

Public service, APRS and the Internet of Things

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Abstract

In this paper we outline a prototype system assembled to improve situational awareness during a large public-safety event by integrating the use of SigfoxTM devices into a pre-existing Amateur Packet Reporting System (APRSTM) systems and infrastructure. APRS mapping is well established at this event already. Here we explain how ultra-low-power embedded systems based on Sigfox devices were integrated into the pre-existing infrastructure.

Index Terms

Packet radio networks; APRS, Internet of Things, ultra-low-power communications;

I. INTRODUCTION

The Sean Kelly tour of Waterford (*The Sean Kelly or SKT* [1]) started in 2007 with approximately 900 participants. It has now developed into a two day festival with over 6500 participants and 500 volunteers. On the Sunday of the festival there are three cycling events with various levels of distance and difficulty. A 50k cycle event which is limited to 1500 participants, 100k event which is limited to 1900 participants, and 160k event which is limited to 1600 participants. The three events run over three different courses covering approximately, 200, 500 and 800 square km of land area respectively.

Civil Defence in Ireland [2] is a volunteer based organization made up of over 4500 members that support the front line emergency services with volunteers trained in: Casualty, Search and Rescue, Auxillary Fire Service, Radiation Monitoring, Welfare and Communications.

Civil Defence supports the frontline emergency services in dealing with severe weather, flooding, major accidents, fire fighting and searching for missing persons. Civil Defence supports hundreds of community events throughout the year. These include large events such as air shows, tall ships, concerts, festivals and sports events.

In this capacity, Civil Defence is the lead agency for medical support during the Sean Kelly tour. As the lead agency, Civil Defence avails of the medical volunteers of the Irish Red Cross (IRC) [3], Order of Malta Ambulance Core (OMAC) [4] and the communications expertise of the Amateur Radio Emergency Network (AREN) [5].

The IRC and OMAC between them provide 8-10 Ambulances and several fast response vehicles. Civil Defence runs the Emergency Operations Centre (EOC), provides another 2 ambulances along with 3 support 4x4 vehicles and a Doctor in the on-site medical center for the day. AREN assists with the setting up of the Emergency Operations Center, communications interoperability, filling in blackspots, and the use of APRS for tracking the sweeper on each of the 50, 100, and 160k events as well as the Doctors vehicle. Several Civil Defence volunteers are also active in AREN.

On a normal Sunday, the National Ambulance service typically would have 1 Ambulance in the vicinity, with 2 more ambulances 40km away in Waterford City. No extra cover is provided by the National Ambulance service on the day.

Typically there are somewhere between 25 and 40 requests for medical assistance, with up to 10 transports to hospital during the day (heavily weather dependent).

II. MOTIVATION

Due to the number of participants, the alternate course route and their geographic distribution, the SKT is resource intensive on all organizations. As there are known gaps in APRS coverage and due to lack of infrastructure and resources on the day it has proven difficult to improve APRS coverage in any meaningful way. During the day, AREN members deploy 6 Byonics Micro-Trak AIO [6] units as well as several vehicles with various manufacturers APRS Capable radios. While very appreciative of our efforts, the Civil Defence officer raised a question during a debrief after the 2015 *Sean Kelly* about whether it would be possible to increase tracking ability to include medical support vehicles. The ideal solution would be low cost, small footprint and quickly deployed requiring no wiring to the vehicle. In looking for mechanisms to 'fill-in-the-gaps', one of the authors suggested looking towards the emerging *Internet of Things* for potential solutions on how to implement a pervasive, low power solution.

Our basic requirements were devices equipped with a GPS receiver capable of broadcasting their position to a distributed network in rural Ireland. The devices needed to be low power (battery if possible) and available for retail purchase. Not requiring an Amateur Licence would simplify device management. As APRS mapping is already in use through [7] and [8], being able to inject the data would leverage existing infrastructure and applications. The two suggested technologies to look at included LoRa [9] and Sigfox [10]. It became obvious quite quickly that the deployment of Sigfox in Ireland was far in advance of LoRa. In Waterford County, there is a planned deployment of some LoRa nodes by the Telecommunications Software & Systems Group [11] of Waterford Institute of Technology, but no solution or infrastructure was available to the authors at the time of this paper. So, at the time of commencing this project it seemed sensible to leverage VT Networks [12] Sigfox network in Ireland (though, at the time of writing it still does not have 100 % coverage of the landmass of Ireland), so based on our purpose and constraints the decision of which technology to use was relatively straightforward.

