Relay Communication Solutions for First Responders

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Abstract. First Responders (FRs) frequently intervene in dangerous environments, result of natural catastrophes, technological disaster or terrorist attacks, for that it is crucial to maintain their protection and operational effectiveness, namely their capacity in terms of situational awareness and communication in adverse situations. In the event of a disaster, communication networks may not be available at all, different reasons e.g. infrastructure collapse, denial of service or even the area of the incident may not be covered by communication services. This paper presents innovate project to respond to emergencies, focus on a resilient network solution easy to be deployed, to mitigate this problem and extent the existent communication networks. The solution uses nodes to relay communications from the nearest point to a farthest point with live communications, permitting long range communication of FR's wearable sensor data. The nodes can be installed in UAVs (Unmanned Aerial Vehicle), mounted on the ground on tripods or even on UGVs (Unmanned Ground Vehicle), the solution is modular and auto-configurable. The core/backbone of the Wireless Resilient communication network is supported in Mesh topology (802.11s), that provides any-to-any connections between nodes, these nodes can be dynamically added or removed, the network will always try to find a path to deliver data, each node is also simultaneously Wi-Fi Access Point (802.11n).

Keywords: Mesh network · First Responder · Resilient network · Relay communication · Extending the communication · Transmitting wearable data · 80211s

1 Introduction

First responders (FRs) are the people who are among the first to arrive and provide assistance at the disaster scene. They are typically professionals with specialized training, including law enforcement officers, firefighters, emergency medical personnel, rescuers, K9 units, civil protection authorities and other related organizations [3].

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Due to the nature of their work, FRs are often operating in risky and hazardous environments, including collapsed, burning or flooded buildings, darkness, smoke, heat, and broken communications. Furthermore, FRs may experience health incidents (e.g. sudden illness, dizziness or exhaustion strokes) during operations, which can prevent them from completing their mission, and, more importantly, put their own life at risk. FRs may often not notice early signs or choose to ignore them in favor of accomplishing their mission, which can lead to become additional casualties of the disaster [2].

FASTER [1] is a research and innovation project, funded by the European Commission, that aims to address the challenges associated with the protection of FRs in hazardous environments, while at the same time enhancing their capabilities in terms of situational awareness and communication. FASTER's overall concept is illustrated in Fig. 1, where it shows that at the heart of FASTER's concept lie the FRs that will be supported by a set of ergonomic and non-intrusive wearable devices that comprise sensors, actuators and displays, as well as artificial intelligence capacity. These will be responsible for assessing the situation, be it either individualized bio-monitoring of the FRs or local environmental sensing. Their purpose will be to deliver information either in a peer-to-peer (P2P) manner among FRs or centralized points of presence. The distinction made between these two schemes is necessary as disasters can manifest in various - typically uncontrollable - ways, necessitating the employment of centralised, decentralised and distributed (P2P) management schemes. To that end, FASTER will

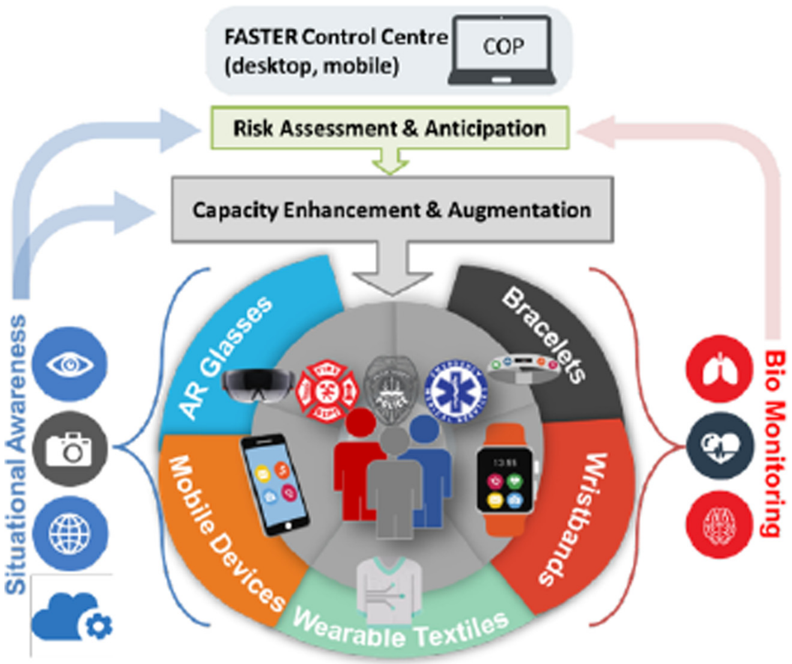

Fig. 1. FASTER core FRs capacity enhancement and augmentation [4].

consider both edge-based and cloud-based processing and analysis technologies to realize a risk assessment and anticipation system that will reach decisions and analyse the overall situation to provide targeted information and instructions to FRs. These will be delivered by the same wearable devices to augment and enhance their operational capacities [4].

