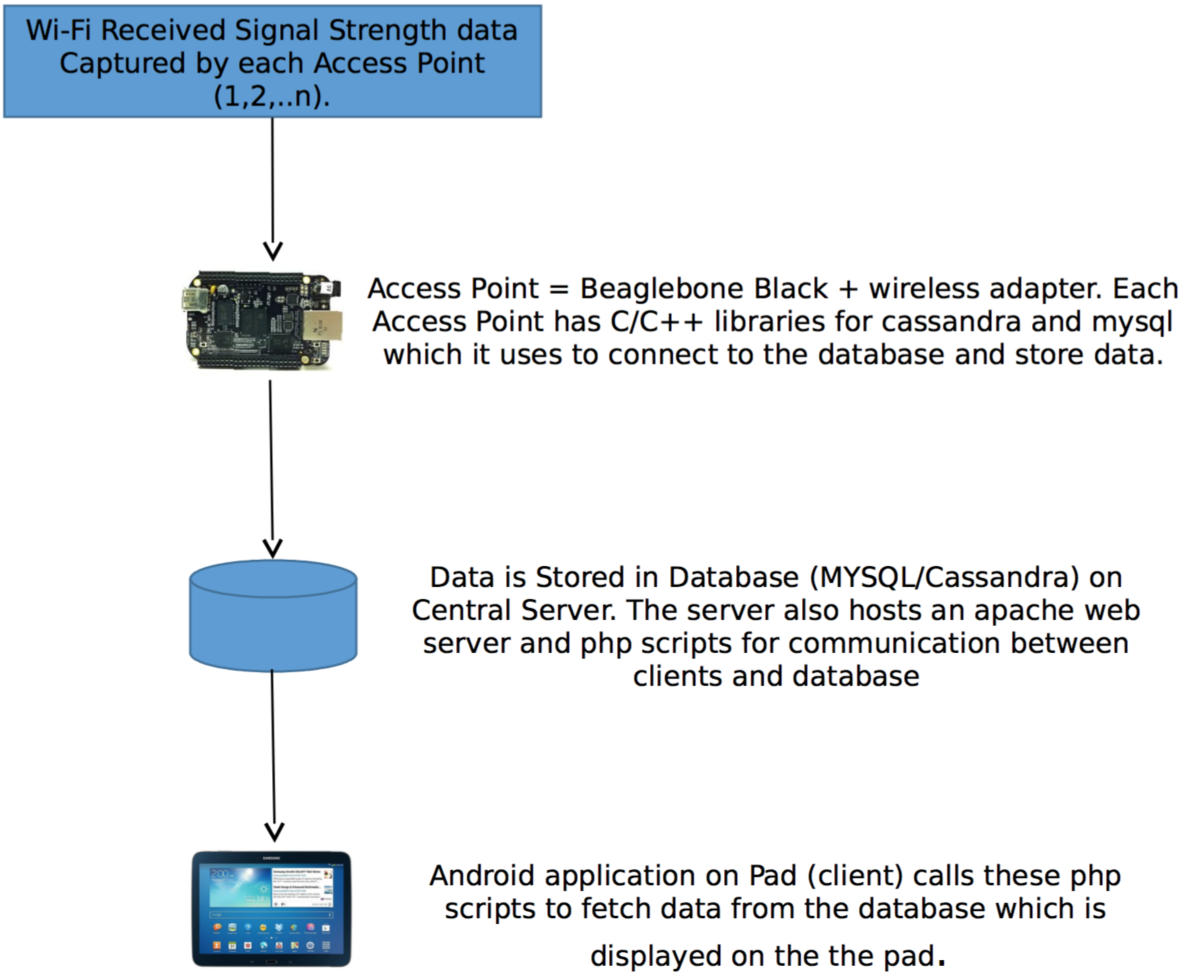
```
srai@cqlsh:has> SELECT *FROM MACTrain;

 block | id     | label | rssi1 | rssi2 | rssi3 | rssi4 | rssi5 | timestamp
-------+--------+-------+-------+-------+-------+-------+-------+--------------------------
    23 | 230002 |  null |   -78 |   -65 |   -73 |   -59 |   -68 | 2015-10-14 11:05:29
    23 | 230003 |  null |   -78 |   -66 |   -73 |   -62 |   -66 | 2015-10-14 11:05:29
    23 | 230004 |  null |   -79 |   -67 |   -78 |   -61 |   -64 | 2015-10-14 11:05:29
    23 | 230005 |  null |   -79 |   -68 |   -79 |   -63 |   -66 | 2015-10-14 11:05:29
    23 | 230006 |  null |   -85 |   -69 |   -78 |   -62 |   -63 | 2015-10-14 11:05:29
    23 | 230007 |  null |   -68 |   -68 |   -74 |   -63 |   -64 | 2015-10-14 11:05:29
    23 | 230008 |  null |   -69 |   -61 |   -73 |   -65 |   -61 | 2015-10-14 11:05:29
    23 | 230009 |  null |   -70 |   -61 |   -72 |   -64 |   -61 | 2015-10-14 11:05:29
    23 | 230010 |  null |   -71 |   -55 |   -73 |   -60 |   -59 | 2015-10-14 11:05:29
    23 | 230011 |  null |   -79 |   -56 |   -72 |   -61 |   -58 | 2015-10-14 11:05:29
    23 | 230012 |  null |   -83 |   -62 |   -72 |   -67 |   -61 | 2015-10-14 11:05:29
    23 | 230013 |  null |   -75 |   -62 |   -72 |   -65 |   -64 | 2015-10-14 11:05:29
    23 | 230014 |  null |   -71 |   -62 |   -73 |   -65 |   -60 | 2015-10-14 11:05:29
    23 | 230015 |  null |   -72 |   -64 |   -69 |   -66 |   -63 | 2015-10-14 11:05:29
    23 | 230016 |  null |   -77 |   -61 |   -78 |   -63 |   -62 | 2015-10-14 11:05:29
    23 | 230017 |  null |   -79 |   -61 |   -72 |   -65 |   -60 | 2015-10-14 11:05:29
    23 | 230018 |  null |   -72 |   -61 |   -73 |   -69 |   -60 | 2015-10-14 11:05:29
    23 | 230019 |  null |   -73 |   -61 |   -74 |   -68 |   -62 | 2015-10-14 11:05:29
    23 | 230020 |  null |   -77 |   -60 |   -73 |   -66 |   -62 | 2015-10-14 11:05:29
    23 | 230021 |  null |   -80 |   -61 |   -74 |   -65 |   -61 | 2015-10-14 11:05:29
    23 | 230022 |  null |   -66 |   -61 |   -74 |   -69 |   -61 | 2015-10-14 11:05:29
    23 | 230023 |  null |   -66 |   -64 |   -74 |   -69 |   -67 | 2015-10-14 11:05:29
```