III. IMPLEMENTATION

After some research into off the shelf Sigfox compatible devices, two Quicksand [13] micro-electronics development kits were purchased [14].

This development kit consists of an MBED Arduino compatible shield along with a Sigfox TD1204 GPS Gateway and Transceiver device, access to code examples, and a years SIGFOX network subscription. As well as the onboard multi GNSS support (GPS/GLONASS), there are various other sensors including temperature, accelerometer, proximity, ambient light, programmable LEDs and user buttons.

The functionality of Sigfox devices satisfies our technical requirements, there are two further considerations, firstly the cost. There is an annual cost for Sigfox devices to be given access to the network.

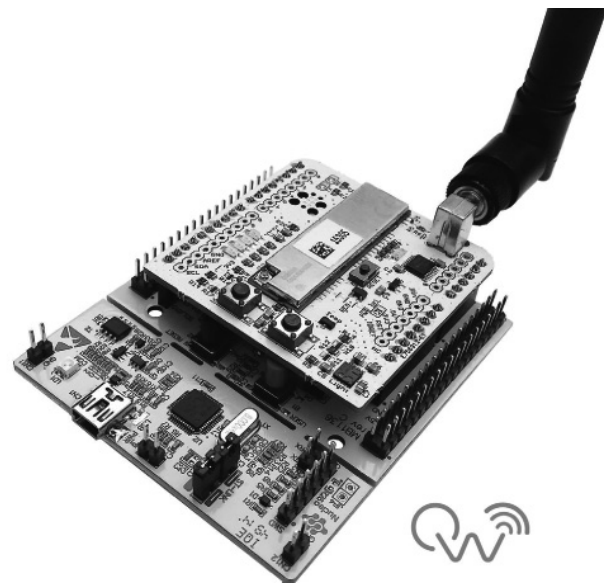


Fig. 1. Quicksand micro-electronics GPS Shield Development Kit

Based on figures supplied by VT Networks that comes to €10.50 (approx. \$12) per device per annum, assuming less than 1,000 devices each transmitting 140 frames or less per day. Secondly, each device is restricted to 140 messages per day or less than 1% duty cycle on the network. This equates to a maximum of 36 seconds per hour of transmission time. As each 12 byte transmission takes up to 6 seconds, this equates to 6 transmissions per hour approximately.

Sigfox devices operate in the ISM bands between 868.1 and 868.3MHz, with a maximum radiated power of 25mW using 100bps DBPSK modulation. For tracking medical support vehicles, 140 messages per day or 6 per hour should adequately address our required resolution of positional information as they spend most of their time strategically parked, awaiting deployment instructions from the EOC.

The TD1204 device chosen has the following characteristics [15]:

- Frequency range = ISM 868 MHz
- Recieve sensitivity = -126dBm
- Modulation = (G)FSK, 4(G)FSK, GMSK, OOK
- Max output power = +14dBm
- Low active radio power consumption
 - 22µA RX (windowed mode)¹
 - 37mA TX @ +10dBm

A. The Quicksand TD1204 Development kit

Getting the development kits operational was possibly the easist task. There is an online compiler at <http://developer.mbed.org>. Some minor modifications² were made to one of the code examples, and messages started to emanate from the development kit.

Using the development kit as it stands, with no attempt at optimization, a power consumption figure of approximately 26mAh at 12.5 Volts was measured over a 48 hour period.

B. Decoding the Sigfox data packet

As mentioned above each data transmission from the development kit consist of 12 bytes of data. Take this frame which was received from the development kit **5d01010067442b6337a03c99** as an example. This frame can be divided into sections in Figure 2, and is examined in more detail in Figure 3.