The whole system will be facilitated by tools for Resilient Communications Support featuring opportunistic relay services, emergency communication devices and 5G-enabled communication capabilities (the Primary network). A FR secondary network, a relay network was developed, to mitigate any degradation of the primary network.

2 FASTER Secondary Network

The FASTER secondary network is composed by secondary network, several relay nodes, which can be deployed installed in Unmanned Aerial Vehicles/Unmanned Ground Vehicles (UAV/UGV - UxV) or for example in tripods a swarm of UAVs can be deployed at the event scene with radio relays payloads constitutes a resilient network.

The UxV Relay for extended communication implements a resilient communication service, employing common devices that will provide, in the worst-case scenario, a degraded service offering the minimal acceptable network performance in order to provide the basic services (FR localization and biometric data) in a crisis scenario. This service ensures communications even in inaccessible areas through the deployment of relay nodes, which will extend the existent communication network by utilizing UxVs to relay communications from the nearest point with live communication.

During the deployment procedures of the sites, after a disaster, the means of communication resources are evaluated and in case of a total disruption or of a high probability of losing the main communications, in this case 4G/5G, a secondary communication structure should be deployed in order to mitigate the loss of the primary communications. In this case, the secondary UxV relay communication structure is deployed, allowing the FR, K9 and other personnel or structures deployed on site to operate without any disruption of its operations.

The relay nodes are based on communication technologies, which work on the 2.4 and 5 GHz unlicensed bands. The transmit power limitations imposed by regulatory requirements limit the range (coverage) that can be achieved by WLANs (Wireless LAN) in these bands. However, the demand for "larger" wireless infrastructure is emerging, ranging from office/university campuses to city-wide deployments.

The wireless local area network standard IEEE 802.11 using the 2.4 GHz unlicensed band it is a low-cost data service and easy solution to deploy, the same hardware (HW) can in simultaneous support two networks, 802.11s and 802.11n:

- Mesh Point (MP), where the 802.11s address the aforementioned need for multi-hop communication introducing wireless frame forwarding and routing capabilities at the MAC layer and brings new interworking and security [5]; and
- Mesh Access Point (MAP), where the 802.11n protocol is used with Multiple-Input and Multiple-Output (MIMO) (2 antennas) to increase throughput over single antenna systems or to improve range of reception, depending on the environment by default the "back compatible" is enable with 802.11 b/g [6, 7].

In Fig. 2, is an example of Wi-Fi UxV relay network deployed in "Flood in urban environment (natural disaster)" is presented. Each node of secondary network has dual functionality, act in simultaneous as:

- Mesh Point, the core network, (802.11s); and as
  Mesh Access Point for FRs (802.11n).

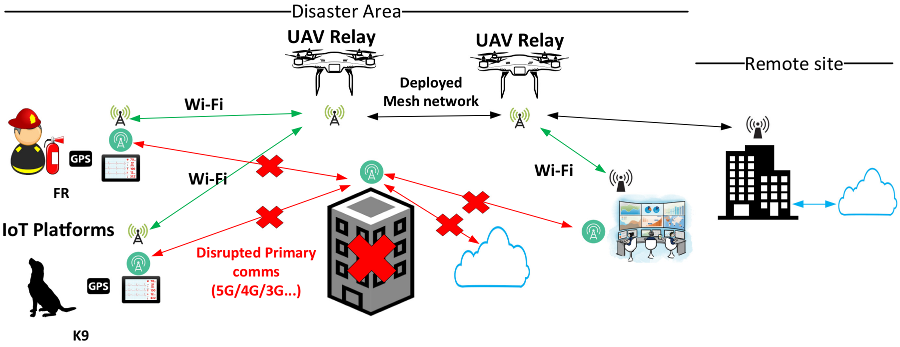

Fig. 2. Overview FASTER secondary network.

3 FASTER Secondary Network Components

One of the objectives of the UxV relay network is to install network nodes in the payload of UAVs and use a swarm of UAVs to deploy the communication network in order to cover the disaster area. A gateway is deployed as well at remote site, which will permit the assets at the disaster area to access the Internet, this solution is based on open source Debian/Linux. The relay networks can be installed in UAVs and on the ground in UGV or over tripods.

