

A Framework for the Analysis of Wildfire Effects in Emergency Communication Systems

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Abstract—This paper aims at the development of a simulation framework to enhance the quality, performance and the resilience of the emergency radio communication systems during a wildfire event. To this extent, this research work includes several studies that will contribute for the better understanding of the propagation effects on radio signals under fire environments, the development of a fire-front building up model, the development of a radio propagation tool to obtain coverage maps based on relevant models for propagation in rural areas, particularly in highly dense forest areas, taking into account the topography and clutter in the radio path and the integration of wildfire build up models into the radio propagation tool for an all encompassing radio coverage tool to aid ground forces in real-time with identification of radio exclusion zones in real-time as fire-front develops.

I. INTRODUCTION

In 2017, deadly wildfires swept Portugal and killed over 106 people and injured more than 320, in what were the deadliest wildfires in the countrys history. Radio communications systems play a major role in supporting wildfire suppression crews in fire-grounds and modern radio communications equipment has given fire fighters the capability to coordinate and cooperate their efforts to extinguish and control wildfire outbreaks. However, since introduction of such equipments to emergency services, little attention has been

given to considering the propagation of radio waves in extreme fire environments.

Early studies show flames are conductive, possessing charged particles created as a product of combustion (e.g., [1]–[4]). This fact is particularly critical whenever the radio link between the base station and the emergency ground forces travels above the fire-front, since the appearance of high plume and the so called cold plasma may severely degrade the radio wave signal, creating radio exclusion zones.

To this extent, understanding the propagation phenomena in wildfires in the frequency bands usually allocated for emergency communications systems and the development of real-time coverage prediction tools to account for the additional signal attenuation caused by the cold plasma barriers, are extremely important to enhance the quality and the performance of the emergency communication systems.

II. RADIO COVERAGE TOOL FOR MISSION-CRITICAL OPERATIONS

To assess the emergency communications network in terms of coverage and capacity, i.e., coverage redundancy, a three-dimensional (3-D) radio propagation tool was developed. The simulation platform is based on digital elevation models to account for the ground topography and clutter, and makes use of specific propagation models (e.g., ITM) to predict the radiowave propagation phenomena.

The developed 3-D simulation platform was then used to predict the coverage map of the entire Portuguese emergency communication network. With this analysis, it was proven that, in normal situations, there is no lack of coverage, since the predicted minimum signal level is way above the -106 dBm threshold (with the security fade margins) defined for TETRA systems. Additionally, it was also proved that the Portuguese emergency communication network has also a strong redundancy in terms of coverage, since there are at least 10 visible base stations in more than 80% of the Portuguese territory. A sample of the coverage map of the Portuguese emergency communication network is depicted in Fig. 1.

The coverage analysis on the Portuguese emergency communications network proved that, in normal conditions, all Portuguese territory is covered by signal levels way above the minimum level threshold foreseen for TETRA and in more

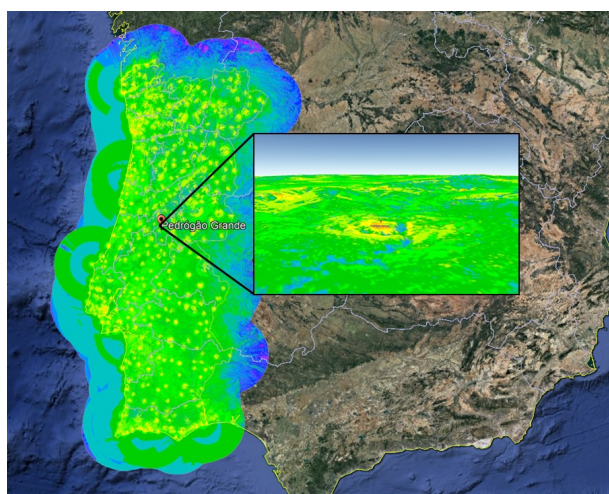


Fig. 1. Coverage map of the emergency network.



Fig. 2. Wildfire plume (cold plasma barrier) of a real wildfire.

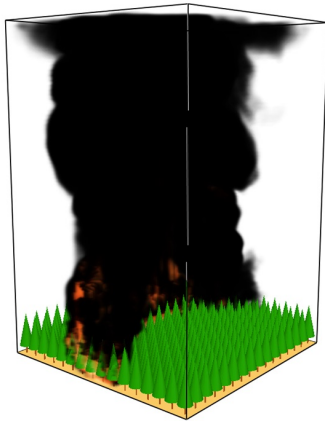


Fig. 3. Fire front model simulation environment.

than 80% of the Portuguese territory there are at least 10 visible base stations. However, in the vicinity of wildfires, the presence of high plumes and cold plasma may significantly affect the performance of radio wave communication systems. In extensive wildfires, the plumes can be higher than 10 km. Fig. 2 depicts the fire plume of a real wild-fire.

In such hostile environments, it is extremely important, not only to understand the propagation phenomena in wildfires, but also to be able to predict the fire-spread direction and speed in real-time, thus anticipating the creation of new radio exclusion zone. To this extent, it is required to effectively study and model the combustion induced plasma using a thermal ionization cold plasma model; to investigate the variations of temperature, fuel and fire characteristics that influence the formation of a volume of free ionized electrons in the combustion and flame regions and to study the influence of the wind effects on the fire-front build up spreading and its impact of the propagation characteristics overtime. These research topics are sought to be conducted using a fire simulator and using experimental data acquired in several measurement campaigns to validate both individual and final models. Fig. 3 depicts the simulation environment of the fire simulation framework.

III. PLANNING AND OPTIMIZATION OF EMERGENCY COMMUNICATION NETWORK

After a proper understanding of the propagation effects on radio signals under fire environments, in terms of additional attenuation (and/or diffuse scattering), and following

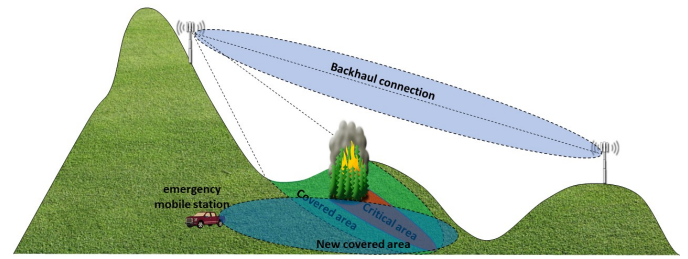


Fig. 4. Mission critical scenario with radio exclusion zones.

the development of a fire-front model to account for fire spread direction and speed based on a certain number of input parameters (e.g., wind speed and direction), a generic and encompassing radio coverage tool should be developed. This platform should include the information of the existing coverage maps, and in an event of a wildfire, it should be able to predict, identify and alert the emergency ground forces to the existence of new radio exclusion zones caused by the cold plasma barrier. The emergency ground forces should be able to use developed simulation platform to analyse the mission-critical scenario, and to be able to assess, in real-time, the best site for the deployment of a mobile base station to cope with the identified radio exclusion zones.

The referred operations theater is depicted in Fig. 4, where the radio exclusion zone caused by the wildfire, identified in red, is canceled by the deployment of the emergency mobile station (blue zone).

IV. CONCLUSIONS

The research work presented in this paper aims at the development of a radio coverage tool to enhance the emergency ground forces communications during a wildfire event. The proposed framework should account, not only for the coverage map of the emergency communication systems, but also the excess attenuation caused by the cold plasma barrier in the vicinity of the wildfire, enabling real-time identification of imminent radio exclusion zones.

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