2) MACRecord



```
srai@cqlsh:has> DESCRIBE MACRecord;

CREATE TABLE has.macrecord (
    macadd text PRIMARY KEY,
    position int,
    record int,
    rssi1 float,
    rssi2 float,
    rssi3 float,
    rssi4 float,
    rssi5 float,
    timestamp timestamp
) WITH bloom_filter_fp_chance = 0.01
    AND caching = '{"keys":"ALL", "rows_per_partition":"NONE"}'
    AND comment = ''
    AND compaction = {'class': 'org.apache.cassandra.db.compaction.SizeTieredCompactionStrategy'}
    AND compression = {'sstable_compression': 'org.apache.cassandra.io.compress.LZ4Compressor'}
    AND dclocal_read_repair_chance = 0.1
    AND default_time_to_live = 0
    AND gc_grace_seconds = 864000
    AND max_index_interval = 2048
    AND memtable_flush_period_in_ms = 0
    AND min_index_interval = 128
    AND read_repair_chance = 0.0
    AND speculative_retry = '99.0PERCENTILE';
CREATE INDEX position ON has.macrecord (position);
CREATE INDEX record ON has.macrecord (record);
srai@cqlsh:has> SELECT *FROM MACRecord;

 macadd            | position | record | rssi1 | rssi2 | rssi3 | rssi4 | rssi5 | timestamp
-------------------+----------+--------+-------+-------+-------+-------+-------+--------------------
 54:B8:0A:09:44:84 |       12 |      1 |   -54 |   -64 |   -85 |   -75 |   -90 | 2016-01-31 13:59:01
 3C:1E:04:0D:72:D8 |       20 |     25 |   -48 |   -49 |   -80 |   -57 |   -65 | 2016-01-31 14:00:51

(2 rows)
```

6. Data Flow in DIOPS



Wi-Fi Received Signal Strength data Captured by each Access Point (1,2,..n).

Access Point = Beaglebone Black + wireless adapter. Each Access Point has C/C++ libraries for cassandra and mysql which it uses to connect to the database and store data.

Data is Stored in Database (MYSQL/Cassandra) on Central Server. The server also hosts an apache web server and php scripts for communication between clients and database

Android application on Pad (client) calls these php scripts to fetch data from the database which is displayed on the the pad.