3.1 Relay Node

The Relay node (RNode), is composed by a hardware processing unit based on "open-hardware" SBC [8], a GNSS receiver, several sensors, a Wi-Fi radio and supporting elements like a battery, user buttons and LEDs and plastic box for protection and fixation on the UAV itself (or UGV).

The GNSS receiver tracks the position of the UAV. The Wi-Fi radio enables connection to the mesh network and provides a local WiFi network access for the ground elements to connect. The following figure, Fig. 3, represents a node with the main hardware modules and presents the payload of the UxV.

The node's weight and dimension were key factors when designing the hardware and box enclosure, because it would be part of the payload of an UAV, which mandates also that it needs to be battery powered (with an aprox. 3 h 50 m of autonomy). In line

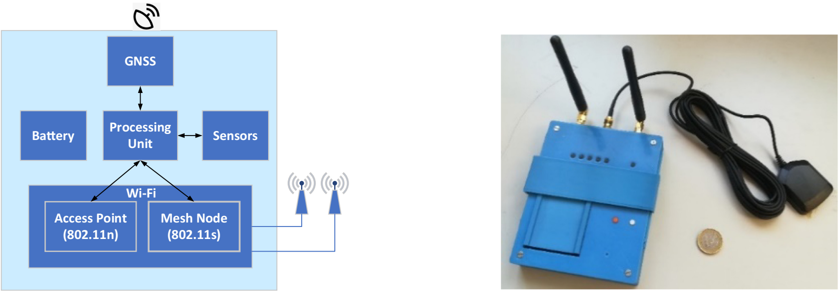

Fig. 3. Diagram of FASTER secondary network RNode and UxV payload.

with these requirements the WiFi hardware is based on the TI/WL1835MOD (WiLink™ 8 single band combo 2.4 GHz 2 × 2 MIMO Wi-Fi®, Bluetooth® & Bluetooth Smart module) [10]. This device acts simultaneously as a Mesh Access Point and a Mesh Point. Open-source Linux device drivers are available. In Table 1 an overview of WLAN specification is presented.

Table 1. Relay node - WLAN specification (overview).

WiFi interface	Wireless mesh	Wireless access point
Protocol	802.11s	802.11n
Frequency	2.4 GHz (24000–2483.5 MHz)	
Channel used (by default)	1	
Authentication[a]	Simultaneous Authentication of Equals (SAE)	WPA2[a] Pre-Shared Key (WPA2-PSK)
Encrypt Method	CCMP	CCMP
Using modulation DSSS and bitrate 1 Mbps		
Max. TX power:	17.3 dBm	
Max. Sensibility	−96.3 dBm	
Antennas[b] (2.4 GHz)	Wireless mesh	Wireless access point
Type	Omnidireccional dipole	
Gain	5 dBi	

[a] WPA3 is also supported
[b] Other type of antennas can be used (e.g. in UGV configuration).

3.2 Relay Gateway

The Relay Gateway (RGw) diagram, Fig. 4 represent the gateway with the main hardware modules, is similar to the RNode diagram (Fig. 3), a hardware processing unit based on "open-hardware SBC [9], and the RGw is supposed to work in ground in a fixed position and connect to a local network, it support more functionalities, features and interfaces and elements than the RNode: an Ethernet interface (10/100Mbps), POE power module (fully IEEE 802.3af compliant, input voltage (input 36-37VDC), buffer battery, user buttons and LEDs, USB Client and Host ports, Bluetooth and plastic box for protection and mechanical fixation. As for the RNode, in RGw the Wi-Fi radio are used to connect to the mesh network and to generate a local Wi-Fi network for the ground elements to connect to, plus a data concentrator for the data provided by the RNodes, Table 2 present antenna specification. The Ethernet interface is used to communicate with the local network switch that will provide access to the Internet. Together, they are used to create a bridge between the mesh network and the internet.

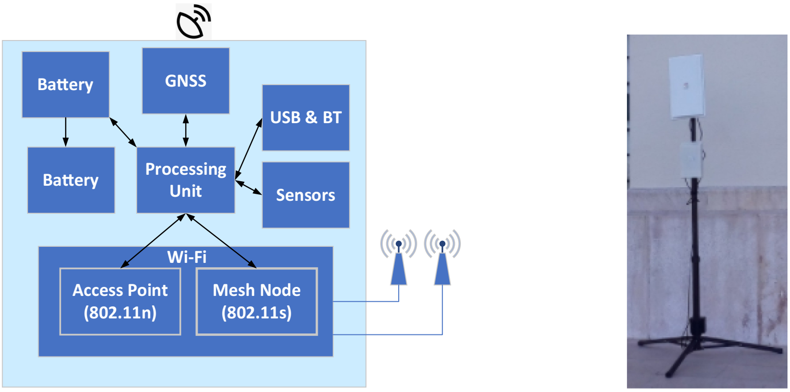

Fig. 4. Diagram and view of secondary network Relay Gateway (RGw).