-	Frame Type	GPS Position	Signs/Altitude	No of Satellites and HDOP
0x5d0	0x1010	0x067442b6337a	0x03c	0x99

Fig. 2. Field Breakdown

Bits	Hexadecimal	Decimal	Description/Meaning
0 - 8	0x5d	93	Unknown
9 - 12	0x0	0	Reserved
13 - 28	0x1010	-	GPS Frame
29 - 48	0x067442b6337a	7096405209978	7° 09.640' 52° 09.978'
49 - 60	0x03c	60	* 2 => 120m Altitude
61	1	1	long. sign { 0 = pos., 1 = neg. } => 1 => -7° 09.640'
62	0	0	lat. sign { 0 = pos., 1 = neg. } => 0 => 52° 09.978'
63	0	0	alt. sign { 0 = pos., 1 = neg. } => 0 => +120m
64 - 66	-	6	satellites in view => 6
67 - 68	-	1	horizontal dilution of precision => 0 (good) to 3 (bad)

Fig. 3. Known fields in a Sigfox frame

¹Listen for one frame, then switch off receiver for one second

²Code available at <https://github.com/jpronans/sigfox2aprs>

C. Sigfox back-end and callbacks

The Sigfox back-end allows the use of callbacks. These can be used to transfer data received from a device out of the Sigfox back-end for further processing. In this case, a simple *HTTP GET* Method was used to call a php CGI script (Figure 4). For debugging purposes the PHP script, saves the the full url to a text file (Figure 5).

```
http://myhost/callback.php?id={device}&time={time}&duplicate={duplicate}&snr={snr} \
&station={station}&lat={lat}&lng={lng}&rssi={rssi}&data={data}&avgSnr={avgSnr}&seqNumber={seqNumber}
```

Fig. 4. Example Sigfox HTTP get callback

```
http://myhost/callback.php?id=1511B&time=1469389143&duplicate=false&snr=12.59 \
&station=2252&lat=53&lng=-7&rssi=-139.00&data=5501010067442b6337b03e9c&avgSnr=24.87&seqNumber=929
```

Fig. 5. Received URL from HTTP callback

This PHP script also decodes the GPS location and saves it in APRS format along with the number of visible satellites and a measure of the Horizontal Dilution of Precision (HDOP) (Figure 6)

```
Lat: 5209.97N, Long: 00709.64W, Sats: 6, HDOP: 0
```

Fig. 6. Decoded GPS output

Finally the PHP script publishes all the available fields from the Sigfox backend as MQTT [16] messages to a MQTT message broker. See figure 7 showing typical output from a MQTT subscriber:

```
sigfox/1511B/lat 5209.97N
sigfox/1511B/lng 00709.64W
sigfox/1511B/sats 6
sigfox/1511B/hdop 0
sigfox/aprs 1511B:5209.97N:00709.64W:6:0
sigfox/1511B/time 1469389143
sigfox/1511B/duplicate false
sigfox/1511B/snr 12.59
sigfox/1511B/station 2252
sigfox/1511B/rssi -139.00
sigfox/1511B/avgSnr 24.87
sigfox/1511B/seqNumber 929
sigfox/telem 1511B:929:12.59:24.87:-139.00:6:0
```

Fig. 7. MQTT messages as seen from output from mosquitto_sub tool

D. Message Queue Telemetry Transport (MQTT)

MQTT is a publish/subscribe lightweight messaging protocol, designed for constrained devices and low-bandwidth, high-latency or unreliable networks. The design principles are to minimise network bandwidth and device resource requirements whilst also attempting to ensure reliability and some degree of assurance of delivery. These principles also turn out to make the protocol ideal of the emerging machine-to-machine (M2M) or Internet of Things world of connected devices, and for mobile applications where bandwidth and battery power are at a premium. There are implementation libraries for the MQTT broker and subscriber components available for most programming languages. The use of MQTT was mostly based on prior experience with the protocol. In this project, it meant that the (PHP) script generating the MQTT data, is completely decoupled from the script (Python) consuming the data and generating the APRS packets to be fed into the Automatic Packet Reporting System - Internet

Service (APRS-IS) [17]. It also allows the flexibility for other decoupled applications to subscribe to the data feed.³

E. MQTT to APRS

A Python script (MQTT subscriber) consumes these messages and uses them to create APRS Position and Telemetry packets. In fact it produces two packets. A position and a telemetry packet. This whole process, from the information arriving into the Sigfox backend, to the packet appearing on the APRS-IS, appears to take approximately 2 seconds.

```
EI0AC-9>APZWIT:!5209.98N/00709.63Wa Sats:6 HDOP:1 Unit:1511B  
EI0AC-9>APZWIT:T#168,011,024,139,006,001,00000000
```

Fig. 8. APRS Position and Telemetry packets as inserted into APRS-IS

F. Initial Tests

Initial tests of the unit were done with the unit static on the workbench just to make sure that everything was working as expected and the code was reasonably robust.