Table 2. Gateway node – RGw WLAN antenna specification.

Wi-Fi (2.4 GHz)	Wireless mesh
Antenna[a]:	
Type	MIMO Sector
Gain	H:14dBi/60° V:12dBi/70°

[a] Other type of antennas can be used

3.3 Network Laboratory Tests

To verify the functionality and performance of this solution, the test setup presented in Fig. 5 was deployed in laboratory with the following components:

- STA - Client Station (Laptop or a Smartphone);
- MAP - Mesh Access Point
- MPP – Mesh Portal (RGw)

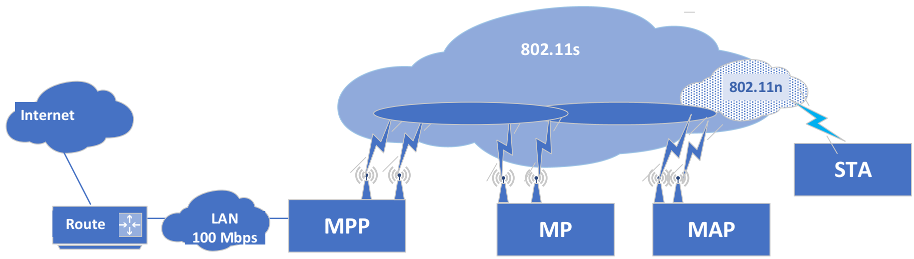

Fig. 5. Secondary network the test setup.

- MP – Mesh Points.

The Table 3 presents the result of test scenario A, using a Laptop 802.11ac as STA and iPerf - an open-source network performance tool for TCP, UDP and SCTP [11] (iper3 v.3.6 [11]) as network analyzer. The iperf tool version 3 was used to assess the wireless network performance. In the receiving node an iperf3 server instance was started in background with the command "iperf3 -s -D", while in the transmitting node a client instance was started in two different ways. The first one used TCP packets to assess the network throughput with the command "iperf3 –c <ip_server> -t30". The second one used UDP packets to assess network stability with the command "iperf3 -u -b <bitrate> -c <ip_server> -t30". The bitrate selected for the UDP test was bellow or equal to the bitrate measured for the network throughput in the TCP test in the same test conditions. Both tests used a randomly generated data block during a 30 s interval. The TCP test used a 128 KB data block, while the UDP test used a 8 KB data block. With the same test setup, another test was performed, the Scenario B – Video Streaming, were a smartphone was used as STA from where the VLC app was launched to access an IP TV service. The smartphone was connected to the MAP node and an HD (1080p) channel was selected for viewing. As a result, the channel view was fluid but with occasional stutters in the video and sound.

Table 3. Lab test – network performance.

Network section		Protocol	Throughput [Mbits/s]
A	External network → MPP	Ethernet*	34.1
	MPP → External network		81.7
B & C	MPP → MP	802.11s	12.2
	MP → MPP		11.7
D	MAP → STA	802.11n	72.1
	STA → MAP		81.7

* Using a BeagleBone Green Wireless Adaptor USB2.0 to RJ45 Ethernet Network.

The preliminary results obtained in the laboratory (indoor) indicated that the network could support the biometric data from FRs. The solution was prepared for outdoor tested as presented in next section (Sect. 4).

4 Outdoor Performance Tests

The outdoor tests were performed in different situation near a small city with medium or rare use of Wi-Fi 2.4 GHz band, considering different distances and avoiding signal obstacles. The network configuration deployments were based on two RNodes and a Client (one MPP, one MAP and one STA, see Fig. 5).

4.1 Link Viability

An overview of power model in a wireless system between two points is presented in Fig. 6.

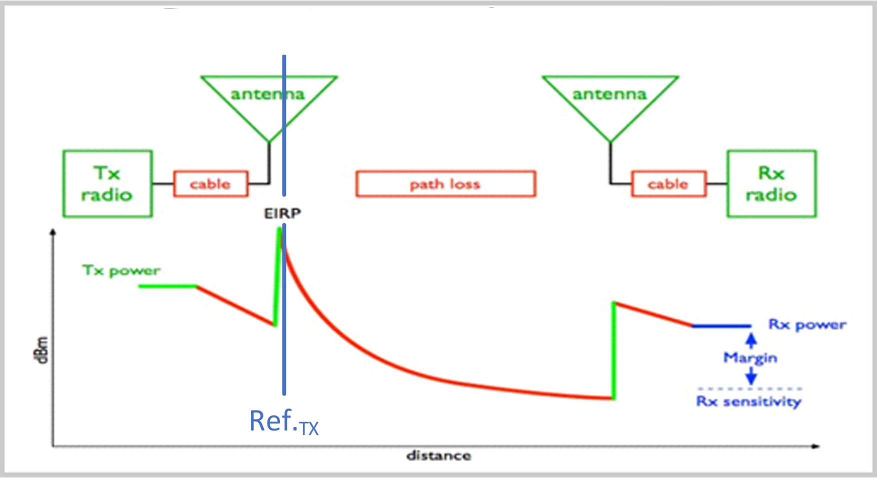

Fig. 6. Power in a wireless system. [12]

Where:

- Path loss, free space loss [12]:

$$Lp\,(\text{dB}) = 32.5 + 20\,log_{10}(d\ [\text{Km}]) + 20\,log_{10}(f\ [\text{MHz}]) \tag{1}$$

In a simplified model objects, interference between channels, ellipsoid Fresnel interruption, other temperature etc. are not considered. All wireless mesh network interconnection (RNodes) are stationary (speed 0 Km/h) as well as the mobile clients (FR). All RNodes have to support client connections, i.e., the need to be simultaneously a Mesh Point and a Mesh Access Point.

- Reference points:

  i) Ref. $_{TX}$ = EIRP, Equivalent Isotropic Radiated Power. (@Antenna Output)
  $EIRP_{MAX}$ = 20 dBm, for Wi-Fi 2400,0–2483,5 MHz (2.4 GHz) - both transmitters are limited, on TX Maximum Radiated Power the power must not exceed 100 mW E.I.R.P. (20 dBm) [16].
  All RNodes are configured to be according with this rule, the TX Maximum Radiated Power to not exceed 100 mW E.I.R.P. (20 dBm).
  ii) Rx power, power received at radio receiver.
  iii) Rx sensibility, the minimum signal strength that a receiver can detect.
  iv) Cable, include all signal loss, like pigtails, cables, connectors.

- Fresnel Clearance, the area around the line-of-sight (LoS), where the radio waves spread out into after leave the antenna the maximum value [17]:

$$Fresnel\ Radius_{max}[\text{m}] = 17.31 * \sqrt{\frac{D[\text{Km}]}{4 * f\,[\text{GHz}]}} \tag{2}$$

Any obstruction of Fresnel Zone must be less than 20%, and, in ideal conditions the Fresnel Zone must be without any obstruction. The Fig. 7 present at graphic of Max. Radius Fresnel versus the link distance at 2.4 GHz.

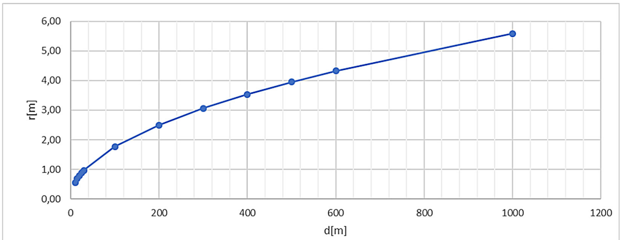

Fig. 7. Wi-Fi 2.4 GHz Max. Radius Fresnel & link distance.

4.2 Outdoor Test

These tests were performed near a small city, were the signal strength of other Wi-Fi network near the MPP (RGw, GPS coordinates "38.643546, −9.222945" area (Viewpoint) is less than −80 dBm. In all scenarios it was guaranteed LoS between RNodes (MPP and MAP). Note that these tests were performed in a public area, with movement of people that could affect the test results (see in Fig. 8 and Fig. 9). The Wi-Fi CH1 was selected (2.412 GHz).

Fig. 8. Test A: network devices

Two different STA devices as been considered an iPhone 4S [13] on link viability analysis and on test field test a laptop HP ProBook 450 G6 Notebook was been used.

Map view (Google Earth) Py and Pz areas

Fig. 9. Test – map.