The next stage involved it being placed into the vehicle of one of the authors and accompanying him on his daily commute.



Fig. 9. Mounting location of the development board for initial tests.

The screenshot in figure 10 shows the track from this test run. The recorded positions are approximately 10 minutes apart as expected. The test unit was left running for several weeks in order to see how well it performed in this non-ideal location. Given the rather poor mounting location in the vehicle (see figure 9). It was a pleasant surprise to see the coverage afforded by VT Network's base stations.

³Facebook is one high-profile user of MQTT for their messenger app due to both its simplicity and scalability

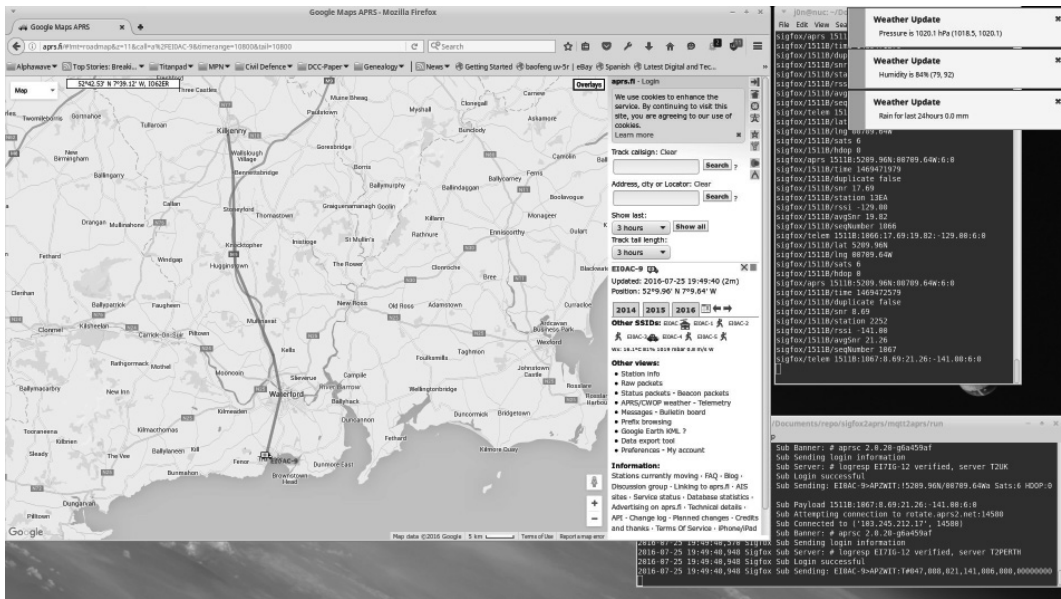


Fig. 10. Screenshot showing station track visible on <http://aprs.fi>

IV. TRIAL RESULTS

It was decided as part of the trial to put the available units into two Civil Defence ambulances. These vehicles are identical to that in figure 11. It was decided to mount the Sigfox units in the area above the drivers head (behind the "Ambulance" lettering). The entire rear of the body of these types of ambulances are fibre-glass. So positioning the unit here keeps it out of the way of any personnel.



Fig. 11. Civil Defence Ambulance

These vehicles act as moving first-aid posts during the event. Essentially leapfrogging between rest stops, when all the cyclists leave one location, the ambulance will move to the next rest stop. After the last rest stop, the vehicles are generally tasked to follow the course stopping at various strategic

locations where it is safe to do so. Sometimes, however, an ambulance may be redeployed to another route entirely.

V. CONCLUSION & FURTHER WORK

At the time of writing, the SKT has not taken place. More detailed results will be available after the weekend of the 21st of August.

There are several improvements that we could make to this prototype. An obvious improvement would be to use either a GPS geofence or the accelerometer to detect movement, and only generate a beacon on these events. Also, the GPS could be shutdown between beacons. No doubt, these changes would increase battery life.

ACKNOWLEDGMENT

The authors would like to thank Will Ferguson of VT Networks for his assistance and patience while getting the prototype operational.

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