Three different topologies of tests tested:

- Test A: All devices at "Miradouro dos Capuchos" (viewpoint): altitude 92 m;
- Test B: MAP and STA moved to Py area: altitude 3 m distance from MPP 526 m;
- Test C: MAP and STA moved to Pz area: altitude 5 m distance from MPP 393 m.

On Test B and Test C, the MPP antenna was aligned with the equidistant point of the remote sites (Py and Pz).

The test conditions in Table 4 software modules installed in MPP and MPA *(hostapd* and *wpasupplicant* updated in project) are presented, software tools in Table 5 and wireless protocols in Table 6.

Table 4. Test – software version installed on MPP and MPA components.

SW modules	Name	Version
OS	Debian	10.9 (Buster)
Kernel	Linux	4.19.94-ti-r59
Driver Wi-Fi	wl18xx	R8.8
Firmware Wi-Fi	wl18xx	8.9.0.0.86
Host Access Point Daemon	hostapd	2.9.0-21-inov3[a]
WPA Supplicant for Linux	wpasupplicant	2.9.0-21-inov3[a]

[a] Updated in the project

Table 5. Test – software tools used.

Tool name	Description	Version
Wi-Fi Analyser [14]	Android application to analyze Wi-Fi signal	3.0
iw [15]	Tool for configuring Linux wireless devices	5.9
iperf [11]	Internet Protocol bandwidth measuring tool	3.6

Table 6. Test – FASTER Wi-Fi SSID.

RNode	Network interface	SSID
MPP (GW)	Mesh (802.11s)	hidden
	AP (802.11n)	FASTER GW
MAP	Mesh (802.11s)	hidden
	AP (802.11n)	UAV01

The network diagram model adapted from Fig. 6 is presented in Fig. 10, where the locations of MAP and STA have the same elevation, and where d_{MAP} and d_{MSTA} are, respectively, the distance between nodes MAP and MPP (RGw) and between the STA (Client) and the MAP node. The height of the MPP antenna is adapted according to the topology of the locations:

$$h_{MPP}[m] = \langle Antenna\ Size_{MPP}[m]\rangle + Antenna\ Size_{MPP} > [m] - Elevation_{MAP} \quad (3)$$

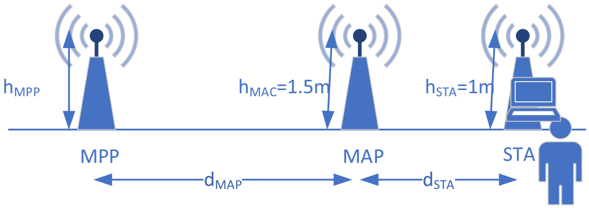

Fig. 10. Test: network deployment diagram.

As mentioned before the *iperf* tool was used to assess the wireless network performance using the same procedure used on Network Laboratory Tests (see Sect. 3.3).

Test A – Miradouro dos Capuchos (Viewpoint)
The Test A, performed at Miradouro dos Capuchos, with all network elements installed at same elevation (Fig. 11).

$h_{MPP} = 1.5m$
$d_{MAP} = 18m$
$d_{STA} = 2m$

Fig. 11. Test A - network devices deployment.

Monitoring the ISM band of 2.4 GHz with the "WiFi Analyzer" tool no other Wi-Fi networks were detected, according with the results presented by the Channel Chart and Time Line Chart of that tool (Fig. 12).

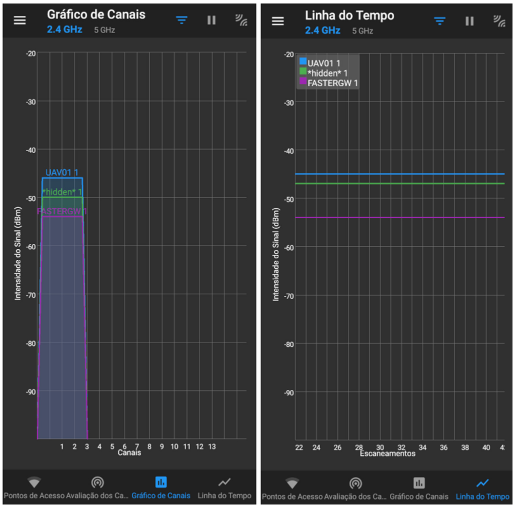

Fig. 12. Test A: Wi-Fi channel chart and time line chart.

This field test, the first to be performed is also useful to verify that all devices and software of the relay network are working properly, run this scenario is a pre-requirement to perform Test B and Test C. The result of field tests is presented in Table 9.

Test B – MPP and STA in Area Py

Monitoring the Wi-Fi of ISM band of 2.4 GHz, in Py area, with the Wi-Fi Analyser tool other Wi-Fi networks where detected near the MAP and STA locations, according with the output, Wi-Fi Channel Chart and Time Line Chart reports (see Fig. 13), only another one Wi-Fi network in CH1 was detected with $S > -70$ dBm (and less -60 dBm), all other

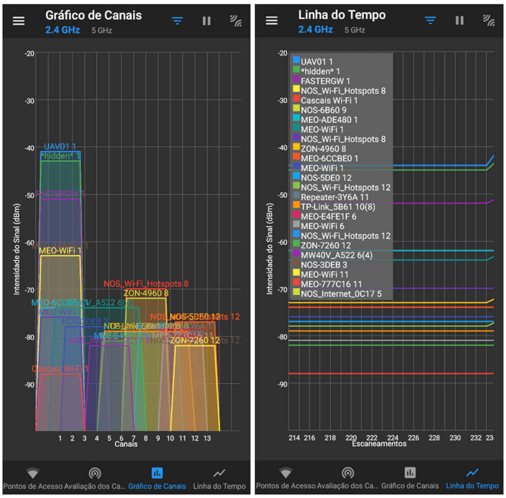

Fig. 13. Test B: Wi-Fi channel chart and time line chart near the MPP (Py).

networks where detected with inferior signal strength, less than −70 dBm, the FASTER Wi-Fi networks (802.11s and 802.11n) where detected with higher signal strength, the signal received from MPP (RGw) is received approx. with −50 dB (more 20 dB). The wireless link represented in a map and h_{MPP} and link distance values are characterized in Fig. 14. View from MPP to MAP and from MAP to MPP is presented respectively in Fig. 15.

h_{MPP} = 90.5m
d_{MAP} = 526m
d_{STA} = 10m

Fig. 14. Test B: map view (google maps), h_{MPP} and link distances.

Fig. 15. Outdoor test B: MPP and MAP view.

The result of link viability is present in Table 7.

Table 7. Rural test B – link viability analysis.

Link (2.4 GHz/CH1)	STA[a] → MAP	MAP → MPP	MPP → MAP	MAP → STA[a]
D [m]	10	526	526	10
Ref. $_{TX}$ [dBm]	13.5 [13]	20.0	20.0	20.0
Path loss	−60.1	−94.5	−94.5	−60.1
G. Antenna Rx [dBi]	5	14	5	0
Cable [dB]	−2.5	−5	−2.5	0
Sensibility[b] [dBm]	−96.3	−96.3	−96.3	−83
Margin Rx [dB]	38.7	30.8	24.3	42.9

[a] STA for reference using a mobile phone: iPhone 4S) d = 86m → Margin Rx (STA → MAP) = 20 dB
[b] Value at bitrate = 1 Mbps (Max. Sensibility)

The result of field tests is presented in Table 9.

Test C – MPP and STA in Area Py

Monitoring the Wi-Fi of ISM band of 2.4 GHz, in Pz area, with the Wi-Fi Analyser tool other Wi-Fi networks where detected near the MAP and STA locations, according with the output, Wi-Fi Channel Chart and Time Line Chart reports (see Fig. 16), the gap between the signal strength between the FASTER networks (802.11s and 802.11n) and other Wi-Fi networks detected is higher compared with the gap detected on Test B. View from MPP to MAP and from MAP to MPP is presented respectively in Fig. 15. The link viability is present in Table 8 (Fig. 17).

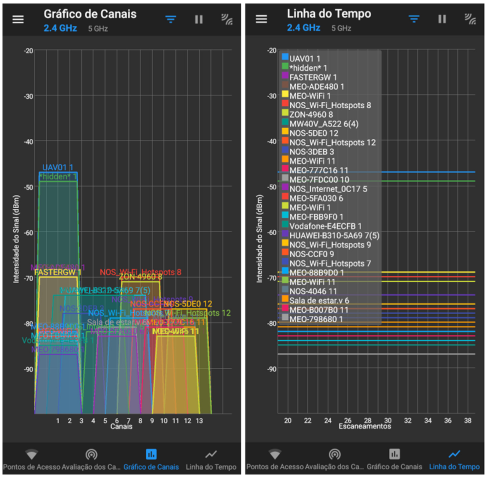

Fig. 16. Test C: Wi-Fi channel chart and time line chart.

h_{MPP} = 89.5m
d_{MAP} = 396m
d_{STA} = 8m

Fig. 17. Test C: map view (google maps), h_{MPP} and link distances.

The result of link viability analysis is present in Table 8.

Table 8. Test C – link viability analysis.

Link (2.4 GHz/CH1)	STA[a] → MAP	MAP → MPP	MPP → MAP	MAP → STA[a]
D [m]	8	386	386	8
Ref. $_{TX}$ [dBm]	13.5 [13]	20.0	20.0	20.0
Path loss	−58,2	−91.8	−91.8	−58,2
G. Antenna Rx [dBi]	5	14	5	0
Cable [dB]	−2.5	−5	−2.5	0
Sensibility[b] [dBm]	−96.3	−96.3	−96.3	−83
Margin Rx [dB]	40,64	33.5	27.0	44.8

[a] STA for reference using a mobile phone: iPhone 4S) d = 86 m → Margin Rx (STA → MAP) = 20 dB
[b] Value at bitrate = 1 Mbps (Max. Sensibility)

The result of field tests is presented in Table 9.

Field Test Results

The Field Tests results are summarized in Table 9, where the Bitrate, Packet Loss, Jitter are presented as well for MAP and MPP nodes the receiver power level and margin.

Table 9. Field test – results.

Link	Bitrate [Mbits/s]	Packet loss	Jitter [ms]	MAP power Rx/Margin[a] [dBm]/[dB]		MPP power Rx/Margin[a] [dBm]/[dB]	
Test A							
MAP → MPP (d = 18 m)	39.4	0/25898 (0%)	0.907	–		−50	24.9
STA → MAP (d = 2 m)	65.5	0/25898 (0%)	0.080	−47	27.9	–	
STA → MAP → MPP	23.6	0/25896 (0%)	1.140	−47	27.9	−50	24.9
Test B							
MAP → MPP (d = 526 m)	2.16	3/2590 (0.12%)	4.986	–		−73	23.3
STA → MAP (d = 10 m)	39.7	N/A	N/A	−62	12.9	–	
STA → MAP → MPP	1.47	4/2590 (0.15%)	6.731	−62	34.3	−67	29.3
Test C							
MAP → MPP (d = 396 m)	1.57	1/2590 (0.039%)	3.361	–		−68	28.3
STA → MAP → MPP	1.46	0/2590 (0%)	3.070	−73	23.3	−68	28.3

[a] Using as reference, modulation DSSS and bitrate 1 Mbps, Max. Sensibility: −96.3 dBm (see Table 1) and −74.9 dBm for results tests with bitrate > 11 Mbits/s (reference value at 54 Mbits/s)

In all situations the margin reported of signal received at RNode, MPP and MAP (mesh network elements), is higher than 23 dB, what give us an indication of the stability of the link of mesh network at these conditions. Remarks:

- For the Wi-Fi clients connect to the MAP/802.11n, in real situation using a stationary UAV, about 10 m to 15 m from the ground and close as possible to the Wi-Fi clients (STA/FRs) to receive information from biometric sources, the signal strength received at MAP is strong enough to establish the data wireless link.
- The bitrate in Test B was higher than in Test C, between MAP and MPP (RGw). An explanation for this is the fact that the wind level at the MPP site was relatively high during the realization of Test C, with strong gusts of wind, which forced extra care on the fixation of the MPP support tripod. Unfortunately, it was not possible to completely eliminate the oscillation of the MPP (RGw) antenna. On all Test Scenarios, the bitrate is enough to support biometric data service (vital data, e.g. temperature, heartbeat).

5 Conclusions and Next Steps

To maintain the FRs protection and operational effectiveness, namely their capacity in terms of situational awareness and communication in adverse situations, result of natural catastrophes, technological disaster or terrorist attacks, event of a disaster, communication networks may not be available at all, different reasons e.g. infrastructure collapse, denial of service or even the area of the incident may not be covered by communication services.

Although the Relay communication solutions for FRs, a resilient network solution easy to be deployed, to mitigate this problem and extent the existent communication networks. The solution allows FRs in network's shadow zones to be networked and at least vital biometric data to continue to be transmitted. The possibility that network nodes can be installed in UAVs or even in UGVs (UxVs) allows a fast and efficient repositioning of each network node and with this change the network coverage on the ground.

The next step, following the positive assessment by the FRs and other FASTER stakeholders, the solution will be deployed using UxVs and carry out the field tests in relevant environment, and plus the validation of a new algorithm for node repositioning to improve network coverage (the result be available to the UxV operator(s) in realtime).

In future this solution can also evolve to interact or support other types of networks as Low Power Wide Area Networks (LPWAN) IoT (as LoRa [18]).

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